Lecture Notes in Networks and Systems 578

Atulya K. Nagar
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Durgesh Kumar Mishra
Amit Joshi *Editors*

# Intelligent Sustainable Systems

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# Lecture Notes in Networks and Systems

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# Preface

The Sixth Edition of the WorldS4 2022—World Conference on Smart Trends in Systems Security and Sustainability—will be held during August 24–27, 2022, in a hybrid mode and organized by Global Knowledge Research Foundation. The associated partners were Springer, Springer Nature and InterYIT IFIP. The conference will provide a useful and wide platform both for display of the latest research and for exchange of research results and thoughts. The participants of the conference will be from almost every part of the world, with background of either academia or industry, allowing a real multinational multicultural exchange of experiences and ideas.

A great pool of more than 1050 papers were received papers for this conference from across 48 countries among which around 144 papers were accepted with this springer series and were presented through Physical as well as Digital platform Zoom during the four days. Due to overwhelming response, we had to drop many papers in hierarchy of the quality. Total 21 technical sessions were organised in parallel in 4 days along with few Keynotes and Panel Discussions. The conference will be involved in deep discussion and issues which will be intended to solve at global levels. New technologies will be proposed, experiences will be shared, and future solutions for enhancement in systems and security will also be discussed. The final papers will be published in 2 volumes of proceedings by Springer LNNS Series.

Over the years, this conference has been organised and conceptualised with collective efforts of a large number of individuals. I would like to thank each of the committee members and the reviewers for their excellent work in reviewing the papers. Grateful acknowledgements are extended to the team of Global Knowledge Research Foundation for their valuable efforts and support.

I look forward to welcome you on the Seventh Edition of this WorldS4 Conference in 2023.

Liverpool, UK — Atulya K. Nagar
Windhoek, Namibia — Dharm Singh Jat
Indore, India — Durgesh Kumar Mishra
Ahmedabad, India — Amit Joshi

# Contents

**AI's Role and Application in Education: Systematic Review** . . . . . 1
Abdulsalam K. Alhazmi, Fatima Alhammadi, Adnan Abdullah Zain, Ezzadeen Kaed, and Balquis Ahmed

**Digital Service Quality from Elderly Generation Perspective to Improve Online Business and Economy: A Theoretical Framework** . . . . . 15
Jamaiah Yahaya, Aziz Deraman, Yusmadi Yah Jusoh, and Sathya Nantha Kumar

**Green Software Product: The Empirical Study on Social Factor and Measurements** . . . . . 25
Komeil Raisian, Jamaiah Yahaya, Aziz Deraman, and Siti Rohana Ahmad Ibrahim

**A Systematic Review and Future Perspective of Mental Illness Detection Using Artificial Intelligence on Multimodal Digital Media** . . . . 35
U. Ananthanagu and Pooja Agarwal

**E-Service Quality: A Literature Review and Research Trends** . . . . . 47
Thanh D. Nguyen, Uyen U. T. Banh, Tuan M. Nguyen, and Tuan T. Nguyen

**A Recommendation Model for Predicting Alzheimer's Drugs' Mechanism of Action** . . . . . 63
Pouyan Nahed, Mina Esmail Zahed Nojoo Kambar, Jorge Ramón Fonseca Cacho, Garam Lee, Jeffrey Cummings, and Kazem Taghva

**Neural Networks for Predicting Severity of Ovarian Carcinomas** . . . . . 75
Rushikesh Chopade, Aditya Stanam, and Shrikant Pawar

**Development of Hybrid Personalized E-commerce Using Collaborative Filtering and Content-Based Filtering for South Cartel Clothing Company** ..... 83
Jcyle Anne T. Balmadres, Kristine Bartolome, Roi Gerome B. Bunyi, Jeffrey Rafael B. Jacobo, Jay-ar P. Lalata, Ace C. Lagman, and Ma Corazon Fernando-Raguro

**Conceptual Design and Early Prototypes of a Gamified Virtual Reality Interview Training Application** ..... 93
David Jennings, Pratheep Kumar Paranthaman, and Nikesh Bajaj

**Improvement of the Production Process, Through Simulation Models, in a Pet Bottle Manufacturing Company** ..... 105
Estefany Yoselyn Torres Tineo, John Milthon Córdova Vásquez, Mario Roberto Huerta Mendez, Omar Alfonso Santos Pacheco, Mg Mario Ninaquispe-Soto, and Dra Yasmina Riega-Virú

**Green Hydrogen for Industry: A Proposed Approach to Manage the Flow of Energy in Industrial Sector in Morocco** ..... 119
Zineb Slaoui, Sanaa Faquir, Khalid Alaoui Zidani, and Ali Yahyaouy

**Methodology for Implementation of Intelligent Risk Management in the Business Processes of Organizations** ..... 127
Petya Bicheva and Evgeni Valchev

**Implementation of a Hybrid Information System in an Intelligent Health Gateway** ..... 141
Guy Lysmos Mezui Eya'a and Mostafa Hanoune

**Posture Control of Collaborative Robotic Manipulator Based on Gesture Sensors** ..... 153
Jingjing Lou, Yunhan Li, Qingdong Luo, Xiyuan Wan, and Pengfei Zheng

**Classifying Students' Academic Performance Using Principal Component Analysis During Pandemic COVID-19** ..... 171
Suharti Siusin, Shazlyn Milleana Shaharudin, Nur Syarafina Mohamed, and Ismail Musirin

**Automatic Control System Based on Industry 4.0, PLC, and SCADA** ... 183
Jonathan Wilondja Kibulungu and Opeyeolu Timothy Laseinde

**Design and Application of the AHP-TOPSIS-2N to Evaluate (Linked) Open Government Data from the Electricity Datasets** ..... 199
Ingrid Palma Araújo, Ana Carla Bittencourt Reis, Ari Melo Mariano, and Vinícius Rodrigues Oviedo

**Online Retail System with Data Forecasting and Android Mobile Application** ..... 217
Irish C. Juanatas, Roben A. Juanatas, Jayson Raymund D. Bermudez, Rene Christopher R. Tio, Jaden Del Rosario, Anne Paula Delos Santos, Ricardo R. Edig, and Dennis Martinez

**TICaP Hub: An Event Management System for FEU Tech's Technology Innovation in Capstone Project Using DigitalOcean Droplets and Cron Jobs** ..... 225
John Raymond Arriesgado, Justine Neil Calaguian, Alena Rose Golpeo, Ace C. Lagman, Miguel Bryan Pajarillo, Peter Carl Pardo, Maria Vicky S. Solomo, and Heintjie N. Vicente

**Theoretical Study of Security for a Software Product** ..... 233
Alin-Marius Stanciu

**An Efficient Workload Distribution Mechanism for Tightly Coupled Heterogeneous Hardware** ..... 243
Ernesto Rivera-Alvarado and Francisco J. Torres-Rojas

**Towards an Intelligent Electric Wheelchair: Computer Vision Module** ..... 253
Jesus Gerardo Torres-Vega, Juan C. Cuevas-Tello, Cesar Puente, Jose Nunez-Varela, and Carlos Soubervielle-Montalvo

**The Text Mining Analysis Approach for Electronic Information and Transaction (ITE) Implementation Based on Sentiment in the Social Media** ..... 263
Fahdi Saidi Lubis, Muharman Lubis, Lukmanul Hakim, and Hanif Fakhrurroja

**The Maze: Scarecrow's Revenge, Agricultural Education and Outreach Through Game Development** ..... 273
Cathryn Hunt and Saman Sargolzaei

**Modeling of Blood Flow Processes in a Living Organism** ..... 283
Yaroslav Yurchyshyn and Vasyl Yurchyshyn

**Using a Q-Methodology in Demystifying Typologies for Cybersecurity Practitioners: A Case Study** ..... 291
Ahmed AlKalbani, Hamed AlBusaidi, and Hepu Deng

**Trust in Smart Homes: The Power of Social Influences and Perceived Risks** ..... 305
Ahmed Shuhaiber, Wed Alkarbi, and Sara Almansoori

**Classification Algorithm for Predicting the Graduation Level: Case Study of e-Learning in Telkom University** ..... 317
M. Azani Hasibuan, Rachmadita Andreswari, Muharman Lubis, Fikli Perdana, and Hanif Fakhrurroja

**Performance Evaluation and Analysis of Wi-Fi Security Protocols** ..... 327
Saptorshi Bhattacharjee and Kishore Kumar Senapati

**Business Information System Analysis Techniques Acceptance** ..... 339
Małgorzata Pańkowska

**'E-Barter' Exchanging System: Toward a Smart and Sustainable Community** ..... 355
Ahmed Shuhaiber, Heyam Salem Ali Alfayadhi, May Mohammed AlAwlaqi, and Maitha Abdulnasser Awadh Ali

**Web-Based Village Bridge and Road Project Monitoring Information System** ..... 373
Robi Gusnawan and Muharman Lubis

**A Case Study in the Application of STPA-sec and CHASSIS for Socio-Technical Cyber Security Risk Management in Health Care from Developing Nations** ..... 383
Joseph Kaberuka and Christopher Johnson

**Taxonomy of Data Quality Metrics in Digital Citizen Science** ..... 391
Krishna Vaddepalli, Victoria Palacin, Jari Porras, and Ari Happonen

**Authentication Protocol for Intelligent Electronic Devices in an Edge IoT Environment with Key Agreement** ..... 411
Elena Shkorkina

**A Channel-Based Attention Deep Semantic Segmentation Model for the Extraction of Multi-type Solar Photovoltaic Arrays from Large-Scale Orthorectified UAV RGB Imagery** ..... 421
Yahya Zefri, Imane Sebari, Hicham Hajji, and Ghassane Aniba

**Towards an E-Psychology Solution to Support, Intervene and Educate the Control of Emotions in Infants** ..... 431
Cleofe Alvites-Huamaní, John Alexander Rojas-Montero, Janio Jadán-Guerrero, and Elías Muñoz-Primero

**SEMAFORE: Secure Mobile Field Diagnostics for Cyber-Physical Systems** ..... 445
Tate Seyler and Denis Ulybyshev

**Redefining the Museum Experiences in the Virtual Age** ..... 459
Janio Jadán-Guerrero, Mónica Mendoza, and Cleofe Alvites-Huamaní

**Auto Train Brain Increases the Variance of the Gamma Band Sample Entropy in the Left Hemisphere in Dyslexia: A Pilot Study** ..... 471
Günet Eroğlu

**Parallel Clustering Method Based on Density Peaks** ..... 479
Libero Nigro and Franco Cicirelli

**Assemblable Musical Device for the Development of Attention in 5-Year-Old Children** ..... 489
Fernando Ibarra-Torres, Gustavo Caiza, Marcelo V. Garcia, and Valeria Barona-Pico

**Ethical Aspects of Work Disability Risk Prediction Using Machine Learning** ..... 499
Katja Saarela, Vili Huhta-Koivisto, and Jukka K. Nurminen

**Awareness and Practice of Green Computing in Higher Education Institutions** ..... 511
Samson Obafemi, Kayode Oyetade, and Morvyn Nyakudya

**New Hybrid Monitoring Approach for Distributed Installations in Rural Areas** ..... 521
Bala Moussa Biaye, Khalifa GAYE, and Cherif Ahmed Tidiane Aidara

**Active Learning of Programming as a Complex Subject Applying Problem-Based Learning for Computational Thinking Development Model (CTPBL) in High School** ..... 527
David Alvarado, Margarita Zambrano, César Villacís, and Fernando Galárraga

**Agents for Change—Profiling South African Construction Quantity Surveyors** ..... 541
Daniël Johannes Hoffman, Derick Eben Booyens, and Karl Trusler

**Data Mining to Support Decision-Making—A Research Approach** ..... 553
Jorge Duque, José Joaquim Moreira, and Joaquim Costa

**Sustainability of Digital Transformation (DX), Institutional Research (IR), and Information and Communication Technology (ICT) in Higher Education Based on Eduinformatics** ..... 565
Kunihiko Takamatsu, Ikuhiro Noda, Kenya Bannaka, Katsuhiko Murakami, Yasuhiro Kozaki, Aoi Kishida, Hiroki Kabutoya, Kenichiro Mitsunari, Ryohei Adachi, Masato Omori, and Yasuo Nakata

**Digital Platform for Monitoring and Comprehensive Support of Children with Autism Spectrum Disorders** ..... 573
I. Nigmatullina, S. Sheymardanov, and M. Abramskiy

**Application of Deep Convolutional Neural Networks MobileNetV2 and Xception for Detecting Cardiac Arrhythmia** ..... 581
Tachanat Akarajaka, Komgrit Leksakul, Chichana Suedumrong, and Nivit Charoenchai

**Showing the Impact of Data Augmentation on Model's Decisions Using Integrated Gradients** ..... 591
Ingrid Hrga and Marina Ivašić-Kos

**Development of a Computer System for the Documentary Process in the Management Process at the Wissen LP Academy** ..... 601
Luisa Paola Jorqueda Vasquez, Luciana Victoria Jurado, Jesus Lagos Morón, Mario Reynaldo Medina Ramos, and José Antonio Ogosi Auqui

**Impact of Digital Marketing on Budamaki Company** ..... 611
Victor Hugo Guadalupe Mori, José Antonio Ogosi Auqui, David Hugo Obando Pacheco, and Jorge Cano Chuqui

**Industry 4.0: Implementation of Technologies in Medical Manufacturing Companies** ..... 619
Victor Hugo Guadalupe Mori, José Antonio Ogosi Auqui, Jimmy Aurelio Rosales Huamani, and José Luis Arenas Ñiquin

**The Potentials of Deep Learning Techniques for the Classification of SARS-CoV-2 Variants Based on Genomic Sequence Information** .... 627
Marion Adebiyi, Miracle Nmesomachi Enwere, Timothy Adeliyi, Abiodun Okunola, and Ayodele Adebiyi

**Smart Traffic Handling Algorithm Using Aggregated Channel Feature** ..... 635
Wania Tahir, Raja Asif Wagan, and Bushra Naeem

**Estimating Nodes' Number in a Nanonetwork Using Two Algorithms** ..... 645
Athraa Juhi Jani

**Digitization Techniques for the Representation of Genomic Sequences in LSTM-Based Models** ..... 653
Marion Adebiyi, Miracle Nmesomachi Enwere, Abenego Shekari, Ayodele Adebiyi, and Francis B. Osang

**On Accountable and Distributed Audit of Outsourced Data** ..... 663
Amit Kumar Dwivedi, Naveen Kumar, and Manik Lal Das

**Predicting the Workload in Debt Collections to Improve the Efficiency of Manpower Planning** ..... 675
Pornpimol Chaiwuttisak

**Artificial Intelligence: Benefits, Application, Ethical Issues, and Organizational Responses** ..... 685
Khalda Ali, Maram Alzaidi, Dimah Al-Fraihat, and Amir M. Elamir

**Model for the Organization of a Cyber-Physical Production System** .... 703
Miglena Temelkova

**A Deep Convolution Network-Based Pneumonia Identification from Thoracic X-Ray Imagery Scans** . . . . . 719
Kamal Upreti, Prateet Mishra, Manish Maheshwari, Prashant Vats, Aisha Dhankar, Reenu Batra, Saneh Lata Yadav, Tanvi Chawla, and Jayant Bhardwaj

**Earthquake Monitoring with MEMS Sensors** . . . . . 729
Vasileios Konstantakos, Ioannis Sofianidis, Konstantinos Kozalakis, Kostas Siozios, Stylianos Siskos, and Theodore Laopoulos

**Self-supervised Learning Approach to Local Trajectory Planning for Mobile Robots Using Optimization of Trajectories** . . . . . 741
Juan Escobar-Naranjo and Marcelo V. Garcia

**Social and Technological Impact of the Simple Taxation Regime on Business Formalization in Colombia in Post-pandemic Times** . . . . . 749
Jasleidy Astrid Prada Segura

**Detection of COVID-19 from X-Ray Images Using Machine Learning Models** . . . . . 759
Md. Masrul Sakib, Meem Karim, Aftab Miraj Swachchha, and Maheen Islam

**Evaluation of Single-Stage, Two-Stage, and Anchor-Free Object Recognition Methods for UAV Detection** . . . . . 775
Rashed Khamis Al Romaihi, Abdelhak Belhi, and Rachid Hadjidj

**A Concept for Restructuring the Production Systems into Cyber-Physical Production Systems** . . . . . 785
Miglena Temelkova

**Impact Assessment of 'ICT Practices' on 'Supply Chain Management Performance' in Automotive Industry in India** . . . . . 795
Jagdeep Singh, Shivoham Singh, Mamta Kumari, and Surendra Kumar Vyas

**An Experimental Study of Machine Learning Algorithms for Predicting Start-Up Success** . . . . . 813
Ajai Mishra, Dharm Singh Jat, and Durgesh Kumar Mishra

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# AI's Role and Application in Education: Systematic Review

**Abdulsalam K. Alhazmi, Fatima Alhammadi, Adnan Abdullah Zain, Ezzadeen Kaed, and Balquis Ahmed**

**Abstract** Artificial intelligence (AI) is advancing at a phenomenal rate, and its applications have permeated our daily lives and changed the way humans learn. However, its use in education has been fraught with difficulties and ethical concerns. The goal of this study is to examine the potential, advantages and problems associated with the use of AI in education. A systematic review approach was used to identify the current research emphasis and offer an in-depth analysis of the function of AI technology in education. A total of 46 related articles were identified from the Scopus database. Three key themes emerged from the review: learning, education and teaching. The findings of this review paper demonstrate that AI has the ability to play a significant role in education and enhance the students' learning experience. It not only assists teachers but is also useful for students too. With the help of AI, new techniques can be developed that can aid in efficient and effective learning and tutoring. This study fulfills the gap in current literature by offering a thematic analysis of the role of AI in education and provides analysis for researchers and practitioners for enhancing AI's contribution in education. The study also highlights that meta-analysis should be employed to understand the effect of AI's role in education.

**Keywords** AI · Education · Role of AI in education · E-learning

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## 1 Introduction

The first artificial intelligence (AI) is a field of science that creates and studies technologies targeted at stimulating human intellect processes. The primary goal of AI is to improve the speed and efficiency of everyday tasks. Consequently, usage of AI is increasing throughout the world [1]. Recent advances in artificial intelligence have had a significant impact on individuals and their daily lives. As the introduction of artificial intelligence and machine learning continues to gain popularity among the general public, its use in a variety of devices, apps and services is becoming more prevalent [2, 3]. AI technology is not only employed in automated parking systems, smart sensors in photography apps and personalized software support, but it has also changed how people learn and how they use technology. AI has advanced swiftly, not just in works of fiction where robots show AI and human-like features, but also in real life, where AI has evolved to deliver a wide range of specialized benefits in virtually every area, including manufacturing. It covers everything from Google's search engines to self-driving vehicles to automated weaponry, and it is constantly evolving [1].

Artificial intelligence (AI) has had a substantial impact on nearly every aspect of human life, including the education system. Since the launch of the first generation of personal computers in the early 1980s, technology has played an important role in education [3]. Instruction, research and documentation of students' grades are among several tasks for which teachers used computers in the classroom. Among students, the use of computers was also common, with pupils employing them for a range of functions such as learning, research and problem-solving. Additionally, computers have been used as a resource platform, such as a library, as well as an information database.

Today, artificial intelligence (AI) technology is transforming schools and classrooms, making instructors' tasks significantly simpler [4, 5]. Over the years, education has seen a gradual but consistent transformation in the materials it uses from the usage of blackboards to whiteboards and, more recently, to the use of projection displays in the majority of educational institutions. Despite the fact that there has not been substantial progress in the use of artificial intelligence in education since the twentieth century, research has demonstrated that the use of AI in education has been steadily improving via the use of various virtual aided applications [6].

The mid-2000s saw a resurgence of interest in "big data," the mining of data from the education sector and the use of technology to help students study at their own pace [1]. These same customized education frameworks are used to defend, promote and advertise artificial intelligence-based solutions in education [7, 8]. The worldwide education business is a multibillion-dollar enterprise. Pearson has been particularly enthusiastic about artificial intelligence in education, and this firm has supported it for over ten years, by endorsing big data analytics and promoting the development of customized AI teaching and learning applications [1].

AI has become increasingly popular in learning practices as a result of advances in information technology. Examples include adaptive learning frameworks, teaching

robots, learning predictive analysis dashboards, e-learning systems and human–computer interactions [8]. Almost three decades after its introduction in education, AI has been identified as a strong tool for generating new perspectives in educational design, technology development and research [9, 10]. Artificial intelligence has emerged as the dominant research focus in the subject of computers and education, with the potential to revolutionize education, perception and society [10]. While AI has the potential to alter education, successful educational results are seldom achieved simply by using sophisticated AI computer technology [2, 9, 11]. Not only are computer programming abilities required for constructing intelligent tutoring and adaptive learning systems, but they are also necessary for replicating the intellect of human specialists. Human tutors use their expertise and experience to address difficulties and help students learn more easily. These difficulties arise as a result of AI's significant reliance on technology and its interdisciplinary nature. Without an understanding of the roles of AI in education and how AI technologies work, researchers may be unable to properly integrate AI applications and activities, let alone raise and investigate important AI research concerns. AI in education is not just a focus of educational data scientists and learning science professionals. For educational technology businesses and philanthropic investors that assist AI-enabled businesses as part of the development of student-centric learning software executed by machine learning, this is a big commercial problem [12].

This study examines the role of artificial intelligence in the education sector. Numerous tactics may be utilized to enhance education and attract students. Two examples are virtual reality and e-learning that have benefited students and educators alike. Additionally, the standard teaching technique may be enhanced using AI technology in education. Today, smart devices have made educational materials easier to find [3]. Several administrative duties have been automated through the use of AI in educational institutions, and others are currently being mechanized in order to give teachers more time to spend with their students [3, 5]. An AI program might act as a tutor, observing the students' learning processes, analyzing their performance and providing immediate assistance based on their requirements. With an understanding of the characteristics and attributes of AI technologies, educators can implement appropriate AI applications in their classrooms to improve students' learning performance, motivation and participation, while academic researchers can investigate the impact of the AI applications.

Although research studies covering AI classifications, strategies, research problems, challenges and future applications are available, limited research exists on the diverse roles of AI in education and the extent of influence AI holds in educational practices [6, 9, 10, 13]. The primary goal of this systematic review paper is to analyze, synthesize and identify the key themes of AI in education to fill the theoretical gap in the literature and offer a roadmap for policy makers, institutions and researchers to better understand AI usage in education. The following section explains the complete review of the reporting and finalizing of studies, followed by results, discussion, conclusions and recommendations for future research.

## 2 Materials and Methods

This section addresses the study's methodology. This includes the study's design, eligibility criteria, data sources and search approaches, as well as the review process and data analysis. Thematic synthesis of the research was carried out in accordance with [14] and [15] guidelines for study design. Thematic analysis assists the researcher in identifying and analyzing recurring themes in the data [14]. A defined theme analysis is a four-step process that includes searching, selecting, extracting and thematically synthesizing.

### *2.1 Searching*

The research to find relevant studies began in April 2021 utilizing Scopus, among other databases. Given that the purpose of this article was to analyze the role, problems and advantages of AI in education, the search included cognate phrases such as "AI," "Education," "Role of AI in Education," "benefits of AI in education" and "challenges." This database was chosen because Scopus has over 22,800 journals and 5000 publishers worldwide. The research yielded 369 publications, which the researchers began selecting and finalizing. Due to the fact that the database and associated search engine operate uniquely, adaptive searches were critical.

### *2.2 Selecting and Extracting*

After defining the keywords and conducting a search for relevant articles, the selection and extraction phases began. This step included a thorough screening, which resulted in the deletion of duplicate articles. The articles were chosen from the period between 2011 and 2021, which was an adequate timeframe to grasp the similarities and concerns critical to AI in education. Additionally, steps were taken to ensure that the topic was aligned with the study, with the primary focus on artificial intelligence in education.

Almost 12% of all the results returned by the search above met the requirement for the role of AI in education. Following a thorough examination of the publications, 46 met the criteria for identifying the role of AI in education. Apart from following the criteria of [1], this inclusion and exclusion are also consistent with the [3] study. The method is depicted in detail in Fig. 1.

The articles selected for this study are those which represent and identify the role of AI in education. Table 1 below shows the list of thematically synthesized articles.

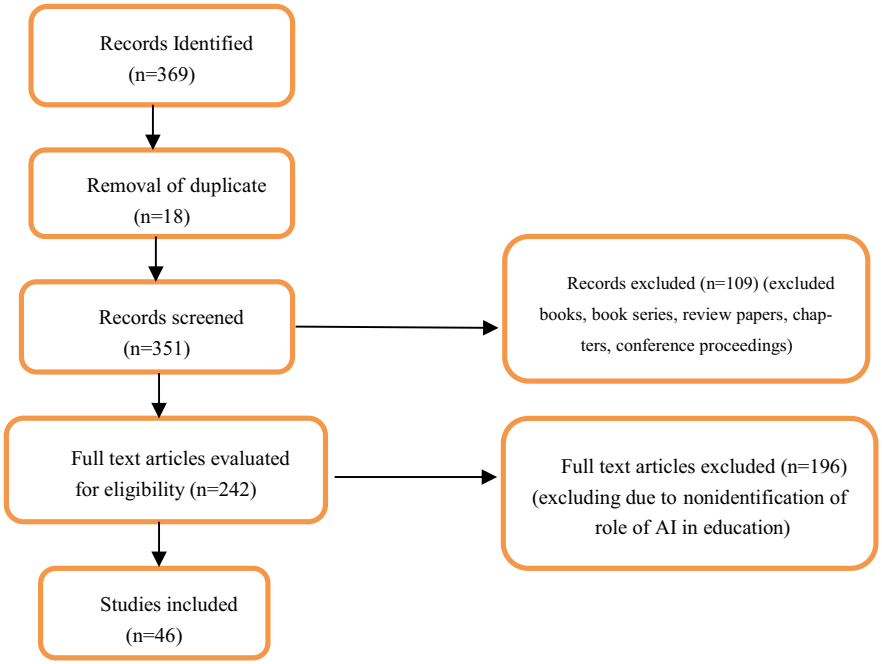


**Fig. 1** Thematic analysis steps

## 3 Results and Discussion

This section thematically addresses the findings from the systematic review of the literature. Furthermore, the implications, limitations and future directions for research are also presented in this section. The study's thematic synthesis took place in two stages. To begin, researchers summarized all excerpts and identified common themes. Next, synthesis was accomplished by categorizing and classifying the various similarities, benefits and concerns found in the studies. Three main themes emerged from the literature emphasizing the role of AI in education, namely learning, education and teaching. The findings provided an all-inclusive analysis of the role of AI in education. Referring to Table 1, it can be observed that one (1) study was published in 2011, 2015, 2017, three (3) studies in 2014 and 2016, four (4) in 2018, eight (8) in 2019, nineteen (19) in 2020 and sixteen (16) in 2021.

**Table 1** Thematically synthesized articles

| No | Author | Learning | | | Education | | | Teaching | |
|---|---|---|---|---|---|---|---|---|---|
| | | LP | LE | LPR | DE | OE | PE | ITS | TA |
| 1 | [16] | ✓ | ✓ | | ✓ | ✓ | | ✓ | |
| 2 | [17] | | ✓ | ✓ | | | | ✓ | ✓ |
| 3 | [18] | | ✓ | ✓ | | | | ✓ | |
| 4 | [19] | | ✓ | ✓ | | | | ✓ | |
| 5 | [20] | ✓ | ✓ | | | | | | |
| 6 | [21] | | ✓ | | ✓ | ✓ | ✓ | ✓ | |
| 7 | [22] | | ✓ | | | ✓ | | ✓ | |
| 8 | [4] | | ✓ | | | ✓ | ✓ | | ✓ |
| 9 | [23] | ✓ | ✓ | ✓ | | ✓ | ✓ | | |
| 10 | [24] | | ✓ | | | ✓ | | | |
| 11 | [25] | | ✓ | | ✓ | ✓ | | ✓ | |
| 12 | [26] | ✓ | ✓ | | | | ✓ | ✓ | |
| 13 | [27] | | | ✓ | | | | | |
| 14 | [28] | | ✓ | ✓ | | ✓ | | ✓ | |
| 15 | [29] | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ |
| 16 | [30] | | | | | | ✓ | ✓ | |
| 17 | [31] | | ✓ | ✓ | | | ✓ | | |
| 18 | [32] | ✓ | | | | ✓ | | ✓ | |
| 19 | [33] | | | ✓ | | | | ✓ | ✓ |
| 20 | [34] | ✓ | | ✓ | | ✓ | | | |
| 21 | [35] | | | | | ✓ | ✓ | | ✓ |
| 22 | [36] | | ✓ | | | ✓ | ✓ | ✓ | |
| 23 | [37] | ✓ | ✓ | | | | | | ✓ |
| 24 | [38] | | ✓ | ✓ | | ✓ | ✓ | ✓ | |
| 25 | [39] | | | ✓ | | ✓ | | ✓ | |
| 26 | [40] | | ✓ | | ✓ | ✓ | | ✓ | |
| 27 | [41] | | ✓ | | | ✓ | | ✓ | |
| 28 | [42] | | ✓ | ✓ | | | | ✓ | |
| 29 | [43] | ✓ | | | | | ✓ | | |
| 30 | [44] | | | ✓ | | ✓ | | | |
| 31 | [45] | | ✓ | | | | ✓ | ✓ | |
| 32 | [46] | | | ✓ | | ✓ | | | ✓ |
| 33 | [47] | | ✓ | | | ✓ | | | ✓ |
| 34 | [10] | | | | | ✓ | ✓ | ✓ | |
| 35 | [48] | | ✓ | ✓ | | | | | |

(continued)

**Table 1** (continued)

| No | Author | Learning | | | Education | | | Teaching | |
|---|---|---|---|---|---|---|---|---|---|
| | | LP | LE | LPR | DE | OE | PE | ITS | TA |
| 36 | [49] | | ✓ | | | ✓ | | | |
| 37 | [50] | | ✓ | | | ✓ | | ✓ | |
| 38 | [51] | | | ✓ | | ✓ | ✓ | ✓ | ✓ |
| 39 | [52] | ✓ | ✓ | | | | ✓ | ✓ | |
| 40 | [53] | | | | | ✓ | | ✓ | ✓ |
| 41 | [54] | | | | | | | | |
| 42 | [55] | | ✓ | | | ✓ | | ✓ | |
| 43 | [56] | | ✓ | | | | ✓ | | |
| 44 | [57] | | | ✓ | | | | | |
| 45 | [58] | | ✓ | | | ✓ | | ✓ | ✓ |
| 46 | [59] | ✓ | ✓ | | | ✓ | | | |

LP = Learning process; LE = Learning environment; LPR = Learning performance; DE = Distance education; OE = Online education; PE = Personalized education; ITS = Intelligent teaching system; TA = Teachable agent

## *3.1 Importance and Key Benefits of AI in Education*

Artificial intelligence is advancing at a frenetic pace, with far-reaching implications for our society and education. While there is still more work to be done, the influence of AI on particular vocations and professions is already evident. Researchers have discussed numerous papers in the earlier part (see Table 1) that demonstrate the impact of AI on education. AI has a plethora of implications for the education industry. There are a number of ways in which AI can assist students with their education. Consequently, instructors may be able to devote more time to mentoring and coaching, such as assisting students in developing social-emotional skills, which are in high demand among pupils.

From the standpoint of education, AI can serve different roles; for example, it can act as an intelligent instructor, tutee, learning tool/partner or policy adviser, as seen in Table 1. In terms of learning, AI can assist as an intelligent tool for enhancing and understanding the learning process, learning environment and learning performance of the students. The availability of an intelligent learning tool or partner is critical from a constructivist and student-centered learning perspective [46, 47, 60]. AI can assist learners in efficiently and effectively collecting and analyzing data [34], allowing them to concentrate on crucial points or higher order thinking (e.g., inference and prediction) rather than on low-level activities (e.g., editing and calculation). Certain technologies may even analyze and show data in a "smart" manner, assisting learners in thinking critically and identifying valuable insights hidden within the data. For example, classic Mind Tools, such as concept mapping tools, help students to organize their knowledge by passively linking the links between ideas. In comparison, an

intelligent knowledge mapping tool might advise or assist learners [53] during the concept mapping process, as well as evaluate the created concept maps.

Furthermore, AI also plays a key role in developing an enhanced learning environment which as a result increases the learning performance of a student [17, 50]. The learning environment is suitable for a wide range of students' ages and knowledge levels due to the variety of game types and difficulty levels and the core action of picking excellent cards being relevant and achievable by all skill levels (from guesswork to advanced strategic reasoning). Furthermore, the researchers [17] observed that almost all the students were engaged, and engagement is required in order to learn in an optimum way. Thus, it is critical to drive engagement by pairing problems and challenges with rewards and inspiring activities [17]. Additionally, it was also noted that a good learning environment blends into learning and guides students and teachers toward interactive learning [50]. Furthermore, studies such as [24, 28, 48, 50, 61] also demonstrated that AI plays a vital role in enhancing the learning environment and thus as a result benefits the education sector from the perspective of both the teachers and students.

The studies reviewed for this paper also highlighted the importance of AI in distance education and online learning. Researchers such as [28, 30, 51, 52] noted that AI applications have huge potential for education. For example, an intelligent tutoring system supported through AI can help students learn new concepts at their ease, thus giving them an experience of personalized education. This approach will catapult remote education into a new era of intelligence and create a movement of intelligent education technologies. AI could play a key role in distance learning and online education and could provide students with a unique education experience and guide teachers to develop more constructive and useful content [37, 40, 49]. A focus on integration of new emerging AI technologies with e-learning systems will contribute to improve students' experiences and learning [62].

An intelligent teaching system is one of the key AI applications used to enhance education and provide unique experiences to students. A study [42] noted that intelligent teaching systems are proposed because they can collect and control data intelligently, thus providing a better understanding of the students. While the standard online education system provides multimedia reading material that incorporates sound, text and images, the intelligent teaching system may give an all-encompassing open interactive teaching environment. For students to study freely, this intelligent system employs computers to imitate experts' and professors' thinking processes and innovative teaching approaches including AI technology and multimedia. As a result, the effect of instruction is substantially optimized. The key to an intelligent teaching system is its ability to assess the impact of learning on the student and to make appropriate suggestions, therefore realizing the intelligence of the learning process [51]. In addition, intelligent teaching systems enable the implementation of a range of teaching and learning approaches, including discovery learning, inquiry learning and collaborative learning, therefore increasing instructor efficiency and assisting students in developing individualized learning and creativity [63].

### *3.2 Challenges in Implementation of AI in Education*

One of the primary goals of the learning environment is to engage young pupils in meaningful mathematical enquiry that promotes knowledge. A critical aspect of developing this learning environment is motivating students to take risks and assisting them in acquiring the information necessary to play successfully.

Another challenge identified from the literature was that building intelligent tutoring and adaptive learning systems requires both computer programming abilities and approaches for imitating human expert intelligence. The latter includes human tutors' expertise and experience in making judgements and choices based on the best available evidence to assist learners in solving problems and improving their learning [10].

Furthermore, other than the above-mentioned challenges, some of the other challenges identified from the literature are the lack of specialist staff to run the software, a lack of infrastructure, lack of teacher trainers and developing skills related to computer usage and increased isolation due to indirect communication because not everyone is required to be in one place as required in traditional learning [26, 46, 52].

Finally, ethical challenges raised by AI are also a source of contention for academics and educators. It is evident that AI has advanced significantly over the last number of years, due to lower processing costs and increased data availability; yet, individual student data may be disclosed, shared or used incorrectly. It is a continuing challenge for educators and artificial intelligence technologists to explore how we access, assess and distribute massive data and the outcomes of data analysis [35, 55, 56].

These difficulties arise as a result of AIED's strong reliance on technology and cross-disciplinary nature. Without an understanding of the roles of AI in education and how AI technologies work, researchers may be unable to properly apply AIED applications and activities, let alone raise and investigate significant AIED research concerns. Therefore, understanding the issues and challenges of deploying AI in education is vital. Even though researchers are focusing on developing models to resolve these challenges, new challenges are arising due to the technicality and high skill requirements. Currently, there is no single fit for all as various institutes have faced various challenges. Currently, positive results have been identified in the areas of engineering and biological sciences, but it would also be interesting to use AI in other fields, such as designing courses and e-learning systems [62]. By incorporating AI technologies into new domains and examining new concerns, researchers may be able to identify solutions to problems that cannot be handled using the standard technology-enhanced learning technique [47, 56].

## 4 Results and Discussion

Advances in artificial intelligence have ushered in a new era of computer-assisted education. By combining human intellect, a computer system may act as an intellectual tutor, tool or tutee and assist in educational decision-making. The marriage of artificial intelligence and education will create new opportunities to increase the quality of teaching significantly. Instructors can take advantage of sophisticated systems that assist with assessments, data collection, progress monitoring and the development of new techniques. Individuals can learn from intelligent tutors and asynchronous learning in order to improve their academic performance. Additionally, integrating AI into education transforms not just education but also human knowledge, cognition and civilizations. As a result, AI in education has emerged as a primary area of research in the subject of computers and education.

With the increasing expansion of artificial intelligence, there is an urgent need to understand how educators can best leverage AI approaches to ensure students' academic achievement. This study examined the role of AI in education from 2011 to 2021. Three major themes emerged from the reviewed literature: learning, education and teaching. The benefits of AI were clearly observed in the study highlighting how AI can be a crucial tool in education. Furthermore, with the help of this study, the challenges associated with AI in education were revealed in relation to methodology, teacher and student responsibilities and social-ethical concerns. These findings may serve as valuable references for educational academics, students and artificial intelligence developers who wish to contribute to relevant studies. Additionally, it is also recommended that instructors collaborate with the AI developers to ensure a bridge between pedagogy and software. This method prepares students not just for professional careers but also for meaningful lives in a complex world.

## 5 Limitations and Future Research Suggestions

Even though this study gives some valuable insights and understanding about the role of AI in education, there are still some limitations. Firstly, the articles analyzed in this study were selected from the Scopus database, while other databases such as WoS or Proquest were not explored. Furthermore, sources such as reports, books, news and conferences were not included in this study. They could be incorporated in the future in order to offer a more comprehensive overview of the role of AI in education.

Secondly, while the current study gives a systematic overview of the role of AI in education, the analysis presented here may serve as a platform for future research integration; however, quantitative perspectives could still be explored. For example, a more formal meta-analysis may be undertaken on a subset of empirical research that revealed effect sizes to determine AI's role in education. Additionally, future

studies could attempt to go back further in history to explore how AI first made its way into education.

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# Digital Service Quality from Elderly Generation Perspective to Improve Online Business and Economy: A Theoretical Framework

**Jamaiah Yahaya, Aziz Deraman, Yusmadi Yah Jusoh, and Sathya Nantha Kumar**

**Abstract** During the current COVID-19 pandemic, older people are encouraged to use information, communication and technology in their everyday lives and discouraged from physical interactions. In Malaysia, it shows that implementing the Movement Control Order (MCO) to control the spread of the COVID-19 pandemic saw a shift in consumer trends, prompting businesses to explore new strategies to interact with consumers. But there is no study indicating the contributions of older people in this new business environment. Several complaints were reported regarding the usability, acceptability, and suitability of these applications for the elderly. The objectives of this study: (1) to investigate issues and challenges on older citizens in current software design quality; (2) To identify current practises on software usage amongst the older citizens, especially in e-commerce and e-business applications; and (3) To propose a model a software design quality that meets older people requirements, limitations, and expectations. The new model helps the developers design and construct software compatible with the elderly based on a quality perspective.

**Keywords** Elderly software quality model · Older generation · Digital service quality · Theoretical framework

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## 1 Introduction

"Digital service" refers to any services carried or subscribed over the Internet or other electronic medium or system to the people and public. The service cannot be attained without using information, communication and technology (or ICT), and the service delivery is automated. In recent years, due to the COVID-19 pandemic, digital services have become more common and avoidable to all generations and levels of people, from school children to the elderly age.

The COVID-19 coronavirus crisis started in 2020 and has emphasised the importance of including older people in the digital world when all activities must be carried out virtually and digitally. A question arises in the software community: How can software firms design products to include generations that came to maturity before the internet? Even before the COVID-19 coronavirus pandemic, designing software to work well for older people was necessary and made sense. According to [1], "longer lifespans have significantly increased the number of older people worldwide, and this trend is continuing. The United Nations expects that by 2050, those aged 65 and above will outnumber the under-25 s in Europe and northern America. But many older people do not use computers. In the UK, only 76% of those aged group had used the internet in the past three months, and just 61% used the internet daily or almost daily." The findings were reported based on the 2019 data by the National Statistics Office [1].

During the COVID-19 pandemic, older people are encouraged to use IT and software in their daily activities and discouraged from physical interaction. In Malaysia, it shows that implementing the Movement Control Order (MCO) to control the spread of the COVID-19 pandemic saw a shift in buyer styles and tendencies, triggering businesses to explore new approaches to interact with customers. Shopee found that the number of Shopee transactions from products and sellers has increased 70 times since the pandemic [2]. At the same time, complaints have been reported regarding the usability, acceptability, and suitability of these applications for more senior citizens. The presence of older people in the design and evaluation of the software applications are needed to ensure their requirement and expectations are met.

## 2 Background Study

Initially, people far younger than the target group designed the software design and assessment practises and processes. The scenario leads to tensions and inconsistencies between practitioners and older consumers [3] regarding their desire, needs, and satisfaction. The consequences of this situation are low usage of software applications that support businesses' sales, unmet demands of older consumers, and frustration and disappointment with the services and products on the online business market [4]. This gap shows that businesses and software engineers need to understand better older consumers' behaviours towards software usage, including their

online and e-commerce behaviour. Gaps of e-commerce knowledge amongst the elderly include how the software and the services are accessed and the system's suitability for their generation. Age factor needs to be considered for supporting designing, advertising, and retailing activities [5] via e-commerce applications. The gaps in knowledge around the technology used by older consumers for e-commerce purposes and variations are overage due to the lack of experience with the current fast-moving technology itself. Understanding the ability from an age perspective and access to e-commerce may increase the e-commerce activity and improve the system development quality [6].

## *2.1 The Elderly Generation*

In Malaysia, the country's total population aged 65 and above increased to 2.23 million in the fourth quarter of 2019 compared to 2.14 million for the same period in 2018 [7]. Based on United Nations (UN) projections, Malaysia is expected to become an older country by 2030, when the population aged 60 and above reaches 15% of the country's total population [8]. Older adults still have difficulty using computers and software in their lives [9]. Similarly, Ref. [10] revealed that on COVID-19 hardship survey discovered that elderly individuals or those in rural areas might not have the Internet access or expertise to secure their benefits in using software apps during the pandemic.

In developed countries, the number of older adults forms 24%, and this number will rise to 33% by 2050. Therefore, there is a need to prolong the active life of older people who want to lead an active, fulfilling, and quality life in their inclusion, socialisation, and independence. Current trends show an essential role of information and communication technologies in this process, especially in this pandemic COVID-19 era. The importance of IT amongst older people was revealed, and it was necessary to explore mobile devices acceptance amongst older people [11].

A paper published by WHO on supporting and protecting older people during the coronavirus pandemic highlighted that everyone is supposed to support and protect older people living alone in the community is everyone's business [12] to ensure their lives are safe and healthy. This support is also concerned with using software applications.

The previously collected data indicated that the elderly aged 65 and above use of technology has increased. But at the same time, this generation is seen as excluded or marginally represented in the digital sphere. The COVID-19 coronavirus pandemic and its general shift to digital life have created a critical need to increase the digital inclusion of older persons [13]. It is vital to study hybrid ways that may involve high-tech and low-tech strategies to deliver trustworthiness amongst older adults in using digital data and services. The hybrid approach will focus on balancing digital and personal touches for the target user group to enhance preparedness and prevention of COVID-19 spread. Furthermore, this topic is essential given the rise of e-commerce and the increased expectation from many businesses (and other organisations) that

all consumers and society are digitally and technology-enabled. Older consumers' competencies in virtual activities are essential for businesses and other community social interactions in today's expectations.

## 2.2 Software Product Quality Model

Literature review shows that there are two categories of software quality models. Several quality models for software and services have been developed, and amongst the well-known are McCall, Boehm, FURPS, ISO 9126, Dromey, and ISO/IEC 25010. Many further works were continued using these basic software quality models as the baseline. McCall's quality software model was first developed around the 1970s and was built in a tree-like design with branches. Even though this model is the oldest software product quality model, it is still valid. Then, a new quality model was developed, known as ISO9126. It was an international standard model widely used as a baseline in research projects in this field.

The ISO9126 model was modified and enhanced to meet the current demand in software quality to establish a new ISO25010 quality model. It determines which quality characteristics will be considered when evaluating the properties of a software product. ISO 25010 quality model consists of eight main quality attributes. Most of the mentioned fundamental quality models focussed on quality attributes' behavioural and technical perspectives. Many extended works were carried out based on these basic models to develop a group of derived quality models such as the PQF model [14], UcSoftC model [15]. These new models focus on user assessment and are based on the user's product quality perspective. This approach was not included in previous quality models.

## 2.3 Digital Service Assessment

Software measurements can be categorised as direct measurements and indirect measurements. Measure and measurements are the essential elements of digital service assessment where quality is not directly measured. Indirect measurement of a software product consists of functionality, complexity, efficiency, reliability, and other attributes that cannot be measured directly. This feature can be measured if broken down into sub-features and metrics that can produce measurable metrics.

Software quality assessment is vital from the different perspectives: technical and human perspectives. Software product assessment means assessing and estimating a product that can meet the desired quality characteristics based on a specific target. For example, the quality model can be constructed from a management perspective [16] and an end-user perspective [14, 15, 17]. The attributes defined in these different models determine the quality status based on the target groups.

## 3 Problem Statement

Many software design activities and marketing practises are devised by people from afar younger group generation. The different generation involvement leads to tensions and discrepancies between practitioners and older users or clients [3]. This results in lower product sales in the businesses, unmet services demand by older consumers, and dissatisfaction with products and services [4]. Companies need to understand older consumers' behaviours, including their online and e-commerce behaviour using digital services. Gaps in ageing knowledge include how goods and services are accessed, and the system's suitability from the elderly perspective is still unknown. The previous study [5] stated that age needs are essential for all marketing and retailing activities. The gap in knowledge about the technologies used by older citizens for e-commerce and other purposes such as social interaction is most likely due to a lack of experience with today's rapidly changing technologies. Understanding the ability from an age perspective increases intervention in e-commerce and system development and quality [6].

In the current COVID-19 pandemic, older people are encouraged to use IT and software applications in their everyday lives and discouraged from physical interactions. In Malaysia, it shows that implementing the Movement Control Order (MCO) to control the spread of the COVID-19 pandemic saw a shift in consumer trends, prompting businesses to explore new strategies to interact with consumers. E-commerce platform such as Shopee and Lazada has shown a tremendous increase in purchasing online since the outbreak. But there is no study investigating the contributions and involvement of the elderly in this new business environment. At the same time, complaints have been reported regarding the usability, acceptability, and suitability of these applications for older citizens. Older people are recommended to be included in the design and quality evaluation and assessment of software applications that meet their requirements and expectations.

## 4 Methodology

The description of the research methodology is explained in this section. The method is carried out in four main phases, as illustrated in Fig. 1.

### *4.1 Phase 1: Conceptual Design*

The current state of the art in software design and quality for the digital services impacts the older generation will be reviewed and updated. This phase examines the existing issues and challenges in software design quality amongst older or senior citizens. The conceptual framework that consists of the theoretical findings will

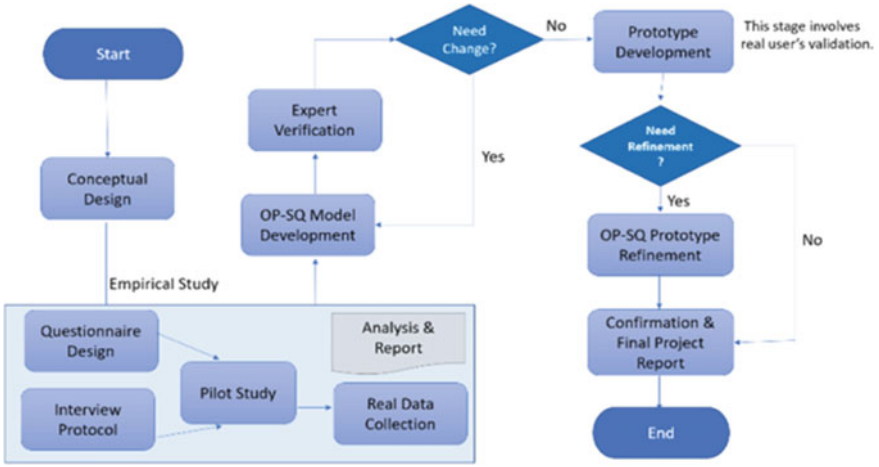


**Fig. 1** Flow chart of research activities

be outlined. Issues and challenges on older citizens in current software and digital services design will be outlined in this phase.

## *4.2 Phase 2: Empirical Study*

This phase will involve surveys and interviews with the elderly. The activity starts with designing the questionnaires and the interview questions. Experts will validate both interview questions and questionnaires through content validation. The pilot test will be conducted to verify the reliability and validity of the instruments. The actual survey will be conducted whereby questionnaires will be distributed to appropriate respondents in Malaysia. The empirical study is the most prevalent methodology in information systems and software engineering nowadays.

The sampling technique is stratified random sampling, which involves respondents from the elderly generation (60 years and above) in Malaysia, both Malaysian and Non-Malaysian citizens. The respondents and informants are the older people aged 60 and above, both male and female. The outcomes from this empirical study will reveal the key issues and challenges, current practises, and quality perspectives in software applications usage by the older generation, especially in e-commerce and e-business applications.

### *4.3 Phase 3: Model Development: The Older People Service Quality Model (OP-SQ)*

The third phase proposes an appropriate digital service design model that meets elderly requirements and expectations. The development of the older people and elderly service design and quality model (or the OP-SQ model) will be based on the empirical and theoretical study findings. The model will consist of components, features, and characteristics suitable for older people's software apps design and will be verified by the experts.

### *4.4 Phase 4: Model Validation Through Prototype Development*

The last phase is to develop a prototype of elderly digital services design based on the proposed OP-SQ model. The OP-SQ model's components will be mapped into the prototype design and development. The prototype will be tested through the alpha test in the laboratory and beta testing, which involve real system users. Feedback from the testing and validation will refine the model and prototype.

## 5 The Theoretical Framework

The theoretical framework overview the definitions, theories, and concepts involved in the proposed study. Figure 2 shows the theoretical framework of the digital services quality design for the elderly generation model. The framework offers the important theoretical components that need to be considered and studied during the theoretical and conceptual design. The framework design is vital to ensure that our proposed research and outcomes are valid and comprehensive based on previous and current works.

The primary outcome of this research is the software quality model (OP-SQ) based on older people's requirements and expectations, which will be derived from the survey findings and theoretical study. The implications and importance of the output of this study are to provide new knowledge in software quality that offers benefits and advantages to the elderly in using application software.

The novelty of this research is the survey findings based on older people and elderly requirements and expectations towards the current software application design and quality. The new OP-SQ model is a newly enhanced knowledge in software engineering that updates the existing software design and quality model that is suitable and acceptable for the elderly.

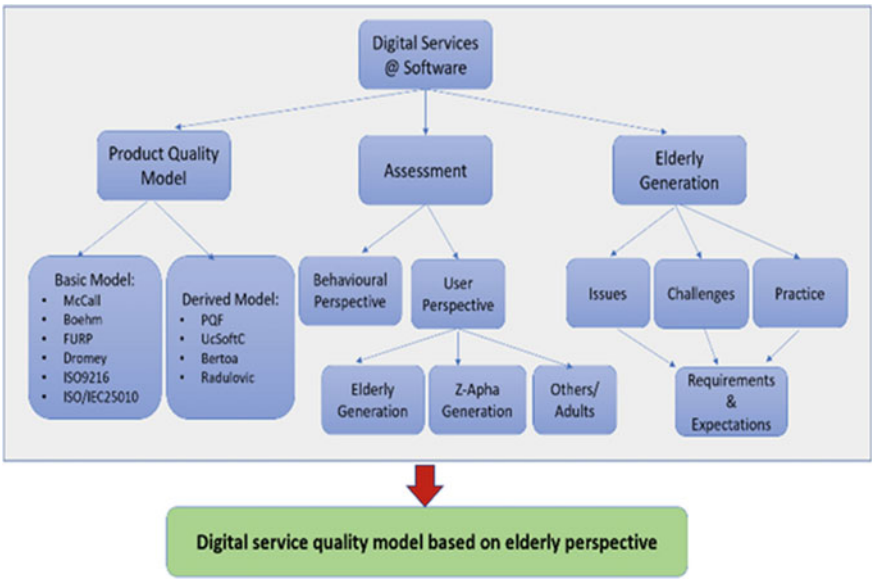


**Fig. 2** The theoretical research framework for the proposed OP-SQ model

## 6 Conclusion

This paper has presented the research proposal for the digital service quality based on the elderly perspective. A comprehensive methodology that consists of four main activities was explained to achieve the research objectives discussed in this paper. The model will be developed based on the empirical surveyed data, which elaborates the appropriate software application design and quality for the elderly. The implications and importance of this research project are to provide new knowledge in the software quality area that provides benefits and advantages to the elderly in using application software. The proposed OP-SQ model offers older people safer and more comfortable lives using online applications, especially during the pandemic. In addition, the result of this research supports the improvement of the economy and e-business where more older citizens participate in digital transactions and purchasing.

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# Green Software Product: The Empirical Study on Social Factor and Measurements

**Komeil Raisian, Jamaiah Yahaya, Aziz Deraman, and Siti Rohana Ahmad Ibrahim**

**Abstract** Today's digitised world is concerned with software products that highlight sustainability and green compliance with social requirements and expectations. Literature investigations reveal that many studies have focussed on green hardware. Nevertheless, little effort was proposed to ensure the greenness of software that complies with the specification. Green software products are essential because they may address issues related to sustainability and ensure that software can be used indefinitely. According to the current literature, investigations on the social sustainability of software products still have a deficit. The green elements are still needed for further investigation in the scope of green assessment of software products. This study aims to identify the principal factor and measurements of the social sustainability requirements of a green software product. The analysis of the factor and measurements shows strong relationships between them. The results are validated through the empirical study conducted with 102 respondents.

**Keywords** Green software product · Social factor · Green social measurements · Empirical study

## 1 Introduction

The use of software in this modern technological world has enormously affected the environment and social sustainability. Previous studies on green computing efforts focused on the environmental implications of sustainability. Still, there are limited

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outcomes of working models or frameworks in software-related subjects. In recent years, producing information technology (IT) products with eco-friendly green software has become the aim of the hardware and software industries. Thus, most software engineers focus on ecological products demanded by the communities and industries. In environmental sustainability, eco-friendly concepts are applied where it revolves around conserving power or energy, reducing carbon consumption, and reducing threatening and hazardous wastes. A similar idea is an understudy with the view of social sustainability, which may lead to green products.

Social sustainability implies maintaining social capital amongst societal groups and saving the unity and harmony of society. Social capital is essential to make up society's fundamental structure [1]. Ref. [2] explored the surrounding social sustainability issues in designing software that generates and enhances social values. It brings awareness to software systems' needs and thus gives direct and indirect effects on the human being towards a sustainable environment. Likewise, social sustainability can be defined as maintaining social investments and assisting societal groups in their associations in harmonised society. It makes the essential structure of society and is believed to reduce transaction expenditures and costs [3]. Additionally, [4] characterised social sustainability as a favourable and long-term situation inside groups, as well as a technique within groups to achieve and maintain that condition.

Previous studies [5–7] revealed that little effort in research had been made on the social sustainability within the software products. Scholars agreed that the earlier works did not include comprehensive dimensions of sustainability [8] except for a few studies that covered the three dimensions of sustainability. Therefore, in this dynamic environment amongst society and people, exploring the social dimension of a sustainable software product that impacts the community is significant since most people use the software in every aspect of their lives.

The structure of this document is as follows: section two discusses the background study, which focuses on social sustainability. It follows with section three, which presents the social sustainability of a software product respectively. The data analysis is presented in section four, and section five explains the relationship between the elements and measurements. Finally, this paper is concluded with a conclusion.

## 2 Background Study

Software that has an indirect or direct impact on society, people, the environment, or the economy as a result of its creation, deployment, or use is classified as sustainable software. It has a lesser unfavourable and maybe positive impact on long-term development [8]. Ref. [9] worked on the social sustainability concept, assessed social sustainability, and discovered substantial limitations in software sustainability and green assessment and measurements. The scope of this study only surveyed common factors in social sustainability and was not specific to the software domain. However, some potential elements of social sustainability and green elements can be identified, such as employee support, health, equity, education, security, social network, etc.

Chitchyan et al. [10] proposed the model related to personal and organisational prosperity as independent groups; thus, several concerns are present that these two should be a part of the more prominent social sustainability group. The gaps discovered include the appropriate tools and methodology, employee sustainability and tool support. Tool and employee support are the primary measurements of social sustainability in the software aspect [10]. Refs. [11, 12] investigated the social perspective of a software product by introducing a social compliance design and accountability design for the ability to maintain social sustainability through societal intervention and innovation. Each of the measurements is directly associated with the subjects of tool support and employee support under social sustainability for software production and development, as demonstrated by [9] and [10].

## 3 Social Sustainability in Software Products

According to [3], social sustainability entails preserving social capital and safeguarding sociocultural groups in their entirety. It is also defined as a good and long-term situation inside groups, as well as a technique for achieving and maintaining that condition [4].

### *3.1 Tool Support*

The term "tool support" refers to the provision of tools that support the work process of a software product [10]. Organisations of software developers use tools to support essential activities, converting client needs into valuable products. Automating software development activities such as analysis, design, implementation, and maintenance are usually supported by the CASE tools. However, there are challenges associated with the case tool usage, which can be related to applying tools and achieving the business goals.

In this study, the term "tool support" refers to the ability to help others with their tools in the process of developing software that meets user demands in producing suitable software products [10]. The main sub-factors of tool support in social sustainability [13, 14] to produce software products can be defined as follows: -

- *Eclipse plugins*: A component of software in Eclipse introduced as a plugin. The platform of Eclipse permits the software developer to enhance applications such as the Eclipse IDE (Integrated Development Environment) with more functionalities via plugins.
- *Transformations*: It is an outline of the transformations and projections toolset. The toolset may consist of tools that change geography data from the point of one map to another.

- *Lexical limitations*: In the viewpoint of computing, lexical analysis and tokenisation are the converting processes of a character's sequence.
- *Setting*: Tool setting identifies geometric information radius, length, or diameter of a cutting tool. It utilises specific software and a device of the toolset, then connects the information to control the machine tool.

Tool support plays the primary role more than individual tools capabilities that support software activities. The corporate ability to efficiently utilise the selected tools collection is essential to automating software production [15, 16]. The support partners with a range of skills to embed sustainable and green techniques are suggested. But, the growing choices and options related to approaches and tools for developing sustainability in software are almost inconsistent or conflicting [17]. Therefore, a systematic mechanism containing basic principles of sustainability is needed to prove that these tools are complementary and can be used with any sustainable software development.

### *3.2 Employee Support*

Offering and assisting employees in the organisation to utilise new tools in excellent software development activities is the definition of Employee Support [10]. This concept might be an exciting aspect of sustainability as every employee can be an "invisible green champion." Ricketts [14] stated that employees were one of the critical factors and secrets to successful and effective social sustainability in an organisation. Improving employee commitment to greening the businesses has several economic and social benefits; it can prompt a more persuaded, productive, and elemental workforce that comprehends the significance of good business morals and corporate obligations [18].

Employee support means support, and training given to the employees to learn new applications and devices and to use the software products [9] correctly. The following are the main sub-factors of employee support in the context to produce green software.

- Performance is considered the real-time advertising item as "Green". It is similar to a TCO Certified item that focuses on the environment and social responsibility.
- The equity category incorporates elements that must reveal equity assessments for everyone. In this aspect of social element and measurement, without considering their gender, ethnicity, age, and social status, provisions for fundamental disabled needs, children or elderly, and proper access are connected to employee support.
- Education indicators are linked to facilities of education provided for the community. This can incorporate the employee's educational or literacy levels, offered employee training areas, student numbers based per teacher, and information on public educational institutions [19].
- Ease of advice provides access to new technology (such as IoT and cloud environment), which can be a typical fight between project managers and team members

regarding their usage [20]. In some situations, fresh graduates are more socially appropriate for people management in specific projects, although having less-experienced team members from industrial backgrounds. Vice versa, there are also conditions in the software project management and software industry, in general, to encourage well-experienced software engineers in the team for green software compliance and new technologies adoption [14].

Keeping employees happy, joyous, and fruitful is crucial because these characteristics have been recognised as the most effective approach to maintaining a productive environment in organisations [21]. In this scenario, the green members are self-organised, famous amongst other employees, and interoperable with other staff and friends. They collaborate to develop and educate dynamic, active, and resilient employees through long-term planning and strategy. Since the term "green" has become more familiar and accepted, a rising number of workers desire to work for a firm that is devoted to sustainability and looks for opportunities to apply green practises. Similarly, employee functions of an organisation can foster a thorough approach to supervision culture and a sustainable environment [22]. The significance of this perspective in a long-term software development perspective can play a critical function in the organisational system.

Today's working from home approach due to the COVID-19 pandemic is being implemented as a new working norm globally [23]. Further study can be carried out to relate this factor as the improvement enables a green working environment for employee support.

## 4 Data Collection and Analysis

The list of acquired possible software companies from private and public sectors in Malaysia was identified. The potential respondents were contacted by phone, WhatsApp and email and invited to participate in this study. The total sample was 220 respondents; 148 (67%) respondents agreed to participate, and 72 (33%) declined. A total of 102 (or 69%) were found to be legitimate, which is a sufficient and acceptable number [21]. Distinctive methods were utilised to collect the data via questionnaires through manual or face-to-face (f2f) techniques, hard mail, and online interviews. F2f meetings were applied to ensure that participants understood each question and answered them accurately and adequately. Most respondents opted to respond to the surveys by email rather than in-person meetings due to the current COVID-19 outbreak. Thus, an online questionnaire was constructed and carried out in this study.

As one of the primary measurements for the social green and sustainability factor, employee support had obtained the "Most Important" consideration and rating from surveyed respondents. Employee support is considered a solid matter as every employee can become a champion in achieving the green target in software products. Besides, previous studies revealed that employee engagement was one of the top secrets to successful and effective social sustainability in organisations.

**Table 1** The degree of importance and interval values

| Degree of importance (DI) | Interval values |
|---|---|
| Not Important (NI) | 1.00–1.80 |
| Less Important (LI) | 1.81–2.60 |
| Neutral (N) | 2.61–3.40 |
| Important (I) | 3.41–4.20 |
| Most Important (MI) | 4.21–5.00 |

Boosting employees' dedication and obligation to greening the business and software development has several benefits towards social and monetary advantages. It can prompt a more persuaded, productive, and efficient personnel that comprehends the significance of good business morals, culture, and responsibilities.

Tool support plays a crucial function in social sustainability, mainly supporting software development activities. The company's ability to use a chosen collection of tools is vital to automating software development in the industry. The practices regarding tool support as a social sustainability measurement in software products were justified as a significant consideration in previous studies, as discussed earlier in this paper.

The respondents were further questioned regarding software product practices that must be performed to produce high green software. The mean value for each attempt was calculated, representing the participants' most preferred answer on average. The questions were answered on a 5-point numerical scale which ranged from Not Important to Most Important. Following that, using SPSS analysis, the scales were mapped to equal intervals. Formula (1) was used to compute the interval range.

$$\text{Internal range} = (n - 1)/n \tag{1}$$

where $n$ is the maximum number in the used scale, which is equal to 5. As a result, the considerable level of the interval size is 0.8, as shown in Table 1.

It was found that respondents mainly chose the 'Most Important' rating for both measurements, as presented in Table 2.

**Table 2** The score of social factors and measurements

| Measurement | Description | Mean | Degree of importance |
|---|---|---|---|
| Tool support | Tools that support work processes to transform customer needs into better and more valuable products | 4.37 | Most important |
| Employee support | Provide appropriate assistance and training to employees to learn and use new software tools | 4.38 | Most important |

**Table 3** The Cohen correlation strength guideline [24]

| Value of "*r*" | Strength |
|---|---|
| Weak | 0.10–0.29 |
| Medium | 0.30–0.49 |
| Strong | 0.50–1.00 |

## 5 The Relationships of the Measurements

To analyse the magnitude and direction of the variables, the Pearson correlation test is proposed. Table 3 indicates the correlation thresholds as suggested by [24], which stated that the score of 0.685 is a solid and significant relationship. Employee support shows the vital measurement to increase social sustainability and green in the software industry sector. According to the investigation, employee support is favourably related to the social aspect in the software product sustainability dimension (Relationship = 0.685). At $p$ .01, the correlation shows that the stated links are recognised. With a significance level of less than 0.01 ($p = 0.000$), the link is statistically significant; consequently, the relationship is acknowledged.

Similarly, many respondents strongly agreed (62%) that there is a strong link between social green and tool support (0.622). The findings show that Tool Support ($r = 0.622$) is positively related to the social sustainability of green software products. Thus, the claimed connection is recognised and accepted.

## 6 Conclusion

This paper has presented the recent literature concerning social factors and measurements about attaining green software products. Based on a sustainability perspective, we focus on the social factors and measures related to green software products. The identified measurements fulfilled the research problem by including the social elements and relationships expected to create a green software product. Two main measures of the social factors are determined from the literature: employee support and tool support. Further research was conducted involving an empirical study investigating and validating the proposed measurements. The findings reveal a strong relationship between the social factors and the measures: tool support and employee support. The results are also consistent with findings from the literature review as discussed in this paper. The social aspect of a green software product may lead to further exploration in the current COVID-19 pandemic, where the working from home (or WRH) approach has been adopted globally.

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# A Systematic Review and Future Perspective of Mental Illness Detection Using Artificial Intelligence on Multimodal Digital Media

**U. Ananthanagu and Pooja Agarwal**

**Abstract** In recent couple of years, social media platform has attained a tremendous growth in sharing information and become an integral part of everyday life. Such real-time information portrays one's daily activities by exposing their private space, behaviour aspects and emotions. With the wide range of availability of personal information on social media, it plays a prominent role on the process of individual's mental illness detection. Although, in the last few decades, mental illness rates create more attention, and also, many cases are not recognized as now. Indications related to the mental illness are visible on web forums, Facebook and Twitter; henceforth, computerized techniques are in demand in earlier detection of mental illnesses and depression. In this case, automated analysis of mental illness detection on social media may provide early accurate detection process. Studies have so far explored how the use of social networking sites is linked to mental illness in users or attempts to diagnose mental illness by analysing user-generated content. The review focuses on the confines of machine learning and deep learning techniques on the diagnosis of mental illness of the publications regulated from 2017 to 2021. Amidst current depression detection algorithm, we spotlight various transfer learning categories and scrutinize the issues. Finally, the presented work providing the research guidelines to the upcoming research works for the detection of mental illness based on transfer learning. The main motive of the manuscript focuses on future prospects of transfer learning-based mental illness detection on digital media stream.

**Keywords** Digital media · Artificial intelligence · Machine learning · Deep learning · Depression · Transfer learning

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## 1 Introduction

Mental disorder comes under the one kind of heath condition which can change the actions, mind and emotions of a person, and it will be effect on physical health of a person. Some of the mental disorder problems are schizophrenia, autism spectrum disorder (ASD), attention-deficit hyperactivity disorder (ADHD), depression. Nowadays, these are more common, and throughout the world, 450 million people are affected by these illnesses. Even though adults and under 18 age category persons also facing these mental disorders. Besides that, mental disorder is considered as the most dangerous and widespread health issue.

For instance, depression can be causing the disability and which may lead to raise the thoughts to commit the suicide. So that, to get a better knowledge on the mental disorder conditions and to take care of patient in a better manner can be done by detecting the mental disorder in early stages. Mental disorders are diagnosed by the self-reports of the person and which is used to identify the particular patterns of emotions or any interactions.

The extensive popularity on the social media gives a chance to decrease the undiagnosed mental disorders. There are numerous numbers of studies are presented for investigating the mental disorder within the social media behavioural along with anxiety, suicidality, stress, depression. In that, the major concern is depression. Depression can be diagnosed even though 13 to 49% people are taking appropriate treatment.

Therefore, for earlier detection, computerized investigation from the social media gives automatic methods. Whether computerized process detects the depression ranges of a user, that person accessed for several assessment because to give a better treatment and support. Computerized forecasting analysis of social media can be executed by developing a predictive framework, which utilizes the extracted features of the social media information.

By utilizing the learning algorithm, the forecasted features are trained. Where some of the data are trained in the training stage and rest of the data are used for the testing stage to prevent the overfitting, this is process named as cross-validation. To test the computerized system, the evaluation metrics are carried out. Moreover, artificial intelligence (AI) and machine learning (ML) methods are employed for increasing the knowledge about the mental illness stages, and also, these methods are used for supports the psychologist to improve the clinical decision-making. Furthermore, deep learning (DL) creates more concern because it transmits the information by the nonlinear computational processing units' layer; this will give a novel model to efficiently get a knowledge from the complicated data. So that in present times, DL methods exhibit better performance to the high data application sectors.

To identify the mental illness with the social media audio, text, images, and video, there must be issues related to the data. Thus, gathering the data and employing the appropriate algorithm for identifying the mental illness in an online environment becomes a challenging task. The major contribution focused on this review article is listed as follows.

- Identify and describe the key requirements to achieve essential procedures of implementing automated mental illness detection programme.
- We compared presently available methodologies and discussed their pros and cons to highlight new directions of research for further improvement in detection of individual mental illness detection.
- Finally, the presented work providing the possible research guidelines to the upcoming research works in depression detection of individuals from multimodal digital media.
- This paper provides better understanding and directs scholars and experts to acknowledge recent evolutions and new orientations in mental illness detection by transfer learning techniques in a better way.

## 2 Systematic Literature Review

Recent studies intended to be forecasting the mental illness through the social media are studied in this section. In addition, we present a detailed analysis of the accompanying research articles on ML, DL, and transfer learning-based approach to diagnosing individual illnesses.

### *2.1 Review Based on Machine Learning Techniques for Mental Illness Detection*

People share their valuable information on social media and that information is collected to predict mental illness using machine learning algorithms. ML techniques that develop computational algorithms or mathematical framework can automatically create hidden patterns from the information. In present times, numerous ML models are established for analysing the health data. However, standard ML methods need a large number of feature engineering in order to work effectively, and it is a necessary step in maximum application cases to get a better performance that may often consume resources and certain period of time. Some of the research works are reviewed as follows.

According to Lekkas et al. [1] the mental illness caused by the usage of digital media like Instagram is predicted by associating the SN (Online Social Networking) data with the machine learning algorithm. The SN data provide the information about the teenage user of Instagram which is used to estimate the performance of the cross-validated model.

Zulfike et al. [2] detected whether the social media users affected by the mental illness or not. This detection included six various machine learning classifier that utilized the information of psychosocial and socio-demographic. Methods like select K-best feature (selectKBest), Boruta feature selection algorithm, and minimum redundancy and maximum relevance (mRMR) are used for feature extraction process

whereas synthetic minority oversampling technique (SMOTE) is used to minimize the class imbalance and provide the accuracy. The drawback in this presented detection model is that it works only by considering Burns Depression Checklist for the depression detection. The mental illness occurred was identified by Facebook post; additionally, mood and attitude of the user are analysed whilst sharing information in social sites.

Tiwari and Das [3] analysed the behaviour and mental illness of the Twitter user for the irrelevant tweets. The data of the Twitter user are collected from the application programming interface Twitter, and the behaviour of the Twitter user is analysed using machine learning technique such as SVM and Naive Bayes. The behaviour of the Twitter user is classified using the test classifier, and the neighbourhood of features is estimated to detect the effects of the mental illness level. Arunima Roy et al. [4], analysed the social media data to obtain the impact of Twitter usage in people's mental health. The future risk is predicted using the suicide artificial intelligence prediction heuristic (SAIPH). The method is introduced to classify the suicidal ideation (SI), and the text-based tweet is modified to scores by using the random forest.

Islam et al. [5], presented a machine learning technique such as support vector machine (SVM) and decision tree. The data of Facebook user are gathered from the online public source, and the feature is classified. The effectiveness of the detection process is measured with a set of psycholinguistic features. Peng et al. [6] presented a multi-kernel SVM-based model for the identification of mental illness people. The feature is classified into user profile, user activity and user microblog text. Theses extracted to represent the social media user behaviour.

This method selects the optimal kernel for various features to identify the mental illness of the social media user. Saravia et al. [7] propose a random forest forecasting framework which utilizes the leverage patterns and user behavioural patterns on the Twitter platform to discover whether the user is affected by the any mental illness.

Tsugawa et al. [8] have presented the model for evaluating the depression stages through the user activities in social media platforms. They were illustrating (1) the features attained from the user posts in the social media platforms, and those features were utilized for forecast the depression with an 69% accuracy; (2) tweet topics were evaluated by the topic model; (3) for detecting the depression, at least, two months of observation data were required even though more observation duration not enhancing the accuracy level.

Nguyen et al. [9] have presented the multilayer perceptron (MLP), and support vector machine (SVM) algorithm was utilized for the classification process to identify the negative emotion thoughts in the social media through the EEG signals. Furtherly, they were examining the seven features by the Fourier and wavelet transforms. After that, they were presented the power spectral density-based (PSD) frequency point feature with the MLP classifier. Tai et al. [10] have presented the feeling distinguisher (FeD) model which was based on the techniques of latent Dirichlet allocation (LDA), supervised latent Dirichlet allocation (sLDA) and Senti Word Net for identifying user's intent and severity of feeling by their social media posts.

## 2.2 Review Done on Mental Illness Detection Using Deep Learning Approaches

Deep learning technique was initially developed from the area of artificial neural network (ANN). Therefore, it was also called as new-generation neural networks. Representation learning is performed by utilizing DL technique that is consider as a class of machine learning technique, and this learning process is conducted by utilizing the numerous layers of data-processing steps in hierarchical architectures. In this part, we have been studied the numerous DL framework structure along with the deep feedforward neural network (DFNN), recurrent neural network (RNN), convolutional neural network (CNN) and autoencoder.

Whilst comparing DL with the ML and AI technologies, DL techniques are providing the end to end mechanism, and by using the multilayer network architecture, the input features are directly mapped into output features for observing the hidden patterns of the data. Uban et al. [11] have presented the DL approach for identifying the mental illness by the various aspects such as content, emotions and style and also interpret their behavioural for better understanding of mental illness signs. They were compared the mental disorder diagnosed user with the normal user to support the psychologist for diagnosing the patients. They were concentrated on the depression and anorexia.

Kim et al. [12] have developed the DL framework for detecting the person mind set by their posts in social media. They were concentrated on the depression, borderline personality disorder, anxiety, autism and schizophrenia. Additionally, this framework was monitoring the mind mentality of the frequent users of social media. Ivan Sekulic, et al. [13] have presented the DL framework for detecting the mental illness of the user through the social media post information. Furthermore, they were discovered the restrictions of their model and examine the phrase related to the classification process by reviewing the model's word-level attention weights.

Rutowski et al. [14] have presented the DL framework for identifying the anxiety and depression through the audio conversation. The audio data include the 16 k communication label for the anxiety and depression. Zogan et al. [15] have presented the multimodal depression detection with hierarchical attention network (MDHAN) which was the amalgamation of DL with multimodal features for identifying the depressed person and clarifies the prediction model. They were focused on the posts of the user and multimodal features of Twitter. They were utilized two mechanisms such as tweet-level and word-level for realizing the sematic sequence feature and computing the importance of every tweet and words of the user posts.

Kholifah et al. [16] have presented the LSTM deep learning approach for detecting the users affected by the mental illness through their posts in Twitter. They were utilized lexicon involved keywords for designate the depression symptoms. They were focused on sentiment, personal pronouns usage, negative words, basic emotions and absolutist word for evaluating the mental health. The accuracy of these approach was less because they failed to optimize the hyperparameter and used less count of data. Lin et al. [17] investigated on mental health problem by utilizing the large data

set from real-world social platforms to methodically examine the users' stress-level condition and social contacts. They were explicated a set of stress associated with the textual, pictorial and social attributes by using the factor graph framework combined with CNN to identify the stress.

Gkotsis et al. [18] have presented the DL neural network model to recognize and categorize the user post from the Reddit platform related to the mental illness. Xu et al. [19] have presented the DL-based multimodal emotion identification system for the clinical and health information. Multi-channel convolutional autoencoder neural network was utilized for extracting the ECG data and emotional text features. This collected information was used for the emotional detection.

## *2.3 Review Focused on Transfer Learning-Based Approaches*

Emotional status of the social media users plays a vital role in the detection of their mental illness. Woodward et al. [20] have performed a recognition of emotional status on multiple multimodal data set. The data in the data set are encoded to a coloured image. The object recognition model is pre-formatted before applying the transfer learning by utilizing the coloured images. Emotion classification of the physiological data by utilizing the one-dimensional convolutional neural network (1D CNN) which uses the large data set. Then, the transfer learning model and 1D CNN are integrated to rectify the small data set problem.

In 2016, the Brexit tweets made a psychological distress amongst the Twitter users. Therefore, Palicki et al. [21] detected the mental illness of the Twitter user against the Brexit tweets by utilizing the transfer learning. The mental status of the Twitter users is understood by the self-reported psychological agony tweets which is noted as a source domain and the distress condition of Brexit tweets are noted as a target domain. The distress level of the Brexit tweets is identified using the index of Brexit distress. Howard et al. [22] utilized the auto-ML tool to predict the mental illness of the social media users. The transfer learning methods are used for the prediction of risk in the labelled data set. This data set includes the posts that are labelled as a perceived suicide risk. The post denoted through the lexicon-based tools which comprises of sentiment reasoner, valence aware dictionary, empath, word count and linguistic inquiry.

Skaik [23] analysed the textual data of social media through NLP. The mental status of the social media users is detected using the machine learning methods. The information concealed in the training data is selected for the application of population by adopting TL. Shickel et al. [24] have presented a sentiment analysis by utilizing the 2D-valence method which includes four sentiment class such as positive, negative, neither positive nor negative, both positive and negative. The classification of emotional valence is formed using the DL model called BERT. This method automated the mental illness framework for the sentiment analysis.

Park et al. [25] have presented the depression detection model which uses the user post on the Twitter to represent the depressive moods. Initially, they were analysed

the tweets for certain duration to analyse the user condition. After that they were employed the crowdsourcing to accumulate the user of Twitter who diagnosed with the depression. De Choudhury et al. [26] investigated the benefits of utilizing the social networks to identify and diagnose the depression. They were utilized the crowd source to accumulate the Twitter user post.

Gao et al. [27] have utilized a cross-subject decoding approach to decode behaviour from the functional magnetic resonance imaging (fMRI) records. Naderi et al. [28] have concentrated on multimodal deep learning structure design which extract the feature from the recorded speech models to detect the mental illness of the social media user. The audio and text segments are extracted using the pre-trained models.

Bae et al. [29] have addressed the heterogeneous nature using the deep learning approach. Structural magnetic resonance imaging was used as a single biomarker. The 3D CNN is utilized the transfer learning for the classification of normal control and DAT scans. Kaya et al. [30] have presented the multimodal emotion detection system though the video. To demonstrate the fine tuning and the flexible registration, they were utilized the deep convolutional neural network features attained from the transfer learning approach, and also, this approach amalgamates the video and the audio features along with the least square regression classifier and weighted score-level fusion. Harati et al. [30] have presented the transfer learning approach for the audio which utilize the lightweight encoder, and it transmits only the encoder weights, enabling a simplified run-time model.

## 3 Evaluation and Analysis

Assessment criteria—there are several methods learned by collecting social media data for information related to the mental health of users. Participants were hired to conduct a depression survey and share their Facebook or Twitter information or data collected from existing social media online. The data sources contain information collected from multimodal digital media to identify user activity who have shared their personal valuable information.

Methods that use public data have the advantage that very large samples, in fact, can be collected faster and cheaper than survey controls although survey-based tests often offer a higher level of validity. Depending on the measurement measures such as accuracy, loss, recall and precision, this review function reports the measurement results obtained by the existing function to indicate testing. The research papers which are analysed the mental illness detection system are mostly based on the three common metrics such as rating prediction metrics, classification accuracy metrics and ranking metrics.

- **Rating prediction metrics**: With the utilization of this evaluation metrics, the detection system can measure the features of user, which is towards to the post.

**Table 1** Summary of papers

| Authors & Citation | Year | Learning model | Technique used |
|---|---|---|---|
| Tsugawa et al. [8] | 2015 | ML | SVM |
| Saravia et al. [7] | 2016 | ML | Random forest predictive models |
| Lin et al. [17] | 2017 | DL | Factor graph model by means of a CNN |
| Kaya et al. [31] | 2017 | TL | Deep CNN-based features obtained via transfer learning |
| Islam et al. [5] | 2018 | ML | Support vector machine (SVM), decision tree |
| Peng et al. [6] | 2019 | ML | Multi-kernel SVM |
| Nguyen et al. [9] | 2019 | ML | MLP (Multilayer perceptron), SVM |
| Lam et al. [32] | 2019 | DL | 1D convolutional neural network (CNN) |
| Gao et al. [27] | 2019 | TL | Cross-subject decoding approach using DTL |
| Naderi et al. [28] | 2019 | TL | Multimodal deep learning structure |
| Bae et al. [29] | 2019 | TL | 3D CNN |
| Roy et al. [4] | 2020 | ML | Neural network |
| Kim et al. [12] | 2020 | DL | Embedding-based convolution layer |
| Sekulic et al. [13] | 2020 | DL | Hierarchical attention network |
| Zogan et al. [15] | 2020 | DL | Multimodal depression detection with hierarchical attention network |
| Kholifah et al. [16] | 2020 | DL | LSTM deep learning approach |
| Rutowski et al. [14] | 2020 | DL | Deep language models |
| Howard et al. [22] | 2020 | TL | Auto-ML along with transfer learning |
| Shickel et al. [24] | 2020 | TL | Deep transfer model called BERT |
| Lekkas et al. [1] | 2021 | ML | Ensemble learning |
| Zulfike et al. [2] | 2021 | ML | AdaBoost classifier with selectKBest feature selection technique |
| Tiwari and Das [3] | 2021 | ML | Naive Bayes & SVM linear |
| Palicki et al. [21] | 2021 | TL | Brexit tweets by utilizing the transfer learning |
| Skaik [23] | 2021 | TL | Machine learning model along with transfer learning |
| Shahabi et al. [33] | 2021 | TL | Deep transfer learning (TL) strategy based on powerful pre-trained CNNs |
| Harati et al. [30] | 2021 | TL | Transfer learning approach with lightweight encoder |

- **Classification accuracy metrics**: This evaluation metrics are utilized to measure the accuracy level of the detection system.
- **Ranking metrics**: Detection model performance is measured by utilizing this evaluation metrics.

## 4 Challenges and Future Implications

Normally, identification of mental illness from the multimodal social media involves numerous tasks because of problems presented in the interaction between the non-face to face and interface amongst the user and computer. The main barrier to detect the mental illness is considered as the language, and it is usually happened at the time of discovering the actual meaning of mental health beyond the languages and words presented in the multimodal social media network. Therefore, numerous techniques are presented for resolving this problem. The gathered articles were published in the year of 2015–2021. The articles which are relevant to the multimodal social media network were chosen for the data, and it should be about identification of mental illness detection. In this review, we acknowledged numerous challenges and defined as below.

A. Quality of Data Sets and Model Interpretation
The main benefit of utilizing the original data set is which involves detailed information relevant to the purposes of a research work for the different field-work. However, developing an original data set can be executed for many times. A system which based on the ML must be carefully exhibits how biases are interrupt the data, and it needs to be trained the model.

B. Detection of Mental Illness Over Time
The challenging task is the detecting the mental illness at correct stage. Mental health condition may vary for every period of time, and it is different from another task like text classification. Various mental health issues are changed within a time so must be carefully construct the ML models. That model must be efficient to identifying the weak signals.

C. Multiclassification of Mental Illness
The earlier studies considered the mental health issues as a normal problem it doesn't focused in detailed. These studies don't include the multi-stages of the mental health issues. Classifying the mental health issues becomes complex task because it has several feature extraction procedures, and it must be executed by the researchers.

D. Pre-processing of Data
Formulating the novel data set becomes the one of the difficulties in identification of mental health issues, through the social media network.

E. Length of Posts
Short post length becomes the peculiar feature of the social media network, and it may be from some words to some sentences in the numerous social media networks whilst developing a ML model to identify the mental health issues from the few post length is considered as a major consideration.

F. Multilingual Content
A multilingual content post in the social media network is easily written through the certain language or an amalgamation of numerous languages in one post. Hence, the major problem of analysing the multilingual texts is rectified in future research.

G. Data Sparsity
The data sparsity issue becomes the one of main issue in the social media network because of the large informal textual distinctiveness. Therefore, minimization of data sparsity issue is rectified in future research.

H. Publicly Available Data Sets
Public data sets are more significant in developing a benchmark data set to analyse the performance of the various algorithms presented in the earlier studies for identifying the mental health issues. The creation of benchmark data set from publicly available users post is the one more challenging task that should be rectified in future research.

## 5 Future Implications

The earlier section challenges are rectified in the future research on the diagnosis of mental illness. Various factors, namely language, methods, type of data extraction and multiple data sources, must be explored. Information is collected from various social networks, namely Twitter, Instagram and Facebook. Meanwhilst, several researchers are developing new or integrated techniques for the diagnosis of a mental health problem. Recent research workers suspect that using a novel approach and employing a new data set could improve research into future mental health discoveries. This feature can improve mental health outcomes.

Recent research workers will see few potentials for data extraction from a multi-disciplinary social network other than the one usually used in earlier studies. Some researchers use a number of user data logs from the different social networks and new data-gathering approaches. The language barrier and the exclusion of other languages from social media networks offer a future scope for investigation on indigenous language and location because various users in the social media use their inherent language rather than using English language. Furtherly, researchers also focus on the other kind of information such as video, photos and audio rather than just texting on social media networks.

## 6 Conclusions

This review work was carried out to evaluate the usage of digital media in the seeking of mental condition. The main motive of this analysis is to make a serious assessment of the mental health issues. This review contains a variety of learning models in machine learning, deep learning and transfer learning strategies. This review work also examines the relevance of pre-mental illness diagnosis by recognizing its data analysis approach, difficulties and restrictions. This review work implies that a multidisciplinary communication network that demonstrates major potential as data sources for diagnosing mental illness. However, a multidisciplinary communication

network can provide relevant information, and the integration of all learning models in the acquisition of mental health can enhance future research. Analyse the mental health problem may reduce the suffering of mental illness otherwise their condition become worsen.

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# E-Service Quality: A Literature Review and Research Trends

**Thanh D. Nguyen, Uyen U. T. Banh, Tuan M. Nguyen, and Tuan T. Nguyen**

**Abstract** E-channels are fast replacing traditional channels as a means of shopping and consumption. E-service is the fusion of two trends: the shift from the commodity economy to services and the expansion of the information economy and the electronic networks. E-service quality (e-SQ) is very significant in the electronic environment. Thus, the studies about e-SQ are vital and meaningful. This study approaches the related concepts to e-services and e-SQ. Besides, this study reviews the related models and scales to e-services and e-SQ. Research also indicates the challenges and research trends related to e-SQ. This research exerts scientific literature synthesis, prioritizing published articles from 2000 to 2020, and articles have been published in the scientific journal with international standards. In addition, this study also analyzes, compares, reviews and evaluates the related issues to e-SQ.

**Keywords** E-services · e-service quality · E-S-QUAL · Service quality · SERVQUAL

## 1 Introduction

Electronic channels are rapidly replacing traditional shopping and consumption channels [1]. From an electronic business perspective, Amazon and Walmart are both typical successful retailers of this trend. In 2000, Walmart launched its first campaign in investing in its cutting-edge e-commerce web page. In 2014, the revenue from its

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e-commerce operation reached 10 billion dollars, which was also considered the fastest growing e-commerce operation globally [2]. Amazon held its initial public offering (IPO) with the price of 1.73 USD per share in 1997. In 2015, Amazon had a market cap of over $ 150 billion and surpassed all the other retail businesses in this sector [3]. Nowadays, the large segments of the service sector, including travel and tourism, airplanes, financial, and banking services, have accepted the online channels considered electronic services. In particular, the electronic service quality (e-SQ) is prominent for various purchasers to experience on online channels.

Electronic services are the fusion of two inclinations: the shift of the conventional economy from merchandise to services and the expansion of the information economy as well as the digital network system. [4]. On the other hand, service quality is deemed as more crucial than the quality of the goods; the world economy tends only to expand its range on service sectors but not pay more attention to other primary sectors (e.g., industry, agriculture) [5]. Hence, both traditional service and e-service marketing are the leading industries in the economy [6]. For example, it is estimated that the GDP ratio of the service sector in some countries such as Hong Kong (92%), the United States (78%), Japan (72%), Singapore (67%), South Korea (58%), Thailand (44%)… [5], these are remarkable numbers. Besides, many parts of the world has modified from the industrial milestone to the information one with the expansion of the knowledge economy, information society, information technology, and globalization trend [6]. The outcome of this development has led to a new economy which has been accelerated since the 1990s, leading directly to the prompt development of information technology, and Internet has eventually evolved into the most powerful engine in commerce [7]. Thus, a totally distinct business field has been created, namely e-commerce, which also has an essential correlation with its related variant (e-services). The combination of international digital marketing and traditional services has generated a particular field in the service sector, namely e-service marketing [6]. e-SQ is deemed as a type of assessing the service quality in the simulated market [8, 9]. Additionally, e-SQ also determines the success, the effectiveness of websites [10], as well as electronic customer satisfaction [11]. Many studies revealed that e-SQ has placed a constructive influence on customer attitudes and behaviors [12]. Hence, the related concepts of e-SQ are an intriguing matter in recent market research (e.g., Fassnacht and Koese [13]). Despite the fact that e-SQ is an incompletely explored aspect of research, scholars still have their approaches to investigate the potential queries, and the recent research is in the early stages of this field.

The study's objective is to approach concepts related to the e-service, present its potential benefits, and also to the e-SQ concepts. Besides, this study also conducted research on theoretical overview of e-SQ related models and scales. In addition, the study also presented research challenges and trends related to e-SQ in reality. The research uses the method of synthesizing scientific documents, with priority given to articles published from 2000 to 2020 and published in reputable scientific journals

(e.g., articles that qualify for the ISI and SJR standard).[1] In addition, the study also analyzes, compares, comments and evaluates issues related to e-SQ.

## 2 Literature Review

### *2.1 Related Concepts*

Electronic service (e-service) refers to providing services on the Internet, including electronic commerce. E-services also involve non-commercial services (e.g., e-government) [14]. Besides, electronic services are a collection of services that are invariably available on the Internet to provide online purchases and sale transactions. This kind of website is distinct from the traditional ones, which only provide descriptive information [15]. Since the 2000s, many researchers have become interested in e-services (e.g., [16]). The NetOffer model proposed by Gronroos et al. [17] recommends different concepts of core services in a service pack that is constantly available in the simulated market; nonetheless, it is still a value-added service that should involve both customers and media. Although expectations are a less critical factor in e-commerce [18], customers can still employ experience-based criteria [19], and traditional services as benchmarks for e-services [18]. VanRiel et al. [16] suggested five different elements in electronic services: (1) core services; (2) conditional services; (3) support services; (4) additional services; and (5) user interfaces which allow purchasers to access to a variety of electronic services.

Service quality is the association between the buyer's expectations with the response performance [20]. High service quality will satisfy the various customer needs and increase competitive advantages [21]. This showed that when service performance was evidently sufficient or above the customers' expectation, the service quality was satisfactory. If the performance is below expectations, it can be inferred that the service was developed with inferior quality. Gummesson [22] discussed the theory of service quality associated with perception and trust. Gronroos [23] stated a concept related to the complete service quality as the customer's perception of the distinction occurring amongst the expected and perceived services. Service quality is generally understood as a scale of service levels that matches the customer's expectations [9]. Besides, Parasuraman et al. [24] define service quality as the assessment of a particular service firm that resulted from differentiating performance with purchaser's expectations of firms in the industry. This notion was promoted into a tool for service quality evaluation called SERVQUAL. Two main streams related to the research field on the service quality scales are: (1) the Nordic perspective [23, 25], using generic service terms to define service quality (e.g., functional, technical). (2) North American perspective [24], using service attributes to describe service

[1] ISI (Institute for Scientific Information), SJR (SCImago Journal Rank).

quality in scales (e.g., reliability, responsiveness, empathy, assurance, materialization). In addition, the different research models related to service quality which have gain much attention, for example, technical and functional quality [25], GAP model [20], aggregate service quality [26], ideal value of service quality [27], benchmarked quality [28], associations with information technology [29], overall attributes [30], retail service quality [31], internal service quality [32], e-SQ [9].

## 2.2 E-Service Quality (e-SQ)

e-service quality (e-SQ) is the assessment of service quality in the virtual market [8, 9]. e-SQ also determines the success and effectiveness of websites [10], customer satisfaction [11].

Parasuraman et al. [12, tr. 217] stated e-SQ as the "*extent to which a website facilitates efficient and effective shopping, purchasing, and delivery*." This statement indicates that the concept of e-SQ rooted from the repurchase intention (e.g., ease of use, product information, ordering information, and protection of personal information) to the post-purchase stage (e.g., distribution, customer service, and return policy). Besides, Parasuraman et al. [12] indicate two different scales for measuring e-SQ, including the basic E-S-QUAL scale and the extended E-RecS-QUAL scale. The E-S-QUAL consists of different dimensions including system availability, privacy, fulfillment, and efficiency. Remarkably, the efficiency mentions the ease as well as the pace of evaluating and employing the websites. The attainment means the growth of the site's intention about the distribution of the commodity's delivery as well as the item availability is fulfilled at a certain level. System availability is related to how precisely the website can place on its technical functions. Privacy mentions the proportion to how safe the website is or not and how it can conduct different protective interface to customer information. It can be seen that E-S-QUAL is related to the overall customers of a website. E-RecS-QUAL is an inferior branch of E-S-QUAL, which focuses on handling services' issues and inquiries. E-RecS-QUAL only gives customers non-routed contact with websites, and this scale includes three dimensions as follows: responsiveness, compensation, and contact. In particular, responsiveness means the effective handling of problems and how it is returned to the website. Compensation mentions how a website could compensate its purchasers for their emerge issues. *Contact* means the process of proactive support with telephone or virtual agents. From the literature review of related studies on e-SQ, the author summarizes and interprets the concept of e-SQ as follows: "*e-SQ includes ease of navigation, site aesthetics and customization, reliability, responsiveness, security/privacy, and information quality*."

For customers, high-standard e-SQ is a tool by which the potential benefits of the Internet could bring [33]. In addition, Parasuraman [34] suggested themes in the online environment, particularly the positive ones (e.g., flexibility, convenience, efficiency…); negative themes (e.g., security failure, malcontrol, risk of obsolescence …), these factors are closely related to service quality in many ways. According to

Santos [9], the interactive nature of the Internet facilitates the search and integration of information to meet customer requirements effectively. Besides, online products' technical features and prices are much easier to compare than traditional channels [33], so online service quality is crucial to customers. Thus, online customers expect the same service quality as the traditional providers could bring. E-SQ can make a valuable difference for business development for online service providers. Website interactive features, various media contents, and customizability [35] attract the attention of businesses in e-commerce [36]. In addition, online companies also provide better services than their rivals which is a determining factor in earning customer loyalty. [37]. Hence, focusing on e-SQ is the primary concern in e-commerce. If the Internet is used correctly, the Internet is a powerful tool for increasing the overall quality of service and setting entirely higher standards in various industries [38].

A high-quality e-SQ is going to supply extended-term benefits for a company [9]. An overall e-SQ model provides a comprehensive framework for e-SQ. It includes distinct trends classified into six positive dimension trends and five recovery dimension trends. Specifically, (1) the recovery dimension is stated as the suitable sketch of how a technology website is utilized in order to offer its customers with comfortable experience, knowledge, and attractiveness of websites. Most of the factors in the recovery dimension can be developed before launching the website as follows: ease of use, alignment, appearance, arrangement, structure, and content. (2) The positive dimensions must be consistent throughout the life cycle of a website. This factor is likely to improve the customer maintenance and enhance the effects of word of mouth (WoM). Besides, Blut et al. [1] suggested a conceptual framework related to disparate elements of e-service quality to its outcomes, including WoM, customer satisfaction, and repurchase intentions. This structure is originated from the means-end chain theory [56]. This model provides a complete comprehension of the elements, sequences, and moderators of e-SQ which serves as a theoretical basis for forthcoming experimental studies.

- **Attributes of e-SQ and the Overall e-SQ**

Several attributes and related scales include classifications of commodities and services [51]. Various models that have been employed to evaluate e-SQ. Accordingly, specific attributes were utilized in each model and its research contexts. Interestingly, some attributes, including web design and security or privacy, are shown in all parts of the studies, while attributes such as system availability and delivery conditions are less likely to exploit in research (e.g., [12]). Besides, distinct models have theoretical overlap and distinctions between them. For example, Wolfinbarger and Gilly [39] examine the e-TailQ model using a variety of samples of their purchasers such as the Internet browsers, goal-oriented customers, frequent purchasers, book/music buyers… Although *website design* and *fulfillment* are very prominent in all samples, *customer service and security or privacy* are considered as less important**.** Among the different e-SQ scales, e-TailQ [39] and E-S-QUAL [12] include the most attributes with 13 dissimilar attributes (each scale contains 13 attributes), and they are among the most commonly quoted sources. Recent research by Blut et al. [1] illustrated 16 attributes of the e-SQ.

- **Components of e-SQ Quality to Its Outcomes**

Originated from purchaser's satisfaction [57], service quality [20], a multi-attribute approach [58] offers the theoretical basis to grasp e-service quality. The various layer attribute approach is derived from the means-end chain theory, which illustrates how customers may assess their spending experiences [56, 59]. In the means-end chain theory, every specific attribute is correlated with a superior-order dimension; each dimension, then, is linked with a superior-order; these procedures can be summarized and perceived as e-SQ. From a consumer psychology perspective [56], the means-end chain theory reveals that purchasers are able to measure their satisfaction in terms of particular and stable circumstances at the attribute level. This procedure later is likely to be synthesized and related to superior-order dimensions [60]. In other words, these dimensions can reveal various higher classifications depending on consumer goals [59] and consumption settings [56].

Regarding the setting of e-service, the means-end chain concept is appropriately precise and theoretically sound [1]. For instance, purchasers can measure their spending experiences which may be rooted from specific attributes such as "*product selection.*" This stage, then, can be related to the superior-order performance dimensions, namely "*website design.*" These dimensions are still associated with e-service quality, which later on will have a connection to critical outcomes, including customer behavioral intentions, customer satisfaction, (e.g., repurchase intentions), and customer behavior (e.g., WoM [61]). The relationship between concepts and empirical research is a key factor in determining the importance of each attribute type and dimension. [62]. Details of theories and components related to e-SQ are presented in Table 1.

- **E-Service Quality: Relevance Across Contexts**

The most vital benefits of e-service are the firm's competence to serve customers across various industries and different parts of the world [1]. Nonetheless, the relationships across different contexts are still remained unclear (e.g., national cultures, legal environments…). Previous research reveals distinctions among countries in service quality (e.g., Furrer et al. [63]), with the notion of technology-related industries (e.g., Yoon [64]). Thus, it is advisable to maintain the relationships of different e-service quality dimensions and overall e-service quality, which nation's level could manipulate. This issue is based on country's culture and regulatory environment [1]. These two factors and theoretical pertinence are still remained as the most popular examined factors in an e-SQ context.

## 3 E-SQ Measurement

Recent studies in the direction of multidimensional e-SQ, from three dimensions [65] to 12 dimensions [66], reveal that there is no homogeneity of e-SQ scales in previous studies. Notably, some scales (e.g., reliability, ease of use) appear consistently in

**Table 1** Summary of studies on e-service quality (e-SQ)

| No | Author | Related theory | | | | Approach | e-SQ | Attribute—e-SQ antecedent | | | | | | | | | | e-SQ outcome | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SERVQUAL | E-S-QUAL | e-TailQ | Others | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
| 1 | Wolfinbarger and Gilly [39] | E-SERVQUAL | | x | SITEQUAL | Customer | Outcome | | | x | x | x | | x | | | | | | | | | |
| 2 | Long and Mcmellon [40] | E-SERVQUAL | | | WEBQUAL | Customer | Outcome | | | | | x | x | | x | | | | | | | | |
| 3 | Parasuraman et al [12] | x | x | | | Organization | Outcome | x | x | x | x | | x | | | | | | x | x | x | | |
| 4 | Bauer et al [41] | x | x | x | | Customer | Outcome | | | | | x | x | x | | | | | | | | | |
| 5 | Sahadev and Puran [42] | | x | | | Organization | Mediate | x | x | x | x | | | | | | | | x | | | x | x |
| 6 | Herington and Weaven [43] | x | x | | SITEQUAL | Customer | Outcome | x | | | | | | | | | | | | | | x | |
| 7 | Gorla et al [44] | x | | | IS success | Organization | Mediate | | | | | x | x | | x | | | | | | | | |
| 8 | Sousa and Voss [45] | E-SERVQUAL | | | | Organization | Mediate | | | x | x | | | | | x | x | x | x | | | | |
| 9 | Tan and Cenfetelli [46] | x | | x | WEBQUAL | Customer | Mediate | | | | | | | | | | | | | | | | |
| 10 | Al-Hawari [2] | | x | | | Customer | Antecedent | | | | | | | | | | | | x | | | | |
| 11 | Yaghubi and Seyedin [47] | x | x | x | SITEQUAL | Expert | Outcome | x | | x | x | x | | | | | x | | | | | | |

(continued)

**Table 1** (continued)

| No | Author | Related theory | | | | Approach | e-SQ | Attribute—e-SQ antecedent | | | | | | | | | | e-SQ outcome | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SERVQUAL | E-S-QUAL | e-TailQ | Others | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
| 12 | Rabaai et al [48] | x | x | | IS-ServQual | Customer | Mediate | | | | | x | x | | | | | | | | | x | |
| 13 | Khan and Rahman [49] | | | x | | Customer | Antecedent | | | | | | | | | | | | x | | | | x |
| 14 | Taherdoost [50] | x | | | | Customer | Mediate | | | | x | | | | | | | | | | | x | x |
| 15 | Jeon and Jeong [51] | | | | | Customer | Mediate | | x | | | | | | | | | | x | | | x | |
| 16 | Ming et al [52] | x | | | IS success | Customer | Antecedent | | x | | | | | | | | x | | | | | x | |
| 17 | Ciuchita et al [53] | | | | Innovation | Customer | Antecedent | | | | | | | | | x | | | | | | x | |
| 18 | Ivanaj et al [54] | x | | | | Learners | Mediate | | | | x | x | x | | | | x | | | | | | |
| 19 | Taherdoost and Hassan [55] | E-SERVQUAL | x | x | SITEQUAL | Organization | Antecedent | x | | x | | | x | | | | | | | x | | | |
| 20 | Rahman et al [21] | x | | | SITEQUAL | Customer | Antecedent | x | | | | | | | | x | | | | | | | x |

(1): Efficiency; (2): System availability; (3): Fulfillment; (4): Privacy or Security; (5): Reliability; (6): Responsiveness; (7): Functionality or Design; (8): Assurance; (9): Ease of use; (10): Information quality; (11): Appearance; (12) Loyalty or e–Loyalty; (13): Perceived value; (14): WoM or e–WoM; (15): Satisfaction or e–Satisfaction; (16): Trust or e–Trust

different models and are commonly used in customer evaluation of e-SQs and are independent of the types of electronic services [13, 18]. Nevertheless, other scales emerge in a particular e-service context. These observed variables are reflected as "*general*" or "*special*" scales in assessing traditional service quality (e.g., Ladhari [67]). The e-SQ scale tends to depend on the involved service industries. Even within the same industry, the scales still rely on the user's type of service (e.g., Banjo [68]). According to theoretical reviews, there are six consistent e-SQ scale concepts as follows: reliability, security, responsiveness, information quality, ease of use, website design.

(1) *Reliability* is deemed as the outstanding aspects of the conventional SERVQUAL scale related to the accurate and punctual fulfillment of an intended service and the safe and correct delivery of products or services at convenient times for customers [33]. In related studies, this scale is determined by the overall service quality [8, 12, 33], satisfaction [8, 39, 69], perceived value [12, 41], intention to buy [8, 39], and repurchase intention [41].
(2) *Responsiveness* related to a willingness to assist customers [70] with rapid responses through their requests and unexpected issues [33]; it also goes along with the availability of other communication channels [41]. In addition, responsiveness also places several effects on other overall service quality and satisfaction [8].
(3) *Ease of use* related to user-friendliness, particularly related to data search [71]. Ease of access refers to how available information has become a primary intention for customers to opt what to make purchase via the Internet [11, 39]. Besides, usability is also deemed as another essential visible feature of e-SQ in an e-business environment that can be intimidated and intricate for numerous users [12].
(4) *Privacy* related to the private and financial information protection [71] and the idea that websites are recognized as secure from anonymous interference by target consumers [12]. This scale is considered as appropriate thanks to examining perceived risks of financial loss and fraud in digital platforms. Security is also one of the most prominent factor in opting e-SQ for consumers of online banking services [72] as well as in affecting the intention to return to the website and purchase [71, 73].
(5) *Website design* related to the esthetics and contents included in structures of the online catalog [74]. The design of a web page is similar to a physical hosting environment that directly affects customers' norms of online service providers and purchase behavioral objectives [75].
(6) *Information quality* related to the completeness and precision of the information users acquire while accessing a web page [13]. This scale becomes vital for pure services such as portal services [54, 65]. In addition, two out of five reference scales for information quality are completeness and usefulness [76]. In these factors, the completeness of the information is measured by observing variables such as comprehensiveness complete and detailed contents.

### Comparing e-SQ Scale with Traditional Service Quality Scale

A significant difference can be witnessed between both traditional services and electronic services, although the e-SQ scale has been identified in many conventional service quality studies. For example, reliability plays pivotal role regarding aspects in the research context of e-SQ (e.g., Cai and Jun [74], Fassnacht and Koese [13], Wolfinbarger and Gilly [39]). Likewise, responsiveness can be counted as one of the scales of the SERVQUAL model, which is also performed in recent research on e-SQ (e.g., Lee and Lin [8], Long and McMellon [40], Oneill et al. [70]). However, the difference between the e-SQ scale and the traditional one is quite apparent, especially for interpreting the different responses in the virtual context from its meaning in the web-based context to traditional interpersonal services [77]. Thus, traditional service quality scales may not be appropriate for evaluating e-SQ.

In particular, several conventional measures of the genuine service quality are not applicable in the distinct situation of e-SQ. In other words, empathy gains little interest in the online environment, perhaps due to the absence of personal contacts in this context. Nevertheless, under certain conditions, the service context empathy will become another crucial aspect of e-SQ [77]. In addition, Sohn and Tadisina [75] identified communication customization with regard to a pivotal concept for internet users in assessing e-services provided on Internet platforms. This scale is also related to personal interaction occurring between the purchasers and enterprises which proposes several similarities to the empathy scale in the SERVQUAL model. The observed variables for evaluating communication customization propose some similarities to those in the SERVQUAL model (e.g., individual attention, understanding of customers' special needs, and ease of communication with employees). Another concept is tangibility, which seems to involve the general concept of ease of use (e.g., webpage design and features, structure and catalog of online stores, esthetics) in the online environment. Some different e-SQ scales include trust (e.g., Barnes and Vidgen [78], Loiacono et al. [66], Sohn and Tadisina [75]), web design and its functions (e.g., Bauer et al. [41], Fassnacht and Koese [13], Yang and Jun [33]), security factors (e.g., Nguyen and Cao [72], Ranganathan and Ganapathy [73], Yoo and Donthu [71]).

Besides, Zeithaml et al. [18] argue that personalized service might not be an essential factor in e-SQ unless unexpected issues arise or customers are obliged to make complex decisions. Therefore, it is evident that there are certain limitations on the conventional service scale for evaluating e-SQ. Hence, according to VanRiel et al. [16], since traditional service scales (e.g., SERVQUAL) were developed for interpersonal relationships, descriptors and observed variables need to be reconstructed before being used in the e-services context. In other words, the SERVQUAL model can be seen as the most popular theory in studying service quality. Yet, Tate and Evermann [79] argued that the SERVQUAL model is outdated and no longer suitable for modern information systems. Hence, many scholars have expressed interest in the concept of service quality added by DeLone and McLean [80] to the initial success model of information systems [81], which is a crucial element of any information system. Specifically, Lai [69] proposes the E-SERVCON model, which is based on

the update of DeLone and McLean [80] and considers the role of service convenience in e-service to evaluate the success of the e-commerce system. In addition, Rabaai et al. [48] also proposed the IS-ServQual model to evaluate the quality of different information systems, which is one of the latest research models that needs examining more experimentally in different information systems projects.

## 4 Directions for Future Research of e-SQ

The conceptualization and measurement of quality are a major problem for e-service studies. Many authors have studied e-SQ and its theoretical gaps [68]. The concepts and e-SQ scale still have many theoretical gaps, and this is a challenge and an opportunity for researchers to continue exploring. Therefore, Barrutia et al. [82] pointed out some challenges in e-SQ research as follows: (1) several e-SQ definitions are still vague and there is no consensus on the main factors in measuring e-SQ; (2) there is a lack of theoretical studies and supporting theories on e-SQ; (3) most of the scales tend to incompletely reflect consumers' perceptions of e-SQ; (4) e-SQ studies in a single-channel direction and it failed to genuinely comprehend the perception of consumers of e-services in the multi-channel context; (5) limitations in the researcher's access to information sources; (6) the positive randomization properties of the scale may not be considered in studies; (7) limitations in receiving information of traditional; (8) there is a growing need for alternative research methods that exist but remain largely unexplored; (9) More in-depth qualitative research is needed to grasp why certain concepts related to e-SQ are needed; (10) the results of e-SQ have not been entirely and comprehensively developed.

Many authors have developed and tested several research models related to e-SQ in different contexts. For example, e-TailQ [39], SITEQUAL [21], WEBQUAL [66], ES-QUAL and E-RecS-QUAL [12], ETransQual [41], PeSQ [11], E-SERVCON [69], and IS-ServQual [48], these models have been widely applied and validated. Some new research directions that could be implemented in the future are to reconstruct the e-SQ scales in distinct contexts which enhance their external validity. In particular, the IS-ServQual model [48] should be deemed as the latest scale to evaluate the quality of information systems because the SERVQUAL model is outdated and no longer suitable for modern information systems [79]. The details of the summary of research models are presented in Table 1. Accordingly, the researches are carried out in the direction of approaching mainly customers (e.g., Al-Hawari [2], Long and McMellon [40], Wolfinbarger and Gilly [39]) and businesses (e.g., Gorla et al. [44], Parasuraman et al. [12], Sousa and Voss [45]). In addition, there is an expert approach (e.g., Yaghubi and Seyedin [47]). Indeed, the majority of related research looks at the relationship between consumers and businesses (B2C). Therefore, the development of e-SQ scales according to the business-to-business (B2B) relationship will be precious. Obviously, customers can be individuals or organizations, so the nature of e-SQ scale settings is conducted as usual with considering the multidimensionality and multi-level.

On the other hand, according to Barrutia and Gilsanz [83], future studies can also develop and compare the e-SQ scale with various e-business system functions. Then, the two-dimensional classification model of Francis and White [13] can be employed. Accordingly, these two dimensions can be exploited to identify e-businesses: (1) complete process that can be differentiated into digital distribution and direct distribution; (2) products. These factors can be distinguished into the purchase of services and the purchase of goods. Through integrating these distinct dimensions, four types of Internet retail are proposed: (i) *direct merchandise*: distribution of goods directly to buyers; (ii) *direct service*: delivery of services directly to the buyer; (iii) *electronic goods*: distribution of goods via electronic channels to buyers; and (iv) *electronic services*: delivery of services via electronic channels to buyers. Potentially, it is more likely that the quality factors for Internet users will vary depending on different types of the Internet retail platforms. Therefore, with future studies, it is possible to determine the correlative significance of service quality scales on those four types as mentioned above of e-business systems.

From the challenges of e-SQ research and related studies, future research directions can be divided into research works with four following factors: (1) cognitive perspective: holistic viewpoints of consumers or organizations; (2) primary recommendation: products and services; (3) target consumers: information search or purchase; (4) -urchase experience: complete or incomplete; and (5) channels: single-channel or multi-channel. In addition, the gap areas reflect the main investigative directions of the future, allowing research to be proposed from a variety of perspectives and contexts. In addition, due to the fact that the provision of e-services is gradually shifting to multi-channel, the background knowledge of e-services needs accumulating more related concepts of service experience which is essential for the delicate coordination between people and technology [84]. Besides, according to Collier and Bienstock [85] also stated that forthcoming studies on e-SQ should focus on answering the questions "*is it necessary to contact the customer in e-service?*" or "*in e-service quality, does less contact with the customer mean a high-quality service or what is the most essential stage in contacting with customers in an Internet transaction?*."

## 5 Conclusion

Electronic services can be grasped as the unification within economic shift from goods to services and the expansion of the information economy and electronic networks. From an overview of the theoretical basis of related studies, it can be seen that e-SQ has been receiving much attention from researchers around the world. The final outcomes of this research indicate the origin of the concepts of e-services and e-SQ. Besides, the research results also provide related issues of e-services and e-SQ: properties of e-SQ and overall e-SQ, components and results of e-SQ, the relation between the contexts of e-SQ. On the other hand, the study also presents ways of measuring e-SQ. In addition, the research results also highlight the challenges and

future research directions of e-SQ. Finally, the research results will be the premise and scientific basis for future studies on e-SQ.

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# A Recommendation Model for Predicting Alzheimer's Drugs' Mechanism of Action

**Pouyan Nahed, Mina Esmail Zahed Nojoo Kambar, Jorge Ramón Fonseca Cacho, Garam Lee, Jeffrey Cummings, and Kazem Taghva**

**Abstract** The text associated with clinical trials contains a fair amount of information that experts regularly analyze and interpret to extract information. In most cases, specialists use the text to create structured data for comparing candidate trials in different aspects. As this process is tedious and time-consuming, automation is important, relying on machine learning applications in natural language processing. In this paper, we explore the feasibility of the mechanism of action (MoA) classification for Alzheimer's drugs by augmenting bidirectional encoder representations from transformers for biomedical text mining (BioBERT) pre-trained model with a five-layer deep neural network. This recommendation model achieves an $F1$-score of 97% on the dataset built based on the material from the Alzheimer's disease drug development pipeline at clinicaltrials.gov and the ALZFORUM therapeutics website. Also, we published our code on a GitHub repository (https://github.com/ULABS-Team/MOABert) that is available for the public to use.

**Keywords** Alzheimer · BioBERT · Deep learning · Machine learning · MoA · NLP

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## 1 Introduction

The text associated with clinical trials contains a fair amount of information that is regularly used for interpretation and analysis by experts. In most cases, experts use the text to create structured data that can be used for comparison purposes among candidate trials. As this process is tedious and time-consuming, there have been several attempts to, partially, automate the process. This automation relies on applications of machine learning in the area of natural language processing.

We use the Alzheimer's disease (AD) drug development pipeline from clinical trials for our studies. The dataset is the therapeutics dataset, from the ALZFORUM therapeutics website (http://www.alzforum.org). This dataset is encoded by the transformers specifically, biomedical bidirectional encoder representation from transformers (BioBERT) in order to help with classification of the mechanism of action (MoA) for a treatment. We augment this BioBERT layer with a five-layer deep neural network to test the feasibility of the MoA classification of the Alzheimer's disease drug description texts.

Our model achieves 97% $F1$-score for classification of the MoA for the Alzheimer's disease drug development pipeline [1]. We also show that this model performs better than other standards machine learning applications such as decision tree (DT). We believe the proposed models can be used in text classification associated with other clinical trials that would require experts' decision making for the texts categories.

We analyze the results and show that our model improves the mistakes made by previous proposed approaches. We explain how it does better than the previous methods and how it makes less type $I$ errors by providing charts and figures. Also, we compare it with DT by bringing an example of the dataset.

Finally, our experiments show the proposed method capability to predict the MoA of drugs. Also, our model overcomes the challenge of disproportionate number of classes and it is able to make decisions unaffected by imbalanced data.

## 2 Background

The development of the electronic health record (EHR) has led to various online systems that collect data from medical research studies [2]. In general, these studies are textual documents that lack structure beyond words, sentences, and paragraphs. In general, people are good at interpreting and understanding texts. For example, one can read a paragraph, identify a personal name or a date, and connect the person to the given date as a birthdate relationship. Unfortunately, interpreting and understanding text is a hard subject to teach a computer. Natural language processing (NLP) addresses the complexity of understanding and interpreting texts. One common NLP application is the extraction of structured data such as proper nouns, dates, drugs, and disease names. The application of NLP to medical textual documents is known

as biomedical natural language processing (BioNLP). This research area started in the late 1990s [3] to address the classification and information extraction (IE) associated with clinical texts or passages. Clinical text classification is accomplished using rule-based NLP tools, standard machine learning (ML) or deep learning (DL) techniques [4].

In rule-based methods, text patterns are used to build rules that may classify texts. The regular expression is an example of these patterns. For instance, Savova et al. [5] applied the regular expression approach to radiology reports to classify records based on peripheral arterial disease discovery to positive, negative, and unknown classes. Another rule-based technique is the use of logic rules, which are manually designed by experts. As an example, the study by Sohn [6] designed a system to classify the smoker level state into: a current smoker, used to be a smoker, non-smoker, and unknown. However, rule-based strategies are arduous because they need extensive collaboration between medical and NLP professionals and are mostly applicable to specific case studies.

The most frequent ML algorithms being used in biomedical text classifications are support vector machines (SVM), logistic regression (LR), conditional random fields (CRF), decision tree (DT), Naive Bayes (NB), and random forest (RF) [7]. It is common to employ different ML algorithms and compare their evaluations. For example, Sarker [8] applied SVM, NB, and maximum entropy (ME) algorithms to identify adverse drug reaction from multiple datasets. Recent progressions in the field of deep learning (DL) have influenced BioNLP research, as DL language models outperform the standard ML algorithms [9]. These algorithms are mostly based on recurrent neural networks (RNNs), convolutional neural networks (CNN), and transformers [10]. One of the drawbacks to these models is the number of resources it takes for training. The development of pre-trained models, such as BERT or BioBERT, replaces the training with fine-tuning, which is much faster and less expensive.

## 3 Materials and Methods

### *3.1 The Dataset and Its Importance*

Alzheimer's disease (AD) afflicts millions of patients worldwide [11]. Because of this, there are always different drugs at different stages of clinical trials development which their MoA is not still precise in prominent drugs' databases such as DrugBank [12] or KEGG. This is where the Alzheimer's disease drug development pipeline [1, 11] comes into play by providing longitudinal perspicuity into trials and drug development for AD. This yearly publication has played a major role in AD research for the past five years.

However, creating this pipeline every year is not an easy task, as the data comes from a plethora of different sources. Furthermore, some of the columns in the pipeline spreadsheet have to be deduced from the data, such as the treatment targets and MoA.

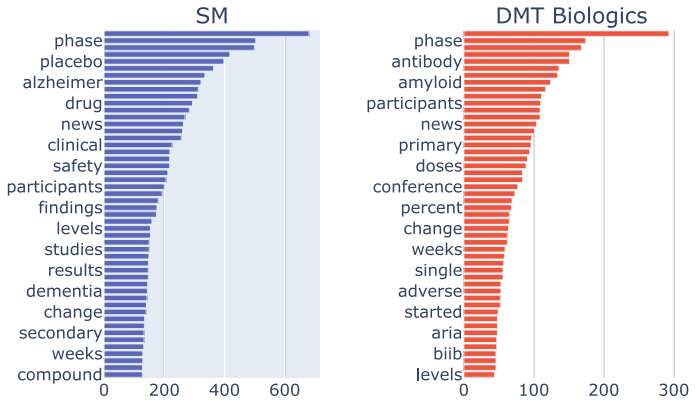


**Fig. 1** Unigram of the Alzheimer's drug dataset for small molecules and disease-modifying therapies (DMT) biologics classes

This requires expert review. Our goal is to use ML and DL techniques to automate the process where possible, and to expedite it where it is not, by suggesting MoA and other spreadsheet columns so that the expert reviewers can choose from the recommended items, just like someone using an auto-complete engine when sending a text message.

Therefore, for the dataset, we use the same sources that have been used to develop the manual pipeline spreadsheet, such as the ALZFORUM website, therapeutics dataset (http://www.alzforum.org), except we automate the process to crawl such information. For the purposes of this paper, we took the previous pipeline [11] records (233 labeled records) and split the labeled data into training, testing, and validation sets. Furthermore, the AD-drugs' MoA are categorized into small molecules (SM) and disease-modifying therapies (DMT) Biologics. See Fig. 1 for details regarding both of these two main categories, and the words that both of these share in their descriptions. As one can see, both classes share words like "phase" in the text, but SM often uses "placebo", whereas DMT uses "antibody". For reference, we split the dataset into four and used 186 records (three parts) as training sets and 59 records (one part) as testing and validation sets.

Along with it being a small dataset, it is also imbalanced, with the first class having 175 records and the latter only 59 records. Using a pre-trained model such as BioBERT and stratification technique have fixed the imbalanced problem. The textual section of the dataset includes 124,180 words and 7693 sentences.

## *3.2 BioBERT for Classification*

We choose the BERT language understanding model to classify the MoA. BERT is a text encoding model that has reached state-of-the-art results in many different tasks.

It is a bidirectional transformer network that is pre-trained on two language modeling tasks on large corpora. Specifically, we use BioBERT [13], is a pre-trained model that is fine-tuned on PubMed and PMC datasets. It is useful for biomedical domain text mining, classification, and other standard NLP tasks. The BioBERT is a fine-tuned version of $BERT_{BASE}$ that contains 12 hidden layers and a hidden embedding size of 768.

The transformer models, such as BERT, process the words of a sentence in parallel, and thus, the notion of word order disappears. [14] In order to maintain the positional information of sentence words, transformers, and consequently, the BERT model uses another kind of embedding, named position embedding. The BERT model uses word embedding and position embedding by adding them together to generate a single embedding to feed to its network.

In the first step, WordPiece tokenization in BERT divides the given input sequence of words in the sentence $t_1, t_2, \ldots, t_l$ into subword-tokens $s_1, s_2, \ldots, s_n$. For example, the sentence 'Hypo-activity of the cholinergic system is associated AD and cognitive decline' is divided into 'H', '##y', '##po', '-', 'activity', 'of', 'the', 'ch', '##olin', '##ergic', 'system', 'is', 'associated', 'AD', 'and', 'cognitive', 'decline'. Then, the model produces a vector representation for each subword-token $e_1, \ldots, e_n \in \mathbb{R}^{768}$. The first word of the sequence is a unique token [CLS] that stands for classification, and it is a representation of the whole sequence. The pre-trained BioBERT model has the limitation of a maximum of 512 tokens as the input sequence. Since our documents are much longer than this imitation, we use the sliding window approach to overcome this problem. We split the document $D$ into windows of size $k$: $D = \{w_1, w_2, \ldots, w_m\}$. Applying tokenization and a sliding window of size 4 on the above sentence will produce these windows: {*'H', '##y', '##po', '-'*}, {*'activity', 'of', 'the', 'ch'*}, {*'##olin', '##ergic', 'system', 'is'*}, {*'associated', 'AD', 'and', 'cognitive'*}, {*'decline'*}. Then, we add [CLS] and [SEP] special tokens to the start and the end of the windows. We feed these input tokens windows into a transformer-encoder layer. The output of the BioBERT is a list of embeddings as follows:

$$E_i = \text{BioBERT}(W_i) \tag{1}$$

In order to classify the given embeddings, we need to have a single [CLS] representation for each of the documents. This single vector is generated by a Sum-Pooling of the [CLS] vector of document $D$ window embeddings as follows:

$$\text{CLS} = \sum_{i=1}^{m} C_i \tag{2}$$

where the $C_i$ is the embedding for the first token of each window that is the [CLS] token. Figure 2 shows the layers of the model in detail.

The output of the BioBERT is then fed into a five-layer fully connected sequential neural network model in order to classify MoA. The first layer of this network has 768 neurons, and all of the following layers up to the last layer have half the size

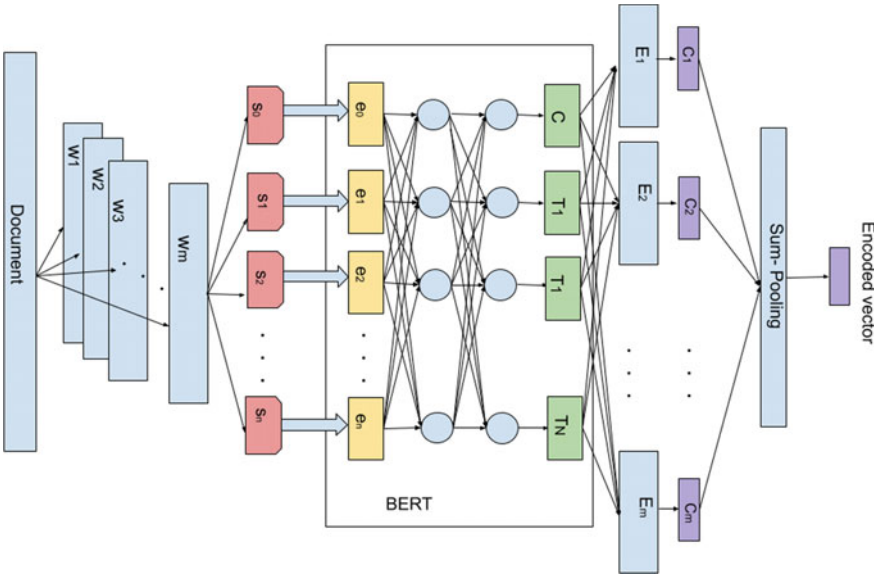


**Fig. 2** Overview of encoding a document into a single CLS vector using BioBERT

of the previous layer, along with a rectified linear unit (RELU) activation function. Hence, the number of units in the layers is 768, 384, 192, and 96, respectively. The purpose of the last layer is to assign a score to each class and it has two neurons with a softmax activation function. We use notations used in LP to show our network notations [15]. This sequential model is defined as follows:

$$h^{(1)} = \text{RELU}(W^{(1)}.\text{CLS} + b^{(1)}) \tag{3}$$

$$h^{(2)} = \text{RELU}(W^{(2)}.\text{CLS} + b^{(2)}) \tag{4}$$

$$h^{(3)} = \text{RELU}(W^{(3)}.\text{CLS} + b^{(3)}) \tag{5}$$

$$h^{(4)} = \text{RELU}(W^{(4)}.\text{CLS} + b^{(4)}) \tag{6}$$

$$\text{output} = \text{Softmax}(W^{(5)}.h^{(4)} + b^{(5)}) \tag{7}$$

We train and optimize this five-layer network with an Adam [16] optimizer and categorical cross-entropy as a loss function. We achieve the best accuracy with window size 50. You can see different experimented window sizes, as shown in Fig. 3.

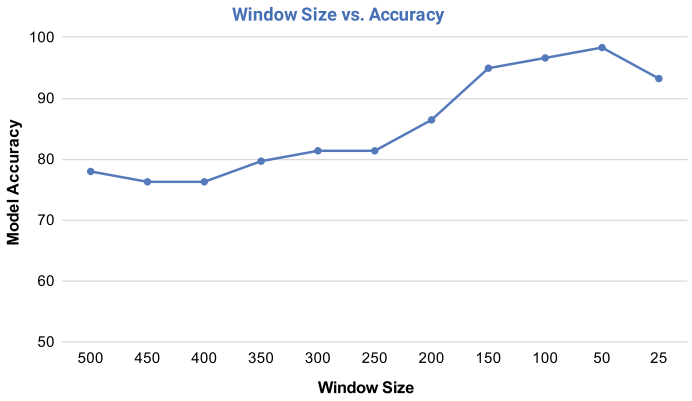


**Fig. 3** Effect of different window sizes on the accuracy of the model. The model achieves the highest accuracy at windows size $k = 50$. By decreasing the value of $k$ to less than 50, the performance decreases significantly

We started with a window size of 500, down to a size of 25. As the size of the window decreased, the performance of the model improved, until we reached the size of 50. By decreasing the size of the window to less than 50, the performance of the model declined.

## 4 Results

We used stratified splitting the dataset, randomly, into training, validation, and testing sets, with a ratio of 6:1.5:2.5, respectively. The training and testing sets were stratified, and there were equal percentages of each target class in each set. In order to show the effectiveness of our model, we compared it with the results of our previous work [17] in terms of precision, recall, $f1$ measure, and accuracy. Among the baseline approaches, as reported previously, the decision tree (DT) algorithm performed the best, so we chose DT for comparison with our new method.

Our experiment with DT used the Gini index as a criterion that computes the overall variance over the tree class, and it is the appropriate measure of node pureness to break the DT tree. The DT in Fig. 4 shows that word "antibody" is chosen by the algorithm to separate the classes in the first level.

We trained and tested our model several times and calculated the average for all metrics. Our recommendation approach outperformed the DT in all four metrics. The final results of the experiments are given in Table 1.

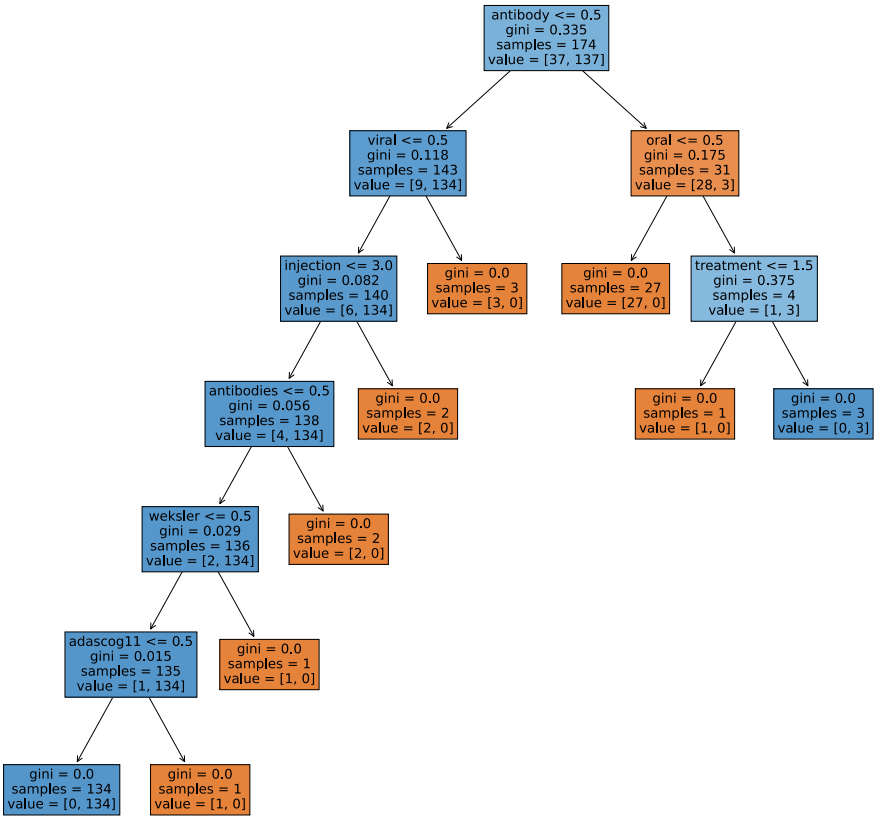


**Fig. 4** Version of trained DT with term frequency features that is visualized. Blue leaves indicate the DMT Biologics class and orange leaves stands for small molecules [17]

**Table 1** Final results of experiment with different algorithms

| Models | Precision | Recall | $F1$-score | Accuracy |
|---|---|---|---|---|
| Decision tree | 0.86 | 1.00 | 0.92 | 0.95 |
| BioBERT-based NN | **0.95** | 1.00 | **0.97** | **0.96** |

The results are reported as precision, recall, $F1$-score, and accuracy

## 5 Discussion

A closer examination of the performance shows that the DT misclassified a few samples of DMT Biologics data points as small molecules. This explains the significant differences in the precision of the two methods. On $I$ errors than the DT, whereas the BioBERT-based NN model approach classifies this example correctly. The DT focuses on the presence of a few words to decide whether a sample belongs to a class

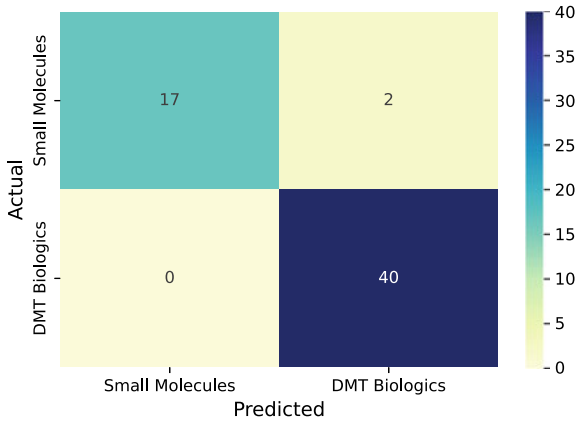


**Fig. 5** Confusion matrix of model predictions on testing set. Model classifies two samples of small molecules as DMT biologics

or not, while the BioBERT-based NN model predicts the labels based on the whole text rather than a few words. In our provided sample, none of "antibody", "viral", "injection", "antibodies", "weksler", and "adascog11" is present in the text. So, the DT that is depicted in Fig. 4 decides to assign it to the second class. Conversely, the BioBERT-based NN model utilities the contextual embedding and uses the information of the whole document to make the decision that enables it to predict the correct label. The number of DMT Biologics was about three times the small molecules samples in our dataset, and it was biased to DMT Biologics; however, unlike the DT model, in which we used synthetic minority over-sampling technique (SMOTE) to have more balanced data, our BioBERT-based NN model was able to predict labels more accurately than the DT without any balancing technique. Although our new model was less sensitive to imbalanced data, biased data still had detrimental effects on the overall performance of the model [18]. As in the BioBERT-based NN model confusion matrix, shown in Fig. 5, we had two types false positive errors. We can interpret this as an effect of the imbalanced data on our model. We believe these types of errors can be reduced using data balancing techniques.

## 6 Conclusion

Our recommendation system proposed a new approach to classify the MoA of Alzheimer's disease drugs by encoding drugs description using BERT architecture. Encoding the input using pre-trained BioBERT-based NN model improves the performance for our task of MoA classification. We also, compared the results of this approach with the previous proposed methods and we showed our model achieves a better score in four metrics compared to the DT model. Our results show that the BioBERT-based NN approach is more resistant to bias data and it is able to over-

come the imbalanced data problem much better than the DT and makes less type false positive errors.

## 7 Additional Files

Reproducible research is key to advancement in the field [19], because of this it is important for other researchers to easily reproduce our results. With that in mind, the project was developed in a Jupyter Notebook. Yu can find the code in this url (https://github.com/ULABS-Team/MOABert) The following two files are required to run the

### *7.1 Clinical_Trials_-_Slipping_Window.ipynb*

The Jupyter Notebook (IPYNB) file contains the environment to run the models. It also contains some of the output that provides insight into how the model increases in accuracy each epoch as it better understands the data.

### *7.2 Clinical_Trials_-_Slipping_Window.py*

The Python (PY) file contains the Python source code providing all steps, from importing the required libraries and other dependencies to run the project, to reading in the data, training the models, and providing metrics on the final trained models.

Should any issue arise reproducing these results or running the associated files, please do not hesitate to contact us.

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# Neural Networks for Predicting Severity of Ovarian Carcinomas

**Rushikesh Chopade, Aditya Stanam, and Shrikant Pawar**

**Abstract** Among gynecological cancers, ovarian cancer is the greatest cause of death. The lack of efficient early detection measures is linked to diagnosis at an advanced stage and a bad prognosis. Several genes have been shown to have significantly expressed in early and late stages of ovarian cancer. The use of a neural network can help infer meaning and find patterns from large data sets. The benefit of a neural network is that it is adaptive in nature, learning from the information it receives and adjusting its weights for a better prediction in instances when the outcome is unknown. Some studies have shown effective utilization of neural networks with miRNA data in ovarian cancers, others have used it in gastric cancers with survival data sets, and this study focuses on testing them on gene expression data in ovarian cancers. We found a robust RMSE values for prediction, a reasonable k-fold cross validation, and robust cross grade-stage predictions. This study defines a clear scope of utilizing neural networks in predicting grades and stages in ovarian cancers.

**Keywords** Neural network · Ovarian carcinomas · Predictions

## 1 Introduction

With 225,000 new cancer cases and 140,000 fatalities each year, ovarian cancer is the largest cause of cancer deaths among gynecological malignancies [1]. The lack of efficient early detection measures is linked to diagnosis at an advanced stage and a bad prognosis. Several genes have been shown to have significantly expressed in early

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and late stages of ovarian cancer. *PALB2* gene mutations have been found in ovarian cancer and are linked to an increased risk of breast and pancreatic cancers [2]. Ovarian cystadenomas, borderline ovarian tumors, and low-grade invasive malignancies were all linked to a missense mutation of the *CHEK2* gene. *BARD1* germline mutations and identified in low-grade serous carcinomas, borderline serous tumors, and low-grade endometrioid. Stable tumors also have occurrence of mutations involving *KRAS, BRAF, ERBB2, PTEN, PIK3CA*, and *b-catenin* genes [3]. In this work, we have focused on 14 genes (*KRAS, BRAF, PIK3CA, ERBB2, CTNNB1, ARID1A*, *PPP2R1A, TP53, BRCA1, BRCA2, RAD51*, *PALB2*, *CHEK2*, and *BARD1*) which are known to be significantly associated with ovarian cancers.

A neural network is a data-processing machine that can be compared to the human nervous system. The strength of a neural network comes from parallel information processing, which allows it to deal with nonlinearity [4]. The use of a neural network can help infer meaning and find patterns from large data sets. A neural network is a model with an activation function that is used to transform input into output by interconnected information processing units. The neural network's first layer receives the raw input, processes it, and sends the processed data to the hidden layers. The information is passed from the hidden layers to the final layer, which generates the output. The benefit of a neural network is that it is adaptive in nature, learning from the information it receives and adjusting its weights for a better prediction in instances when the outcome is unknown. A learning rule is used to optimize the weights of the links in a network. A least mean square, gradient descent, newton's rule, and a conjugate gradient are examples of learning rules [4]. The backpropagation error approach can be utilized in conjunction with the learning rules. The weight at each link is then optimized based on the mistakes at each unit [5].

This paper tests the usage of neural networks in predicting the severity of ovarian cancers in terms of grade and stage. Some studies have shown effective utilization of neural networks with miRNA data in ovarian cancers, others have used it in gastric cancers on survival data sets, and this study focuses on testing them on gene expression data in ovarian cancers [6–8].

## 2 Methods

Data Collection: Library "*curatedOvarianData*" was utilized to retrieve TCGA data set, *TCGA_eset* with 578 patients and 13,104 gene profiles. The gene expression matrix was logarithmic base 2 transformed with features patients grade and stages. Both the grade and stages were classified on scale 1–3. Some of the patients had missing stage or grade values, after removing these final data for 457 patients was selected for further analysis.

Neural Network Construction: Neural network was constructed on 14 selected genes (*KRAS, BRAF, PIK3CA, ERBB2, CTNNB1, ARID1A*, *PPP2R1A, TP53, BRCA1, BRCA2, RAD51*, *PALB2*, *CHEK2*, and *BARD1*) for stage and grades separately. Library *neuralnet* was utilized to construct the networks. Figures 1 and 2

depict the constructed networks each for grade and stage. 457 patient's data was randomly shuffled into training and testing sets followed by data normalization with function *(x){((x-min(x))/(max(x)-min(x)))}*. The idea of normalization was to perform scaling of data. Function *compute()* was used to generate the neural net model. Some parameters to replicate our results for network construction were startweights = NULL, learningrate.limit = NULL, learningrate.factor = list(minus = 0.5, plus = 1.2), learningrate = NULL, lifesign = "none", lifesign.step = 1000, algorithm = "rprop + ", err.fct = "sse", act.fct = "logistic", linear.output = TRUE, exclusion = NULL, constant probability = FALSE, and weights = NULL.

Root Mean Square Error (RMSE) and k-fold Cross-Validations: RMSE was calculated using following formulae.

$$\text{RMSE} = \left(\text{sum}\left(\left(\text{Test data \$stage} - \text{Model}\right)^2\right)/\text{nrow(Test data)}\right)^0 \cdot 5$$

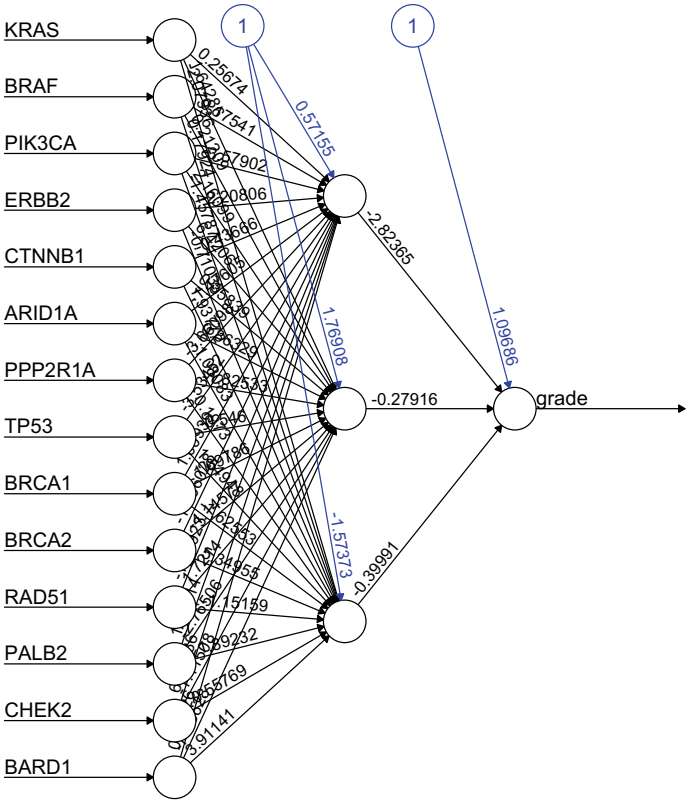


**Fig. 1** Generated neural network for predicting cancer grade on expression of 14 genes

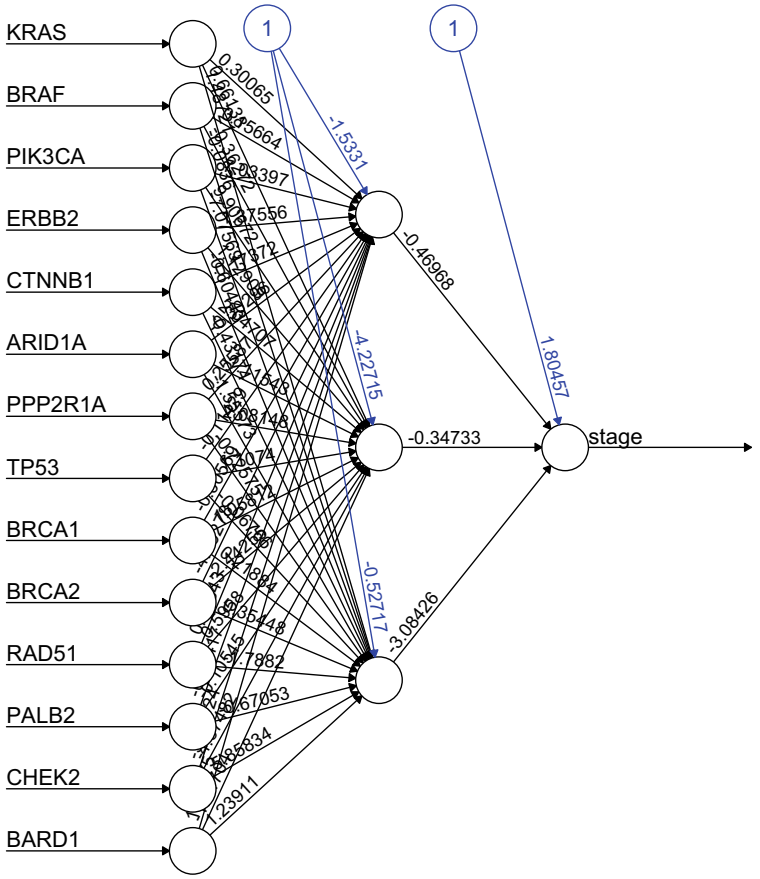


**Fig. 2** Generated neural network for predicting cancer stage on expression of 14 genes

Libraries *boot* and *plyr* were used for cross-validations. The number of items in the training set, *j*, is changed between 1 and 20, with 100 samples selected from the data set for each *j*. In each case, the remaining components are assigned to the test set. Each of the training data sets is used to train the model, which is subsequently tested on the test sets. Each test set's RMSE was calculated. This method evaluates for model robustness and assures that our results are free of sampling bias.

All the code for accessing TCGA data, generating neural networks and k-fold cross-validations can be found at authors GitHub account: https://github.com/spawar2/Neural-Networks-for-Ovarian-Carcinomas.git.

## 3 Results

Robust stage and grade networks with strong RMSE values for prediction:

A robust network with weights of 0.5, 1.7, −1.5, and 1.0 were observed for grade and −1.5, −4.2, −0.5, and 1.8 for stage. The testing data had prediction RMSE values of 0.4 and 0.5 each for grade and stage networks. Figures 3 and 4 (Left) depict the cross plots for predicted grade vs actual grade and predicted stage vs actual stage. The predicted grades ranged from 1–4, majority of them clustered around 2.5–3.5, while the predicted stages ranged from 0–4, majority of them clustered around 1–3.5.

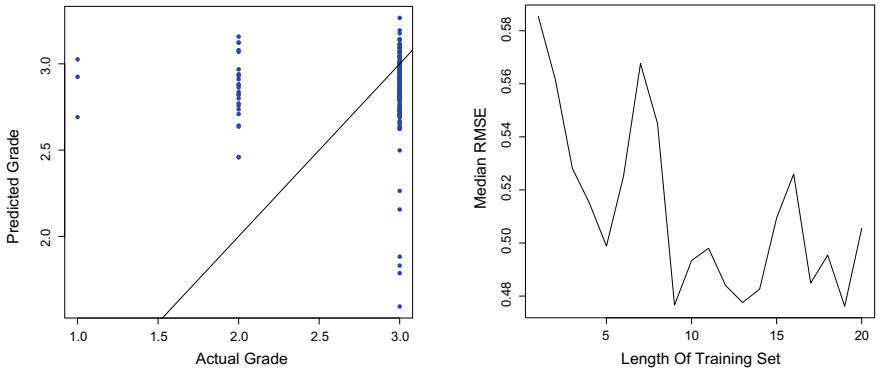


**Fig. 3** (Left) Cross plot for predicted grade vs actual grade (Right) RMSE values for cross-validations

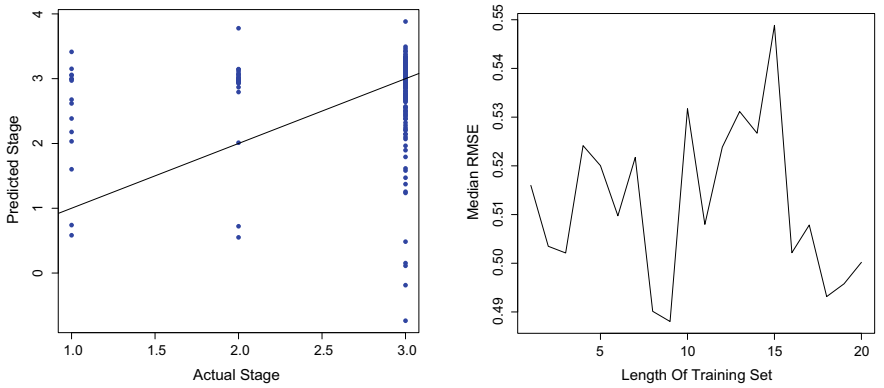


**Fig. 4** (Left) Cross plot for predicted stage vs actual stage (Right) RMSE values for cross-validations

Reasonable k-fold cross-validations:

We used the RMSE approach to evaluate our neural network method, which is a residual method of evaluation. The main disadvantage of residual evaluation approaches is that they do not provide us with information about our model's behavior when new data is supplied. We attempted to address the "new data" issue by dividing our data into training and test sets, building the model on the training set, and evaluating the model by computing the RMSE on the test set. A holdout method was the training-test split. The holdout approach has a drawback in that the variance of the performance evaluation metric might be considerable depending on the items assigned to the training and test sets. We used k-fold cross validation to solve this problem. This method can be thought of as a recurrent holdout technique. The entire data set is divided into k equal subsets, with one subset serving as the test set and the rest as the model's training set. This strategy decreases the reliance of performance on the test-training split and reduces the variation of performance measurements by giving each data point a chance to participate in both the test and training sets. The median RMSE of our model reduces as the duration of the training set increases, as seen in Figs. 2 and 4 (Right). The training-test split affects the performance of a neural network model.

Robust cross grade-stage prediction:

To test accuracies of our generated grade model on stage predictions, we generated network on grade and did cross plot for stage. A reasonable RMSE of 1.2 was observed for this plot (Fig. 5), and stating cross plotting or cross predictions can be achieved utilizing neural networks.

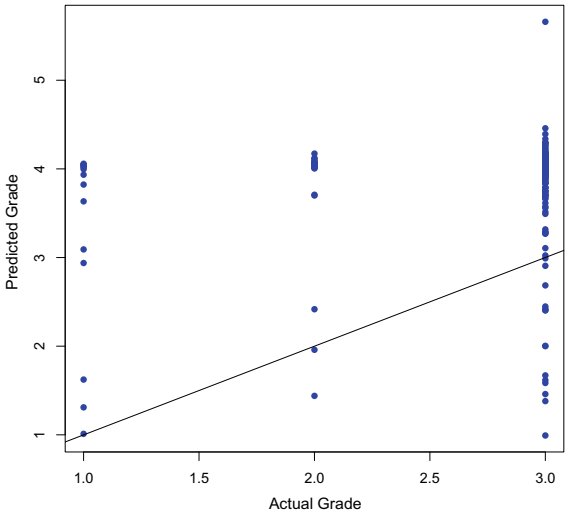


**Fig. 5** Cross plot for predicted grade vs actual grade on model built on patient's stage data

## 4 Discussion and Future Scope

This study defines a clear scope of utilizing neural networks in predicting grades and stages in ovarian cancers. Our study does have several limitations. More research is needed to see if incorporating clinical risk variables will boost its effectiveness still more. Confirmation in additional cancer data sets is required to evaluate and establish the generalizability of our findings. Other confounding factors like age, drug treatment, chemotherapy, and surgery needs to be taken into consideration while constructing a network. Finally, because the neural model favors genes that give unique information, our gene expression panel relies on a lower number of genes. We are now looking at the performance characteristics of our neural network in both high-risk and low-risk groups, as well as developing improved models for this and other diseases. Lastly, our neural network model adds to the toolkit of alternatives for ovarian cancer diagnosis.

**Competing Interests** The authors declare that they have no competing interests.

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**Supplementary File** Expression_Matrix.csv: Gene expression matrix for selected 14 genes.

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# Development of Hybrid Personalized E-commerce Using Collaborative Filtering and Content-Based Filtering for South Cartel Clothing Company

**Jcyle Anne T. Balmadres, Kristine Bartolome, Roi Gerome B. Bunyi, Jeffrey Rafael B. Jacobo, Jay-ar P. Lalata, Ace C. Lagman, and Ma Corazon Fernando-Raguro**

**Abstract** E-commerce plays an essential role in selling products or services online because it can reach more customers than traditional retail. If the customer data is appropriately mishandled, it disrupts the business' data organization and poor customer relationship management. The study focuses on creating an e-commerce website that efficiently handles the data and integrates a personalized hybrid recommender system. Content-based and collaborative filtering methods were used in the recommender system to improve customer relationship management, streamline procedures, organize inventory and sales, and increase profits. Sales forecasting using ARIMA was also added to use the customer data for efficient business decisions. ISO 9126 was the software quality model used to evaluate the developed system using the software quality characteristics functionality, usability, maintainability, and efficiency. The system got an overall mean score of 4.57, which is excellent, which means the system can perform smooth transactions from ordering up to the checkout and organized products, sales, and inventory. The integration of the recommender systems was able to give recommendations based on the customer's preferences, which enhances the user experience that may lead to an increase in sales of the business since the suggestions are tailored recommendations to the users.

**Keywords** E-commerce · Recommender system · Sales forecasting · ARIMA · Content-based · Collaborative filtering

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# 1 Introduction

E-commerce is becoming more and more relevant in our daily lives. It is revolutionizing the way people do business around the world. The internet allows people to buy and sell almost everything, including books, electronics, clothes, apps, and furniture. People can purchase or sell whatever they want, anytime they want, with the help of e-commerce. According to the study of Orendorff [1] about the developments on e-commerce from 2014 to 2023 and projections for the future of the industry, global e-commerce revenues are expected to grow by 276.9% over the most recent monitored time frame and Asia–Pacific region accounts for more than 70% of all global e-commerce activity.

According to estimates from 2019, the Philippines has 76 million active social media users [2]. E-commerce in the Philippines will reach $12 billion by 2025, after generating $3 billion in 2019. During the first six months of 2020, the number of consumers and pesos sold has more than doubled. Metro Manila accounts for 38% of all e-commerce transactions, 9% in Cavite and Laguna, 6% in Cebu, 6% in Pampanga and Bulacan, 3% in Davao, 3% in Rizal, 2% in Iloilo, and 2% in Batangas. The remaining areas are too limited to be classified [3]. E-commerce is emerging and becoming more relevant to companies as technology advances, and it is something that should be taken advantage of and incorporated. E-commerce refers to buying and distributing goods and services over the internet and processing funds and records to conclude transactions. Hence, effective e-commerce development is needed for helping buyers to save time, shop quicker, and recommend products based on their preferences [3]. Features of e-commerce typically include a simple transaction processing of buy and sell of products, selecting categories, adding products to cart, filtering items to their desire, ease of digital payment, and the tracking and delivery of the product purchased. Some e-commerce businesses go beyond the traditional process and add personalization to improve customer experience. Hence, these sites use consumer transaction history to suggest products tailored to their interests.

## *1.1 Background of the Study*

South Cartel 55 is a local clothing brick-and-mortar store that sells different apparel brands in its store located at Calamba, Laguna, Philippines, established in June of 2020. South Cartel's products are streetwear clothing, common among numerous urban youth subcultures. The products include but are not limited to shirts, shorts, hoodies, and many others.

The process of the brick-and-mortar store's transactions traditionally displays the products categorized and waits for customers to feel free to come in and check out their product. Once the customer finds the product that satisfies, the purchase transaction is done over the counter, where the consumer pays for the product according to the product's respective price via cash or card. The transaction is then recorded

using a logbook to keep track of products, orders, sales, and stocks. Manual product suggestions to consumers are also initiated when customers are curious about more product designs and variations.

The store also has a delivery mode of transaction but is only limited within reach in their area. The store supports online transactions, which are presented through the Facebook platform. The purchasing transaction online is done through Facebook chat with the user and an online bank transfer for payment. The order will also be logged manually through their logbooks.

The business's current problem is the limited access to customers since most transactions happen only in a brick-and-mortar store. On the Facebook platform, not all items are adequately displayed since Facebook is a single-column scroll type of app wherein it is not easy to browse other items that they offer. Another problem is the manual listing of order transactions in logbooks which may lead to inaccuracies and errors in the computation of sales and stock data.

Currently, the company needs to acquire more customers and showcase products to the audience for them to be discovered; also, handling customer data is a problem since they only use paper methods. To aid consumers in buying items remotely from the local clothing store and grasping a larger audience, the researchers aim to create an e-commerce website with the integration of a weighted hybrid recommender system and sales forecasting for the client known as South Cartel 55. Hybrid RS issues more accurate suggestions by analyzing aggregate data on the user and the item, thus leveraging the power of multiple data sources and improving the performance of existing RS with particular data modalities [4]. A weighted hybrid recommender system will solve the uniqueness issue, manual recommendations, and limited access to items that could assist customer satisfaction. Limited access to customers will be solved by creating e-commerce since it will be available throughout the internet. Lastly, the inventory, order transactions, and sales will all be recorded automatically in the admin dashboard of the system to have centralized storage and accurate management of data for the business.

## 2 Methodology

### *2.1 Conceptual Framework*

The conceptual framework in Fig. 1 shows what inputs and processes are needed to develop the e-commerce site with the recommender system and the sales forecasting. It shows the inputs that are divided into what requirements are needed in the making of the project; there are knowledge requirements, hardware requirements, software requirements, and people requirements.

The requirements listed will be utilized in the process stage, where the scrum methodology is applied. The scrum methodology will be used by the researchers in developing the project since it is suitable for changes. Scrum offers value to the client

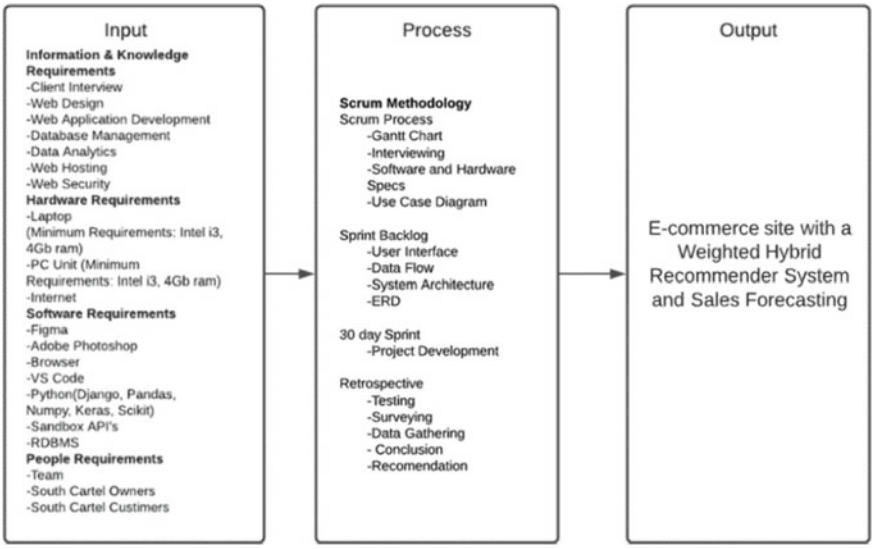



**Fig. 1** Conceptual framework

throughout the project's development. It is adaptive, rapid, flexible, incremental, and effective [5]. The process includes the scrum process, sprint backlog, 30-day sprints, and the retrospective in the project's development. The output of the variables after the process is the e-commerce system. Each sprint will be reviewed and repeated, if necessary, when the client advises changes. When the system is evaluated and reviewed in the final release, the system will be completed and ready for the client to implement for their business operations.

## *2.2 Recommender System Algorithm*

Data whether explicit or implicit data will be gathered from the users as seen from Fig. 2. Explicit data is data that is provided intentionally such as product ratings; hence, implicit data is the opposite. Since it is complex to feed in both data at the same time, the implicit data will be converted to explicit data and will be stored in a single preference table and will be assigned scores for each activity; for example, if the product is browsed, it would produce a score of three, and if the products are added to cart or favorites, it would produce a score of five.

The hybrid recommender system consists of two filtering algorithms which are the content-based filtering and collaborative filtering. The content-based filtering will take in a random item's features in the user's preference table and compute the cosine similarity of the product to the other products in the database and rank them in descending order based on the similarity computed. The similarity between cosines

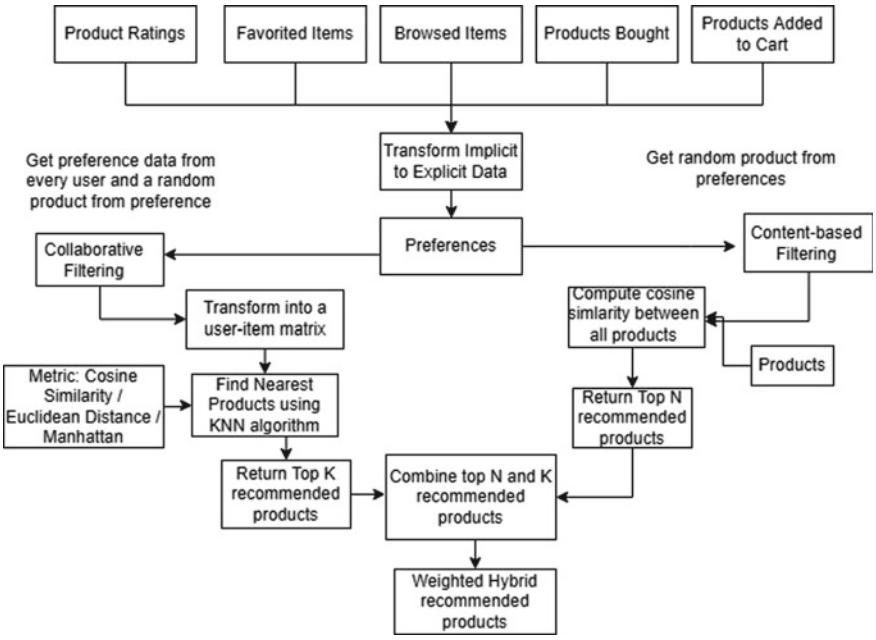



**Fig. 2** Weighted hybrid recommender flow

looks at the angles of cosine between two vectors (e.g., $A$ and $B$). The lower the cosine angle, the more similar the $A$ to the $B$. In this, it would produce the top $N$ recommendations based on the items' details provided.

$$\text{Similarity}(A, B) = \cos(\theta) = \frac{A \cdot B}{||A||||B||} \tag{1}$$

For collaborative filtering, it will use an item-based approach wherein it will use the KNN algorithm. K-nearest neighbor (KNN) is a machine learning system that identifies comparable user classifications based on common item ratings and predicts using the top-k closest neighbor rating average. The technique used to find the closest neighbors is "brute," and the metric can be cosine similarity, Euclidean distance, or Manhattan; depending on the results it generates, the researchers will choose the best one. Finally, once both filtering methods produce recommendations, the results of each filtering method will be weighted and merged into one set of recommendations for a user.

*ARIMA Equation for Sales Forecasting*. The sales forecasting module will forecast weekly sales; hence, it would need weekly sales data which is provided by the client. The forecasting will be done after the cleaning and transforming of the data and then fed to the ARIMA model. The Autoregressive Integrated Moving Average (ARIMA) model is a model that aims to forecast future securities or market movements by evaluating differences in values in the series rather than real values of the data fed

into the model.

$$Y_t = \alpha + \beta_t Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_p Y_{t-p} \epsilon_t + \varnothing_1 \epsilon_{t-1} + \varnothing_2 \epsilon_{t-2} + \ldots + \varnothing_q \in_{t-q} \quad (2)$$

### *2.3 Evaluation Procedure*

It is imperative to discover any flaws or faults early in the development process to ensure that the final software product meets the expected specifications and is defect-free. As a result, alpha, beta, and user acceptability tests were performed in the system to assure the software's reliability and high performance throughout operation.

In evaluating the developed system, survey questions consisting of four main factors from ISO 9126 evaluation metrics, namely functionality, usability, maintainability, and efficiency, were given to the respondents to collect information about the system. The researchers used purposive sampling in gathering respondents such as IT expert, admin, staff, partner, and customer. The system demonstration was conducted via online conference to show how the system works on the user and admin sides. The researchers allowed the respondents to use the system and provided the survey questions to learn more about what needs to be modified and adjusted about the system. The researchers utilized the Google Forms platform to collect responses from the desired participants. The researchers gathered a total of 59 respondents, consisting of forty (40) customers, ten (10) IT experts, five (5) partners, two (2) staff, and two (2) administrators.

The use of mean in this study is important to know the average rating of the system. The Likert scale and interpretation for mean range of the system evaluation are as follows. The Likert scale's numeric scale and its interpretation are 5-excellent, 4-good, 3-fair, 2-poor, 1-very Poor. For the interpretation of mean range, numeric scale and its interpretation are 4.51–5.00 is excellent, 3.51–4.50 is good, 2.51–3.50 is fair, 1.51–2.50 is poor, and 0.00–1.50 is very poor.

## 3 Results and Discussion

### *3.1 The Developed System*

The developed system shows an e-commerce website where customers can browse and buy products with integration of hybrid personalized recommender systems to enhance user experience. It is written using Python Django Framework, HTML, CSS as a programming language and PostgreSQL to store customer information. The use of Python served as the basis of the e-commerce project that supports machine

learning, data analysis, and web development. HTML, CSS, Bootstrap, jQuery, and JavaScript were used for the front-end side. While for the creation of the user interface and logo, Figma and Adobe Photoshop are used. VS Code, sandbox APIs, and a browser were used to test and run the code. The website includes nine (9) major features of the study which include accounts module, product module, inventory module, ordering module, delivery module, reports module, recommender system module, payment module, and sales forecasting module (Table 1).

**Table 1** User interfaces

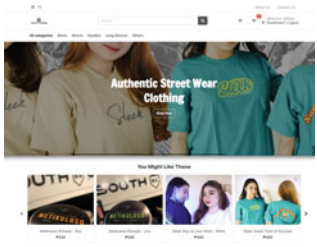
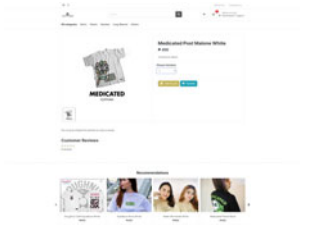
| Page | Description | Interface |
|---|---|---|
| Home page | The home page displays the general top selling, trending, and recommended products for the user. It also has a navigation bar where the user can navigate to different functions of the website. The homepage also shows the effect of algorithm of the hybrid filtering methods |   |
| Product details page | The product detail page displays the specific product picked along with recommendations based on the tags and descriptions of the product picked which also uses the content-based filtering method |   |
| Admin user-level dashboard | The admin dashboard consists of options for handling accounts, products, orders, viewing reports, and viewing carts. The dashboard is a summarization of important reports and orders that are needed to be monitored by the admin | |
| Sales forecasting page | The sales forecasting page shows the weekly and monthly sales and their forecasted value based on the data collected by the system | |

**Table 2** Summary of composite mean

| Criteria | Composite mean | Verbal interpretation |
|---|---|---|
| Functionality | 4.60 | Excellent |
| Usability | 4.66 | Excellent |
| Maintainability | 4.45 | Good |
| Efficiency | 4.57 | Excellent |
| Overall mean | 4.57 | Excellent |

### *3.2 Results of Evaluation*

The survey questions consisted of four main factors from ISO 9126 evaluation metrics, and software testing was done through alpha, beta, and user acceptance testing. The four main factors are functionality, usability, maintainability, and efficiency.

Table 2 shows the system evaluation metrics on different aspects evaluated which are functionality, usability, maintainability, and efficiency that make up the system evaluation. The functionality criteria got a composite mean of 4.60 with "excellent" interpretation because the system can successfully create an account, modify carts, track order, identify and recommend products, predict future sales, and generate reports. The usability criteria have a mean of 4.66 with "excellent" interpretation because the system can be accessible to all and provided a user-friendly interface. The maintainability shows 4.45 mean with "good" interpretation because the system can run smoothly, handles loads of orders, and has good error handling. The last criteria are efficiency, having 4.57 mean "excellent" interpretation for its easy-to-use buttons, respond quickly, handle critical statuses of orders, and perform efficient transactions. The highest criteria are usability with 4.66 mean with "excellent" interpretation because users can easily interact with the system and easily understand buttons and bar. Meanwhile, the lowest is maintainability due to unexpected errors while navigating the system and its features. The overall mean of all criteria resulted in 4.57 which is equivalent to "excellent" which can be concluded that it is ready for its implementation.

## 4 Conclusion

This paper presents a developed e-commerce website where customers can easily browse and buy products online with the addition of a hybrid personalized recommender system to improve user experience, deliver relevant content based on user's preference, organize the data such as inventory and sales, and drive traffic on the website that will increase the profit of the business. It is very important in developing the modules to consider various aspects to make the system functional, usable, efficient, and reliable. It is essential to consider the different types of users who

utilize the system, which grants specific privileges to users allowing them to access or accomplish certain tasks or functionalities of the system, which will not compromise security. A single hub for products data must be provided that contains all the information related to the product and ensures all information about the products is up to date and free from errors and inconsistencies. It is essential for a system to determine the optimum level of inventories to ensure enough stock to fulfill the customers' orders and appropriate warning of the inadequacy of the supplies in the system. It is also vital that the customers can track their orders and at the same time view the history of purchases, cancel orders, and send refund requests which can be helpful for the customers in monitoring and managing their orders. The generation of accurate reports such as inventory, general sales, top-selling brands, and categories plays a crucial role in planning effective sales strategies and monitoring the performance of sales and marketing teams. In building the recommender system, the primary consideration is the type and kinds of data collected from the system's users. The items added to the preferences table such as user's favored, viewed, bought, added to cart, and rate products make the recommender more accurate in suggesting products based on the preferences of the users, whether registered or not. The use of ARIMA model in forecasting the weekly and monthly sales allows owners to make better decisions for their business. The composite average of the evaluation of the system is 4.57, which is described as "excellent" means the system performed outstandingly based on the required functionalities, and it was able to personalize the user experiences in the system through the recommender system.

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# Conceptual Design and Early Prototypes of a Gamified Virtual Reality Interview Training Application

**David Jennings, Pratheep Kumar Paranthaman, and Nikesh Bajaj**

**Abstract** This paper explores the important factors of job interviews that can be gamified and incorporated into a virtual reality interview training application. Virtual reality and gamification have demonstrated benefits in training, simulation, and education. Specifically, virtual reality can be helpful in creating simulations of realistic job interview scenarios and environments for providing interview training for users. Existing interview training applications lack elements of gamification. In this paper, we have proposed a conceptual design of gamified interview training application in virtual reality. In the conceptual design, we have established six stages, each highlighting crucial aspects of interview preparation and training. Currently, a prototype for each stage exists, with each one connected and a user interface system setup.

**Keywords** Virtual reality · Gamification · Interview training · Virtual reality interactions · Simulation

## 1 Introduction

Virtual reality (VR) has potential benefits in training and education that are explored through research. As the role of VR expands, the necessity to provide potential improvements in learning and training has also expanded. In this work, we plan to combine VR with gamification. The gamification of VR applications intended for training and education provides scope for research, as gamification could alter the

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effectiveness of VR. Also, the concept of gamification has been widely used in several domains like education, driving safety, and language learning [4, 9, 11, 12, 21].

VR interview training is largely unexplored, with only a few available applications that lack beneficial gamification techniques. A gamified interview training application can potentially develop important skills necessary for interviews in a fun and engaging manner. We propose a system that defines core interview aspects and transforms them into gamified stages within a VR application. As the user progresses through the stages, they will be provided with informative feedback and tips on how to further improve interview skills. The current progress of the application development process includes the creation of all six prototype stages, each containing a simple user interface. The blueprint for the application's flow has been created and will serve as the guideline for connecting the stages into a cohesive application. The conceptual design and prototype description for all the six stages have been presented in this paper.

## 2 Related Work

There are a few interview training applications, with even fewer available as VR applications. An interview training application by Virtro [19] simulates a mock interview, in which the user chooses a custom interview scenario and answers questions asked by a virtual human. The application provides statistical feedback regarding the interview time length, longest response length, shortest response length, and questions answered. A transcript and audio recording of the mock interview are available to the user for review. However, this application is not available in VR. Another application called "VirtualSpeech" [20] developed an interview training course to prepare users for job interviews. The course includes access to a VR application in which the users practice for interviews. The VR application offers audio recordings of the interviews for users to review and provides feedback on the users eye contact in the interview. The users are asked a set of questions from over 200 possible questions used by various companies in real interviews [20].

A research study conducted by [2] compiled various studies in the effectiveness of VR as a method of training for orthopedic surgery. Ten studies were collected and analyzed to measure how VR has affected the training process for orthopedic operations. Another study [6] focused on the use of VR and augmented reality (AR) educational tools for teaching anatomy. Of the 22 studies used in the review [6], five of them compared the effectiveness of VR with traditional learning methods. In those five studies, VR was found to be effective and enjoyable and was only less effective when compared to live dissection in one study.

The research carried out by [3] analyzed the effects of applying gamification to laptop security training. With 273 participants, the study was able to compare a group that participated in gamified training with a control group that participated in a non-gamified version of the training. This study found that the users of the gamified system felt more satisfied, but did not have any significant differences with the control

group in terms of declarative knowledge tests. The control group was found to score higher in procedural tests than those using the gamified system [3].

A separate study demonstrated a teaching case that utilized gamification and VR to facilitate learning engineering and architecture. Students in the class were provided a game narrative to follow, in which they designed buildings in various pavilions on a virtual island [18]. The students completed design projects in virtual reality while being a part of a competitive environment since the students would eventually vote on the best designed pavilions. Other gamification techniques such as points and badges were included. The student reports revealed that they enjoyed using multiple technologies such as VR and the use of a gamified narrative. However, some gamification aspects such as points and badges received negative reports [18].

Research study carried out by [14] tested the effectiveness of a job interview training application in VR with adults with autism spectrum disorders (ASD). The VR application used consisted of simulated job interviews with a virtual character. The participants chosen to use the VR application reported that it was easy to use, enjoyable, and effective in preparing them for future interviews [14]. These statements were supported when the VR application users had higher improvements in live interview role-play performances than the users not using the VR application [14].

The current literature reports reasonable results of utilizing VR for job training, education, and interview training. However, studies produced mixed reports on the effectiveness of gamification. Therefore, upon completion of this application, our primary aim will be to evaluate the effectiveness of gamification in VR for interview training.

## 3 Conceptual Design and System Overview

The gamified virtual reality interview training application (G-VRIT) being developed will consist of six consecutive stages that provide small gamified challenges for the user in virtual environment. Each stage targets a specific core aspect of interviews for the user to learn and practice. The term core aspect refers to the primary skills required for an interview. As the user progresses through the stages, the challenges will increase in complexity and length. To avoid cybersickness, there will be comfort checks between each stage, allowing the user to take breaks if needed. Due to the rarity of research articles describing core interview aspects, multiple opinion-based blogs and websites were also used for insight as we defined and selected six core aspects of interviews to provide the foundation for the G-VRIT. Each stage facilitates the user's learning and provides practice with each core interview aspect with the intention of preparing the user for real-world interviews. Each stage provides a small challenge in which the user will be awarded points for adequate performances. Frequent feedback on the user's performance is provided throughout each stage.

### *3.1 Core Aspects Addressed in G-VRIT*

**Aspect 1—Preparation**. Firstly, appearances and interview preparation were commonly mentioned in the sources as important aspects involved with the interview process. The sources commonly suggest "dressing the part" and wearing an outfit that resembles the culture and position of the job, although business casual attire is considered a safe and common outfit option for interviews [10, 16]. Dressing professionally ensures that interviewers are not distracted by appearances and can instead focus on personality and responses [1]. Interview preparation refers to organizing and bringing documents related to the interview, such as resumes, certificates, and samples of work [1, 16]. Providing relevant documents for the interview contributes toward a positive and lasting impression and can build an appearance of professionalism [1]. Dressing appropriately and bringing relevant documents are both components of interview preparation which is the first core interview aspect used in G-VRIT.

The first stage of the application is the preparation stage and this includes organization, bringing relevant items and documents, and dressing appropriately. In this stage, the user will be within a room with tables in front of them. Various items cover the tables, and the user must select which items to bring to an interview. Points will be granted for the selection of items deemed useful and relevant to interview context while points will be deducted for selected items not relevant to the given interview scenario. Items deemed appropriate to bring will include paper documents, pens, and portfolios. An adjacent table will be covered in various clothing items that the user can choose from. The user must choose various clothing items to wear for the interview, and points will be awarded for selected business style clothes. Points will be deducted for selected clothes that are deemed casual or inappropriate for the interview context. Through this small challenge, the user will learn the basic VR interaction mechanics in the application (aiming and selecting objects) and will also learn more about what to wear and bring to interviews.

**Aspect 2—Eye Contact**. Eye contact appears frequently as an important form of nonverbal communication needed to make a lasting impression in interviews. Eye contact demonstrates focus and attentiveness while avoiding appearing dispassionate during the interview [1, 5]. Eye contact even contributes toward appearing enthusiastic, which is commonly referred to as a helpful strategy for interviews [15]. Due to the frequency in references as an important factor for interviews and the potential for a simple training exercise, eye contact is the second core interview aspect used in our application. The second stage is centered on eye contact and gaze, and this stage consists of a room with two rows of tables and a virtual avatars representing an interviewer at each table. The user is prompted to look at the highlighted avatar, and the highlighted avatar will change to provide consistent movement and changes in the user's gaze. Points will be deducted for not keeping the gaze on the highlighted targets while points will be awarded for keeping the gaze properly on target. After ninety seconds have passed, the challenge is concluded and the user will be provided feedback on their eye contact.

**Aspect 3—Time Management**. Multiple sources cited the importance of staying on task and arriving at the interview on time. Some sources recommend arriving 10–15 min early [1] to not only make final preparations, but learn more about the office environment [16]. Arriving late is generally seen as inexcusable and can have a profoundly negative effect on the interview results [10]. This skill will be tested in the third stage, which takes place in the lobby of the office building. The user will have a timer representing how much time they have left before they need to reach the next stage. The user must traverse the lobby, but will come across several distractions that the user can optionally interact with. By interacting with these distractions, time will be deducted and will affect the user's performance score for this stage. The goal of this stage is to demonstrate one's focus and their time management as they attempt to reach the interview on time.

**Aspect 4—Question Answering**. The next imperative core aspect of interviews is the ability to effectively and honestly answer questions. Interview participants need to be prepared for four types of interview questions: situational, past behavioral, background, and job knowledge [7]. Assessing performance on question answering factors such as honesty and enthusiasm cannot be easily tested in a virtual application. Instead, the fourth stage provides simple practice for answering each of the four types of questions identified. The stage consists of a small office space with a single desk between the user and a virtual interviewer. The virtual interviewer will ask several questions from the identified types of interview questions and the user will be prompted to respond. The user can use the VR hand controller to aim at multiple choice options given and select the appropriate option by clicking a button on the VR hand controller. This will provide experience with answering common interview questions that the user may experience in live interviews.

**Aspect 5—Question Asking**. Multiple sources [1, 5, 16] indicated that asking questions as an integral part of interviews as it demonstrates a strong sense of interest in the job. Asking insightful questions can lead to gathering more crucial information relating to the job culture and environment.

Stage 5 not only covers question answering, but also question asking. The user needs to understand that job interviews are a way, in which the user can learn about the job position and culture to determine if the job is a good fit for them. Asking questions is the best method of learning about the job culture and position. The user will be in an interview space with a single virtual interviewer behind a table. Several potential questions to ask will be presented to the user, who will be prompted to select one of the questions to ask. Points will be rewarded for selecting relevant and insightful questions while points will be deducted for selecting off-topic or shallow questions. This stage will not only help the user understand the importance of asking questions, but will provide example questions to ask during real-time interviews.

**Aspect 6—Follow-up**. Multiple sources cited sending a follow-up email or letter as an important yet overlooked step toward getting hired [1]. After the interview, interview participants can gain an edge in the interview process by demonstrating appreciation to the interviewer by sending an email or letter[10]. This follow-up also demonstrates the interview participants interest in the position [1]. The user's

insightfulness to send a follow-up will be tested in the last stage, where they have the option to take the proactive step of sending follow-up emails or conclude their progression through the simulated interview process.

## 4 Early Prototype of G-VRIT

As an early prototype development, we created the layout and UI for the six stages. For this prototype development, we used Unity game engine and Oculus Quest integration SDK package, and interfaced an Oculus Quest 2 with Unity Project. The purpose of the prototype is to test the user experience as they progress through each stage and interact with the UI. Players will be able to move throughout each stage with limited teleportation capabilities in order to simplify movement and reduce the possibility of VR sickness. Players will be able to move their head (for gaze) and their hands, but there will not be any room scale movements or frequent body actions (such as tilting the body left/right). Between each stage will be a user comfort check to ensure that the user's are aware of possible side effects due to prolonged VR usage. At the beginning of each stage, the user will be shown the goals and challenges of the stage through a UI screen. The stage's goals, score, and timer will be shown throughout each stage so the user can keep track of their progress.

By the end of six stages, the user will be given a performance score for each stage on the scale of 1–5. The performance score is dependent on the number of points the user receives during that stage. Each stage has a unique tiered scoring system, in which it identifies the number of points required in order to reach different performance scores. The goal of the user is to achieve maximum score (i.e., 5) on all six stages. Also, users will be given a chance to replay any of the stages again and can practice on the task associated with the stage. The overall goal of this conceptual design is to develop a VR application that provides a fun and gamified environment that still effectively trains the user to prepare for live job interviews. Safety is still a strong consideration, and comfort checks between each stage will ask the user if they would like to take a break to avoid common cybersickness symptoms such as nausea and ocular discomfort [8]. The application will be in a first-person perspective with hands presence in VR, which has a greater chance of inducing cybersickness, especially if the user is moving [13].

### *4.1 Early Prototype of Stage 1*

Stage 1 in G-VRIT focuses on preparation, where the user needs to identify the essentials (items to carry and attire) required for the interview. For this, we created a scene in Unity of a simple bedroom connected to a living room. Worldspace UI will provide the user with visible options of where they can interact with objects and complete the provided objectives. The user will be tasked with selecting relevant

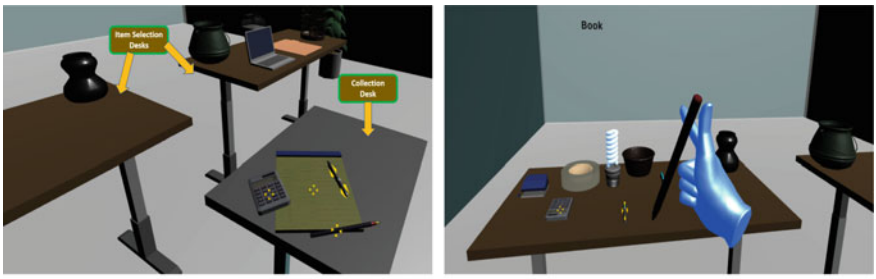


**Fig. 1** **a** Item selection and collection desks present in Unity scene, **b** distance grab mechanics performed in VR mode. A pen was grabbed from the item selection table by pointing right index finger on the pen and selecting the trigger button on the Oculus right hand controller

interview items at a desk covered in various office items (pen, notebook, laptop, folder) and other irrelevant items to interviews (owl cage, flash drive, calculator, and flower vase). Across the desk is the location of the clothing selection task, where a clothing rack with various items of clothing ranging from professional to casual can be chosen and placed on a drawer. By placing the clothing item on the drawer, the user confirms their selection. After completing both objectives of choosing items and selecting clothes, the user will then need to maneuver through the bedroom and living room to reach the door. By interacting with the door, the user can complete the stage and progress through the application.

This stage will be the first demonstration of hand presence in VR mode, wherein the hand controllers of Oculus Quest 2 were mapped to virtual hands in the VR environment. Using the virtual hands, the user will be able to perform distance grab on items and for this, the user needs to point an item using index finger (either right or left) and grab the item by selecting the trigger button on the Oculus hand controller. With this distance, grab the user will be able to select the appropriate office/interview items from the selection desks and drop them on the collection desk. The collection desk is the place where the user accumulates all the essentials. When an item is placed on the collection desk, then the name of the item appears on the UI that is placed in front of the user (see Fig. 2). So in this prototype, the users will practice the selection mechanics in VR using distance grab and also practice selecting the items relevant for the interview context (see Fig. 1b).

## *4.2 Early Prototype of Stage 2*

The prototype of stage 2 includes a room with two rows of tables and each table has a chair behind it and an avatar will be seated on the chair (in total there will be seven avatars seated in the room). The user character in the VR environment will be standing in front of these seven avatars. This prototype stage tests the gaze tracking

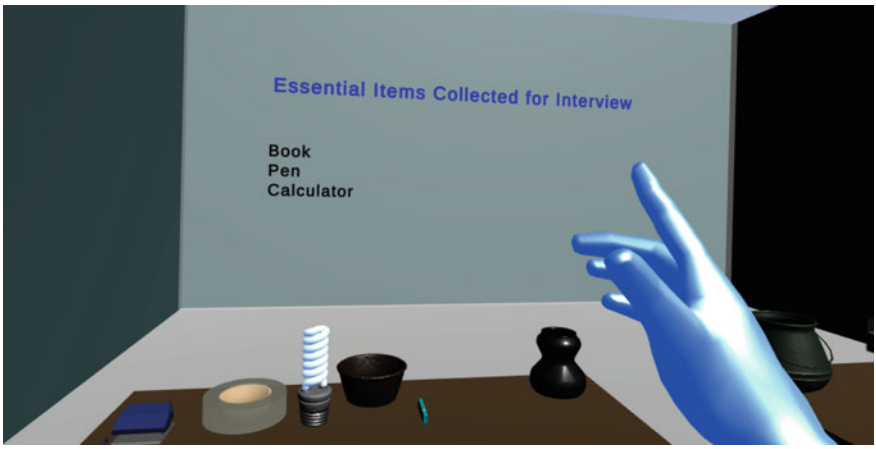


**Fig. 2** UI represents the list of the items currently present on the collection desk

system which will be used to test user's ability to keep eye contact. In the current implementation, a reticle pointer (red sphere in the scene) was set up in the scene center and this pointer is associated with the user's gaze. We used the center point anchor of the Oculus Quest 2 VR headset as a reference for this gaze tracking system. Using the reticle pointer, the user will be able to aim/gaze at the avatars present in the scene (see Fig. 3). In the future implementation of this system, the user will be prompted to look at the avatars and keep eye contact with the highlighted avatar. As the highlighted avatar changes, the user will need to shift their gaze and keep consistent eye contact with the changing targets.

### *4.3 Early Prototype of Stage 3*

Stage 3 revolves around the core interview aspects of focus and time management. The user will be in the lobby of an office building and given a goal of reaching the door leading to where the interview will take place. In this lobby, the user must navigate a room of distractions in order to reach their goal. The user will have the option to interact with the distractions, but these interactions will lead to point deductions as a negative feedback loop. This stage is designed to strengthen a user's ability to focus on their goal and avoid tempting distractions. The lobby room and furniture are complete, but the distractions need to be built and implemented into the scene.

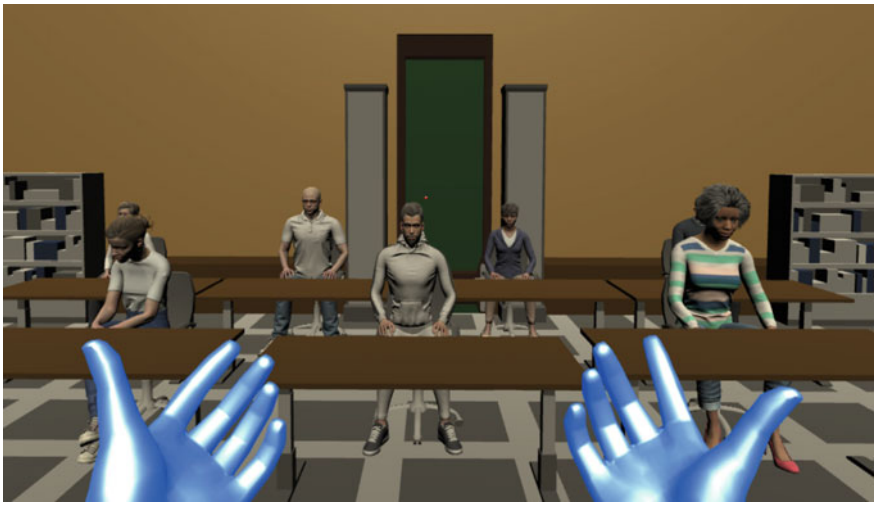

**Fig. 3** Snapshot of stage 2 in G-VRIT—the goal of the user is to establish eye contact with all the avatars in the room. The reticle (tiny red sphere) at the screen center can be used as a reference for gaze

## *4.4 Early Prototype of Stage 4*

In stage 4, users will be in a small waiting room with several chairs, a coffee table, and a reception desk. The user can maneuver around the waiting room and interact with small objects (magazines, posters, framed awards) that will provide small details regarding the company and the interviewer. This information will be used in a later stage, as this stage will only act as a second preparation stage. Users have the option to skip these interactions at the cost of not gaining points and being unprepared for the next stage. This is intended to represent the importance of researching the company, job position, and interviewer in order to impress and sell yourself during the interview. The mechanics behind clicking to interact has been implemented, but the actual details still need to be written and included in the UI that will appear. To move to the next stage, users can interact with the door to the office, which will be labeled with a worldspace UI.

## *4.5 Early Prototype of Stage 5*

Stage 5 is the longest stage, as it includes the interview between the user and a virtual interviewer. This stage involves the core aspects of question asking and question answering. The user will be in a simple office environment with a desk and virtual interviewer in front of them. The office environment is populated with various office

assets (laptop, wall decor, pencils, phone) to add immersion to the scene. Once the interview begins, the questions the interview asks will appear at the top of the screen in UI. The user will be provided with multiple choice options presented on more UI. For each question, there will be a bad response, a good response, and the best response for the users to choose from, and they will be given points according to which response they choose.

Once the question answering phase is complete, the users are provided the opportunity to choose questions to ask the interviewer. The user will not receive a response from the interviewer as this phase will only focus on the user's question asking capabilities. The user will be provided with three questions to choose from at a time, one irrelevant question, one semi-relevant question, and one completely relevant question. Points will be given for each response, depending on the response. After choosing three questions to ask, the interview is concluded, and the user will begin the transition to the next stage after reviewing the stage summary and comfort check. The specific question answering and asking options need to be written and added along with their corresponding UI.

### *4.6 Early Prototype of Stage 6*

State 6 is the follow-up stage, where users will revisit the same bedroom and living room scene from stage 1. Starting in the bedroom, the user can maneuver throughout this scene and interact with various items (TV, computer, door) that are marked with worldspace UI. The user will gain points through interacting with the computer and clicking on UI that will confirm sending a follow-up email. This is to encourage reaching out and offering gratitude to the interviewer for providing the opportunity to interview, thus possibly improving the user's chances of landing a job. The user has the option to interact with the door and end the application, but won't receive any points and it will be reflected in the application summary.

## 5 Conclusion and Future Work

The G-VRIT application is currently in the middle of development, with UI improvements, scripts, polishing environment details, and mechanics incorporation still remaining. The next step in development is to incorporate the game mechanics developed and tested in separate projects into the main application while improving the visual aesthetics of the UI. When developing the final application, recorded audio will replace UI messages, although subtitles will be available. With a completed G-VRIT application in VR, user testing would be the next step. In the user testing stage, two methods of data collection will be used to collect both objective and subjective data regarding user experience with the application. An electroencephalography (EEG) device will record raw brain data related to the user's interest, excitement, stress,

and focus, and this data will be used as objective user experience data. A modified version of the user acceptance scale created by Van der Laan et al. [17] will allow the playtesters the opportunity to provide feedback regarding the usefulness and satisfaction of the application for users. This acceptance scale will provide information regarding ease of use, importance of gamification in this application, comfort, effectiveness of tasks in each stage, and user experience. The testing stage will also be an essential phase in understanding any potential flaws/usability issues in the application.

Thus, in this paper, we have illustrated the conceptual design of the G-VRIT application. With the challenges and tasks related to each of the core interview aspects, this application could potentially provide useful training for job interview preparation in a VR setting. Although there are existing interview training applications, we plan to incorporate specific gamification techniques to enhance the learning experience and simulate the real-world interview scenarios.

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# Improvement of the Production Process, Through Simulation Models, in a Pet Bottle Manufacturing Company

**Estefany Yoselyn Torres Tineo, John Milthon Córdova Vásquez, Mario Roberto Huerta Mendez, Omar Alfonso Santos Pacheco, Mg Mario Ninaquispe-Soto, and Dra Yasmina Riega-Virú**

**Abstract** This research work develops an analysis based on the results of the simulation of the production flow of a PET plastic bottle factory in San Juan de Lurigancho, Lima–Peru, using data collection techniques through the review of records and direct observation. Likewise, data processing techniques were used through the application of the statistical software StatFit, which was processed and simulated by the ProModel software. The objective is to generate a proposal to improve the production flow of the companies in this area, based on the results obtained in the case study model. Among the results, it was found that the reorganization of the workers' functions is more efficient, and by improving the percentage of machine utilization, the incidence of bottlenecks is reduced. The results were validated by applying the statistical test called tests of means. Finally, the findings showed that it is possible to improve time in the production flow. It was also found that it is not necessary to hire or dismiss someone for improvement, only a better organization of the points involved in the process was needed.

**Keywords** Production · Waiting line · Model · Simulation · Process improvement · Improvement proposal · Data collection

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## 1 Introduction

Plastic continues to be one of the most widely used materials in packaging as an equivalent to paper, glass, or metal. The low cost of plastic packaging promotes its use in large industries, making it a business with great impact. It is specifically noted that in Spain, the production of plastic bottles accounted for 39.9% of the economy in 2016 [1].

The plastic bottle market was valued at US$159.68 billion and is expected to reach US$240 billion by 2025. Most bottles are made from polyethylene terephthalate (PET), producing bottles of different sizes and shapes that need caps, and other types of bottles that do not [2].

Industries that produce plastic bottles have been experiencing various problems over the years that affect the fulfillment of their objectives. The problem identified is that the production line is unable to respond to sudden changes in demand, generating high levels of in-process product and raw material inventory [3].

Likewise, the problem of bottlenecks, for example, in foreign territories such as Spain, has severely affected the economy. 70% of the manufacturing companies were conditioned by the shortage of raw materials and subsequent downtime in their production process due to insufficient capacity in certain areas of the industry; the workflow was not continuous, and more time than necessary was spent on some processes [4].

From the observations, it is highlighted that the classic blowing process compared to the injection process causes failures in the finished containers, resulting in 13% of containers with poor quality, besides the loss of the raw material used. Therefore, it is necessary to improve the production process, as well as to propose improvements to solve the problem [5].

The high frequency of bottlenecks in production processes, and the great negative impact that it implies, such as raising production costs, requiring more production time and compromising customer satisfaction by delivering late orders, leads the solution team to develop methods to identify this problem in a production system which evaluates whether to use the traditional procedure or the procedure based on simulation, both requiring a field study for data collection, possible identification of bottlenecks, details of the production process considering behaviors, and results for both methodologies [6].

This research work presents a proposal to improve the processes that are affected by the so-called bottlenecks of the analyzed company, through a system simulation model in ProModel software, which represents through animation the current situation of the company and allows to efficiently evaluate the necessary changes in the system. The objective is to improve the production process in order to eliminate the problems that are exposed. For this purpose, the manufacturing process of two different bottles (product 1 and product 2) will be analyzed. The problem identified in the PET-bottle manufacturing process of a Peruvian company (which was used as the basis for this research) is the length of its processes which require more time than estimated, especially in the production flow of 350-ml bottles for soft drinks

(product 1) and bottles for alcohol (product 2). The processes that precede and follow do not manage to keep up with the continuous production flow, due to unforeseen downtime caused by the lack of capacity and other reasons. During the working day, bottlenecks are identified at different points of the production flow, preventing the company from meeting the required demand in the planned time.

## 2 Methodology

### *2.1 Methodology Aspects*

This study is classified as a descriptive, quantitative, and cross-sectional research work, which helps [7]:

- Identify bottlenecks in the PET-bottle manufacturing process.
- Interpret the results obtained in the ProModel software version 7.0.
- Analyze waiting times in each area. There are 19 locations, 9 entities, and 8 resources (operators) in total involved in this process.
- Propose improvement alternatives in the production flow.

### *2.2 Data Collection*

**AppSheet**. The reports generated by the supervisors were used, which are filled out using the Appsheet application, redirecting the information to a Microsoft Excel table, compiling five months of information. See Fig. 1.

**Direct Observation**. Direct observation was carried out using a data collection form as shown in Fig. 2, which was used for one week to obtain information on the production system times of each of the machines, to be processed later.

### *2.3 Data Processing*

**StatFit**. ProModel software extension used to obtain the types of distributions followed by the study variables and their acceptance rate.

**ProModel**. Specialized software for discrete process simulation, with which we were able to model the process, obtain results, subsequently, evaluate the data obtained, and make proposals for improvement See Fig. 4.

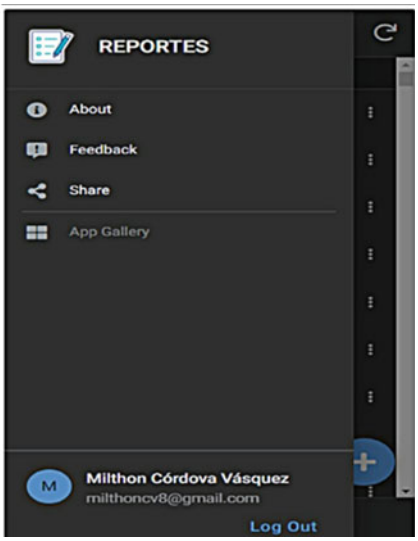



**Fig. 1** Production per hour and the percentage of failure per hour of each of the products to be analyzed have been screened

**Fig. 2** Data collection form, by 24 days

| Collection sheet | | | | | |
|---|---|---|---|---|---|
| Business | | | | Date: | |
| Product | | | | | |
| Description | | | | | |
| Time | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 |
| | | | | | |
| 7 | 8 | 9 | 10 | 11 | 12 |
| | | | | | |
| 13 | 14 | 15 | 16 | 17 | 18 |
| | | | | | |
| 19 | 20 | 21 | 22 | 23 | 24 |
| | | | | | |

## 3 Results

The following information was obtained from the collection of data using the observation sheets:

- Travel time of production operators.
- Processing time per machine.
- Maximum capacity per machine.

This information was processed in the curve fitting and statistical analysis software called StatFit, by which the best distribution representing the data initially obtained was found. Travel times of production operators in product 1 are shown in Table 1, describing the operator in charge and the corresponding type of distribution.

**Table 1** Travel time of production operators for the product 1

| Operator position | Location destination | Distribution |
|---|---|---|
| Distribution | Raw material area | Uniform (15,20) |
| Bagger | Product basket 1 | Lognormal (2,0.11,0.53) |
| Machinist 1 | Industrial oven machine | Lognormal (1,−0.39,0.3) |
| Machinist 1 | Blowing machine | Lognormal (1,0.58,0.40) |
| Machinist 1 | Inspection area | Lognormal (1,0.36,0.48) |
| | Caps counting area | |
| | End caps warehouse | |
| Inspector 1 | Bagging area | Probability |
| Inspector 1 | Waste area | Probability |
| Bagger 1 | Pre-warehouse area | Lognormal (4,0.80,0.38) |
| Bagger 1 | Distribution area | 15 min |

Likewise, the information regarding the following product to be analyzed is shown, see Tables 2 and 3.

**Table 2** Travel time of production operators for the product 2

| Operator position | Location destination | Distribution |
|---|---|---|
| Bagger | Raw material area | Uniform (15,20) |
| Bagger | Product basket 2 | Lognormal (2,0.13,0.37) |
| Machinist 2 | Industrial oven machine 2 | Lognormal (2,−0.52,0.33) |
| Machinist 2 | Blowing machine 2 | Lognormal (3,−0.01,0.59) |
| Machinist 2 | Inspection area 2 | Lognormal (1,−0.22,0.46) |
| Inspector 2 | Bagging area 2 | Probability |
| Inspector 2 | Waste area | Probability |
| Bagger 2 | FP warehouse area | Lognormal (4,0.801,0.38) |
| Bagger 2 | Distribution area | 15 min |

**Table 3** Processing time at locations

| Location name | Distribution (Product 1) | Distribution (Product 2) |
|---|---|---|
| Industrial furnace | Lognormal (1–0.36,0.20) | Lognormal (2,−1.17,0.272) |
| Blowing machine | Lognormal (4–0.28,0.37) | Lognormal (7,−0.06,0.602) |
| Inspection area 1 | Lognormal (1–0.36,0.20) | Lognormal (1,−0.36,0.20) |
| Bagging area 1 | Lognormal (4–0.28,0.37) | Uniform (3,4.12) |
| Caps counting area | Wait 30 s | |
| End caps warehouse | Wait 30 s | |

**Table 4** Locations characteristics

| Location name | Maximum capacity | Other characteristics |
|---|---|---|
| Raw material warehouse | Infinite | Arrival frequency 4700/minute |
| Product basket 1 and 2 | 1150 preforms | |
| Industrial oven | 50 preforms | |
| Machinist 1 | 2 preforms | |
| Machinist 2 | 2 preforms | |
| Inspection area 1 and 2 | 50 preforms | |
| Bagging area 1 and 2 | 100 preforms | Exit in packs of 100 units |
| Pre-warehouse | 100 preforms | |
| Final warehouse | 100 preforms | |
| Caps warehouse | Infinite | Arrival frequency 2700/minute |
| Caps counting area | 100 caps | Exit of packs of 100 counted caps |
| End caps warehouse capacity | 10 caps | Exit of packs of 100 units of caps |
| Distribution area | 300 packs | Exits every 24 h |
| Waste area | 1000 failed preforms | Exit every 12 h |

Table 4 describes the maximum capacity of each location, besides other characteristics obtained from the data collection techniques.

The aforementioned information was processed in the specialized ProModel software version 7.0. The following is a representative diagram of the general production flow of the company. This production process has two arrivals, one of them is the caps warehouse, and the other is the raw material warehouse.

All the processes through which the raw material has to pass to finally achieve the finished product are described. See Fig. 3.

## *3.1 Creation of Locations*

The 19 locations were created from the build/locations. In addition, the maximum capacity of each location was recorded, see Fig. 4.

## *3.2 Creation of Entities*

8 entities were created from the build/entities. The term ‘entities’ represents the physical elements that were simulated. See Fig. 5.

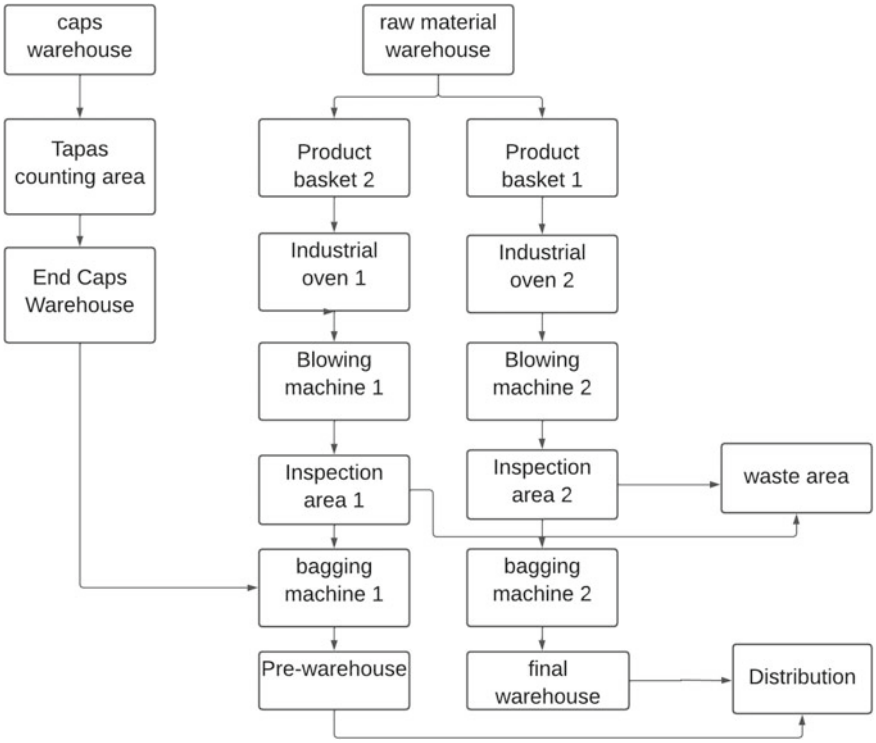
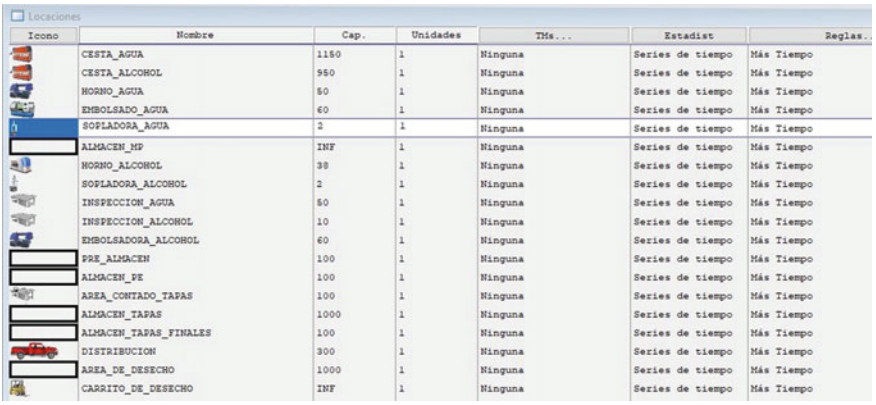



**Fig. 3** Optimal model process of the system



Locaciones

| Icono | Nombre | Cap. | Unidades | TMs... | Estadist | Reglas.. |
|---|---|---|---|---|---|---|
| | CESTA_AGUA | 1150 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | CESTA_ALCOHOL | 950 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | HORNO_AGUA | 50 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | EMBOLSADO_AGUA | 60 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | SOPLADORA_AGUA | 2 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | ALMACEN_MP | INF | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | HORNO_ALCOHOL | 38 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | SOPLADORA_ALCOHOL | 2 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | INSPECCION_AGUA | 50 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | INSPECCION_ALCOHOL | 10 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | EMBOLSADORA_ALCOHOL | 60 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | PRE_ALMACEN | 100 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | ALMACEN_PE | 100 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | AREA_CONTADO_TAPAS | 100 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | ALMACEN_TAPAS | 1000 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | ALMACEN_TAPAS_FINALES | 100 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | DISTRIBUCION | 300 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | AREA_DE_DESECHO | 1000 | 1 | Ninguna | Series de tiempo | Más Tiempo |
| | CARRITO_DE_DESECHO | INF | 1 | Ninguna | Series de tiempo | Más Tiempo |

**Fig. 4** Representation of fixed places for the production, storage, activities, and decision making of the productive system

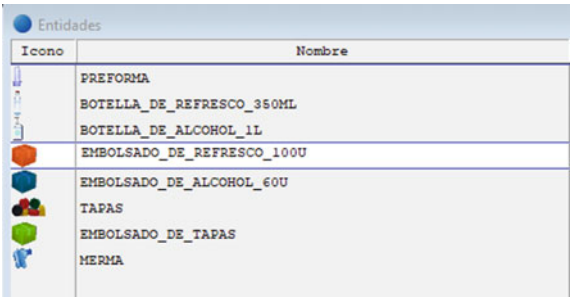



**Fig. 5** Raw material, products, and objects that are part of the transformation or purpose of the production process

## *3.3 Construction of the Processes*

The processes were created from the build/processes, generating the start and end routing lines of an entity, each process corresponds to the sequential order of the production flow until the final product is obtained. See Fig. 6.

Finally, the layout of the study case is obtained by applying the simulation model in the specialized ProModel software, as shown in Fig. 7. The planned simulation time was 6 days (1 week of work) and 5 runs.

At the end of the simulation time, the software shows in Table 5, and the summary of the total exits of both products, among other results.

The results obtained were found to be close to the company's current situation. Among other results of the simulation, two major problems in the production flow are shown, one of them being the low percentage of location utilization and the high percentage of idle time of the operators. These aspects have a negative influence, causing more downtime and delays in the rest of the production line, i.e., bottlenecks at different points of the system.

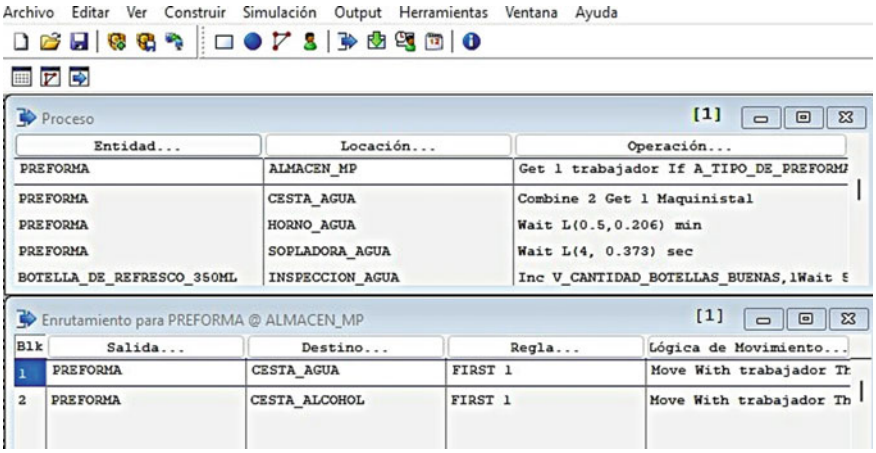



**Fig. 6** Entities time operations, resources, destinations, or processes

**Fig. 7** Structure/layout developed on ProModel software

**Table 5** Summary of results

| Entity name | Total exits | Current quantity in the system |
|---|---|---|
| Preform | 130,976 | 1,000,574 |
| Product 1 | 31,050 | 49 |
| Product 2 | 18,250 | 0 |
| Product bagging 1 (100 u) | 619 | 2 |
| Product bagging 1 (100 u) | 363 | 2 |
| Caps | 31,100 | 27 |
| Bagging of caps | 621 | 1 |
| Reduction | 15,564 | 0 |

## *3.4 Analysis of Results*

**Percentage of location utilization**. The location with the lowest percentage of utilization of their resources is.

- Industrial oven machine with 1.46% of utilization.
- Blowing machine with 2.62% of utilization.
- Inspection area with 8.22% of utilization.
- Pre-warehouse with 2.68% of utilization.
- End caps warehouse with 7.95% of utilization (Fig. 8).

**Percentages of Operators Utilization**. Figure 9 shows the positions with the highest percentage of idle time.

- Machinist 1 with 100% idle time.
- Inspector of products 1 and 2 with 100% idle time.
- Loader with 100% idle time.

**Fig. 8** Excessive waiting time to which the entities are exposed, which explains why the percentage of utilization at their respective work locations is low

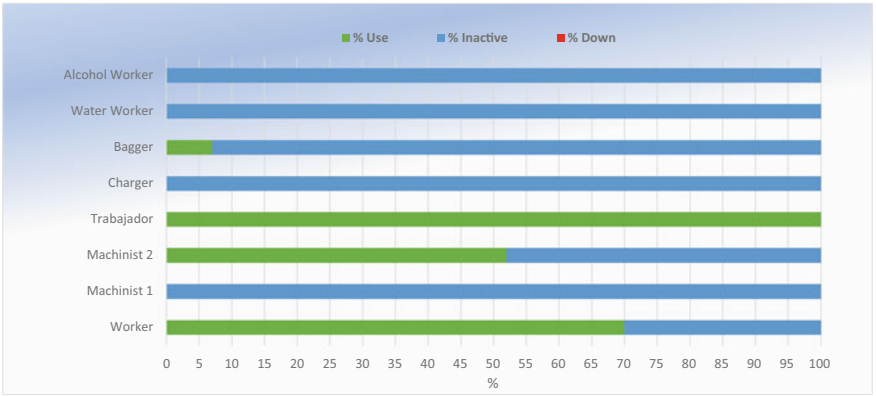



**Fig. 9** Jobs with the highest percentage of downtime

- Bagger with 100% idle time.

In this way, the simulation shows two problems that influence the incidence of the so-called bottlenecks, the low percentage of location utilization, and the excessive idle time of some operators, which particularly affects the area in charge, as well as the continuity of the production flow in general, being very frequent the production downtime and blocking times between machines.

The main contribution of this research is to improve the production flow. According to the results obtained, it is demonstrated that this application identifies

the incidence of bottlenecks, among other areas that require improvement. Therefore, the percentage of operation by resources (operators) and the capacity used in locations are to be increased. For this reason, the following improvement proposal is made.

- Add more functions to the operators that were identified as having a high percentage of idle time.
- Designate a bagger for product 1 line.
- Reduce the speed of arrivals so as not to cause too many bottlenecks.
- Add a third operator (bagger) to support the bagging area.

After making these proposed changes in the initial simulation model, and to solve the previously identified problems, the layout of the improvement proposal was created. See Fig. 10.

At the end of the simulation, the ProModel software provided the following results. With the implementation of a support machinist in the production process of product 1, it is evident that basket 1 has reduced its utilization to 69.78%. The percentage of the bagger utilization increased from 0.72 to 45.08% due to the doubling of the arrival time to 21.55 arrivals per minute. The caps area has managed to speed up the counting and sending of caps to the bagging area. Fair arrivals had an impact on the increase in the utilization percentage, the alcohol bagging machine increased to 25%, and the blowing machine increased to 4.58%. See Fig. 11.

Restructuring resources by assigning them new work functions has helped to increase their utilization percentages. The worker reached 100%, the bagger went from having 0% utilization to 28% utilization supporting the Machinist 1, Machinist

**Fig. 10** Layout implemented with improvement proposals

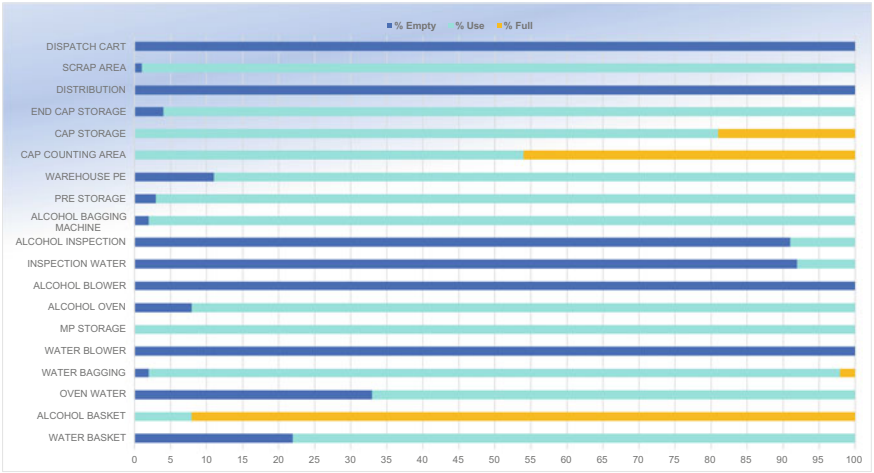



**Fig. 11** Arrivals according to the implementation summary

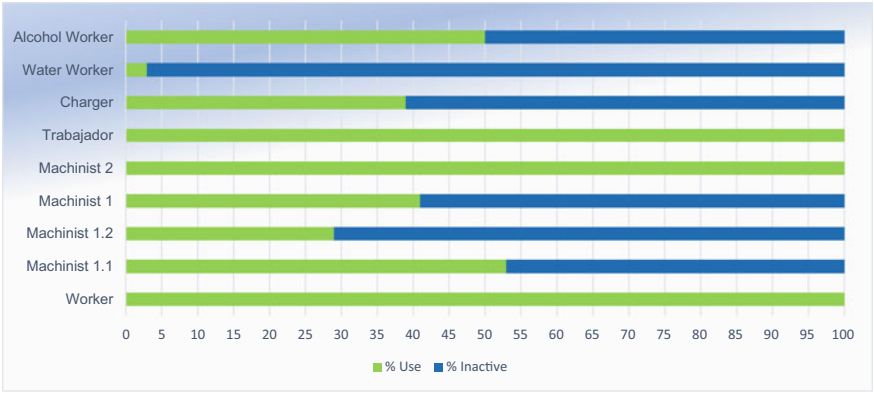



**Fig. 12** Increased utilization percentages by assigning new functions

1.2, and the inspectors of both products increased their utilization percentages by 15.54% and 9.55%, respectively. See Fig. 12.

## 4 Discussion

To initiate a process improvement, the business strategy and the objectives pursued must be analyzed. It is very important to know the organization's goals and prioritize those that are not being met to detect the processes that are not contributing to the achievement of the goal [9].

A company's priority is to find ways to reduce production times in order to analyze whether it is feasible to expand the list of customers or whether it is necessary to acquire new machinery to meet the new demand. Regarding the choice of the best alternative, it was concluded that the implementation of scheduling is a good option compared to the purchase of a new machine, since it does not generate additional costs and also reduces waiting and production times in both processes [8].

During the literature review, very interesting proposals were found to model and solve this problem, in which it is concluded that the use of simulation is a very useful tool to identify internal problems in the production of plastics, effectively representing the behavior of the system, and guaranteeing improvements in the production process. The company implemented the scenarios proposed by the model, achieving a significant 70% reduction in raw material waste [10].

However, the author's proposal is adopted in comparison with the scheduling solution, which consists of ordering the jobs from the highest to the lowest according to the processing time, in which there is a portfolio of customers. The research does not have a customer portfolio. Therefore, to improve the system flow, it is considered relevant to optimize the resources that currently exist and through efficient changes in the system, resulting from the ProModel simulator, the problem of bottlenecks is solved without incurring additional expenses. One of the changes in the system of this research is to opportunely reassign the functions of the operators.

## *4.1 Conclusion*

By applying a simulation in the specialized ProModel software, it has been possible to improve the percentage of waiting time used in the bottle manufacturing production flow, which leads to a reduction in the frequency of bottlenecks.

The ProModel software provides results of the current system under study, to measure and choose the alternative solution that improves productivity. To do this, simulation stages, such as system definition, model formulation, variable identification, data collection, implementation, and interpretation, were used [11].

With an efficient reorganization of workers' functions, it is possible to speed up the production flow of soft drink bottles—water and alcohol.

The use of the ProModel software simulator has allowed us to see the operability of operators in the production system. Using the system simulation, it has been possible to identify the points that cause bottlenecks for their proper analysis, which allows creating proposals and implementing solutions for the production system.

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# Green Hydrogen for Industry: A Proposed Approach to Manage the Flow of Energy in Industrial Sector in Morocco

**Zineb Slaoui, Sanaa Faquir, Khalid Alaoui Zidani, and Ali Yahyaouy**

**Abstract** Worldwide warming could be a critical concern that raises a require for cleaner energy generation with the aim of reducing carbon emission impacting negatively on the global climate. Green hydrogen is considered the clean energy of tomorrow, as it is produced entirely from renewable sources, it must play a key role in the energy transition the production of green hydrogen is strongly affected by the intermittent behavior of renewable generators. There are several methods used to produce this type of energy that can be used in different sectors. Morocco is one of the countries interested by this type of energy and started projects to produce green hydrogen and used it especially in the industrial sector. This paper proposes a comparative study between the different methods of producing green hydrogen and proposes a new approach to manage the flow of energy in the industrial sector. The produced hydrogen provided by renewable sources can be used either when batteries are discharged to their minimum with no load satisfaction or when the storage batteries are charged in their maximum and the surplus of energy produced by the renewable sources is lost. The amount of oxygen derived can also be stored or sold in the industrial market.

**Keywords** Green hydrogen · Electrolysis · Renewable energies · Energy management algorithm

## 1 Introduction

As the world's population grows, researchers have focused in recent decades on harnessing renewable energy resources to meet clean and less expensive energy demands [1]. Wind and solar energy are the most used [2].

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These renewable energies can be used to produce electricity and heat water but also to produce green hydrogen which is considered as a clean energy vector in the event of a surplus of energy and which can be at its tower used in different ways.

Hydrogen it is not a source of energy, but simply an energy carrier that offers flexibility with a low carbon impression since it is produced as a result of a chemical reaction based on a primary resource [3]. For the production of di-hydrogen $H_2$ the main resources exploited are water and hydrocarbons and it can be stored in several ways, in liquid or gaseous form [4].

Green hydrogen is considered the future of tomorrow and also a future decarbonized energy system, as it is produced from renewable sources. This type pf energy could be efficiently stored and used to reduce the reliance on fossil fuels.

The appearance of renewable energies (wind, solar, biomass, etc.) seemed as a hope for humanity [5], but since the green energies of wind or photovoltaic are subject to intermittency: within the nonappearance of wind and sun, the production of electricity is troublesome, on the other hand, when there's as well much, it causes a surplus of energy within the network, for this reason, green hydrogen generation, is heavily influenced by the irregular behavior of renewable generators where it entirely derives from [6]. Within that context, uncertain analysis becomes critical for properly managing this energy holder.

Nowadays, approximately 120 Mt of hydrogen is generated annually, having two-thirds being pure hydrogen and one-third being a mixture of hydrogen and other gases [7]. The European Commission (EC) presented the European Green Deal in late 2019 [8], highlighting the key policy initiatives for achieving net-zero greenhouse gas (GHG) emissions by 2050. Clean hydrogen is identified as a priority area for achieving carbon neutrality by 2050 in the Green Deal.

Hydrogen is regarded as a critical input to the upcoming energy system as an efficient power carrier for industry and transportation, aiding in the reduction of GHG and air pollution. The Green Deal aims may be divided into two phases: phase 1 (now until 2030) and phase 2 (from 2030 to 2050) [7].

Hydrogen can be used in the industrial sector to provide low carbon energy to the industrial units concerned.

Morocco is one of the countries that started to invest in projects to produce green hydrogen from renewable sources of energy. For the last ten years, Morocco has surged as the regional champion in clean energy, adding to the country's competitiveness. The drop in the price of a clean energy kilowatt hour, as well as the richness of Moroccan sites incorporating strong sunlight and strong wind velocities, offer a real capacity to promote hydrogen and variants without $CO_2$ [9].

However, since the green energies of wind or photovoltaic are subject to intermittency: within the nonappearance of wind and sun, the production of electricity is troublesome, on the other hand, when there's as well much, it causes a surplus of energy not used within the network [1]. In addition to that, green hydrogen generation is heavily influenced by the irregular behavior of renewable generators where it entirely derives from. Within that context, uncertain analysis becomes critical for properly managing this energy holder [10].

This article compares different methods of green hydrogen production and targets the industrial sector to manage energy flows in this sector. This approach can be implemented in future work by an intelligent method to predict the amount of green hydrogen production from renewable sources and manage the flow of energy in a factory especially when storage batteries are discharged to their minimum with no load satisfaction or when the storage batteries are charged in their maximum and the surplus of energy produced by the renewable sources is lost the green hydrogen produced in the system remains a possible solution. Another advantage is that an amount of oxygen also derived can be either used in the factory or sold in the industrial market.

## 2 Green Hydrogen Production

### *2.1 A Green Hydrogen in Morocco*

A large part of Morocco's energy consumption is still based on fossil fuels: 31% on crude oil, 17% on coal and 4% on natural gas [11]. Morocco is among the countries best known for its abundant renewable energy resources [12].

Morocco has established an optimization model that is conducive to the production of green power, based primarily on the increase of clean energy. He made a breakthrough in the deployment of clean energy ten years ago, showing audacious and vigilant objectives about the capacities to be placed to exceed the 52% mark on the horizon 2030, it is revealed at COP21 that the green hydrogen market and its variants in Morocco could increase supply of between 13.9 and 30.1 TWh in 2030, which could attain between 67.9 and 132.8 TWh in 2040 and 153.9 and 307.1 TWh in 2050 [9] (Table 1).

Numerous important projects are already on the site in the country. As part of the Moroccan-German partnership an ambitious project for the production of green hydrogen from renewable sources is undertaken by the Moroccan Agency for Sustainable Energy–Masen. The primary objective of this project is to supply a green hydrogen plant with an electrolysis capacity of approximately 100 MW by building a hybrid photovoltaic and wind power plant [9].

MASEN recently unveiled the largest green hydrogen and ammonia project Hevo Ammonia Maroc, with an estimated total investment of over $850 millions. This project will be carried out by Fusion Fuel Green Plc an Irish green hydrogen technology company that will provide the technology needed to produce the 31,000 tons of green hydrogen needed each year [13].

The production of green hydrogen in Morocco will promote its growth as we see on the table, and will contribute to the decarbonization of its industry as a first objective seen that green hydrogen demand is higher in the industrial sector during the coming 10 years.

**Table 1** Evidence of potential supply in Morocco for green hydrogen applications and variants (IN TWH) [9]

| Application | Sector | References | | | Optimistic | | |
|---|---|---|---|---|---|---|---|
| | | 2030 | 2040 | 2050 | 2030 | 2040 | 2050 |
| Exports | Exports | 10.3 | 45.9 | 114.7 | 21.7 | 91.8 | 229.5 |
| Matter first | Industry | 3.1 | 14.1 | 20.7 | 6.8 | 19.8 | 21.4 |
| Energy | Transport | 0.5 | 5.0 | 11.2 | 1.4 | 13.9 | 37.7 |
| | Industry | 0.0 | 2.7 | 5.4 | 0.0 | 6.7 | 14.4 |
| | Residential | 0.0 | 0.0 | 1.3 | 0.0 | 0.0 | 3.1 |
| Storage of energy | Storage of electricity at the level national | 0.0 | 0.2 | 0.6 | 0.2 | 0.6 | 1.0 |
| | Storage of electricity for export | | | | | | |
| Total demand in TWH | | 13.9 | 67.9 | 153.9 | 30.1 | 132.8 | 307.1 |

## *2.2 Hydrogen Production Methods*

Several methods are listed to produce green hydrogen:

- **Steam natural gas reforming**: is the most validated technique. It involves reacting methane with water to obtain a mixture containing hydrogen.
- **Electrolysis of water**: the electrolyzer used to split water molecules into hydrogen and oxygen by passing an electric current.
- **Gasification**: produces, by combustion, a mixture of CO and $H_2$ from coal [4] (Table 2).

**Table 2** Physico-chemical hydrogen production methods: principle, advantages and disadvantages (Rafrafi 2012) [5]

| Techniques | Principles | Benefits | Disadvantages |
|---|---|---|---|
| Reforming | Heating at high temperature (at 840–950) to get items gas then separated by a temperature game | Mature technology, inexpensive | $CO_2$ emissions, use fossil fuels |
| Electrolysis of the water | Separation of the molecule Water 80 °C, reaction inverse of a stack | Mature technology, no $CO_2$ emissions | Energy expensive, facility size |
| Pyrolysis of biomass | Heating at high body temperature complex organics, to produce items simple | No production of $CO_2$ | Energy expensive |

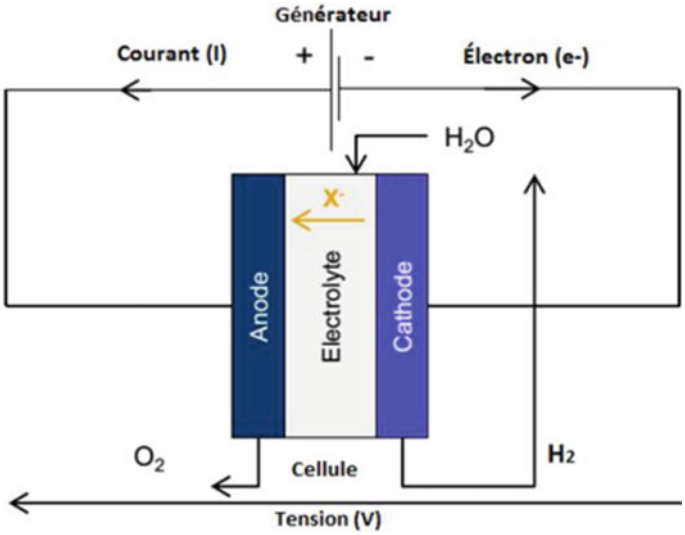


**Fig. 1** Diagram of cell operation. *Source* SBC energy institute 2014, hydrogen-based energy conversion [14]

Currently, the best method to produce hydrogen without greenhouse gas emissions is via the process of electrolysis of water using of course a renewable source such as wind or solar energy [3].

Hydrogen produced by electrolysis of water is a technique that breaks down, with a supply of electricity, the $H_2O$ molecules into dihydrogen ($H_2$) and oxygen (O) and the electricity provided is itself electricity from renewable sources [14]. The process of electrolysis is described in the formula below (Fig. 1):

$$H_2O + \text{electric energy} \rightarrow H_2 + 1/2[O]2 + \text{the heat} \quad (1)$$

The bipolar electrodes (anode on one side and cathode on the other), allow the cells to be arranged in electrical series in current technologies, which allows better compactness and a higher current density. It remains an aspect important in the nominal operation of an electrolysis. In fact, the rate of hydrogen production of the cell increased with the voltage at the terminals of the cells while cell efficiency decrease. So, it is the role of the producer to make a compromise between these two criteria.

Then the cells are organized in assemblies by stacks, then coupled to various devices to obtain the optimal conditions in water and electricity at the input, as well as storing the hydrogen at the output (compressor, tank). Moreover, the electrolysis process being exothermic, a device for eliminating the heat produced is also installed. This together forms the electrolysis.

The production of one kilogram of hydrogen, allowing a journey of 100 km for any light fuel cell vehicle, requires 44 to 55 kWh of electricity and 11 L of water [14].

## 3 Energy Management Algorithm

Given a load demand in a factory, the proposed algorithm to manage the flow of energy between the renewable sources and storage units while producing the green hydrogen and using it when needed is presented in the figure below [12] (Fig. 2):

Psys represents the power of the system calculated from the PV panels power (Ppv) and the WT power (Pw) at each time period ($t$) as follows [15]:

$$\mathrm{Psys}(t) + \mathrm{Ppv}(t) + \mathrm{Pw}(t) \tag{2}$$

Pload represents the load power demand in a factory.

PNet is the difference between the data generated by the input sources and the load must be calculated each period by the equation [12].

$$\mathrm{PNet}(t) = \mathrm{Psys}(t) - \mathrm{Pload}(t) \tag{3}$$

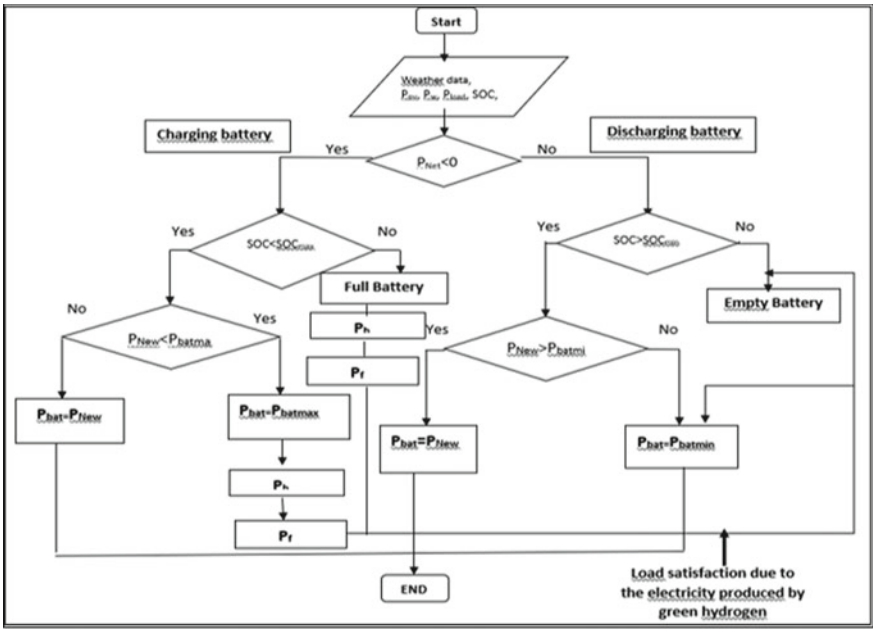


**Fig. 2** Flow chart representing the energy management system in the industrial sector [12]

The second parameter to consider in the blur is the SOC which will be calculated every time period t (1 h) by the following formula [15]:

$$\mathrm{SOC}(t) = \mathrm{SOC}(t-1)/\mathrm{Pbat}(t-1) \tag{4}$$

SOCmin = 30% (the battery is at its minimum level and cannot be discharged).

SOCmax = 80% (the battery is at its maximum level and cannot be charged).

The power produced by the sustainable sources of energy can bypass the load demanded by the factory which will lead to a positive value of Pnet. In this case the batteries can play their role to store the extra energy provided taking into account the charging limit of the batteries which should be below 80%. If more energy was left then the water can use it to generate green hydrogen(electrolysis) and produce pure oxygen. These last can be either used by the factory or stored for later purposes.

In case of luck of energy, the value of Pnet will be negative which lead the system to get the energy demanded either from the batteries or the stored hydrogen [15].

Hydrogen could thus be the solution for energy transition: renewable electricity can be used to generate green hydrogen, which can then be used to power industries and reduce electricity rate where it is difficult to decarbonize through electrification [16].

## 4 Conclusion

Helping to reduce the consumption of electricity remains a primary objective of our article. At the same time, protecting nature from pollution, and given that the demand for electricity in the industry sector remains very high, we have targeted this sector in the first instance. Among potential alternative energy sources, green hydrogen is considered as mentioned in our article, a clean fuel with a low environmental impact. For this reason, green hydrogen is an alternative and a solution to manage the industry's flows in the future.

This article presented a comparison of the different technologies for the production of green hydrogen, which aims first and foremost to develop the industrial sector in Morocco without any greenhouse gas emissions.

The paper also proposes an algorithm to manage the flow of energy produced by the renewable sources placed in a factory. Since our choice of green hydrogen production was based on the water electrolyzer, we ensure that all of the hydrogen produced in industry is green [10]. The algorithm presented in this paper will be implemented on the basis of an intelligent method to control the energy produced by sustainable energies that will lead to the reduction of $CO_2$ in the industry.

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# Methodology for Implementation of Intelligent Risk Management in the Business Processes of Organizations

**Petya Bicheva and Evgeni Valchev**

**Abstract** The dynamics which the business environment and business processes develop in modern conditions require minimizing threats from both external and internal factors. In this article, we present a different point of view—the ability to overcome major problems through the usage of intelligent risk analysis. It combines the established stages of the risk management process according to ISO 31000 (risk management) and the capabilities of artificial intelligence. The contribution of this paper is in the mechanism of acquiring added value through the usage of artificial intelligence. This is the way, the risk analysis of business processes can process extremely large amounts of data in real time; to automate complex and time-consuming risk management processes; to respond optimally and adequately to current threats. The purpose of this paper is to offer a new look at risk analysis methodology. Examining the process and going through all stages of management, it reveals the possibilities of the concept/technology to predict and react intelligently to respond long before their occurrence; to help turn threats into opportunities. In order to prove the applicability of the methodology, we consider various cases and follow their development, with and without the participation of artificial intelligence. All this is aimed at reducing the frequency and severity of risk events in the management of business processes.

**Keywords** Risk management · Business processes · Artificial intelligence · Roadmap · Intelligent risk assessment

## 1 Introduction

The risk management in business organizations is already a conscious process, performed at all hierarchical levels and a part of the responsibilities of each

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employee. Gaps by its identification, subsequent analysis, and evaluation can lead to reduced quality, increased costs, delays, complaints, and legal issues [1]. Due to the complexity of interconnected management of all business processes in recent years, the necessity of a new perspective has emerged risk-oriented business process management (R-BPM). The integration of both areas—risk management and business processes—ensures their higher stability and efficiency in conditions of high environmental dynamics. The need for this collaboration has been confirmed by researches of many scientists. Suriadi and his team compare and classify different approaches to business process and risk management, looking for research gaps so far [2]. According to Tjoa and his team, the lack of interrelationship between business processes and risk assessment can lead to significant deviations, including those related to incorrect assessments of investment security [3]. Thabet and his team propose a model for collaboration between these two areas [4]. Integrating risks at the business process level is a research topic that challenges a new perspective on risk management. It can be said that risk management in business processes (R-BPM) is considered a new management paradigm [5, 6]. Among the main objectives are to expand the scope of risk management beyond the functional view, covering elements of the process that may be affected by the chain effect of other risks [4]. The difficulties in this integration are dictated by the need to build extremely complex models that take into account both the risk and the various aspects of the business process [4] in its unity and in collaboration with other business processes taking place inside and outside the organization.

The main problem subject to this paper is that despite the high degree of technical digitalization and integration in organizations, businesses are increasingly facing serious risk challenges due to highly dynamic changes in the environment. The emerging threats in the individual business processes are causing a chain effect on all major processes in organizations. This in turn leads to severe economic consequences, supply disruptions, loss of customers, etc.

In this article, we state that risk management in the business processes of organizations is more effective when using intelligent risk analysis (IRM), based on the capabilities of artificial intelligence. In the last few years, the increased efficiency of providing high quality AI systems has been widely discussed [7–9]. To achieve our goal, we demonstrate the advantages of IRM over traditional risk management and offer a methodology (IRM-BPM) applicable both in individual processes and with a significant effect on the interconnected action of all processes in the organization and throughout the chain with all stakeholders.

## 2 Intelligent Risk Management (IRM) Capabilities

Here, we introduce the concept of intelligent risk analysis, by which we mean risk management through artificial intelligence. This type of management aims for a high degree of interconnectedness and information about the potential effect of the risk

of a business process on all other processes taking place in the organization and throughout the chain of stakeholders.

In recent years, there has been increasing talk of AI entering risk management. AI is defined as the next step in company risk management [10]. In addition, Aziz and his team (2022) identify that new AI-based intelligent systems are a key technology that will determine competitive positions in future [11]. The reasons for its growing importance lie in the growing success of research and the introduction of new applications based on this technology [12].

Among the main advantages that give it significant advantages over traditional risk management can be noted:

1. Regarding the identification of internal risks in individual business processes: AI reduces manually collected data; provides clearer risk identification; shows real-time results. AI processes internal risk information and relates it to relevant processes in real time.
2. Regarding the identification of external risks: AI performs scanning and filtering of third party information and links it to the business processes in the organization.
3. With regard to risk analysis and assessment: Illustrates the probability and impact of single risks, taking into account all current data and linking them to historical models; the relationships between certain risks are assessed through machine learning models, identifying relationships that are not easily noticeable.
4. With regard to the impact on risk: AI allows for faster and more adaptive responses to risk treatment measures [13].
5. Regarding risk monitoring and control: AI provides greater resilience, by avoiding accidents, faster response times by sending higher level warnings, and triggering the whole risk management process from scratch [14];
6. AI already has proven experience in recognizing dangerous situations [15].

## 3 Integration of Intelligent in Risk Management in Business Process (IRM-BPM)

A comprehensive understanding of the process of risk integration allows organizations to determine the effect on their productivity, functionality, competitiveness, etc. The various procedures applied for software integration cover a series of standardized steps. According to Henderson, they can be systematized into the following: (1) defining the requirements that the system must meet, according to the management; (2) conducting a feasibility analysis; (3) software infrastructure design; (4) management plan according to deadlines and alternative options; (5) integration of the system, outlining the processes, the applied methods and logistics; (6) implementation of the decision and training of employees; (7) system maintenance [16]. We apply a procedure for integrating risk into the business processes of organizations within four main stages: (1) analysis; (2) preparation for implementation; (3) implementation and implementation; (4) monitoring.

### *3.1 Roadmap of the IRM-BPM Integration Process*

For better illustration, the procedure is visualized in the form of a roadmap in Fig. 1. Basically, this roadmap follows the familiar procedures for implementing specialized software.

The added value in this roadmap is related to the properties of IRM-BPM and the ability of the risk management process to be carried out autonomously, through the capabilities of artificial intelligence and its individual tools. The risk management process follows the standard ISO 31000: 2018 risk management, in its sequence

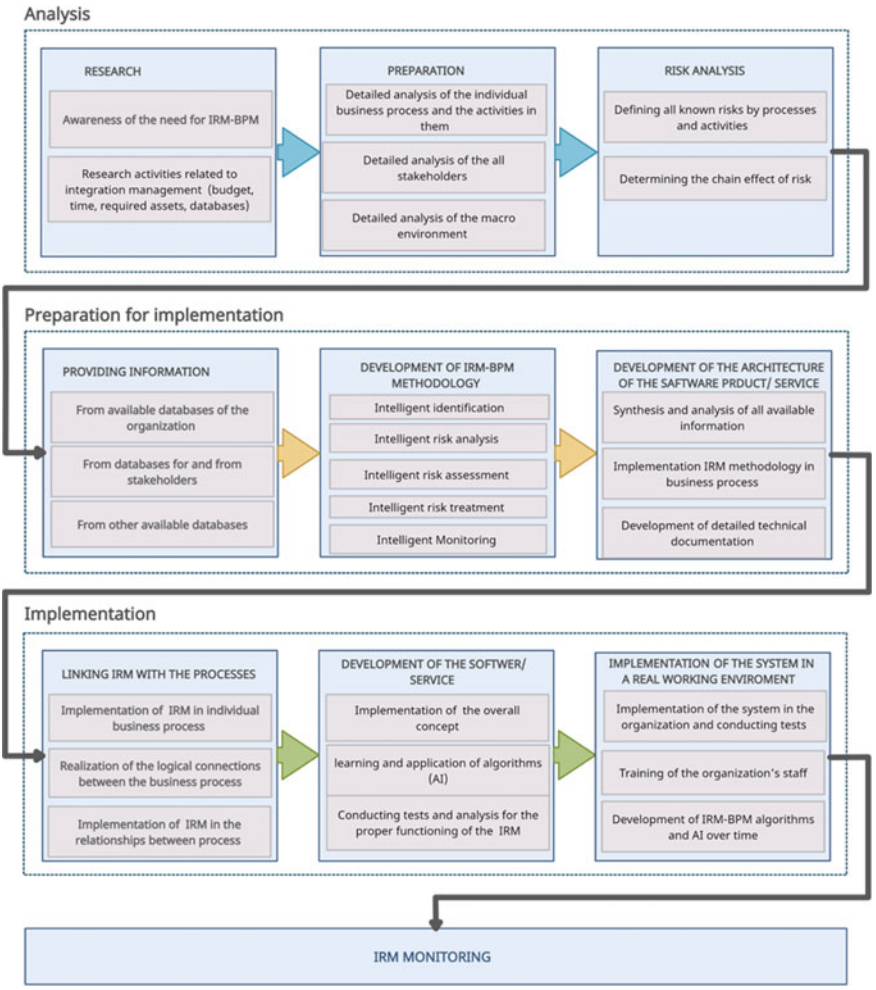


**Fig. 1** Roadmap of the IRM-BPM integration process

of applied stages of management, and to them is added a conceptual vision for the application of individual tools of artificial intelligence (Fig. 2).

The IRM-BPM methodology starts with risk identification. Within its framework, input information is needed for all business processes performed in the organization, as well as details of the activities taking place in them. In addition, an initial expert analysis of the activities is required, which defines all dependent factors and parameters that affect them. On this basis, the relationships between the individual parameters and their relevant activities and processes are expertly determined. Other required information that is needed for further analysis of artificial intelligence is related to the definition of historically known risks from the internal and external environment of the organization.

The availability of the information provided so far is the basis for triggering smart risk identification. Its implementation is based on many principles, the main of which are:

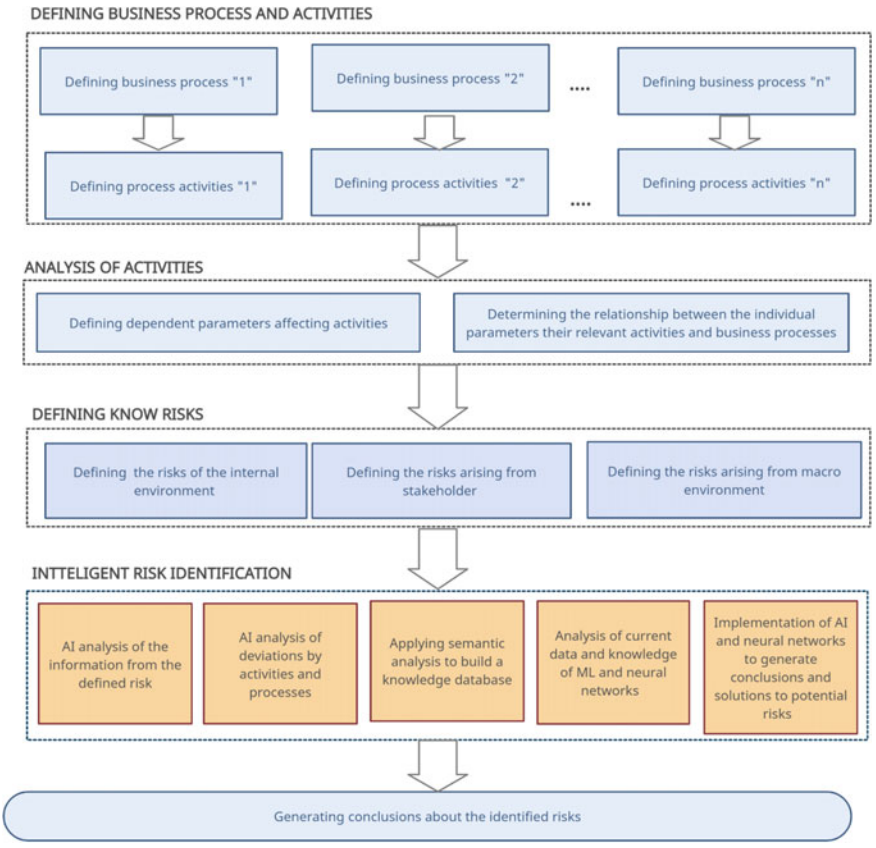


**Fig. 2** Intelligent risk identification in the business processes of the organization

- AI analysis of information from defined risks—based on the historical definition of process risks, artificial intelligence could analyze huge amounts of input and output data that have been used to define and deal with risks. Through intelligent risk analysis of the complete processes and solutions, AI, using specific methodologies and algorithms, processes all possible scenarios, and its main task is to specify and express the best methods for proactive action based on input information. Using as examples historical scenarios, as well as methods for in-depth study of information flows, it provides an opportunity to initiate increased levels of potential risks, as well as opportunities for preventive correction. One of the most appropriate methodologies for AI analysis is deep learning, which allows in-depth study of the dependencies of information. Deep learning is realized with the help of neural networks. Deep learning is not an algorithm in itself, but rather a family of algorithms that apply deep networks with unobserved learning. Theirs goal is to capture nonlinear patterns in data by adding layers of parameters to the model [17].
- AI analysis of information by activities and processes—granulation of processes by specific activities, increases the ability of artificial intelligence (AI) to identify and deal with risks before they manifest and cover the entire process. Conducting intelligent risk analysis using modern concepts of artificial intelligence and machine learning provides an opportunity to analyze tens of thousands of input parameters in real time, as well as analysis of millions of parameters historically. Artificial intelligence provides monitoring of information flows by activities, providing an opportunity to eliminate a specific risk situation and redirect the resource to other supporting ones. The resulting information is stored in BIG databases and knowledge for further processing and analysis. The aim of the end result is to be optimal and in line with the current situation.
- Application of semantic analysis by activity processes—semantic analysis of information is the main building block of artificial intelligence. Semantic artificial intelligence is a strategy applied throughout the life cycle of the data. It combines different methods and tools for accurate classifications, data combination, and automated data quality management. This leads to higher accuracy of forecasting and classification, calculated by algorithms for machine learning. The main advantage of semantic analysis is the possibility of work with structured and unstructured data and use them for general analysis. In this way, data from diverse sources can be linked to provide for machine learning in a more cost-effective way [18]. Through methodology and the construction of semantic networks and knowledge bases, "machines" are enabled to analyze unstructured data and knowledge from different sources, classifying them and transmitting them semantic value. Through semantic analysis, the ability of AI to look for and find problems (risk threats) in the non-formalized information flow is ensured.

Semantics, on the other hand, is a key building block of AI, without which machines' understanding of the world around them boils down to a relatively simple method of analyzing only structured and predefined information.

- Analysis of available data and knowledge from ML and neural networks—in addition to the above information and based on AI, ML semantic networks and others, machine learning (ML) enables systems to study the overall flow of information by looking at it from the point of view of the smallest building block—information, up to extremely high levels involving the relationship of each data or information in a large information cluster. The cluster, in turn, provides data and knowledge, as a set of information units with semantic direct and indirect value, to all other information units. In this way, neural networks are generated and used, which provide the analysis and work with the relationship of information to the overall information flow and the desired goals and opportunities for analysis and risk management.
- Application of AL and neural networks to generate conclusions and solutions to potential risks—after applying the technological and conceptual capabilities of AI, semantics, neural networks, others. The neural network is the basis of artificial intelligence. In essence, neural network is a paradigm for information processing based on the way in which biological neurons process information. It is made up of many interconnected groups of artificial neurons that connect with each other through mathematical computational models. More specifically, the neural network is find node layers containing input layer, one or more hidden layers, and source layer. Each node or artificial neuron connects to another and has a related weight and threshold. If the output of each individual node is above the specified threshold value, this a node is activated by sending data to the next layer of the network. Otherwise in this case, no data is transmitted to the next layer of the network [19]. The next most important feature of AI is the ability to be proactive. Proactivity is a method of making preliminary decisions and applying measures to a specific situation or activity even before it occurs. Proactivity allows technology to present proven and protected conclusions about situations even before they occur. The application of proactive measures based on the conclusions, solutions, as well as the proposals of the technology for preventive risk management, provides experts with a much more detailed and precise point of view, which in turn reduces a large part of the risks and losses their occurrence.

The most significant contribution of intelligent risk identification is that based on known risks and relationships AI conducts its own analysis taking into account changes in all internal and external factors and draws conclusions, generating the current risk profile of potential risks to each business process in the organization (Fig. 3).

The second stage, which includes the IRM-BPM methodology, is follow-up with risk analysis. This stage is performed autonomously, without the need for a human name, within which intelligent characteristics and risk assessment are performed. Base for conducting and obtaining the data from the smart identification and subsequent analyzes from the AI tools for the main dependencies and characteristics of the risk.

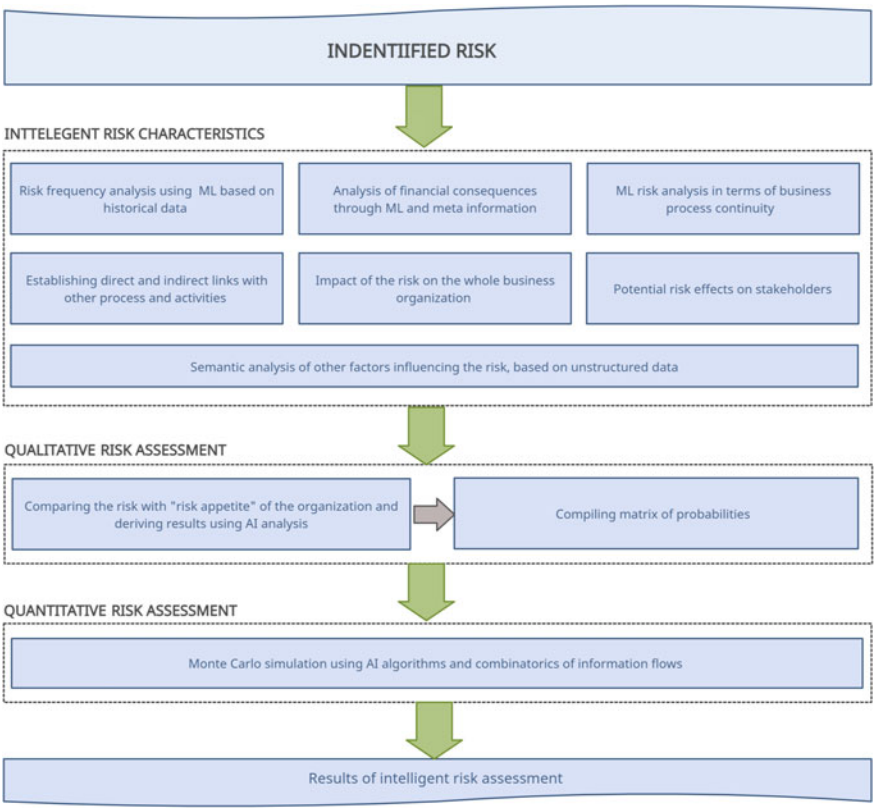


**Fig. 3** Intelligent risk assessment

- Analysis of the frequency of risk with ML based on historical data—the frequency of risk recurrence is a major factor in permanent risks. Therefore, proper repeatability analysis is essential to address the risks. How often a risk occurs depends on many factors, and often the time to re-initialize a particular risk varies according to these factors. This means that it is not possible to perform frequency analysis using statistical methods. For this purpose, machine learning (ML) is applied, as well as all relevant historical data and knowledge. Observed machine learning—with it the algorithms for machine learning—can apply what they have learned in the past to new data using labeled examples of predicting future events. Starting from the analysis of a known set of training data—the algorithm produces a specific function for forecasting the initial values. The training algorithm can compare its result with the correct one, predicted result, and find errors to modify the model [20]. The methodology allows the analysis of data decades ago and the diagnosis of major and minor factors that provoke risk. Machine learning is an appropriate methodology, because in this case no real-time analysis is required, but rather

a comprehensive analysis of the information, which helps to diagnose the most probable intervals for the manifestation of risk in relation to the input information.

- Analysis of the financial consequences through ML and meta information—from the point of view of risk analysis and business organization, the financial consequences of the realization of a certain risk are at the forefront of importance and criticality of risks (others are environmental risks, risks related to stakeholders, etc.). The financial consequences of significant risk, especially when it reaches its peak, can stop the whole process, and in the worst case, the existence of the business organization.

The intelligent identification of the financial consequences of the realization of the risk is performed on the basis of ML. For this purpose, additional "meta" information is used to contribute to the initialization of financial problems. Again, based on historical data and knowledge, as well as current ones (in real time), ML is able to index financial implications and give experts the time and opportunity to reduce impacts as well as redefine the performance of the activity or process.

- ML Continuity Risk Analysis BP—ML is an extremely suitable method for performing risk analysis in terms of sustainability and continuity of a business process or activity. The analysis of many combinatorics historically, through the use of semantic and neural networks, enables technology to "lose" many scenarios in order to choose the most optimal one, with the highest levels of ability to deal with or reduce risk and consequences.
- Providing direct and indirect links with other processes and activities—based on the technological capabilities for the implementation and use of intelligent risk analysis (using all the tools and methods listed so far), AI provides unlimited capacity to identify direct and indirect links at a certain risk with other (seemingly irrelevant) processes and activities. The complexity of the interconnections of information, processes, and activities exceeds the ability of conventional technological methods to find indirect connections. This is the main reason why AI is extremely useful, starting from the analysis of a specific activity, moving on to the processes to the activity and developing the perspective on the analysis of apparent and apparent relationships and relationships through which a single risk can have a detrimental effect on the overall business organization or project. Combinatorics, which is implemented at a higher level by neural networks, allows to compare in advance each impact of risk on all processes and activities, and based on comparisons, the technology visualizes the critical points of importance in other processes.
- Impact of risk on the entire business organization—as mentioned above, each risk in itself has the potential to affect the overall business organization. Technological expertise, and especially the opportunity for proactive action and monitoring, provides an opportunity for the organization to take expert measures, reducing the realization of potential risk. The preventive approach, especially at the level of business organization, directly and indirectly affects many processes and activities in a positive aspect. Intelligent risk analysis, with the help of modern technology, has a direct impact on the sustainability of the organization. Based on the analysis

of data, knowledge, models, unstructured information, and the use of specific algorithmic approaches provide an increase in long-term sustainability of the business organization.

- Potential effects of risk on stakeholders—all stakeholders are all participants in the process or activity that are outside the scope of the business organization (competitors, institutions, customers, contractors, etc.). For smart risk identification, the data and processes of all stakeholders are taken into account. In this way, the AI's ability to predict and identify probabilities arising from factors outside the scope of the business organization and influencing business processes is developed. This is the main reason for the need to analyze the information flows, data, and knowledge of third parties to which the final results of the relate processes.
- Semantic analysis of other factors influencing the risk—semantic analysis allows the analysis of NOT defined causal relationships to other factors indirectly influencing the risk. There is no expert methodology allowing the extraction of information and knowledge from all indirect sources and events. Therefore, semantics is a science that allows the extraction of knowledge through various advanced models that are interpreted in terms of specific risk and used to complement the overall picture of risk identification.

Within the qualitative assessment, each of the characterized risks is compared with the level of risk appetite of the organization, through AI analysis. Artificial intelligence optimizes the process to the extent that it facilitates expert assessment by applying an analysis based on all available information and predicting the company's risk appetite. In this way, its level (low, medium, high) is established. By autonomously generating a probability matrix based on neurons and semantic networks, it is possible to transform the obtained data and derive a probability matrix in which the location of each risk is determined according to the intelligent qualitative risk assessment.

For higher accuracy in intelligent risk assessment, quantitative assessment is also performed. It is conducted on the basis of Monte Carlo simulation, whose functions have been improved, through AI algorithms, tracking the overall processes and combinatorics of information flows, based on which useful models are implemented, through which full monitoring and quantification. The results of the intelligent risk analysis stage are summarized in the generation of an intelligent assessment of each individual risk (Fig. 4).

The whole intelligent analysis conducted through the capabilities of artificial intelligence gives grounds to move to the next stage of risk management, namely the treatment of risk and its monitoring.

Due to the dual nature of risk, here, intelligent analysis continues in two directions—on the one hand, it must respond to the possibilities of risk, and on the other to the threats it poses. As their possible answers differ, they are grouped separately. The most important decision that the tools of artificial intelligence (in this case ML analysis) should make at this stage is the choice of an appropriate response to each individual risk and its impact on all related activities and processes.

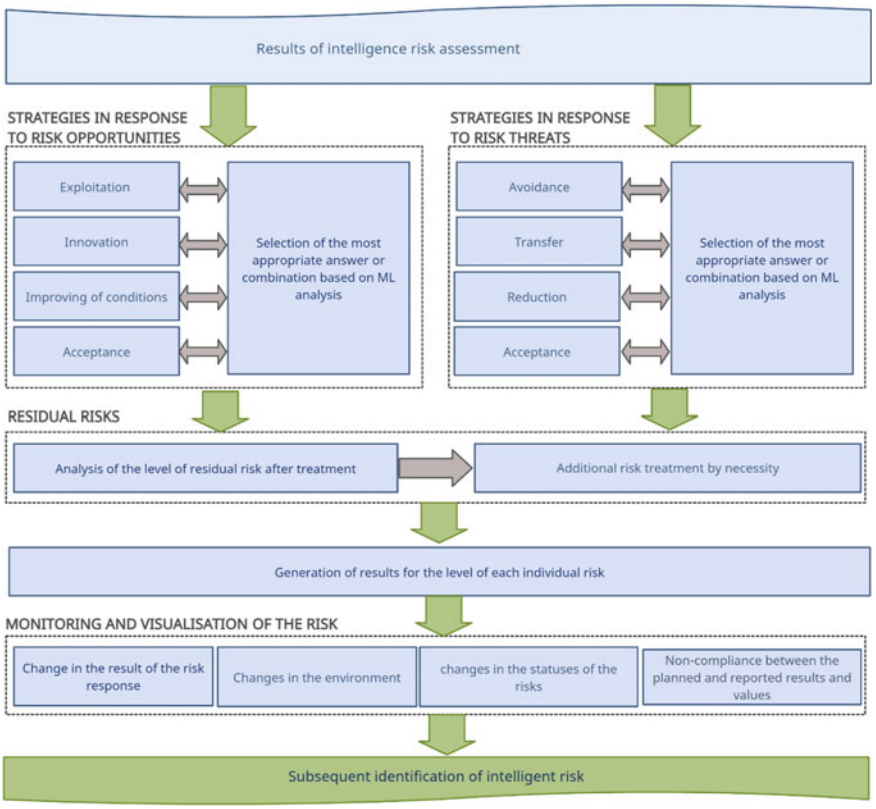


**Fig. 4** Intelligent risk treatment and monitoring in the business processes of organizations

In order to obtain a high level of assurance and follow-up training for ML, additional analysis is conducted to provide information on the level of residual risk after risk treatment. ML plays an important role in implementing maximum optimization and proactively ignoring or minimizing the risk factor. An important stage is the training of ML based on the implemented utility models and the input useful information coming from various sources. If it does not meet the risk profile of the ML organization conducts a new analysis and proposes measures for additional impact, the process is repeated until the maximum knowledge of the ML is reached, through which the analysis process reaches high levels of truth.

The results of the risk treatment are derived with the actual values of each individual risk after the impact on it, i.e., in accordance with the risk appetite acceptable to the organization.

The high dynamics of the environment requires constant monitoring for changes in the effect of the risk response; changes in the environment; changes in risk status; discrepancy between planned and reported results and values. The intelligent tools

mentioned so far, used for analysis, application of activity and acquisition of knowledge, are becoming an excellent monitoring tool. The monitoring provides connection and presentation of the synthesized and normalized information to the experts with the help of modern technologies for monitoring warring intelligent agents for active and proactive presentation of information and statistics in a way suitable for reading and understanding by expert staff.

In case, the analyzes of the artificial intelligence register the presence of a new risk, or a change in the status of the managed so far, the process starts again with intelligent risk identification.

## 4 Conclusions

AI is still considered a sensitive topic to which many experts in risk management and business processes have reservations. In recent years, this trend has been gradually changing, with science, technology, and expertise collaborating and making steady progress. The purpose of this material is to present a conceptual methodology aimed at increasing the sustainability of business processes by integrating intelligent risk management in each of them and in their entirety. We offer a roadmap for risk integration, with all the stages that the organization has to go through. In addition, we reveal how the risk management process in business processes can be autonomous and far more sophisticated than the previous experience, thanks to the various tools of artificial intelligence. In this way, risk identification is much more comprehensive, based on intelligent analysis of various structured and unstructured databases and establishing links between different sources of information. Risk systematization is based on various ML applications. The qualitative and quantitative evaluation process have also been improved with the help of AI. ML analysis also finds a solution in applying responses to each specific risk. The analyzes of the various instruments of artificial intelligence also help in the monitoring of the environment, taking into account the changes in the risk parameters, etc.

By integrating the IRM-BPM methodology, business organizations will increase their competitiveness. The main contributing points of IRM-BPM in business processes are related to increasing autonomy, the ability to improve over time, obtaining accurate results based on comprehensive data, real-time risk management without the need for additional human resources, minimized costs, and others.

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# Implementation of a Hybrid Information System in an Intelligent Health Gateway

**Guy Lysmos Mezui Eya'a and Mostafa Hanoune**

**Abstract** We present in this article a hybrid and advanced information system in an intelligent gateway for health. Indeed, our intelligent gateway has a set of modules that allows: Firstly, ensure good communication with applications, peripherals and external devices through the use of secure communications protocols. In a second step, to properly manage the information processing system coming from the sensors thanks to advanced data processing methods (centralized, random and dynamic) and finally, in a third step, to optimize not only the bandwidth of the network but also the local and remote data storage space through the use of modern and personalized data compression mechanisms (predictive compression, compression by sampling and compression by scheduling). During this approach, we used the global variables to determine the limits of the volumes of data stored during a determined period to control the stop and the resumption of data transfer. Finally, a comparative study of information systems in a gateway has been highlighted to highlight the performance and efficiency between the traditional information system and that of the modern one (ours).

**Keywords** Hybrid information system · Data compression mechanisms · Data processing · Smart gateway · Smart health · IoT for health · Information system (IS)

## 1 Introduction

The implementation and use of a reliable and robust information system in medical structures is a key solution, following the growing need for system interconnections. This necessitates requirements in terms of interoperability of biomedical systems, precision and reliability of information [1]. This is why IoT solutions for health must include superior hardware (new technologies) and implement secure architectures of advanced information systems, i.e., modern and intelligent. This is the case of

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our intelligent gateway which locally integrates an advanced information processing system, to ensure the corrective measures of the storage and transmission of data in real time to applications, peripherals and external devices [1].

In this article, we will present in the first section the overall architecture of the information system of our smart health gateway and its internal and external operating system. In the second section, the sources of inspiration of this work that we used as references; Sect. 3 will present the two types of information system architectures, i.e., traditional and modern; Sect. 4 will be characterized by the description of the operating system and information processing of our intelligent gateway; Sect. 5 will highlight a comparative study between the information system of a traditional gateway and that of the modern hybrid and intelligent. And to end with Sect. 6 which will close the document with some perspectives.

## 2 Related Works

During this research work, we had the opportunity to approach and be inspired by several projects related to our work. Here we present some of this work:

The first is a case study of a Smart e-Health Gateway called UTGATE. The authors implemented some higher-level features to offer several services such as local data storage, local real-time data processing and embedded data mining [2].

The second is the implementation of an integrated access gateway (IAGW) that connects to an operator's machine-to-machine platform (M2M P/F). The authors have integrated into their gateway standard interfaces to support several applications in home environments, ranging from site configuration to accessing compression nodes and services [3].

The third is a solution develop for the smart health system, based on IoT to solve system interoperability issues. The authors used the different web technology standards and communication protocols with respect to the specifics of the IoT system. [4].

The fourth is a prototype Intelligent Navigation and Information System (SNIS) for museum navigation and exploration. The objects inside the museum exchange information to better orient visitors to the different sections and to the objects in the museum. The system was deployed in Chakdara Museum with 381 users to get the results [5].

## 3 Presentation of Information System Architectures

It is a question in this part of presenting the two types of architectures of the information system, that is to say modern and traditional in the case of use of a gateway for a network of wireless body sensors (WBAN). The WBAN makes it possible to link the nodes of the sensors in independent ways. These sensors can be placed in

clothing, on the body or under a person's skin. The network is spread over the entire human body, and the nodes are connected via a wireless communication channel in a star or multi-hop topology.

### *3.1 Architectures of the Traditional Information System*

There are several types of WBAN-based health surveillance systems designed for particular biomedical data and diseases. These systems usually have three main parts: Sensor nodes, a gateway and a backend part. Figure 1 gives a detailed description of these components [6]. (see Fig. 1).

In Fig. 1, the first part of the architecture is characterized by a biomedical sensor node with several physical devices. Some of these sensors are implantable or wearable on the person's body to collect contextual and medical data such as temperature, location, humidity, SpO2, ECG, EMG and EEG. The collected data is transmitted to a gateway via specific communications protocols (Wi-Fi and Bluetooth).

The second part of the architecture is a gateway that ensures the transmission of data from the sensor node to the remote or cloud server. However, if the gateway does not work properly or a bottleneck occurs, the entire system will be affected. Therefore, it is recommended not to directly access real-time biological data on a cloud or remote server.

The third part of the architecture is characterized by its backend. First, it is made up of a cloud server to store, process and serve data. Secondly, of several services which differ according to the technologies of the system used. These services are responsible for representing the data in real time for the various analyzes and medical follow-up by the doctor. Therefore, Fig. 2 below illustrates the process of assisting patient assistance information [7]. (see Fig. 2).

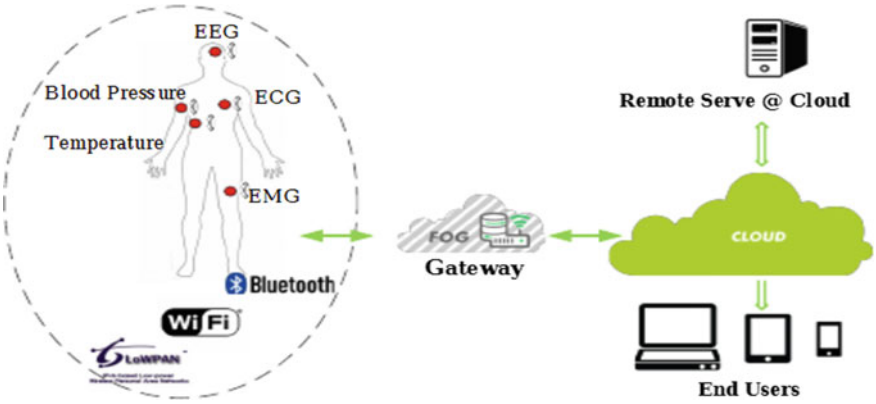


**Fig. 1** Traditional IoT-based health information system architecture

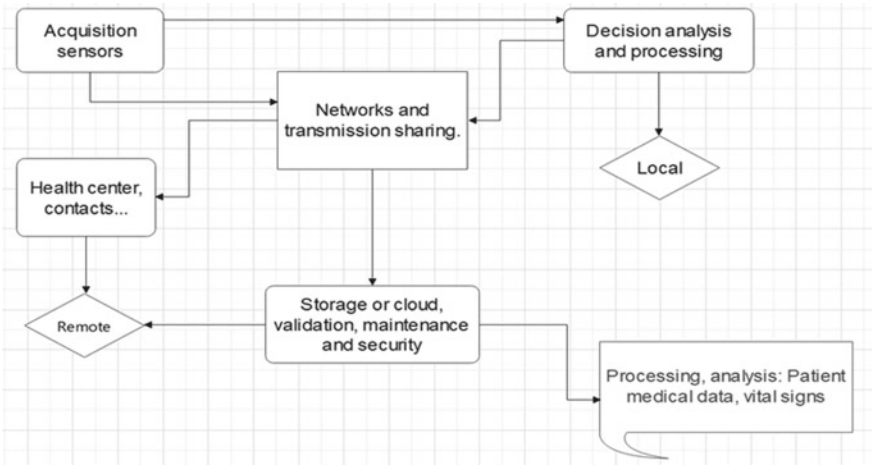


**Fig. 2** Diagram illustrating the patient assistance process

## *3.2 Architectures of the Modern Information System*

Our intelligent gateway is based on the same objectives as the traditional gateway. The first is to share the flow of data or information between patients, medical entities and healthcare personnel. The second is to improve the quality of remote care for patients from their home to the medico-social and health accommodation structure (see Fig. 3).

The information system of our gateway differs from that of the traditional one on the means of data processing, on the compression of the data and on the technologies used. In addition, it provides a system for recognizing and classifying intelligent data resources, relative to their native formats.

**Fig. 3** Information system architecture and the intelligent and modern gateway

# 4 Description of the Architecture of the Operating System and the Information Processing of the Intelligent Gateway

Our gateway has both a hybrid data compression architecture that is efficient with respect to data processing and the intelligent choice of data formats to compress. (see Fig. 4).

## *4.1 Data Recognition, Verification and Identification Process*

The original data flow is subject to a data format recognition verification system, managed by a controller agent called data flow analyzer. The latter analyzes data and formats through in-depth research on several existing data models. In addition, it performs a one-to-many (1: N) comparison of existing patterns to establish the identity of the document or data. (see Fig. 5).

## *4.2 Data Processing Techniques*

The identified data is subjected to a compressor agent specific to the data types and the performance criteria of each algorithm (compression speed and compression ratio). However, advanced data processing techniques are identified with respect to sensor characteristics.

We have three methods: The first is centralized data processing which uses cyclic data monitoring at each detected data stream. This supervision is carried out thanks to a controller agent, which filters and segments the data according to their nature,

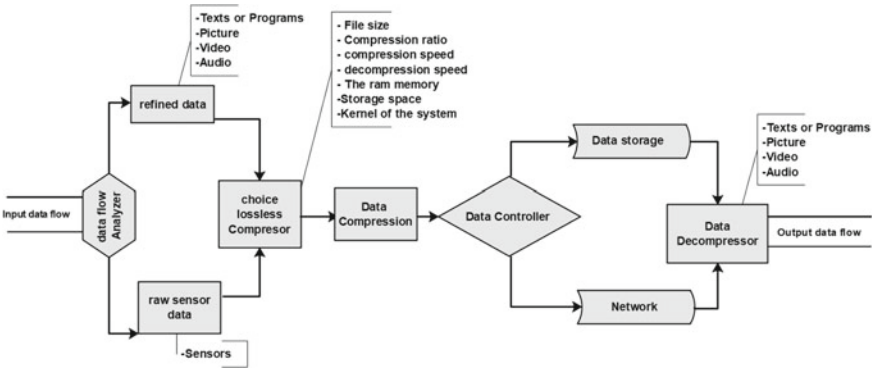


**Fig. 4** Gateway hybrid data compression system architecture

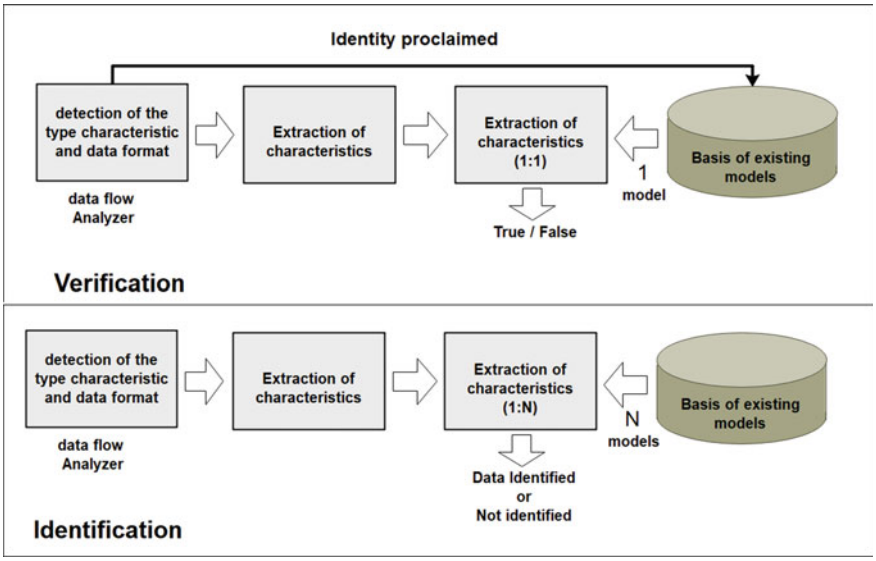


**Fig. 5** Block diagram of data recognition, verification and identification processes

their size and their sensitivity over regular time intervals. The second is random data processing which consists in randomly processing the data sent while the behavior of the compression node is stable. This method makes it possible to merge the data transmitted to the local processing unit according to their natures and their sources. This fusion is carried out thanks to a processor which is called **ExecuteStreamCommand** and which uses a personalized instance to transform all the data into a single block of data of limited size (see Fig. 6).

The third is dynamic targeted data processing. It allows to dynamically choose which node to interrogate in order to improve the frequency of data processing and

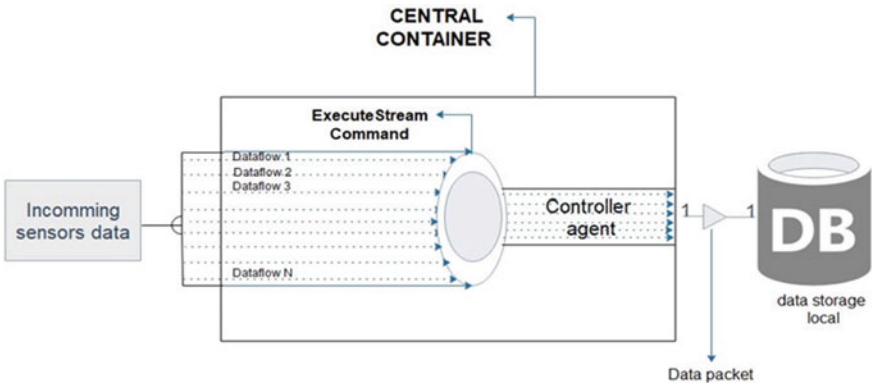


**Fig. 6** Random processing of data

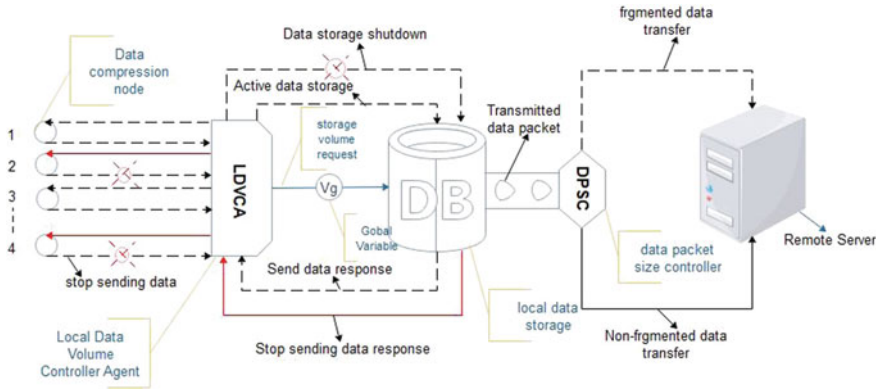


**Fig. 7** Dynamic data processing

to reduce the local storage space. However, the gateway cannot know beforehand whether the behavior of the compression node is stable before asking it. Thus, a node that is unstable can cause the gateway to regularly request it to send data. (see Fig. 7).

## *4.3 Data Compression Mechanisms*

In this part, we present the existing data compression mechanisms in our intelligent gateway in order to improve the collection and processing of data. On the one hand, these mechanisms make it possible to optimize the data storage space required for the proper functioning of the gateway. On the other hand, to accelerate the processing of the data stream to guarantee a fast and lossless transfer of data on the WSN and WLAN networks. Moreover, we apply to these mechanisms some lossless data compression algorithms which are: LZ4, LZO and Bzip2 [8]. These compression techniques can be classified into three categories: predictive compression, sampling compression and scheduling compression.

**Predictive compression**. A forecasting model is established when sampling data flows from the sensors, so that future values can be predicted with near precision. (see Fig. 8).

The diagram above shows that each data node is characterized by a predictive data model, managed by a data model manager according to the measurement parameters (type of measurement, ladder, precision, value, moment and ID sensor).

**Sampling compression**. It is based on pre-designed data collection criteria (types of data, collection time and size of data to be collected). A sample pattern is established during the first data collection, so that future values can be predicted with very good

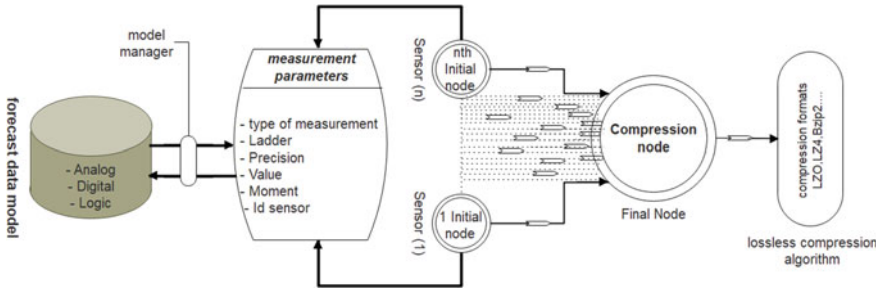


**Fig. 8** Predictive compression mechanism

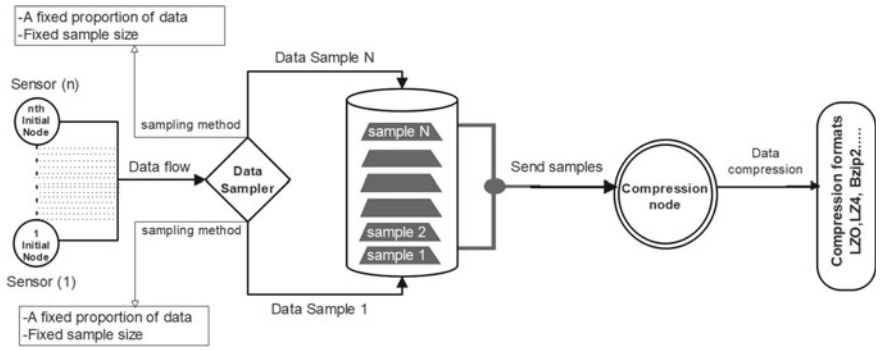


**Fig. 9** Sampling compression mechanism

accuracy. This approach reduces the number of data samples and also the amount of data to compress for each sample. (see Fig. 9).

**Compression by scheduling**. It consists first of all in deleting redundant information from the sensors and merging the remaining data. And in a second step, send a single data stream to be compressed for a group of sensors instead of each sensor sending its data individually. Thus, the number of packets sent will be reduced for data compression. However, the nodes send their packets to a single node called compression node. The packet to be compressed is constructed from combinations of packets received from several nodes. (see Figs. 9 and 10).

## 5 Comparative Analysis

In this part, we present a comparative study on the three components representing three phases of the production process: inputs, throughputs and outputs. Inputs are the resources used to obtain the information or data. Throughputs are service

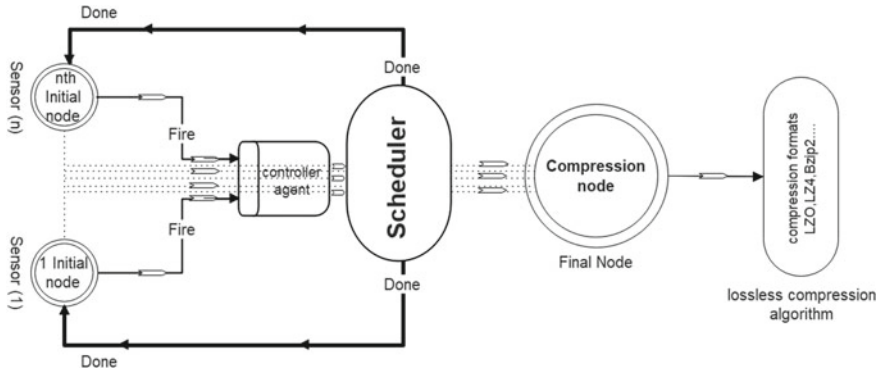


**Fig. 10** Scheduling compression mechanism

resource transformation processes (data processing). Finally, the outputs are the results obtained.

## *5.1 Highlighting Performance (The Inputs)*

It is in this part to bring out a comparative study of the use of material resources and their components (Table 1).

## *5.2 Highlighting the Treatments (The Throughputs)*

It is in this part to bring out a comparative study of the use of material resources and their components (Table 2).

## *5.3 Highlighting the Results (The Outputs)*

It is in this part to bring out a comparative study of the use of material resources and their components (Tables 3 and 4).

**Table 1** Highlighting performance (The inputs)

| Resources | Traditional information system (TIS) | Modern information system (MIS) |
|---|---|---|
| Health sensors | SpO2, ECG | SpO2, ECG |
| Motherboards | Pandaboard | Raspberry Pi 4 |
| Processor | Texas instruments OMAP4460, cortex-A9(ARM), (SMP) at 1.2 GHz | Broadcom BCM2711, quad-core Cortex-A72 (ARM v8) 64-bit SoC @1.5 GHz |
| Ram | 1 GB low-power DDR2 | 8 GB LPDDR4 |
| GPU | / | OpenGL ES 3.0, 4 K HEVC decoding at 60 fps |
| Connectivity | Onboard 10/100 Ethernet | Gigabit-Ethernet |
| Wireless connectivity | 802.11 b/g/n (based on WiLink 6.0)<br>Bluetooth v2.1 + EDR (based on WiLink 6.0) | Bluetooth 5.0 and Wi-Fi 802.11b/g/n/ac |
| Dimensions | Height:114.3 mm and Width:101.6 mm | Height:56.5 mm and Width:85.6 mm |
| Weight | 74 g | 56 g |
| OS | Linux | Raspbian |
| Model and protocol of communications | IC2, HTTPS, MQTT, Web sockets | IC2, RFB, MQTT, HTTPS, FTP and web socket |
| Server | Remote server | Remote server and cloud |

**Table 2** Highlighting the treatments (The throughputs)

| Information processing | TIS | MIS |
|---|---|---|
| Type of files used | XML, JSON, TXT and HTML | XML, JSON and TXT, HTML, PNG, JPEG, TIFF, MP3 and MPEG |
| Data compression algorithms | LZO and LZ4 | LZO, LZ4 and Bzip2 |
| Use of compression nodes | Yes | Yes |
| Use of data compression mechanisms | No | Yes |
| Use of advanced data processing methods | No | Yes |
| Integration of APIs for calls and messaging | No | Yes |
| mechanisms of security | Iptables | Uncomplicated fireall (UFW), iptables, ssh and watchdog |
| Data transfer to remote server | Yes | Yes |
| Server | MySQL | MySQL and My SQLite |

**Table 3** Test results for ECG (outputs)

| Features | TIS | MIS |
|---|---|---|
| File size (bytes) | 840 | 3933 |
| Compressed file size (bytes) | 39 | 359 |
| Compression ratio (%) | 5 | 9 |
| Compression gain (%) | 95 | 91 |
| Processing time (MS) | 18 | 14 |

**Table 4** Test results for SpO2 (outputs)

| Features | TIS | MIS |
|---|---|---|
| File size (bytes) | 840 | 3933 |
| Compressed file size (bytes) | 39 | 359 |
| Compression ratio (%) | 5 | 9 |
| Compression gain (%) | 95 | 91 |
| Processing time (MS) | 18 | 14 |

## 6 Conclusion and Outlook

Ultimately, the implementation of an intelligent and hybrid information system in our gateway intended for biomedical applications. It is of great importance in real-time data processing. As a result, the design of our solution derives from the technique of recognizing data resources and their original formats. This technique allows firstly to optimize the storage space thanks to advanced data processing techniques. And in a second step, automate the intelligent choice of the best data compression mechanism that integrates the data compression algorithms according to the metric criteria (Compression rate and processing time compared to the real-time data latency requirements IEEE 1073). Finally in a third step, integration of Application Programming Interface (API) for the management of messaging and automated calls following an urgent situation. The situation is considered urgent if the values coming from one of the sensor nodes are beyond the standard recommended by WHO. Our future research will focus on the integration and use of our APIs on other healthcare systems. This integration of APIs will aim to ensure the integrity of the data and interconnect several medical systems in real time on the medical follow-up of the patient.

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# Posture Control of Collaborative Robotic Manipulator Based on Gesture Sensors

**Jingjing Lou, Yunhan Li, Qingdong Luo, Xiyuan Wan, and Pengfei Zheng**

**Abstract** As one of the common ways of human–computer interaction, gesture control has attracted wide attention of researchers. In this article, we design a posture control system that control a six-joint collaborative robotic manipulator-xArm by the gesture detected by Leap motion gesture sensor. To accomplish this, the kinematics properties of xArm is analyzed, the transformation matrix is derivated by coordinate transformation, in order to avoid the duplicate data of moving target points that caused by Leap motion's typical working frequency being lower than xArm's maximum receiving frequency, a constraint criterion is designed. Experiments show that this method can track the palm posture detected by Leap motion gesture sensor in real time, and then control xArm accurately.

**Keywords** Collaborative robotic manipulators · Leap motion · Gesture control · Space transformation

## 1 Introduction

In recent years, with the development of science and technology, the application of robotic manipulator is more and more extensive, and its application involves assembly, sorting, handling, grinding, etc. More and more attention has been paid to the safety problem in the process of cooperation between human and the robotic manipulator, especially in many industrial scenes, in order to ensure the safety, it is necessary to keep a safe distance between operators and the robotic manipulator. At this time, it is necessary to choose the appropriate method of human–machine interaction, and among which gesture control is one of the more used methods.

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The principle of gesture control is to detect the position and movement of the hand by gesture sensor, identify and judge it, and convert the identification and judgment results into corresponding signals or instructions to control the corresponding equipment. In this process, the accuracy of gesture recognition is the premise of effective control of the robotic manipulator. At present, the commonly used gesture recognition methods can be divided into two categories: contact and non-contact.

The contact methods are as follows: (1) the method of using the arm/wrist ring/band [1–3]. This kind of method uses wearable sensors to detect muscle electrical signals to judge gestures, and then control the corresponding equipment, the representative one is Myo armband. Myo armband can interact with the controlled device by detecting the changes of bioelectrical signals generated by muscles when the arm moves, and cooperating with the physical movements of the arm. Its recognizable gestures include double-clicking, opening, clenching fist, rotating, towards left and right, etc. This kind of method has great limitations because there are few gestures that can be judged, and the band needs to touch the skin directly to detect the gestures relatively accurately. (2) The method of detection by smart gloves [4–7]. Operators wear smart gloves equipped with flexible sensors, and the sensors transmit the detected pressure and tension signals to the controller for processing, so as to control the equipment. This kind of smart gloves can detect many gestures, such as VIRDYN MHand, Smartgloves, and SenseGlove Nova. But, these gloves are often equipped with various sensors, signal transmission devices and even control boards. It is bulky, inconvenient to wear and use, and expensive, some need to be equipped with virtual reality devices such as HTCVive. (3) Other wearable devices. As in the literature [8], the author designed a wristband device fitted with an accelerometer. The operator can control the movement of the equipment after wearing this wristband. Its principle is to detect the movement and rotation of human hand in $x$, $y$, $z$ three directions through acceleration sensor. Limited by the inherent characteristics of accelerometer, the control actions that can be achieved are also more limited, and because the detection is the acceleration information of the sensor, using other ways to make the sensor move with the hand at the same time (such as holding it in the hand) can also achieve the same result as wearing it on the wrist.

Non-contact control methods can be classified into four categories: (1) using web cameras [9–11]. In this way, a pre-trained model is usually used to recognize the RGB images, and the recognized gestures are used to control the operation of the equipment. Although the system structure is simple, the identification equipment is cheap and easy to obtain, but limited by the principle of image acquisition, this kind of method has the following disadvantages: it is easily affected by external environmental factors such as light; Recognizable gestures are limited; it is difficult to obtain the position information of hands. (2) The way to use the depth camera. This method judges gestures by fusing 2D and 3D data acquired by depth camera. As in this paper [12], the author estimates the pose of 2D hand bones from 2D images acquired by depth camera, and fuses them with depth images of hands to obtain 3D hand pose. This type of method are also used in research papers [13–15]. It can obtain more gesture information, but its recognition process is complicated, and the accuracy is affected by the fusion results. (3) ways of using structured light technology. In this

way, the hand skeleton model is constructed by the light information sent by the sensor and its return signal, and the gestures are judged according to the signal. The representative products are Kinect and Leap motion. Kinect can not only recognize gestures, but also recognize arm and body movements, and its detection distance is also far. In the papers [16–20], the authors use Kinect for gesture recognition. Leap motion can recognize more gesture signals and return the spatial position information of the hand. But its detection range is small, so it can be used in situations where the detection distance is not high but the recognition accuracy is high. The related research can be found in the literatures [21–25]. (4) Use lidar to recognize gestures. In the literatures [26, 27]The authors use lidar to recognize gestures. Lidar has a large detection range, which can detect the movements of human body, arms and even palms at a long distance, but its judgmental gestures are limited.

The existing research on gesture control for robotic manipulator mainly focuses on controlling the movement of robotic manipulator in XYZ direction in cartesian coordinate system and controlling the action of end effector, but there are few studies of the posture control of the robotic manipulator. In this paper, the Leap motion gesture sensor is used to detect the movement of palm, so as to control the posture of the tool center point (TCP) of a six-joint collaborative robotic manipulator (including $x$, $y$, $z$, *roll*/$R$, *pitch*/$P$, *yaw*/$Y$ in Cartesian coordinate system) (Fig. 1).

The follow-up contents of the paper are as follows: 1. System framework, including the functions and characteristics of each component of the system; 2. Control method, which describes the control principle and coordinate transformation process in detail; 3. Test and analysis, describe the test method, analyze and discuss the test results; 4. Conclusion: summarize the research results and look forward to the future research.

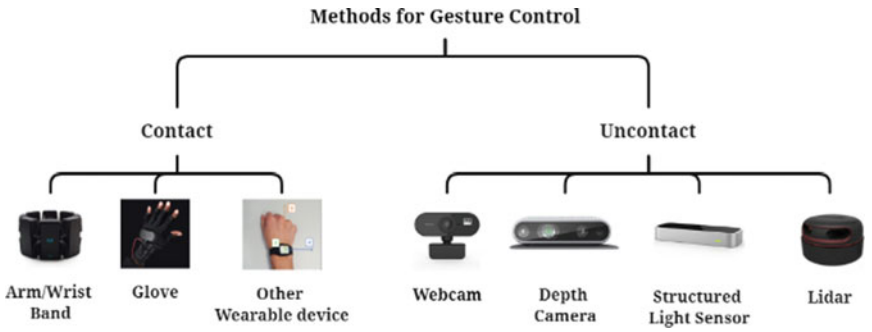


**Fig. 1** Different methods for gesture control

## 2 System Framework

The designed system consists of the following devices: Leap motion gesture sensor, six-joint collaborative robotic manipulator-xArm, and PC. PC sends control signal to lauch Leap motion and get its feedback signal. After the feedback signal is processed, the posture of xArm, a six-joint collaborative robotic manipulator, is controlled. The system structure is shown in Fig. 2.

### *2.1 Leap Motion Sensor*

Leap motion is a gesture detection sensor module produced by Ultraleap Company, which can capture the user's palm and finger movements for interaction with digital content. It is small in size, high in accuracy and fast in response, and can be integrated into enterprise hardware solutions or connected to virtual reality/mixed reality devices for design and development. The sensor can track the movement of the hand in a three-dimensional space of 60 cm or more, with a typical field of view of 140 × 120° (as shown in Fig. 3). With software or SDK, it can identify 27 different hand elements including bones and joints, and its typical working frequency is 120 Hz, which can fully meet the demand of real-time gesture signal acquisition [28].

### *2.2 Six-Joint Collaborative Robotic Manipulator xArm6*

The controlled object is a 6-joint collaborative robotic manipulator-xArm6 (hereinafter all expressed as xArm). The arm span of this manipulator is 700 mm, the repetitive positioning accuracy is ± 0.1 mm, and the maximum speed is 1 m/s. The working area is shown in Fig. 4, and users can use the SDK provided by the manufacturer for rapid secondary development [29].

**Fig. 2** System framework

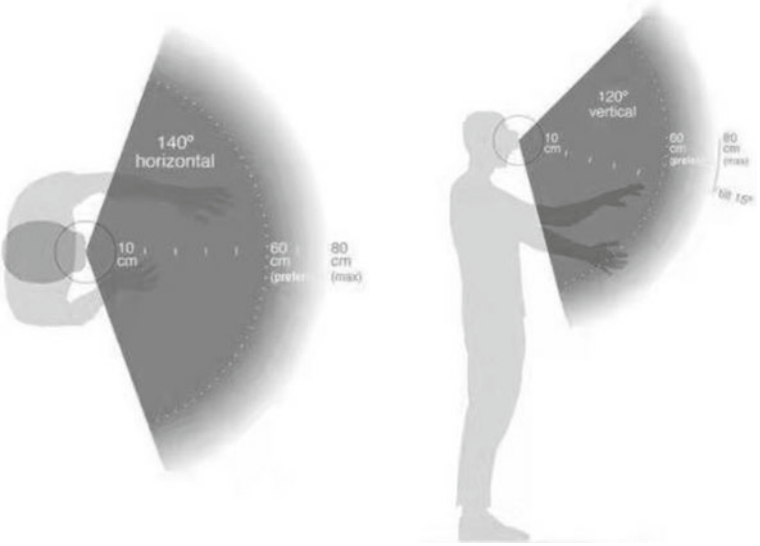


**Fig. 3** Detection area of leap motion

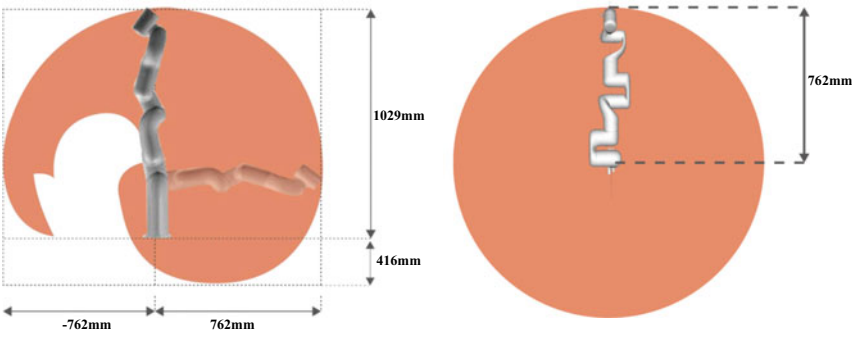


**Fig. 4** xArm working area diagram

## *2.3 PC*

A computer with operating system of Windows 10 is used as the control device, and the Leap motion python SDK [30] needs to be installed on the computer, xArm python SDK [31] and other corresponding python libraries. The control program is written in Python3.9.7.

## 3 Control Method

The palm posture and xArm posture are uniquely determined by six parameters ($x$, $y$, $z$, *roll*/*R*, *pitch*/*P*, *yaw*/*Y*). However, the reference coordinate system is different, to control the posture of xArm, it is necessary to convert the palm posture detected by Leap motion into the posture of xArm TCP.

Leap motion uses right-handed cartesian coordinate system, and its origin is the center point of the upper surface when placed horizontally, which is defined here as $O_L(x_L, y_L, z_L)$. *roll*/*R* is the angle of rotation around $z$ axis, *pitch*/*P* is the angle of rotation around $x$ axis and *yaw*/*Y* is the angle of rotation around $y$ axis. Because the palm position of the hand is uncertain every time when it enters the detection area of Leap motion, in order to make the initial position of the controlled object xArm not change with the initial palm position, it is necessary to make the four-finger direction consistent with the negative direction of z axis of Leap motion coordinate system during the test, and define the current palm position detected by Leap motion as the coordinate origin under the new coordinate system (later expressed by LeapNew coordinate system), which is expressed as the directions of $O_H(x_H, y_H, z_H)$. The directions of $R$, $P$, $Y$ are the same when the coordinate origin is $O_L$, as shown in Fig. 5a.

For xArm, the origin of its base coordinate is $O_B(x_B, y_B, z_B)$, and the tool coordinate system is obtained after the base coordinate system rotates 180°around its $x$ axis, when the end effector is not installed, the origin of the tool coordinate system is the center point of the flange. Define the origin of the tool coordinate system as $O_E(x_E, y_E, z_E)$, as shown in Fig. 5b, among them:

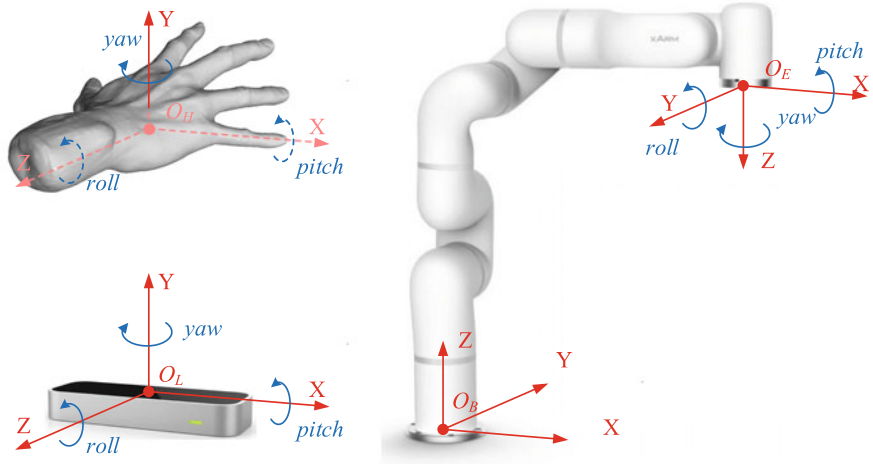


**Fig. 5** Schematic diagram of the origin of coordinates

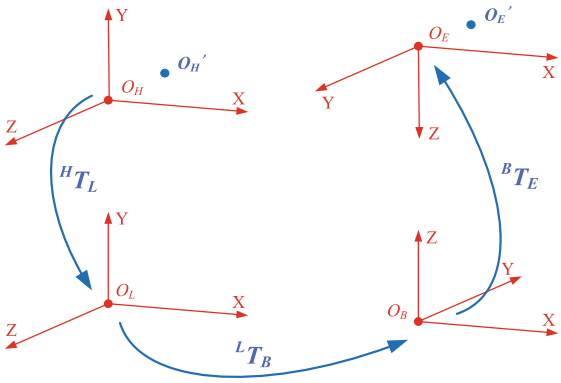


**Fig. 6** Schematic diagram of coordinate transformation

$$\begin{cases} x_E = max(x_A)/2 = 381\ mm \\ y_E = 0 \\ z_E = max(z_A)/2 = 514.5\ mm \end{cases} \tag{1}$$

Suppose a point $O_H^{'}$ in LeapNew coordinate system, which is transformed into a point $O_E^{'}$ in xArm tool coordinate system, the transformation process is shown in Fig. 6, ${}^{H}T_L$ shows the transformation matrix of palm reference plane (the plane where the palm is located in Fig. 5a is defined as the reference plane) and Leap motion coordinate system, ${}^{L}T_B$ is the transformation matrix of Leap motion coordinate system and xArm base coordinate system, ${}^{B}T_E$ is the transformation matrix of xArm base coordinate system and tool coordinate system.

According to the coordinate transformation relationship, it can be known that the transformation relationship between the datum plane of xArm flange and the datum plane of palm is shown in formula (2), where the ${}^{T}H_E$ is unchanged, that is, when the palm position changes, the center point of xArm end flange should also make corresponding movement to ensure that the ${}^{T}H_E$ is a fixed value:

$$ {}^{H}T_L \cdot {}^{L}T_B \cdot {}^{B}T_E = {}^{H}T_E \tag{2}$$

The aforementioned question of palm-center posture transforming into the posture of xArm TCP can be translated into: When palm-center is at $O_H^{'}$, what is $O_E^{'}$ can ensure that ${}^{T}H_E$ remains unchanged. The specific steps to solve this problem are as follows:

(1) Acquiring $O_H^{'}$, , and the parameters ($x$, $y$, $z$, $R$, $P$, $Y$) of $O_H^{'}$ can be obtained by Leap motion sensor detection. Therefore ${}^{L}T_{H'}$ is known.
(2) The transformation matrix between Leap motion coordinate system and transformation matrix ${}^{L}T_B$ of the xArm base coordinate system is a fixed value.
(3) Obtaining $O_E^{'}$, the position and posture of ${}^{B}T_{E'}$ in the system of the collaborative robotic manipulator can be obtained by the upper computer software.

According to the above conditions, the following relationships can be listed:

$$ {}^{E'}T_B \cdot {}^{B}T_L \cdot {}^{L}T_{H'} = Inv\left({}^{H}T_L \cdot {}^{L}T_B \cdot {}^{B}T_E\right) = {}^{H}T_E \tag{3} $$

In the formula (3), other parameters are known or available except for ${}^{E'}T_B$, thus a unique ${}^{E'}T_B$ can be obtained by calculating. The above formula can be simplified as follows:

$$ \begin{aligned} & {}^{E'}T_B \cdot {}^{B}T_L \cdot {}^{L}T_{H'} = {}^{H}T_L^{-1} \cdot {}^{L}T_B^{-1} \cdot {}^{B}T_E^{-1} \\ \Rightarrow\ & {}^{E'}T_B \cdot {}^{B}T_L = {}^{H}T_L^{-1} \cdot {}^{L}T_B^{-1} \cdot {}^{B}T_E^{-1} \cdot {}^{L}T_{H'}^{-1} \\ \Rightarrow\ & {}^{E'}T_B = {}^{H}T_L^{-1} \cdot {}^{L}T_B^{-1} \cdot {}^{B}T_E^{-1} \cdot {}^{L}T_{H'}^{-1} \cdot {}^{B}T_L^{-1} \\ \Rightarrow\ & {}^{E'}T_B = {}^{H}T_L^{-1} \cdot {}^{B}T_E^{-1} \cdot {}^{L}T_{H'}^{-1} \\ \Rightarrow\ & {}^{B}T_{E'} = Inv\left({}^{H}T_L^{-1} \cdot {}^{B}T_E^{-1} \cdot {}^{L}T_{H'}^{-1}\right) \\ \Rightarrow\ & {}^{B}T_{E'} = {}^{L}T_{H'} \cdot {}^{H}T_L \cdot {}^{B}T_E \end{aligned} \tag{4} $$

After substituting the known information, ${}^{B}T_{E'}$ can be expressed as:

$$ {}^{B}T_{E'} = \left[\begin{array}{c|c} R_{H'} & \begin{matrix} x_{H'} \\ y_{H'} \\ z_{H'} \end{matrix} \\ \hline 0\ 0\ 0 & 1 \end{array}\right] \cdot \left[\begin{array}{c|c} R_L & \begin{matrix} x_L \\ y_L \\ z_L \end{matrix} \\ \hline 0\ 0\ 0 & 1 \end{array}\right] \cdot \left[\begin{array}{c|c} R_E & \begin{matrix} x_E \\ y_E \\ z_E \end{matrix} \\ \hline 0\ 0\ 0 & 1 \end{array}\right] \tag{5} $$

Therefore, the position and posture of $O_E^{'}$ can be obtained accordingly.

In order to make the collaborative robotic manipulator respond to the gesture signal detected by Leap motion in real time, the xArm controller is set to joint servo (servoj) mode and servo_cartesian motion function is used. In this mode, the maximum receiving frequency of the controller is 250 Hz, and xArm will move to the position point in the given Cartesian coordinate system with the fastest speed and acceleration.

However, the typical working frequency of Leap motion is 120 Hz. During the operation, xArm has reached the target point, but Leap motion has not sent a new posture signal. At this time, the pose information obtained by xArm from Leap motion sensor is still the posture of the previous target point, so the posture information will be repeated, that is, invalid posture information will appear. During this time, the collaborative robotic manipulator will stay at previous position until it receives a new signal.

Figure 7 is the data diagram of repeated target points during testing at different speed (*speed*) and accelerations (*mavcc*) when servo_cartesian motion function is used. Each of the four tests has a 1000 step count, and the palm moves randomly in the detection area of Leap motion sensor during testing. From the data in the figure, it can be seen that there are repeated data under various motion parameters. Table 1 shows the absolute value and proportion of duplicate data, in which $\max_r$

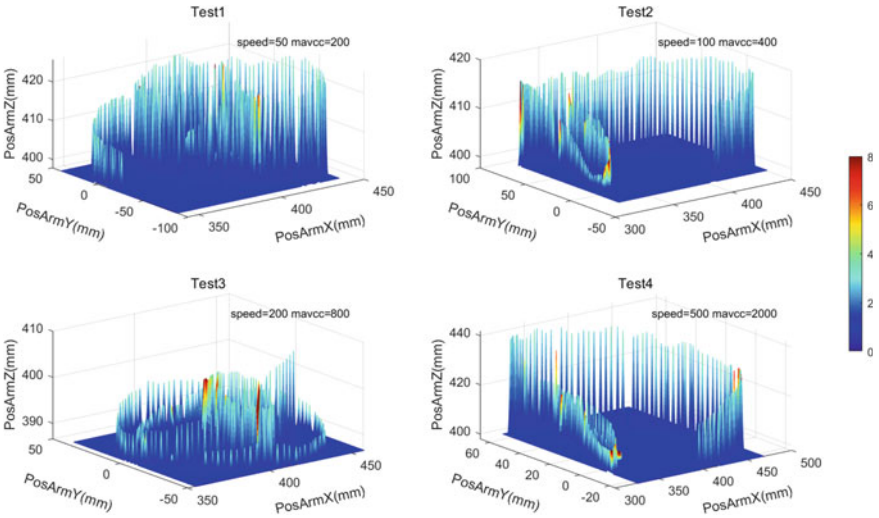


**Fig. 7** Schematic diagram of repeated target point data at different speed (*speed*) and accelerations (*mavcc*)

**Table 1** Repeated target point data

| Test | Speed (mm/s) | Mavcc (mm/s$^2$) | Max$_r$ | Rep (%) | | |
|---|---|---|---|---|---|---|
| | | | | $\geq 2$ | $\geq 3$ | $\geq 4$ |
| 1 | 50 | 200 | 10 | 29.1 | 29.0 | 11.2 |
| 2 | 100 | 400 | 8 | 29.5 | 29.3 | 10.3 |
| 3 | 200 | 800 | 8 | 29.0 | 28.9 | 11.3 |
| 4 | 500 | 2000 | 10 | 29.1 | 29.1 | 10.8 |

is the maximum number of repetitions of the same target point, and *rep* represents duplicate data.

## 4 Testing and Analysis

### *4.1 Experimental Setup*

Use the platform shown in Fig. 8 to test, and calculate the position tracking error and the delay time response of the position tracking in each step of the test. For the convenience of judgment, calculate the Euclidean distance with the position tracking error of $PO_E^{'}$ and $O_E^{'}$ by Formula 6, ignoring *roll*, *pitch* and *yaw* data. The position

tracking response delay is the difference between the time to obtain the palm position (*tic*) and the time to complete the current circular motion instruction (*toc*).

$$\begin{aligned}\text{Error} &= \text{Distance}\left(PO_E^{'}(i), O_E^{'}(i)\right) \\ &= \sqrt{\left(x_{PO_E^{'}(i)} - x_{O_E^{'}(i)}\right)^2 + \left(y_{PO_E^{'}(i)} - y_{O_E^{'}(i)}\right)^2 + \left(z_{PO_E^{'}(i)} - z_{O_E^{'}(i)}\right)^2}\end{aligned} \quad (6)$$

When the program runs, firstly initialize the TCP point of xArm, that is, the origin $O_E$ of the tool coordinate system, set xArm's motion mode to 1 (servoj mode), and then start Leap motion to monitor gestures. When the palm enters the Leap motion detection area, set the current palm position to $O_H$ (this setting is only performed once), and then use the posture of $O_E^{'}$ calculated by Formula (5) to control xArm to move to the target position by using the servo_cartesian motion function in xArm-Python-SDK according to the calculated posture. In order to avoid duplicate data and make xArm track the gesture data detected by Leap motion effectively, a constraint condition is designed: the xArm motion instruction can only be executed when the target posture is different from the previous posure. The specific procedure flow is as follows:

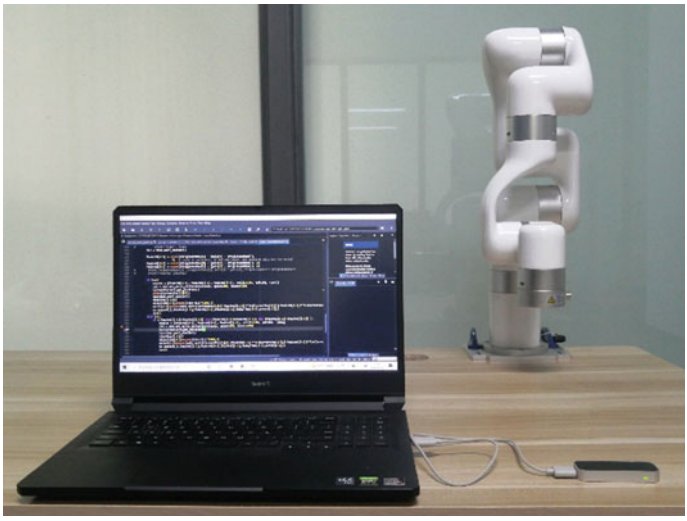

**Fig. 8** Test platform

**Control Algorithm**

Initial $O_E$,step
arm. set_mode (1)
Thread.start()
*flag*←1
**for *i* in range (1,step + 1) do**
**if *flag*==1 do**
$O_H$←hand.palm_position(),roll,pitch,yaw
*flag*←0
*tic*←time.perf_counter()
$O_H^{'}(i)$←hand.palm_position(),roll,pitch,yaw
**if *i*==1 do**
calculate $O_E^{'}(i)$
arm.set_servo_cartesian ($O_E^{'}(i)$)
$i = i$+1
**else if *i*>1 do**
**if** $O_H^{'}(i) == O_H^{'}(i-1)$ **do**
calculate $O_E^{'}(i)$
arm.set_servo_cartesian ($O_E^{'}(i)$)
$i = i$+1
*toc*←time.perf_counter()
$PO_E^{'}(i)$←arm.get_position()
*delayTime*(*i*) ← *toc*–*tic*
$error(i) \leftarrow |PO_E^{'}(i)O_E^{'}(i)|$
**end**

## 4.2 Experimental Result

Select the same parameters of speed and mavcc as those in Table 1 for 4 tests, and record the posture tracking error and the tracking response (*delayTime*) data in each step during the test. Figure 9 shows the relationship data between posture tracking error in every steps. Figure 10 shows the data of the relationship between the response delay of posture tracking in every step. Table 2 records the corresponding data of four tests, including the minimum error (min_*e*), maximum error (max_*e*), average error (avg_*e*), minimum delayTime (min_*d*), maximum delayTime (max_*d*) and average delayTime (avg_*d*) of each test, with two decimal places reserved.

According to the data in the chart, under the parameters of four speed and acceleration, most tracking errors are less than 10 mm, and the average error is about 3 mm, and quite a few points can achieve error-free tracking. Because xArm moves to the target point with the fastest speed and acceleration in the joint servo mode (servoj), it has good real-time performance, and the response delay of average position tracking is about 4.3 ms.

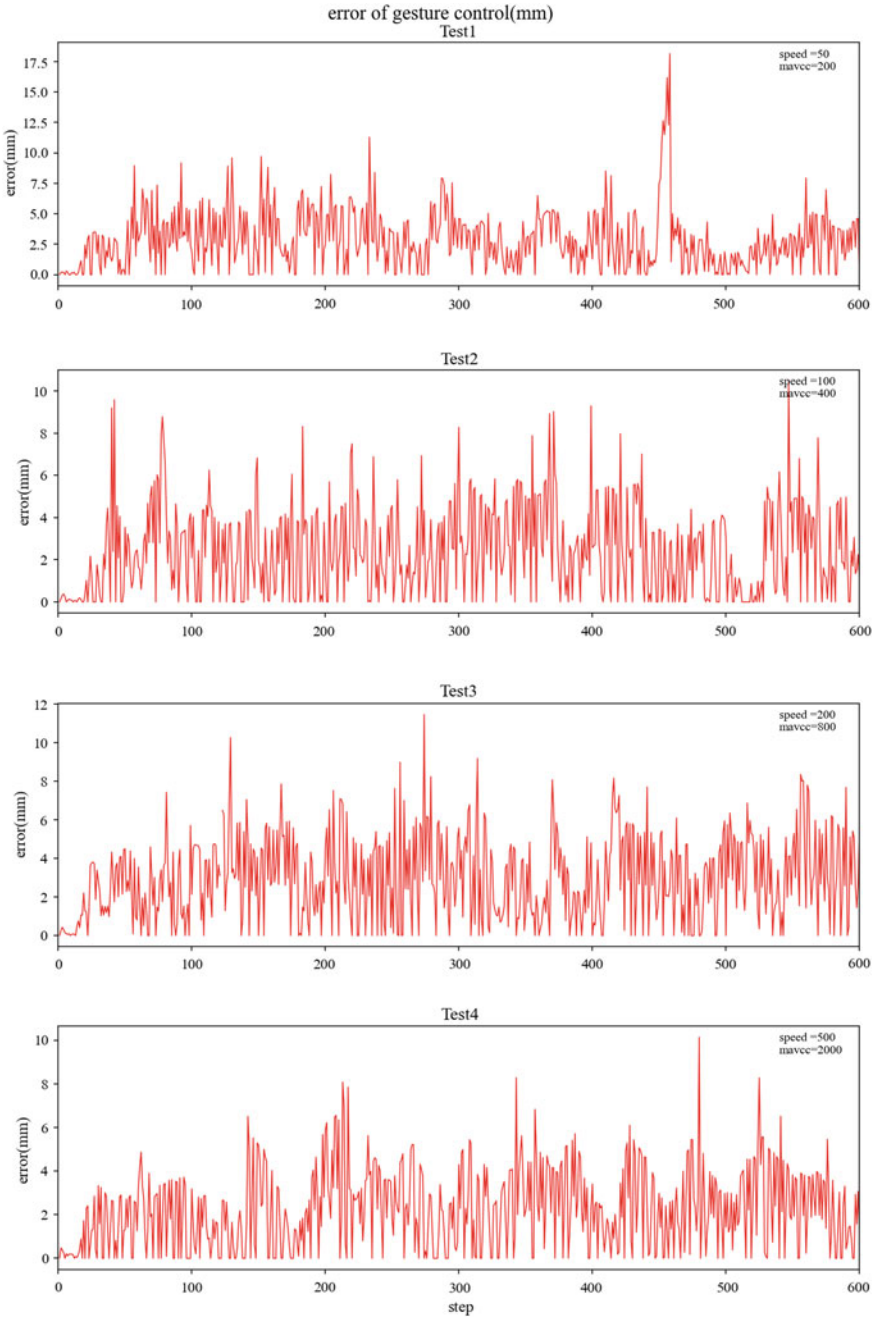


**Fig. 9** Pose tracking error

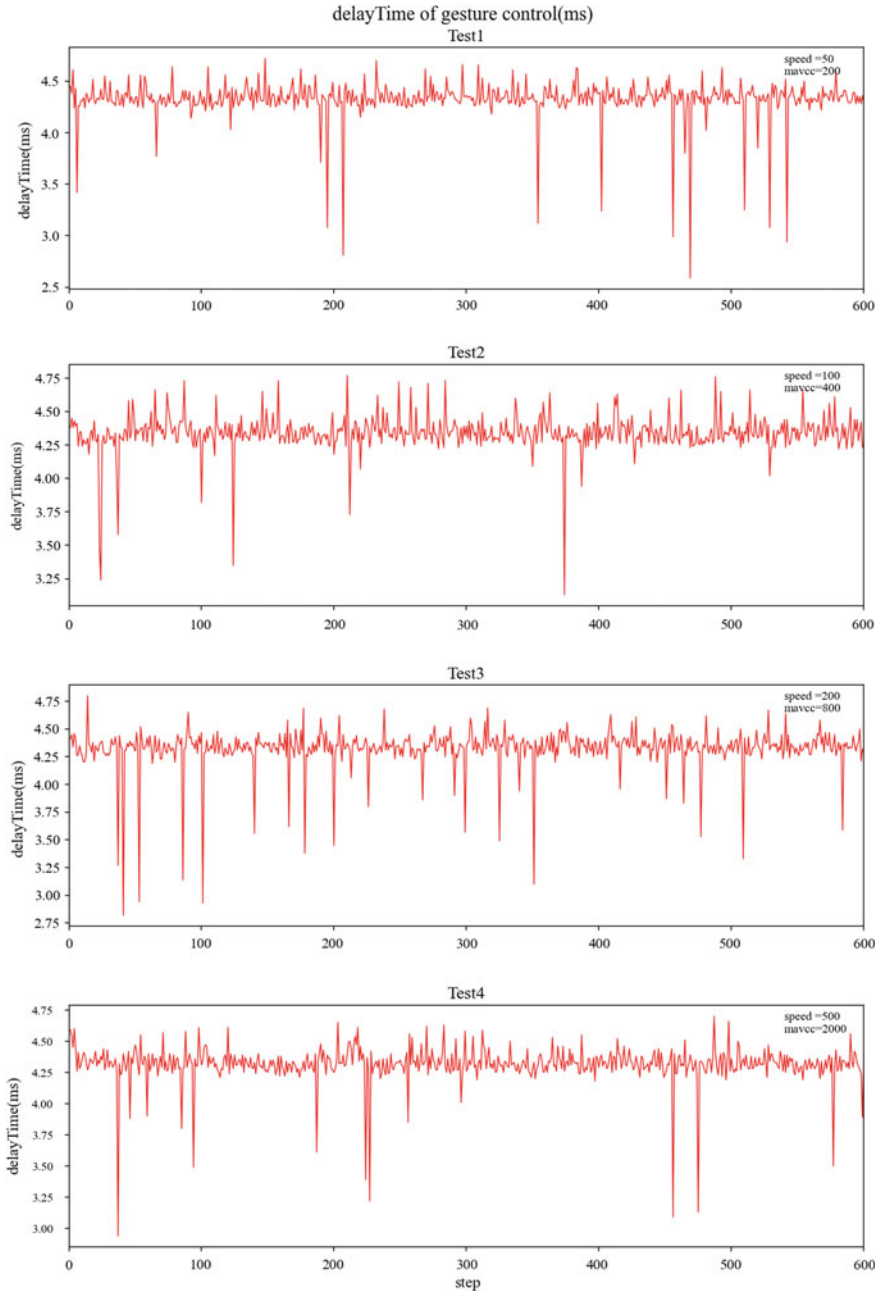


**Fig. 10** Pose tracking response delay

**Table 2** Position tracking error and tracking response delay time of 4 tests

| Test | Error (mm) | | | *DelayTime* (ms) | | |
|---|---|---|---|---|---|---|
| | min_e | max_e | avg_e | min_d | max_d | avg_d |
| 1 | 0 | 18.16 | 3.01 | 2.59 | 4.81 | 4.32 |
| 2 | 0 | 10.49 | 2.38 | 3.08 | 4.77 | 4.34 |
| 3 | 0 | 11.46 | 3.19 | 2.82 | 4.8 | 4.33 |
| 4 | 0 | 10.14 | 2.41 | 2.93 | 4.7 | 4.31 |

In the control process, the observed trajectory of xArm looks smooth, but in fact, there is noise in the data. For example, if the operator wants to control xArm to Stay steady in a certain position, the palm also needs to remain stationary. However, due to human physiological characteristics, there are still small jitters when the palm is still (such as physiological hand shaking), so xArm also tracks these jitters and makes small movements. In order to reduce noise, the mean filter is used to filter the data. The specific methods are as follows, $QO_E^{'}(j)$ represents the filtered value in $j$ step:

$$\begin{cases} QO_E^{'}(j) = \sum_{i=0}^{i=j} O_E^{'}(i) & (j < 10) \\ QO_E^{'}(j) = \sum_{i=j-9}^{i=j} O_E^{'}(i) & (j \geq 10) \end{cases} \tag{7}$$

Use the method to filter the data of the above four tests, and the filtering results are shown in Fig. 11. For example, (a) is the data of Test1, the horizontal axis represents step, the vertical axis of the three subgraphs is the value of $x$, $y$, $z$ of xArm TCP, the red curve represents raw data, and the blue curve represents the filtered data It can be seen from the data in the figure that the curve composed of the raw data is jagged, that is, the movement of xArm is not smooth, although the amplitude of this jitter is relative small. After mean filtering, the trajectory of xArm becomes smoother.

## 5 Conclusion and Future Work

In this paper, the problem of using Leap motion gesture sensor to control the movement posture of six-joint collaborative robotic manipulator-xArm in spatial cartesian coordinates is studied, the kinematics analysis of xArm is carried out, and the transformation matrix of palm position mapping to the position and posture of xArm tool center point (TCP) in Leap motion detection area is deduced. The experimental results show that the tracking error of this method is within an acceptable range, and its tracking response speed can meet the real-time requirements.

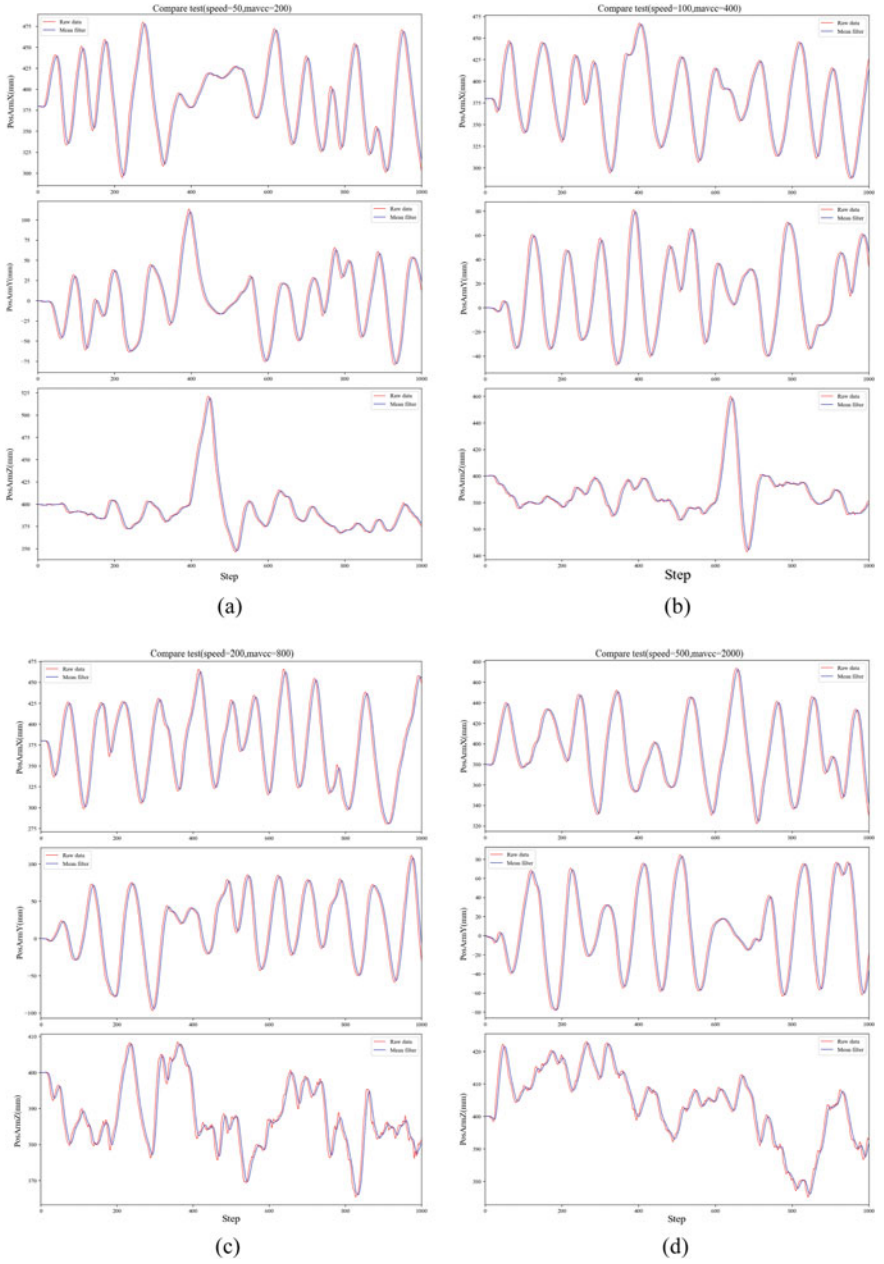


**Fig. 11** Comparison between raw data and filtered data

The technic proposed above can be applied to scenes that are not suitable for people to carry out on-site operation, such as assembly work in harsh working environment like high temperature. The use of gesture control can protect people from injury to the greatest extent. However, the mean filter will reduce the real-time performance to a certain extent. We can see from Fig. 11 that although the smoothness has been improved, there is a certain lag in the tracking data. This problem needs to be overcome by designing better filters. On the other hand, the research of this paper is based on a manipulator without end tools. In the actual scene, the manipulator often needs to install end effector to perform specific tasks. Therefore, the follow-up research will be carried out for the manipulator with end effector such as gripper or bionic hand.

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# Classifying Students' Academic Performance Using Principal Component Analysis During Pandemic COVID-19

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**Abstract** As a result of the COVID-19 outbreak in Malaysia, educational institutions, including universities, were forced to conduct all academic activities online. If online learning continues in subsequent academic sessions, it may have a big impact on the academic performance of the student. Thus, the purpose of this study is to classify student's academic performance by using principal component analysis (PCA) before and during pandemic COVID-19. The sample consisted of 234 undergraduates from the Department of Mathematics at the Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris (UPSI). Data collection is conducted using a questionnaire. Data were gathered from students' grades for each subject in the first semester of the session 2019/2020, which is during face-to-face learning, and each subject's grade in the second semester of the session 2019/2020, which is during online learning. The finding of the study was divided into two parts which are preliminary analysis and further analysis. According to the eigenvalues greater than one criteria (Kaisar, 1960), when using the correlation matrix in eigen analysis, only, values greater than one should be included in the analysis. As a result, the researcher decided to cut-off the dimension at the second dimension from the eigenvalues obtained by the R software because the eigenvalues for the second dimension were greater than one which is 1.111. For further analysis, the researcher will be using the principal component one in classifying students based on their overall academic achievement, and principal component two will be used in classifying in which semester they did best in. With regard to overall academic performance, the majority of students' 51.4% were in the classification of good performance, while just

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24.3% were considered excellent performance. Further, 15.7% of students are categorized as performing averagely in their academic performance, whereas 8.6% are categorized as performing below average. The results indicate that 65.7% of students performed similarly in both semesters, indicating that most students are performing in their academic performance either before or during the pandemic COVID-19, while only 14.3% of students performed in semester 1 session 2019/2020, which is during face-to-face learning, and only, 20% of students performed in semester 2 session 2019/2020, which is during online learning.

**Keywords** Classification · Academic performance · Online learning · Principal component analysis

## 1 Introduction

In December 2019, a new extreme acute respiratory syndrome coronavirus 2 (SARS-CoV-2) epidemic broke out in Wuhan, Hubei Province, China, and quickly spread across the world [1]. The World Health Organization has given this disease the designation COVID-19. Malaysia had their first confirmed case on January 25, 2020, and the first confirmed death on March 17, 2020, after it was first described in China in December 2019 [1]. The Ministry of Health (MOH) announced 5,251 COVID-19 cases in Malaysia as of April 17, 2020, with 86 deaths and 2967 cases of recovery [2]. The positive rate of COVID-19 Malaysian patients initially decreased at a regulated rate as the number of patients increased as foreigners arrived in Malaysia [3]. This makes Malaysia's prime minister to take action and declare Movement Control Order (MCO). The government has agreed to enforce the Movement Control Order across the country from Wednesday which was March 18 to March 31, 2020, according to Prime Minister Tan Sri Muhyiddin Yassin [4]. This order was mainly to totally forbid Malaysians from having activities such as religious, sports, social, and cultural. Not just it effecting our daily life activities, it was also affecting the learning system. All educational institutions, including preschools, primary schools, high schools, and colleges, were forced to close for the time being. The government advises educational institutions to keep using online platforms for teaching and learning activities. This was to ensure that their students have access to information. Teachers and lecturers also must be using e-learning platforms such as Google Classroom, Google Meet, Zoom, and others to carry out their classes. Teaching and learning materials presented using these platforms have visual graphics, words, animation, video or audio to ensure the student have access to knowledge [5]. There are also benefits of online learning in many ways, but we still can see there is also a negative side to it. Based on past research done by [6], they found that online learning has a positive impact on student's academic performance. Online learning improves student overall performance with lessons was being recorded with higher quality conferring larger academic benefits when others online educational activities were managed in the same way. Not all students can adapt this e-learning method because some of them are still traditional

learners [1]. Some student might not be able to learn effectively through this online platform because they might be more preferred and easier to understand what their lecturer deliver by face-to-face classes. If this situation kept happening, it can affect student's academic performance. So, this research is conducted to observe and classify student's academic performance using principal component analysis before and during pandemic COVID-19. To succeed on the global stage, university students must build the fundamentals of self that are intelligent, professional, imaginative, and have a deep belief in work ethic and great spiritual values [6]. Having a good grade or good academic performance is really important for a student to ensure their brighter future. The country's social and economic growth is inextricably related to the academic success of its students [7]. Students' academic achievement becomes essential in producing the highest quality graduates who will serve as great leaders and manpower for the nation, and thus be responsible for the country's economic and social growth [8]. There were many factors that can affect student's academic performance. Teaching and learning process, facilities that being provided by the university, influence from parents and friend and student's financial [9]. More than that, from the past research that had been done by [7], it also said that student's communication skill, learning facilities that being provided by university, proper guidance, and stress from family was also being the factor that affecting student's academic performance. Other than that, by performing the classification of student's academic performance, this will also help lecturer and also student itself. By this, specific information can be obtained on any student regarding his or her academic performance [1]. Classification on academic performance will also help lecturers to take necessary actions such as giving more attention to particular students, using different method of teaching and conducting exam. Which mean lecturer can take do some improving or change on how they should convey the lesson so that student will be easier to understand and lecturer can improve student's academic performance since from the classification lecturer can know whether majority of the student is performing excellent or below average based on their grade for each subject. Since the MCO first implemented, Universiti Pendidikan Sultan Idris (UPSI) was also included for applying online classes for students and lecturers learning process. Because of that, students and lecturers need to continue their classes through online platform such as Google Meet, Webex, and so on for whole semester. Not just the use of online platform being the priority toward lecturer to convey their teaching, but application like WhatsApp and YouTube was mostly being used by lecturers and students in order to communicate with each other and share any learning material. The key focus of this study was on classifying student's academic performance of UPSI undergraduates after they completed one semester of online study. In this research, we aimed to classify students' overall academic performance and to classify their relative academic performance per semester at Universiti Pendidikan Sultan Idris under Faculty of Science and Mathematics who take course Bachelor of Mathematics with Honors (AT14) and Bachelor of Science (Mathematics) with Education (AT48) before and during pandemic COVID-19 based on their grade taken for each subject in semester 1 session 2019/2020 and semester 2 session 2019/2020. This research will be observing UPSI undergraduate student's result that mainly focuses

for student under Faculty of Science and Mathematics that taking course AT14 and AT48. Result from the approach will give results in form of classification of the student overall general performance and semester basis.

## 2 Methodology

### *2.1 Research Design*

Design of the study is defined by different definitions, one of which believes that it is a strategy for processing data acquired based on particular and systematic planning of the relationship between the variables identified in the study. Because the researcher used numerical data, the study was designed in the form of a quantitative method. This study was conducted at Universiti Pendidikan Sultan Idris (UPSI), a university in Tanjong Malim, Perak, Malaysia.

### *2.2 Data Collection*

The dataset that being used in this study was mainly focusing on undergraduate student from UPSI. The data were collected by using research instrument that had been choose which is questionnaire and distributed through online platform. The questionnaire consists of five part which is respondent's demography, student's academic information, online learning, student's learning environment, and lastly student's perception toward online learning. The population that been choose for this study is the undergraduate student from Faculty of Science and Mathematics in UPSI which total of 600 student, and this study will be selecting 234 undergraduate students of Mathematics from UPSI at the department of Faculty Science and Mathematics who's taking course Bachelor of Mathematics with Honors (AT14) and Bachelor of Science (Mathematics) with Education (AT48) randomly based on the Krejci and Morgan Table (1970). The questionnaire was responded by Mathematics' undergraduate at UPSI that consists of students from semester 3 until 7 with 43% of the student was male and 57% of the student was female. The total respondent was 234 students consist of 59.4% of AT14 students and 40.6% of AT48 students.

### *2.3 Data Analysis*

The process of gathering, modeling, and analyzing data, known as data analysis, extracts insights that support decision-making [10]. For this study, data obtained from the questionnaire that had been distributed through an online platform will

be analyzed by employing the principal component analysis (PCA). PCA will be employed as the method to filter or reduce the large dataset that had been collected early before the data were processed to classify the student's academic performance. Principal component analysis (PCA) is a technique for forming new variables which are linear combinations of the original variables [10]. The main idea of PCA is to reduce the dimensionality of data set consisting of a large number of interrelated variable, while retaining as much as possible the variation present in the data set [11]. There were no correlations between the new variables, while the maximum number of new formable variables matches the number of original variables. Since the principal components are linear combinations of the original variables, the linear combination must often be interpreted or given significance. The use of the loading of the principal components is one of the ways to do the interpreting. Loadings are the simple correlation between the original variables and the principal component. They indicate the extent to which the original variables have an impact on the formation of the principal components where the higher the magnitude of the loading the more influential in forming the principal component score, and it goes vice versa. Choosing which principal component loadings to use in the interpretation of each component is an important decision in principal component analysis. There are general rules that need to be considered which is a guideline often used by researchers, but this first rule was not based on a mathematical proposition. In this study, researcher consider principal loading greater than 0.50 or less than −0.50 as significant. A loading of 0.5 or above as a cut off point is appropriate [12]. So, larger absolute sizes of loadings indicate greater loading significance in construing the principal component structure. These rules are relatively constructive when the sample size equals or more than 50 [13]. There are also views noting that loadings greater than 0.32 or less than −0.32 are considered poor, greater than 0.45 or less than −0.45 are considered fair, greater than 0.55 or less than −0.55 are considered good, greater than 0.63 or less than −0.63 are considered very good, and greater than 0.71 or less than −0.71 are considered excellent. These standards are intuitively engaging as they are linked to the component's amount of variance accounted for; specifically, these benchmarks highlight the variables that account for more than 10%, 20%, 30%, 40%, and 50% of the variance in the component, respectively [14]. Reference [14] recommended that for samples of 100, loadings greater than or equal to ± 0.19 and ± 0.26 are for the 5% and 1% significance levels, respectively. For sample sizes of 200, ± 0.14 and ± 0.18 are recommended for the 5% and 1% levels, while for sample sizes greater than or equal to 300, loadings of ± 0.11 and ± 0.15 are recommended.

**Table 1** Eigenvalues of six courses from two semesters

| | Eigenvalue | Proportion | Cumulative percentage (%) |
|---|---|---|---|
| Dim 1 | 1.857 | 30.945 | 30.945 |
| Dim 2 | 1.111 | 18.523 | 49.468 |
| Dim 3 | 0.821 | 17.439 | 66.906 |
| Dim 4 | 0.817 | 13.608 | 80.514 |
| Dim 5 | 0.684 | 11.392 | 91.906 |
| Dim 6 | 0.486 | 8.094 | 100.000 |

## 3 Result and Discussions

### *3.1 Results for Eigenvalues in PCA*

The *R* software's study yielded the results that the researcher obtained. As a result, the eigenvalue and principal component loadings were used in further analysis. The preliminary analysis and further analysis of the PCA results will be discussed in two parts.

Table 1 shows eigen analysis of six courses from two semesters, with three courses from semester one and three courses from semester two. The weights of the principal components obtained are referred to as eigenvalues. According to the eigenvalues greater than one [15], when using the correlation matrix in eigen analysis, only, values greater than one should be included in the analysis. Thus, it can be observed that two main components should be kept using the eigenvalues larger than one based on Table 1.

### *3.2 Results for Component Loadings of PCA*

The principal components are used to further examine the student's performance. The results obtained from the *R* software will be classified in this further investigation. The researcher will use principal component loading to classify students based on their overall academic achievement and which semester they do best in.

From the principal component analysis results, there are six principal components produced since there are six variables involved in this research. It will be recalled that the eigenvalues suggested that three principal components will be retained for this further analysis, but for the further analysis, researcher will use until principal component two for further analysis due to the relevance of these components to the topic under discussion.

Based on the Table 1, the first principal component, PC1, contributes for 30.9% of the total variation in the data, as can be seen in Table 2. The first principal component, PC1, can be viewed to be a weighed total of all the different courses. The second principal component accounts for 49.5% of the overall variance in the data and 80.4%

**Table 2** Principal component and their eigenvalues

| Variable | PC1 | PC2 | PC3 | PC4 | PC5 | PC6 |
|---|---|---|---|---|---|---|
| SMG3013 | −0.575 | −0.052 | 0.094 | −0.360 | −0.233 | −0.688 |
| SMN3033 | 0.516 | −0.106 | −0.174 | 0.194 | −0.754 | −0.293 |
| SMQ3013 | −0.232 | −0.429 | −0.646 | 0.488 | 0.255 | −0.204 |
| SME3013 | −0.080 | 0.827 | −0.046 | 0.476 | 0.069 | −0.274 |
| SMN3043 | −0.210 | −0.315 | 0.692 | 0.604 | −0.110 | 0.016 |
| SMQ3033 | −0.546 | 0.136 | −0.249 | 0.053 | −0.543 | 0.569 |

when combined with the first principal component. The coefficients of variables representing first semester courses are positive, while those representing second semester courses are negative, as can be seen in the second principal component. As a result, the first semester courses contrast with the second semester courses on the second principal component. The first two principal components have been maintained in this study for further analysis due to the topic's importance.

Based on the table above, each of the variable will be representing each of the subject that taken by the student in the first semester and second semester. Subject to be taken by each student in semester 1 is Geometry (SMG3013), Multivariable Calculus (SMN3033), and Programming Language for Numerical Computing (SMQ3013), while subject to be taken by each student in semester 2 is History of Mathematical Sciences (SME3013), Ordinary Differential Equations (SMN3043), and Technology in Mathematical Sciences (SMQ3033). Determining which principal component loadings to use in the interpretation of each component is an important decision in principal component analysis. Significant principal component loadings are larger than 0.30 and less than −0.30. Loadings more than 0.40 and less than −0.40 are seen as more significant, whereas loadings greater than 0.50 and less than −0.50 are regarded as extremely significant. As a result, the greater the absolute size of the loadings, the more important the loading is in understanding the principal component structure. The subjects SMG3013, SMN3033, and SMQ3033 were very significant in PC1 since their loadings were larger than 0.50 or less than −0.50 which is −0.575, 0.516, and −0.546, respectively, as seen in Table 2 above. Only, SME3013 was considered extremely significant in PC2 since it has principal component loading greater than 0.50 which is 0.827, while only SMQ3013 and SMN3043 were considered very significant in PC3 since it has principal component loadings greater than 0.50 and less than −0.50 which is −0.646 and 0.692, respectively. Thus, all variables were deemed significant and important in this research.

### 3.2.1 Classification Using Principal Component Scores

The principal component scores for the first two components of the first 15 students are shown in Table 3.

**Table 3** Principal component scores for first 15 students

| Observation | PC1 | PC2 |
|---|---|---|
| 1 | −1.121 | 0.082 |
| 2 | −2.391 | 0.341 |
| 3 | 0.341 | −1.784 |
| 4 | −1.784 | 0.406 |
| 5 | −2.567 | 0.666 |
| 6 | 0.866 | 0.278 |
| 7 | −2.141 | −0.526 |
| 8 | −2.250 | 0.601 |
| 9 | −1.158 | 0.666 |
| 10 | 0.675 | −1.900 |
| 11 | −1.579 | −1.366 |
| 12 | −1.798 | 0.889 |
| 13 | −0.627 | −1.561 |
| 14 | −1.163 | 0.710 |
| 15 | −0.528 | 0.630 |

A closer look of the component scores for PC1 indicates that the first rank value corresponds to the score with the lowest negative score, while the highest rank value corresponds to the score with the highest positive score. If the values of the scores are large, PC1 can result in a very small negative number for any combination of course values. A very small component score also indicates an excellent performance or extremely high scores across all courses, whereas a very high component score indicates a very low score across all courses, and hence a bad performance. Also, for PC1, a component score closer to 0 (or a zero score) indicates that the student performs very well in some courses while performing below average in others. As a result, the first-placed student has the smallest component of −2.567, indicating that he or she has the best grades. Similarly, the last-placed student has a component score of 3.185, indicating that he or she has received the lowest grades in most courses. 0.065 is the component that is closest to 0. This reflects a 64th-placed student. This student received great marks in a few (2) of the classes and fared just averagely in the others, according to the original grades. As a result, a closer look of the original grades and their components leads to the classification.

From Table 4 below , it is shown that a student with a component score (S) under −1 is viewed as an excellent, while a student with a component score (S) larger than 2 is seen as performing below average. Students with a component score (S) between $-1 \leq S \leq 1$ are considered to have good overall academic performance, while those with a component score (S) between $1 \leq S \leq 2$ are considered to have average overall academic performances. Based on Table 4, it can be seen that 24.3% of the student classified as excellent, while 8.6% of the student were classified as performing below average. The majority of students are classified as performing good

**Table 4** Classification of students' overall academic performance

| Principal component score | Performance | Percentage (%) |
|---|---|---|
| $S \leq -1$ | Excellent | 24.3 |
| $-1 \leq S \leq 1$ | Good | 51.4 |
| $1 \leq S \leq 2$ | Average | 15.7 |
| $S \geq 2$ | Below average | 8.6 |
| Total | | 100 |

**Table 5** Classification of student performance by semester

| Principal component score | Performance | Percentage (%) |
|---|---|---|
| $S > -1$ | Semester 1 session 2019/2020 | 14.3 |
| $S < -1$ | Semester 2 session 2019/2020 | 20 |
| $-1 \leq S \leq 21$ | Both semester | 65.7 |
| Total | | 100 |

with 51.4%, and only, 15.7% student were classified as average in their academic performance. Similarly, a close analysis of the component scores for PC2 suggests the classification criteria in Table 5 that can be used to classify students based on their semester performance.

A student with a component score (S) less than one ($S < -1$) is considered to be performing better in the second semester than in the first, whereas a student with a component score (S) larger than one ($S > 1$) is considered to be performing better in the first semester than in the second. Students with component scores (S) in the $-1 \leq S \leq 1$ range, on the other hand, are considered to have similar levels of achievement in both semesters. As shown in the Table 5, the majority of students (65.7%) perform similarly in both semesters, while only 14.3% of students perform in semester 1 session 2019/2020, and 20% of students perform in semester 2 session 2019/2020.

## *3.3 Discussion*

All of the study's objectives and questions indicated have been answered as a result of these findings. Table 4 shows how student academic performance is classified before and during a pandemic based on their grade taken for each subject in semester 1 session 2019/2020 and semester 2 session 2019/2020. As shown in the table, majority of the student's overall academic performance (51.4%) were in the category of good, while just 24.3% of the student's academic performance was classified as excellent. It can also be seen that 15.7% of students are categorized as performing averagely in their academic performance, and 8.6% are labeled as performing below averagely in

their academic performance. Table 5 refers to the second objective of this research, which is to classify students' relative performance in terms of their grades taken for each subject in semester 1 session 2019/2020 and semester 2 session 2019/2020. As shown in the table, 65.7% of students perform similarly in both semesters, indicating that the majority of students perform in their academic performance either before or during the pandemic COVID-19, while only 14.3% of students perform in semester 1 session 2019/2020 and 20% of students perform in semester 2 session 2019/2020. The majority of students perform well in both face-to-face learning and online learning during both semesters. Therefore, online learning does not affect their academic performance.

## 4 Conclusion

The focus of this research is to classify student's academic performance for undergraduate student of Mathematics from Universiti Pendidikan Sultan Idris at the department of Faculty Science and Mathematics who's taking course AT14 and AT48. As a result of this study, most students perform well in online and physical classes on an overall academic scale. However, there are still a few students who perform below average on their overall academic performance. Based on the semester basis, since the majority of students perform well both in the face-to-face and online classes during the semester, it can be said that online learning has no effect on student academic performance. Even so, most students perform better when they are learning on the online classes than when they are attending face-to-face classes. As a consequence of this study, it is hoped that educational management, as well as the ministry of education, will be able to improve their strategy for conducting physical and online classes in order to improve the student's academic performance.

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# Automatic Control System Based on Industry 4.0, PLC, and SCADA

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**Abstract** The recent trend of automation, Industry 4.0 (I4.0), has enabled industries to become more efficient, flexible, smart, autonomous, reliable, and customizable. This new trend improves and replaces existing semi-automatic processes with fully self-controlled systems through its technologies such as smart sensors, programmable logic controller (PLC) and supervisory control and data acquisition (SCADA). Industrial systems or equipment, like a small-scale steam plant, having manual or semi-automatic processes, do not operate effectively as expected due to their actual methods of operation and lack of innovative technologies. Such systems need more attention and monitoring to avoid breakdowns. This research paper aims to demonstrate the reliability and efficiency of a PLC and SCADA-based system using I4.0 technologies through a mini steam plant. This research is essential to support the development of I4.0 systems and provide necessary information about the recent trend of automation. The proposed system has advanced features such as sensors, PLC, SCADA, and private cloud. The research results obtained from the LOGO Soft Comfort V6.1 and Wonderware Indusoft Web Studio 8.1, respectively, a PLC software and SCADA software, confirm that the mini steam can operate automatically and efficiently and can be well monitored.

**Keywords** PLC · SCADA · Industry 4.0 · Automation

## 1 Introduction

Automatic control system or automation refers to the effective control of machinery or industrial processes with little to no human intervention. Industrial processes that have manual labor tend to be less efficient and sometimes struggle to meet the increasing demands of production on time. Relying on manual operations across the entire production chain may cause downtimes or slowdowns in deliverables, backlogs and an increase in overtime. With the new industrial revolution, Fourth

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Industrial Revolution (4IR), automation has even reached a higher level and consideration. Most industries tend to be more autonomous, efficient, and customized by using 4IR technologies such as cyber-physical systems (CPS), Internet of Things (IoT), and cloud computing [1]. The 4IR, also called Industry 4.0 (I4.0), is the new trend toward advanced automation and data exchange between industrial processes and technologies which include IoT, CPS, cloud computing, etc. Programmable logic control (PLC) and supervisory control and data acquisition (SCADA) also play major roles in advanced automation. Effective and safe operations of industrial processes are achieved through the application of PLC and SCADA [2]. PLC and SCADA systems are extensively used in industry to control, monitor, supervise, and acquire data of industrial processes. These processes can be industrial, facility, or infrastructure. SCADA systems are used in several industrial automation applications to supervise and monitor the floor-level equipment (sensors and actuators) which are controlled by PLCs [3]. They are often interconnected and interfaced with each other via communication protocols. This journal manuscript aims to demonstrate the effectiveness of automatic control systems based on I4.0, PLC, and SCADA. The entire paper is organized into six sections. The first section is an introductory part of the overall topic. The second section presents previous studies done related to the topic. The third section explains the automation system based on PLC and SCADA. The fourth section shows the proposed PLC and SCADA automation design. Finally, section five presents and discusses the results of the proposed system, while section six is a conclusion of the present paper.

## 2 Related Work

PLC and SCADA have widely been used to increase the flexibility, reliability, and productivity of industrial processes. New trends in manufacturing processes have made use of automation at every stage, such as machining, material handling, assembling, production, packing, and inspection [4]. Reference [5] developed an automatic control system to autoconfigure parameters of a small-scale beverage bottling process using ZENON SCADA and S7-1200 Siemens PLC linked via the TCP/IP communication protocol. Their study was more focused on computing smart strategies (Simulation) in PLC and SCADA rather than building any type of hardware. The results obtained were as close as possible to the daily production target. This was done by configuring the everyday production as a function of time and automatically applying programming settings to boost the system when the goal is not achieved. Reference [6] also developed a smart bottle filling process using PLC and SCADA and went further by developing an effective storage and management system of the packed bottles. For the warehouse management systems, they focused on the identification of items (using photoelectric sensors and a barcode scanner both connected to the PLC) and their subsequent storage in the appropriate location (using automated storage/retrieval systems made of cranes, run by motors programmed on the PLC, that move in dedicated aisles between shelves used for storage).

The application of PLC and SCADA-based automation also goes beyond the manufacturing sector. It is also used in thermal power plants (large and small scale). Thermal power plants comprise various important components, with the boiler considered a critical one, requiring continuous inspection and monitoring for greater reliability and efficiency. Various methods are used to control the boiler system, with the combination of PLC and SCADA being one of them. This method of boiler automation reduces errors caused by humans, prevents the damage of equipment, and most importantly, increases the overall efficiency of the power plant [7]. The research conducted by [7] outlines the design and development of a boiler automation system using PLC (Delta WPLSoft with ladder diagram programming) and SCADA (Wonderware Intouch), which are interfaced via communication cables. The SCADA system was used to monitor the boiler temperature, pressure, and water level data obtained by means of different types of sensors. The corresponding outputs were transferred to the PLC, which controlled the same boiler parameters. Additionally, the automation system was designed to shut down immediately if the temperature and pressure in the boiler exceed the predefined values, and in case of an emergency, different automated safety valves are used to release high-pressure steam, and the concerned operator is informed through an alarm. Furthermore, a condition-based monitoring system based on PLC and SCADA is also implemented to enhance the boiler efficiency. Monitoring parameters of condition (temperature, vibration, etc.) in machinery with the purpose of identifying significant changes indicating a developing fault are known as condition monitoring. It is a key element of predictive maintenance which requires comprehensive information about the devices' current state of health. Reference [8] developed an early detection technique for a boiler feed pump using data based on a SCADA system which acquired measurements captured by control devices, real measurement data, and events obtained from an existing coal-fired power plant in Poland. The SCADA system served as a historical data system for the condition monitoring applied. To easily detect anomalies in the boiler feed pumps, the authors of this research developed a predictive maintenance algorithm, a compound process done separately for each signal monitored. Reference [3] also conducted a study on monitoring a boiler feed pump vibration using PLC and SCADA. He made use of a sensor of vibration (Model U1-FH) and a device of vibration control (Model AVR-148), serving as inputs for the PLC. The present SCADA system was developed to trigger the alarm if the supervised vibration reaches the highest value, which was adjusted in advance to alert the operator or give out an instruction to stop the machine before any accidents or damages occur.

## 3 Automation System

Sensors and actuators are the first important elements in industrial automation. They are input and output devices installed on the factory floor and are information carriers (sensors). Secondly, systems and internal service controllers such as PLCs are used to monitor and manage the system devices and processes. Then, the use of applications

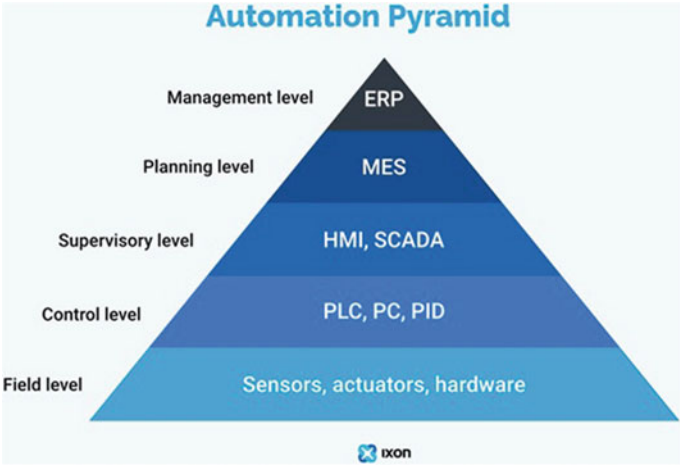


**Fig. 1** Automation pyramid

such as SCADA to super-vise and monitor the information inherent in the devices and machines of the factory floor represents the automation level higher than PLCs. The level four or management level, Manufacturing Execution System (MES), is where capabilities and services are exploited. In the level five or planning level, Enterprise Resource Planning (ERP), the production chain's management system is referred to and includes purchasing, sales, human resources, engineering, quality, production, and logistics. All these five levels form the automation pyramid (Fig. 1) and represent the automation technology of modern industries [9]. This paper focuses only on the first tree level of the automation pyramid.

## *3.1 Field Devices*

Field devices are components of the industrial automation system that connect the industrial control and management systems to their physical environment. They deliver information to the system and also the means to continually adjust the physical environment to make it more efficient. They are also the basic core of any Industrial Internet of Things (IIoT) or machine-to-machine (M2M) architecture, and they communicate with other devices or a central processor through an interconnection [10]. Generally, the field devices considered are sensors and actuators. Sensors are input devices. They collect data (pressure, temperature, feeds, speeds, and so on), convert them to electrical signals, and transfer them to controllers such as PLCs, which process them and send an output signal to actuators. Actuators turn valves, pumps, relays, motors, and other devices on and off or change their condition to control processes.

### *3.2 System Controller*

The control of the field devices is done by special computers such PCLs and proportional-integral-derivative (PID), with PLCs being mostly used. They efficiently and flexibly perform automation duties in smaller to larger performance range. They feature a broad variety of integrated communication and technological functions, particularly space-saving and compact design. They also have a function to run a diagnosis and easily locate errors in the system. These controllers acquire data from the different field sensors, execute the stored user program, and finally transmit correct output commands to the field actuators. They are linked to the field devices via different types of communication protocols (wired or wireless).

### *3.3 Supervisory System*

The field devices are visualized, supervised, and monitored by a SCADA or HMI application. This centralized system collects and processes data in real time and sends commands to the process controller from a remote location. SCADA is connected to the PLC through a wired or wireless communication protocol. Both SCADA and PLC receive inputs from the field devices and return outputs in order to control processes, but SCADA is often used to reset or refine data at the control level.

## 4 Case Study Application

Aiming to prove the potential of a PLC and SCADA-based automatic control system, a case study was conducted using a small-scale steam generation plant of the Thermodynamic laboratory of the Mechanical and Industrial Engineering Technology department at the University of Johannesburg. This study focused on simulating the system processes rather than implementing or building any type of hardware.

### *4.1 Small-Scale Steam Generation Plant*

The small-scale steam generation plant is semi-automatic and produces steam that is used for some experimental laboratory apparatus/units. The system's automatic components are the boiler, the boiler chemical pump, boiler feed pump, the blowdown pump, and the feed tank recirculating pump, and they are all controlled by control relays. The other components of the system are controlled manually. The steam plant has three subsystems: the boiler water supply or the boiler water treatment (Fig. 2), the steam generation (Fig. 3), and the steam distribution (Fig. 4). The mini steam

plant operating processes start from getting water from the main water supply pipe to supplying steam to the experiment apparatus through a pipework. Table 1 presents in detail the operating processes.

The small-scale steam plant presents several issues that lead to its inefficient operation. The processes comprised many manual actions, and they were considered plausible issues since human errors may occur or some actions may be forgotten. A steam leakage and high-pressure drop could be observed in the system as the pressure of steam in the boiler critically differed from the ones in the piping system and the experiment unit, with both pressures indicated by pressure gauges.

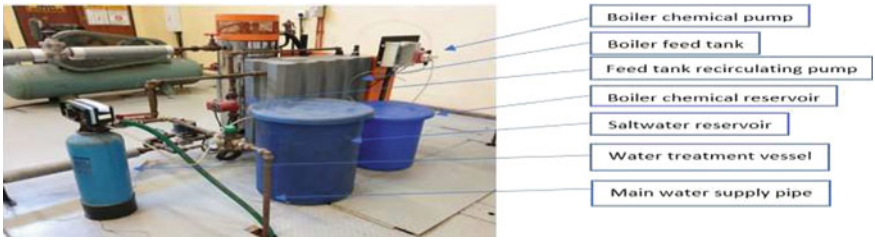


**Fig. 2** Boiler water treatment subsystem

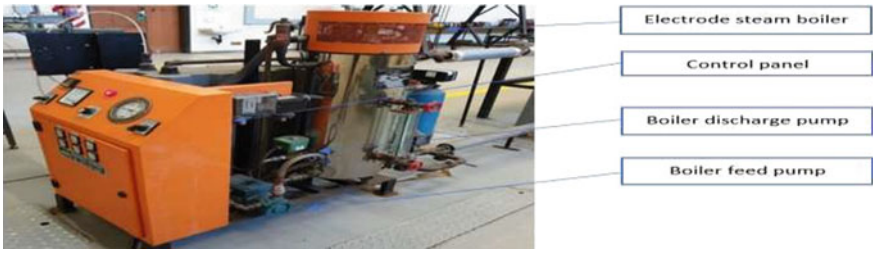


**Fig. 3** Steam generation subsystem

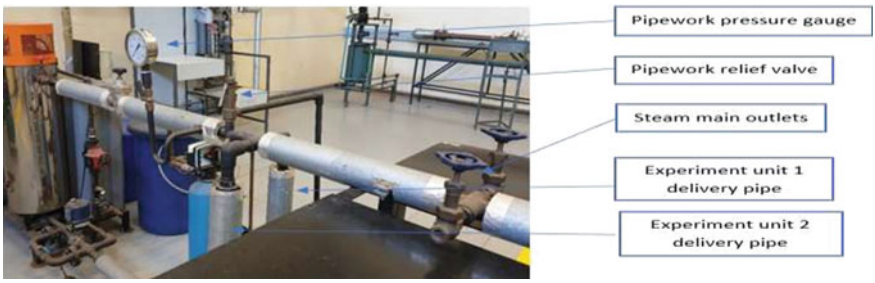


**Fig. 4** Steam distribution subsystem

**Table 1** Current small-scale steam plant operation processes

| Process | Event |
|---|---|
| 1 | Water is collected from the main water supply pipe by manually opening a valve |
| 2 | Water goes to the water treatment vessel to be mixed with salted water |
| 3 | The mixture liquid goes to the boiler feed tank |
| 4 | The bypass and boiler steam outlet valves are closed, and the boiler feed water valve is opened manually |
| 5 | The main power supply of the whole system is manually switched on together with the boiler |
| 6 | The boiler chemical is periodically and automatically pumped into the boiler feed tank |
| 7 | The boiler is allowed one to two minutes to preheat |
| 8 | Manually from the control panel, the centrifugal feed water pump is switched on, and the current load is set |
| 9 | The boiler starts generating steam automatically |
| 10 | The boiler steam outlet valve is manually and gradually opened after the steam reaches the working pressure (550 kPa) |
| 11 | Steam goes through the piping system and is distributed to the experiment units |

## *4.2 Proposed Automation System*

The proposed automation design is realized based on the possible solutions to improve the existing small-scale steam plant. The developed system is fully automatic, while the current one is semi-automatic. The setup of the existing design did not completely change; instead, features that were not previously available were just added to make the new system fully automatic, smart, and effective. The new features are sensors, automatic valves, a PLC to control them, and a SCADA system to monitor and supervise the whole system. Six float switch level sensors are used to control the water level in the saltwater tank, boiler chemical tank, boiler feed water tank, and the boiler. To monitor the health of the boiler feed pump, two sensors (the LM35 temperature sensor and the piezoelectric vibration sensor) are used, whereas to monitor the health of the boiler, the RTD Pt100 and the pressure transmitter are implemented. A sludge blanket level detector is also present inside the boiler to detect the accumulated sludge and sends a signal to the PLC. An acoustic steam leak detector is implemented to detect any steam leakage in the piping system and close to the boiler steam outlet valve. Solenoid valves are also implemented into the system to control the flow of the main water supply, the boiler feed tank outlet water, the boiler inlet water, the bypass water, and the boiler outlet steam. Besides solenoid valves, automatic safety vales are also retrofitted in the boiler and piping system to automatically release steam when the pressure goes beyond the predefined values. The SIMATIC S7-1200, a Siemens PLC product, is proposed to control the field devices, while the SIMATIC WINCC supervises and monitors the whole system. The PLC is linked to the field devices via the Profibus decentralized peripherals

(DP) wired communication protocol and to the SCADA system via radio modems (wireless communication protocols). A private cloud, Ubuntu, is also implemented into the system to facilitate access to data and services from any location other than the mini steam plant. Figure 5 is the process flow diagram of the proposed system, and it also represents the overall design, Table 2 has the description of terms assigned to components in the process, and Fig. 6 is the automation architecture of the system. Additionally, the new system is designed to shut down immediately if the pressure and temperature inside the boiler exceed the required values, and safety valves are automatically activated to release high-pressure steam. The operator of the system will also be informed through an alarm if anything goes wrong or needs to be attended.

The followings are the step-by-step operation of the proposed design:

- The whole system starts running by pressing the start button (from the control room or on the field).
- The main water supply valve opens to supply water to the boiler feed tank by passing through the water treatment vessel. The valve will close when water in the boiler feed tank reaches the high-level sensor and will reopen when water reaches the low-level sensor.
- The boiler is also switched on once the whole system starts running, then after two minutes, the boiler feed water tank outlet valve and the boiler water inlet valve open, and the boiler feed pump starts running. The boiler is permitted two minutes to preheat so that water starts heating up quickly once it gets in.
- When the steam pressure inside the boiler reaches 550 kPa (boiler working pressure), the boiler steam outlet valve gradually opens to supply steam to the piping system.

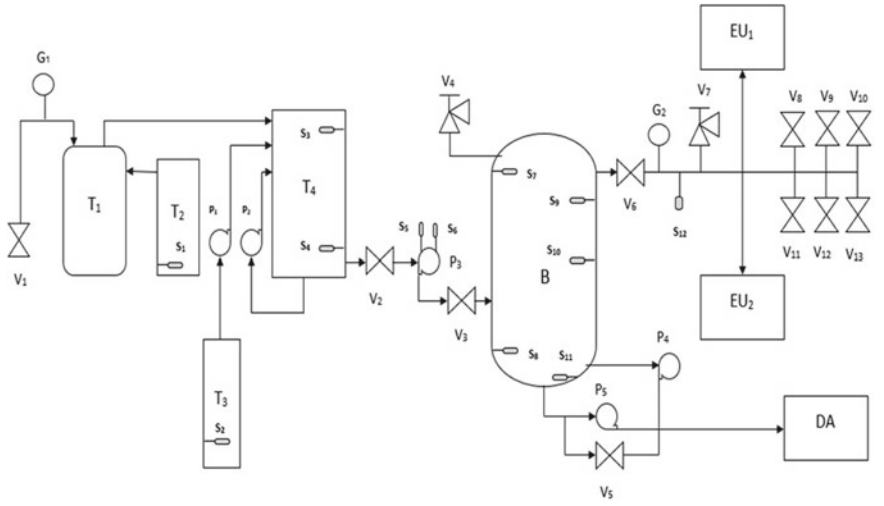


**Fig. 5** Process flow diagram of the proposed automatic small-scale steam plant

**Table 2** Description of process flow diagram terms

| Term | Description | Term | Description |
|---|---|---|---|
| B | Electrode steam boiler | S8 | Boiler low-level sensor |
| EU1 | Experiment unit 1 | S9 | Boiler temperature sensor |
| EU2 | Experiment unit 2 | S10 | Boiler pressure sensor |
| G1 | Main water supply pipe pressure gauge | S11 | Boiler sludge detector |
| G2 | Piping system pressure gauge | S12 | Steam leak detector |
| P1 | Boiler chemical pump | T1 | Water treatment vessel/tank |
| P2 | Boiler feed tank recirculating pump | T2 | Saltwater tank |
| P3 | Boiler feed water pump | T3 | Boiler chemical tank |
| P4 | Boiler discharge pump | T4 | Boiler feed water tank |
| P5 | Boiler blowdown pump | V1 | Main water supply valve |
| S1 | Saltwater tank low-level sensor | V2 | Boiler feed water tank outlet valve |
| S2 | Boiler chemical tank low-level sensor | V3 | Boiler water inlet valve |
| S3 | Boiler feed water tank high-level sensor | V4 | Boiler safety valve |
| S4 | Boiler feed water tank low-level sensor | V5 | Bypass valve |
| S5 | Boiler feed pump temperature sensor | V6 | Boiler steam outlet valve |
| S6 | Boiler feed pump vibration sensor | V7 | Piping system safety valve |
| $S_7$ | Boiler high-level sensor | V8-13 | Piping system outlet valves |

It should also be noted that the bypass valve closes when the system starts running and opens when the system stops running. The boiler steam outlet valve closes two minutes after the system stops running to empty steam in the boiler. Moreover, when the saltwater and boiler chemicals reach their low-level sensors in their respective tanks, the operator will be informed through an alarm on the SCADA screen.

## 5 Experimental Results and Discussion

### *5.1 PLC Simulation*

The proposed automation design of the small-scale steam plant was simulated using LOGO Soft Comfort V6.1 software with the ladder logic/diagram (LAD), PLC programming language. The circuit is read from left to right and from top to bottom, with the red color indicating power on and the blue indicating power off. Light bulbs represent the outputs of the system and are switched on or off depending on the commands coming from inputs. The PLC simulation results show that the proposed design operates automatically and efficiently, as explained in the mode of operation and shown in the process flow diagram. Once the start push button is pressed, the main water supply valve opens to deliver water to the system, and the boiler switches

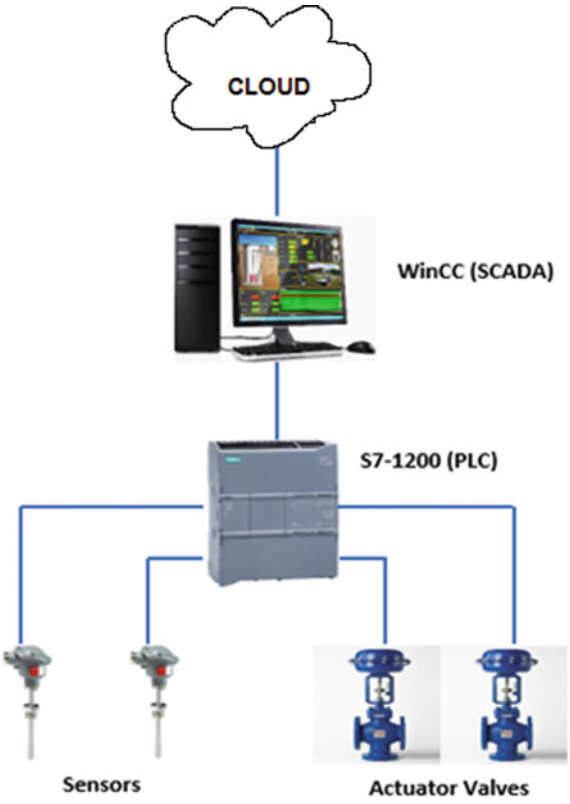


**Fig. 6** Small-scale steam plant automation architecture

on to start heating up. Two minutes later, the boiler starts receiving water from the feed tank through the feed pump (Figs. 7 and 8). Afterward, the boiler steam outlet valve automatically opens to supply the generated steam to the pipework when a boiler steam pressure of 550 kPa is reached and detected by the pressure transmitter (Fig. 9). A LED signal warning light is also automatically activated in response to the sensing of low water in the different tanks, the sludge accumulation in the boiler, the steam leakage in the piping system, the parameters of condition of the feed pump and boiler reaching unsafe values. The alarm is only activated together with the LED signal warning light when the boiler pressure significantly exceeds the predefined safety value of 605 kPa, as illustrated in Fig. 10, and the system automatically shuts down. Figures 10 and 11 illustrate when the stop pushbutton is pressed and when the pressure transmitter senses a boiler pressure of more than 605 kPa. When the stop push button is pressed, the whole system is shutdown except the boiler steam outlet valve, which closes two minutes later to allow steam to leave the boiler, whereas when the boiler pressure exceeds 605 kPa, the alarm, LED signal warning light, boiler safety valve, and piping system safety valve are all activated, and the whole system is shutdown.

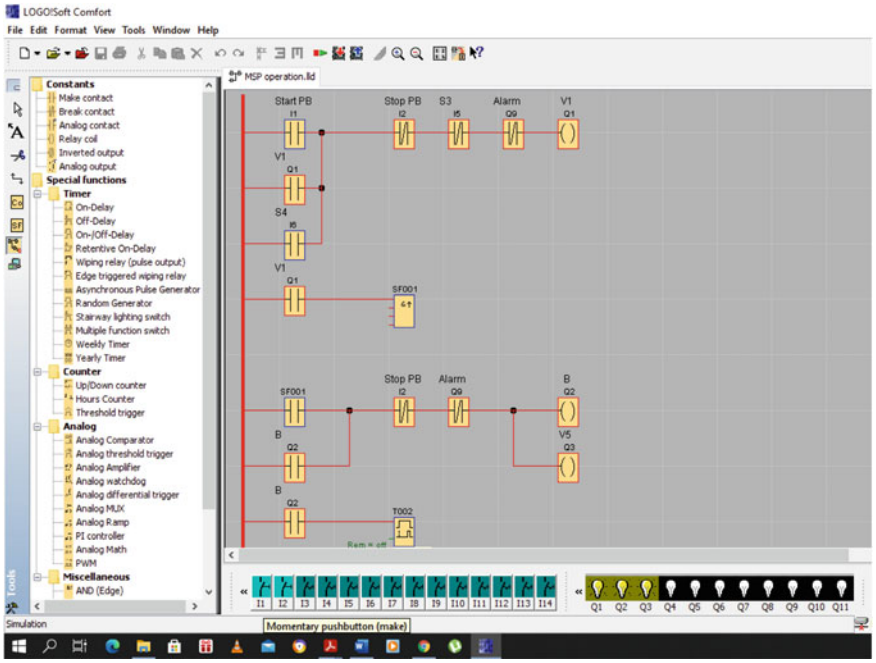


**Fig. 7** PLC simulation results (mode of operation step 1)

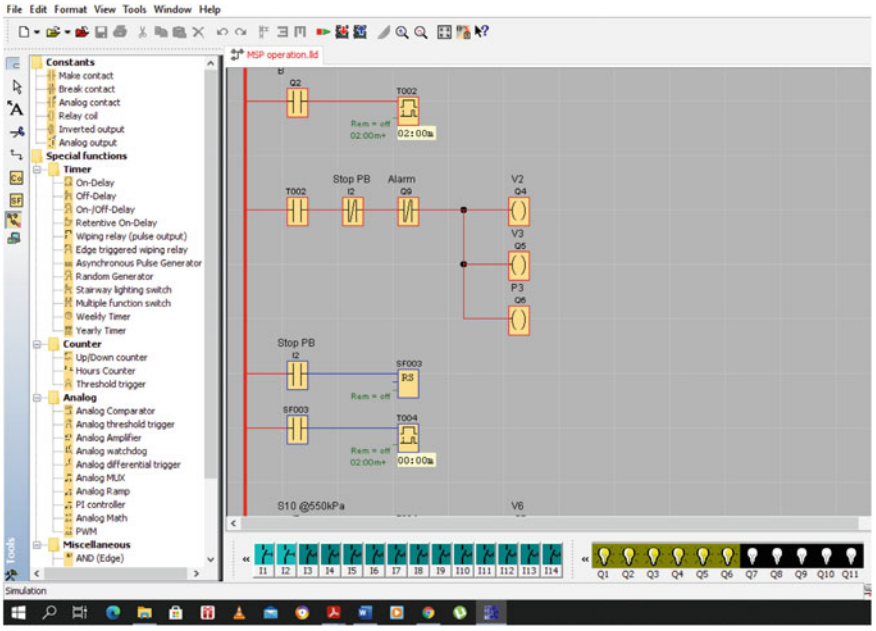


**Fig. 8** PLC simulation results (mode of operation step 2)

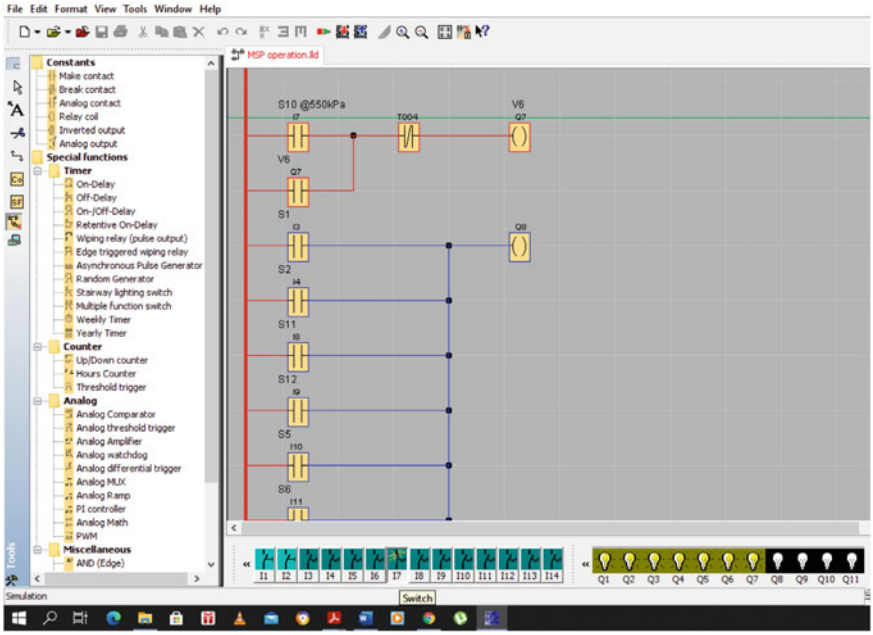


**Fig. 9** PLC simulation results (mode of operation step 3)

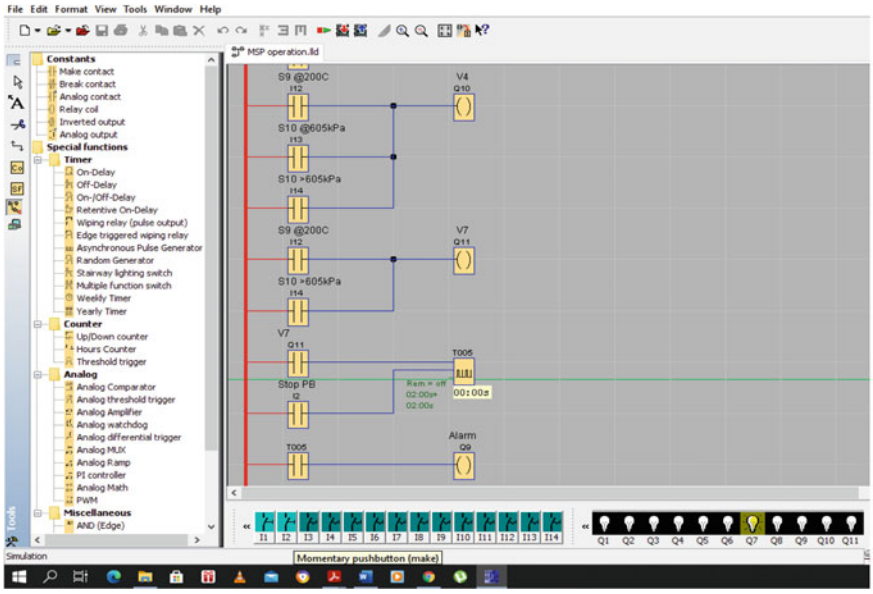


**Fig. 10** PLC simulation results (stop process)

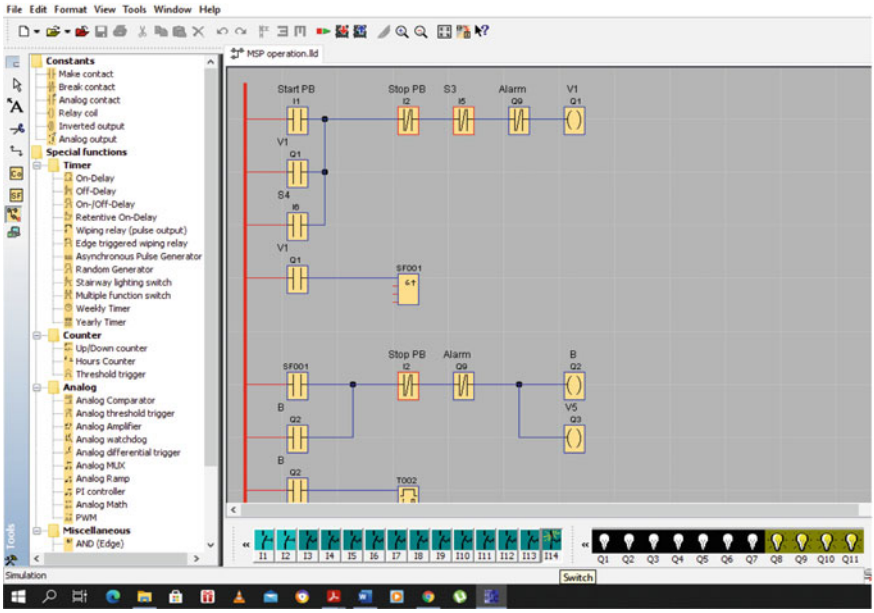


**Fig. 11** PLC simulation results (automatic shutdown)

## *5.2 SCADA Simulation*

The SCADA simulation of the proposed automatic small-scale steam plant was done by Wonderware Indusoft Web Studio 8.1. The SCADA simulation was done only for the condition monitoring of the mini steam plant. The SCADA- based condition monitoring system is implemented to identify changes in the boiler and feed pump parameters and alert the operator by means of alarms through the SCADA screen. The SCADA simulation results confirm that the condition monitoring of the boiler and the feed pump is achieved effectively. Warning messages or alarms are displayed in the SCADA screen whenever the parameters of condition in the boiler and feed pump are either too high, high or low (Fig. 12). Hence, this process proves that the health of the boiler and the feed pump is well monitored, and the system can then operate efficiently. Figure 13 shows that the parameters of condition can also be monitored or supervised by referring to trends (graphs) used for real-time data analysis and comparison of values/data. The different parameters of condition have different graph colors, and once they change to black, the operator will understand that they have reached or exceeded their respective predefined safety values. From the SCADA simulation, historical data were also acquired in the form of a generated report. These data are the saved real-time data and are useful as they will enable the operator to track and analyze the improvement and behavior of equipment and schedule maintenance before the equipment breakdown.

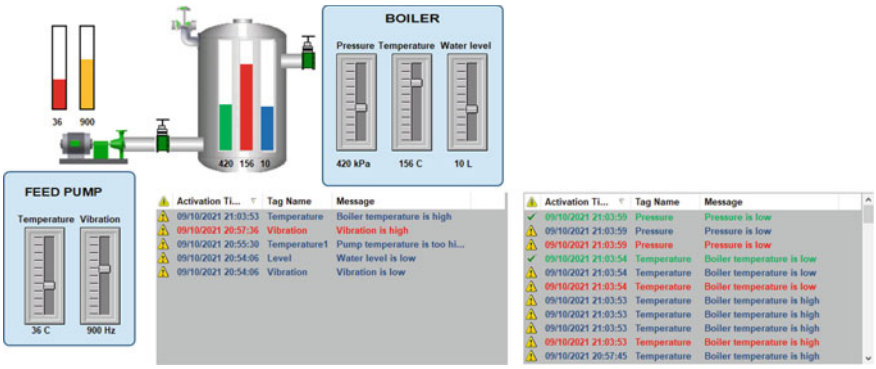


**Fig. 12** SCADA simulation alarm result

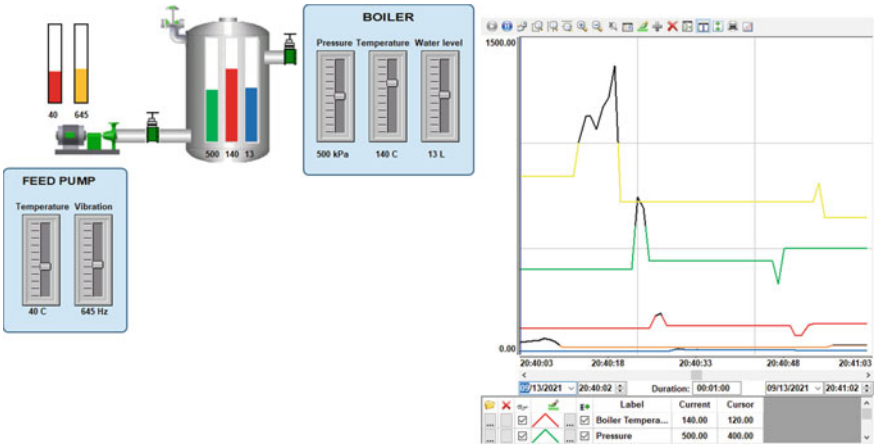


**Fig. 13** SCADA simulation trend result

## 6 Conclusion

In this study, the effectiveness of an I4.0 and PLC SCADA-based automatic control system is demonstrated. A small-scale steam plant was used to test and prove the automatic concept. SCADA and PLC simulations were done on the proposed automatic design rather than building any type of hardware and conducting experiments. The results of the PLC and SCADA simulations demonstrate that the proposed system of the mini steam plant can operate automatically and effectively, therefore meeting the automatic control requirements. The PLC system implemented controls automatically the processes of the whole mini steam plant by means of the different sensors that serve as inputs and actuators as output, while the SCADA system allows a good condition monitoring of critical equipment. The results obtained in this research

confirm that the proposed system of the mini steam plant is better, effective, and smart than the existing one. The new features such implemented as sensors, PLC, SCADA, and cloud system allow the fully automatic control of the mini steam plant, unlike the existing one, which is semi-automatic. For future work, necessary protocols and applications can be configured to allow monitoring of plant data using internet services or from a decentralized server. More features of Industry 4.0 can be added, and simulations and experiments can be done on other industrial prototypes.

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# Design and Application of the AHP-TOPSIS-2N to Evaluate (Linked) Open Government Data from the Electricity Datasets

**Ingrid Palma Araújo, Ana Carla Bittencourt Reis, Ari Melo Mariano, and Vinícius Rodrigues Oviedo**

**Abstract** This study proposes to simplify and automate this process, combining two different methods of decision support through multicriteria analysis in a model capable of judging and prioritizing risk criteria in the context of Open Data, presenting the results via iterative online dashboards developed in R. The methodology followed combines the AHP and TOPSIS-2N methods, creating a ranking of the open governmental dataset of the electricity sector in light of the risk criteria evaluated by the proposed model. The AHP technique was used to specify and normalize the importance of each criterion, considering the consistency aspects of the decision matrix. The next step was to apply the TOPSIS-2N method to sort and prioritize these datasets. The results present the datasets that should be improved concerning the respective metadata and the prioritized themes to make the decision-making for the management of the respective bases more agile and assertive.

**Keywords** Open data evaluation model · AHP-TOPSIS-2N · (linked) Open government data · Electricity sector open data · Hybrid multicriteria decision support model

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# 1 Introduction

In the last decade, it is noted the publication of laws, decrees, among other national and international regulations that foster initiatives and strategies for the implementation and publications of datasets in open format, having as an example the current Open Data Policy (Decree No. 8.777/2016). However, its wider implementation requires the identification of obstacles that prevent public agencies from implementing an Open Data strategy or ensuring its sustainability [1].

The Open Data Plan (PDA) is a government instrument created to execute the Open Data Policy in a certain body and must promote and define criteria for the expansion of the amount of open data available on the Brazilian Open Data Portal (PBDA),[1] as well as the correction and updating of this base, as recommended by the Digital Government Strategy[2] and the Organization for Economic Cooperation and Development.

The PBDA is the federal government's official website, which gathers data considered open from different versions (distributions). Structured as a web catalog, the Portal organizes datasets that can be easily found, accessed, and used by any person or computerized tool. Currently, this portal has more than 10,000 datasets and approximately 51,000 cataloged resources.

Despite the actions implemented by the PDA, it is evident, in a recent study presented by [2], the growing demand for data and information related to the electricity sector, inferring that the required data were not found or published properly in the PBDA or, if available, have outdated or wrong values. In the aforementioned article, the authors used the topic modeling approach and text mining techniques to map the topics of the issues most demanded by society and other stakeholders within the Ministry of Mines and Energy (MME). The results pointed out that the most frequent themes are related to issues under the National Electric Energy Agency (ANEEL), which ratifies the scope mentioned in Sect. 1.4.

Allied to the problem at hand, it was found a small number of datasets cataloged in the PBDA, held by government agencies of the electric power segment. There are 44 electricity datasets available on dados.gov.br (see Table 1). The low quantity of data from the electric power sector cataloged in the PBDA leads, specifically to those responsible for implementing the Open Data Policy of this segment (MME and ANEEL), to uncertainties and risks in decision making related to the adequacy of these databases or in the identification of potential topics for data opening.

## *1.1 Context and Issues*

Although the Open Data paradigm creates opportunities for economic development [3], encourages scientific production [4–6], and increases civil society's participation

[1] https://dados.gov.br/.

[2] https://www.in.gov.br/web/dou/-/decreto-n-10.332-de-28-de-abril-de-2020-254430358.

in government by informing itself about the public manager's decision-making [7], it also generates problems such as the opening of inaccurate/inconsistent, sensitive, and/or private data, potential risks of inappropriate interpretation and misuse of the data, or even the non-use of these open bases, which may result in organizations' aversion or reluctance to adhere to the OGD initiative [8], as well as the reluctance of managers to open their bases.

The aforementioned works point to the need for a *framework* (model) capable of assessing criteria that are relevant to the context of *open data*. On the other hand, it is also verified the inexistence of multicriteria methods applied in the referenced works, especially those that deal with specific data from the electricity sector.

The systematic literature review conducted by [9] showed that only 11% of the scientific productions involving *open data* evaluation techniques applied quantitative methods, representing a large difference between the number of qualitative (47%) or purely interpretive (38%) scientific productions compared to less subjective approaches.

These questions raise a research gap due to the incipiency of a model that supports decision-making to improve open data and enhance the process of opening and publishing these data, to better direct resources and efforts to the criteria and *datasets* evaluated. Thus, in the governmental context, assessing the level of openness of data in the electricity sector so that the bases made available in the PBDA are closer to the *open data* standard illustrates the research problem to be explored.

## *1.2 Research Issues*

We formulate the following key issues to guide this work:

- Are there theoretical foundations and methodological references for opening and making databases available in light of a risk assessment that follows the main decision support models?
- What are the most commonly used methodologies in sorting and prioritizing topics, themes, or databases that are candidates for openness and that rely on a risk assessment/analysis?
- What criteria are most used, appropriate, and relevant to the openness of data regarding the context of the Brazilian electricity sector? And how to measure such risk criteria?

## *1.3 Goals*

The objective of this work is to propose a decision support model that allows evaluating, in light of the risk criteria related to the Linked Open Data OGD principles, the level of openness of the electricity sector databases cataloged in the PBDA. To do this, it is necessary to (i) Identify, select and measure the relevant risk criteria for the context of Open Government Data in general and specific to the electricity sector;

**Table 1** Content analysis scope/alternatives

| Body/Entity | Empirical Corpus | | *Dataset* found on PBDA |
|---|---|---|---|
| | Documents | PDA | |
| MME | 0 | 1 | 2 |
| EPE | 2[a] | 0 | 0 |
| ANEEL | 0 | 1 | 42 |
| Eletrobras | 15[b] | N/A[c] | 0 |

[a]Ten Year Energy Plan 2030 and National Energy Plan 2050
[b]Management Reports for the years 2005–2019
[c]N/A = Not Applicable. Eletrobras, despite being linked to the MME, is a mixed economy company and therefore not required to publish its data in the PBDA [10]

(ii) Identify the multicriteria decision support method(s) adherent to the problem studied; (iii) Identify the potential themes for opening data in the electricity sector; (iv) Build the model, considering the risk criteria and methods identified; and (v) Validate the proposed model systematics based on the critical analysis of specialists.

### *1.4 Scope and Delimitation*

Considering the scope of the context, this study is limited to the construction of a model that supports the decisions of the Ministry of Mines and Energy (MME) managers **to better assess the level of openness of data in the Brazilian electricity sector**, which comprises a strategic business area of the MME for the country, involving important natural resources for the economic and socio-environmental development.

**Dataset Selection**

According to the summary presented in Table 1, in addition to the documents (power sector reports and plans), 44 sets of data developed/held by the above-mentioned units were found and analyzed.

The content of this research is available and organized at the following electronic address: https://github.com/ingridpalma/mestrado.

## 2 Background

### *2.1 Linked Open Data (LOD)*

According to [11–13], **Linked Open Data** reflects the Semantic Web by discovering, linking, storing, and consuming datasets available under open licenses by converting them to RDF according to the Linked Data principles mentioned above.

To encourage the publication of Linked Open Data, "*especially proprietary government data*", [11] proposed a system, called the "5 Star System", to rate the data published in the open standard. This system, anchored by the Linked Open Data (LOD) project created in 2007 by the World Wide Web Consortium (W3C), has driven the evolution of the current *document-oriented Web* to a *Web of Linked Data* or *Semantic Web* [14, 15].

This transformation from the traditional (document-oriented) Web to the Semantic Web, supporting interconnection and exchange between heterogeneous data clouds, relies on APIs common to the LOD cloud.[3] highlighting the Representational State Transfer (REST) architectural style, implemented by services known as RESTful and modeled by URIs that allow operating on data networks that constantly change their values.

The goal of the LOD project is to identify diverse datasets available under open licenses and convert them into RDF according to *Linked Data* principles, thus enabling the automatic connection of Open Data generating an informational context from the semantic representation of linked data. In this way, not only syntactically linked pages published on the Internet can be identified and processed automatically, but all semantically linked Open Data of different contexts and levels of granularity [14].

**LOD Principles**

The LOD principles are described below:

(P1) The license is the central metadata for the available resource to be considered open data. The resource must be in the public domain[4] or provided under an open license, which refers to legal conditions, (reasonable) restrictions, conformities, clauses, and principles related to the open data concept under which the data is subject. It is the concession of data for broad access and reuse, and/or redistribution, requiring, at most, the crediting of authorship to the original source and sharing by the same license. Among the best known are Creative Commons and Open Data Commons[5];

(P2) Machine-readable: converting the database into a set of machine-processable instructions (e.g. CSV, XML, JSON, GeoJSON, XLS);

(P3) Non-proprietary format: standardized format by means of which information is encoded for reading and storage in a digital medium for free use without any restrictions or patents (e.g. use of CSV files instead of Excel);

(P4) RDF and SPARQL standard: allows queries, via SPARQL language, to be made to RDF databases, which is a framework for representing information on the Web [16];

[3] A LOD cloud diagram can be viewed at the following address: http://lod-cloud.net—This diagram is generated from the metadata available in https://ckan.org/.

[4] According to art. 41 of Law No. 9610 of February 19, 1998 (Copyright Law), property rights end after 70 years from the death of the author.

[5] The OKF presents a list of licenses at http://opendefinition.org/licenses/.

(P5) Linked RDF (RDF bases according to Linked Data or JSON-LD principles, which allows the use of ontologies for data description and discovery); and
(P6) Hosted and published: refers to the technical aspects recommended for cataloging, hosting, and publishing data on the Web.

## *2.2 LOD Risk Criteria*

From the literature review based on the six Linked Open Data principles, we have identified the following Risk Criteria:

**License not Suitable (or Not Compliant) with the Dataset (RC1)**

According to the Open Knowledge Foundation (OKF), a license can be considered *open*, *closed*, or *unknown*. In this situation, identifying a given dataset under an unknown license increases the level of uncertainty of the respective base [17]. As the first principle to be addressed by [11], the Open License confirms its relevance when [18] relates it directly to the domains of data application, attribution, linking, storage and sharing, since data can pose risks regarding reliability, quality, and format [19]. Thus, the license is the form that the owner or manager of data has to authorize free access, re(use), redistribution of such data for any purpose (especially for commercial purposes, which must respect the protection of personal data). In addition, it protects the organization against the possible risks mentioned above, detailed by [19].

**Heterogeneity of Metadata (Data) Syntax, Schema or Semantics (RC2)**

Heterogeneous metadata schemas and semantics are the main risk factors for *Semantic Interoperability*, which is generally solved by using best practices within the Web Ontology Language (OWL) [20]. In this case, the challenge lies in the use of different ontological models, in addition to the technical and computational constraints for using this structure [21]. Factors such as availability, completeness, compliance with standards/good practices, consistency (not using duplicate licenses, for example), and level of accuracy of the metadata describing the published data may impact the identified Criterion RC2, so that the description correctly reflects the relevant characteristics of the referenced resources (dataset/documents) [22].

**Dissemination/Publication of the Dataset (Resource) in Proprietary Format (RC3)**

Jack Schofield's First Law of Computing[6] states that one should not deposit data into a piece of software without later guaranteeing to take it back into the proprietary domain. Proprietary formats are controlled by a specific software company or entity. In this case, there is a risk that this entity no longer supports the proprietary file format previously made available. Nevertheless, non-proprietary tools usually have

[6] https://www.theguardian.com/technology/2003/jul/24/onlinesupplement.columnists.

**Table 2** Risk criteria based on LOD principles

| ID | Risk criteria | LOD principle |
|---|---|---|
| RC1 | License not suitable (or not compliant) with the Open dataset | Open license (P1) |
| RC2 | Heterogeneity of metadata (data) syntax, schema or semantics | Machine-readable (P2) |
| | | PRDF Pattern and SPARQL (P4) |
| | | Connected RDF (P5) |
| RC3 | Dissemination/publication of the dataset (resource) in proprietary format | On-proprietary format (P3) |
| | | Hosted and published (P6) |

more complete documentation, with publicly documented code, which increases the likelihood of getting more support for open standard-oriented technologies.

The criteria identified above have been outlined in Table 2 and associated with the principles that underpinned the election of each Risk Criteria.

## 3 Multi-criteria Methods and Open Data Risk Criteria

This topic presents a literature review of the principal and most recent works related to decision models for data openness, focusing mainly on the risk criteria addressed in the respective studies.

As observed in [23], there are still few works that address decision models for the selection and prioritization of potential themes for the opening of government data. This finding highlights the existence of a theoretical gap in the use of these models concerning the main data sets produced or held in custody by government entities.

In [24, 25], there is concern about the absence of specific measures regarding the openness and cataloging of public data. However, such works present purely qualitative models regarding potential criteria.

In the bibliographical research for the theoretical foundation of this research, we identified numerous methods that deal with decision-making based on multiple criteria related to the public sector. We observed in the listed works that, in general, decisions involve a network of players with conflicting needs and interests. Among the principal works that approach decision-making methods as a way to simplify complex decisions and make them less subjective are [26–30]. From the cited studies and the literature review, the following approaches about the techniques and decision-making models directed to the opening of data are revealed (Table 3).

**Table 3** Risk criteria identified and measured by Bayesian networks

| ID | Risk criteria based on [31] |
|---|---|
| RC4 | Inaccurate, vulnerable, or identified error data (or metadata) |
| RC5 | Non-anonymized private and/or personal data |
| RC6 | Sensitive, confidential, secret, restricted data and/or data from restricted databases |
| RC7 | Complex data (different sources/origins/curators) and structurally heterogeneous data |
| RC8 | Duplicate and/or outdated data |

Adapted from [31]

## *3.1 AHP-TOPSIS*

Kubler et al. [32], after identifying the absence of measurement models that evaluate the quality criteria of data and metadata published in open data portals, applied the AHP and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) techniques to evaluate the quality of these publications in 144 portals evaluated, comparing the relevant metadata concerning the preferences and needs of users. The proposal presented in that study, which is very close to the scope of this paper, uses the AHP to weight the preference criteria, subsidizing the TOPSIS in the final ranking of the alternatives (144 portals). The authors use 5 dimensions (Usage, Completeness, Openness, Addressing, and Retrieval) that, gathered together, parameterize and measure the quality of those portals concerning the available content.

Using the same hybrid approach of AHP-TOPSIS, [33] presents a proposal to verify the optimal location for the installation of a commercial gas station. The mentioned study involved the analysis of a geospatial open data set, considering the following three criteria: site competition, traffic conditions, and site popularity.

The study proposed by [34] adopts the Fuzzy AHP-TOPSIS technique to prioritize OGD strategies and actions, involving 27 criteria distributed into 5 dimensions (Legal, Cultural, Social, Technical, and Economic). In total, ten strategies were identified as priorities for adoption in public organizations.

## *3.2 MCDA on Electricity Sector Open Data*

The reasons why energy sector data should or should not be open are evaluated by [35], who has presented a qualitative (orientative-conceptual) model, discussing the benefits of such openness and the reasons why such data should remain closed.

The main criteria belonging to the *Benefits* and *Risks* Domains, selected and transcribed in Table 4, supported the mentioned work and inspired the construction of the proposed model.

**Table 4** Dimensions of risks and benefits of opening energy data. Adapted from [35]

| Benefits | Risks |
|---|---|
| Innovation and service quality | Ethical and safety issues |
| Feedbacks and more effective collaboration | Unwanted Exposure |
| Collaborative industry burden sharing | Additional workload |
| Productivity increase | Institutional or personal inertia |

Adapted from [35]

Aiming to improve the efficiency of public resources, [36] combined several MCDA methods to carry out comparisons of public infrastructures in 18 cities in Lithuania targeting electric vehicles. A group of public managers and researchers, mainly from the energy, transport and environmental sectors, were consulted for the elucidation or definition of the main factors and dimensions related to the scenario addressed.

There are also the models presented by [37], who highlighted energy sector data considered relevant to the stakeholders of this sector. According to the authors, these data should be open and shared between science-politics-market to create more effective models to identify and solve critical technical problems in the sector (such as energy efficiency, energy conversion processes, energy infrastructure operation, etc.).

## 4 Creating the Decision Model

This stage corresponds to the construction of a preference system in which alternatives are evaluated against the criteria selected for the model under development, so that possible solutions are recommended and validated before the next stage is reached.

The construction of a model is in line with the decision problem at hand (ranking of alternatives/datasets evaluated according to the chosen criteria), and no method in the literature is considered better or worse for all cases. Thus, it is recommended to be clear about the motivation to choose the most appropriate method for the proposed model [17, 38, 39].

Multicriteria Decision Analysis (MCDA) provides a framework for structuring and solving numerous decision problems by exploring criteria relevant to a specific context, which are weighted and evaluated through a preference system using methods and techniques recognized by MCDA and/or Multicriteria Decision Making (MVDM) approaches[7] [40, 41].

[7] The MCDA and MCDM approaches are considered synonymous in this paper.

### 4.1 Risk Criteria

In this paper, the risk criteria for the data openness decision-making process are considered and classified into five different main dimensions, which are:

*Metadata*: refers to metadata as restrictions applied on a dataset, i.e., the legal conditions for broad access and reuse and/or redistribution of the data.

*Feedback (Positive and Negative)*: A binary field available in PBDA that evaluates aspects of the dataset from the user's point of view.

*Update*: refers to the time elapsed (in days) since the last update of the data set. This criterion should observe, among others, the periodicity defined for updating the base.

*Resource*: refers to the measurable aspects of the Ontology and Semantics domain. This criterion represents the total number of resources (distributions) of a dataset published in PBDA and identified by the URI/URL, which is machine-readable. Each resource refers to a specific available form of a given dataset and may be in a proprietary or open format (XLS, CSV, HTML, ODS, JSON, XML, RDF, among others).[8]

The weighting and validation of the criteria, which can be independent of each other and meaningful to the problem, indicate how close an alternative is to the goal. Thus, the next Topic targets this stage, highlighting this application through the AHP technique.

According to [26, 41], the variables can be highly correlated among themselves. Thus, to verify the common characteristics between the selected databases and themes that emerged from the content analysis, it is necessary to discover the importance of the weights of each criterion. In this first moment, a single decision-maker was used to judge the preference matrix.

### 4.2 AHP-TOPSIS-2N Decision Support Model

The choice for the hybrid AHP-TOPSIS-2N method is justified by the following reasons: (a) Quantity of alternatives: the elements of the problem (criteria and alternatives) can be easily structured in a hierarchical model; (b) Reduction of computational complexity and human effort required, particularly regarding the construction of the AHP matrix for pairwise comparison; (c) The numerical scale used removes the need to apply techniques that deal better with less precise categorical parameters. On the other hand, it brings less flexibility regarding the evaluation of the model by the experts; (d) TOPSIS-2N allows the generation of two rankings with distinct normalizations, enabling a comparison of the results presented and a better robustness analysis; (e) Effective integration of the risk criteria to the decision makers' preferences.

[8] A more complete list of machine-readable formats is available at: https://github.com/ingridpalma/mestrado/blob/main/machine_readable.

The weighting and validation of the criteria, which can be independent of each other and meaningful to the problem, indicate how close an alternative is to the goal. Thus, the next Topic targets this stage, highlighting this application through the AHP technique.

**Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)**

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) algorithm, developed by [42], seeks to evaluate the performance of each alternative concerning its proximity (similarity) to the ideal solution. Consequently, the TOPSIS technique confers the rank of "best alternative" to the one closest to the Positive Ideal Solution (PIS). The best alternative has the shortest distance from the PIS and farthest from the Negative Ideal Solution (NIS). The PIS ($A^x$) maximizes benefits/opportunities and minimizes costs/risks, on the other hand, the NIS ($A^-$) maximizes costs/risks and minimizes benefits/opportunities. This euclidean calculated distances is realized by the Eqs. 1 and 2.

$$A^* = [v_1{}^*, ..., v_m{}^*] = (\max v_{ij} | j \varepsilon C_b), (\min v_{ij} | j \varepsilon C_c) \tag{1}$$

$$A\text{-} = [v_1{}^-, ..., v_m{}^-] = (\min v_{ij} | j \varepsilon C_b), (\max v_{ij} | j \varepsilon C_c) \tag{2}$$

Two variables are used to evaluate the performances of alternatives in this model, they are:

- Cost and/or negative risk (which aims to be minimal, that is, the lower the value, the closer to the Ideal) and
- Benefit and/or opportunity (aims to maximize its value, that is, the higher it is, the closer to the Ideal).

In this way, the algorithm selects the best performances for each criterion (cost or benefit), creating positions in higher vectors for those with higher efficiency (i.e., benefits) and lower positions for those criteria that have a metric distance from the optimal alternative. This relative proximity between the proposed alternatives and the optimal solution is determined by Eq. 3.

$$C_{\text{TOPSIS}} = \frac{S_i^-}{S_i^- + S_i^+} \tag{3}$$

**Analytic Hierarchy Process (AHP)**

The three main elements of the AHP (Analytic-Hierarchy Process) are hierarchy building, priority analysis, and consistency check [43]. According to [44], the AHP Technique facilitates decision-making by analyzing the distribution and impacts caused by multi-variables relevant to a specific context, which are transformed into criteria and sub-criteria, and organized hierarchically in relation to the objectives for

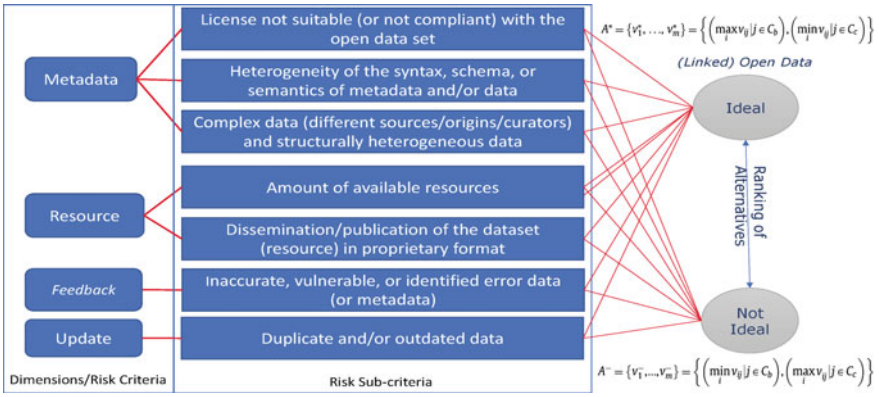


**Fig. 1** Hierarchical structure of risk criteria

solving a complex problem. In turn, the alternatives (possible solutions) are compared to the decomposed criteria and sub-criteria. To do this, weights must be assigned to each criterion so that they can be compared among their peers, identifying the degree of importance among them [45, 46].

**Hierarchical Problem Structuring**

The first step in structuring the problem is to build the decision hierarchy, which, according to [26], consists of the decomposition of a complex problem into a hierarchical system of defined alternatives. The issue of this research is divided into the hierarchical structure represented in Fig. 1 and consists of four distinct levels, which are:

- Level 1: Sort the Databases of the electricity sector cataloged in the PBDA;
- Levels 2 and 3: Dimensions, Criteria and Risk sub-criteria listed from the literature review, referenced in Tables 2 and 3;
- Level 4: Ranking of alternatives, in this case, Databases sorted by risk levels, according to their respective characteristics and evaluated criteria.

## 5 Results and Analysis

### *5.1 Ranking of Alternatives*

The first results of this work present the list of criteria and sub-criteria (see Fig. 1), the priority themes for the decision-makers (government), and, finally, the preliminary ranking of the databases opened and cataloged in the PBDA and their respective comparative analysis (Fig. 2).

In the last level of the AHP structure, the Ranking of Alternatives is represented by a heat map illustrated by Fig. 3. The bases with the best and worst placement (DB39

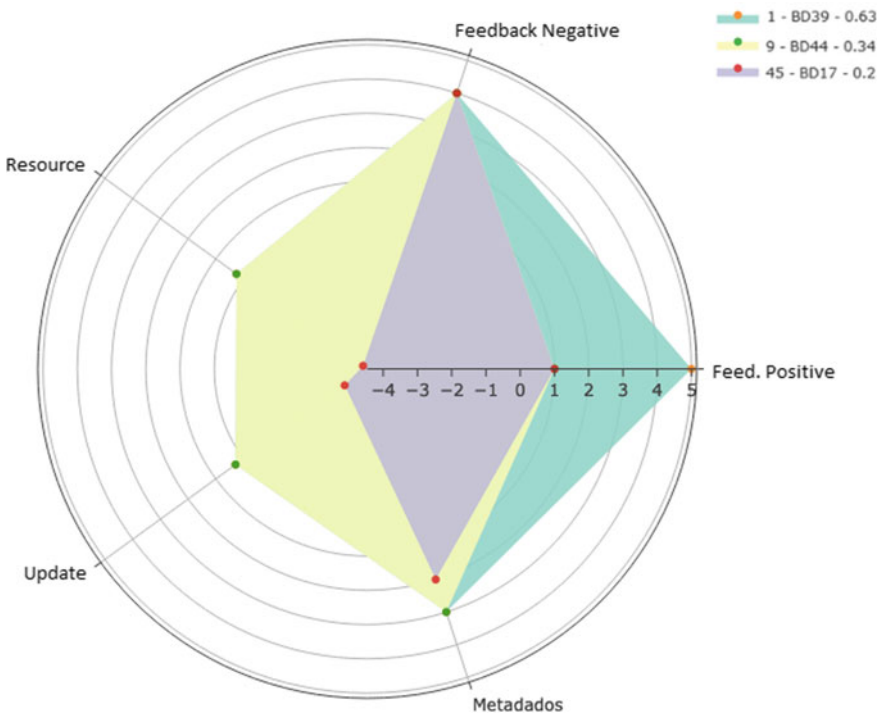


**Fig. 2** Comparison between bases DB39, DB44, and DB17

and DB17, respectively) and also the one positioned in the middle range of the vector (DB44) were selected for the preliminary comparative analysis. With this analysis, it is intended to offer subsidies that reduce the subjectivity of the decision-maker about which bases and criteria should be effectively deployed efforts and resources to improve the PDA review process.

The preliminary comparative evaluation of the mentioned Datasets is represented by the graph in Fig. 2. These sets refer to the bases DB39, DB44, and DB17 (Generation by source; Light for All and More Light for the Amazon Programs, and Light for All Program, respectively).

In the graph, the criterion of greatest impact for the analyzed Bases stands out: Negative Feedback, followed by the criterion Resources. Inferring, thus, that contingency actions should be directed to these dimensions, prioritizing the improvement of the BD17 base.

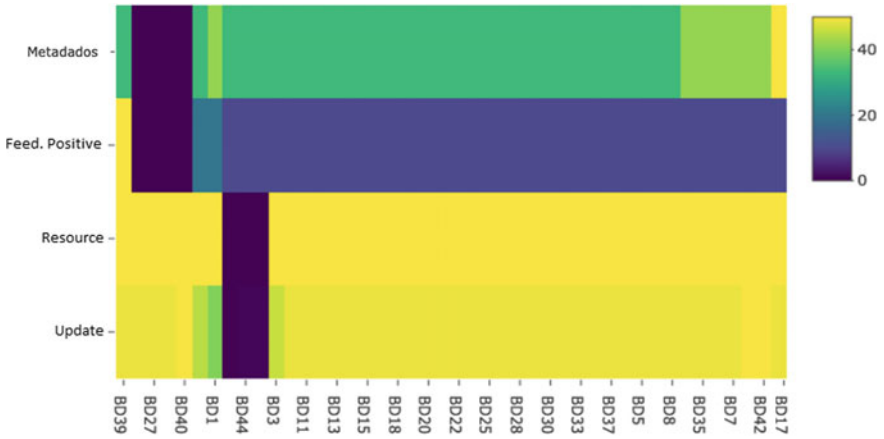


**Fig. 3** Ranking of all evaluated alternatives

The results were imported into RStudio software to use the ahptopsis2n package,[9] implemented by [47], allowing the application of the AHP technique combined with the TOPSIS method, using two normalizations (2N).

The script adapted for this research, the dataset, among other descriptors and algorithms used for the development of this work are available in the repository: https://github.com/ingridpalma/ppca. The semi-automated model was developed in R using the free open-source software RStudio, which is a development environment for the statistical field, presenting the results via online dashboards developed with the Shiny package. The application can be accessed at https://ingridpalma.shinyapps.io/Analise/.

## 6 Conclusions and Future Research

The AHP-TOPSIS-2N Model allowed us to evaluate datasets of the electricity sector cataloged in the PBDA, as well as the criteria with the greatest impact on those with the best and worst performance in the ranking presented in the modeling.

One of the actions that can be implemented from this pilot is to compare the identified risk criteria with the information available in the respective Open Data Plans of the MME and ANEEL to propose the adoption of the criteria that best define this standard for the sake of improving the Open Data Policy of the national electricity sector.

[9] http://cran.rstudio.org/src/contrib/Archive/ahptopsis2n/ahptopsis2n_0.1.0.tar.gz.

Although the proposed model is focused on the cataloging of power sector databases, it is essential to evaluate the quality of the content of these databases, leveled to the respective purpose and metrics considered in the opening. Still, for future works, a scoring criterion can be elaborated to indicate the level of openness of each data set, using an automated index.

In terms of future perspectives, the application of the hybrid AHP-TOPSIS-2N method may be expanded with the inclusion of new metrics, new criteria, and dimensions based on a more complete and updated literature review.

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# Online Retail System with Data Forecasting and Android Mobile Application

**Irish C. Juanatas, Roben A. Juanatas, Jayson Raymund D. Bermudez, Rene Christopher R. Tio, Jaden Del Rosario, Anne Paula Delos Santos, Ricardo R. Edig, and Dennis Martinez**

**Abstract** Online shopping has become one of the most prominent forms of retail for businesses. This is due to the advancement of web services, and mobile applications that have become accessible, and effective with the utilization of the Internet. Accordingly, this study aims to further scrutinize the discussed application of online shopping. Therefore, an online retail system with mobile application through Android was developed, deployed with the purpose of managing the products, and services that are offered by the company, with the standardization of data forecasting to make accurate prediction of future trends. To standardize and validate the attributes of the said system, a descriptive research method that used a survey instrument based on the Likert scale, and the functionality, usability, reliability, performance, and supportability (FURPS) model. The said survey instrument collected 200 responses with purposeful sampling treatment and converted into distinct inputs with the use of the weighted mean formula. The functionality, usability, and reliability were rated as acceptable, with weighted means of 4.5, 4.5, and 4.5, respectively. The performance and supportability were rated as perfectly acceptable, with weighted mean scores of 4.7 and 4.6, accordingly. The system's overall attributes were rated perfectly acceptable, with a weighted mean of 4.6, suggesting that it managed and analyzed sales, services, and inventory data.

**Keywords** Retail system · Data forecasting · Mobile application

## 1 Introduction

Online commerce is growing in the Philippines. A 2015 research indicated 90% of Filipinos favor Internet shopping. Online shopping was favored for its ease, reduced pricing, and special offers. With 37.7 million e-commerce consumers in

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2018, 30.2 million in 2016 and 53.8 million people by 2022. Statista anticipated 47 million e-commerce users in November 2018, bringing in $840 million. Despite its rising popularity, the Philippines continues to trail behind Southeast Asia in e-commerce sales growth [1].

An effective inventory management system helps optimize supply chain decisions. A sophisticated inventory management system might aid decision-makers. A simplified and regulated view of inventory data will also help entrepreneurs acquire precise supplier knowledge. A company's capacity to make faster and more informed inventory decisions is enormous [2].

Modern business intelligence includes sales forecasting. Pair plots are used to analyze sales distributions and visualize data. It finds sales drivers and connections. Regression algorithms presume that past data trends will repeat. The correctness of the validation set affects the amount of iterations. Machine learning generalizes patterns over the whole dataset. This effect can be used to predict sales when limited prior data is available, such as when launching a new product or business [3].

The growth of a local incubator and angel investor network has boosted digital platforms and online commerce. With no middlemen, both parties save money. Platforms may also simply integrate and give add-on services to users. Diverse industries in the Philippines have benefited from digital (e.g., Apple iOS and Google Android). Platforms increasingly use cloud computing for storage and hosting. Retails increasingly use AI and machine learning to boost process efficiency and accuracy [4].

## 2 Methodology

Systems architecture is utilized to create the concepts that act as the foundation for the current system. It is a conceptual model used to outline its structure and behavior. This includes a technological foundation, a list of system components, and end-user requirements. For the established online retail system, the web site and mobile application have four modules that are accessible to the customers as shown in Fig. 1. The essential components of the system architecture for customers are service reservation system, product viewing module, login module, and payments system. The service reservation system allows customers to inquire about service reservations, which are then validated by the inventory system. Customers view products on the product viewing module, where customers can also validate inventory stocks and add items to the cart module. The cart module runs this information through the inventory system to check stock levels and, once validated, sends it to the customer. Customers are directed to either login or sign up for an account via the login module. Customers check out their orders through the payment system, which stores sales data and sends an order invoice to the product receiving module.

The system architecture dedicated for the employee as shown in Fig. 2 is product receiving module, product and service reservation module, inventory system, login module, and data forecasting system. The product receiving module enables employees to validate delivery information provided by customers. Employees

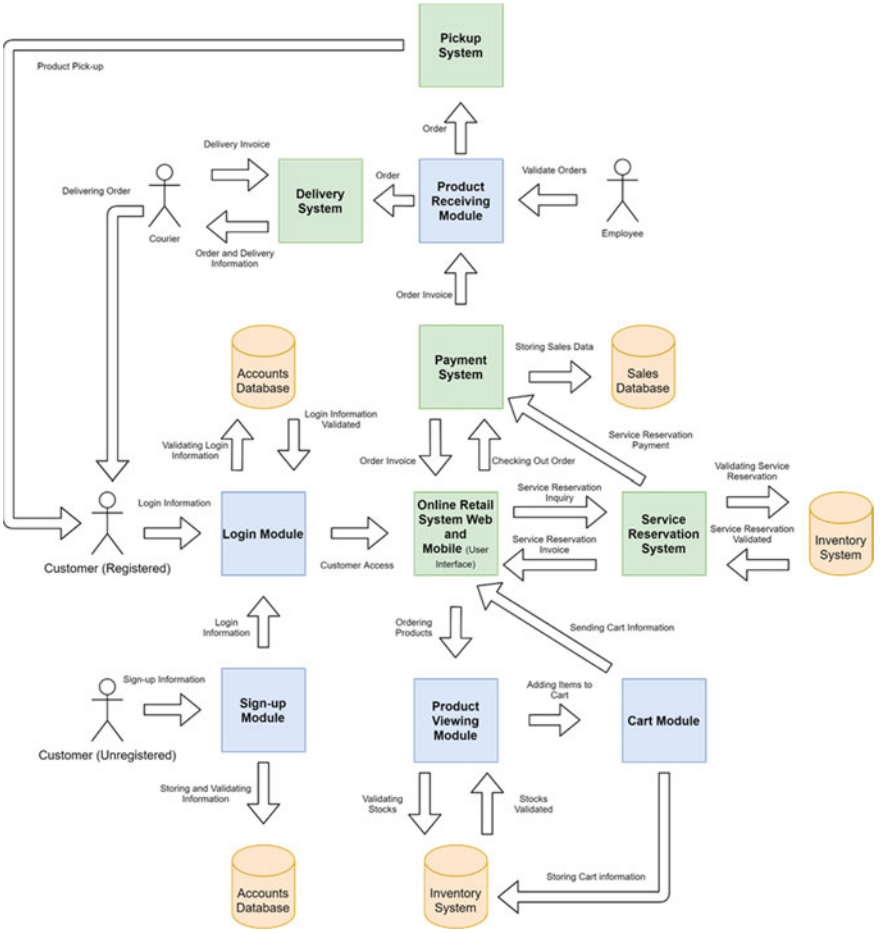


**Fig. 1** System architecture of the study (Customer)

update items and catalogs in the product and service pages, which are finalized in the inventory system, where they can add, edit, and archive items. Inventory validation is sent to the inventory system, which then provides inventory validation reports. When users enter their login information into this module, it is validated against the accounts database. The inventory system sends quotations to the sales database, which sends sales data to the data forecasting system, allowing forecasting reports to be displayed.

Purposive sampling is used to acquire data, which is subsequently examined. The weighted mean was used to compute the percentage. The necessary equation to come up with the weighted mean is composed of different variables.

To collect the required data objectively and apply the statistical techniques, a survey tool was designed with the FURPS model. Purposive sampling was used to

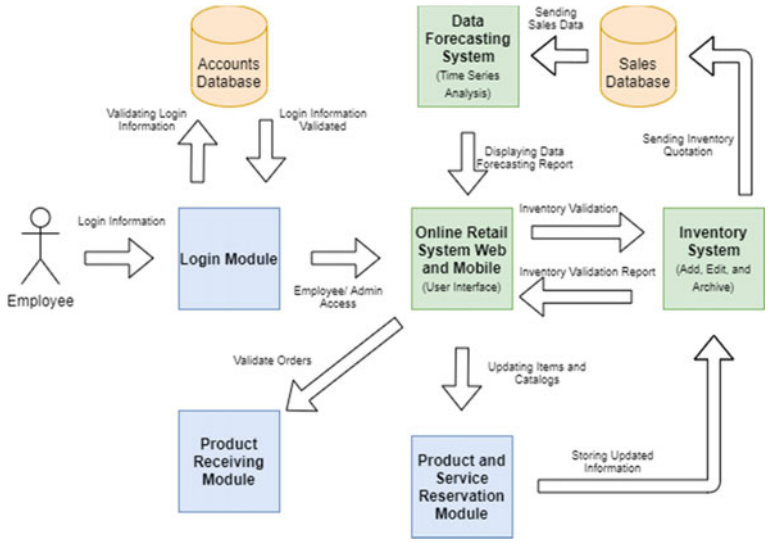


**Fig. 2** System architecture of the study (Employee)

acquire 200 responses from the specified survey instrument. The respondents' replies were then analyzed using the weighted mean and explained using a provided metric as given in Table 1.

The system was designed using existing programming languages, web frameworks, and integrated development environment. For the web application, CodeIgniter, HTML, CSS, Bootstrap, SQL, and PHP were used to program its functionalities. As for the mobile application, Android studio, Java, and XML were used to build it.

Figure 3 shows the product page for the customer side of the web site (on the left) and mobile application (on the right). The page is accessible to a customer by clicking products. It contains a search functionality with a sort by the product categories, view order functionalities, and product details.

Figure 4 illustrates the checkout page that allows the customer to check out and pay for the order. The customer may see the orders' summary. The customer can also select preferred payment method on this page.

**Table 1** Standardized point, mean range, and evaluation of the mean range

| Point | Mean range | Evaluation of the mean range |
|---|---|---|
| 5 | 4.6–5.0 | Perfectly acceptable |
| 4 | 3.6–4.5 | Acceptable |
| 3 | 2.6–3.5 | Neutral |
| 2 | 1.6–2.5 | Slightly unacceptable |
| 1 | 1.0–1.5 | Unacceptable |

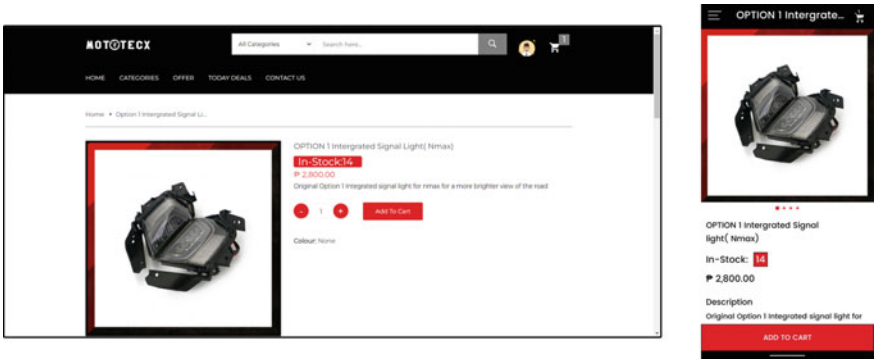


**Fig. 3** Product page

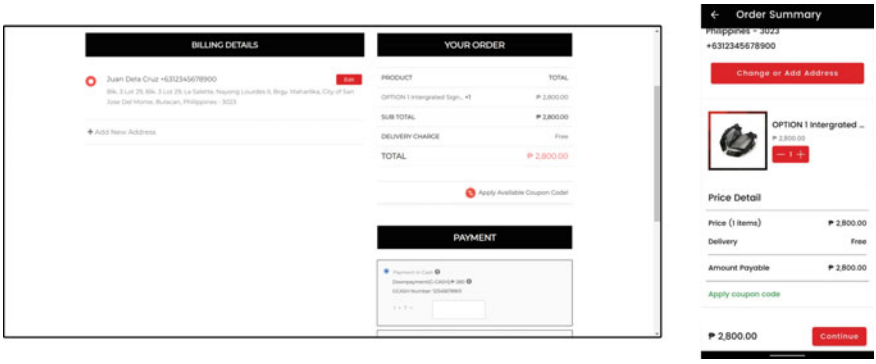


**Fig. 4** Checkout page

The dashboard is an interface for the online retail system. The administrator may access the system summary and other features including the inventory system and data forecasts as shown in Fig. 5.

The inventory system page lets the administrator manage products and services. The processes are automatically updated in the database, making it a dynamic inventory management system as illustrated in Fig. 6.

Consequently, the data forecasting page contains the graph represented through moving averages with simple linear regression of the sales trends of the products and services recorded by the system as presented in Fig. 7.

## 3 Results and Discussion

Table 2 contains the evaluation results that shows the functionality, usability, and reliability, and all have a computed weighted mean of 4.5, and all are described as

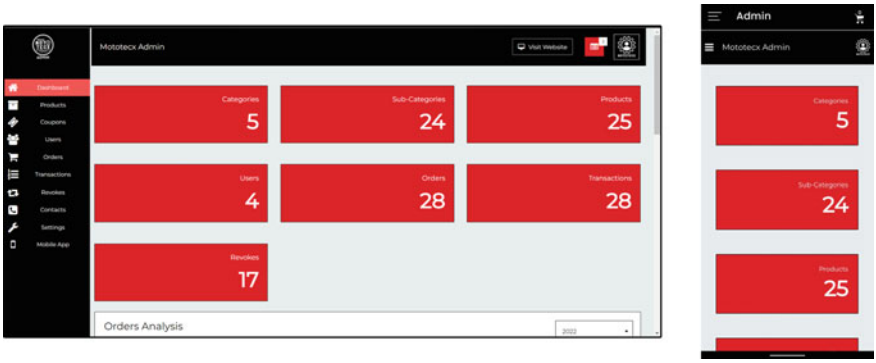


**Fig. 5** Dashboard

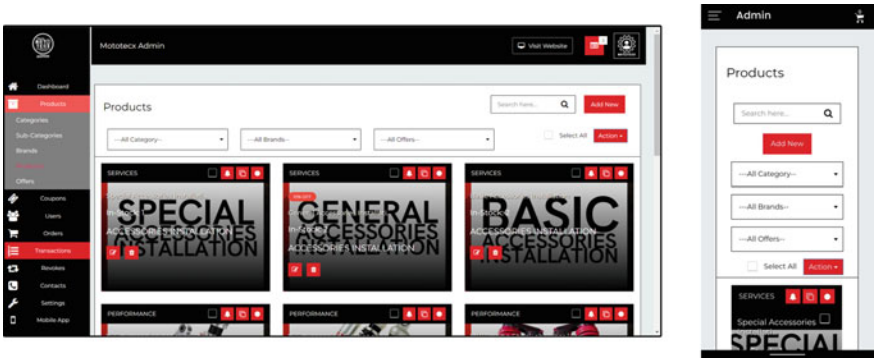


**Fig. 6** Inventory system

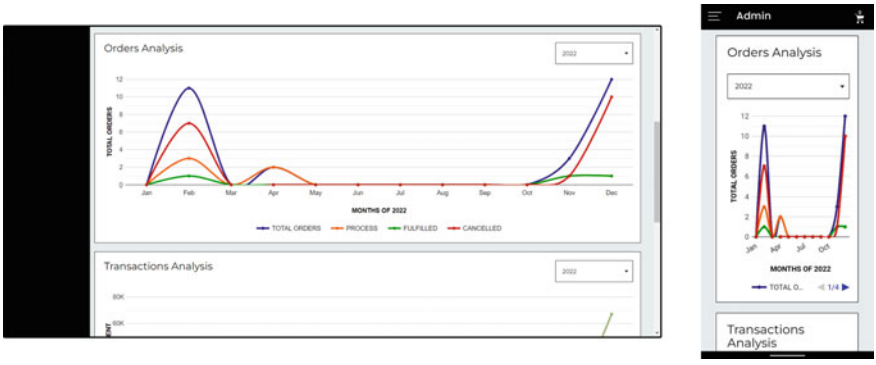


**Fig. 7** Data forecasting

**Table 2** Evaluation of the weighted mean based on the FURPS model for the online retail system with data forecasting and android mobile application

| Criteria | Weighted mean | Description |
|---|---|---|
| Functionality | 4.5 | Acceptable |
| Usability | 4.5 | Acceptable |
| Reliability | 4.5 | Acceptable |
| Performance | 4.7 | Perfectly acceptable |
| Supportability | 4.6 | Perfectly acceptable |
| Overall weighted mean | 4.6 | Perfectly acceptable |

acceptable. Performance and supportability have weighted means of 4.7 and 4.6, respectively, and both are evaluated to be perfectly acceptable. The overall weighted mean computed from the discussed criteria is 4.6, which is perfectly acceptable.

## 4 Conclusion

The online retail system with data forecasting is designed to analyze and manage sales, services, and inventory data that is integrated into a web and Android mobile application. The online retail system provided to view retail products and manage service reservations. The inventory management of the system served to manage orders, paid retails, receiving, and retail catalogs. The data forecasting system analyzed the data from paid product orders and fully paid service reservations received. It was represented through moving averages with simple linear regression and accompanied with distinguished sales trends descriptions to back up the forecast.

Based on the evaluation of the respondents, the recommendations are to include better payment gateway security and accessibility, an iOS version to increase system portability to Apple devices, and an integrated delivery system to execute product orders promptly.

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# TICaP Hub: An Event Management System for FEU Tech's Technology Innovation in Capstone Project Using DigitalOcean Droplets and Cron Jobs

**John Raymond Arriesgado, Justine Neil Calaguian, Alena Rose Golpeo, Ace C. Lagman, Miguel Bryan Pajarillo, Peter Carl Pardo, Maria Vicky S. Solomo, and Heintjie N. Vicente**

**Abstract** FEU Tech's College of Computer Studies hosts an annual event known as Technology Innovation on Capstone Project (TICaP), which exhibits the different capstone projects of each specialization. This event allows the students to view the different projects of the FEU Tech PBL students and recognizes the group with the best capstone project and other special awards. However, problems were encountered while managing the event resulting in disorganized planning and management. The proponents developed an event management system named TICaP HUB to solve the different problems experienced by the organizers in planning and managing the event. The team conducted a system evaluation and survey of the PBL and non-PBL students, including FEU Tech faculties. Using the Likert scale for the system evaluation, the Web application has an overall weighted mean of 4.72 and 4.71 for the mobile application. This outcome can be interpreted that the users strongly agreed with the FURPS evaluation of the system. With the results acquired from the respondents, the proponents conclude that using the TICaP HUB can significantly help the users efficiently manage the TICaP event and lessen the time consumed in planning and organizing for the said event.

**Keywords** TICAP HUB · Event management · Task management · Event scheduling · Project assessment · CRON jobs · Digitalocean droplets

## 1 Introduction

Events are important occasions that do not occur in day-to-day basis. On some organizations, it can occur as conferences and seminars, while it can also be a competition or tournaments if the event focuses on sports. The quality of an event depends on how the organizers manage the preparation and planning stages for the said event. Event management tools are helpful for the organizers accurately track the assets of their

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organized event. Having a dedicated management tool increases guest attendance by 20%, productivity by 27%, and profit margin by 20–30% on average [1]. Similarly, management tools need to cater the needs of an organization and an annual organizational event. For instance, FEU Institute of Technology hosts an annual event known as Technology Innovation in Capstone Project (TICaP). It is an event that enables the senior students to showcase their capstone projects among their peers and other guests. The said event needs a dedicated event management tool in order to solve some underlying problems in task distribution, insufficient event reminders, unified way to vote, and a platform to document previous TICaP.

With that in mind, the proponents developed TICaP Hub to serve as an event management system for FEU Institute of Technology's Technology Innovation in Capstone Project in order to aid on the abovementioned issues. The said event management tool will also allow the future organizers to collaborate properly on various TICaP assets. This will enable the organizers to efficiently create, plan, manage, and monitor the cumulative progress of the events held during the celebration of TICaP.

## *1.1 Objectives*

The study's major goal is to create TICaP Hub, a Web and mobile application enabling the users to easily manage, create, and oversee the overall progress of the Technology Innovation in Capstone Project (TICaP) events in FEU Institute of Technology.

In a more specific note, this study aims the following objectives:

1. To develop a Web application that has the following features:
a. Task Monitoring System
b. Event Scheduling System
c. Project Assessment System
d. Documentation Management System
e. Voting System (Election of batch officers, appointment committee heads, assignment of committee members)
2. To develop a mobile application version that will allow the PBL students to access and monitor the assigned tasks from their respective committees.
3. To provide notifications for scheduled events and meetings of the committee.
4. To generate a digital certificate for the awards and participation of the presenters and panelists that will be automatically sent to the key person's respective emails.
5. To test and assess the quality of the system in terms of its functionality, usability, reliability, portability, and security (FURPS).

## 2 Related Literature

An event is something that occurs in a particular situation which may be unusual or important [2]. Moreover, it is also described event as something that is planned and organized [2]. Hence, management is needed in order to plan a specific event. Specifically, event management is the process of planning the event [3]. It is also described as something that includes a variety of functions for executing large-scale events which might include conferences, concerts, sport matches, festivals, and ceremonies [4]. Having an event management tool will surely improve the effectivity of event management. An article entitled "Tips for Effective Events Management" enumerated the three important concepts that enable the event planners to prepare for a highly successful event. The three concepts include the law of timing, the law of space, and the law of tempo. The aforementioned concepts will be accomplished using an event management software [5]. Having an event management software will also enable real-time feedback from the key persons of an event which will enable the event organizers to perform needed adjustments as soon as possible to give the attendees a wonderful experience [6]. According to an article titled "6 Benefits of Investing in Event Management Software," the author enumerated the six benefits of event management software which includes improving engagement, automation, snapshotting, professionalism, highly targeted marketing, and holistic solution. It also points out that investing in these kinds of systems will help improve the engagement with other team members exponentially [7]. Moreover, there is a rising demand for event management in Philippines [8]. Events are also being localized since various events are being conducted outside Metro Manila. With that being said, the country is expected to have a high demand for an event project manager that can utilize all of the needed resources for the success of the event [8]. Droplets is a virtual machine that was base from Linux and runs on top of a hardware that is virtualized. Using Droplets, the system can be deployed in many ways such as through UI, CLI, API, and/or Terraform provider. It can also be scaled vertically and horizontally and offers various tools for deployment [9]. Due to its capabilities, Droplets is a great platform to deploy the event management system. Similarly, cron job is a type of command found in Linux that is utilized for scheduling tasks that need to be performed on a later time in the future. It can also be used to create a schedule for periodic tasks that needs to be executed repeatedly [10].

There is a rising growth in the event management industry in Asia. However, few degree programs are offered by the universities that are situated in the said continent [11]. Event management is a multimillion-dollar industry that is steadily growing as more shows and events are being created locally and abroad [12]. It is also important to have a standardization in managing events, and there is an opportunity for event management in Batangas due to growth of events present in the locality [12]. Event management system is also important in the development of cultural events in Bangladesh. Using the online platform, event performers were able to connect to a customer that needs their service [13]. In terms of the Web application platform, there are various specifications needed for an event management system. For one,

the management system must enable the user to create, view/read, update, and delete various events posted in the system. The various levels of user access from the Web application system must also be considered [14]. There is also a rising popularity of android as an operating system for most smartphones which can then be used to develop an event management application that could somehow improve the obstacle in using the traditional means of managing events which includes paper works, and/or long lines at the registration desk [15].

## 3 Materials and Methods

TICaP Hub is a Web-based event management tool that may be used before, during, and after a TICaP event. It is also a technological answer to TICaP's absence of a unified event execution platform. The course adviser can track the progress of each committee in their assigned duty using the task management module. Students who are members of the organizing committee, on the other hand, can report on the duties they are presently working on as well as the tasks they hope to complete in the following week. The officers of the aforementioned committee will be chosen using the voting module of the TICaP Hub. Important schedules and forthcoming events relating to TICaP will also be sent to the key persons of a TICaP event. The system will also act as a platform for panelists, guests, and students from lower year levels to examine the PBL 4 students' capstone projects and vote for their favorite project on several special awards. The panelists will have access to an evaluation module during the project presentation, where they will be able to directly evaluate the capstone projects from each group. Finally, the recipients of various special awards will receive their certificates automatically via their registered email, which will be prepared and transmitted by the TICaP Hub.

The minimum system requirements to access the Web and mobile application include at least 1.9 GHz × 86- or × 64-bit dual core processor (i3 or higher), 4 GB RAM, 128 GB hard drive storage, 14″ (1366 × 768) monitor at 60 Hz, Wi-Fi, and integrated Intel UHD Graphics. Meanwhile, software requirements includes Web browsers (Safari, Google Chrome, Mozilla Firefox, Microsoft Edge, etc.), desktop OS (Windows 7 or above), smartphone OS (Android 4.0 and above), and QR code reader/scanner. The project was conducted from January to November 2021 and is currently hosted on Digital Ocean. The following figure is the index page of TICaP Hub (Fig. 1).

## 4 Results and Discussion

The proponents of this study conducted a system evaluation to gauge TICaP Hub in terms of its FURPS (Functionality, usability, reliability, performance, and supportability) [16]. The system evaluation was participated by 51 respondents which are

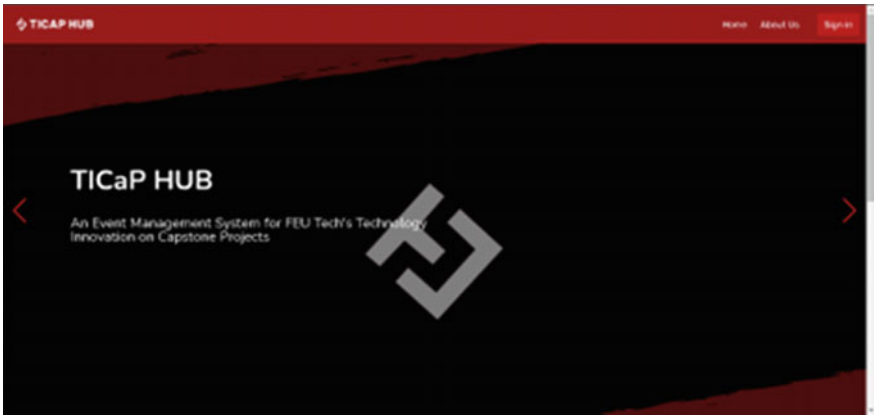


**Fig. 1** TICaP Hub general page

**Table 1** Summary of FURPS evaluation for web application

| Criteria | Weighted mean | Response description |
|---|---|---|
| Functionality | 4.74 | Strongly agree |
| Usability | 4.70 | Strongly agree |
| Reliability | 4.68 | Strongly agree |
| Performance | 4.74 | Strongly agree |
| Supportability | 4.73 | Strongly agree |
| Overall Mean | 4.72 | Strongly agree |

*Legend* Strongly Agree (4.21–5.00), Agree (3.41–4.20), Neutral (2.61–3.40), Disagree (1.81–2.60), Strongly Disagree (1.00–1.80)

composed of PBL course advisers, IT faculty, project-based learning (PBL) students, and non-PBL students. The Likert scale used includes a 5-point scale with 5 being the strongly agree and 1 being the strongly disagree (Table 1).

The table above illustrates the weighted mean obtained for the Web application based on the administered survey to the respondents, which is composed of IT professionals and non-IT professionals. As stated above, functionality and performance were the highest weighted mean, peaking at 4.74, whereas reliability got the lowest weighted mean accumulated at 4.68. Nonetheless, the overall mean for the Web application evaluation is 4.72, which directly translates to strongly agree based on the Likert scale.

In terms of functionality, the respondents strongly agree that the system contains functionalities that will enable the users to view and collaborate on an assigned task, allows the panelists to input grades, enables the system to generate QR codes for attendance and generates notifications and digital certificates. In terms of usability, the respondents strongly agree that the system has a user-friendly interface, has a clear and readable font styles, and that it has relevant color scheme. The respondents

**Table 2** Summary of weighted mean for mobile application

| Criteria | Weighted mean | Response description |
|---|---|---|
| Functionality | 4.76 | Strongly agree |
| Usability | 4.68 | Strongly agree |
| Reliability | 4.73 | Strongly agree |
| Performance | 4.70 | Strongly agree |
| Supportability | 4.70 | Strongly agree |
| Overall Mean | 4.71 | Strongly agree |

*Legend* Strongly Agree (4.21–5.00), Agree (3.41–4.20), Neutral (2.61–3.40), Disagree (1.81–2.60), Strongly Disagree (1.00–1.80)

also agree that the system includes the expected buttons on the Web site and that it includes features such as navigation bar, carousel which allows them to navigate the Web site easily. In terms of reliability, the respondents strongly agree that the system is reliable in terms of validating various user inputs, does not perform unexpected behavior during its operation, synchronizes its data across the Web application, is free from runtime errors, and delivers the data accurately. In terms of performance, the respondents are satisfied with the system's performance in terms of its speed when redirecting to various modules; response time when the user modifies their data, loading speed when data is fetched from the server, and that it saves the user input to the server accurately. In terms of supportability, the respondents have construed that the system supports the responsiveness of the screen dimension in any device, can work on any computer with a minimal RAM, uses a considerable amount of data to load the resources, supports any type of browser, and that the Web site has capability of running on different desktop operating system (Table 2).

The table above shows the weighted mean obtained for the mobile application based on the respondents' answers to the survey. The said respondents are composed of IT professionals and non-IT professionals. The system's functionality garnered the highest weighted mean, peaking at 4.76, while usability got the lowest weighted mean at 4.68. However, the overall mean for the mobile application evaluation is 4.71, which has a description of strongly agree based on the Likert scale.

In terms of functionality, the respondents confirm that the mobile application has the needed functionalities such as the working login page, ability to send and retrieve data from the cloud server, and a fully functioning task management system. In terms of usability, the respondents agreed that the fonts styles used in the mobile application are clear and readable; the UI of the mobile application is appealing and efficient, and that the color scheme used is relevant and prevents discomfort in the eyes. In terms of reliability, the respondents were able to see how reliable the system in terms of giving accurate data to the users, giving zero error during runtime, and is synchronized to the Web site. In terms of performance, the respondents are satisfied with the loading time and the efficiency of the mobile application in fetching data.

In terms of supportability, the respondents strongly agree that the mobile application can run on most android devices that are currently available in the market and can be used on various screen dimensions while also having a considerable application size.

## 5 Conclusion

The development of TICaP Hub served as a dedicated event management tool for the future TICaP events. The aforementioned system was able to provide solution to the underlying issues experienced on the past TICaP execution. Problems such as lack of task coordination, uneven distribution of tasks, and inability of the PBL Adviser to see the progress of committees were given a solution. The proponents also gauge the system by conducting FURPS evaluation to the target users of the system. After the system evaluation, the participants strongly agreed that TICaP Hub is useful for TICaP planning and was able to meet its objective.

## 6 Recommendations

Based on the information that was observed and gathered by the proponents, they believe that the system must add a functionality in the mobile application of the system that will allow the panelists to evaluate the project exhibits the same as in the Web app, add dedicated modules for the appointed committee heads in the system, improve the user interface of the existing system, and integrate different technologies that will enhance the user experience of the users in the system.

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# Theoretical Study of Security for a Software Product

**Alin-Marius Stanciu**

**Abstract** In the beginning, some of the most fundamental aspects of security, like confidentiality, integrity, and availability are presented. Then, the attacker's key motivators are mentioned. In the following parts, the focus is on the ways of designing and developing a secure software product. So, from a design point of view, the secure software development life cycle and how a security management process should take place are described in multiple phases starting from security threat and risk analysis phase to security testing phase and malware scanning. To keep track of vulnerabilities that might appear in the future, especially for 3rd party products, a security vulnerability management process should be used. Finally, some of the most common vulnerabilities and ways to assure secure code are presented in the secure development chapter. Making source code security analysis by using static/dynamic/interactive application security testing tools with manual code reviews is some important factors in assuring secure software development.

**Keywords** Software security · Confidentiality · Integrity · Availability · Secure coding guidelines · Design for security

## 1 Introduction to Product Security

Customers, regulators, and security authorities do not accept insecure products. There must be a continuous delivery of secure products and systems. In order to achieve this goal, there must be a good security awareness at all levels. People might be thinking that if they are not directly involved in product security that they should not care about it. The reality is that security risks are external and internal. In order to achieve this, everyone needs to have a basic understanding of where things might go wrong, and how hackers might take advantage of small mistakes that in many cases could easily have been avoided in the first place.

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In information security, the main security requirements are described in the CIA (confidentiality, integrity, and availability) triad security model [1].

Confidentiality assures that unauthorized disclosure of information is prevented.

Integrity stands for the correctness and reliability of a system. It applies to its hardware and software, and especially also relates to the consistency of the handled and stored data. Availability guarantees reliable access to the services provided by a system to authorized users [1].

Security should be a top priority of any software product. The security level is an important indicator that helps in order to know if the products are sufficiently secure or not. The goal is to develop products that have sufficient security level. In general, the least secure component of a systems sets the bar for the system's security level. One can expect that eventually, attackers will find the easiest way to achieve their goals.

In product security, we have to aim for "sufficiently secure" systems. Probably, many will realize that "sufficiently secure" is not the same as "perfectly secure." It might come as a surprise that perfect security is rarely the goal and is usually unrealistic when developing a system. The reason behind this is that it would become extremely expensive to create a perfectly secure system. For complex systems, it would probably even become infinitely expensive. Realistically, the security level doesn't need to be perfect. It only needs to be higher than the capability of the potential attackers.

The attacker's key motivators are either financial gain or espionage. These account for more than 93% of breaches [2]. The remaining 7% of the attacks are done for the fun of it, ideology, or grudges. There is a continuous challenge to always provide sufficiently secure products. There is an unfair battle with the attackers. It is needed to always provide sufficiently secure products by defending against potential threats and attacks. Meanwhile, the attackers would only need one weakness in the cyber-system to launch a malicious act.

## 2 Design for Security

### *2.1 Secure Software Development Life Cycle*

The software development life cycle process, or shortly SDLC, is a process used by the software industry to design, develop, and test high-quality software. The SDLC aims to produce high-quality software that meets or exceeds customer expectations, reaches competition within times and cost estimates. The SDLC is a framework defining tasks performed at each step in the software development process [3].

In SDLC, security-related activities were only conducted during the testing phase. As a result of that approach, many issues that should have been discovered and addressed earlier in the development process were identified later than they should have been. Some issues were not detected at all.

The concept of secure SDLC aims to ensure that security-related activities are an integral part of the development process. It defines its own phases that run in parallel with SDLC phases: governance, design, implementation, verification, and operations. They may include, but are not limited to, architectural and design analysis from security perspective, risk analysis, security review, code reviews, and security testing as an integral part of the process [4].

Building secure software is not only the responsibility of software engineers or personnel working in product security, but also the responsibilities of all the stakeholders in the SDLC which include management, project managers, business analysts, quality assurance managers, technical architects, security specialists, application owners.

Secure SDLC is set up by adding security-related activities to an existing development process, for example, writing security requirements alongside the collection of functional requirements, or performing an architecture risk analysis during the design phase of the SDLC. Secure SDLC is not a new concept; many companies and governmental institutions have also seen benefits of secure SDLC process and implemented their own versions in the past. Those versions should constantly get improved. When we discuss security processes for the software products, we can distinguish between proactive and reactive approach. They are equally important. Secure SDLC is part of the proactive approach.

Proactive approach is used to build up security from the start of the process, while reactive approach, security vulnerability management, is necessary when certain threats are detected after the product is already offered on the market, and they need to be addressed. Or, if they were unknown of undetected during the proactive process phases.

## *2.2 Security Management Process*

The design for security (DFSEC) process should consist, in general, of the following phases:

- Security threat and risk analysis where we identify, analyze, and classify threats and risks.
- Privacy threshold and impact assessment to identify privacy threats and risk, possible safeguarding controls and countermeasures, scheduled monitoring activities and residual risks.
- Security and privacy requirements management where security and privacy requirements are composed using baseline requirements and threat and risk analysis as a basis.
- Security architecture specification in which are defined high-level description of how product or systems meets the security and privacy requirements.
- Implementation phase aiming to design the product following the best practices, implement the product following the best secure coding practices, and tightening

the product (removing unused libraries, patching the product, and limiting network access, performing security hardening).
- Security testing and malware scanning where the product and system are tested against the security requirements to known and unknown security vulnerabilities and scan the product prior to publishing to ensure it is not malware infected.
- Lastly, it is needed to be prepared a DFSEC compliancy statement. Statement of compliancy assessment records level of compliancy [4] to DFSEC activities and baseline requirements.

During feature screening, it is important to identify what threats and risks may exist for a product or may evolve from the implementation of new features. Two phases of DFSEC are in focus during the feature screening.

**Security threat and risk analysis** phase is one of the first activities of DFSEC. All products undergo a detailed threat analysis using a structured, top-down process for analyzing exposure of critical asses against a set of applicable threats taking into account the deployment environment and attack vectors. The result is a set of potential weaknesses, prioritized by risk. Potential countermeasures are then identified and prioritized [5].

**The Privacy Threshold and Impact Assessment** phase is about creating an inventory of personal data used in the product and then identifying privacy threats and risks. Threats and risks are then analyzed and prioritized, and possible safeguarding controls and countermeasures are defined for them [6].

In system design, the output from the security threat & risk analysis is used as input for defining security and privacy requirements on how to mitigate the identified critical threats and risks by system design. In system design, the focus is on two phases:

- **Security and privacy requirements** are composed using the threat & risk analysis as a basis and then combining it together with the baseline requirements. Baseline requirements are requirements that meet the market expectations and are best practices to mitigate security weaknesses and are defined in the product security and product privacy baseline documents. Security requirements define the essential controls that must be implemented to protect the product or system [7, 8].
- System design yields the **Product Security Architecture Specification** as part of DFSEC. The product security architecture specification handles all the security and privacy-related aspects for applications, and platforms, like user security and privacy-respecting operations, communication matrix, traffic separation, protocol, data security, and software security [8, 9].

In software development, in addition to the developed software, also, 3rd party software, be it commercial or open-source software, is used. At beginning of the software development, it is defined which 3rd party software, for example, operating system, protocol stacks, and databases, will be used in the product. For this software components, it is necessary to know if and which security vulnerabilities they have,

which are fixed from previous releases. The following phases of DFSEC are part of software development:

- **The software Design** phase should follow the best practices as documented in the product security policy and by using security design patterns. The design should also be privacy-respecting as specified in the product privacy policy and guideline document.
- **The secure coding** phase is about following the best practices and security coding guidelines while implementing the software. Most software bugs are caused by mistakes in either the program source code or its design. There are guidelines available for C, C++, Java programming languages, and Web applications. For checking the quality, static code analyzing tools are strongly recommended.
- **Security hardening** phase which consists of activities to "harden" or "tighten" the product, to protect against security threats. Hardening activities will include all the system components, for example, operating system, services, middleware, databases. Additionally, unused libraries are being removed; unused services are deactivated, and network access is limited by closing all unused ports. All this is done to reduce potential attack vectors. All hardening activities must be documented in the hardening specification.

In the integration and verification phase, the product or system must be tested against the security requirements and known or unknown security vulnerabilities. The following phases of DFSEC are relevant for integration and verification:

- **Security testing** checks if security vulnerabilities are still existing. It can also include port scanning, Web application vulnerability scanning, robustness testing, and (distributed) denial of service testing. All tests performed during security testing phase must documented, and the result reports should be based on the modular test report templates [10].
- **Malware scanning** during which the product image is scanned prior to publishing to ensure it is not malware infected.

## 3 Security Vulnerability Management

In addition to the DFSEC, which is a proactive process, security vulnerability management (SVM) is a reactive approach, and it keeps products secure during their whole lifetime. Assisting the normal maintenance process, SVM provides information about security vulnerabilities and available patches for the used 3rd party products. The SVM process provides product lines information about known vulnerabilities in their products. By registering all the used 3rd party components to some SVM tool, the R&Ds will receive notifications whenever there is a new vulnerability in any of the components they use. By registering the used component, SVM assures that all the relevant vulnerability information is available to the R&Ds. This also helps to avoid information overload by filtering all the vulnerability information that is not

relevant for a particular product. All SVM-related actions should be documented in the SVM tool [11–13].

In our current connected world, there are many vulnerabilities that arise every day. This vulnerability information gets scanned and filtered. Such examples are related to database, Web-server products, protocols, cloud technology, and virtualization. All the vulnerability notifications are stored in a central tool of SVM. In the SVM tool, it maintains a knowledge database that contains up-to-date information about security vulnerabilities detected in the products, in free and open-source software, and 3rd party software used in them. The SVM database contains all product and solution-specific information as a result of the vulnerability and countermeasure assessment, so the product security community gets information for the vulnerabilities relevant to their product line.

Several independent approaches to identify, estimate, and prioritize information security risks make it difficult and confusing to compare their results. Because of this reason, the industry was looking for an open framework to determine and communicate common risk factors and the severity of a security vulnerability. Also, to use a common algorithm to leverage a common vulnerability management policy that defines a maximum allowable time to validate and respond to a vulnerability should be a top priority for the industry. There is also the need to provide contextual risk information to better understand the risk of a vulnerability for a specific organization. To answer these challenges, the organization FIRST offers the common vulnerability scoring system (CVSS) [14]. The CVSS assesses the security vulnerabilities of the product or system, and then returns a score reflecting the severity of each vulnerability [14, 15]. Some of CVSS characteristics are as follows:

- It is a quantitative methodology that returns a risk score between 0 and 10, making it easy to understand the severity of the risk [14].
- It is adopted by major vendors all over the world [14].
- It becomes the fundamental part of the SVM tool, especially to identify, estimate, and prioritize information security risks.
- It is also part of the vulnerability information in vulnerability databases, as the National Vulnerability Database (NVD) and the Common Vulnerability and Exposure (CVE) [16].

The CVSS methodology consists of metrics, score, and vector. CVSS uses a variety of metrics to calculate the risk of a vulnerability. To structure the assessments, these metrics are organized in 3 metrics groups, and they are as follows: base, temporal, and environmental. The temporal and environmental metrics groups are optional. From each of the metrics group, a CVSS score is derived. The higher the score, the higher is the severity. The CVSS vector is a cryptic description of the involved metrics and values and is used to communicated details of the risk assessment to other stakeholders [14].

## 4 Secure Development

Developers need to ensure that the code they create and maintain does not contain potential attack vectors. Secure software development can be understood as the effort to create code in a defensive manner, aiming to avoid mistakes that could possibly lead to an exploitable vulnerability or help an attacker in any way.

Also, the code needs to be "hardened." A good analogy for security hardening is removing undesired features from a castle to ensure that attacker have a hard time getting in. Within this analogy, one can understand secure coding as ensuring that the material of the castle and its features are built of, are strong and of high quality. When a castle is made of low-quality bricks or even sand instead of solid stone, it wouldn't be hard for an attacker to get in.

Secure code is robust, so it has to issues coping graciously with unexpected events and abnormal input. One of the worst security vulnerabilities of a product could be the possibility to crash with unexpected protocol input. A good real-life example of a vulnerability like this is the legendary "Ping of Death" denial of service vulnerability from the 1990s. There TCP/IP implementations crashed when receiving a "ping" message larger then specified [17].

Typical security mistakes in coding can cause critical weaknesses in software that can lead to serious vulnerabilities. These weaknesses are often easy to find and exploit. They are dangerous because they will frequently allow attackers to completely take over execution of software, steal data, or prevent the software from working as intended.

Some of the most common vulnerabilities are as follows:

- Injection vulnerabilities (SQL, OS commands, etc.).
- Buffer overflow or underflow.
- Missing or weak authentication or authorization.
- Lacking input validation and reliance on untrusted inputs.
- Use of external code without integrity checks.
- Use of broken, weak, or custom algorithms (encryption/hashing).
- Hard-coded secrets.
- Lack of proper error handling.
- Path traversal.
- Web application vulnerabilities (XSS, CSRF, etc.).

A small, simple vulnerability can cause lots of problems and significant damage. Some of the most important basic principles and secure coding rules that should be followed are as follows:

- Security by obscurity—it is not an option. Always consider the source code as being publicly available.
- Common security pitfalls—familiarize with the common security flaws caused by special characteristics of the used programming language and avoid them.
- Known vulnerabilities—ensure that used constructs, functions, and libraries are not known to cause security vulnerabilities.

- Unvalidated external input—all external input must be validated. Allow only data with expected content to enter the system.
- All available security measures—use all security measures provided by the used programming language and frameworks.
- Failing securely—do not disclose any data that would not be disclosed ordinarily even when something unexpected happens during runtime.
- Least possible privileges—make sure that only the least possible privileges are being able to fulfill the intended task are granted.
- Expecting the unexpecting—ensure that it is always checked for even extremely unlikely security critical events.
- Readable code—write code that has a homogeneous style throughout the whole project is reasonably commented, easy to read thus unambiguous and maintainable.
- Regular security review, quality assurance and testing throughout development—to ensure that the end result really is secure, it is important to perform regular security reviews, quality assurance, and testing throughout the development process.

## *4.1 Code Security Review Methods*

A secure core review is a specialized task involving manual and/or automated review of an application's source code in an attempt to identify security-related weaknesses (flaws) in the code. Code security review methods should be used throughout the development process and not just at the end of the development process [18].

Source code security analysis (SCSA) improves product security by finding vulnerabilities during development. The main methods of SCSA are manual code review and using an automated static application security testing (SAST) tool. SAST tools complement manual review of code and can greatly accelerated detection of software defects early in the software development cycle. As with manual code reviews, SAST identifies programming errors, hardening deficiencies, and poor coding practices. SAST tools provide the benefits of more complete code coverage, integrated software and vulnerability expertise, and a rich set of quality metrics [19] Some key points for code security review are as follows:

- Static and dynamic code analysis.
- Identifying vulnerabilities earlier in the life cycle.
- Manual code reviews and inspections.
- Secure coding guidelines continuously reviewed and updated.

SAST is traditionally augmented with dynamic application security testing (DAST), also known as penetration testing. This black box testing subjects the application to known attacks over interfaces and notes the output for indications of problems. It can also produce missed vulnerabilities and false positives. Because of the black box testing, the tool cannot report the source code lines which need

attention. It will only report the input and output messages. DAST tools automate security tests for a variety of real-world threats and may be part of the security testing (integration and verification) or continuous integration pipeline. Manual testing aims to the same with more advanced methods [20].

Recently, a new technology called interactive application security testing (IAST) has been introduced which combines SAST with penetration testing. IAST uses detailed internal application state monitoring to correlate with penetration testing attacks. This results in a vulnerability overview without time wasting false positives. In addition to that, exact source code line locations are identified where the fix for certain vulnerability should be applied [21, 22]. These dynamic approaches have limited visibility as they typically do no evaluate the source code. However, tools such as IAST and approaches as a combination of penetration testing and source code reviews can achieve combined benefits of static and dynamic approaches.

## 5 Conclusions

When building an application, there are a lot of things to consider. Every security decision should start from the design of the application. What security measures should depend on multiple factors as the use case of the application or the size of the application. As the product gets bigger, more steps are required for ensuring security. These is no perfect recipe for obtaining perfect security, but combined solutions should minimize the chance of a successful attack. Multiple solutions for ensuring security for the entire life cycle of an increasing software product, starting from designing the product to developing and maintaining the product were presented in this paper. As the product gets bigger and more complicated, there is a need for more advanced solutions for ensuring the security. So, by this means, security management process and security vulnerability management process were presented.

This paper can be taken as a small guideline and resource for increasing the knowledge and awareness of information security. There are a lot of topics that have not been covered, including topics that dive into the depths of information security. The security principles from this paper can be applied to real-world software.

The security principles and guidelines should be taken into considerations because we live in a society that has become more and more reliant of software services, and if those are compromised, there can be a huge impact on society, starting from huge economic collapse to even a fully system failure that can cause great chaos on our planet. So, when developing a highly critical, important application not only every step and process from this paper should be applied, but also the best security practices available.

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# An Efficient Workload Distribution Mechanism for Tightly Coupled Heterogeneous Hardware

**Ernesto Rivera-Alvarado and Francisco J. Torres-Rojas**

**Abstract** The Accelerated Processing Units (APUs) are tightly integrated heterogeneous computing platforms that contain a CPU and GPU in a single integrated circuit. As their internal computing resources use the same memory (RAM), they can efficiently share data structures. This opens up the opportunity for creating new types of specialized algorithms for the APU. In this research, we designed a specialized load distribution mechanism for the APU and used image rendering as our test load as it is a highly expensive computational task. We found out that our workload distribution mechanism provides better performance than conventional workload mechanisms for GPUs and multicore CPUs.

**Keywords** Image rendering · System-on-chip · APU · Tightly coupled heterogeneous hardware · Heterogeneous computing · Workload distribution · Computer architecture · SoC

## 1 Introduction

The Accelerating Processing Unit (APU) is a system-on-chip (SoC) that was born in 2011 [6]. This device is a heterogeneous computing platform that contains a GPU and CPU in the same integrated circuit. Both processors share the same Random Access Memory. This shared memory characteristic provides their internal computing units with the possibility of sharing data structures very efficiently [6]. The opportunity of creating specially crafted mechanisms that uses specific architectural features of this system-on-chip (SoC) can be generated for performance evaluation well-known workloads [6]. Several researchers have identified the opportunity to explore and evaluate the performance of these SoCs in workloads where GPUs have poor performance, like applications that require a lot of memory transfer operations with the CPU, or when the task is highly sequential [6].

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Computational expensive tasks like image rendering are ideal for evaluating the performance of different computing platforms [3, 9]. Several reasons limit realistic image rendering in conventional processing architectures. Some of them are:

- Frequent PCI-Express memory transfers become a bottleneck in applications that require a lot of memory transactions [6].
- Discrete GPU and CPU systems don't have memory coherence or a way to share data structures in an efficient manner [5].
- GPUs don't perform well in tasks that have several branches, sequential code, a high number of memory accesses, or recursion (photo-realistic image rendering is naturally recursive) [3, 4].

In this research, we created a load distribution mechanism for the internal compute units of the APU. We tested our implementation with a realistic image rendering algorithm (ray-tracing) and compared it's performance against the CPU and GPU architectures when processing the same task to check if the APU is a viable architecture for accelerating computationally intensive workloads through heterogeneous computing.

Section 2 presents a summary of the different approaches that have been done to improve the ray-tracing performance. Our proposed workload distribution can be found in Sect. 3. The experiments, analysis method, and hardware used are shown in Sect. 4. The obtained results from our tests are presented in Sect. 5. Analysis and discussion of the obtained results are found in Sect. 6. Finally, our conclusions and future venues can be found in Sect. 7.

## 2 Background

CPUs (Central Processing Units) are the dominant processors for general-purpose computing. This system's complexity and processing power have increased as they incorporate in the specialized silicon circuitry for specific computational tasks like video and multimedia decoding [8]. Nonetheless, there is a wide range of functions were the CPUs don't perform well like when the task at hand involves the processing of vast amount of mathematical operations, or the job is highly parallelizable beyond the number of available cores that the architecture has [3].

Rendering highly realistic images is an example where CPU performance is poor. This task is highly parallel (beyond the number that commercial CPUs have), and requires a lot of computational power for mathematical calculations. Specialized graphics hardware was developed to overcome the limitations of CPUs while rendering images. This dedicated hardware becomes what we currently know as GPUs (Graphics Processing Units). These systems included a vast amount of small cores optimized for mathematical operations needed in image rendering [14]. The acceleration in rendering time provided by GPUs made them the default architecture for image rendering and videogames [14].

General-purpose computing on graphics processing units (GPGPU) is a term coined for the use of a GPU (which are designed for computer graphics) for computing tasks that are typically processed by using a CPU [6]. Their use as general-purpose processing devices has improved the performance of many computation heavy jobs like the ones found in scientific research, bioinformatics, weather simulations, and AI [3]. The GPU has become the goto architecture for several tasks that require large amounts of parallelization and calculations [6].

Nonetheless, there is a wide range of applications where GPUs don't perform well, like tasks that require a lot of communication with the CPU and memory transactions to RAM. The reason for the bad performance is the PCI-Express bus, which becomes a bottleneck when a lot of transfers to the GPU are required [6]. Currently, there aren't widely available mechanisms for sharing memory objects between the CPU and GPU memories [6]. Also, depending on the nature of the task, it will not perform well in a GPU. For instance, intrinsically serial applications, with many conditional statements, have recursive functions or uses memory pointers [3, 4].

Some research has directly pointed that persistent memory transactions are the main hitter factor for the degradation of GPU performance in some tasks [16], so new mechanisms for improving the performance of the GPUs in this kind of jobs are being explored.

## 3 Design

We designed a workload distribution mechanism specially crafted for SoCs that contain a GPU and CPU in the same integrated circuit. Hardware that complies with these characteristics is being used broadly in consumer electronics as a low-cost processing solution [6]. Our solution uses all internal computing capable resources of this SoCs. Tightly coupled systems like the APU has the capability of efficiently sharing data structures within its internal computing units [6]. We vastly took advantage of this feature, so both the integrated CPU and GPU use the same memory objects in our solution.

The implementation uses the C programming language [13] to distribute and process work in the internal CPU and OpenCL for the internal GPU. The design makes both internal units use the same data structures to avoid memory transaction performance impact. Our design avoids memory latency problems present in discrete GPUs by using the APU's memory sharing capability; this means both the internal CPU and GPU uses and share the same memory objects stored in RAM.

Our crafted workload distribution mechanism is shown in Fig. 1. First, the complete task is divided into work units of the same size. In the CPU side of the SoC, a thread is created for each of the logic cores. Each core will take a work unit, process it, save the result, and check if there are more work units available; if not, the thread finishes. Since the GPU has many compute cores, larger work units used for the CPU are needed [1] to maximize utilization. The load size that the GPU takes is given by the number of compute cores that the GPU has, so in this case, it will take a work unit

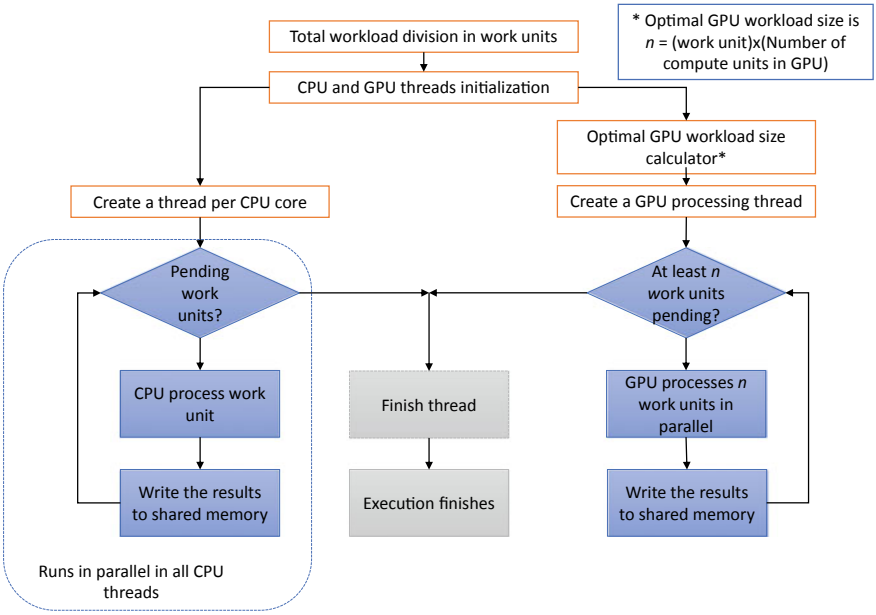



**Fig. 1** Proposed workload distribution mechanism for tightly coupled heterogeneous computing hardware

for each GPU compute core. The GPU operates with only one thread that uses this amount of work, once that processing is finished, saves the result, and it checks if there is at least "a number of compute cores in the GPU" work units available, if there aren't, the GPU thread finishes and the remaining work is performed by the CPU threads. It's important to mention that in all this process, the GPU and CPU share the same memory, and thus, the same memory objects, which improves performance since it avoids memory transactions that negatively impacts the execution time of a task [6].

To make the comparison as fair as possible the integrated CPU of the APU and the discrete CPU used for the experiment uses exactly the same C code for rendering. Similarly, the integrated GPU of the APU and the discrete GPU uses the same OpenCL routine. In this way we eliminate language and implementation differences between the architectures to precisely evaluate our workload distribution mechanism.

## 4 Methodology

We decided to use a factorial **Analysis of Variance** (ANOVA) experiment as it allowed us to measure the impact that the research factors that we defined for this experiment have on performance [7], which is our response variable.

Factors are chosen as inputs that could affect in one way or another, the response variable [7]. With the ANOVA tool, we can determine if the selected factors impact rendering time has statistical validity.

For the research, we used the following factors and levels:

- **Objects**: The amount of objects directly impacts rendering time as the scene is more complex [9]. The following amounts were used: 4000, 16,000, 65,000 and 260,000.
- **Anti-aliasing effect**: Anti-aliasing directly impacts rendering time as it increases the number of collisions detected [9]. The following two levels were used for the experiment: No anti-aliasing, with anti-aliasing.
- **Architecture**: This is the defining factor for testing our work distribution method to improve performance. The experiments ran in the following architectures: GPU, APU and CPU.

The total possible combinations of the defined factors and their levels are $4 \times 2 \times 3 \times 3 = 24$. We ran each combination 15 to increase the ANOVA analysis accuracy [7]. So in total, we performed $24 \times 15 = 360$ runs of the experiment.

All the equipment where we ran the experiments had 16 GB of dual channel RAM at 3200 MHz, 512 GB SSD storage with stock cooling. For the computing platforms, we used an Nvidia GeForce 1660Ti with 6 GB VRAM as the GPU, an AMD Ryzen 3600x (6 cores/12 threads) as the CPU, and an AMD Ryzen 4600G (6 cores/12 threads with an integrated GPU) as the APU. Despite the naming convention difference between the CPU and APU (3000 series and 4000 series), both share the same underlying CPU core architecture regarded as AMD Zen 2. The retail prices of the three computing platforms is $270 for the GPU, $250 for the CPU and $200 for the APU.

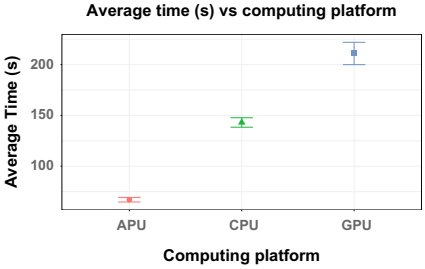
This research differs from the approach taken in [11] as they proposed using the APU for computationally expensive tasks. It is also different from [12] as they focus on improving the performance of the ray tracing algorithm's BVH acceleration structure. Finally, it differs from [10] as they compare the performance of basic and advanced ray tracing features in APUs.

## 5 Results

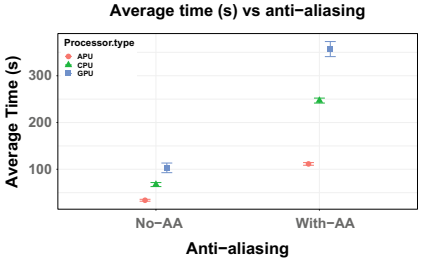
The results obtained through the ANOVA showed that all the selected factors and their interactions have an impact on rendering time [15], as seen in Fig. 2. Figure 3 contains the average rendering time in all the analyzed scenarios where lower scores (rendering time) mean better performance and the whiskers represent the standard error. The description of each scenario is contained within the legend of each picture.

| | Sum Sq | Df | F value | Pr(>F) |
|---|---|---|---|---|
| | <dbl> | <dbl> | <dbl> | <dbl> |
| Processor.type | 55.7435562 | 2 | 373.6746528 | 3.836092e-86 |
| Objects | 432.9288204 | 3 | 1934.7471135 | 1.458062e-211 |
| Anti.aliasing | 178.8350208 | 1 | 2397.6265195 | 5.242794e-155 |
| Processor.type:Objects | 17.4806848 | 6 | 39.0603523 | 6.079011e-36 |
| Processor.type:Anti.aliasing | 0.4830103 | 2 | 3.2378398 | 4.047650e-02 |
| Objects:Anti.aliasing | 3.9559261 | 3 | 17.6789261 | 1.116507e-10 |
| Processor.type:Objects:Anti.aliasing | 0.3585694 | 6 | 0.8012185 | 5.695039e-01 |
| Residuals | 25.0616877 | 336 | NA | NA |

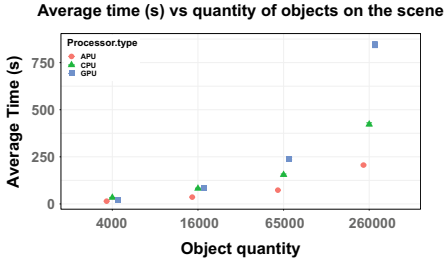
**Fig. 2** ANOVA table for the executed experiment




(a) Average rendering time per computing platform.




(b) Average rendering time in function of anti-aliasing




(c) Average rendering time per object quantity.

**Fig. 3** Average rendering times—architecture versus each other main factor

Post-hoc analysis was conducted using the pairwise t-test to determine the statistically different scenarios. The study concluded that the averages between the CPU, GPU, and APU architectures are statistically different, as well as the averages of the architectures when the anti-aliasing factor is present or when the object quantity is 65,000 or more.

Figure 4 displays an example of the output image generated from our experiments with 16,000 objects in the rendered scene.

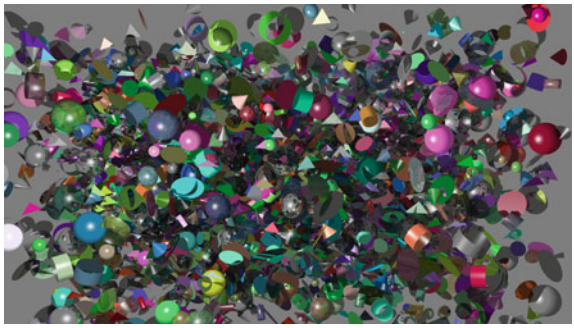


**Fig. 4** Example output image with 16,000 objects

## 6 Discussion

With the ANOVA analysis, we can conclude that the factors and their interactions impact the response variable with statistical significance. This allows us to conclude from Fig. 3a and post-hoc analysis that our proposed workload distribution mechanism for the APU is statistically better than the GPU and CPU architectures in rendering time.

The analysis from our tests showed:

- Anti-aliasing increases rendering time as it increments the amount of mathematical operations due to the generation of secondary rays. Figure 3b shows that our workload distribution mechanism for the APU performs better that the CPU and the GPU when anti-aliasing is present, which is the most computationally intensive scenario.
- Memory accesses and mathematical computations increase as there are more objects in the scene. Again, Fig. 3c shows that our workload distribution mechanism for the APU performs better than the other computing platforms in the most complicated scenario with 260,000 objects. One of the APU's main advantages is that its internal units can easily share memory objects, without the need for PCI-Express bus transactions [2].
- The post-hoc analysis showed that the APU advantage becomes significant in the most complicated scenarios with anti-aliasing present and the most object quantity in the scene, while for simple scenarios there is no statistical difference.

Our research points out that our workload distribution mechanism for the APU provides an average performance gain above 58% compared to the classic load distribution mechanisms used for the other two computing platforms.

## 7 Conclusions and Future Venues

We created a workload distribution mechanism for the tightly coupled heterogeneous architecture known as the APU in this work. The results obtained from the experiments show the potential of accelerating computationally intensive applications through APU's and our design. To increase performance, we took advantage of the APU's internal characteristics, like its ability to share memory objects within its internal units and its efficient work coordination mechanisms.

In the future, we would like to perform these experiments in newer hardware to check and analyze if the results hold. We would also like to apply this workload distribution mechanism for other applications besides image rendering. Finally, we would like to optimize the code that ran in the CPU and GPU as it is the same that the APU used in its internal units to verify its impact on all platform's comparative performance.

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# Towards an Intelligent Electric Wheelchair: Computer Vision Module

**Jesus Gerardo Torres-Vega, Juan C. Cuevas-Tello, Cesar Puente, Jose Nunez-Varela, and Carlos Soubervielle-Montalvo**

**Abstract** Handicapped people represent fifteen percent of the world population. Autonomy is one of the key things that disabled people seek to have. Intelligent wheelchairs could contribute to people's autonomy by removing assistance needs and performing tasks such as autonomous navigation, real-time object detection and obstacle avoidance. The present work proposes a new intelligent electric wheelchair architecture, and then focuses only on the computer vision module. To test this module, a new dataset was created with twenty different classes, using three different vendor cameras at the same location with the same illumination conditions. We employ YOLOv4, a real-time object detector based on CNNs, installed into an embedded system, the LattePanda Alpha 864s minicomputer. Mean average precision was the metric used to evaluate the performance, in terms of localization and classification of objects. The iDS camera, an RGB color format and high-resolution images, demonstrated to have the best performance.

**Keywords** Wheelchairs · Autonomous driving · Convolutional neural networks · YOLOv4 · Mean average precision · Embedded system

## 1 Introduction

There are more than 1000 million disabled people in the world, representing the 15% of the world population; from this, almost 190 million need assistance services frequently [1]. According to the 2020 population and housing census, there are around 6,179,890 disabled people living in Mexico, representing 4.9% of the entire population in the country [1]. Of this population, the 48% exhibits difficulties in walking, moving, go up or down stairs, requiring assistance from a third party, a wheelchair, a walker, or any kind of artificial device. The assistance requirements for elderly

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people or disabled persons have a direct impact into their autonomy, restricting them to perform simple tasks such as moving from a room to another. Mobility limitations are the most frequent disabilities in Mexico [1].

An autonomous driving system, such as an intelligent electric wheelchair, is an alternative for handicapped people that could contribute to give them back most of their autonomy by allowing them to move with no assistance from other people. Intelligent electric wheelchairs are expected to perform autonomous navigation, following predefined or real-time trajectories, by means of non-mechanical commands from the user. Autonomous navigation requires real-time object recognition to identify obstacles in the wheelchair's trajectory. Also, computer vision could help handicapped persons to find objects such as medicines, medical devices, food or any other important objects in an indoor environment. Some solutions have been proposed using convolutional neural networks (CNNs), user's gaze images, voice commands and environment images as data input, performing better in outdoor environments and exploring without taking care of objects around the wheelchair or along the trajectory [2, 3]. These projects have demonstrated that sensing the environment through cameras, CNNs and object detectors [4] shows a better performance in computer vision tasks for object recognition and navigation when automating wheelchairs [2, 5].

This paper proposes a new architecture for an intelligent electric wheelchair that is capable to perform autonomous navigation in an indoor environment, being aware of obstacles around it. Within the architecture, the computer vision module, together with other modules, is in charge of detecting obstacles, navigate without collide and also identify objects of interest to the person. This research focuses on the computer vision module, where a comparison among three different vendor cameras is presented using You Only Look Once v4 (YOLOv4). We use the mean average precision (mAP) metric in order to evaluate the performance of the object detection task in terms of localization and classification.

The paper is organized as follows: Sect. 2 presents the current state of the art. Section 3 covers the general architecture and the computer vision module. Section 4 presents the YOLOv4 architecture. Section 5 describes the experimental setup. Section 6 contains the results, and Sect. 7 presents the conclusions and future work.

## 2 State of the Art for Intelligent Electric Wheelchairs with Computer Vision

There are many approaches for autonomous vehicles using different techniques. This paper involves deep learning techniques for autonomous driving using cameras. For this reason, this work presents only a state-of-the-art study that includes projects related to intelligent electric wheelchairs using deep learning.

Table 1 summarizes the comparison of the related work. Through this table, one can identify several attributes of the proposed solutions: (i) if the study captures pictures from the environment (images); (ii) the performing environment, i.e., either

**Table 1** Summary of the state of the art. Intelligent electric wheelchairs with deep learning and computer vision tasks

| Year | Images | Type | HW | Recognition | Obstacle avoidance | Measures performance | Refs. |
|---|---|---|---|---|---|---|---|
| 2020 | ✘ | Indoor | ✘ | ✘ | ✔ | ✔ | [2] |
| 2020 | ✘ | Indoor | ✔ | ✘ | ✘ | ✔ | [6] |
| 2020 | ✔ | Outdoor | ✘ | ✔ | ✘ | ✔ | [5] |
| 2020 | ✘ | Outdoor | ✔ | ✘ | ✘ | ✘ | [7] |
| 2019 | ✔ | Outdoor | ✘ | ✔ | ✘ | ✔ | [3] |
| 2017 | ✔ | Outdoor | ✘ | ✔ | ✘ | ✘ | [8] |

outdoor or indoor; (iii) if the study involves embedded systems because an electric wheelchair is an autonomous vehicle that requires specific HW; (iv) if the study contains modules for object recognition or image classification; (v) if the study implements obstacle avoidance techniques; (vi) if it measures the performance with formal metrics. Finally, we highlight that only one work implements obstacle avoidance through ultrasonic sensors. Few research projects have developed systems capable of performing object recognition in an indoor environment. Also, few of the projects found implement embedded systems (HW) capable of performing all the required tasks. Therefore, the opportunity areas detected are related to indoor environments, embedded system platforms, object recognition and obstacle avoidance.

## 3 Intelligent Electric Wheelchair Architecture

In Fig. 1 is the proposed architecture for an intelligent electric wheelchair, where all the modules communicate among them. The description of each module is as follows:

*Intelligent System*. This is the main module where all the decisions are taken. The input to the main module depends on the needs of disabled persons: (i) a touch screen, (ii) voice commands, (iii) brain data (i.e., EMOTIV EPOC), (iv) web interface, etc. It also receives the information from the navigation and computer vision modules, and it sends the instructions to the joystick controller.

*Navigation*. This module involves all related to localization of the wheelchair that is origin and destination points. At the first stage, the wheelchair will move in a controlled space. The next stage is that the wheelchair can learn the environment. Undergoing research involves reinforcement learning, so the wheelchair can adapt and create the navigation map by itself. Our goal is to use only cameras as sensors because current technology provides stereo depth, collision avoidance and positional tracking, e.g., Intel RealSense [9].

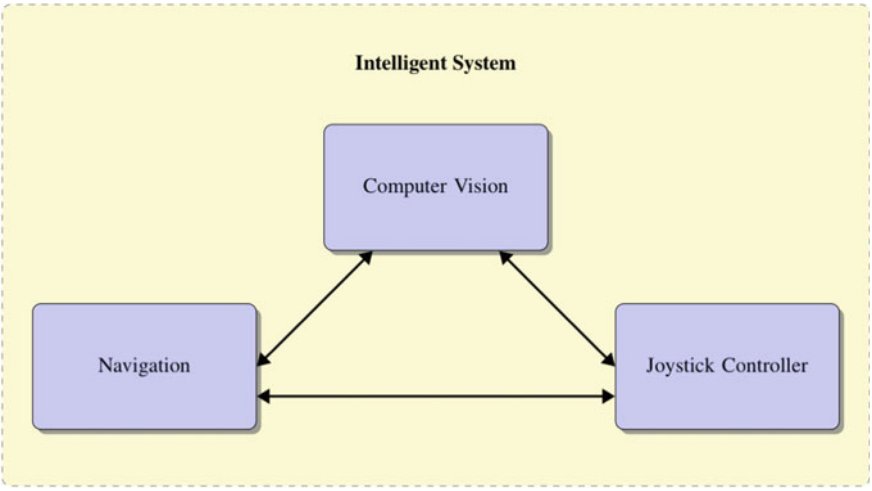


**Fig. 1** Architecture of an intelligent electric wheelchair

*Joystick Controller*. This module means automatizing the joystick by adapting servo motors, so it can be controlled automatically; see [2]. This module is also called the embedded system or hardware system. It receives the movement instructions from the main module. And it also receives information from the navigation and computer vision modules because the navigation map and the obstacle avoidance information are obtained through these modules.

*Computer Vision*. This module is the main topic of this paper. It requires a camera in order to obtain all the information about the environment. The camera will be located in front of the wheelchair. This module has the restriction that all algorithms must run on an embedded system where the hardware resources are limited, compared to a personal computer or a workstation. Additionally, the image processing must be in real time. The following sections explain the undergoing research, experiments and the future work.

## 4 Computer Vision Module

The main task of this module is to identify objects in the environment through the images obtained from a camera. Depending of the selected camera, this module can also help to the navigation module if the camera provides stereo vision, where the depth of objects could be obtained.

YOLO is one of the state-of-the-art object detectors based on CNNs, because it is one of the most accurate (Average Precision 10% higher) and fast (FPS 12% higher) [4]. We use the fourth version of YOLO, known as YOLOv4, with the fol-

lowing architecture [4]: (i) *Backbone*: Named as CSPDarknet53, is an architecture that contains 29 convolutional layers $3 \times 3$, a $725 \times 725$ receptive field and 27.6 M parameters. This architecture shows a good performance with MS COCO dataset. (ii)*Neck*: Spatial Pyramid Pooling network (SPP-net) and Path Aggregation Network (PANet) [4]. (iii) *Head*: Same head architecture used in YOLOv3.

## 5 Experimental Setup

In this section, we describe the different cameras under study, the dataset and the metric used to evaluate the performance of our computer vision module.

**Cameras Description**. There are many factors that have a direct impact on the performance of the object detector, such factors include the image resolution, color formats, environmental conditions. Through this paper, we analyze three different cameras: (i) *Common Webcam* from the brand perfect choice was selected for this study because the low cost, availability and similarity in characteristics to other cameras; (ii) *iDS Camera*, Model UI-1240SE-C-HQ developed by IDS Imaging Development Systems with CMOS color sensor and 8-bit depth RGB camera [10]; (iii) *Intel RealSense T265 Camera* is based on a fusion of visual and inertial sensors, used in robotics, drones and virtual reality [9]. The tracking camera has two "fisheye" lenses, an Inertial Measurement Unit (IMU) module and an Intel-own ASIC processor for parallel processing.

**Embedded System Design Platforms**. The wheelchair can be seen as an autonomous vehicle, so embedded system design platforms are needed in the processing stage. None of the projects presented in the state of the art is capable to perform object recognition in real time using embedded systems, along with obstacle avoidance and navigation algorithms; see §2. The embedded system used across the literature is a Raspberry Pi [6]; other works require the use of computers with more computational resources such as GPU, memory and CPU. The hardware capacity needed to accomplish all the tasks proposed in this paper requires a more powerful embedded system platform than a Raspberry Pi. Therefore, all experiments presented here were developed using a LattePanda Alpha 864s [11].

**Dataset**. A dataset was created with images commonly found in indoor environments to test the object detector. To achieve reliable results, the images created had to be from a real environment with objects that are part of the pre-trained classes in YOLOv4. The dataset consists of three different scenes: office, living room and dining room. First two scenes contain four different images, and the third scene contains three, each image with a different perspective at the same reference point. Since we used three different cameras, this yields a total of 33 images. We classify 20 object classes (backpack, book, bottle, bowl, cellphone, chair, cup, dining table, fork, handbag, keyboard, knife, laptop, mouse, person, potted plant, remote control, sofa, spoon and TV monitor).

**Fig. 2** Example images of the office scene: **a** webcam perfect choice, **b** iDS, **c** Intel RealSense T265. All cameras are located at the same reference point

Figure 2 shows an example of an office scene, where objects commonly used within an office appear such as a laptop, a cell phone, a keyboard, a mouse, a book, a backpack, a chair and a TV monitor with its remote. For each image, it was necessary to generate the bounding box of each object in each image. This is our ground truth dataset, which is necessary for the mAP metric described below.

**Mean Average Precision (mAP)** is an evaluation metric used for object detection [12]. The object within an image is located and classified by an object detection algorithm. *Precision* is used to measure how accurate the model is where Precision $= \mathrm{TP}/(\mathrm{TP} + \mathrm{FP})$. *Recall* is used to measure the sensibility of the model, where Recall $= \mathrm{TP}/(\mathrm{TP} + \mathrm{FN})$. *Intersection over Union* ($IoU$) measures the overlap between the bounding box of the ground truth and the predicted bounding box, where IoU $=$ Area of Intersection/Area of Union. If the $IoU$ is equal to one it implies that the predicted and the ground truth bounding boxes perfectly overlap [13]. In object detection, precision and recall are calculated based on an $IoU$ threshold. The next step is to calculate the average precision (AP) for each class. Once the AP is calculated for a single class, the calculations are repeated for all classes with the same $IoU$ threshold and confidence threshold, and this experiment was repeated for all cameras. Mean average precision (mAP) can be calculated as the average of all the APs.

## 6 Results

Experiments are performed for different $IoU$ thresholds, so we calculate mAP for 0.5, 0.55, 0.65, . . . , 0.95 values.

Figure 3 shows the results, where iDS camera has the best performance with mAP@0.5:0.05:0.95 = 0.70138, right away the common webcam with a value of 0.6515 and finally the Intel RealSense T265 with 0.48146. iDS camera captures higher resolution and brighter images in comparison with the common webcam. The resolution allows to detect more objects with a higher confidence and get less false positives. Also, the CMOS color sensor with 8-bit depth in the iDS camera represents

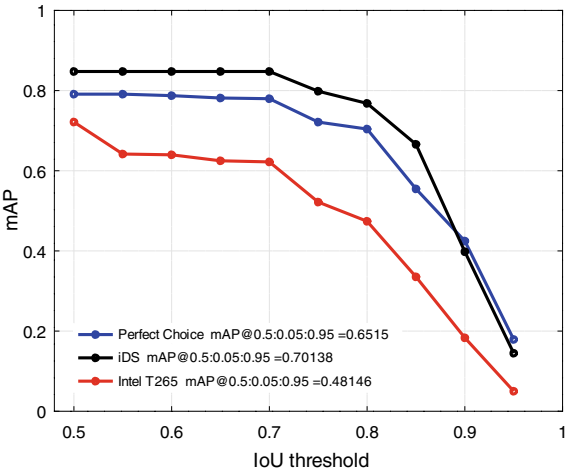


**Fig. 3** Comparison of performance for three cameras analyzed. Each point is the mAP calculated at a specific $IoU$ threshold

**Table 2** Prediction average time and mAP for each camera

| Camera | Average time (s) | mAP@0.5:0.05:0.95 |
|---|---|---|
| Perfect choice | 13.264867 | 0.65150 |
| iDS | 18.685641 | **0.70138** |
| Intel RealSense | **12.489101** | 0.48146 |

an important feature to capture a high-quality image which can be better processed by the object detector. A color image is another important factor.

**Prediction Time**. Table 2 shows the average time of each camera for the prediction analysis, where the best results are in bold. As the iDS camera showed better results with mAP@0.5:0.05:0.95 = 0.70138, the average processing time is significantly higher compared with the others, such as Intel RealSense T265 camera with a low resolution and the lowest prediction average time. If the implementation of the object detector requires a higher mAP value, regardless of processing time, a color camera with a higher resolution is the best option. Nevertheless, if the processing time is an important feature of the implementation, a hardware architecture equipped with a GPU and a camera with high resolution may bring better results.

## 7 Conclusions and Future Work

We introduced a new architecture toward an intelligent electric wheelchair, and we presented the results obtained for the computer vision module. Also, a new dataset was generated to measure the performance of three different cameras. Besides the images captured with cameras, it was also necessary to generate a ground truth dataset

containing the bounding boxes of all objects within the images. The YOLOv4 object detector was used in this module, which is based on CNNs, and running on an embedded system platform (LattePanda). The mAP metric was used, where the iDS camera shows the best performance with mAP@0.5:0.05:0.95 = 0.70138, see Fig. 3. The iDS camera suggests that taking RGB and high-resolution images are the best characteristics to use with the object detector. On the other hand, Table 2 shows that iDS camera has the worst prediction average time. This research is not only intended to help handicapped people to retrieve part of their autonomy, but also it can be used for any autonomous systems guided by cameras. As further research, these are the research directions: (i) re-train the CNN inside YOLOv4 to recognize objects that currently cannot identify; (ii) real-time processing, use of different embedded system platforms such as Jetson Nano, which is another minicomputer from NVIDIA with GPU [14]; (iii) exploring new technologies, including cloud computing, distributed systems and parallel computing, in order to achieve a better prediction time for the computer vision module and a remote-controlled wheelchair.

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# The Text Mining Analysis Approach for Electronic Information and Transaction (ITE) Implementation Based on Sentiment in the Social Media

**Fahdi Saidi Lubis, Muharman Lubis, Lukmanul Hakim, and Hanif Fakhrurroja**

**Abstract** Currently, the establishment of legal act in cyberspace is the inevitable consequence of globalization to ensure the legal certainty of the people who interacting within internet. With the number of legal infringement in cyberspace increasing each day, the needs of internet regulation have becoming a world concern. Indonesia is one of top ranking country with high number of internet users, which want to safeguard the public interest with a comprehensive law through "Undang-Undang Informasi dan Transaksi Electronik" (UU ITE). Therefore, the current use of this act is retrieving the diverse feedback and responses from citizens in Indonesia since it was signed or after the amendment for several aspects. The availability of social media networking enables them to react to the subject concerning legal issues within internet. Thus, this research work used text mining technique to find out the perceived issues, challenges, and benefits of ITE implementation from citizens' opinions, comments, and perceptions in social media of Twitter. The result of this study grouped into two main topics; legal consequences and precedence.

**Keywords** Text mining · Assessment · UU ITE · Implementation

## 1 Introduction

At around twenty years ago, the term of cyberlaw is not well known in some countries, even in America, in which mostly people have been confused of that term. Even, the mainstream legal profession will find it like something out of cartoon or make-believe, it was not regarded as real law. But, with a prominent promotion by some countries, the transition of cyberlaw has happened gradually hand in hand with an exponential development of new communication technology. Indeed, the transition

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also impacted the way of people's life and culture. Ironically, a decade after that has witnessed rampant cases of infringement and violation on an unprecedented scale in cyberspace. Some notorious crimes such as computer related fraud, cyber piracy, intellectual property fraud, misuse of devices, and so on are more prevalent in the developing countries, simply because cyberspace has no geographical boundaries. There are no physical characteristics of sex, age, etc., of the "netizen" who commits an offense in the cyberspace. These are what of the majority of countries worrying about: (1) lack of territorial border [1], (2) anonymity and identity [2], and (3) freedom of expression [3]. It can be seen that the country like Brazil was placed in the worst standard of cyber safety due to uncertainty law that cover the privacy of data transfer and the weakness of its regulation on combating cyber threat according to Kaspersky lab report in 2011 [4]. In short, the effect of this condition will have a disastrous impact on the stability of a country as well. This is due to the fact that most countries in the entire world hinge on the information and communication technologies (ICT) advances [1].

In the sector of business and commerce, the face-to-face transaction potentially replaces with online communication, and then the conventional legal system which used paper-based has changed to electronic-based. So, how about legal issues impacted by internet proliferation? It can be an impediment if the lawmaker and business retain with the existent legal system. Thus, the legal system needs transition and should be more adaptable with internet proliferation [5]. In fact, a sequence of efforts has been made by governments and organizations around the world in order to deal with the issue on legal effect of internet. To achieve a consensus with everyone to agree with whatever decision takes by authorities in the cyberlaw is almost impossible, although many countries have updated their cybercrime laws such as Australia, Canada, Estonia, India, Japan, etc. Only a few of those countries have developed comprehensive with mature cyberlaw. Indeed, some countries even started their early stage to draft and to implement cyberlaw [6].

The enactment of legal act in the cyberspace has gain huge perspective of governments, organizations, businesses, individuals, and other relevant parties around the world. The earlier stage was begun in 2003 to propose the draft of first Indonesia's cyberlaw. After several years of debate, the law was subsequently signed by the legislature in 2008. The urgency of implementing ITE has been confirmed by numerous cybercrime activities such as spam, copyright infringement, identity theft, piracy, phishing, cyber games of chance, etc. In the following decades, previous laws, such as telecommunications law, govern the telecommunications sector in general, licensing, operations, network provision, and other procedural matters, regardless of the cyberlaw context, it has been indicated incapable of controlling the activities of the virtual world [7, 8]. There are many ICT-based methods could be used by government agencies to allow citizens to create political contents. The existing and planned policies that posted in the website as well as other form of media related to the government agencies are able to allow the citizens to respond immediately. However, the content derived from the political forums, blogs, news website, Twitter, and Facebook are the most useful political content [9].

## 2 General Description of UU ITE

The concept of Indonesian cyberlaw, known as UU ITE, was not submitted until 2005 even though it was drafted in 2003, but the house of representative makes a significant stride until passed it in 2008. Even nowadays, some argues that Indonesia has not any specific cyberlaw that guaranteed legal act in cyberspace, otherwise it adopted ITE law No. 11/2008 for Indonesian Cyberlaw's umbrella. Besides, it also implemented related-laws such as Regulation No. 82/2012 (electronic system and transaction operation), Consumer Protection Law (1999), Pornography Law (2008) (cyberlaws in Asia), Copy Right Law No. 19/2002, and so on. ITE is not the only one of law elucidates cyberspace regulation in Indonesia, but it has another act that legislated cyberlaw enforcements which is Telecommunication Law No. 36/1999. ITE addressed a comprehensive content that encompasses various relevant cases in cyberspace, particularly e-commerce and cybercrime, while Telecommunication Law is a substitute of Law No. 3/1989 which regulates specifically of national telecommunication. Basically, Telecommunication Law is "lex generalis" of ITE law that do not detail specifically about internet and telecommunication instructive description [10].

In general, Indonesia lagged behind in term of cyberlaw implementation comparing to Malaysia that had passed a broad set of acts that now considered as Malaysian Cyberlaw. There are the statutes that had approved by Malaysian Parliament such as Communication & Multimedia Act 1998, Malaysian Communications & Multimedia Commission Act 1998, Digital Signature Act 1997, Telemedicine Act 1997, Optical Discs Act 2000, and the amendments of the copyright Act 1987 [11]. Currently, through a decade ago, Malaysia also passed the Personal Data Act 2010, while previously has been established Payment System Act 2003 [8] to support electronic commerce and online transaction legal measures. It is unlike in India, the country which implements a single act that deals with cyberlaw, which is 2000 The Information Technology Act [12]. However, the host is not an arbitration agent who has the power to provide some sort of legal guarantee to the parties in a dispute between the seller and the buyer. In the event that the buyer claims that the goods received are different from the specifications stated in the contract while the seller claims, otherwise, for example the hostel has very limited ability to participate and stay [13].

The current cyberlaws that were drafted are Information Technology Crime Act (RUU TIPITI), Multimedia Convergence Act (RUU Konvergensi Multimedia), and Information Technology Utilization Act (RUU PTI). ITE Law could not stand alone unless it needs support from others developed law, the new development and regulation has to be done by Indonesia legislative because this is the first law governing ICT provision. That limitation, therefore, cannot cover up all issues simultaneously in cyberspace [8]. For instance, the person who commit cybercriminal could also be punished with Criminal Procedural Law Codex (UU KUHAP), Pornography Act (UU Antipornografi No. 44/2008), Copyright Act (UU Hak Cipta No. 19/2002), Consumer Protection Act (UU Perlindungan Konsumen No. 8/1999), and so on

[14]. Recently, the first amendment was made. Together with the government, the parliament approved about some revision of ITE Law in October 27, 2016 (Revision UU No. 11/2008 about Information and Electronic Transaction). The ministry of Information and Technology claimed that there will no criminalization in term "freedom of expression", in the early state it was pros and cons in the public. With this improvement, the government expected no multi-interpretation [15]. The concept of ITE adopted the principles of The United Nations Commission on International Trade Law (UNCITRAL) Model law on electronic commerce and signature, European Union (EU) Directives on electronic commerce and signature, and convention on cybercrime [16]. The law intentionally used to legalize the ICT usage, and embodiment of the convergence of telecommunication, media, and informatics laws. The initiative of ITE was drafted by two government's agencies; the Ministry of Industry and Trade come out with the bill about the electronic transaction, meanwhile the Department of Tourism, Post and Telecommunication also initiated the similar type of bill on information technology. After some years of bargaining, the government undertook the two initiatives to become the collaborated drafts (Table 1) [7].

ITE law contains 13 chapters and 54 articles. It does cover comprehensive subject matters such as legality of electronic contract and signature, personal data protection, privacy concern, improper practice of domain registration, intellectual property rights, definition of the cybercrime, and the consumer protection. However, other than subject matters that stated above will govern by subsidiary regulation [7]. Meanwhile, the existence of ITE not only applied far beyond Indonesian territories but also prevail for extraterritorial of Indonesia. Some difficulties might be appear in how to reach a borderless virtual world, particularly the perpetrator who conduct illegal act against such provision outside Indonesia. In converse condition, the provision compels anybody who resides in Indonesia or abroad to be obedient and conscious

**Table 1** Structure of ITE law

| No | Total articles | Concerning | Arrangement |
|---|---|---|---|
| 1 | 4 articles | General provisions, principles, and objectives | 1–4 |
| 2 | 8 articles | Electronic information, records, and signatures | 5–12 |
| 3 | 4 articles | Provision of electronic certification and electronic sys | 13–16 |
| 4 | 6 articles | Electronic transaction | 17–22 |
| 5 | 4 articles | Domain names, intellectual property right, and protection of privacy rights | 23–26 |
| 6 | 11 articles | Prohibited acts | 27–37 |
| 7 | 2 articles | Dispute resolution | 38–39 |
| 8 | 2 articles | Roles of the government and roles of the public | 40–41 |
| 9 | 3 articles | Investigation | 42–44 |
| 10 | 8 articles | Penal provision | 45–52 |
| 11 | 1 articles | Transitional provision | 53 |
| 12 | 1 articles | Concluding provision | 54 |

about this regulation and so on [17]. In addition, it also affected certain provision in other laws such as the law of contract and the law of evidence.

## 3 Result and Discussion

Most of the users disagree with an arbitrary power which often prosecuted the users of internet. Some of them also worried about the freedom of expression on the internet that anytime could convict them. In addition, the connection starts with one tweet of particular events posting by news portal or government verified account. The tweets from the users of @sj12th87, @zaeffendy, @radityadika, @kompascom, and @detikcom posted frequently by other users to show that they interested to involve in. Mostly, these tweets send by the news portals, fans page, official account of governments, and the famous one. From this network connection, we can observe which users influence another user to retweets the message, and how big the network is. So, we can see what are the current issues has discussed. In addition, for further reference, in case of government agencies, they can observe the particular accounts of Twitter to see the trends that evolve among them (Table 2, Fig. 1).

The normative issue is one of the major concerns of Twitter users regarding "Pasal UU ITE" such as elastic articles, defamation of other reputation, consumer protection, and arbitrary power still prevails among internet users in Indonesia. There are many controversial cases assumed against human right and freedom of expression. Some coercive diplomacy has been done focusing to improve the articles which posed many disputes such as the subsection 27/3 and 45/1 that would intimidate the freedom of speech and expression [18]. The use of text mining can help to identify the perception on specific issues by following the pattern on Twitter to make accurate prediction about the future trends, such as the box office success although it is not a representative sample of any populations [19]. Furthermore, to assess adaptation readiness factors such as political leadership, institutional organization, decision making and stakeholder engagement, availability of usable science for decision making, funding for adaptation planning and implementation or evaluation, and public support for adaptation, a text mining analysis has a change to be adapted. It is because the source of information for assessing readiness for adaptation relies on speeches of leaders, adaptation planning documents, consultation document, gray literature, opinion polls on perception of climate change, and so on. At certain situation, the researcher should be consider the relevancy of specific Twitter post, which requires more manpower to choose related post manually or analyze them to specific condition such as sarcasm, metaphor, or any other variant of language attribute, even though the total number of this kind of post is not really significant to deter overall trend analysis [20, 21].

Moreover, a defamation lawsuit still prevails around the internet users in Indonesia, which also disputed in term of ITE enforcement. The action of libel in internet occurred frequently that disadvantage others' reputation. The assumption is the freedom of expression underlying defamation because it is a human right to

**Table 2** List of popular tweets regarding "Pasal UU ITE"

| No | Popular tweets for "Pasal UU ITE" | Retweets counts |
|---|---|---|
| 1 | "Pasal karet UU ITE kembali memakan korban. Lindungi hak konsumen! Kami bersama Acho #Achogasalah" *(Elastic articles of UU ITE getting more casualties. Please do protect consumer right! We stand with Acho #Achogasalah)* | 744 |
| 2 | "Ngamuk2 waktu temenya kena UU ITE tapi mendukung Jokowi dengan PERPPU dan tambahan pasal pada UU ITE itu. Kalian memperjuangkan" *(Mad (of someone) when his friend subjected as infringement of UU ITE, otherwise do supported Jokowi with government regulation in lieu of law and additional article taken from UU ITE. You are struggling)* | 257 |
| 3 | "Kalau semua kritik bisa berakhir pencemaran nama baik dengan UU ITE dan pasal yang dicari-cari, penjara penuh" *(When criticism categorized as defamation with non proper article of UU ITE, there is no empty jail)* | 190 |
| 4 | "Padahal kalau pengelola Apartemen Green Pramuka mau menuntut kerugian tidak tepat menggunakan pasal pencemaran nama UU ITE" *(Even if manager of Green Pramuka Apartment demanded compensation, unless it does not fit with defamation cases in UU ITE)* | 113 |
| 5 | "Satu lagi kekonyolan pasal karet modelan UU ITE, pada akhirnya yang terancam ya kebebasan & hak semua orang" *(Another unreasonable of elastic article which designed in UU ITE that going as threat upon freedom of expression & all human right)* | 100 |
| 6 | "Dalam laporan polisi, Acho dijerat pasal 27 (3) UU ITE dan 310–311 karena dianggap merugikan Apartemen Green Pramuka" *(According to police's report, Acho has prosecuted with article 27 (3) UU ITE and 310–311 because of his commits has caused disadvantages (presumption) upon Green Pramuka Apartment)* | 93 |
| 7 | "Terima kasih, semoga tak perlu ada lagi konsumen yang dipidanakan dengan pasal karet UU ITE karena makin lama makin gila" *(Thank you, hopefully no one would criminalized with elastic article of UU ITE anymore that going crazy day by day)* | 83 |
| 8 | "UU ITE pasal karet bener-bener" *(Absolutely, UU ITE could interpret elastically)* | 43 |

free to express their feelings, opinions, and facts in internet. According to the ITE, a defamation case regulates in the article 27 Sect. (3), and also referring to the article 28 Sect. (2). Those articles interest Twitter users in Indonesia since it were convicted many victims. The controversies of these articles still a hot topic to be discussed in the social media. It is such a dilemma to express an opinion in the social media, where the definition of libel never elucidates with clear statement that somehow could abuse by certain parties for their own benefit. In short, the dispute becomes a trend when the cybercrime cases are occurred. For instance, there are recent cases occurred in Indonesia regarding cybercrime convicting citizens in Indonesia: such as the Ellyrisman cases and the Otto cases, which went viral in the Twitter when the data were collected. Since technical measures alone cannot prevent crime, effective

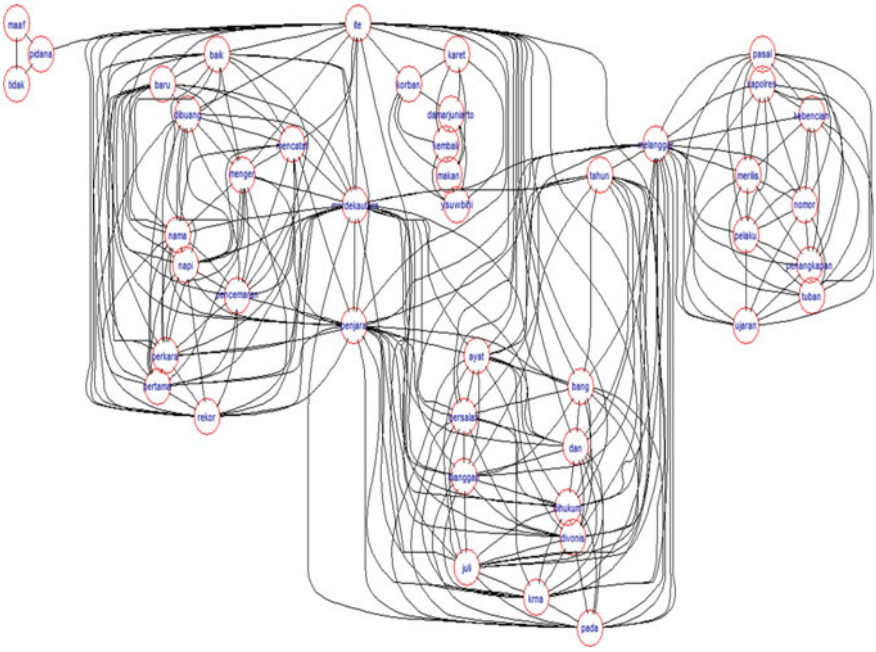


**Fig. 1** Word associations in the dataset

cybercrime investigation and prosecution of law enforcement agencies is essential to prevent the loss of vital information, many states and governments are currently enforcing strict laws on electronic securities, so everyone that is related to the legal should also be trained in cybersecurity and free from increasing cybercrime [22]. The way people today store, reformulate, process information, and ultimately generate income from it, has marked a shift from businesses based on raw materials and exploiting workers to businesses based on information and knowledge. Information is increasingly becoming a commodity rather than a mere business tool [23]. It is about digitizing physical objects and objects, enabling them to communicate information about themselves and their environment to each other. A connected environment like this can undoubtedly affect various aspects of life be it trade, services, health or education, as well as public governance [24].

## 4 Conclusion

To explore the Twitter data, there are many methods can be used such as multinomial Naïve Bayes tree and many more. Meanwhile, the classification methods to perform sentiment analysis enable to classify negative, neutral, and positive opinion. These available tools and methods have big potential to benefits the government agencies in

Indonesia to reassess about social trends in the societies. Besides, the government has to see what the urgent issues are coming from policy implementation, especially ITE implementation that attracted many attentions of "netizens" currently. Some studies revealed that there is a strong correlation between political opinions expressed via Twitter and official poll data even though it has some drawbacks such as poor data with little predictive value because the sample of social media data cannot represent the wider public. However, with exponential web-generated contents available in the social media networking graced the social science sector, particularly government agencies, without doubt can transform public sentiments, responds, and ideas to become "a new eyes" for government in Indonesia.

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# The Maze: Scarecrow's Revenge, Agricultural Education and Outreach Through Game Development

**Cathryn Hunt and Saman Sargolzaei**

**Abstract** Extended reality is known as a technical term encompassing augmented, virtual, and mixed reality. It is a niche technology domain that finds its way through virtually every sector, from academia to businesses and industries. Its success is due to the level of immersion it brings to the user. The COVID-19 pandemic, with its unprecedented consequences and lockdowns, amplified the advantages of immersive education and learning through extended reality technology. The technology extension to smartphones and Web pages has enabled its accessibility to a level expected to grow beyond the pandemic era. Due to the rural locations of farms, agriculture is a great candidate where extended reality technology can strengthen its reach to a more enormous population for education, promotion, and outreach. The current study, at the intersection of the agricultural sector and extended reality technology, presents the development of a three-dimensional interactive game to promote the Tennessee corn. The game is developed in Unity engine (version 2020.3.12). It is a single-player, first-person perspective game, where the arrow keys make a farmer character navigate turns and obstacles within a corn maze. Scarecrows will appear over the game course and force the player to answer a trivia question about corn production and usage. The player moves forward unchanged with correct answers to the trivia questions; however, the player will lose a life from their five-life total with an incorrect answer. The goal is to escape the maze by correctly answering trivia questions, navigating the maze, and finding bonus lives scattered throughout. The study discusses the design process of player movements, camera movements, objects interactions, and other game-play mechanics. With our target audience primarily set to middle school students in rural areas, the game was successfully developed and released as a Web-based game (https://bar.rancsgroup.com/TheMaze/). Our current plan is to extend the game with optional difficulty levels as well as release smartphones applications through major platforms.

**Keywords** Agriculture · Augmented reality · Game development · Education · Mixed reality · Virtual reality

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## 1 Background and Motivation

Coronavirus disease 2019 (COVID-19) pandemic has hit our societies in anomalous ways, including the assertion of accessibility barriers for delivering quality education [1, 2] and outreach experiences due to campus closures, events cancellations, social distancing, and enforced lockdowns. Aside from infrastructural issues, technology affordability, and accessibility, disparities are reported in remote instruction and distant delivery of education [3]. Global reports [4–7] highlight the discipline-dependent differential impact of online delivery in the field of agricultural and veterinary sciences due to the nature of educational content such as visual perception and hands-on learning. It altogether calls for an urgent pedagogical curriculum development that satisfies immersive learning experiences while remotely delivered. Extended reality (XR) technology has recently enabled such solutions to provide an immersive learning experience. Extended reality is a technical term that encompasses a broad spectrum of computer-based solutions that transforms observations to immersions [8]. One end of the spectrum is virtual reality (VR) technology, where immersion occurs in a fully animated virtual world.

In addition, styles of learning have advanced, and technology has been integrated into more and more classrooms. Student success has increased with more educators converting to an active style of learning; active learning is a learning process that requires the student to be fully engaged through participation and reflection. The differences between active and passive learning include student involvement, the environment's focus, and the roles of students and teachers. First, an active form of learning requires the student's input, while a passive environment does not require anything but the student's presence. Second, passive environments emphasize the teacher and his/her knowledge on the subject, but active environments are more student centered. Moreover, as mentioned before, the passive environment focuses on the teacher's mastery of the material, and it places the students in situations where the student accepts all the information.

On the contrary, an active environment focuses on the student, making the teachers more of a facilitator which encourages the students to be critical of the information they are being taught. According to the National Training Laboratory's Learning Pyramid, learning methods begin with passive activities such as lecturing, reading, audio–visual, and demonstration, and progress to more active activities such as discussion, practice doing, and teaching others. Consequentially, as learning progresses from passive to active, the average retention rate of students is directly proportional and increases as well.

Corn is a wild grain that is part of the grass family, which refers to grains gathered from grasslands that can yield extremely large harvests. The cultivation of corn was believed to have started somewhere from 6,000 to 10,000 years ago when it was known as maize, and it was first domesticated in Mesoamerica, modern-day Mexico. It then spread to the Native Americans who introduced it to the European colonists which caused the crop to spread to all areas that were suitable for its cultivation.

Being one of America's most important crops due to its usage versatility and its sustainability in growth, US corn is mainly used for animal feed, fuel development, exports, and food. Additionally, since 1980, corn farmers have reduced soil loss per acre by 58%, declined necessary use of irrigation water per bushel by 46%, decreased the amount of land required to produce a bushel of corn by 41%, improved energy use efficiency per bushel by 41%, and reduced greenhouse gas emissions per bushel by 31% (according to the Tennessee Corn report in 2021). By educating students on the production process, usage, and history of this crop, in high corn production areas, such as West Tennessee, we can continue to encourage the long-term success of corn producers and therefore extend the positive economic and environmental effects of such production.

The current study presents the development of a three-dimensional interactive game, called 'The Maze: Scarecrow's Revenge', to promote corn education. The game is developed in Unity engine (version 2020.3.12). It is a single-player, first-person perspective game, where the arrow keys make a farmer character navigate turns and obstacles within a corn maze. Scarecrows will appear over the game course and force the player to answer a trivia question about corn production and usage. The player moves forward unchanged with correct answers to the trivia questions; however, the player will lose a life from their five-life total with an incorrect answer. The goal is to escape the maze by correctly answering trivia questions, navigating the maze, and finding bonus lives scattered throughout. The remaining sections provide detailed steps for the game development process.

## 2 Game Design

The first step for game development was to lay out all conceptual ideas associated with player control, game mechanics, effects, and user interface. The initial idea was to create a first-person perspective game where the arrow keys move the player asset forward, back, and side-to-side. During the game, scarecrows would emerge from the corn, and the goal of the game was to answer the scarecrows' trivia question as well as navigate the maze. As the game progressed, there would be bonus lives and more scarecrows to make the game more difficult. The lives would decrease on an incorrect trivia answer, and the game would end when the user runs out of lives or exits the maze. After laying out the ideas, it was then time to create a primitive design of the maze and the player, enemy, and bonus life assets. To each asset, a box collider, game tag, and rigid body component were added to make each asset behave in line with the laws of physics. Figure 1 describes the main game states and their corresponding methods along with excitation signals that trigger inter-state transitions.

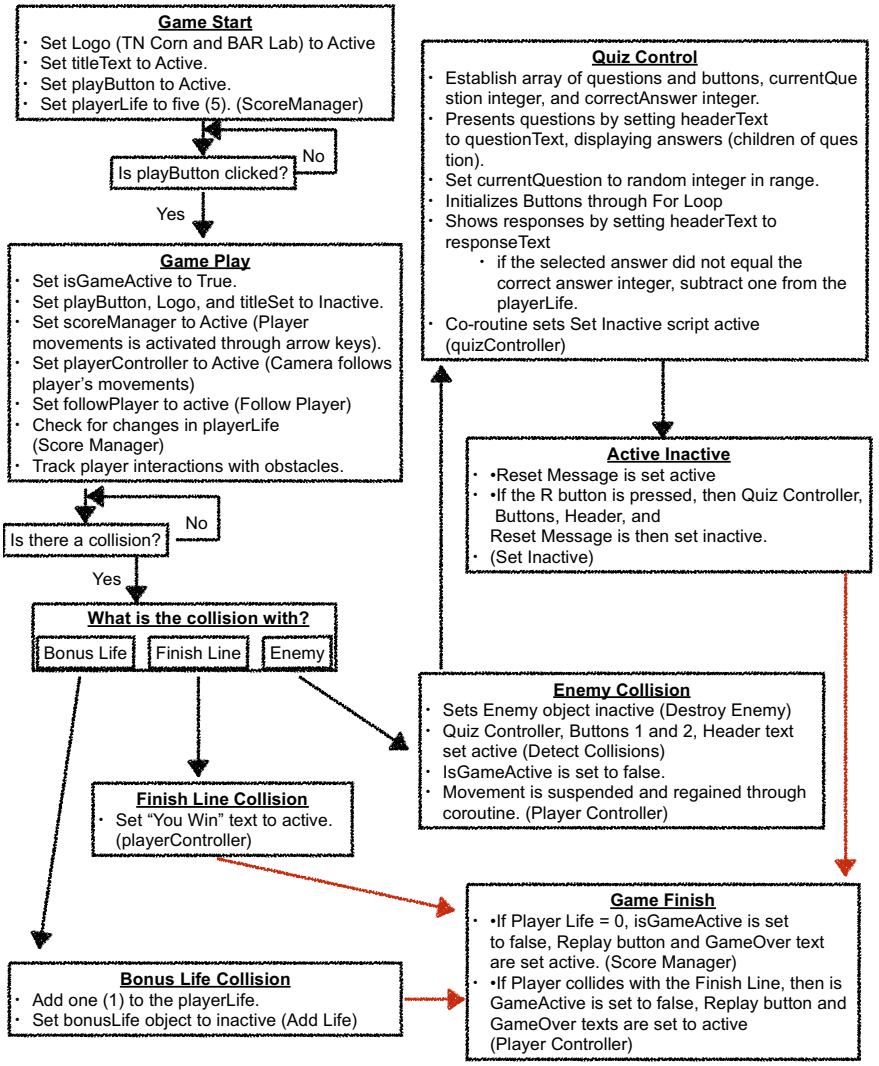


**Fig. 1** Pseudocode of the 'The Maze: Scarecrow's Revenge' game

## *2.1 Player Movement*

To make the player asset recognize arrow key inputs as commands to move, a new C# script named 'PlayerController' needed to be created and applied to the asset in the hierarchy. In this code, we needed four public floats for speed, turn speed, horizontal input, and forward input and assign values to the speed and turn speed. Then, in the update method, which updates once every frame, we gave the horizontal and forward inputs designated controls on the keyboard by referencing the axis name.

After assigning specific keys, we then set the player's translate to a forward vector multiplied by speed and the forward input and set the player's rotation to an up vector multiplied by turn speed and the horizontal input.

Consequentially, to maintain the first-person perspective, we then needed to update the camera's position to be the same as that of the player. We created a new C# script called 'FollowPlayer' and applied it to the main camera in the hierarchy. In this script, we created a public game object to reference the player asset within the script, changed the update method to a late update method, and set the camera's position to that of the public game object. By changing the update to a late update method, we allowed all other script's update methods to be called before the camera's which caused the camera to follow the player's movement.

## *2.2 Interaction*

Now that the player could move around the maze, and all the objects had box colliders on them; it was time to create the trivia game and find a way to trigger it on collision. First, we made a list of ten questions that covered information ranging from the uses, growing process, types of, and history of corn. Then, we created the UI system needed to carry out the trivia process; we created two blank buttons and one blank header text object. We then created an empty game object called the 'QuizManager' which had the C# script controlling the trivia game applied to it. This code created a serialized array of questions and buttons and coordinated the activation of questions and corresponding answer choices which were displayed on the button and header objects.

By creating an array of questions, we were able to use a random range command to shuffle the questions selected and match these questions to the answers displayed on the buttons through a for loop. The buttons were then programmed on click to display response, and a coroutine was started. The coroutine was designed to wait for a certain number of seconds and then restart the trivia questions. Next, we needed a way to start and stop the trivia game within the maze after colliding with the enemy objects. We first added a new C# script called 'DetectCollisions' and applied it to the enemy objects. In this script, we created an OnCollisionEnter command which compared the tags of objects that collided with it. We used an if statement that said if an object tagged as the player collided with its box collider, then the QuizManager object was turned on in the hierarchy, therefore beginning the quiz game. Moreover, to properly start and end the quiz game, we needed a way to set all the UI active and inactive.

In turn, we created a new empty game object called SetInactive which had a C# script applied to it which created variables to reference the UI. Using an if statement, we set all the UI inactive on the press of the r button, and we added a reference activating the SetInactive object/script in the coroutine of the QuizManager. We then created another UI text element instructing the user to press the r button to reset, after the response was displayed for the button clicked which would disable all the

QuizManager and its UI elements. Therefore, each time the player asset collided with an enemy asset, the answers and questions were displayed; on click, the response was displayed; the game waited for a few seconds; the reset message was activated, and the r button became the active way of ending the trivia question.

## *2.3 Adding Difficulty*

To make the game challenging, we then added a public life total as well as scattered bonus lives throughout the maze. To make the life total, we needed to add another UI text element and anchor it in the corner of the screen. We created an empty game object called the ScoreManager which had a C# script applied to it which made the life total able to be edited and displayed on the new UI text in the corner of the screen. In the start method, the life float was initialized and set equal to five, and it was displayed through the referenced UI element.

We could then update and edit this public float by calling it from other C# scripts. On the bonus life assets, a C# script was added called 'AddLife'. By making these assets triggers, we were able to use an OnTriggerEnter method that used an if statement, stating if an object tagged as player collided with the bonus life asset, then the bonus life object would be destroyed, and the ScoreManager's public life float would increase by one. Conversely, we added a reference to the ScoreManager's public life again in the QuizManager's ShowResponse method which used an if statement to say if the answer selected was not correct, then the public life's total would be reduced by one.

## *2.4 Modifying User Interface (UI)*

It was then time to make modifications to the user interface, giving the game a cleaner and more realistic look, replacing the primitive assets, adding effects, and adding a play and game over button. We decided to use the Unity Asset Store, free3D.com, and Textures.com to find desired assets and materials. From the Unity Asset Store, we selected a scarecrow, heart, background music, and sky dome backgrounds which were used to add a more immersive feel to the game. The scarecrow replaced the enemy primitive asset; the heart replaced the bonus life primitive asset; the background music was assigned to the player's audio listener, and the dark cloudy background was applied to the sky dome. From textures.com, we selected a raked soil material to use as the texture of the game's plane. We then downloaded a three-dimensional corn stalk from free3D.com which was placed throughout the maze. We also used a fog effect found in Unity's Course Library which was directly placed into the scene.

Next, we added title text, game over text, and you win text UI elements. We added a public variable to the ScoreManager script to reference the game over text and

added a new GameOver method. In this method, we used an if statement to state if the public life float was equivalent to zero, then a public bool, isGameActive, would be set to false, and the game over text element was enabled. To initialize this Boolean, we set the bool to true in the start method of the ScoreManager. Now, we needed UI buttons to play or replay the game. After creating these buttons, we needed to give them purpose through the on-click assignments in the hierarchy. We added a restart method to ScoreManager which referenced the game's built-in scene manager and reloaded the scene, and the method was inputted into the button's on-click.

Additionally, we created a BeginGame method in the ScoreManager which turned all the UI to be inactive (title text, quiz game UI, game over text, replay button), and this method was inputted into the play button's on-click. Finally, the game was fully functional, and after many text runs needed some slight modifications to be fully completed. We added our sponsoring logos through a rotated plane with the image as its material, which was enabled in the start method of the ScoreManager but disabled by the BeginGame method. We then wanted to restrict the player's movement during the trivia question, and before the play button was selected, so in the PlayerController script, we used an if statements which said: If the player collided with the enemy, the isGameActive was set inactive, and a coroutine suspended the player's movement, then allow the movement codes to be used. We also added a collider to the finish line, and within the OnCollisionEnter method, used an if statement to trigger the You Win text UI.

## 3 Results

Figure 2 portraits a few screenshots of the current version of 'The Maze: Scarecrow's Revenge' game showing the game start, game end, enemy collision, presentation of trivia questions, and hidden bonus life throughout the maze. The game is currently accessible through the Web (https://bar.rancsgroup.com/TheMaze/). While our primary target audience is middle school students in rural areas, the game has attracted interest from a variety of age populations. Through interactive games such as the one we have developed, the students can learn visually and kinesthetically, and therefore develop deeper, longer-lasting retention of material while learning about the importance of corn.

## 4 Conclusion and Future Works

Students yield higher retention rates with more active styles of learning, such as game development. To aim this goal, we have utilized game development to educate about agriculture. Corn is one of America's most important crops as it is extensively versatile and sustainable in its use. The long-term success of corn producers and positive economic and environmental effects in rural areas have a direct linkage to

**Fig. 2** Screenshots of the game start, game end, enemy collision, trivia question, bonus life

education, outreach, and promotion of the great effort being made in this exciting era. Our current study goal was to design an interactive form of learning using 3D software, specifically with the purpose of educating students on the importance of corn production, while creating an active learning environment. Unity 3D was the software selected as the game development engine. While the game is currently accessible via the Web, our plan includes extending its accessibility over major smartphone platforms. In addition, we plan to augment the game with options such as challenging level encompassing the difficulty of trivia questions and maze complexity.

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# Modeling of Blood Flow Processes in a Living Organism

**Yaroslav Yurchyshyn and Vasyl Yurchyshyn**

**Abstract** Inquisitive scientists have been modeling living matter for years, and we can expect to see some breakthroughs in this field. In our paper, we want to convey that this is of concern to us to a certain extent, and we want to touch on what in our opinion is only a small, but very important part of the problem. This is the modeling of blood flow processes. This is not the results of research or experiments. This is how we perceive this process, and we want to share our vision with the scientific community. For us, the heart is no longer a pump of the circulatory system, but a complex multifunctional organ that, in a very rough approximation, acts like an escapement (ratchet) mechanism in a mechanical clock and is a kind of Helmholtz resonator, creating soliton processes in the circulatory system. We propose that the circulatory system of a living organism is treated as a physical system using existing scientific and technical innovations. We look at the possibility of using scientific and technical innovations of physical systems in related medical systems. The possibility of using a new model of the circulatory system of a living organism is discussed.

**Keywords** Circulatory system · Circulatory system models · Cardiovascular system · Blood flow through vessels · Soliton fluid motion · Solitons in living organisms · Nonlinear wave interactions · Rh factor

## 1 Introduction

The modeling of living matter is of great importance not only for medical science, but also for physics, artificial intelligence and science in general.

We are sure that these issues are of interest to many scientists, and we expect major surprises in this regard. These issues are interesting and complex, but to some extent remain unexplored. Our attention is drawn to the circulatory system of a living organism as a complex mechanism in which we see certain patterns with purely technical devices. At the same time, we believe that many technical innovations can

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be used in the modeling of the cardiovascular system, and we have not found what we are proposing in any previous publication.

We believe that the heart is not a pump of the circulatory system. In our opinion, it performs other functions. At the same time, please note that this is the opinion of technical scientists, but not of medical professionals. In this case, we do not regard it as a medical system, but as a physical system, and we propose it in this context.

We do not consider the circulatory system as a system for transporting nutrients to the body, but we perceive this as a proven and indisputable fact. We see a different role of the heart. For us, the heart is not a pump, but a much more complex mechanism, which leads to the movement of blood through the vessels. It is not only similar to the escapement mechanism in a spring-driven mechanical clock, but also acts as a generator of the corresponding waves as a kind of Helmholtz resonator.

We are not putting forward for discussion the results of experiments and studies.

This is our perception of this process, and we are putting our thoughts out there for discussion by the scientific community. We are interested in hearing the opinions of other scientists in this regard.

We consider this work as a discussion paper, whose purpose is to draw the attention of the scientific community to the treatment of the circulatory system as a physical system, using the scientific advances that have been made.

## 2 Medical Technologies and IT

Technological progress now surrounds us in our daily lives with informatization, technolization, robotization, and intellectualization. The achievements in the field of artificial intelligence and robotization are quite incredible. And the medical industry has not been left behind. Modern scientific and technological achievements are helping to fight diseases of almost all human organs. The introduction of IT in health care is continuing to gather pace. Many renowned organizations are working with these issues, and thousands of medical institutions are making use of their achievements.

These issues are not the subject of this paper, so we will not dwell on them. In this paper, we want to treat the circulatory system of a living organism as a physical system and consider another model for how it functions.

## 3 What We Do Not Agree With and What We Are Proposing

We will not dwell on the implemented models of the cardiovascular system. They have been sufficiently well described and implemented. But, it seems to us, as technical specialists, that they do not accurately reflect the real state of this system [1].

The movement of blood through the vessels has a wave-like character. But, this is not like the well-studied sound, light and radio waves, or waves that describe quantum phenomena. All these waves reflect their linear interactions. When two waves are superimposed, another wave arises, whose shape is determined by the simple addition of the two initial waves. Of course, this linear property is approximate and may be violated under certain conditions.

The wave process of movement of blood through the vessels reflects nonlinear interactions.

We believe that the heart does not act as a pump to ensure the movement of blood through the vessels, and chemical processes are not essential to maintain the required body temperature. We consider the circulatory system as a system for transporting nutrients to the body and take this as a proven and indisputable fact. But, in this, we see a different role for the heart.

For us, the heart is no longer a pump of the circulatory system, but a complex multifunctional organ that, in a very rough approximation, acts something like the escapement (ratchet) mechanism of a mechanical clock and is a kind of Helmholtz resonator, creating soliton processes in the circulatory system. And the required body temperature is provided by the movement of blood through the vessels like (in a very rough approximation) the operation of a household refrigerator, as the temperature of the cooling radiator (grid) of the rear wall of a household refrigerator.

Why are these issues of interest to us? To answer this, we will put technical and medical issues to the side and look at some household ones.

A female person close to us has the so-called negative Rh factor. We know well what this is, and not from literary sources, but from our lives. Her two children are Rh positive, and one of the authors watched their birth. He still recalls how the children turned blue and yellow and still feels the horror that seized him because of the fear of losing them. The doctors reassured him that everything would be OK, and that this was happening due to the negative Rh factor of his wife.

The term "Rh factor" comes from the name of the rhesus macaque, in whose blood a specific antigen was found. The presence or absence of the Rh factor in human erythrocytes determines if they belong to the Rh-positive (Rh + ) or Rh-negative (Rh-) blood group.

Now, for medical professionals, the Rh factor or Rh rhesus is one of the 29 blood group systems recognized by the International Society of Blood Transfusion (ISBT). The Rh blood group system consists of blood groups defined by 59 antigens encoded by more than 200 alleles [2]. Antigens with enhanced immunogenic properties are of the greatest practical importance for medicine, and namely: D, C, c, E, e. The terms "Rh positive" and "Rh negative" refer only to the presence or absence of the Rho(D) antigen, which has the highest immunogenicity. In addition to its role in blood transfusion, the Rh blood groups (Rho(D) antigen) are an important cause of neonatal hemolytic jaundice and erythroblastosis fetalis.

While this is important for biologists and medical professionals, it says little to physicists.

Discussing these issues among ourselves, we were ever more inclined to believe that this whole theory of the rhesus macaque may not correspond exactly to reality and that the real problem is hidden somewhere else. Other things were also surprising.

During the second half of the 20th century, the era of washing machines was just being born, and we washed our children's diapers in the traditional way—in a basin with water. And we squeezed the water out of them by wringing. At the same time, the woman in question would often lash out at her husband, telling him that he was doing it wrong. This really annoyed her and frightened him. He never paid attention to how his wife wrung out the laundry: clockwise or counterclockwise. It didn't matter to him whether she was doing it to the right or to the left, but to her it does. And that was also a big issue for us: why is this so?

Such an issue probably would not have arisen if the woman was left-handed, but she writes with her right hand and prefers to work with her right, like the authors of this paper.

In such situations, we, one way or another, approach the issue of the so-called Rh factor. First of all, what is it? And most importantly—what is its nature?

The Rh factor was discovered in 1937 by Landsteiner and Wiener, who named it after a similar factor found in the blood of the rhesus macaque. The Rh factor is a protein found on the surface of red blood cells in some people. The blood of those who have it is called Rh-positive; those who do not—Rh-negative. The presence or absence of this protein is an individual feature, not a pathology. About 85% of people have this Rh factor and, accordingly, are Rh-positive. The remaining 15%, who do not have it, are Rh-negative. The blood of Rh-positive and Rh-negative people is incompatible: When blood with an Rh-positive factor enters the bloodstream of an Rh-negative person, the latter causes the formation of antibodies (a reverse immune reaction), which leads to the serious condition anaphylactic shock. Therefore, Rh-negative patients can only be transfused with Rh-negative blood, and Rh-positive patients may receive any blood.

Everything is simple and clear even to the layman, except for the question: "What does this have to do with the macaque, and what does our mother and my wife have to do with it?".

I have always wondered: At the birth of an Rh-positive child from an Rh-negative mother, we did not have a blood transfusion, and there were no questions about proteins, but there was a big scare. So it is not just about that. In addition, my wife, who is not left-handed, often tried to turn off the water by turning the water tap in the opposite direction (counterclockwise), actually opening it completely but thinking that she was shutting it off. And this often led to flooding of the kitchen when the water came back on following interruptions in the centralized water supply. And in such cases, it was not about the Rh factor or proteins. I wanted to know why this was the case.

Nothing else came to mind except that the blood in the vessels of my Rh-negative wife flows in the opposite direction to that of an Rh-positive person. The direction of movement here refers to the helical movement of blood through the vessels clockwise or counterclockwise.

Look at how water flows out of a tub. When there is not much water left, you can see the water swirling in the drain hole of the tub. You can change the direction of the swirling water by hand, and for a while, the water will flow out in the new direction. But, after a while, it will return to its original direction. All this is well known and is mentioned for reference purposes only. Many people know about how water flows out of a tub in our latitudes and how water flows out of a tub south of the equator. The only question is—where does the rhesus macaque live, with which this issue was closed? And most importantly, why do my wife and our mother get annoyed when we wring out wet laundry in the opposite direction than she does? Because the blood in our vessels and her vessels flows in opposite directions (clockwise and counterclockwise).

This leads to the idea that the heart is not a pump. The heart is an escapement (ratchet) mechanism. Like the pendulum of a mechanical clock. But, there is more. For us, its structure is strikingly similar to the Helmholtz resonator.

The traditional Helmholtz resonator consists of a container ($V$) with a neck ($L$), a narrow port, or opening through which the container is connected to the environment. Given the narrow neck, the velocity in it is high compared to the velocity inside the container. The medium in the neck is an oscillating mass, and the volume of the medium in the container plays the role of an elastic element. It is clear that this division is only approximately true since some part of the medium in a cavity has an inertial resistance. However, if the ratio of opening area to the cross-sectional area of the tank cavity is large enough, this approximation is accurate enough. The main part of the kinetic energy of vibrations is concentrated in the neck of the resonator, where the vibrational velocity of the particles (for example, air) has the highest value. And the wavelength at the resonant frequency depends on the medium that fills the Helmholtz resonator, only on its geometric parameters. This is physics.

You may notice that this Fig. 1 is not an exact model of the heart. Look at the following diagram.

This is an image of a purely technical device for creating certain flows, and it is given to confirm the similarity of the heart model we see with the Helmholtz resonator. Compare the above Fig. 2 with the structure of the heart. For us, the similarity is striking, despite the slightly different application.

So, the real mechanism of blood movement is not entirely accepted either. It has an obviously soliton character. And pay attention to the pulse.

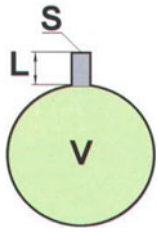


**Fig. 1** Helmholtz resonator

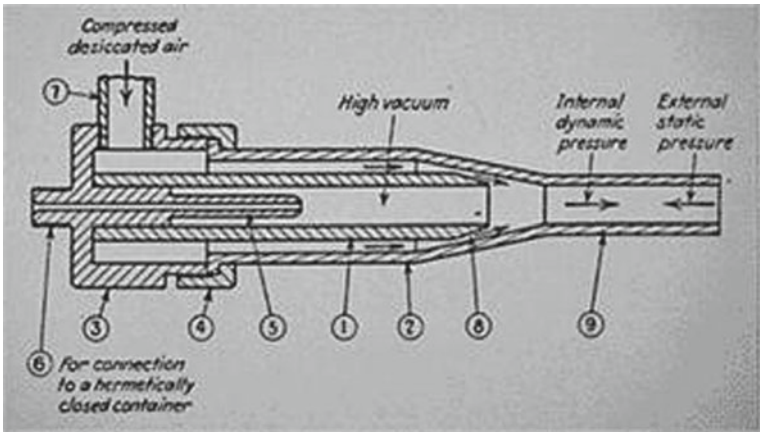


**Fig. 2** Technical device for creating energy flows

Arterial blood begins its movement as a soliton generated by the heart. This process has some differences from the classical Russell soliton, but its generation is related to the Russell soliton [3, 4].

## 4 Conclusion

1. The movement of blood through the vessels has a wave-like character. But, this is not like the well-studied sound, light, and radio waves.
2. The wave process of movement of blood through the vessels reflects nonlinear interactions.
3. The heart does not act as a pump to ensure the movement of blood through the vessels, and chemical processes are not essential to maintain the required body temperature.
4. The circulatory system of the living organism as a complex mechanism has certain similarities to purely technical devices.

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# Using a Q-Methodology in Demystifying Typologies for Cybersecurity Practitioners: A Case Study

**Ahmed AlKalbani, Hamed AlBusaidi, and Hepu Deng**

**Abstract** The increasing number of cybersecurity breaches has forced organizations to apply specific strategies for ensuring business continuity and minimizing business risks. The complex socio-organizational dynamics in organizations influence the adoption of cybersecurity measures. This has created difficulties to align the implementation of cybersecurity measures with cybersecurity compliance. This study constructs a typology of cybersecurity practitioners in public organizations based on their perception of cybersecurity measures using a Q-methodology. Based on the analysis of the collected data from 14 participants in different organizations, the study reveals three distinctive typologies of cybersecurity practitioners including strategy, management and operation, and technology. Such proposed typologies can be used for developing cybersecurity mitigation strategies and understanding the prioritization of cybersecurity measures for their implementation.

**Keywords** Cybersecurity · Cybersecurity controls · Typology · Q-methodology

## 1 Introduction

The increasing dependence of individual organizations on information and communication technologies [1] has led the possibility of cyber-crime [2]. This forces organizations to apply specific strategies for ensuring business continuity and minimizing business risks [3, 4]. As a result, effective management of cybersecurity is becoming

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crucial to the success of organizations [5]. In this context, the management of cybersecurity is about the implementation of specific policies and measures for fighting against cybersecurity attacks [3].

Organizations are facing difficulties in maintaining effective implementation and compliance with different industrial standards such as ISO27001 [6, 7]. According to the 2019 global survey by Fire-Eye (Nov. 2019), 54% of organizations in Japan have found it difficult to achieve a balance between cybersecurity and operational requirements, and a similar case in German with 53% reporting difficult. The complex socio-organizational dynamics influence cybersecurity practitioners in prioritizing the adoption of cybersecurity measures [2, 8–10].

The literature has investigated typologies for understanding the prioritization of cybersecurity measures in organizations [11–14]. Ackermann [15] uses an integrated method for information security risk analysis to prioritize information security practices in organizations. Da Veiga [16] apply an organizational culture perspective for monitoring and implementing specific actions to information security controls. Such studies have shown how to prioritize the implementation of cybersecurity measures. There are, however, many other issues for understanding the prioritization of cybersecurity measures that need to be investigated [17–19].

This study attempts to construct a typology of cybersecurity practitioners in public organizations based on their unique organizational cultures using a Q-methodology approach. Specifically, it investigates the priorities of cybersecurity practitioners who understand their organizational cultures for the implementation of cybersecurity measures. The rest of this paper is organized as follows, a literature review is presented in the next Sect. 2, to assist in developing an instrument that consolidates cybersecurity measures based on industrial standards such as NIST, ISO27001 to collect data. The research methodology and analyzes are then presented in Sect. 3, 4, followed by the research findings and discussion in Sect. 5. Finally, the paper is concluded (Sect. 6) with implications and limitations.

## 2 Literature Review

The presence of dynamic and daunting cybersecurity threats forces organizations and industries to adopt specific policies and standards for minimizing business risks [16, 20]. Such threats including information leakage, malware, social engineering, and targeted exploits have been rapidly increased during the past few years [21]. They have created direct consequences on the corporate liability, loss of credibility, and operational disruption. This has led organizations to continue to improve their security practices for establishing a proper use of their organizational resources [8, 19].

The development of cybersecurity standards is becoming increasingly important in organizations [22, 23]. Effective implementation of cybersecurity standards implies having an efficient system for executing cybersecurity controls [21, 24]. Such standards include ISO 27001 standard, control objectives for information and

related technologies (COBIT), information technology infrastructure library (ITIL), national guidelines for information security such as (NIST 800–53). The application of these standards is increasing worldwide.

Cybersecurity practices must be designed and implemented to support organizational objectives in balance with the operational requirements [25, 26]. The ISO/IEC 17799 code of practice intends to serve as a single reference point for identifying the range of controls needed for most situations where information systems are used. It consists of 11 control sections that form the guidance and recommendations for cybersecurity. Wangen et al. [27] develops a framework for estimating cybersecurity risks using a predefined set of criteria. Lee et al. [7] proposes a method for assessing information security controlling status in accordance with measuring security controlling items and compliance degree. These studies combine technical, procedural, and people-orientated controls that provide a complete portrait of cybersecurity measures elaborated with a unique prioritization to allow planning of efforts and resources in organizations.

Different approaches have been developed to enable the prioritization of cybersecurity measures for their effective implementation [28, 29]. Kolkowska and Dhillon [3] uses a value-based method for capturing the rationalities behind different information security practices. Safa et al. [22] focus on employees' involvements such as knowledge sharing, collaboration, intervention, and experience toward the implementation of cybersecurity practices. Nasser et al. [4] examines the maturity level of information security management to decide the type of protection strategies and policies to be taken. These studies have focused primarily on the factors related to users' attitudes, intentions, and behaviors. There are, however, many other factors related to the complex socio-organizational dynamics that affect the implementation of cybersecurity measures in organizations [2, 23, 30].

This research investigates the priorities of cybersecurity practitioners for the implementation of cybersecurity measures. As a result, an in-depth literature review has been conducted to identify a comprehensive list of cybersecurity measures. A Q-methodology is used to identify the priorities of cybersecurity measures. The potential findings from this typology would add insights to the current discussion by explaining how cybersecurity measures can be prioritized for demystify the effectiveness of cybersecurity controls.

## 3 Research Methodology

This study uses a Q-methodology approach to explore, classify, and prioritize cybersecurity measures into distinct groups. Such an approach uses a combination of enquiries including Q-sorts (i.e., card-sorting), semi-structured interviews, and observation. Each participant is requested to sort the cards from the "high priority" to the "less priority" on a scale, which ranges from +6 to −6 based on the distribution illustrated in Fig. 1. After card-sorting, a semi-structured interview is conducted with each participant to capture on why they sort the cards in such a way, especially

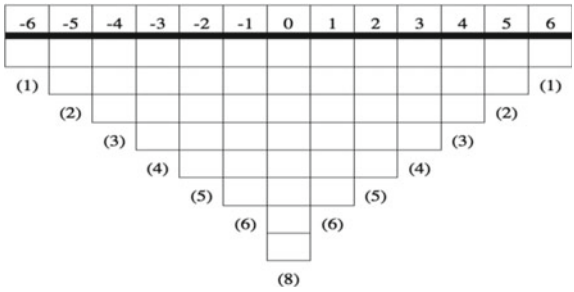


**Fig. 1** Q-distribution

controls located at the extreme (i.e., +6 and −6) or middle positions (i.e., 0). The card-sorting data is analyzed with a Q-method package in R [31]. The interview data is used to aid the interpretation of the findings. Further, the demographic and cybersecurity experience for each participant are collected.

## *3.1 Research Methodology*

This study has adopted a Q-methodology approach using a composed Q-set statements that have been extracted from the exiting literature with reference to ISO 17799 standard. The key cybersecurity controls statements have been mapped to the guiding principles to ensure that the identified controls are comprehensive and to ensure that each statement has the practice that is most likely to have an impact on effective cybersecurity governance. The final list of 40 statements is shown in Table 4.

## *3.2 Profiles of the Participants*

The study recruits cybersecurity practitioners from different organizations representing different sectors in Oman. The participants are invited to attend an individual interview and a Q-sort session at their working place. Initial confusions have been perceived for card-sorting procedure as compared to the traditional survey method, this has been clarified and answered. Participants are selected based on the minimum of 5 years' experience in cybersecurity field. Among 17 participants, 14 met our criteria and were set up appointments to participate in this study. The demographics of the 14 participants are displayed below Table 1, with the average age of 35–45 years old having 5 females and 9 males.

**Table 1** Demographic of participants

| ID | Age | Gender | Sector | ID | Age | Gender | Sector |
|---|---|---|---|---|---|---|---|
| 1 | 46–51 | Male | Health | 8 | 31–35 | Female | Education |
| 2 | 41–45 | Male | Telecom | 9 | 35–40 | Female | IT |
| 3 | 31–35 | Female | Finance | 10 | 31–35 | Male | IT |
| 4 | 31–35 | Female | Education | 11 | 36–40 | Male | Finance |
| 5 | 46–51 | Male | Military | 12 | 31–35 | Female | Oil and gas |
| 6 | 41–45 | Male | IT | 13 | 41–50 | Male | Services |
| 7 | 31–35 | Male | Military | 14 | 36–40 | Male | Finance |

## 4 Data Analysis and Results

The principal component analysis with Spearman's correlation and cluster rotation is used in this study to identify the three typologies in R using the Q-method package. The total explained variance of the three typologies is 48% (Table 2). One of the participants has not loaded on any of the three typologies (i.e., a confounded case), thereby it has been dropped from subsequent analysis. All typology 1, 2, and 3 are clearly loaded with minimum of 4 interviewees reflecting highly reliable (>0.80).

Table 3 summarizes correlations and squared correlations between typologies z-scores. It is evident that a degree of similarity between Factor 1 and Factor 3 is

**Table 2** Factors' loadings

| Participants | Typology1 | Typology2 | Typology3 |
|---|---|---|---|
| Participant (7) | 0.4860X | 0.0759 | 0.0974 |
| Participant (11) | 0.6391X | 0.2215 | 0.1485 |
| Participant (12) | 0.5024X | 0.1823 | 0.0622 |
| Participant (14) | − 0.5241X | 0.0387 | 0.0003 |
| Participant (2) | − 0.0406 | 0.7119X | − 0.0338 |
| Participant (6) | 0.2077 | 0.5805X | − 0.0693 |
| Participant (9) | − 0.3356 | 0.4991X | 0.1619 |
| Participant (8) | − 0.2903 | 0.5587 | − 0.3052 |
| Participant (1) | 0.2589 | 0.1815 | 0.6050X |
| Participant (4) | − 0.0602 | − 0.1447 | 0.4898X |
| Participant (5) | 0.0342 | − 0.0208 | 0.5229X |
| Participant (13) | − 0.0165 | 0.4420 | 0.6286X |
| Participant (10) | − 0.2210 | − 0.1749 | 0.6020 |
| n | 4 | 4 | 5 |
| Eigenvalue | 2.43 | 2.41 | 2.77 |
| Expl var (%) | 13 | 14 | 21 |
| Reliability | 0.923 | 0.923 | 0.941 |

**Table 3** Correlations between factors

| | Typology1 | Typology2 | Typology3 |
|---|---|---|---|
| Typology1 | 1.0000 | 0.1284 | 0.2259 |
| Typology2 | 0.1284 | 1.0000 | 0.2415 |
| Typology3 | 0.2259 | 0.2415 | 1.0000 |

22.6%, and a degree of similarity between Factor 2 and Factor 3 is 24%. However, surprisingly, Factors 1 and 2 are not similar (12.8%).

Table 4 presents the array of items z-scores that reflects the related weighted average for each of the identified factor. This identifies the priority of the cybersecurity measures.

## 5 Research Findings and Discussion

The result identifies three typologies with regards to the Q-sort analysis for the 40 control statements. The factor loadings and weightings are computed to classify the 14 cybersecurity practitioners into three typologies, labeled according to the major characteristics of their operational requirements with respect to the Q statements. The three typologies identified are related to strategy (Typology 3), management and operations (Typology 2), and technology (Typology 1) that have been very well identified in Table 2.

The strategy typology comprises executive level sponsorship for cybersecurity in terms of support and commitments. This is due to the fact that cybersecurity governance is accepted as an integral part of good Corporate Governance [19]. The management and operations typology are to manage information security within the organization (ISO 17799, 2005) that may include program organization and legal and regulatory considerations. The technology typology refers to the mechanisms implemented to secure an IT environment [11]. Further, the results show that there are six items non-significant either at $P > 01$ and $P > 05$. These items numbered (4,12,17,26,28,37) that do not distinguish between any pair of the three typologies.

**Typology 1: Technology**

The technology typology is related to the traditional focus of cybersecurity that involves the implementation of technical and physical controls to secure the organization's environment [18]. Such controls include managing information security assets, implementing reliable access controls, and conducting penetration test. The results represent a group of four cybersecurity practitioners from different industries, including three in finance sector, one military, and one oil and gas. Three of them are males with an average age between 31 and 35. This group has an eigenvalue of 2.43 and explained variable of 13 percent.

This type of cybersecurity practitioners stands out from the rest with high focus on prioritizing controls related to technical, especially controls that are related to the

**Table 4** Control statements and z-scores

| S | Control statement | Typo1 | Item | Typo2 | Item | Typo3 | Item |
|---|---|---|---|---|---|---|---|
| 1 | Governing information security technologies | 2.122 | 39 | 2.028 | 5 | 2.040 | 30 |
| 2 | Governing information security processes | 1.470 | 25 | 2.027 | 24 | 1.775 | 22 |
| 3 | Governing employees' behaviors toward information security | 1.374 | 13 | 1.658 | 37 | 1.717 | 32 |
| 4 | Integration of technology, processes, and people for information security | 1.309 | 40 | 1.645 | 7 | 1.263 | 2 |
| 5 | Information security awareness training | 1.277 | 31 | 1.526 | 30 | 1.156 | 6 |
| 6 | Leading by example for information security | 1.017 | 19 | 1.204 | 33 | 1.126 | 5 |
| 7 | Incorporating information security into everyday work practices | 0.943 | 5 | 1.108 | 31 | 1.117 | 34 |
| 8 | Having a security-aware organizational culture | 0.873 | 18 | 0.717 | 23 | 1.015 | 10 |
| 9 | Following a code of practice for information security | 0.859 | 36 | 0.657 | 14 | 0.800 | 35 |
| 10 | Conducting risk assessments | 0.765 | 32 | 0.608 | 38 | 0.683 | 25 |
| 11 | Managing information security assets | 0.743 | 24 | 0.559 | 9 | 0.675 | 1 |
| 12 | Managing information security activities of external stakeholders | 0.715 | 22 | 0.548 | 8 | 0.586 | 16 |
| 13 | Physical and environmental security controls (e.g., guards, locks) | 0.637 | 15 | 0.547 | 32 | 0.581 | 3 |
| 14 | Communicating information security | 0.620 | 11 | 0.275 | 40 | 0.446 | 13 |
| 15 | Access controls in terms of applications (password, access control list) | 0.590 | 7 | 0.225 | 4 | 0.332 | 28 |
| 16 | Developing in-house information security controls | 0.435 | 34 | 0.216 | 27 | 0.227 | 4 |
| 17 | Acquiring and/or customizing off-the-shelf information security products | 0.384 | 20 | 0.154 | 28 | 0.218 | 29 |
| 18 | Information security incidents management | 0.369 | 8 | 0.106 | 26 | 0.218 | 11 |
| 19 | Business continuity management | 0.318 | 30 | − 0.000 | 10 | 0.047 | 19 |
| 20 | Complying with information security regulations (inside of country) | − 0.075 | 4 | − 0.060 | 20 | 0.037 | 12 |
| 21 | Complying with information security regulations (outside of country) | − 0.097 | 9 | − 0.094 | 34 | − 0.000 | 15 |

(continued)

**Table 4** (continued)

| S | Control statement | Typo1 | Item | Typo2 | Item | Typo3 | Item |
|---|---|---|---|---|---|---|---|
| 22 | Having security leadership | − 0.274 | 1 | − 0.167 | 35 | − 0.004 | 7 |
| 23 | Defining roles and responsibilities for information security activities | − 0.284 | 17 | − 0.214 | 22 | − 0.048 | 31 |
| 24 | Having well-defined and clear information security policies | − 0.357 | 28 | − 0.226 | 25 | − 0.094 | 39 |
| 25 | Conducting penetration test | − 0.463 | 6 | − 0.272 | 19 | − 0.226 | 36 |
| 26 | Establishing an environment of trust among users and management | − 0.464 | 14 | − 0.428 | 3 | − 0.237 | 37 |
| 27 | Establishing an environment of trust among organization and third parties | − 0.477 | 37 | − 0.489 | 39 | − 0.549 | 40 |
| 28 | Internal audit | − 0.501 | 23 | − 0.500 | 16 | − 0.644 | 21 |
| 29 | External audit | − 0.547 | 2 | − 0.608 | 12 | − 0.665 | 33 |
| 30 | Organizational structure for information security | − 0.548 | 38 | − 0.669 | 11 | − 0.666 | 17 |
| 31 | Information security officers have high authority | − 0.680 | 12 | − 0.716 | 36 | − 0.825 | 9 |
| 32 | Information security officers are knowledgeable | − 0.732 | 35 | − 0.881 | 6 | − 0.888 | 18 |
| 33 | Promoting information security ownership | − 0.786 | 26 | − 0.931 | 17 | − 0.996 | 14 |
| 34 | Enforcing information security policies | − 0.875 | 3 | − 1.037 | 15 | − 1.100 | 23 |
| 35 | Having metrics and measurement for information security | − 1.143 | 21 | − 1.037 | 18 | − 1.109 | 27 |
| 36 | Responding to information security incidents | − 1.373 | 33 | − 1.039 | 1 | − 1.432 | 38 |
| 37 | Having ethical code of conduct (e.g., job roles) | − 1.439 | 10 | − 1.252 | 13 | − 1.549 | 24 |
| 38 | Establishing a trusted information security relationship with stakeholders | − 1.778 | 29 | − 1.384 | 29 | − 1.572 | 26 |
| 39 | Implementing reliable security technology controls | − 1.946 | 27 | − 1.718 | 21 | − 1.577 | 8 |
| 40 | Acquiring information security certifications | − 1.982 | 16 | − 2.088 | 2 | − 1.879 | 20 |

use and setting of reliable secure technologies (39: +2). This, of course, includes conducting penetration testing (25: +1.5). This group appears to rely on technical solutions for making sure of business continuity (19: +1). Customizing off-the-shelf information security products (17: −2) has been seen not important, yet interestingly, has been ranked higher than the other groups, therefore, not distinguished with any pair of the three typologies. Further, the statement about "developing in-house

information security controls" is ranked significantly lower (16: −2) which further justifies the complexity of the related sector for the identified group. Nevertheless, a careful observation could tell that this group of cybersecurity practitioners feels more confident about maintaining sustainable operation technologies.

This type of cybersecurity practitioners does not seem to be interested in aligning strategic controls, perhaps because their operational requirements in these sectors are having standardized and mature cybersecurity governance (3: −0.875, 2: −0.547, 1: −0.274). The only statement being ranked higher than the other groups is "acquiring information security certifications" (40: +1.3), this has been explained by two participants, and this control is used in their industry as a way to maintain competency in the global market.

It is also worth noticing that conducting penetration test has high priority (25: +2). One participant actually has explained that the reason and motivation are to maintain readiness to respond for cybersecurity incidents (36: +0.859). These cybersecurity practitioners are not concerned about establishing an environment of trust (27: − 1.9), as one has discussed that operational processes are clear enough to define roles and responsibilities.

This group views about having high authority (31: +1.277) is unique and highly ranked compared to other two groups. Further, this group does not care about promoting information security and ownership (33: −1.37, 14: + − 0.464) because cybersecurity is well incorporated into everyday work practices (7: +0.59), whereas awareness programs are perceived as unimportant unless when introducing new cybersecurity systems (5: +0.943). Overall, this type of cybersecurity practitioners believes that enterprises should accommodate reliable technical security solutions for sustainable operations and incident responses.

**Typology 2: Management and Operations**

The main objective of the management and operations typology is to incorporate the organizational strategy, legal and regulatory, and organizational structure for managing cybersecurity within the organization (ISO 17799, 2005). This typology mainly focusing on maintaining the operational security requirements by following a code of practice for cybersecurity (9: +0.559). Four participants represent this category, among which three are male. All participants are having higher qualification and more experience with an average age between 38–45. This group of security professionals has an eigenvalue of 2.41 and explained variance of 14 percent.

This type of security practitioners appears to focus on compliance with cybersecurity code of practice. They are interested in incorporating information security into everyday work practices (7: +1.6), as well as defining policies, roles, and responsibilities for information security (24: +2, 23: +0.7). Results show an emphasis for establishing an environment of trust among users, management, and third parties (26: +0.106, 27: +0.216, 38: +0.608) that indicates a unique concern regarding this aspect. Similar to the previous group, participants are also concerned about influencing security policies in their organizations, and this supported by having high authority for cybersecurity practitioners in organizations (31, +1.108). This group further reveals the importance of having ethical code of conduct that describes job

roles and responsibilities (37: +1.6). This group approach is more of information security awareness and training (5: +2, 8: +0.5) to influence cybersecurity.

This group shows a strong disinterest in external audit (29: −1.3), however, results show quite opposite for internal audit (28: +0.154). A participant has mentioned that internal audit can generate a direct internal influence in organization, for example, to comply with cybersecurity policy, where external audit in many cases has created misunderstanding and interpretation among top management. This argument is supported by positive ranking of the statement about knowledgeable cybersecurity management (32, +0.5). Of course, complying with outside of country for information security regulations statement (21: −1.7) is less important to this group, where addressing cybersecurity regulations inside the country more important (20: 0.60), one participant has discussed that it is more important to protect their organizations from the country legal system.

The integration of technology processes and people for cybersecurity is highly prioritized (4: +0.225). This group is fully aware of such challenges related to integration, and two have reported that the evolving of technology and organizational changes has direct effect to sustain the integration. On the other hand, one participant has highlighted that acquiring compliance certification (40: +0.275) will enable maintaining good level of integration and management of changes. Likewise, the other participant mentions that promoting information security ownership (33: + 1.204), and advancing its communication (14: +0.657) will smooth the flow of integration activity. Overall, this type of cybersecurity practitioners believes that by maintaining the development of protective systems and provision of security policies and regulations can efficiently reduce the risk of cybersecurity threats.

**Typology 3: Strategy**

The security practitioners in this group differentiate themselves from the rest, with their unique strategical preferences for sponsoring cybersecurity in organizations. In particular, this group focuses on governing cybersecurity policies and procedures that define how an organization can direct and control the use of its resources to protect its information. This group consists of five cybersecurity practitioners having different genders. More specifically, there are two females and three males working in different industries, including education, military, health, and services with an average age between 40–50. This group has an eigenvalue of 2.77 and explained variable of 21 percent.

The results show that organizational structure for information security (30: +1.5) is highly prioritized, and this indeed consistent to the need for defining the roles and responsibility for cybersecurity governing. The result also shows high priority for governing information security processes effectively (2: +1.263), as participants have mentioned that having security leadership (22, +1.775), and leading by example (6: +1.156) enable effective governing for cybersecurity. Similarly, participants have showed the importance in governing security technologies effectively (1: +0.675) as way for maintaining integrity and availability for the operational processes. All participants in this group agree that creating positive working environment leads to influence employees' behaviors toward information security policies and controls (3: +

0.581). Further, this group has shown the value of enforcing information security policies (34: +1.117) where different case for the previous group (manage and operate), in fact, this group sees that it is more important to find different ways for enforcing cybersecurity policies that will enable to cultivate cybersecurity requirements.

Participant's perception in this category believes that compilation of the mitigation strategies is crucial for addressing cybersecurity threats. This type of security practitioners believes that conducting frequent risk assessments (10: + 1.015) aims to identify the required security controls. One participant emphasis that having an updated risk assessment supports the link between the cybersecurity strategy and other strategies such as IT to meet the organization's objectives both in short and long terms. This group also raises the concept of metrics and measurement as a priority statement (35: + 0.800), this allows to show the effectiveness in addressing cybersecurity risks, and the achievements toward the organization's strategy. In response, one participant explained that having metrics and measurement for cybersecurity in place assists organizations in converting today's security incidents, for example, an into tomorrow's business opportunities. Overall, this type of cybersecurity practitioners believes that with the sound of leadership efforts leads to effective cybersecurity in organization.

## 6 Conclusion

This study constructs three typologies of cybersecurity practitioners. Specifically, it provides a complete portrait of prioritizing cybersecurity measures based on the perception of cybersecurity practitioners in organizations. It shows that each typology has direct effect on executing cybersecurity measures.

There are several limitations in this study which can be addressed in future. First, this study of cybersecurity practitioners is exploratory and represents the opinions of only 14 participants which cannot confirm its uniqueness. Second, the research findings remain limited, since these findings have been validated in a single country. As a result, replicating this study in other countries with different organizational and cultural settings would be a fruitful direction to assess and gage the generalizability of the findings.

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# Trust in Smart Homes: The Power of Social Influences and Perceived Risks

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**Abstract** The increased reliance on smart technologies has caused people to consider smart homes. A smart home is using basic assistive devices to build a home environment that contains many technological features and home appliances that are connected and integrated. In order to adopt smart homes, it is needed that users trust this technology, and the factors that influence trust are yet to be discovered. Thus, the aim of this study is to gain a deeper understanding of customer trust in smart homes by empirically exploring the factors that influence customers' trust in smart homes, understanding how those factors are intercorrelated, and the influence of power and direction of each factor. To address the research aim, an online survey is conducted to explore the perceptions of the residents of the UAE residents through a convenience sampling approach. As a result, most people believe that smart homes are reliable and competent. By collecting 158 responses and analyzing them through the SEM-PLS approach, it is found that the social influence, perceived security risks, and perceived financial risks significantly impact customers' trust in smart homes and that the social influences can significantly impact people's perceived risks (security, privacy, and financial risks) as mediators to trust in smart homes.

**Keywords** Smart homes · Trust · Social influence · Perceived risks

## 1 Introduction

People opt for smart devices that can be remotely monitored and controlled. Sensors and other embedded components can be found in almost all devices these days, and the increased reliance on technology has caused people to install smart home technologies. Currently, the smart home penetration rate is around 13 percent and is likely to grow to 19 percent by 2026 worldwide [1]. The average amount of money spent on smart homes per household will be close to $255 annually [2]. Thus, smart home technology is going to be the revolution in technology. The smart home

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concept aims to build a home that is embedded with modern, unique devices, and efficient designs [3]. According to Shuhaiber and Mashal [3], a smart home is using basic assistive devices to build a home environment that contains many technological features, and these features are automated, and the smart devices can communicate. In smart homes, many devices such as lighting systems, home security systems, entertainment systems, door locks, televisions, thermostats, home monitors, cameras, lights, and even appliances such as the refrigerator can be controlled through one home automation system and could be directly connected to each other.

Smart homes are commended for their ability to help save on electricity bills and make cities more sustainable. Smart homes can act as a solution catering to strategic energy planning and facilitating the implementation of national energy policy [4]. According to Li et al. [5], a smart home is a residential-based platform that uses the Internet of things (IoT), computer technologies, control technologies, image processing technologies, and communication technology to connect several facilities through the network to do the automation requirements of the smart system, as well to provide user control and management [6]. By adopting and deploying smart home devices, people can realize the intelligent and interactive use of energy and resources. Smart homes can help us improve voltage profile, reduce electricity wastage, and monitor power consumption demographics [5].

Technically, as the smart home system is a type of control system that is based on the one-chip computer, this one-chip could access and control home devices through smartphones and the Internet. Also, an intelligent home control system is managed through a collection of data acquisition and a control module which includes a set of commands and the TCP/IP protocol. The command control has three main sections in the smart home, telephone remote control, network remote control, and on-site operation [5].

Most smart homes have a communication network that allows users to interact with their smart devices. Using this communication channel, the user can interact with their smart devices like air conditioners, washing machines and even food processors, smoke detectors, gas leak detectors, anti-thefts, emergency assistance, and other home security functions. The only constraint is that the devices on the receiving end must have some sort of smart control built into them as well [6]. Smart devices and non-smart devices can be made compatible by the installation of modified IoT modules.

Smart homes are considered efficient in collecting the electric information, analyzing it, and managing the resources through the connectivity of power service systems (PSS), intelligent interactive terminals, smart sockets, smart appliances, and smart home appliances [5]. The PSS is the most important component of the smart home. PSS deals with the electricity service system by monitoring, analyzing, and controlling electricity usage. PSS is a way of realizing orderly electricity management and the intelligent service of energy efficiencies [5]. Therefore, smart home devices can achieve economic operation and energy control.

Overall, smart homes are considered a trendy technology that contribute significantly to people in their daily life activities. In order to adopt smart homes, it is needed that users trust this technology, and the factors that influence trust are yet to

be discovered. However, little is known about customers' trust in smart homes, what factors would impact their trust, and in what direction [6]. Thus, the aim of this study is to gain a deeper understanding of customer trust in smart homes by empirically exploring the factors that influence customers' trust in smart homes, understanding how those factors are intercorrelated, and the influence of power and direction of each factor. The next section identifies the trust factors in focus and describes smart homes in the context of the study, The United Arab Emirates (UAE).

For this purpose, this article is structured as follows: relevant research articles from prior studies in terms of scope and method are briefly introduced in Sect. 2. The research methodology and objectives are concisely summarized in Sect. 3. Next, in Sect. 4, the discussion and findings present the significance of the study. Section 5 is dedicated to a conclusion. Finally, the limitations and future works are mentioned in Sect. 6.

## 2 Literature Review

### *2.1 Smart Homes in UAE*

A report published in 2021 expects that there will be 0.4 million people with smart homes in the UAE by 2026, and the investments in the field of the Internet of things are expected to increase from $574.89 to $672.75 million [1]. The UAE Telecommunication Regulatory Authority (TRA) has devised the IoT policy and IoT procedures which are collectively called the IoT framework [7]. The agenda is to support ongoing innovation and meet all the reasonable demands for IoT services [8]. The top priority is to provide secure IoT services and provide clarity for IoT market development.

### *2.2 Factors of Trust in Smart Homes*

Many factors play a significant role in building trust in smart homes. Some factors are considered technology-oriented, whereas other factors are more relating to humans and their intrinsic values. The section will shed the light on the factors that are considered the major trust drivers and establish the relationship among them through hypotheses.

**Trust.** Trust is a positive belief that smart homes are reliable, competent, trustworthy, and transparent [9]. In order to perceive a trustworthy smart home, the smart home devices should show predictability, controllability, efficiency, dependability, responsiveness, and durability [10]. Trust in smart homes, as in any IoT application, is not easy to be developed, as it varies from psychological, social, to economic views. Trust is also fragile, which means it could easily defect if the person faces risky situations in dealing the smart devices. It is worth mentioning that lack of trust

does not imply distrust, as trust and distrust have 2 different scales, and this research intends to focus on the factors that influence trust in smart homes in either positive or negative direction and do not assume that the UAE context faces a distrust instance.

**Perceived Risks.** Smart homes could be associated with several types of risks from users' perspectives. Those perceived risks are security, privacy, and financial risks. Those perceived risks could play a challenging role to trust in smart homes and use them, especially since those challenges are being developed every day that are affecting the efficiency and the effectiveness of the smart home devices and more seriously, the entire smart home. Many smart home devices and appliances are manufactured conveniently, however, there are a lot of risks attached to it all, at least from the user's perspective.

*Perceived Security Risks.* Smart homes, like any IoT application, are prone to security threats. If hacked, the Google device can continuously listen to the conversations, track movements, and aid in a privacy breach [11]. For instance, smart door locks are beneficial as they eliminate the need to carry keys or remember combinations. These locks are controlled by mobile phones. A hacker can gain hack into the system, gain access to the lock, and intrude into the house. Similarly, locks making use of biometric data like fingerprints can be easily tampered with [11]. If the user has installed a stove that can be remotely controlled, the hacker can gain access and set the house on fire.

IoT security attacks are divided into three categories: physical attacks, network attacks, and software attacks. Node tampering, malicious code injection, and sleep deprivation attacks are the most common forms of physical attacks. Sleep deprivation attack is conducted by disturbing the sensor's sleep cycle which results in reduced battery life and eventually device failure [12]. Traffic analysis is a type of network attack where hackers collect valuable information by deciphering and analyzing communication patterns [12]. Software attacks, on the other hand, are easy to perform as most IoT and smart home devices have weak software. Social engineering attack is conducted to exploit the vulnerabilities of the IoT system. Viruses and Trojans can be injected into the system for monitoring, tampering, and even stealing data. DoS attack gives the attacker complete control over the application layer, whereas a DDoS attack can deny access or even block legitimate users [11]. Security threats and cybersecurity attacks can indeed affect users' trust in smart homes. Therefore, we hypothesize that:

H1: Perceived security risks can significantly and negatively impact users' trust in smart homes.

*Perceived Privacy Risks.* The smart home has a system that can access personal details such as the user's name, gender, home address, and calendar appointments [2]. In general, smart technologies are accompanied by risks of spying. Hackers are armed with remote administration tools (RAT) that can be used to hack devices that have cameras. These hackers scare their victims by manipulating their smart devices which leaves them powerless [12]. A couple had to face such an issue, they had a baby who was awakened by a man shouting through his baby monitor. No doubt

that these technological advancements are revolutionary, however, they cause a lot of cyber liability and data breaches [13].

People are becoming increasingly unsure about their privacy due to vulnerabilities associated with IoT devices. Data can be easily misused so people are becoming mindful of their data. Those privacy breaches and data leakage can affect people's trust in smart homes. Thus, it is hypothesized that:

H2: Perceived privacy risks can significantly and negatively impact users' trust in smart homes.

*Perceived Financial Risks.* The financial risks or concerns start with the smart home purchase and configuration, including the cost of the appliances, the installation, maintenance, and repair expenses [5]. Smart homes devices' costs could be high, compared to the cost of the normal devices, and the return of investment of those smart home devices integrated into one solution may not be satisfying to some consumers, especially those who deal with high operating costs but less energy savings and power expenses reduction [3]. In case, the costs of operating smart homes were high (such as maintenance and management), and the smart appliances cost more than expected, this can affect the users' trust in the smart home in general. Thus, we hypothesize that:

H3: Perceived financial risks can significantly and negatively impact users' trust in smart homes.

**Social Influence.** Social influence means the change in an individual's thoughts, feelings, or behaviors because of other people [14]. With new technology trends, there will be a social influence among the people, some of them will ignore it, and some of them will adopt it. The social barriers to smart homes in some people belong to two problems, the first problem is dealing with the technological and instrumental concerns, and the second is the obstacle that is raised by users of such tools. According to the previous research, most of the researchers agreed that the main smart home obstacles among people, in general, are divided into four categories such as privacy and security, reliability, satisfaction, and the trusting on device controlling [14, 15].

The sub-indicators of privacy and security are the smart systems of surveillance, the smart devices and systems of detection, and the smart system of identification. All these systems might affect the trust in the smart home in a bad or good way, some people fear losing or stealing/her private data and affecting others with the same feelings when sharing an idea or advice. However, the sub-indicators of reliability are the smart system of forecasting the emergency, the smart system of environmental situations and status, the smart system of remote control devices, and the privacy protection.

Therefore, we hypothesize that:

H4: Social influence significantly influences users' perceived security risks of smart homes.

H5: Social influence significantly influences users' perceived privacy risks of smart homes.

H6: Social influence significantly influences users' perceived financial risks of smart homes.

H7: Social influence significantly influences users' trust in smart homes.

## 3 Research Methodology

This study followed a quantitative approach to address the research aim and answer the research questions. An online-based survey that includes items in a five-point Likert scale was used to assess factors such as social influence, trust, and the three types of perceived risks. The survey questionnaire was available through Google Forms, and the link to the survey was circulated among the respondents through social media networks (Twitter, Facebook, LinkedIn, and Instagram). A convenience sampling approach, followed by a snowball technique (to increase the response rate), was considered to approach respondents who are aware of smart homes in UAE, residents in any emirate in the UAE, and age range between 18 and 65. A total of 158 responses were recorded during a one-month duration (7 April–7 May, the year 2022), and all responses were found complete and unbiased. The survey was available in one language (English).

Then, the data were downloaded from the Google Form in an excel sheet format. Afterward, all survey items were checked and recorded in order to prepare them for analysis. By reviewing the items, the responses were completed and deemed valid for the research and showed readiness for analysis.

## 4 Findings and Discussion

The SEM-PLS approach includes two model testing: the measurement and the structural models. The measurement model represents the relationships between the manifest variables (items) and the latent variables such as the estimates of the validity and reliability, whereas the structural model represents the relationships between the latent variables, through which the research hypotheses could be tested. The structural model results show that all item loadings scores are above the threshold of 0.6 [16], and therefore, all items demonstrated validity, as shown in Table 1.

In addition, the reliability estimate is assessed through the Cronbach's Alpha measure scores. As shown in Table 2, the Cronbach's Alpha scores of all constructs exceeded the cut of point of 0.7 [16]. Also, the validity of the latent constructs was also assessed through the average variance estimated (AVE). As a result, all latent constructs demonstrated validity as all associated AVE scores exceeded the threshold of 0.5.

**Table 1** Item loadings

| | Financial risks | Privacy risks | Social influence | Security risks | Trust |
|---|---|---|---|---|---|
| FinRisk1 | 0.913 | | | | |
| FinRisk2 | 0.846 | | | | |
| FinRisk3 | 0.887 | | | | |
| PrivRisk1 | | 0.902 | | | |
| PrivRisk2 | | 0.859 | | | |
| PrivRisk3 | | 0.924 | | | |
| SI1 | | | 0.905 | | |
| SI2 | | | 0.919 | | |
| SI3 | | | 0.93 | | |
| SecRsk1 | | | | 0.858 | |
| SecRsk2 | | | | 0.849 | |
| SecRsk3 | | | | 0.778 | |
| SecRsk4 | | | | 0.869 | |
| Trust1 | | | | | 0.866 |
| Trust2 | | | | | 0.91 |
| Trust3 | | | | | 0.918 |
| Trust4 | | | | | 0.855 |

**Table 2** Validity and reliability estimates

| | Cronbach's Alpha | rho_A | Composite reliability | Average variance extracted (AVE) |
|---|---|---|---|---|
| Financial risks | 0.857 | 0.86 | 0.913 | 0.779 |
| Privacy risks | 0.877 | 0.891 | 0.924 | 0.802 |
| Security risks | 0.86 | 0.86 | 0.905 | 0.704 |
| Social influence | 0.907 | 0.918 | 0.942 | 0.843 |
| Trust | 0.91 | 0.911 | 0.937 | 0.788 |

As for the discriminant validity, it was demonstrated by having the diagonal scores of the equation: SQRT(AVE) to be greater than all constructs' intercorrelations, as displayed in Table 3.

Secondly, the structural model is evaluated, and the hypotheses were tested. The path coefficients (beta scores), T-statistics, and P-values of the SEM-PLS bootstrapping algorithm were calculated and examined. As a result, the majority of the hypotheses were supported, as the p-values were found below the cut-off point of 0.05 [16], except for the two hypotheses associated with the influence of financial risks and privacy risks on users' trust. All hypothesis results are shown in Table 4.

The research model was tested in SmartPLS3.0 statistical software as shown in Fig. 1.

**Table 3** Discriminant validity and constructs' intercorrelations

| | Financial risks | Privacy risks | Security risks | Social influence | Trust |
|---|---|---|---|---|---|
| Financial risks | 0.882 | | | | |
| Privacy risks | − 0.726 | 0.896 | | | |
| Security risks | 0.68 | − 0.675 | 0.839 | | |
| Social influence | − 0.33 | 0.285 | − 0.375 | 0.918 | |
| Trust | − 0.593 | 0.509 | − 0.743 | 0.58 | 0.888 |

**Table 4** T-statistics and P-values of regression paths

| Regression path | H# | Original sample (O) | Sample mean (M) | Standard deviation (STDEV) | T-statistics (\|O/STDEV\|) | P-values |
|---|---|---|---|---|---|---|
| Security risksTrust | H1 | − 0.565 | − 0.563 | 0.085 | 6.651 | 0 |
| Privacy risksTrust | H2 | − 0.083 | − 0.078 | 0.095 | 0.876 | 0.381 |
| Financial risksTrust | H3 | − 0.158 | − 0.155 | 0.086 | 1.973 | 0.048 |
| Social influenceSecurity risks | H4 | − 0.375 | − 0.382 | 0.072 | 5.197 | 0 |
| Social influencePrivacy risks | H5 | 0.285 | 0.291 | 0.083 | 3.448 | 0.001 |
| Social influenceFinancial risks | H6 | − 0.33 | − 0.334 | 0.076 | 4.315 | 0 |
| Social influenceTrust | H7 | 0.58 | 0.583 | 0.051 | 11.479 | 0 |

## 5 Discussion and Conclusion

In the current research model, trust in smart homes in UAE is explained in 66.8% by exogenous variables (perceived security risks, privacy risks, financial risks, and social influences). It is worth mentioning that perceived security risks scored the biggest impact on trust in smart homes ($\beta$ = -0.565, T-statistic = 6.651, P-value = 0.00). Security risks are perceived as a significant negative factor that can mitigate consumer trust in smart homes. Similar to Karale [12], security risks in the form for cybersecurity attacks, hackers, viruses, Trojans, and malicious software can decrease the level of consumer trust regarding any smart device or appliance. In order to deal with those security vulnerabilities, users should be educated about some security countermeasures, such as smart contracts, blockchain technology, and trust frameworks, such as the Hawk framework (cryptographic protocols), and a trusted

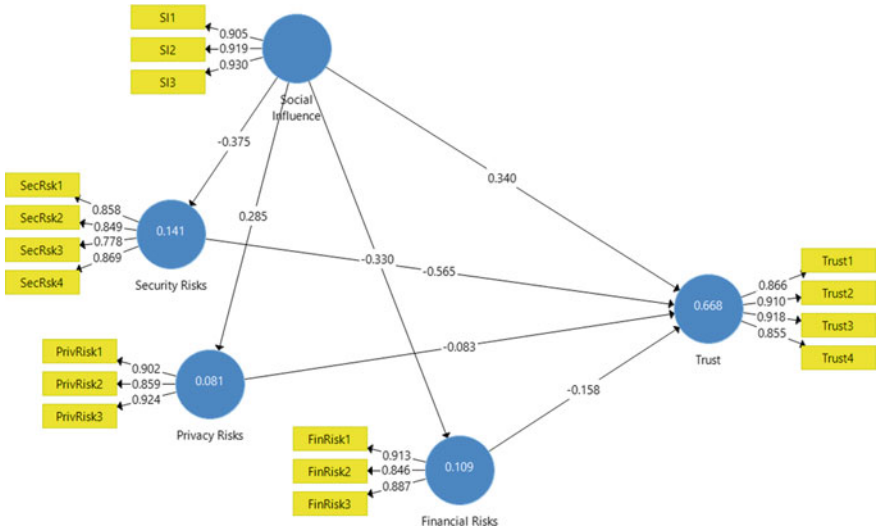


**Fig. 1** Research model (tested in SmartPLS software)

execution environment (TEE) which ensures greater privacy and superior execution (Karale [12]).

Similarly, perceived financial risks deemed to have a significant negative impact on users' trust in smart homes in UAE ($\beta$ = -0.158, T-statistic = 1.973, P-value = 0.048). It seems that people's concern to lose their money in paying for smart devices and appliances can decrease their trust in smart homes. This finding is considered genuine, as no previous studies have examined the relationship between perceived financial risk and trust in smart homes.

Surprisingly, perceived privacy risks were found to have no significant influence on users' trust in smart homes. This could be justified that either people feel confident that their personal data regarding energy consumption is protected, or they do not have big concerns to get their private data breached or shared with a third party. On the other hand, the 'social influences' factor is evident to have a significant impact on all types of perceived risks and a direct impact on trust in smart homes in the UAE (as in Table 4). Social influences are considered as the major driver of trust in smart homes, by influencing the perceived security, privacy, and financial risks through word of mouth, online reviews, and social media content posted by significant others (family members, friends, colleagues, and relatives) [17]. People sharing information about smart homes in UAE can impact their attitudes, behaviors, and their intrinsic values including trust.

## 6 Research Limitations and Future Works

The current research has a few limitations. Firstly, the survey instrument used in the study is prone to design, selection, and response bias. The researchers, however, tried to minimize the effect of the bias by hiring the items of the survey from the relevant literature and employing a panel of three scholars in the domain to check the face validity of the survey instrument. Future work includes extending the research model by including cultural factors, such as the cultural dimensions by Hofstede (individualism/collectivism, uncertainty avoidance, power distance, masculinity/femininity, and long-term orientation). Also, it would be indicative to test the model in other contexts worldwide and to conduct a cross-societal comparison among those contexts.

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# Classification Algorithm for Predicting the Graduation Level: Case Study of e-Learning in Telkom University

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**Abstract** E-learning is one of the technologies used to support the learning process in university level. Telkom University with the university base on technology, Telkom University so intensively apply the learning using e-learning in order to become effective and efficient method. E-learning is used to reduce the cost and time spent learning in an offline class. With e-learning a review system can be done anywhere, because students do not need to come to the classroom to study. Simply by passing the Internet network can already attend the class. With the existing data in the e-learning system can be obtained some information by processing the existing data. This research will be predictions of student data contained in e-learning to determine the performance of algorithms C4.5, Naïve Bayes and Bayesian network, which will be used to determine what factors affect the level of graduation of students to a course. The process will go through several stages of data retrieval, preprocessing and classification, and the process will be done gradually to get the results of all the process.

**Keywords** Classification · Naïve bayes · Bayesian network · e-learning · C4.5 algorithm

## 1 Introduction

Technological advances in various fields are very rapid, one of which is technology in the field of education is e-learning, which is electronic platform that provides content material and proper media such as video and audio that allow student to study independently or discuss the topic in the forum in term of enhancing their capability and understanding [1]. Currently, this kind of process e-learning has become mandatory in certain university to support the learning process such as Telkom University. By

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prioritizing technology, Telkom University is applying many modules, components and various type of approaches to allow this kind of learning model got accepted by students and catering their diverse and different characteristics. This effort is very aggressive because students already need and rely upon the online advice and recommendations revealed by the above data because most of them consume information and interact with society through social media. Therefore, it is merely one reason behind the surge of interest in the new systems that deal directly with opinions as a first-class object, while after all, there are hundreds other reason that make e-learning become critical in the nowadays education process to deliver effective and efficient learning-teaching process. Actually, it aim to the reduce costs and time spent studying in a class offline or face to face wherein student can study by themselves anywhere, anytime and with any devices. These borderless attribute can allow the university to allocate their resources such as lecturer to other contribution spot such as research or working towards society. Therefore, before the implementation take place, the institution should conduct the requirement analysis, instructional design and evaluation mechanism to anticipate accessibility, availability and skill problem that could occur in the process [1].

In general, e-learning is supported by the learning management system (LMS) concept, which can provide a lot of information through data generated in processes through customization of setting based on student and lecturer preferences or personalization in term of history logs or personal data. Some of the information that be presented in term of monitoring process of the student activities carried out in the platform and potential problems in the learning process, which can be used to predict graduation. By revealing this kind of information, the lectured can anticipate the worst case scenario about student before the assumption take place. It is extremely positive effect and critical contribution on the learning process carried out both from the perspective of lecturers or students. In this case, the Moodle Telkom University as the platform used in e-learning process will become the object of research, where the data specifically related to the courses at the faculty of engineering and the application of graduation prediction becomes the theme to be raised by modelling the prediction through the graduation rates from the student based on the percentage of the course.

The data mining method is considered to be the most effective for processing data that has been obtained from e-learning because this method has been extremely popular in term of the extraction process of unknown or raw data into useful data in the form of information [2]. From this concept, it can be taken that the data originating from e-learning is in the form of abstract data which will later be used as useful information in the form of a prediction model of student graduation towards the subject. With the above concept, the researchers will compare three algorithms, namely C4.5, Naïve Bayes and Bayesian network algorithms, which are based on the literature that can be gathered so far by the researchers by comparing several algorithms, there are three that have the best performance. C4.5 algorithm is the popular algorithm in the classification process where uses the decision tree concept in which there is a tree-like structure that starts from the root attribute and ends with leaf nodes [2]. Then, there is the Naïve Bayes and Bayesian network algorithms

that use the Bayesian classifiers concept by using probability operations so that they have maximum accuracy results [3]. This research utilized WEKA application due to personal preferences subjectively to do the process of classification in term of case studies by applying the raw data that has gone through the data mining process, respectively.

## 2 Literature Review

Commonly, the techniques used in the data mining was classified into supervised (classification, decision tree, Bayesian, neural network, association rule mining, regression, etc.) and unsupervised learning (clustering, association, etc.), which is based on the existence of the model development to identify the antecedent for analysis or estimation where certain algorithm has been used to discover problem and prediction, respectively [4]. In comparison, statistical techniques cannot be useful regardless specific assumption about data, while decision tree are not considering complexity or large amount of data in the process of diagnostic. In addition, neural network has difficulty in term of input features, which do not acceptable result [5]. Interestingly, data mining can deliver various advantages based on the context such as help marketing companies to develop historical model to forecast the sales or determining the campaign method, so with banking institution by presenting loan information and credit reporting [6]. Still, proper policy should be in place to support proper response from relevant staff to prevent worst case scenario [7]. Meanwhile, merchandise planning, basket analysis, customer life time value, customer churn, market segmentation and growth prediction can be analysed by combination of data mining algorithm such as association rules, clustering and prediction by considering slow changing the dimension of the data, the transformation of the data value and the model used aligned with the business users [8]. There are two stages in the classification algorithm, which is first, the algorithm attempts to find a model of class attributes as a function of other variables of the data set. Second, a previously designed form is applied to a new data set and does not appear to specify the corresponding category for each record [9].

In addition, C4.5 algorithm is an algorithm used to carry out the classification process using decision tree techniques [10]. It is the development of algorithm ID3 with the same concept, namely the concept of decision tree. The advantage of the C4.5 algorithm related to the capability to process the numerical data, ability to handle missing attribute values, feature to predict data performance and become the one of the most effective algorithms to solve the above problems [10]. The process carried out by the C4.5 algorithm is as follows [3], which are selecting the attribute as root, creating a branch for each value, dividing each case in one branch and repeating the process in each case branch so that all cases in the branch have the same class. Advantages in this process are rules that are very easily understood and interpreted by the user and the processed data tends to be abstract so that when it has gone through the process in the C4.5 algorithm the user will get the desired

information. In WEKA, the C4.5 algorithm is represented by the J48 algorithm that applies the decision tree concept and uses entropy and gets the value [3]. On the other hand, Naïve Bayes is a classification method that can be used to predict the probability of class membership. It comes from the theory of Bayes that has the ability to make quite similar classification of decision trees [11]. The algorithm in this process does not rely on attributes, so the process is relatively fast but in practice there are still frequent dependencies between the features [3], which also use very intuitive techniques. Unlike other neural networks, Bayes classifier do not have many free parameters to adjust, simplifying the design process considerably [12]. In other hand, Bayesian networks are derived from the Bayes algorithm theory, an approach used for uncertainty measured in probability [13]. In searching for data models, Bayesian network algorithms have two processes carried out, namely learning parameters and structures. Learning parameters are generally carried out together with the structure learning process, while structural learning is a trial and error process, with models from all nodes to the results model or vice versa [14].

Due to large availability in which diverse type of online resources that provide platform to allow different character of people to interact, the process for data acquisition become more subjective and depend to the type of media use and the attribute of analysis want to perform [15]. However, there are several challenges in the sentiment analysis such the representative word or statement to state the opinion that can be considered negative and positive due to ambiguity, context or metaphors [16]. Some people have their own characteristics to express their opinion, in which prejudice, presumption and background can determine the meaning of their statement. Another one related to object and feature identification that should be clear before the process has been conducted to distinguish the topic has been given in certain statement and to decide the relevant technique to extract the information [17]. Thus, the grouping process in which determines the synonym and antonym are critical because different word or phrase can be used to refer explicitly and implicitly to certain attribute of something. Meanwhile, opinion also change over time due to trend, demand, pressure or other factors that influence the paradigm or framework of the views. Furthermore, the opinion also has strength, which cannot be considered as merely positive and negative due to the dynamic environment or flexible condition of certain object such as enhancement, improvement or modification [18, 19].

To solve various challenges in term of technicality, managerial, classification, categorization, emotional, ontology, dependency and expression, researches introduce various paradigm by exploiting artificial intelligence, lexical resources and semantic web techniques such as Sentic Computing, ConceptNet, AffectiveSpace, The Hourglass of Emotions, The Human Emotion Ontology and SentiWordNet [20–22]. The foundation of opinion mining is to define assessment, synonym, conclusion, attitude, feeling, idea, impression, judgement, reaction, point of view, sentiment, speculation and thought to distinguish the aspect, entity and the expression [23]. Actually, the opinion has been defined as a quintuple ($o_j, f_{\mathrm{jk}}, oo_{\mathrm{ijkl}}, h_i$ and $t_i$) which defined object of opinion, the feature of the object that opinion is expressed, the sentiment polarity, the opinion holder and the time when the opinion is expressed, respectively [24].

Meanwhile, there are also some common type of errors when analysing the misclassified samples such as shortened messages, abbreviation, slang-version, misspelling, humour, irony and sarcasm and human tagging errors [24, 25]. Interestingly, the researchers can define the perspective of corpus analysis as subjective, which the text usually describe themselves (first person), simple past tense, using adverbs or address the audience (second person) or as objective, which the text usually in the frequent use of modal verbs, superlative adjective, past participle, address by reference or citation [26]. On the other hand, the better result can be obtained through a term presence rather than its frequency and unigrams outperform bigram and trigram when performing the sentiment classification of movie reviews [27]. In other research of product review polarity classification, it was found, otherwise, which bigram and trigram work better compare to unigram [7, 28–30].

## 3 Research Methodology

The researcher uses the first three useful collection of data, namely data from five subjects which are "computer network", "software defined network", "introduction to computer systems", "basic telecommunications systems" and "computer network designs" that is obtained from the system log of e-learning in the Telkom University. In addition, the second data is the final grade of the data index of the students derived from Igracias Telkom University or "single sign on" type platform in the university. Lastly, the third data is the student pop quiz scores obtained from Moodle as the e-learning platform. In this phase, the researcher processes student log data into three stages, which the first is separating the required data and then allocating the module data from student log data that meets the criteria based on five specified activities, namely quiz, assignment, forum, file and interactive content. Then, the second stage is to separate the data obtained from the previous process based on the five activities mentioned, while the third stage is to calculate the data that has been generated previously to produce the amount of access from each activity.

All of the above stages will be processed using Pentaho Data Integration (PDI). Furthermore, the resulting data will be combined with the final student grade index data and the average results of the pop quiz score. After that, the data will be combined to allow the classification process to be carried out. Figure 1 shows the process of separating student log data based on modules that fulfil the five specified attributes, which the process uses several tools that have been provided in Pentaho Data Integration (PDI). Figure 2 shows the process of separating student log data based on predetermined activities, which also utilized several tools that have been provided in PDI. Meanwhile, Fig. 3 shows the detail process of separating student log data based on predetermined activities through specific calculation. After completing the three processes above, the last process is to combine the results of calculating the number of access activities of each subject with the student index value. Afterwards, they will be combined again with the data quiz pop value that has been calculated

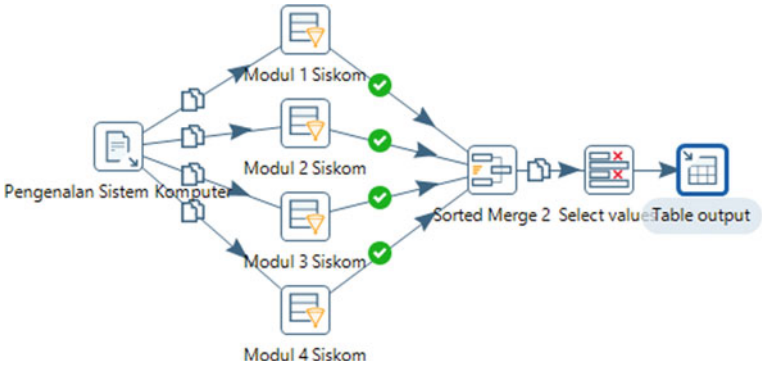


**Fig. 1** First selection process based on module

on average and then combined into one file in this case called DataGabungan.csv, which has be done manually because PDI do not have feature to allow this process.

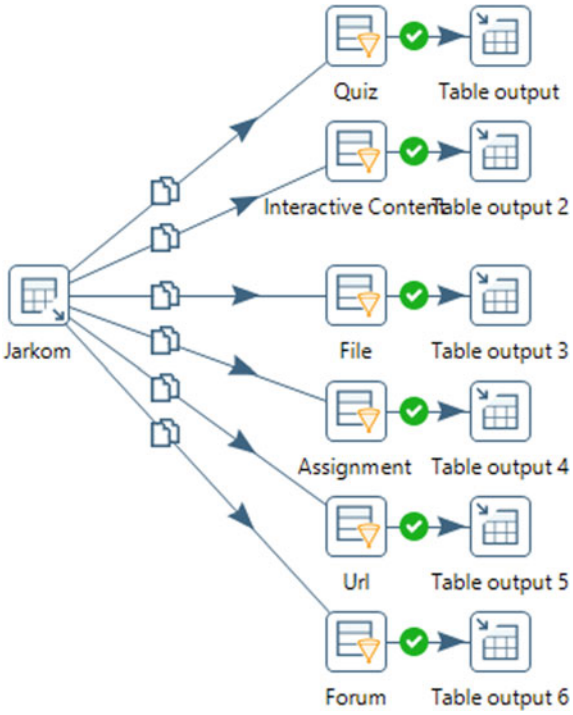


**Fig. 2** Second selection process based on activity

**Fig. 3** Calculation process of total access based on activity

## 4 Performance Comparison

Text, opinion and sentiment mining is another form of data mining which have shared similar and different attributes or characteristics that can be used to explore the important information, specific pattern and collaborated knowledge within the platform that is required human interpretation to make it accurate and precise based on the context [31]. Interestingly, some study also compare the implementation of J48 of C4.5 algorithm with Naïve Bayes classifier for predicting the survivability of lung cancer that confirm J48 marginally better than the Naïve Bayes techniques but detailed description of the data and the required preprocessing activities should be taken in the notes with some issues appeared during experimentation [32]. In the algorithm performance analysis stage, the results of the classification process performance will be compared so that the algorithm has the highest performance of the three algorithms used. In this process, the algorithm will be compared based on TP rate, FP rate, precision, recall and F-measure. From the results below, the results of the C4.5 algorithm show that true positive are from the average (0.515), bad (0.515), excellent (0.865) and good (0.740) with the average (0.739). Meanwhile, from the other results below, the results obtained from the Naïve Bayes algorithm that true positive are from the average (0.356), bad (0.844), excellent (0.585) and good (0.265) with an average (0.441). Lastly, from Table 1, 2 and 3, the results obtained from the Bayesian network algorithm that true positive are from the average (0.069), bad (0.800), excellent (0.643) and good (0.689) with the average (0.441).

From the results of the comparison of the algorithm performance, it was found that C4.5 algorithm had the highest accuracy with a result of 73% and with an average "true positive rate (TPR)" of 0.739, then the Bayesian network algorithm had an accuracy of 56% with an average TPR of 0.561 and the last algorithm Naïve Bayes with 44% accuracy with an average of TPR of 0.441. However, certain circumstances should be put into the context as Naïve Bayes as a simple method in certain cases

**Table 1** Performance result from C4.5 algorithm

| TP rate | FP rate | Precision | Recall | F-measure | MCC | ROC area | PRC area | Class |
|---|---|---|---|---|---|---|---|---|
| 0.515 | 0.046 | 0.732 | 0.515 | 0.605 | 0.540 | 0.884 | 0.671 | Average |
| 0.756 | 0.032 | 0.694 | 0.756 | 0.723 | 0.696 | 0.976 | 0.688 | Bad |
| 0.865 | 0.137 | 0.759 | 0.865 | 0.809 | 0.707 | 0.922 | 0.798 | Excellent |
| 0.740 | 0.167 | 0.732 | 0.740 | 0.736 | 0.572 | 0.852 | 0.745 | Good |
| 0.739 | 0.122 | 0.738 | 0.739 | 0.733 | 0.621 | 0.892 | 0.743 | |

**Table 2** Performance result from Naïve Bayes algorithm

| TP rate | FP rate | Precision | Recall | F-measure | MCC | ROC area | PRC area | Class |
|---|---|---|---|---|---|---|---|---|
| 0.356 | 0.192 | 0.313 | 0.356 | 0.333 | 0.157 | 0.669 | 0.288 | Average |
| 0.844 | 0.231 | 0.260 | 0.844 | 0.398 | 0.385 | 0.879 | 0.404 | Bad |
| 0.585 | 0.137 | 0.680 | 0.585 | 0.629 | 0.466 | 0.813 | 0.678 | Excellent |
| 0.265 | 0.167 | 0.495 | 0.265 | 0.346 | 0.118 | 0.619 | 0.492 | Good |
| 0.441 | 0.168 | 0.500 | 0.441 | 0.442 | 0.265 | 0.716 | 0.506 | |

**Table 3** Performance result from Bayesian network algorithm

| TP rate | FP rate | Precision | Recall | F-measure | MCC | ROC area | PRC area | Class |
|---|---|---|---|---|---|---|---|---|
| 0.069 | 0.022 | 0.438 | 0.069 | 0.120 | 0.109 | 0.731 | 0.338 | Average |
| 0.800 | 0.103 | 0.429 | 0.800 | 0.558 | 0.533 | 0.924 | 0.425 | Bad |
| 0.643 | 0.149 | 0.683 | 0.643 | 0.663 | 0.502 | 0.839 | 0.686 | Excellent |
| 0.689 | 0.369 | 0.536 | 0.689 | 0.603 | 0.311 | 0.688 | 0.536 | Good |
| 0.561 | 0.204 | 0.556 | 0.561 | 0.524 | 0.354 | 0.768 | 0.537 | |

can be outperform decision tree, k-nearest neighbour, Dominggos and Pazzini due to the data independence or zero–one loss function used in the classification or even the process of distribution among all attributes over classes [33–35]. Even though the probability estimates that are produced are inaccurate, Naïve Bayes often generate true maximum probability of the accurate class, which shows good performance may be limited to context of categorical output [34]. At certain occasion, the fast calculation time by decision tree can be occurred due to the absence of classification process, which bigger training set lead to bigger memory requirement and larger distance calculation must be performed [12].

## 5 Conclusion

After conducting multi-stage research on testing the performance of the C4.5, Naïve Bayes and Bayesian network algorithms to measure the accuracy of student data derived from the Telkom University, in this case, implemented on Moodle e-learning's data log. The researcher concludes that the C4.5 algorithm is the most effective with a classification value of 73% while it also has the greatest data accuracy with a TPR of 0.739. However, it is recommended that the interpretation results should consider the other aspects of external and internal motivation such as role model, facilities or infrastructures, reward and punishments, culture, etc.

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# Performance Evaluation and Analysis of Wi-Fi Security Protocols

**Saptorshi Bhattacharjee and Kishore Kumar Senapati**

**Abstract** In the twenty-first century as the technology evolves in a rapid pace, more and more number of users and businesses are getting connected to the Internet. A vast majority of these users use the wireless mode (Wi-Fi) for getting connected to the Internet. As the number of users and the online transactions rises in billions so is the risk of a cyber-fraud, due to the vulnerabilities present in the Wi-Fi protocols (WEP, WPA and WPA2). Security remains a huge challenge as Wi-Fi passwords could be cracked from both home and enterprise-level networks by using the tools and by performing social engineering attacks. Data protection is a huge challenge for computer scientists, and in this work, the investigators have identified the loopholes of Wi-Fi encryption protocols. The identification procedures are tested on a test network with various Wi-Fi encryption protocols in a controlled laboratory setup. Data packets from the wireless networks could be easily sniffed by using aircrack-ng software suite for capturing the handshake and ultimately for cracking the password from huge wordlists. The process of cracking the password could also be speed up by using a Graphics Processing Unit (GPU) which performs set of repetitive tasks in a faster way and helps in extracting passwords. The overall investigation helps investigators to understand the vulnerabilities present in the modern-day Wi-Fi protocols. Hence, it has been proposed the use of RADIUS server model like in an enterprise network and the use of Wi-Max standard of security for better safety measures.

**Keywords** Wi-Fi encryption protocols · WEP · WPA · WPA2 · Aircrack-ng · GPU-based cracking · RADIUS server

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# 1 Introduction

Wi-Fi was introduced to the world back in September 21, 1997 by IEEE 802.11, and this marked the beginning of wireless technologies. Ever since then plethora of devices, namely laptops, tablet PC's, mobile phones, wearable gadgets and many more devices got added to the Internet via wireless means. With the introduction of Internet of Things, even household devices like refrigerators, washing machines, etc., have also got connected to the Internet via wireless means by using Wi-Fi. However every scientific inventions comes with its own set of drawbacks and so does the Wi-Fi. [1]

Wi-Fi has often seen many security challenges as it is relatively easier to snoop a wireless network than a wired one. However, data is encrypted before transmission over the network, yet there are flaws in the design of the wireless security protocols which leads to the theft of data and there is information breach. Hence, the security protocols of wireless networks have evolved from Wired Equivalent Privacy (WEP) to Wi-Fi Protected Access (WPA) to Wi-Fi Protected Access2 (WPA2) to finally Wi-Fi Protected Access3 (WPA3). WEP being the first and the oldest security protocol could be cracked by using tools such as aircrack-ng in very little or no time at all. The succeeding protocols, namely, WPA and WPA2 also fall prey to different cryptographic and statistical attacks, and the passwords used to encrypt data from those networks could be compromised and hence leads to data breach. The process of password cracking could be speed up to a great way by the use of Graphics Processing Units (GPUs). GPUs are optimized in a way to perform repetitive set of tasks in a much higher speed than CPU's, and hence, the use of GPU's in password cracking is an enhanced step to crack the password of the network. GPUs are also efficient in performing complex mathematical calculations and computing hashing algorithms in very less time; hence, password cracking with password cracking tools such as hashcat when used along with GPU could speed up the process of cracking and can exploit the vulnerability that is present within the Wi-Fi encryption security protocols.

# 2 Wi-Fi Security Protocols Review

## *2.1 Wired Equivalent Privacy (WEP)*

WEP was released back in the year 1997 to provide a strong mechanism to the wireless Internet to encrypt data in a secure way. It was intended to provide security to the level that of wired networks, hence the name. It is the first wireless security protocol, hence, a very old one. It uses RC4 as its base algorithm for encryption. The key stream comprises the initialization vector (IV) and the key (password). The IV too small and comprises only 24-bits, which is normally sent in plain text and hence

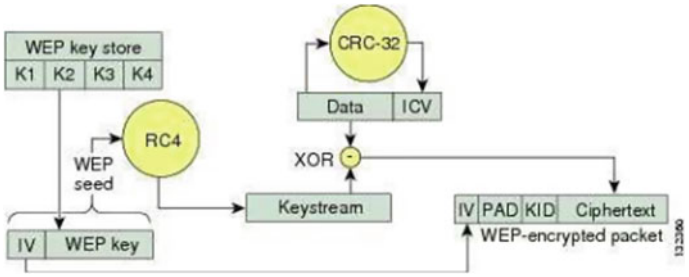


**Fig. 1** WEP encryption process [1]

is easy to capture and crack. This is still used in some of the older devices running older encryptions (Fig. 1). [2]

## *2.2 Wi-Fi Protected Access (WPA)*

The weaknesses of the WEP led IEEE to come up with a newer standard of security, and hence, Wi-Fi Protected Access or WPA was formed. This kept using the RC4 algorithm but added an extra layer of security in the name of Temporal Key Integrity Protocol (TKIP). The TKIP is 128-bit dynamic key as compared to the static key of WEP which remains unchanged. It uses a longer key which lengthens the initialization vector (IV) to 48 bits. TKIP generates different keys for each client and alters keys for each successive packet. This was found to be more secure than its predecessor WEP (Fig. 2). [2]

## *2.3 Wi-Fi Protected Access 2 (WPA2)*

Wi-Fi Protected Access 2 or WPA2 is the strongest to the previous two versions and was introduced back in the year 2004. From 2006 onwards, Wi-Fi alliance directed that all potential Wi-Fi gadgets must adhere to the latest WPA2 protocol for ensuring safety. WPA2 is based on the Cipher Square Chaining Message Confirmation Code Convention (CCMP) which is a better technique for encrypting data. WPA2 uses Advanced Encryption Standard (AES) which is a symmetric block cipher with key length of 128 bits and IV of 48 bits.

WPA2 is available in two modes, namely personal and enterprise networks. In personal networks, the pre-shared key (PSK) mode is used, which is the key is to be shared to the clients beforehand for them to connect and use the network. This key is same and common to all the clients using this network. In the enterprise model, there is a RADIUS server implementation which provides individual pair of login credentials to each client connected to the network. This mode of WPA2 is found

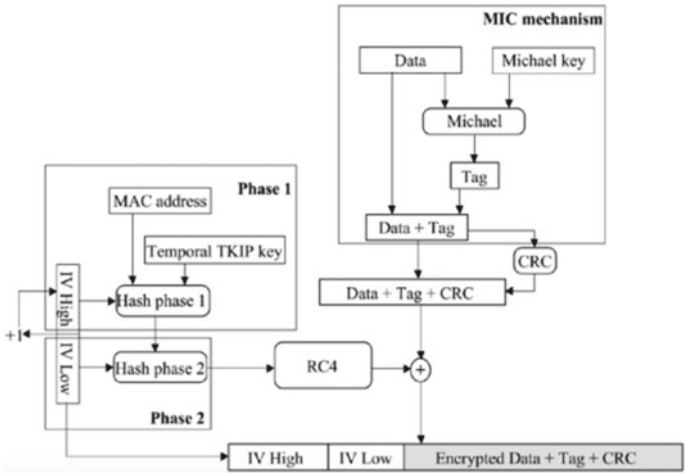


**Fig. 2** WPA encryption process [1]

to be safer, yet some recent studies have shown some weaknesses in the enterprise model which prove to be a challenging aspect from security point of view (Figs. 3 and 4). [2]

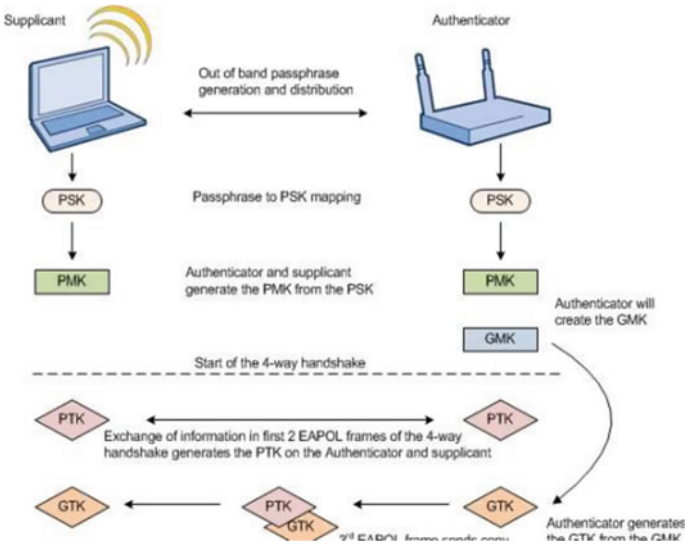


**Fig. 3** WPA2 encryption process [1]

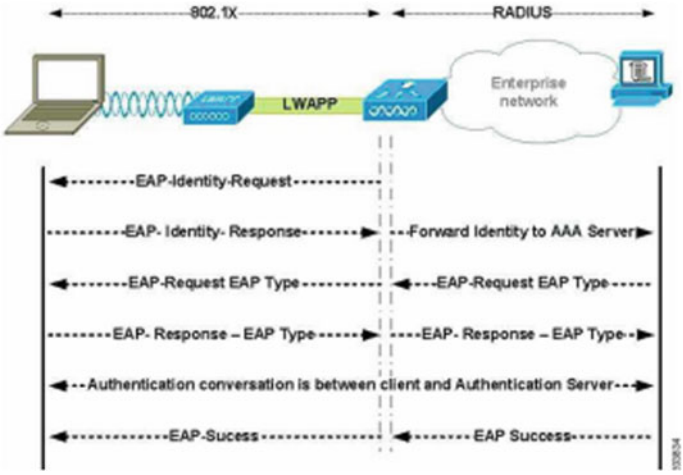


**Fig. 4** WPA2 enterprise encryption process [1]

## 3 Tools for Wi-Fi Cracking

### *3.1 Aircrack-Ng*

Aircrack is an open source complete suite of tools for assessment of Wi-Fi network security for the purpose of testing its strength and detecting the vulnerabilities present in them. The different aspects of Wi-Fi security that it covers are:-

**Monitoring**: This includes capturing of packets and analyzing them for information.

**Attacking**: Packet injection, deauthentication attacks, evil twin attacks to name a few.

**Testing**: Testing of the Wi-Fi card and capability of driver.

**Cracking**: This includes WEP and WPA (both 1 and 2).

### *3.2 Hashcat*

Hashcat is password cracking tool. This can be used to obtain passwords by the use of cryptographic hash functions and easily detects the actual passwords. Hashcat can also be used along with the GPU which fastens up the cracking process.

## 4 Proposed Work

The 4-way handshake is captured by using airodump-ng by targeting a particular test network. Each key is selected from the wordlist and a new Message Integrity Code (MIC) is generated, and the captured MIC is verified against the generated MIC, and if match is found, then that key turns out to be the password (Fig. 5).

4.0.1 The network adapter is connected to the Kali Linux Virtual Machine and its mode is changed from Managed to Monitor to capture data.
4.0.2 If the connection turns out to be WEP, then large number of packets are captured, which also captures the initialization vector IV. The password could be captured by analyzing those captured packet by using aircrack-ng.
4.0.3 Else if the connection turns out to be WPA/WPA2, then we have to first capture the 4-way handshake.
4.0.4 Create a long wordlist by using crunch.
4.0.5 Cracking the key by using the wordlist and aircrack-ng by applying a wordlist attack.

### *4.1 Security Testing for WEP Networks (Fig. 6)*

4.1.1 Changing the mode of the wireless adapter from Managed to Monitor.
4.1.2 Capturing large no. of packets—using airodump-ng
4.1.3 airodump-ng –bssid < MAC id > – < channel > –write basic-wep wlan0

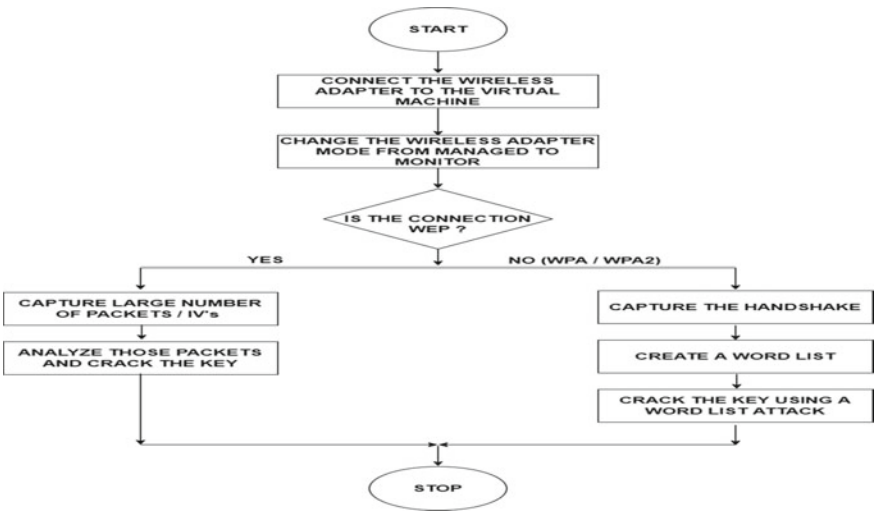


**Fig. 5** Flowchart for the cracking process

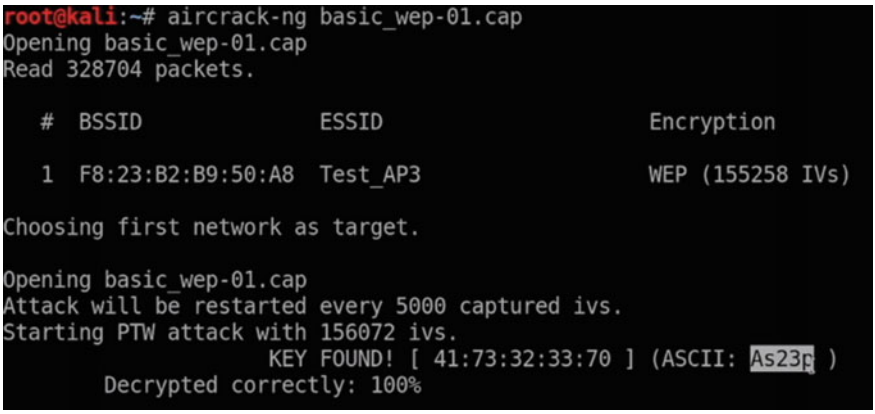


**Fig. 6** Extracting WEP password

4.1.4 Analyze the captured IV's and crack the key—using aircrack-ng
4.1.5 aircrack-ng basic-wep-01.cap

## *4.2 Security Testing for WPA/WPA2 Networks (Figs. 7 and 8)*

4.2.1 Capturing a Handshake

airodump-ng –bssid <Target MAC> –channel no –-write wpa-handshake wlan0
aireplay-ng –-deauth 4 –a<Target MAC> -c<Client MAC> wlan0

4.2.2 Creating a Word List (Using Crunch)

Crunch <min> <max> <characters> -o Filename
crunch 6 8 aegt012345 –o longlist.txt

4.2.3 Cracking with wordlist of 100 M passkey/passcode

Cracking using aircrack-ng
aircrack-ng wpa_handshake.cap –w longlist.txt

**Fig. 7** Capturing handshake

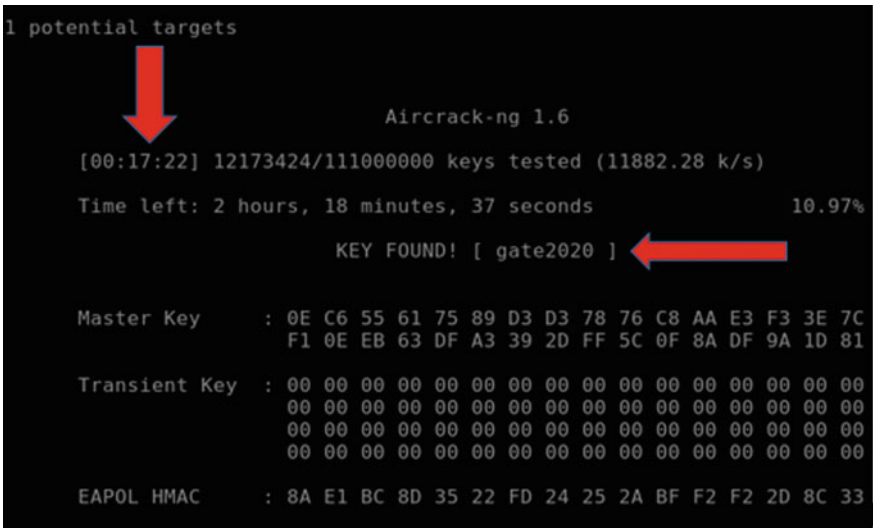


**Fig. 8** Cracking the key in WPA/WPA2

## *4.3 Enhanced Cracking Using Hashcat*

The cracking process mentioned in the above section could be speedup by using a Graphics Processing Unit (GPU). GPUs are optimized for performing repetitive set of task in a much faster way, and hence proves useful in our investigation work.

Converting the (.cap) handshake file to (.hc22000) file.

The handshake file (.cap) needs to be converted to a relevant file which Hashcat can read. This created a compatible file for Hashcat which is (.hc22000) file, which is now placed at the same directory where Hashcat is placed (Fig. 9).

Invoking hashcat with the following command

hashcat –m 22000 –d 1 handshake.hc22000 longlist.txt

## *4.4 Security Testing for WPA2 Enterprise (Radius Server)*

WPA Enterprise uses authentication where each user gets their separate login credentials to connect to the network. Authentication over here is managed by a central server also termed as RADIUS server. This is unlike to the home network, where same pre-shared key (PSK) is used for all of the clients to connect to the network.

In enterprise network, the user could be duped by creating a fake access point and then de-authenticating the user from the network. While trying to connect back, there

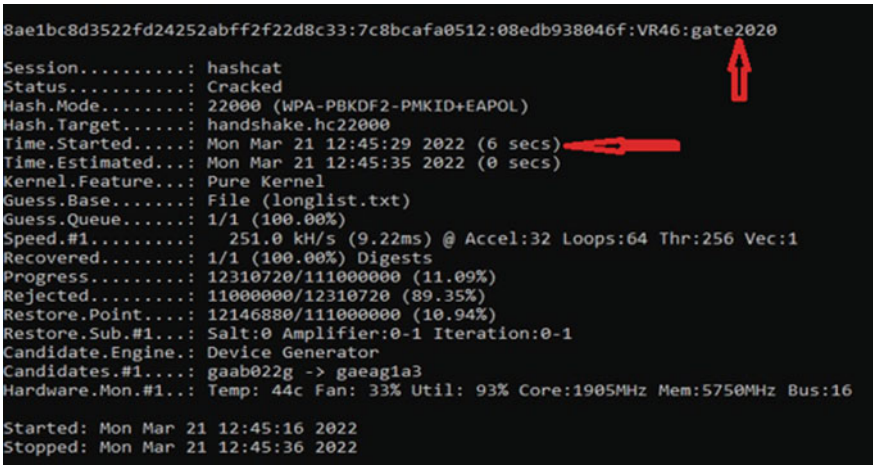


**Fig. 9** GPU-based cracking using Hashcat

can be a misunderstanding and the user might connect to the wrong network with the same name which is created by the attacker. This helps to capture the credentials and decrypt them. The entire process is termed as Evil Twin attack.

For this, we need to install modified version of **hostapd** to generate duplicate access point. It is designed to run fake access point for WPA Enterprise with free radius server.

apt-get install hostapd-wpe

Change the SSID field to the target network name in the configuration file and leaving the rest to be the same.

leafpad /etc./hostapd-wpe/hostapd-wpe.conf

Set up the fake access point.

hostapd-wpe/etc/hostapd-wpe/hostapd-wpe.conf

When user tries to connect to the network, the username, challenge and response get captured. The captured challenge and response are in NetNTLM encryption format and can be decrypted by using asleap using a dictionary attack (Fig. 10).

asleap –C <challenge> -R <response> -W <wordlist path>

**Fig. 10** Cracking WPA enterprise password

**Table 1** Comparison result

| Mode of Cracking the key | Time Taken |
|---|---|
| Aircrack + Wordlist(111 M keys) | 17 min 22 s |
| Hashcat(GPU Enabled) + Wordlist(111 M keys) | 6 s |

### *4.5 Experimental Results*

**Laboratory Configurations**
Penetration testing OS—Kali Linux,Wi-Fi adapter with the facility of monitor mode, Aircrack-ng software suite, Airodump-ng, Aireplay-ng, Crunch, Hashcat.

**Physical Machine**
Processor—Intel Core i5-10400F 2.90 GHz
Installed Memory–16 GB
GPU—Nvidia GeForce GTX 1650 SUPER–4 GB
Operating System—Windows 10 Home, 64-bit

**Virtual Machine**
Installed Memory—8 GB
Operating System—Kali Linux 2021

After successful testing of the WPA/WPA2 protocol, it was observed that it around 17 min and 22 s to crack the key using aircrack-ng software suite, when using a wordlist of around 111 million passwords.

Whereas when the handshake file was converted to its corresponding WPA/WPA2 hash value for using it in hashcat, it was observed that the password was successfully cracked in only 6 s which is a huge improvement to its previous method (Tables 1 and 2).

## 5 Conclusion and Future Scope

Wireless LAN is picking up high popularity; it is very crucial to keep the security perspective in mind so as to secure the communication. Out of all, the wireless LAN technologies available the Wi-Fi technology have gained highest popularity yet it is to be understood that it is not so secure. IEEE has chosen a few standards for wireless security protocols, namely WEP, WPA and WPA2. WEP is the first security protocol but was not able to keep pace with the security challenges that gets arrived. At that point, WPA was introduced which overcomes the shortcomings of WEP, and TKIP algorithm was introduced to strengthen the protocol. This was succeeded by WPA2 which used Advanced Encryption Standard (AES) at its core with the support of CCMP. But this might still fall in prey to the attack due to various statistical and brute force attack.

Hence, to prevent the user from vulnerabilities, they must:-

**Table 2** Comparison of the Wi-Fi security protocols

| Parameters | WEP | WPA | WPA2 |
|---|---|---|---|
| Type | To provide security in contrast to wired networks | Implementing major IEEE 802.11i with WEP without new hardware | Complete IEEE standards are implemented with new WPA enhancements |
| Encryption | Rivest Cipher 4 (RC4) | Temporal key integrity protocol (TKIP) | Advanced encryption standards (AES) |
| Authentication | WEP-Open and WEP-Shared | WPA-PSK and WPA Enterprise | WPA2-PSK and WPA2-Enterprise |
| Data integrity | CRC-32 | MIC | CBC-MAC |
| Key management | Not provided | 4-way handshake is used | 4-way handshake is used |
| Compatibility | Only compatible with older hardware | Compatible with both older and newer hardware | Compatible only with newer hardware |
| Vulnerability | High | Medium | Low, but vulnerable against DoS attacks and MAC spoofing |
| Deployment complexity | Easy to deploy and configure | Moderate to deploy | WPA2 requires configuration is complicated |
| Replay attack protection | None | Implements sequence counter | Implements 48-bit datagram |

5.0.1 Always utilize WPA2 over any other protocol.
5.0.2 Use longer key length which eventually increments the key space and consequently decreases the chances of brute forcing the password.
5.0.3 Use of enterprise model with RADIUS server execution is suggested for domestic use.
5.0.4 Implementation of WPA3 security model in modern devices.

As a future work to this, there can be more elaborate testing of the WPA2-Enterprise network which can explore many more of its weaknesses and ways to penetrate the network. RADIUS server model of implementation could be thoroughly tested for loopholes. Research on WPA3 model of security is needed so as to predict its weaknesses. Wi-Max model of security could be an add-on to the already existing model.

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# Business Information System Analysis Techniques Acceptance

**Małgorzata Pańkowska**

**Abstract** Nowadays, companies are conscious of the importance of information system business analysis (BISA) and business architecture (BA) development to represent and manage information technology (IT) in a holistic way. Business organizations require hybrid approaches that combine different modeling techniques. This paper covers literature survey of information system analysis techniques, their applicability in university teaching and in research projects, and their acceptance by students. This paper includes a system analysis acceptance model for assessing students' attitudes to use the system analysis modeling techniques. Furthermore, this study allows to compare BISA techniques in the aspect of their acceptance. Findings of this paper could support modeling business organization assets and activities and may encourage business analysts to simultaneously learn and apply the modeling techniques. Constantly, the most popular modeling techniques set covers business process modeling notation (BPMN), unified modeling language (UML), data flow diagram (DFD), and decision trees.

**Keywords** Business information system · System analysis · Modeling technique · Technology acceptance · Method acceptance

## 1 Introduction

System architecture modeling and business information system analysis concern application of models, techniques, and software tools. The basic issue is what a model is and how it can be used. In this paper, at first, model is a concepts' view developed for information system implementation, and next, model is an abstract structure of interrelationships among socio-economic variables. Hence, we focus on business information system analysis for information system conceptualization, which is considered as initial stage in system life cycle.

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The paper covers four research questions and six hypotheses. The research questions refer to analysis and modeling techniques applied in research projects and in university education processes. Research questions are needed in the descriptive literature reviews. Hypotheses are formulated for verification of the business analysis acceptance model. The paper is organized as follows. The next part covers literature review on business information system analysis and business modeling, and explanation of their similarities and differences between them. The third section includes literature survey on teaching of BISA techniques at universities during information system development courses. Later, students' survey results are presented, and the system analysis acceptance model is specified, estimated, and discussed. Finally, conclusions are formulated.

## 2 Business Information System Analysis Techniques in Literature Survey

Business organization modeling as well as system implementation require identification of stakeholder information and communication. Business stakeholders may have unique information requirements and make idiosyncratic decisions. Therefore, their information system needs are different although comparable.

According to *A Guide to the Business Analysis* [1], techniques used at the business analysis stage include benchmarking and market analysis, business capability analysis, business model canvas, business case analysis, concept modeling, data mining, document analysis (i.e., reports, agreements), analysis of performance metrics and key performance indicators (KPIs), mind mapping, modeling roles, responsibilities and structures, process modeling, and strengths, weaknesses, opportunities, threats (SWOT) analysis. Defining information system requirements and solutions is based on business capability analysis, concept modeling, data dictionary construction, data flow diagramming (DFD), data modeling with UML. Business analysis techniques are differently classified. There are techniques oriented toward risk recognition, values, opportunities, potential benefits, business rewards, functions, actors, data, computing circumstances, and outcomes (Fig. 1).

Business models as abstract representations of an organization may include the application of different techniques, and the set of these is always open. New techniques are added or existing ones modified. Business analysis is realized for information system development as well as for enterprise architecture development, and particularly for business architecture. Gharajedaghi defines business architecture as a system, for which purposes, functions, elements, processes, and nature of interactions among them are defined [2]. In literature review, business analysis concept has much more (almost eight times more) connotations than business architecture. In this study, literature survey has allowed to present the research results on business architecture analysis models and techniques and particularly to receive answers to the following questions (RQ):

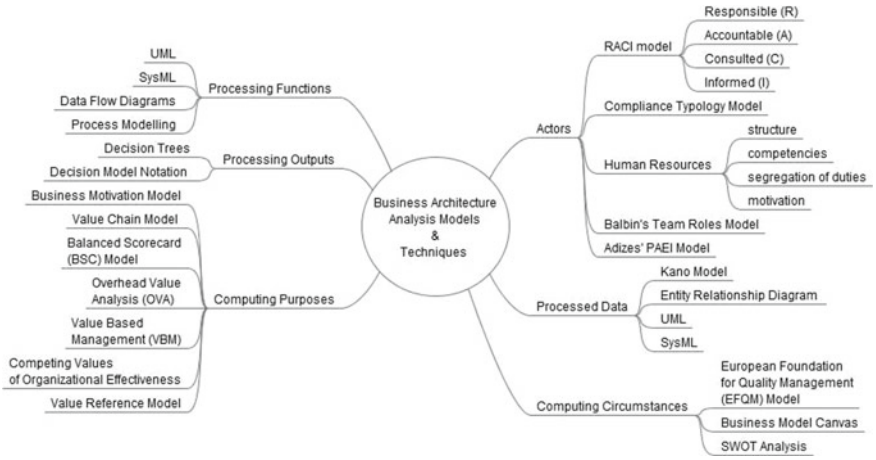


**Fig. 1** Business analysis models and techniques

**RQ1**: What modeling techniques are applied for business information system analysis?

**RQ2**: What modeling techniques are applied for business architecture analysis?

The fundamental surveys have been done using the following publication repositories: Association of Information Systems electronic Library (AIS eLib), IEEEXplore, SAGE Journals, ScienceDirect, and Scopus. The literature surveys covered materials published in years 2010–2022. Taking into account RQ1, the searching was conducted via the search string "business" AND "analysis". Unfortunately, the search results mostly were not strictly connected with information modeling. The papers were on general business activities in economics aspect. The dispersion of business analysis applications and techniques was high, so in the next step, the searching was realized through the string "business" AND "architecture". This approach permitted to reveal publication on business information analysis techniques. In general, we have received 26,651 searching results. In Fig. 2, the graph is based on standardized numbers of publications in repositories because of highly differentiated numbers of volumes in repositories. The standardization was done in the following way:

$$x_{ij}^{s} = x_{ij} / \mathrm{AVG}(x_i) \tag{1}$$

where $j = 1 \ldots m$, m–number of techniques, $i = 1 \ldots n$, n–number of repositories, $x_{ij}$–original value, $x_{ij}{}^{s}$–standardized value.

The volume of publications in repositories is consistently growing. However, some techniques, i.e., decision trees, influence diagram, data structure design, Unified Modelling Language (UML), Business Process Model and Notation (BPMN), and Web Ontology Language (OWL) are notably more popular, and hence, more important than others, i.e., ArchiMate, Business Motivation Model (BMM), Case Management Model and Notation (CMMN), Decision Model and Notation (DMN), System

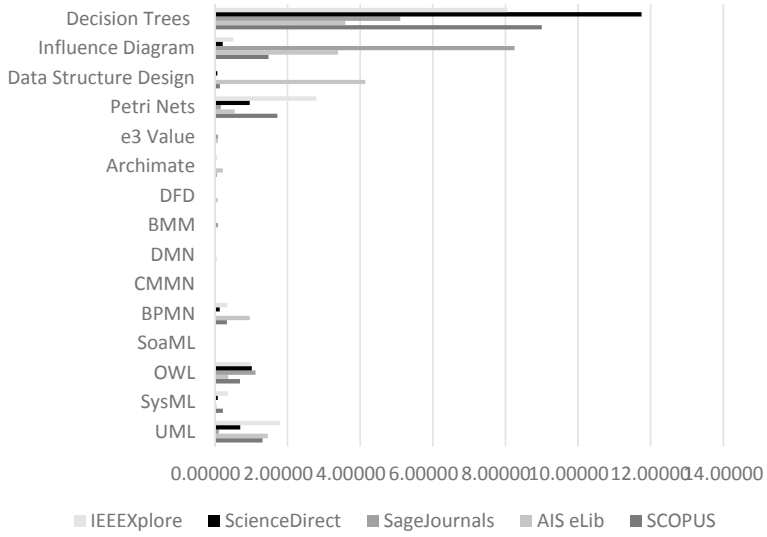


**Fig. 2** Publications on modeling techniques in repositories

Modeling Language (SysML), or service oriented architecture modeling language (SoaML) (see Fig. 2). Particularly, Scopus and ScienceDirect emphasize publications on the applications of decision trees.

These observations encouraged to analyze modeling techniques recommended by object management group (OMG) or suggested within the EA frameworks. The ArchiMate language is known as providing rich modeling expressions, ranging from motivation aspects (such as requirements and goals) to system design aspects (such as software applications and their corresponding ICT infrastructure). Hence, ArchiMate models provide anchors to other domain-specific languages, e.g., BPMN, UML, SysML. Object management group promotes the development of business models and modeling languages, and they offer model-driven architecture (MDA) approach. According to Laaz et al. [3], the use of BPMN has been adopted by researchers and system developers as standard metamodel dedicated to the system design in the MDA oriented approach. Zhou et al. [4] argue that notations, i.e., ArchiMate, UML, SoaML, or SysML, belong to architecture modeling notations, BMM and CMMN notations are known as goal-based modeling notations, and BPMN is applied as a workflow-based modeling notation. Business architecture analysis requires considering the business organization contexts, e.g., social, economic, political, or legal and in these contexts, architecture is a process of mapping the business's vision into particular information systems.

As business architecture is a part of enterprise architecture, it is necessary to review what modeling techniques are proposed within EA frameworks. Basten and Brons [5] revealed that EA frameworks support the following universal modeling techniques:

- ArchiMate in The Open Group Architecture Framework (TOGAF),
- Business Process Management in the Guide to the Enterprise Architecture Body of Knowledge (EABOK),
- UML in Zachman Framework,
- Business Motivation Model (BMM), ArchiMate, and UML in NATO Architecture Framework,
- UML in Department of National Defense and the Canadian Forces Architecture Framework (DNDAF),
- UML in France DGA Architecture Framework (AGATE),
- Organization chart and business process models in Treasury Enterprise Architecture Framework (TEAF),
- UML in Standards and Architectures for eGovernment Applications (SAGAs).

Although developers of EA frameworks can ensure unique modeling languages and techniques, they do not avoid the use of universal tools.

## 3 Business Information System Analysis Techniques' Teaching

Higher education is constantly experiencing a teaching paradigm shift. In the evolution of business information system analysis techniques and tools, universities and particularly computer science schools respond by incorporating new academic programs, update their courses and contents, and develop new teaching methodologies. Educational data mining and learning analytics have the potential to prepare recommendations for teaching improvement and administration. Based on a systematic and purposeful sampling of publications included in repositories, i.e., AIS eLib, Sage Journals, ScienceDirect, Scopus, and IEEEXplore, we collect and analyze 2,577 contributions published between 2010 and 2022 to initiate further research on BISA techniques' acceptance. The research question was formulated as follows:

**RQ3**: What techniques are applied in business information system analysis (BISA) teaching process?

The search string "business AND information AND system AND analysis AND technique AND teaching" was selected, and only, documents published during the last 12 years were considered. Unfortunately, it was not easy to find papers, which answer precisely that question. Authors describe their teaching methodologies, but they focus on rather different issues, e.g., role-play case [6] ethics and social responsibility, professional conduct, privacy, intellectual property, green computing issues [7], virtual learning environments [8], successful integration of research and teaching activities [9], application of design thinking in teaching program [10], gamification in university course teaching [11], or personal learning environment development [12]. Reviewing the abovementioned repositories allows for conclusion that the most suitable publications are located in AIS eLib repository. It was noticed that 86% of all

found publications are stored in AIS eLib repository. However, even there, authors mainly focus on UML and ArchiMate applications. Beyond that, BPMN and DFD modeling notations are used, but they do not write on application of CMMN notation nor SysML language.

### *3.1 Students' Preferences Concerning Business System Analysis Techniques*

In the survey on acceptance of business information system analysis techniques, 88 students were involved (29.5% are women). They are 22–35 years old. They are the first semester master level students registered for the Information System Analysis and Modeling course in computer science specialization. On bachelor level, they have had an opportunity to learn UML, Python language, SQL databases, and fundamentals of statistics and decision support systems. In general, 128 students have been registered on the course on Information System Analysis and Modeling, but unfortunately, 20 students (i.e., 15.6%) did not initiate studies. Hence, 108 students were asked to participate in the survey, and only, 88 students (i.e., 69% of all students registered for this course) eventually accepted the invitation and provided answers in questionnaires. First, students were asked to present in Likert scale their preferences concerning the usage of modeling techniques in business information system analysis. All the modeling techniques (i.e., UML, SysML, Web Ontology Language OWL, SoaML, BPMN, Case Management Model and Notation CMMN, Decision Model and Notation DMN, DFD, ArchiMate, e3 value, Petri Net, data structure diagram, influence diagram, and decision trees) included in Fig. 3 were explained to students. Students admitted that just UML, BPMN, DFD, ArchiMate, and decision trees techniques are very useful in comparison with others. As the students emphasized the usefulness of UML, BPMN, DFD, ArchiMate, and decision trees, the Spearman correlation coefficient (i.e., $r_s$) was estimated in the following way:

$$r_s = 1 - \left(6 \sum d_i^2\right) \Big/ \mathrm{n}\left(\mathrm{n}^2 - 1\right) \tag{2}$$

where $d_i$ is the difference between ranges for observation "$i$" and $i = 1..\mathrm{n}$, $\mathrm{n} = 88$.

The Spearman correlation coefficient indicates a positive or negative association of ranks (Table 1). The closer $r_s$ is to zero, the weaker the association between the ranks. Generally, a value of $r_s$ greater than 0.7 is considered as a strong correlation; values between 0.5 and 0.7 mean a moderate correlation, and values less than 0.4 are considered as weak or no correlation.

While the Pearson correlation measure is appropriate for measurements taken from an interval scale, the Spearman correlation is appropriate for measurements taken from ordinal scales. The correlations among ArchiMate, UML, and BPMN ranks are moderate (Table 1). Students emphasize usability of UML and BPMN for business architecture analysis. The UML language is more preferred than SysML,

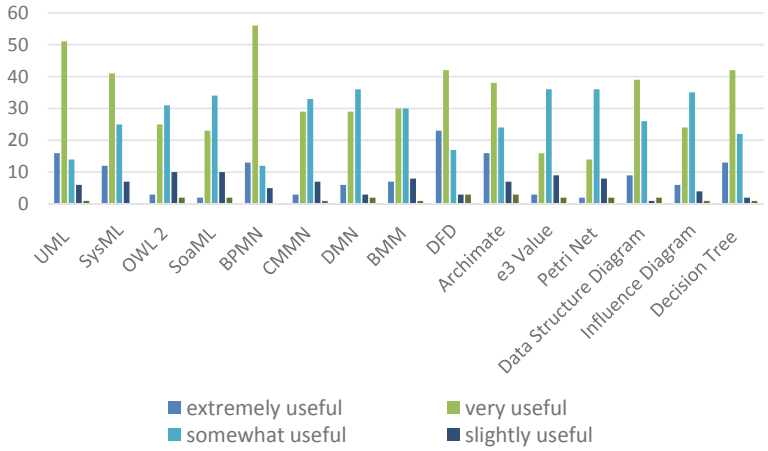


**Fig. 3** Analysis and modeling technique preferences revealed in students' survey

**Table 1** Spearman coefficient values of rank correlations

| | UML | BPMN | ArchiMate | DFD | Decision trees |
|---|---|---|---|---|---|
| UML | *x* | 0.6567 | 0.5804 | 0.5605 | 0.3906 |
| BPMN | 0.6567 | *x* | 0.5349 | 0.4472 | 0.3809 |
| ArchiMate | 0.5804 | 0.5349 | *x* | 0.6070 | 0.3087 |
| DFD | 0.5605 | 0.4472 | 0.6070 | *x* | 0.3199 |
| Decision trees | 0.3906 | 0.3809 | 0.3087 | 0.3199 | *x* |
| % of students stating this technique is extremely useful or very useful | 76.1% | 78.4% | 61.4% | 73.9% | 62.5% |

for which only 60.2% students declared that it is extremely useful or very useful. Surprisingly, a certain portion of students highly evaluate DFD diagramming. This 30-year-old technique is still acceptable and used. However, there is no standard notation for DFD nor recommended standard tools. Decision trees technique is also highly acceptable; however, the correlations with other ranks are not significant.

## *3.2 Business Information Analysis Acceptance in Literature Review*

In TOGAF framework, enterprise architecture covers business architecture and other ICT resources architectures, which are connected together in a comprehensible system. The complex EA can be evaluated as a whole, but usually, its components acceptance is evaluated. Hence, the application of technology acceptance models and

methods is popular. There are many applications of the most popular models, i.e., technology acceptance model (TAM) [13], technology acceptance model 2 (TAM2) [14], unified theory of acceptance and use of technology (UTAUT) [15], diffusion of innovation model (DIM), or status quo bias (SQB) [16].

Although the technology acceptance models are developed to evaluate an organization's or an individual consumer's attitude to technology, in this paper, the research question is formulated as follows:

**RQ4**: Can the structural equation modeling (SEM) be applied for business information system analysis acceptance evaluation?

The survey has included papers published in 2010–2022 and stored in popular repositories, i.e., Scopus, IEEEXplore, AIS eLib, Sage Journals, ScienceDirect. The searching string covered words such as "Structural Equation Modeling" AND "Business Information System". Unfortunately, the TAM model is mostly used for technology acceptance evaluation. However, there are 827 papers, which answer the RQ4 question. In TAM model, the acceptance of a new technology depends on potential user perception of its usefulness and ease of use. Developed by Moody [17] and applied by Gonzalez-Lopez and Bustos [18] method evaluation model (MEM) assumes that acceptance of a new method depends not only on these variables, but also on the intention to use, and the actual efficiency, effectiveness, and use of the method.

In general, the TAM model is applied for analysis of acceptance of different factors in education processes. For example, Perez-Perez et al. [19] revealed through SEM that information quality was important predictor of students' satisfaction, while satisfaction was the most relevant determining factor of perceived learning outcomes. Das et al. [20] used the SEM technique to present that the learning process and student satisfaction were improved by using pre-class learning videos. Godin and Goette [21] proposed the technology acceptance research for analysis of virtual teamwork training. Hanham et al. [22] analyzed relations among student experiences, tutoring services, perception of academic capabilities, and their impact on academic performance.

### *3.3 Study on Business Information System Analysis Acceptance by Students*

The proposed model aims to identify key variables that encourage to apply a business information system analysis. The TAM and MEM models were inspiration for looking for factors influencing the use of this business analysis by students. In general, structural equation modeling (SEM) is defined as a comprehensive statistical approach to hypotheses' testing on relations among observed and latent variables [23]. Structural equation modeling is realized in two ways, i.e., covariance-based (CB-SEM) and partial least square modeling (PLS-SEM). PLS-SEM is applied in

this study. The following constructs supported by MEM and TAM approach were proposed:

- *Perceived usefulness (PU)*, i.e., degree to which a student believes that the business information system analysis will be effective in achieving its intended objectives, which might include usefulness, relevance to modeling purpose, and model comprehensibility.

  Proposed hypothesis is as follows:

**H1**: Perceived usefulness has a positive impact on the attitude.

- *Perceived ease of use (PEOU)*, i.e., degree to which a student believes that using the business information system analysis would be easy and free of effort in aspects such as learning and using.

  Proposed hypotheses are as follows:

**H2**: Perceived ease of use has a positive impact on perceived usability.

**H3**: Perceived ease of use has a positive impact on attitude.

- *Attitude (ATT)*, i.e., the intention of a student to engage in specific behavior defined by the subjective norms and position. The relationship between attitude and intention to use has been strongly emphasized in the TAM theory. Proposed hypotheses are as follows:

**H4**: Attitude has a positive impact on the intention to use.

**H5**: Attitude has a positive impact on the actual use.

- Actual usage (ACU), i.e., degree to which students actually use the business information system analysis.
- Intention to use (ITU), i.e., extent to which a student intends to use the business information system analysis.

  Proposed hypothesis is as follows:

**H6**: Intention to use has a positive impact on the actual use.

The dataset was created to check the quality and to perform the estimation. The presented model (see Fig. 4) consists just of items connected to the variables. Table 2 includes items in the survey. In this survey, 88 students have participated, and it was the same group of students as for survey in Fig. 3. They have taken the course on Information System Analysis and Modeling, and they have known the techniques specified in Fig. 3. During that course, they have learnt what business information system analysis is; hence, in the survey, it can be shortly named system analysis, as it is in Table 2. The reliability of the variables was tested using Cronbach's alpha and composite reliability (CR). The results for reliability and validity are included in Table 3 for the overall sample. All the Cronbach's alpha and CR values are recommended to be higher than 0.700. The average variance extracted (AVE) and composite reliability

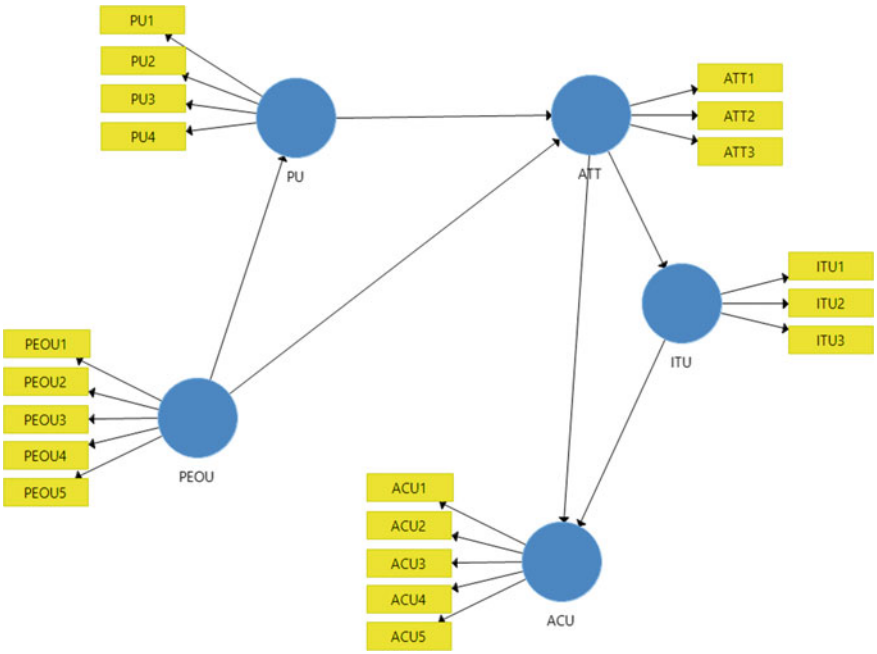


**Fig. 4** Model showing the factors influence on the business system analysis acceptance

(CR) values are to be higher or close to 0.500 and 0.700, respectively, what confirms convergent validity.

The values in Table 3 encourage to change items in the model. The new model is included in Fig. 5. After removing items PEOU1 and ACU2, the reliability and validity measures are included in Table 4.

According to the TAM methodology, variables in Tables 4–6 have appropriate values. The composite reliability meets the condition > 0.7. Cronbach's alpha is also within the recommended range from 0.7 to 0.9. All the constructs differ significantly because the Fornell-Larcker criterion is assessed (Table 6).

The $f^2$ effect size for path ATT − > ACU (0.214), ITU − > ACU (0.202) is low (Table 7). This measure has average value for the path PEOU − > ATT (0.398) and PEOU − > PU (0.365). ATT − > ITU (0.870) and PU − > ATT (0.605) paths have high values of $f^2$ (Table 7). The test results show that proposed dependencies have a significant impact on the intention to use business system analysis. Particular attention should be given to two latent variables: intention to use (ITU) and attitude (ATT). They are strongly connected. They should be considered as priority for business system analysis teaching and should be continuously supported during the teaching process. Perceived usability has a significant positive impact on students' attitude (0.519). Perceived ease of use has positive impact on perceived usability (0.517) as well as on students' attitude (0.421). Students' attitude has an average

**Table 2** Items in the survey

| Latent variables | | Items |
|---|---|---|
| Perceived usefulness | PU1 | I think system analysis is useful in my work |
| | PU2 | Using system analysis increases my productivity |
| | PU3 | Using system analysis improves my work efficiency and my effectiveness |
| | PU4 | Using the system analysis makes it easier to do my work |
| Perceived ease of use | PEOU1 | System analysis allows me to access data and information anytime and anywhere |
| | PEOU2 | I can access system analysis software at any time through any device with a browser |
| | PEOU3 | I feel comfortable because I can freely use system analysis resources as I need |
| | PEOU4 | Learning to use the system analysis is easy for me |
| | PEOU5 | My interaction with system analysis software is clear and understandable |
| Attitude | ATT1 | I have a positive attitude toward system analysis software |
| | ATT2 | I believe that the use of system analysis is a good solution |
| | ATT3 | I believe that access to system analysis software is more desirable than other services |
| Intention to use | ITU1 | I will likely continue to use system analysis services |
| | ITU2 | I intend to make the most use of system analysis services |
| | ITU3 | I will continue to use system analysis software if I have access to them |
| Actual use | ACU1 | I use the system analysis software more frequently than other software |
| | ACU2 | Using the system analysis helps me better understand my tasks |
| | ACU3 | To me, using system analysis is more efficient than other description method |
| | ACU4 | I have not encountered any restrictions when using the system analysis software |
| | ACU5 | I didn't encounter any problems when using the system analysis software |

**Table 3** Construct reliability and validity—preliminary model

| | Cronbach's alpha | rho_A | Composite reliability | AVE |
|---|---|---|---|---|
| ACU | 0.72267 | 0.72117 | 0.81782 | 0.47329 |
| ATT | 0.77080 | 0.77122 | 0.86789 | 0.68688 |
| ITU | 0.88757 | 0.88960 | 0.93025 | 0.81637 |
| PEOU | 0.66685 | 0.68185 | 0.79067 | 0.43769 |
| PU | 0.81208 | 0.81229 | 0.87653 | 0.63970 |

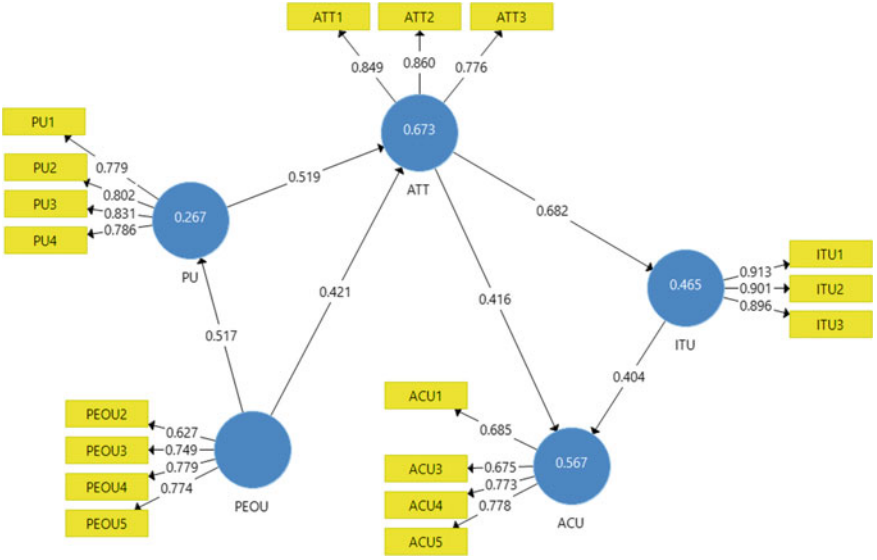


**Fig. 5** Final model with estimated coefficients

**Table 4** Construct reliability and validity—final model

| | Cronbach's alpha | rho_A | Composite reliability | AVE |
|---|---|---|---|---|
| ACU | 0.70544 | 0.70089 | 0.81930 | 0.53237 |
| ATT | 0.77080 | 0.77364 | 0.86796 | 0.68715 |
| ITU | 0.88757 | 0.88832 | 0.93027 | 0.81643 |
| PEOU | 0.71863 | 0.73706 | 0.82335 | 0.53995 |
| PU | 0.81208 | 0.81323 | 0.87650 | 0.63970 |

**Table 5** Bootstrapping path coefficients for final model

| | Original sample | Sample mean | Standard deviation | T-statistics | P values |
|---|---|---|---|---|---|
| ATT − > ACU | 0.41648 | 0.41655 | 0.08947 | 4.65484 | 0.00000 |
| ATT − > ITU | 0.68216 | 0.68346 | 0.07279 | 9.37102 | 0.00000 |
| ITU − > ACU | 0.40434 | 0.40212 | 0.08473 | 4.77182 | 0.00000 |
| PEOU − > ATT | 0.42127 | 0.41981 | 0.08269 | 5.09438 | 0.00000 |
| PEOU − > PU | 0.51706 | 0.52517 | 0.08395 | 6.15898 | 0.00000 |
| PU − > ATT | 0.51931 | 0.51784 | 0.07563 | 6.86664 | 0.00000 |

**Table 6** Fornell-Larcker criterion

| | ACU | ATT | ITU | PEOU | PU |
|---|---|---|---|---|---|
| ACU | 0.72964 | | | | |
| ATT | 0.69231 | 0.82887 | | | |
| ITU | 0.68845 | 0.68216 | 0.90357 | | |
| PEOU | 0.64768 | 0.68978 | 0.52291 | 0.73482 | |
| PU | 0.46682 | 0.73713 | 0.63160 | 0.51706 | 0.79981 |

**Table 7** $f$ square for final model

| | ACU | ATT | ITU | PEOU | PU |
|---|---|---|---|---|---|
| ACU | | | | | |
| ATT | 0.21404 | | 0.87036 | | |
| ITU | 0.20174 | | | | |
| PEOU | | 0.39808 | | | 0.36490 |
| PU | | 0.60493 | | | |

impact on the actual use (0.416). Also, the intention to use has positive impact on actual use (0.404).

Results of the SEM analysis can be applied for learning process improvements and to understand students' attitude, behavior, and intentions. In this way, it is presented that in the teaching process usability and ease should be strongly emphasized as determinants of students' attitude. The study has some limitations. Firstly, it was narrowed to students registered to the course on Information Systems Analysis and Modeling. Probably the results would be different if the study covered bigger research samples. Secondly, there are some non-observable factors influencing the students' attitude, i.e., teacher competencies, technique availability, as well as accessible software tools.

## 4 Conclusions

Teaching enterprise architecture, business system analysis, and business information system analysis at universities is a challenge because of the interdisciplinary nature of these subjects and their close connection with practice. In addition, contemporary methodologies contain many details that are relevant to specific contexts. Although there are several methods and approaches for enterprise modeling, they do not emphasize the shift from business—IT alignment to business information systems coherence. The paper highlighted the application of modeling techniques for business system analyses. Use of these techniques allows to visualize activities and assets, and interrelations among them. The study aimed to present that business system analysis is important and needed.

EA frameworks and business information system development methodologies include certain suggestions concerning the modeling tools, but mostly, software developers are allowed to choose techniques and software tools on their own. SEM methodology has enabled business system analysis to be viewed from a students' perspective although in future this approach should be combined with other method application, e.g., students' interviewing. The results of such a study can determine the relevant teaching approach and recognize students' acceptance. It allows for better adjustment of the teaching as well as setting targets for future course design. The findings of the study might also be useful for practitioners, who are involved in promoting the business system analysis in IT companies.

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# ‘E-Barter’ Exchanging System: Toward a Smart and Sustainable Community

**Ahmed Shuhaiber, Heyam Salem Ali Alfayadhi, May Mohammed AlAwlaqi, and Maitha Abdulnasser Awadh Ali**

**Abstract** The developed e-bartering system enables people within a society to exchange surplus goods and items that are not needed without monetary payments and share services and experiences. This bartering system aims at achieving social and environmental goals, such as increasing community cohesion and public benefits and filling individuals’ needs smartly, improving the communal harmony and happiness among society members and achieving more green and sustainable society. From an environmental point of view, the system is conscious of the importance of waste risks to the environment and the importance of reusing items and recycling them. The methodology followed for developing the system was the system development life cycle, where the e-bartering website went through the phases of the planning, analysis, design, and implementation. A short survey was also shared among the community members of the United Arab Emirates as a market research tool to understand people’s willingness to accept this system and use it.

**Keywords** Bartering · Community · Exchanging · Products · Items · Services

## 1 Introduction

‘E-barter’ is an online trading system that is locally developed in the United Arab Emirates. The system offers bartering for all the seven Emirates in the country throughout the Internet, which allows the exchange of goods and services without using money or at least a direct monetary intermediary such as the financial cards. It includes many groups of society members, such as individuals, companies, and governmental agencies. The e-barter exchanging system allows the exchange of many products and services under a social deal determined by the barter.

The e-barter system has many advantages. For instance, this online exchanging system can help in increasing the community’s cohesion, items recycling, fostering public benefit, and filling individuals’ needs without the need of having money in any

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form. That's what can make the e-barter exchanging system is vital to any society. The concept is to exchange surplus items, the un-needed ones, or the ones with less benefit to that individual, with a higher beneficial item. Secondly, it improves communal harmony and is willing to exchange products and services. Thirdly, this system is considered green and sustainable and provides a smart solution for community members to exchange items, better understand others' backgrounds and cultures, and get items that may not be available in their local market.

The e-barter exchange system has many functionalities of using the website such as the ease of navigating the website as a barter, accessing the information that the barter is looking for, the ability to list the exchanging items and a description, and smoothly exchange the product or service that the barter wants. Also, the website is well designed through graphical user interfaces and presentation layers and elements.

## 2 Literature Review

### *2.1 Previous Research*

Few articles related to the e-bartering systems were found in the literature, and thus, the researchers present them all in detail, as below:

**Xiamen University (2018)** [1]. Debashish Das from Xiamen University Malaysia in 2018 highlighted the importance of the concept of online exchange of several items and products provided under one platform within a certain price range are exchanged between users. The bartering concept is not common these days since people uses cash currency and online payment methods. But when the ancient concept of barter is developed and combined with modern technology, it will inevitably be very useful. An example of this is the Swapper mobile application, which is an easy-to-use electronic barter application. This article dealt with comprehensive research on the application of the concept of barter using modern technologies. One of its most important benefits is that it meets the needs of society, helps in solving the problems of unnecessary spending of money, and overcomes some environmental issues through this type of trading. The e-barter exchange system resolves the problem of unnecessary spending in addition to reducing the disposal of goods undesirable at home. This type of systems is entirely related to e-commerce and the online retail industry, but also provides a new chain of recycling.

**Cambridge University (2020)** [2]. A case study was conducted by Cambridge University on the reintroduction of bartering as before. The aim of this study is to create an economic sector free of fiat currencies and cryptocurrencies. The study touched on several aspects of bartering, including the benefits of economic barter on companies, individuals, and governments. The study also mentioned the transformation of ordinary individuals into merchants in the field of tangible or digital goods and services. The researchers confirmed that most of the technological equipment needed in building a new barter system is available today, such as encryption, smart

contracts, and fair exchange protocols. The study touched on the pros and cons of the electronic barter system. The main advantages of barter are the ease of finding a matching barter, a standard measure of value, and the ease of amassing wealth. The study also touched on the negatives, including mediated trade, transparency, privacy, delays, fees, and financial exclusion.

**Istanbul Gelişim University (2017)** [3]. According to barter system, it is an innovative and alternative financial and trade model during the periods of economic crisis and recession and it's important for businesses (2017). The article indicates the advantages of bartering from a business and economic perspective. To illustrate companies, have some issues with holding their business using traditional marketing methods and financing techniques. Using barter offers to the companies to exchange services and goods without using money. For example, reducing overstock, maximizing idle capacity, improving sales, expanding markets, providing interest-free loans, saving money, debt restructuring, and foreign trade facilitation. The article shows the three types of barter which are retail barter, corporate barter, and international barter. It means when a company is a member of a barter organization, then they purchase goods or services from this barter market and sell the goods or services they create or exchange in this barter market. However, corporate barter means exchanging goods or services between two parties, and both are buyer and seller. International barter refers to governments of two countries or companies in different countries. As a result of the research, barter has been discovered to be a creative alternative to the traditional interest-based attitude and is considered a sort of alternative and finance that contribute to the country's economy.

**Hua, Zhang, Cheng, Wang, and Zhang (2020)** [4]. The article highlighted the advantages of barter on the inventory and it's an alternative way to move the unrequired inventory. Companies tend to barter exchange due to it being an increasingly popular method in business and they exchange unsold products in return for products they need via barter exchange platforms. Barter exchange has several advantages over traditional methods for moving unwanted inventory, including the ability to dispose of unsold items at a cheap cost. A company can buy the goods it needs without payment, preserving vital liquidity, moving distressed inventory, increasing sales volume, locating new clients, opening new markets, and dealing with stochastic demand. As a result, more businesses are participating in barter agreements. The statistic shows barter exchange is estimated to account for around 30% of worldwide trade volume. In 2011, the total value of products exchanged on barter systems was US$ 12 billion. The purpose of barter is to keep exchange volumes stable and balanced while increasing the utility of the participants.

**Challenger, Tezel, Alaca, Tekinerdogan, and Kardas (2018)** [5]. In this study, the researchers attempted to fix the issue in agent-oriented software engineering. The main issue with the current model is that the multi-agent system (MAS) is naturally prone to having issues, and the fix to that is for researchers to use a different MAS development methodology and it's based on domain-specific modeling language, which is called SEA_ML. This new methodology covers the whole process of analysis, modeling, code generation, and implementation of a MAS in the semantic web. Using SEA_ML development methodology has been proven to exemplify the

development of the semantic web-enabled MAS for e-barter. Comparing this development methodology, it has achieved results that have validated the generation and development time than using the more traditional MAS methodologies. As more than half of the agents and artifacts are fully implementing the use of e-barter, they were automatically able to obtain the generation features just by using the proposed methodology.

We conclude from previous academic articles that the old concept of bartering combined with modern technology can provide a new type of green life and a sustainable community. Bartering reduces the disposal of unwanted goods at home and can create opportunities for the poor and recycling through a currency-less lifestyle. The main advantages of bartering are the standard measure of value and ease of wealth creation. On the other hand, its negatives are intermediary exchange, privacy, and financial exclusion. Bartering has been discovered as a creative alternative to the traditional interest-based attitude and is considered a type of alternative and financing that contributes to the country's economy.

In 2019, the total value of products exchanged on barter systems in America was $12 billion. The purpose of barter is to maintain the stability and balance of exchange. The multi-agent system (MAS) has achieved impressive results in the development of electronic exchange. Agents are automatically able to obtain system benefits through electronic bartering. Previous academic articles touch on the new concept of barter, its advantages, disadvantages, and challenges over the past decades.

## 3 Research Methodology and Findings

The development methodology considered for this system is the system development life cycle (SDLC). The SDLC is a systematic and organized approach that consists of subsequent rigid phases to complete the development of a system software [6]. The phases of the SDLC followed in this research are planning (includes the cost/benefit financial feasibility study), the analysis (functional and non-requirement, data modeling process modeling), design (data and decisions), and the implementation which includes coding and testing. The next sections will demonstrate the details of each phase.

### *3.1 The Planning Phase*

**Technical Feasibility**. The e-barter exchanging system requires both hardware and software components, as those components are important resources to investigate their costs and benefits in technical feasibility. With interdependent integrated components, the e-barter exchange system is created to meet specified objectives. First, the website consists of components that come together to accomplish goals. The website is well designed with a suitable layout and a standardized design, such as

the header, sidebar, and footer, and includes structural features. Second, the website includes some of the component functions that react with other components such as layouts, images, and typography. Third, the website's elements are interdependent according to the objectives; they are managed and linked together. For effective functioning, the system requires input and output for the system to receive action from the user. Hardware requirements are needed to test the system, store, and gather information such as computers and the Internet. The computers that we used to build our website are compatible with different operating systems such as Windows, macOS, and Linux. Moreover, to run the e-barter exchange system quickly and smoothly, a RAM with a size of at least 2 GB should be used. The software requirements for e-barter exchange system are integrated operating system, web browser, and online website builders. The efficiency of the software is our top priority, and there are many advantages related to it, such as maintainability, flexibility, and portability, which will lead to the efficiency and speed of function of the system. Both software and hardware will help to enhance the development of the level of efficiency and the quality of the system which will satisfy customers and make it a unique experience.

**Financial Feasibility**. The planning phase includes the financial feasibility study. The budgeting was implemented using Excel (see Fig. 1) which displays the cost/benefit analysis feasibility study.

## *3.2 The Analysis Phase*

The analysis section consists of three main aspects: business requirements, user requirements, and system requirements.

**Business Requirement**. The website has business requirements that help the website function efficiently.

- The priority of the website is to facilitate the exchanging process among barters and to achieve a high level of customer satisfaction.
- Apply an advertising revenue model as the main source of income to the website.

**User Requirement**. Users have an exceptional effect on the website, as they are the most significant stakeholders.

*Users*

- Users will get a smooth bartering experience throughout all seven emirates.
- Users will not need to use cash to exchange products or services.
- Users will receive documented contracts guaranteeing their rights when exchanging products or service.
- Users will get points and rewards.
- Users will be able to get adequate support from the system for technical problems.

**E-Barter Trade System**

**Cost/Benefit Analysis**

**30.9.2021**

| Data | Rate |
|---|---|
| Required rate of return (RRR) | 10% |
| Tax rate | 5% |

| Initial Investment in System | YEAR | 1 | 2 | 3 |
|---|---|---|---|---|
| Hardware (e.g., servers) | AED25,000.00 | | | |
| Software (e.g., e-commerce catalog software) | AED20,000.00 | | | |
| Development (e.g., third-party site design and development) | AED55,000.00 | | | |
| **Total Initial Investments** | **AED100,000.00** | | | |

| Benefits from System | YEAR | 1 | 2 | 3 |
|---|---|---|---|---|
| Direct sales | | AED15,000.00 | AED50,000.00 | AED75,000.00 |
| Incremental sales resulting from enhanced promotional/salesperson effectiveness | | AED25,000.00 | AED25,000.00 | AED25,000.00 |
| Incremental sales resulting from increased partner participation | | AED25,000.00 | AED25,000.00 | AED25,000.00 |
| Reduced travel costs | | AED25,000.00 | AED25,000.00 | AED25,000.00 |
| Reduced customer service costs | | AED50,000.00 | AED50,000.00 | AED50,000.00 |
| **Total Benefits** | | **AED140,000.00** | **AED175,000.00** | **AED200,000.00** |

| Costs (Excluding Initial Capital Investments) | YEAR | 1 | 2 | 3 |
|---|---|---|---|---|
| Cost of sales | | AED7,500.00 | AED25,000.00 | AED37,500.00 |
| Maintenance | | AED15,000.00 | AED15,000.00 | AED15,000.00 |
| Project management, customer support | | AED35,000.00 | AED35,000.00 | AED35,000.00 |
| Online advertising, search-engine registration | | AED10,000.00 | AED10,000.00 | AED10,000.00 |
| Depreciation on capital expenditures (calculation uses three-year period) | | AED33,333.33 | AED33,333.33 | AED33,333.33 |
| **Total Costs** | | **AED100,833.33** | **AED118,333.33** | **AED130,833.33** |

| Totals | YEAR | 1 | 2 | 3 |
|---|---|---|---|---|
| Net Benefits (Costs) | | AED39,166.67 | AED56,666.67 | AED69,166.67 |
| Tax | | AED1,958.33 | AED2,833.33 | AED3,458.33 |
| Value after tax | | AED37,208.33 | AED53,833.33 | AED65,708.33 |
| Depreciation added back | | AED33,333.33 | AED33,333.33 | AED33,333.33 |
| Cash flow | **-AED100,000.00** | AED70,541.67 | AED87,166.67 | AED99,041.67 |
| Cumulative cash flow | **-AED100,000.00** | -AED29,458.33 | AED57,708.33 | AED156,750.00 |

| Evaluation Metrics | Values |
|---|---|
| Net present value (NPV) | AED110,578.83 |
| Internal rate of return (IRR) | 62.05% |
| Payback period (in years) | 1.34 |
| Break Even Point | 2500 |
| Annual Return on Investment (ROI) | 25.99% |

**Fig. 1** Cost and benefit analysis

*IT Support*

- IT support will be able to solve any technical problem faced by the users.
- IT support will be committed to fixing any potential vulnerability in the system.
- IT support will have access to users' contact information for security purposes.

**System Requirement**. We need to ensure that the system will operate effectively and that it is ready to start.

*Functional Input*

- The system requires/not requires any cash payments/monetary payments.
- The system allows choosing the barter's name.
- The system provides a virtual smart assistant feature.
- The system provides both paid and free subscriptions.

*Functional Output*

- The system shows a notification that the exchange process is successful and has been completed.
- The system sends notifications of all the products and services that the user would like to exchange.
- The system suggests a list of users who would like to exchange.
- The system gives the option to cancel the order in the first step of the contract.

*Functional Process*

- The system allows the exchange process between users.
- The system approves the products to be exchanged.
- The system settles barter transactions legally.

*Non-functional Performance*

- The system must work all seven days a week.
- The system must provide its services 24 h a day.
- System response time is less than 1 min.
- The system must accommodate more than 10,000 swaps at a time.
- The system must have a large capacity server.
- The system must be approved for exchange operations within ten minutes.
- Servers in the system must be maintained every two months.
- The system has the potential to expand later in the future.

*Non-functional Control*

- The system must restrict people's access to specific areas and actions. Accordingly, the data is encrypted and accessible to only authorized persons.
- IT support should perform system maintenance regularly.
- Managers should only approve contracts submitted by users.
- Information technology support shall track all barter transactions and take the necessary actions in the event of any dispute.

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*Functional Process*

- The system allows the exchange process between users.
- The system approves the products to be exchanged.
- The system settles barter transactions legally.

*Non-functional Performance*

- The system must work all seven days a week.
- The system must provide its services 24 h a day.
- System response time is less than 1 min.
- The system must accommodate more than 10,000 swaps at a time.
- The system must have a large capacity server.
- The system must be approved for exchange operations within ten minutes.
- Servers in the system must be maintained every two months.
- The system has the potential to expand later in the future.

*Non-functional Control*

- The system must restrict people's access to specific areas and actions. Accordingly, the data is encrypted and accessible to only authorized persons.
- IT support should perform system maintenance regularly.
- IT support should perform system maintenance regularly.
- Managers should only approve contracts submitted by users.
- Information technology support shall track all barter transactions and take the necessary actions in the event of any dispute.

**Data Gathering Survey**. We have created a short questionnaire survey as market research to understand the demand for this system and the people's perceptions about it. By sharing the survey randomly with people of the UAE through social media networks (Instagram, Twitter, and LinkedIn), 80 responses were found complete and unbiased. These are the most important questions in the e-barter exchange system survey.

(1) Perceived security risks: The majority of the respondents indicates their agreement about some security risks to be associated with the e-barter system, and thus, security countermeasures should be seriously considered. Figure 2 shows the associated statistics.
(2) E-barter trustworthiness: As in Fig. 3, more than three quarters of the sampled respondents (77.3%) think that e-barter is trustworthy, which indicates that it could be reliable, competent, and dependable.
(3) Perceived usefulness: Many respondents (68.2%) think that e-barter would be beneficial to them, which indicates a high possibility to use it when available (Fig. 4).

**Process Modeling**. The context diagram represents the process of an electronic bartering system that will allow users to exchange services or goods with each other. The diagram has four external entities which are user, contract, item, and IT support. The process will start with the user exploring the website and asking to exchange

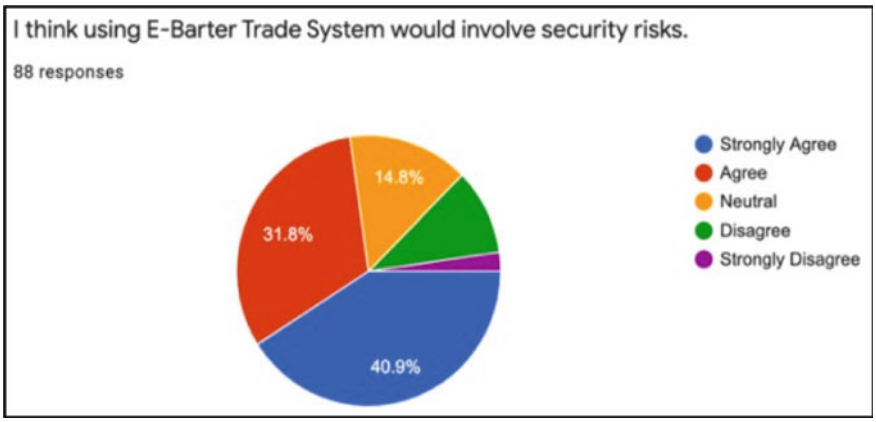


**Fig. 2** Survey question 18

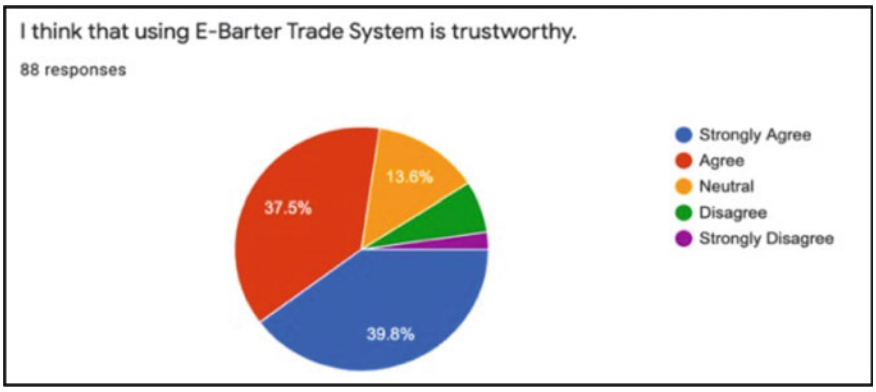


**Fig. 3** Survey question 15

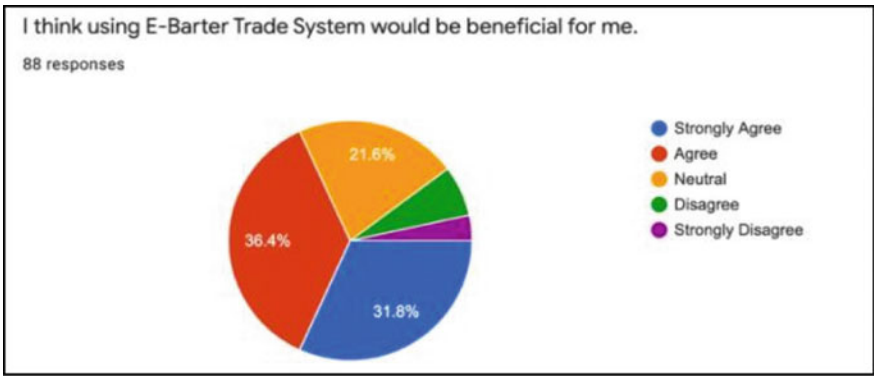


**Fig. 4** Survey question 24

a good or service from the second user. Each user will have an automated tour guide with a virtual assistant to help users use the website. After that, the item will be booked by the user, and it will be removed from the homepage. If the item is available, and both users agreed on that item, they must fill out the contract papers. Then, the system will have to check if the customer entered the correct information. Before the exchange process, if there is an issue or problem with the user or system, it will send a request to IT support and the IT support will send back the approval (as in Fig. 5).

As an extension of the context diagram, the level 0 data flow diagram contains five processes that we categorize according to context. The diagram shows specifically the design of the system and how it will function. Firstly, users register with contact information to the system and if they have an account, they can apply a username and password to log in. All the records will be saved in the data store named User Records. If the user faces an issue, a help request will be sent to the IT support and get the approval from them to solve the issue. Secondly, after login, the system checks user authentication to allow users to search for items. The system will check if the item is available to get the item details. During this process, the details of selected items will be saved in the item database. Thirdly, after the item is selected, the user will be able to start exchanging.

After signing the contract, the user will receive a confirmation message if the exchange request is accepted, then the user will need to sign a contract which will be directly stored in contracts records (see Fig. 6).

**Data Modeling**. The entity-relationship diagram (in Fig. 6) shows how the user interacts with the system. For the ERD, we have six entities which are the User, Contract, IT Support, Item, Exchange_process, and Shopping Cart.

To have a Shopping Cart, an Item should exist. In that case, one and only one User may have many Items. Then, one and only one User may have one Shopping Cart, and one and only one Shopping Cart must have Items. Before the exchange

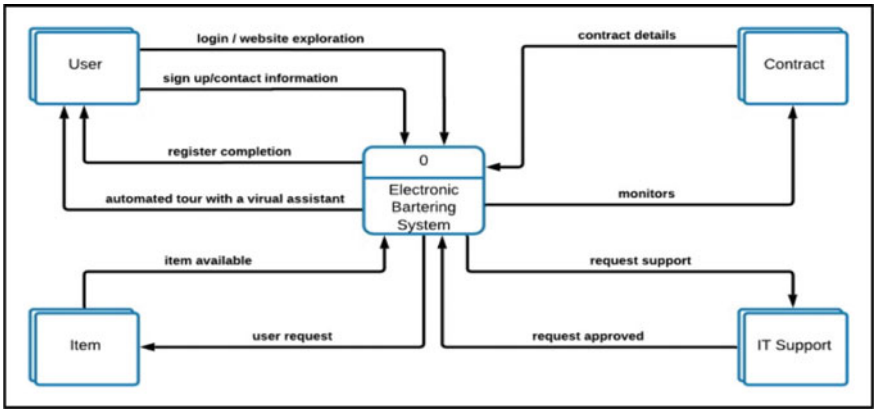


**Fig. 5** Context diagram for e-barter exchange system

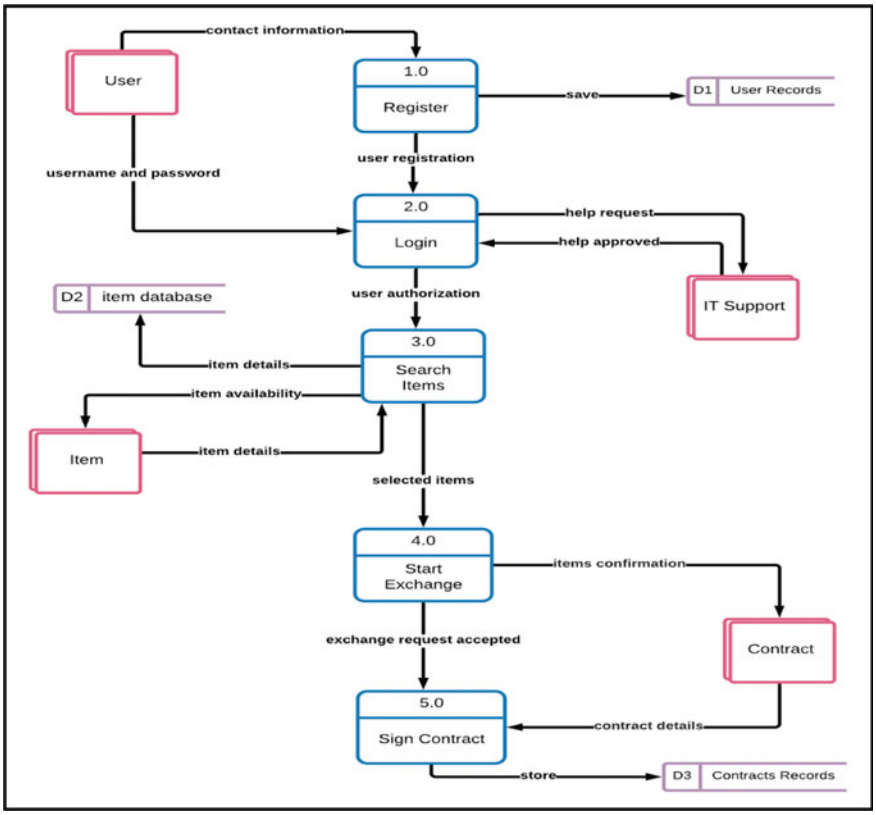


**Fig. 6** DFD level 0

process begins, a User must have a contract to sign. So, one and only one User may sign many Contracts. Once the User signs the Contract, one and only one User may request many exchanging processes. However, if the User faced an issue in the system, the User would need IT Support for help. In that case, many Users may need one IT Support (see Fig. 7).

Do you want to exchange? If the answer is yes, do you want to exchange product/service? If the answer is yes, do you want to exchange from a preferred user? If the answer is yes, get an e-barter exchange card with "100 points".

Do you want to exchange? If the answer is yes, do you want to exchange product/service? If the answer is yes, do you want to exchange from a preferred user? If the answer is no, then find a new user.

Do you want to exchange? If the answer is yes, do you want to exchange product/service? If the answer is no, then, do you want to donate? If the answer is yes, you will get a 5% coupon. However, if no, then try suggesting something else.

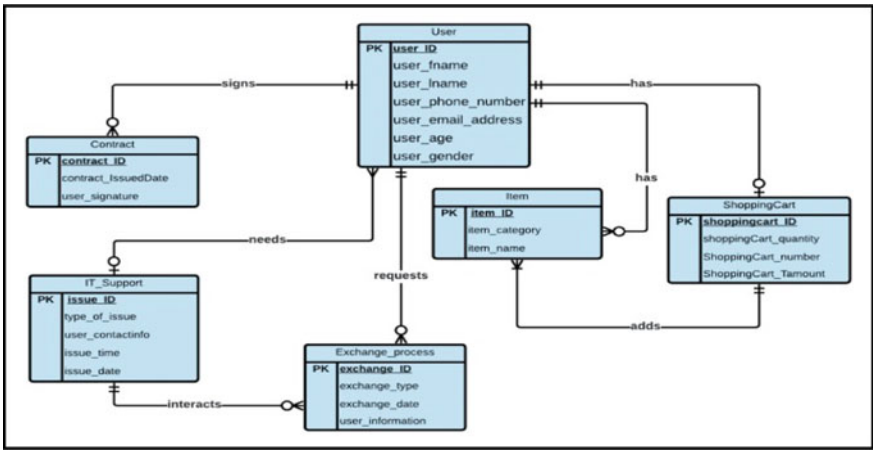


**Fig. 7** ERD for e-barter exchange system

## *3.3 Design Phase*

**Graphical User Interface (GUI)**. In the user interface part, we have created an e-barter exchange system website. The website contains six main pages: Home, About Us, Products, Services, FAQ, and E-Barter policy. Find the instructions below on how to exchange a product or service in e-barter exchange system (see Fig. 8).

- Go to "http://www.e-bartersystem.com/".
- Scroll down to the bottom of the page.

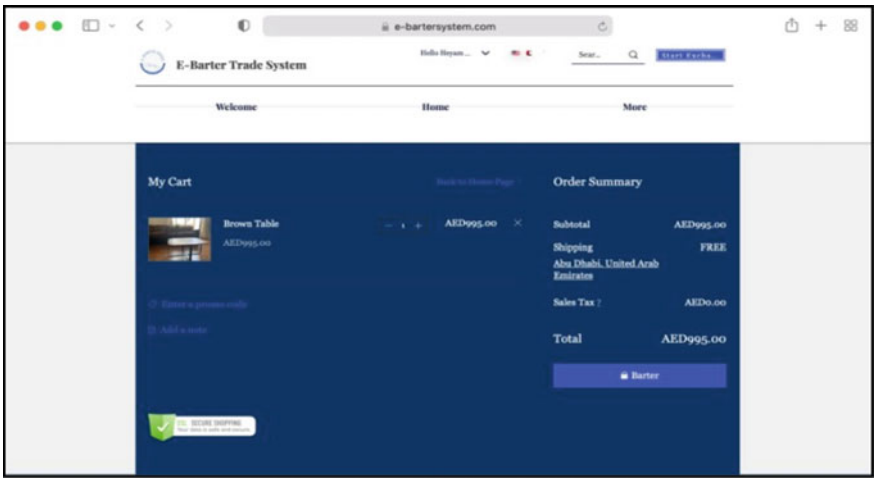


**Fig. 8** Exchange an existing product

- Go to Barter by Products → Choose "Electronics" Button.
- Scroll till you find the iPhone → Click on "Quick View".
- Click on "View more details" to view the specifications and barter information.
- Click on "Add to Cart" Button.
- Click on "View Cart" Button.
- Click on "Barter" Button.
- View the "Secure Checkout".
- Click on "Place Order" Button.
- It will show up a summary invoice of the product you chose.

The below instructions are for how to upload your own product or service in the e-barter exchange system (see Fig. 9).

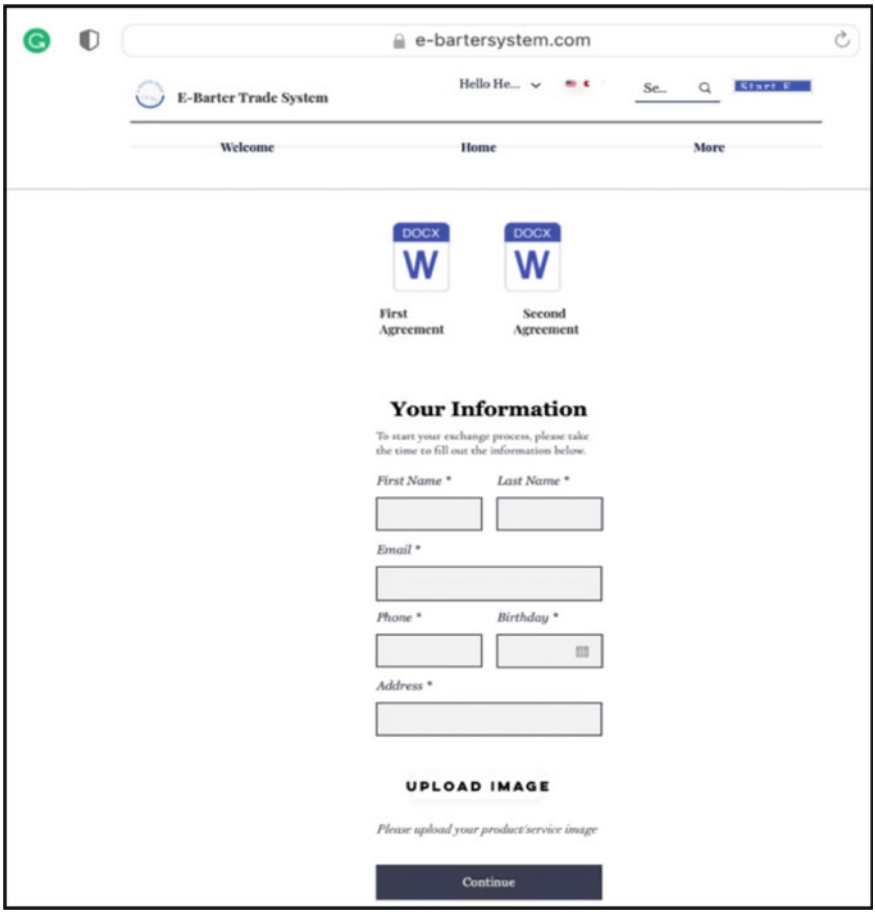


**Fig. 9** Upload a product or service

- Go to "http://www.e-bartersystem.com/".
- Go to the "Products" page.
- Click on the "upload" button.
- Download "Contract 1" and "Contract 2".
- Fill the form by entering your information such as "First name, Last name, Email, Phone number, DOB, Address".
- Upload a picture of the product that you want to upload.
- Click on the "Continue" button.
- Choose "Product" for the question shown "Is it a product or a service?"
- Choose "Shopping Item" for the question shown "What is the item classification?"
- Write your product name.
- Write your product specification and description.
- Upload your filled contracts.
- Click on the "Submit" button.
- Your exchange process has been submitted.

**Coding and Documentation**. We did the relational databases using Oracle Live specifically SQL. The relational databases design is designed in the basis of the entity-relationship diagram (see Figs. 10 and 11).

### *3.4 Testing Phase*

**Alpha and Beta Testing**. In the beginning, the products included on the website were confusing. However, we figured out that these products must be in six different categories which are furniture, books, motors, equipment, electronics, and fashion. Also, in the products section, we were having only nine products randomly, however after testing the website, we added more than 150 products and services.

Subscription plans were also added to the website. We conducted several tests to generate straightforward subscription plans on the website. The subscription plans were classified into three levels: silver membership, gold membership, and diamond membership. The user can reach many advanced features such as an unlimited number in exchange products or services, answering user's calls and emails within 24 h, and up to 40 GB of local storage.

## 4 Conclusion

In conclusion, the main purpose of building the e-barter exchange system is to address the issues of excessive spending on commodities and waste, which is caused by overconsumption, un-needed items, or less important ones. The system will contribute to the development of sustainability, raise awareness of waste hazards to the environment, and increase the interdependence of society.

```
-- ShoppingCart

create table ShoppingCart
(shoppingcart_ID NUMBER(10),
shoppingCart_quantity
varchar2(20),
ShoppingCart_number
varchar2(20),
ShoppingCart_Tamount
NUMBER(6,2),
user_ID    NUMBER(10),
PRIMARY KEY (shoppingcart_ID),
FOREIGN KEY (user_ID)
REFERENCES Client (user_ID));

DROP TABLE ShoppingCart;
```

```
-- Item table

create table Item (item_ID
NUMBER(10), item_category
varchar2(20), item_name
varchar2(20), user_ID
NUMBER(10),
shoppingcart_ID    NUMBER(10),
PRIMARY KEY (item_ID),
FOREIGN KEY (user_ID)
REFERENCES Client (user_ID),
FOREIGN KEY (shoppingcart_ID)
REFERENCES ShoppingCart
(shoppingcart_ID));

DROP TABLE Item;
```

```
-- IT_Support table

create table IT_Support
(issue_ID    NUMBER(10),
type_of_issue varchar2(20),
user_contactinfo varchar2(20),
issue_time  TIMESTAMP,
issue_date  DATE, PRIMARY KEY
(issue_ID));

DROP TABLE IT_Support;
```

```
-- Client table

create table Client (user_ID
NUMBER(10), user_fname
varchar2(10), user_lname
varchar2(10),
user_phone_number NUMBER(10),
user_email_address
varchar2(20), user_age
NUMBER(2), user_gender
varchar2(8), issue_ID
NUMBER(10), PRIMARY KEY
(user_ID),


FOREIGN KEY (issue_ID)
REFERENCES IT_Support
(issue_ID));

DROP TABLE Client;
```

**Fig. 10** Relational database code

```
-- Contract table

create table Contract
(contract_ID    NUMBER(10),
contract_IssuedDate DATE,
user_signature  varchar2(20),
user_ID         NUMBER(10),
PRIMARY KEY (contract_ID),
FOREIGN KEY (user_ID)
REFERENCES Client (user_ID));

DROP TABLE Contract;
```

```
-- Exchange_process table

create table Exchange_process
(exchange_ID          NUMBER(10),
exchange_type       varchar2(20),
exchange_date             DATE,
user_information    varchar2(20),
issue_ID     NUMBER(10), user_ID
NUMBER(10),      PRIMARY      KEY
(exchange_ID),
FOREIGN KEY (issue_ID)
REFERENCES IT_Support (issue_ID),
FOREIGN KEY (user_ID)
REFERENCES Client (user_ID));
DROP TABLE Exchange_process;
```

**Fig. 10** (continued)

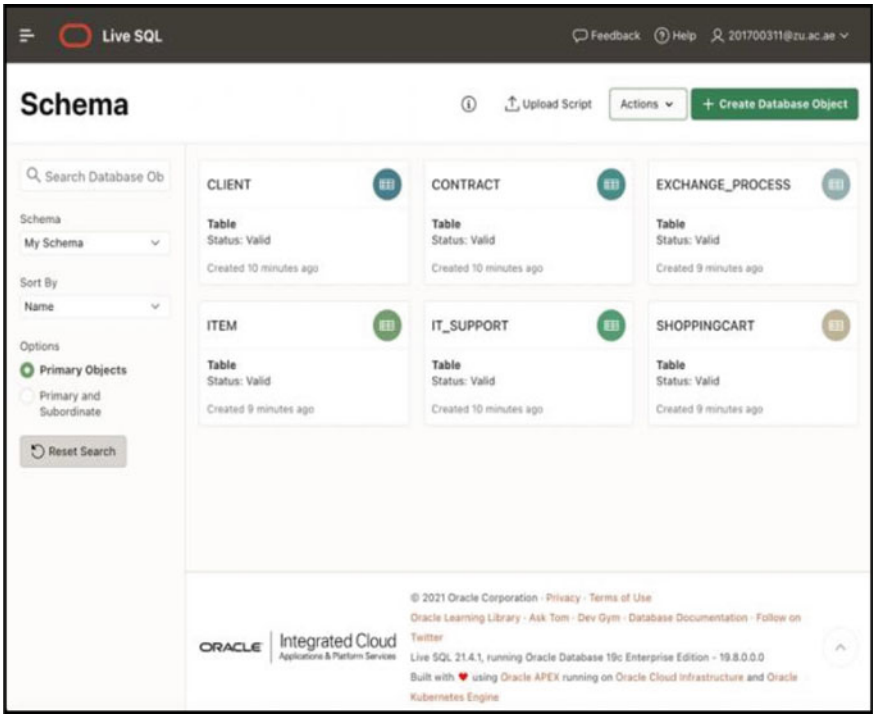


**Fig. 11** Relational database schema

There were some limitations of this study. Firstly, geographical limitations when we surveyed the people of the UAE, and thus the results are limited to this context. Secondly, the survey questionnaire instruments were prone to bias because the number of respondents was not equal across the seven Emirates, as a random sampling approach was followed to initially understand people's perceptions about the e-barter system.

As a future development work, firstly, and a response to the respondents' concern about the system security, we are planning to maintain the security of the website through artificial intelligence (AI) technologies. Secondly, we plan to expand the functionalities and features of the website to include a consultancy option, social media platforms, and a feedback posting feature. Thirdly, it is planned to build a well-designed mobile application as a second layout for the website. Finally, it is considered that a delivery company could be established, for the bartering purposes, to deliver the products between barters.

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# Web-Based Village Bridge and Road Project Monitoring Information System

**Robi Gusnawan and Muharman Lubis**

**Abstract** In this era of globalization, developments in an area have begun to increase over time both in terms of technology and development, and this is indicated by the large number of large-scale projects built by the government and private sectors such as road and bridge construction. Based on data from the Ministry of PUPR in the 2018 Statistical Information Book regarding the allocation of APBN funds to the Ministry of PUPR shows that the largest APBN allocation is allocated to Directorate General of Highways at 40.04%. The data shows that the highest allocation of funds is allocated to build village road and bridge infrastructure, and this indicates that the government is taking priority in carrying out village infrastructure development; therefore, a Project Management is needed. In the process of implementing Project Management, there is often a problem both at the time of planning and when the project is running, things that are commonly experienced by the developer include financial problems such as budgeting, estimation, resources, costs that are not in accordance with the plan and the embezzlement of funds by unscrupulous persons. These problems can occur due to several important factors such as communication and transparency, hence the Project Management Information System is developed, which aims to facilitate stakeholders in monitoring and ensuring that funds budgeted by the government can be channeled and absorbed optimally, and reports absorption of funds are carried out transparently, to minimize fraud and errors in the village infrastructure development process, by using the Rational Unified Process (RUP) method. The system is designed in the cloud thus all the parties involved in the project can control the entire process and absorption of funds that occur directly so that the infrastructure development process can be right on the target according to the predetermined plan.

**Keywords** Project management · Information system · Monitoring project · Rational unified process · Road and bridge infrastructure

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## 1 Introduction

Development in developing countries, such as the Republic of Indonesia contains two dimensions, goals and processes. The goal of development is better living conditions as desired by the community. Meanwhile, the process to achieve that goal is stated in various development strategies [1]. The success of development cannot be separated from the active role of sector sources, especially the development of the road and bridge transportation infrastructure sector. The wide area of land transportation services that must be accessible, which covers the entire territory of Indonesia, requires particular handling in improving the quality of land transportation services that are safe, secure, easy to reach, competitive and integrated. Based on data from the Ministry of PUPR in the 2018 Statistical Information Book regarding the allocation of APBN funds to the Ministry of PUPR, viewed from the organizational unit, the largest APBN allocation was allocated to the Directorate General of Highways at 40.04%. Then the percentage of APBN allocation for the ten other organizational units in sequence, namely the Directorate General of Natural Resources is 32.91%; Directorate General of Human Settlements by 15.97%; Directorate General of Housing Provision by 8.74%; Balitbang by 0.54%; Secretariat General by 0.52%; BPSDM by 0.43%; Directorate General of Construction Development by 0.30%; BPIW of 0.24%; Directorate General of Housing Financing 0.23% and the Inspectorate General 0.09% [2].

Many allocations of funds are allocated for village infrastructure development, both in the form of roads and bridges, this shows that the Indonesian government is very serious in developing village infrastructure, so there is a need for a management project. In projects, the source of the problem is very wide. For example: (1) cost, scope, time schedule, materials and targeted benefits; (2) Dependencies, business as usual/operations, resources and products; (3) Project stakeholders, organization and staff; (4) Everything that arises from the project that cannot be completed immediately [3]. The resource factor is one of the success factors in a project where the communication approach is vertical and horizontal which the project manager must often [4]. In the development of infrastructure projects in villages, there is often a lack of community participation in the planning and monitoring process of village funds, this problem occurs due to several important factors such as communication and transparency [5]. In projects or mega-projects financial problems such as budgeting, estimation, resources and costs that are not the same as planning or the act of embezzling funds by irresponsible people [6]. Based on these problems, it is necessary to develop a Project Cost Management Information System in order to be able to estimate, budget and monitor village infrastructure development projects so that the funds budgeted by the government can be channel optimally and minimize errors in village infrastructure.

## 2 Literature Review

Developing Project Management application required a business model used as Foundation in the development process [7]. Following design Project Management application business model (Fig. 1).

1. Initialization project is the first phase in a project. In this phase, the problem business identified and cases a business that provides various choice solutions are also defined.
2. In the planning process, we see the project in the form of a baseline Work Breakdown Structure (WBS), Gant Chart and S-Curve.
3. Implementation or project execution and control show that this phase includes each activity and work listed in the project plan. When activities and work are performed, management is applied to unify and control project outcomes. This series of processes includes changes (Re-BoQ and Re-Schedule), risks and issues, reviewing quality and measuring each project's results against predetermined criteria.
4. Project closure includes handing over project results to project owners, handing over project documentation, terminating contracts with business partners, releasing project resources and communicating project closure to all stakeholders. The final step is to conduct an implementation review to measure the overall success of the project and to list valuable lessons for future projects [8].

In the application that will be built, project stakeholders are directly related to project work. Stakeholders consisting of The Ministry of PUPR act as an agency that can assist in finding existing projects in Indonesia so that applications can be implemented according to the needs of large or small-scale projects. Then, village or regional government act as an agency that can assist in finding projects that exist in the regional and village scope so that applications can be implemented on a regional and village scale. Next, project consultants wherein help in implementing the application and introduces the application to other consultants. Lastly, project contractors to help in implementing the application and introducing the application to other contractors [9]. The calculation method using the earned value method is an effective method for controlling project costs. By comparing the planned costs with the work that has been completed and the actual costs at any time, to estimate the effect of the construction project implementation costs. The use of EVM involves three basic parameters:

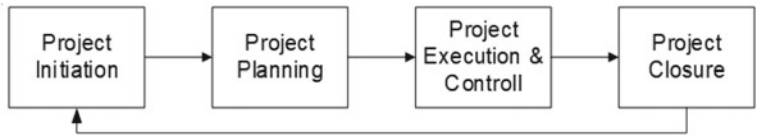


**Fig. 1** Business model

1 Budgeted Cost for Work Scheduled (BCWS), BCWS = number of jobs scheduled × budgeted price.
2 Actual Cost for Work Performed (ACWP).
3 Budgeted Cost for Work Performed (BCWP), BCWP = amount of work done × budgeted price.

On this basis, cost managers can perform analysis and control of project schedules and project costs according to several indicators, such as Cost Variance (CV, CV = BCWP-ACWP), Schedule Variance (SV, SV = BCWP-BCWS), Cost Performance Index (CPI, CPI = BCWP/ACWP) and Schedule Performance Index (SPI, S PI = BCWP/BCWS) [10].In Project Management, it is necessary to adapt to the project being carried out because there are differences in each project and the project techniques that are widely used are network planning techniques (such as PERT, Critical Path Methods and Gantt Charts) and risk management (risk identification, prevention and contingency planning) [11]. The Project Management Information System is a tool that can help project managers and teams plan, schedule, monitor and report on the project. PMIS is usually a computer-based system assisting project managers in project development. Project Management Information Systems also have the ability to calculate schedules, costs, expectations and likely outcomes. However, the use of the Management System does not as well as assess the expert judgment of the project manager and project team. The purpose of PMIS is to automate, organize and provide control over the Project Management process [12].

This Project Management Information System uses the Laravel framework which is a Hypertext processor (PHP) programming language framework intended for web-based application development by applying the Model View Controller (MVC) concept [13]. This Information System uses a Multi-Tier architecture which is a very similar method to Three Tier. The difference is, in Multi-Tier, the User Interface and Data Processing sections will be clarified. What distinguishes this architecture is the presence of a Business Logic Server. Database Server and Business Logic Server are part of Data Processing, while Application Server and Client Terminal are part of the User Interface [14]. It also uses Cloud Computing as a model for enabling ubiquitous, convenient, on-demand network access a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can run quickly [15].

## 3 Research Method

This paper uses the Rational Unified Process (RUP) method was chosen because it corresponds to a case study that occurred where rebuilding an existing application with a different platform based on data in the form of application manuals, application development process documents, application flow documents and database

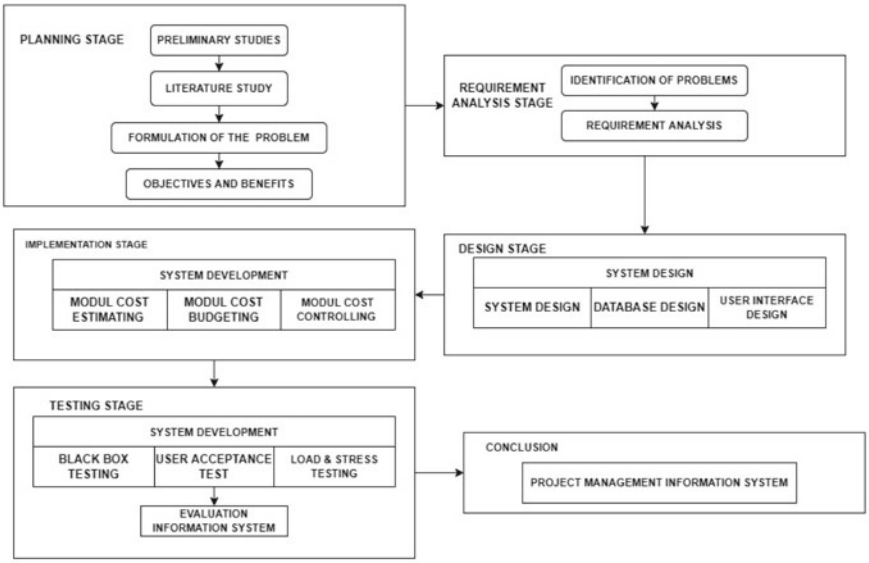


**Fig. 2** Stage developing RUP methods

requirements previous apps [16]. Rational Unified Process (RUP) is a software engineering process model used to increase the productivity of software development teams within an organization [17] (Fig. 2).

## 4 Result and Discussion

In this research, the system can only estimate the project development planning costs and does not cover the entire Project Management. The Project Cost Management Information System developed has three features including estimating, budgeting and monitoring. Business process analysis is an analysis that can be used to describe a business process activity. Each stakeholder performs a specific task that is their specialty to achieve a concrete goal (Fig. 3).

Business process flow in the Project Management application. The business process starts at the Initiation, inputting new project data which will be managed by the application, after creating a new project, the Human Resources input list involved with the project. Followed by the BoQ List and Equipment List needed by the project and continued in the Planning process in this process, we see the project in the form of a Work Breakdown Structure (WBS) baseline, Gant Chart and S-Curve. After the Planning process, it will go to the Execution and Controlling process in this process to ensure that there is no change in project data. If there is a change in project data, it will carry out the Edit Planning process, otherwise it will proceed to the Progress Evaluation process, List Certificate Payment, Progress and Visual Report

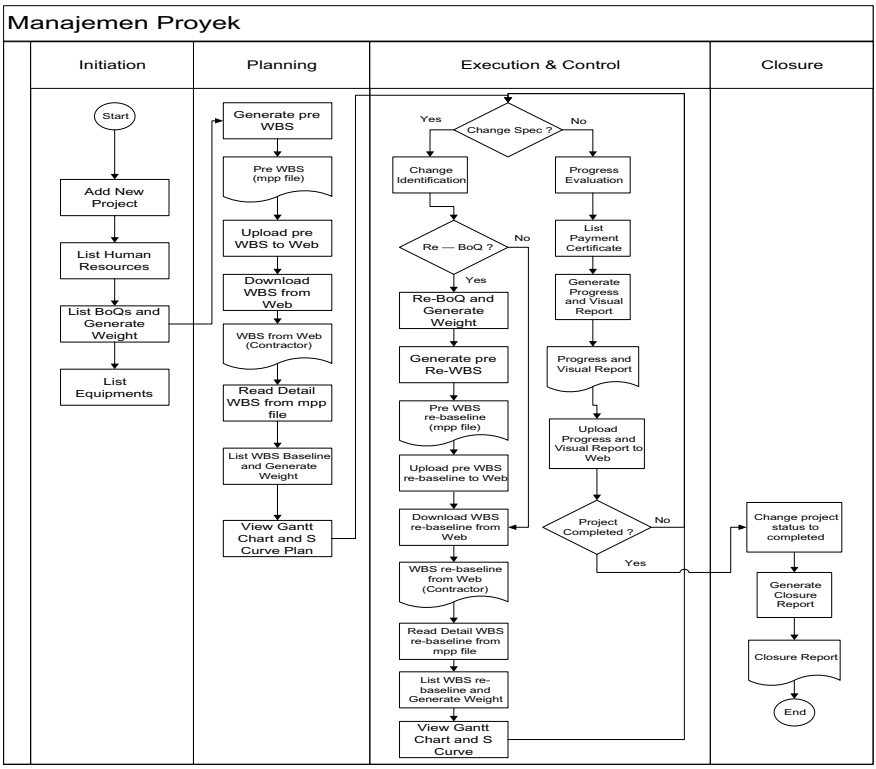


**Fig. 3** Business process the project management information system

and Project Completed, if the project is declared Complete, it will enter the Change Status Complete process, Generate Closure Report and finally the Closure Project process. The following is a picture of the business process The Project Management Information System.

## *4.1 Technology*

Applications built utilize Php technology with laravel framework, Lumen and MPX. This thing could support architecture multitier that will used in implementation application. System performance need n tier support because possibility will used by many users for control project. One project handled by app allow own user more from four people, then if many existing projects in the database so the more lots of data and access application this. Configuration this n tier shared becomes a number of types that is user tier (client), presentation tier, business tiers and resources tier. Resources tier useful for store-related data with application controlling project. In the database

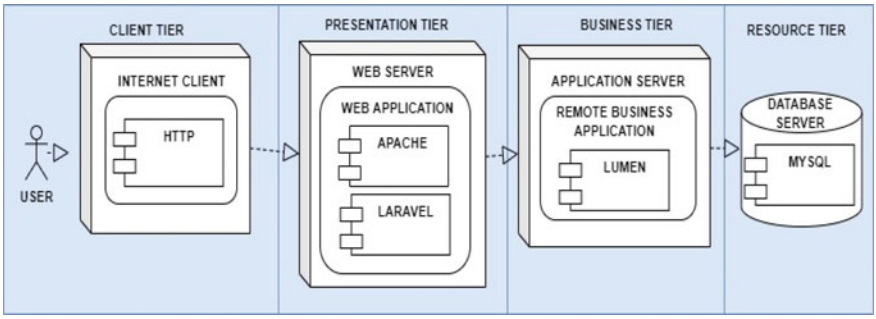


**Fig. 4** Component diagram

tier, there is a working DBMS for manage data. On research, this XAMPP is used as a DBMS because could accommodate need application. Presentation tier is designated part accessed directly by user application. Due to direct part touch with user, presentation tier only contains http files as interface user. Business logic tier is the part in it, and there is query for access databases, whereas client tier is used part user for access application (Fig. 4).

## *4.2 Planning Feature*

Planning is a feature used to prepare project plans that will be executed in the Project Management application. This feature has a submenu consisting of Project, BoQs, Baseline WBS, Contractor Equipment and Mobilization of Consultants. The following figure is an example of one of the Planning features, namely Project which is used to view a list of Projects in the Project Management application, this feature has a table consisting of a Project Name column, Description and an action column consisting of Edit, Set default and Delete buttons (Fig. 5).

## *4.3 Load and Stress Testing*

Load and Stress Testing tests send requests to the Application Server with the intention of knowing how capable the Application Server can receive requests to the maximum. The tested server has a CentOS Operating System specification with a storage capacity of 1 Gigabytes. The Load and Stress Testing and the resulting output are a conclusion regarding the number of Requests, Data Usage, Response Time, Error and Standard Deviation (Fig. 6).

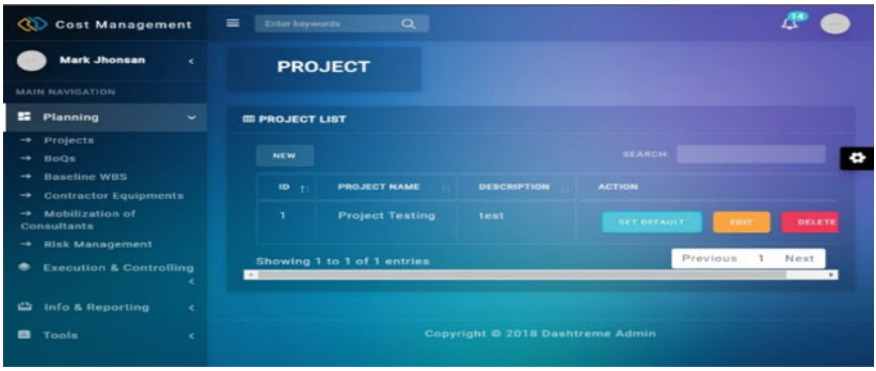


**Fig. 5** Planning feature

| Label | # Samples | Average | Min | Max | Std. Dev. | Error % | Throughput | Received KB/sec | Avg. Bytes |
|---|---|---|---|---|---|---|---|---|---|
| DataPositionCategoryByid | 6 | 13305 | 894 | 53539 | 18421.08 | 0.00% | 2.8/min | 0.01 | 260.8 |
| DataCurrencyByid | 1 | 5306 | 5306 | 5306 | 0.00 | 0.00% | 11.3/min | 0.06 | 333.0 |
| DataPositionCategory | 6 | 8773 | 1006 | 36293 | 12474.32 | 0.00% | 4.6/min | 0.03 | 422.8 |
| DataCountryByid | 16 | 12164 | 420 | 82607 | 21753.63 | 6.25% | 6.2/min | 0.05 | 520.6 |
| DataPosition | 13 | 20628 | 592 | 97977 | 28779.94 | 7.69% | 5.1/min | 0.04 | 527.1 |
| DataBussinessTypeByid | 25 | 11892 | 297 | 53388 | 15180.93 | 8.00% | 9.6/min | 0.09 | 563.2 |
| getLastProjectID | 36 | 18513 | 204 | 103805 | 27244.16 | 13.89% | 13.8/min | 0.13 | 585.6 |
| DataLastInput | 15 | 12344 | 395 | 65254 | 15975.18 | 13.33% | 5.8/min | 0.06 | 672.7 |
| DataPersonilByid | 2 | 40411 | 3415 | 77407 | 36996.00 | 0.00% | 1.1/min | 0.01 | 677.0 |
| DataPositionByid | 12 | 14260 | 515 | 68238 | 18465.82 | 16.67% | 4.7/min | 0.06 | 724.2 |
| DataCityByid | 5 | 22917 | 1114 | 83292 | 31245.29 | 20.00% | 2.0/min | 0.03 | 776.0 |
| DataCurrency | 1 | 5686 | 5686 | 5686 | 0.00 | 0.00% | 10.6/min | 0.15 | 894.0 |
| DataContractor | 2 | 4426 | 2802 | 6051 | 1624.50 | 0.00% | 7.7/min | 0.11 | 894.5 |
| DataBussinessTypeby | 23 | 25926 | 314 | 104800 | 34849.66 | 17.39% | 8.9/min | 0.14 | 947.5 |
| DataBussinessType | 31 | 11144 | 270 | 58497 | 14966.43 | 19.35% | 11.9/min | 0.20 | 1018.0 |
| DataUnit | 1 | 21199 | 21199 | 21199 | 0.00 | 0.00% | 2.8/min | 0.05 | 1069.0 |
| GetDataProjectSetDefault | 56 | 19468 | 209 | 102680 | 24740.65 | 35.71% | 21.5/min | 0.38 | 1089.6 |
| DataProjectByid | 88 | 27879 | 210 | 104492 | 25879.57 | 36.36% | 33.8/min | 0.60 | 1095.5 |
| GetDataProject | 100 | 30578 | 274 | 109670 | 30565.09 | 12.00% | 38.3/min | 0.78 | 1244.8 |
| DataCityByCountryId | 4 | 22317 | 2103 | 67049 | 26600.87 | 25.00% | 1.6/min | 0.03 | 1265.2 |
| DataPositionbyPersonil | 10 | 28308 | 1092 | 98790 | 34713.13 | 40.00% | 3.9/min | 0.08 | 1271.2 |
| DataBusinessPartnerByid | 3 | 11978 | 2511 | 28923 | 12009.41 | 33.33% | 1.3/min | 0.03 | 1292.7 |
| DataBusinessPartner | 3 | 27555 | 1890 | 77583 | 35379.13 | 0.00% | 1.6/min | 0.04 | 1456.7 |
| DataPersonil | 2 | 11566 | 3188 | 19945 | 8378.50 | 0.00% | 3.7/min | 0.09 | 1516.0 |
| DataCountry | 19 | 15907 | 285 | 86985 | 24044.76 | 15.79% | 7.4/min | 0.18 | 1543.7 |
| DataPersonilbyPosition | 2 | 17286 | 6989 | 27583 | 10297.00 | 50.00% | 54.9/hour | 0.03 | 1849.5 |
| DataUnitByid | 1 | 92020 | 92020 | 92020 | 0.00 | 100.00% | 39.1/hour | 0.03 | 2556.0 |
| DataCity | 6 | 13289 | 1486 | 27818 | 10627.58 | 16.67% | 2.4/min | 0.96 | 24554.8 |
| TOTAL | 489 | 21917 | 204 | 109670 | 26899.99 | 20.45% | 3.1/sec | 3.92 | 1287.9 |

**Fig. 6** API test result

## 5 Conclusion

Business process Project Management uses the business model canvas to design business management strategies. In the business plan, the early adopters of the Project Management customer segment are Consultants, Contractors and owners. Then the Project Management value proposition is a user who subscribes at a low cost that will make it easier for users, in addition to the business model canvas

to describe the author's application using business process analysis and use case diagrams. The Project Management application consists of several features, namely Planning, Execution, Controlling and reporting. Each of these features has different functions and has its own submenu, the first of which is the Planning feature which is used to prepare project planning. Both Execution and Controlling features are used to execute the project and monitor the project during the project. The three Info and Reporting features are used to create a final project report and inform the status of the project completed or not yet completed. The Project Management application system architecture consists of several components, namely a web server, database server, Internet service provider and client. The purpose of this architecture is for information technology to meet the strategic business needs of the organization. Therefore, the Project Management Information System architecture combines information needs, IS components and supporting technology.

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# A Case Study in the Application of STPA-sec and CHASSIS for Socio-Technical Cyber Security Risk Management in Health Care from Developing Nations

**Joseph Kaberuka and Christopher Johnson**

**Abstract** Healthcare organizations continue to face an increasing range of cyber threats. In developing nations, considered capabilities of healthcare systems including fragmented governance, limited resources and experience; it is important to identify methods that can be beneficial in the socio-technical analysis of breaches given that at the moment the level of detail and the socio-technical focus varies between incidents—some reports do not mention socio-technical issues at all—and without consistent methods we cannot be sure whether this was due to the fact socio-technical factors were not important or whether they were not just considered by the analyst. We address these problems by evaluating the application of two promising approaches STPA-sec (System Theoretic Process Analysis) for cyber security and a focused method for use case and misuse case scenarios, CHASSIS (Combined Harm Analysis for Safety and Security of Information System). STPA-sec has been able to capture ranges of socio-technical risks threatening cyber security of picture archiving and communication system (PACS) in this hospital by making rapid integration in a resource-constraint area. However, our results show that given a variety of socio-technical risks in this area—interaction of fragmented components, organizational vulnerabilities, it can be hard for only a high-level and abstract methodology; hence, it is needed to identify other forms of breaches to the analyzed system; for that reason, CHASSIS is used to support STPA-sec analysis; this provides to the local analyst another point of consideration in handling different socio-technical risks.

**Keywords** STPA-sec · CHASSIS · Health care · Socio-technical · Cyber security risks

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## 1 Introduction

Cyber security decisions in organizations are socio-technical in nature. Given this reality, many organizations continue to heavily invest in technology to solve cyber security problems than a broader socio-technical perspective [1]. Socio-technical vulnerabilities have contributed to the success of different forms of cyber-attacks in health care [2, 3]. Yet current existing methods are limited to simple scenarios [1, 4] than a systematic analysis of the issues. Therefore, in this work, we are evaluating two promising approaches: STPA-sec [1, 8] and CHASSIS [5], in the aim of supporting the Rwandan hospital to contain the socio-technical cyber security risks against PACS. We are unaware of any studies that considered the benefits of this rigorous analysis in one case study for socio-technical and cyber security risk management analysis in health care from this area. This a significant omission given the sheer volume of the threats to healthcare systems today and the recognition of the effect of the socio-technical risks to cyber threats across different domain [4]. The following sections describe the application of the two approaches on Rwandan healthcare system analysis. Qualitative methods—interviews ($n = 18$) and focus group ($n = 6$) with the hospital administrators in this organization validate our arguments in the methods applications.

## 2 STPA-sec

STPA-sec is a variant of systems theoretic accident modeling and processes (STAMP) for cyber security analysis [1]. The method uses control structures to determine socio-technical cyber security risks [7, 9]. This is done by the method generating a larger set of causal scenarios for the system-level vulnerabilities Table 1. STPA-sec determines how the controlled system can get into a number of vulnerable states that violate particular security constraints. In this context, these are strongly influenced by the high-level organizational relationships of the control structure (Fig. 1).

The role of the functional control structure in Fig. 1 is to provide the basis for socio-technical analysis and cyber security constraints for PACS within the hospital,

**Table 1** STPA-sec PACS system-level vulnerabilities and constraints

| System-level vulnerabilities | System-level constraints |
|---|---|
| **H-1**: Deficient separation of duties and permissive privileges among PACS users violate the principle of least privileges | **C-1**: The management of privileges, permissions and other security features that are used to perform PACS system's access control should be very well designed and implemented |
| **H-2**: Lack of clear security policy, i.e., Internet policy and guidelines among PACS users does not improve ethical responses to cyber security issues | **C-2**: Organizational security policy should be communicated and acknowledged by each and every department with an adequate policy awareness program and clear enforcement |

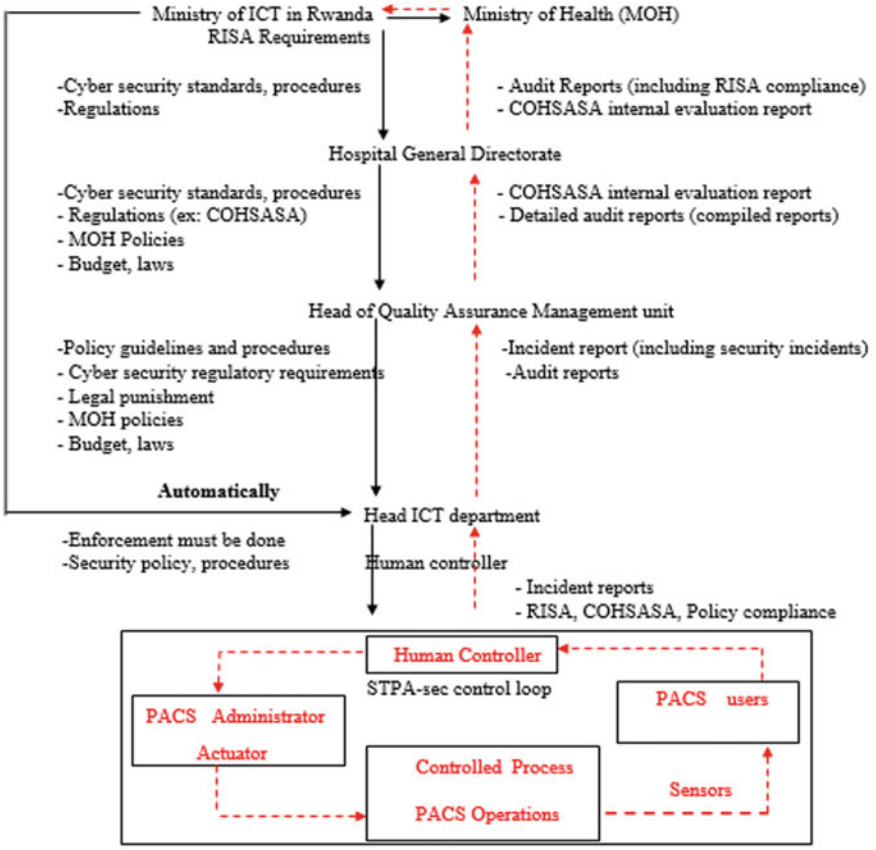


**Fig. 1** High-level control structure model

for example, the enforcement of organizational policies and cyber security standards for PACS operations. STPA-sec begins with questions about what essential services, functions that must be secured against disruptions and what could represent unacceptable losses to the system [1]. In controlling these potential losses against PACS, Fig. 1 (high-level model in STPA-sec control loop) is used as guide for conducting the analysis where each control action is assessed for their role to cause vulnerability. In Table 1, the approach identified socio-technical risks (part of vulnerabilities and constraints) to PACS system in this hospital influenced by the high-level control failures among controllers in connection with Fig. 1.

STPA-sec control loop operating at each level of the high-level model in connection with Fig. 1 is used by the analyst to determine system-level risks. Therefore, this high-level model analysis helps analysts consider potential conflicts in goals and responsibilities within the wider socio-technical system. Thus, the identification of these risks can help the analyst set up the high-level insecure control actions (UCAs) to the target system in Table 2 (part of an insecure scenario).

**Table 2** Unsecure control actions (part of UCAs) in hospital PACS and validation

| Insecure control actions | Causal scenario |
|---|---|
| The organization allows the sharing and distribution of image data under PACS while PACS communications and networks are not encrypted [H-2] | PACS allows for internal and external image review by users within the hospital and external to the hospital infrastructure. The distribution of the data under PACS should be secure. Securing this process requires security controls—data encryption controls and this is not enforced. One of the reasons this is happening is the lack of adequate policy to that would allow policy application to secure data in transit M11, M12, M13 "*I don't think we have policy and resources to address those issues."* The organization follows MOH policy in designing internal policies, and this does not enforce such requirement M7, M9, M10 "*We follow the recommendations from the Ministry of Health and if the resources are required it's for the management to raise the budget*" |

### *2.1 STPA-sec Limitations in the Hospital's Remote PACS Analysis*

Interviews and focus groups analysis reveal a number of socio-technical vulnerabilities including for example, a fragmented decision making between levels of the hierarchy controlling PACS operations in connection with Fig. 1, "*The PACS manager should inform the users about the risk associated with the PACS because this is a complicated system with many protocols and standards to observe*" ***M7***. This means, securing PACS ecosystem in this evolving organizational and fragmented structures can be a major challenge. Due to its focus on control loop, it can be hard for analysts to evaluate and process all control variables in this particular context. Equally, processing image data or sensitive PHI for internal or external under PACS within STPA-sec control loop analysis can be exposed to other unidentified threats and the analyst may not be sure of how to defend against them; since what goes on with PACS generated data in particular context is beyond STPA-sec control loop analysis. Therefore, an additional methodology to support STPA-sec analysis would be beneficial for the analyst in this particular context.

## 3 CHASSIS

Introduced by Raspotnig et al. [5], CHASSIS is a method used in this case study to supplement STPA-sec analysis system.

The strength of CHASSIS is that it helps the analyst find vulnerabilities or hazards that are related to operation and use of the system. This helps local analyst in this hospital to be able to identify other possible vulnerabilities to PACS system and generate constraints (Table 4) to supplement STPA-sec control loops model constraints (Table 3) in connection with Fig. 1. CHASSIS begins by defining the system functions, services and key users involved (actors, process and system interaction) use cases (UC) and misuse cases (threats in the use cases T-MUC) example in Fig. 2, and the analysis in this application focuses on cyber security aspects as separate assessment [5, 7]. This choice is justified by the adoption of the method in other similar application by the UK Ministry of Defense [6].

Though CHASSIS struggles to identify the external component influencing PACS, the results show that the approach can support the analyst evaluating other risks to PACS (Table 5).

**Table 3** Socio-technical security constraints with STPA-sec

| Managerial | Organizational | Technical |
|---|---|---|
| External/internal control | Internal control | Internal control |
| **C-1**: Establish clear procedures with external stakeholders for policies, standards, guidelines compliance evaluation | **C-1**: Provide clear organizational policies, operating procedures and active enforcement plan across different levels to promote secure behaviors | **C-1**: Implement least privileged principle to enforce privileged based user permission in order to manage access rights for PACS |
| **C-2**: Establish clear procedures to evaluate the level of cyber security and security assurance with PACS third party service provider | **C-2**: Regular training to promote awareness of emerging threats, system security and usability | **C-2**: Enforce the configuration policy on the firewall for the blacklist and whitelist traffic |
| **Total: 2 main constraints** | **C-3**: Establish clear policy and enforcement procedures for business continuity | **C-3**: Provide anomaly detection tools to detect potential attacks |
| | **C-4**: Establish clear internal procedures as per agreement between parties to achieve the service level agreement with the supply chain and subcontractors | **C-4**: Implement proper authentication and authorization mechanism for PACS access control |
| | **Total: 4 main constraints** | **C-5**: Enforce security requirements for PACS interacting modality systems |
| | | **C-6**: Implement and enforce physical access security with access rights restrictions |
| | | **Total: 6 main constraints** |

**Table 4** Socio-technical security constraints with CHASSIS

| Managerial | Organizational | Technical |
|---|---|---|
| External constraints | Internal constraints | Internal constraints |
| **C-1**: Establish clear procedures to achieve service level agreement with the supply chain | **C-1**: Enforce the creation of adequate policies in line with recognized guidelines and standards and provide budget for implementation | **C-1**: Implement and ensure critical in-house applications and systems receive regular security updates from trusted and certified sources |
| **Total: 1 main constraint** | **C-2**: Provide resources to report security incidents and breaches across different levels | **C-2**: Separate different application layers (PACS critical functions—PACS web access, PACS database servers) with the firewall |
| | **Total: 2 main constraints** | **C-3**: Ensure and enforce regular systems patching and application vulnerabilities |
| | | **Total: 3 main constraints** |

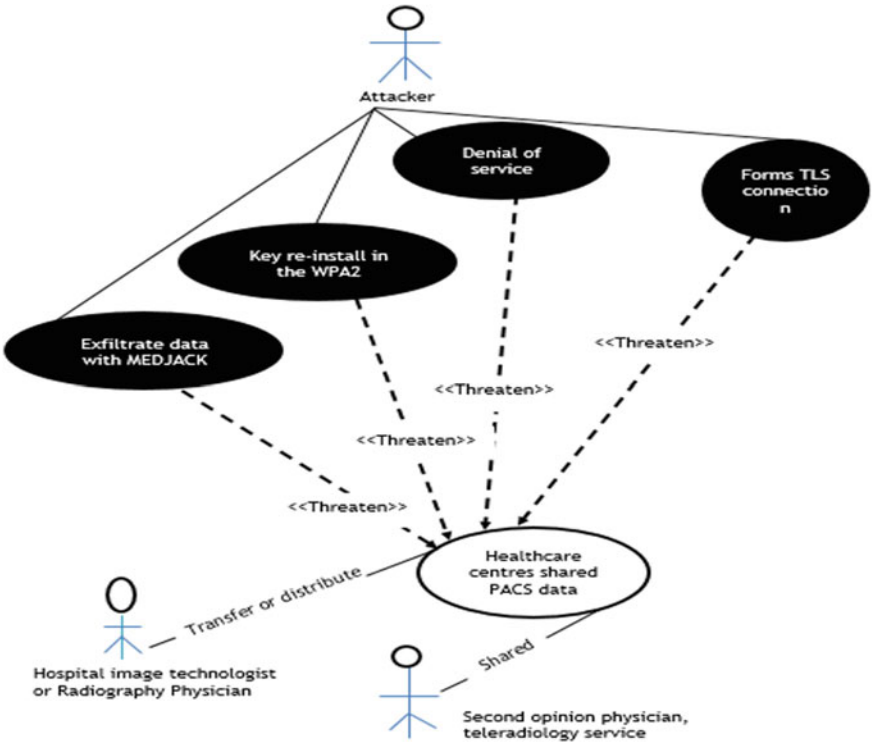


**Fig. 2** Hospital PACS remote access use case

**Table 5** Summary mitigations in two approaches

| Categories | STPA-sec | CHASSIS |
|---|---|---|
| Managerial | 2 | 1 |
| Organizational | 4 | 2 |
| Technical | 6 | 3 |
| | **Total: 12** | **Total: 6** |

## 4 Conclusion

This work focuses on identifying methods that can be of support to the analyst in the socio-technical analysis of breaches in this area of limited resources and various socio-technical vulnerabilities. We evaluate two promising approaches STPA-sec and CHASSIS for socio-technical cyber security risk management of PACS. Our results show that an additional support can be beneficial for the analyst using STPA-sec. Future work should aim to identify whether misuse scenarios in the CHASSIS elements, and T-MUC could be used to improve STPA-sec analysis of unsecure scenarios. Qualitative methods, interviews and focus group, were used to validate arguments in both applications. However, the number of interview participants $n = 18$ and focus group $n = 6$ is relatively low, future work would seek to increase this and investigate if more stakeholders' perceptions revealed through interviews and focus groups would helped validate other root causes of underlying socio-technical cyber security risks against PACS operations that are not identified in this study. We believe the lessons learned from this work might inform other developing countries facing an increasing range of threats in health care and future risk assessment with a socio-technical focus.

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# Taxonomy of Data Quality Metrics in Digital Citizen Science

**Krishna Vaddepalli, Victoria Palacin, Jari Porras, and Ari Happonen**

**Abstract** Data quality is key in the success of a citizen science project. Valid datasets serve as evidence for scientific research. Numerous projects have highlighted the ways in which participatory data collection can cause data quality issues due to human day-to-day practices and biases. Also, these projects have used and reported a myriad of techniques to improve data quality in different contexts. Yet, there is a lack of systematic analyses of these experiences to guide the design and of digital citizen science projects. We mapped 35 data quality issues of 16 digital citizen science projects and proposed a taxonomy with 64 mechanisms to address data quality issues before, during and after the data collection in digital citizen science projects. This taxonomy is built upon the analysis of literature reports ($N = 144$), two urban experiments (participants = 280), and expert interviews ($N = 11$). Thus, we contribute to advance the development of systematic methods to improve the data quality in digital citizen science projects.

**Keywords** Citizen science · Digital citizen science · Data quality · Data quality issues · Data quality mechanisms · Taxonomy

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## 1 Introduction

Citizen science initiatives are an outstanding example of modern participation that has become popularized as mobile technologies have spread into our daily lives [1] as new data technologies are transforming even the most traditional industries to be more open [2]. Citizen science is an established research practice where citizens of a place join hands with professional scientists to facilitate scientific research [3–6]. In digital citizen science, participants collect, categorize, transcribe, or analyze scientific data about a phenomenon of common interest with digital tools [7]. Platforms such as Safecast and Ushahidi have leveraged mobile and web technologies to engage millions of people in the observation of social and natural phenomena in their proximity [8].

Digital citizen science platforms provide a way to monitor social and environmental challenges, with technology, in large scales [9–11]. However, they face multitude of challenges which range from security related concerns [12, 13], data quality [14], accessibility, and interoperability issues [15, 16], lack of a defined set of reusable techniques and frameworks [17, 18] that help in providing a sustained and continuously motivating participation [19–21]. Additionally, in the same way the industry is moving more and more toward digitalized services [22] and managing their assets as fleets [23] instead of separate units.

Authors identified the severe lack of proper protocols/methods in citizen science projects which can make all collected data to be useless. Issues varied from designing the project to validating the data. No proper mechanisms were found to solve the issues. This motivated us to work on improving the data quality part of citizen science projects so as to make the process standardized and useful. We seek to contribute to address the data quality issues [24] in digital citizen science initiatives. Digital citizen science requires that its data is valid to be used as evidence for scientific research. However, often observations made by people for a research project can have many anomalies that lead to incomplete or inaccurate data collection. This mainly happens because of (a) the absence of standardized procedures, (b) lack of motivation, (c) insufficient training, (d) overwhelmed or inattentive actions, (e) digital literacy barriers, (f) issues of bias i.e., a tendency to over-report certain observations and to underreport others, and (g) a general reluctance to report day-today issues [25–27].

The 35 data quality issues mapped were reported in 16 digital citizen science projects. With the map, a taxonomy with 64 mechanisms to help to address those data quality issues before, during, and after the data collection, within digital citizen science projects was made. Result a based on the analysis of literature reports ($N = 144$), two urban experiments (participants = 280), and expert interviews ($N = 11$). This work contributes to advance the development of systematic methods to improve the data quality in digital citizen science projects.

## 2 Related Work for Digital Citizen Science Projects Data Issues

Section for related work on data quality, assessment, and common data quality issues.

### *2.1 Data Quality*

Data quality is highly context dependent. Unacceptable quality of data in one context may well be at an appropriate level in some other context [28]. Thus, the quality is closely linked with the fitness/error free nature of the data, in correlation to the intended use case [29] and what is need for the data, for e.g., is it a casual, business supporting data [30] or business/research critical data [31]. There exist hundreds of attributes that can be used in evaluation of the data quality [32–34]. After preliminary research, we identified a few attributes that affect the data quality in digital citizen science projects significantly. Bobrowski et al. [35] presents a grouping of these attributes (patterns) into 4 different types of effects on data quality (see Fig. 1).

**Intrinsic data quality** is a set of attributes of data quality which includes attributes like accuracy (the level of correctness of the data), objectivity (the level of unbiasedness of the data), reputation (similarity of the collected data), and believability (the credibility of data). **Contextual data quality** determines the context where the data is being used and includes attributes such as added-value (the level to which data can add the value), relevancy (the amount of data ready for use, i.e., error free), timeliness (the availability of output on time), completeness (all required values are available) and appropriate data amount (the minimum amount of data that helps

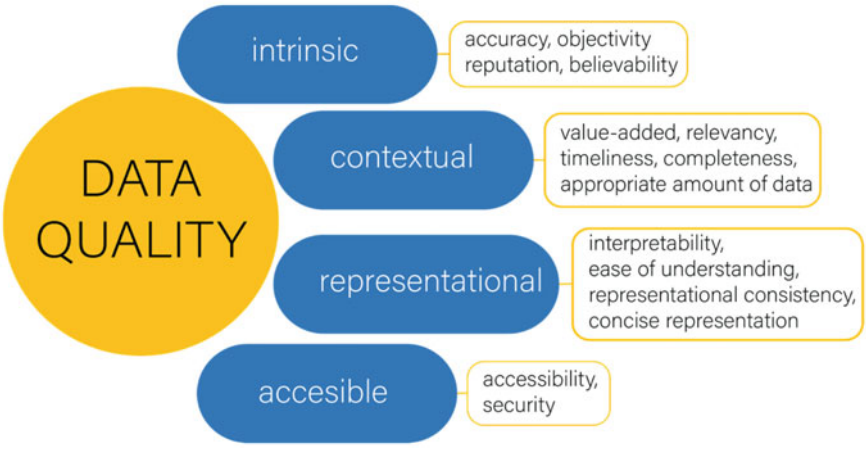


**Fig. 1** Data quality patterns [35]

analyze a situation). **Representational data quality** refers to the ability to interpret the collected data and includes attributes like interpretability (the extent of clarity in terms of usage of language, symbols, units and definitions), ease of understanding (the level to which data can be understood by different stakeholder), representational consistency (data is expected to be the same for the same situation), concise representation (the extent to which data is compactly represented). **Accessibility-related data quality** explains the availability of the data and includes attributes like security (the level to which the data is available for different stakeholders) and accessibility (the amount of data available and retrievable).

To fulfill the data quality requirements of digital citizen science projects, [27] has proposed three key steps for successful data collection and submission of data by the citizens-clear protocols for data collection, simple and logical forms, all necessary help for the participants in the process of data collection and submission. In addition, citizens might have both reluctances to report something they see as a "common" issue and tendency to over-report some others. This may lead to a biased dataset.

**Data Quality Issues in Digital Citizen Science**

When working with citizens in any digital citizen science projects, the project will face various issues of data quality. We identified 35 commonly encountered issues in digital citizen science projects and categorized them under seven different themes-hardware issues, participant issues, issues due to biases, validation issues, loss of data, issues that affect quality, and miscellaneous issues (as shown in Fig. 2).

In general, any issues that the participants might have (based on hardware or their own behavior) will have an effect on the amount and quality of the data collected. On the other hand, validation of the data plays an important role to evaluate the quality of the data and as such one should understand the issues that may affect the validation. The final quality of the data is a sum of all these issues.

**Measuring, Analyzing and Assessing Data Quality**

With the growth of data generation, collection, warehousing, management, and use (e.g. in customer management) the interest [36–38] and role of data quality has increased. Success of companies may well depend on the quality data available with them [39].

The initial step for improving data quality is to understand what makes a data to be of good quality and bad quality. Hence, there is a necessity to measure data quality in order to be able to understand how valuable the information is and how to improve it. Measuring also helps the understanding of the value of data. This helps us know what we need to improve in order to increase the quality. Also, measuring the data quality would clarify the goals of a quality management strategy [40]. Organization of the data is an important part of measuring the quality of data. There are certain quality attributes which are related to the data model, i.e., the way the data is organized [40].

Strong et al. [35] presents three important stages of analyzing data quality of a project-problem identification, problem analysis and problem resolution. Problem identification stage focuses on identifying various data issues. The analysis stage paves the ways of resolving the issues and finds the correct tools and methods that

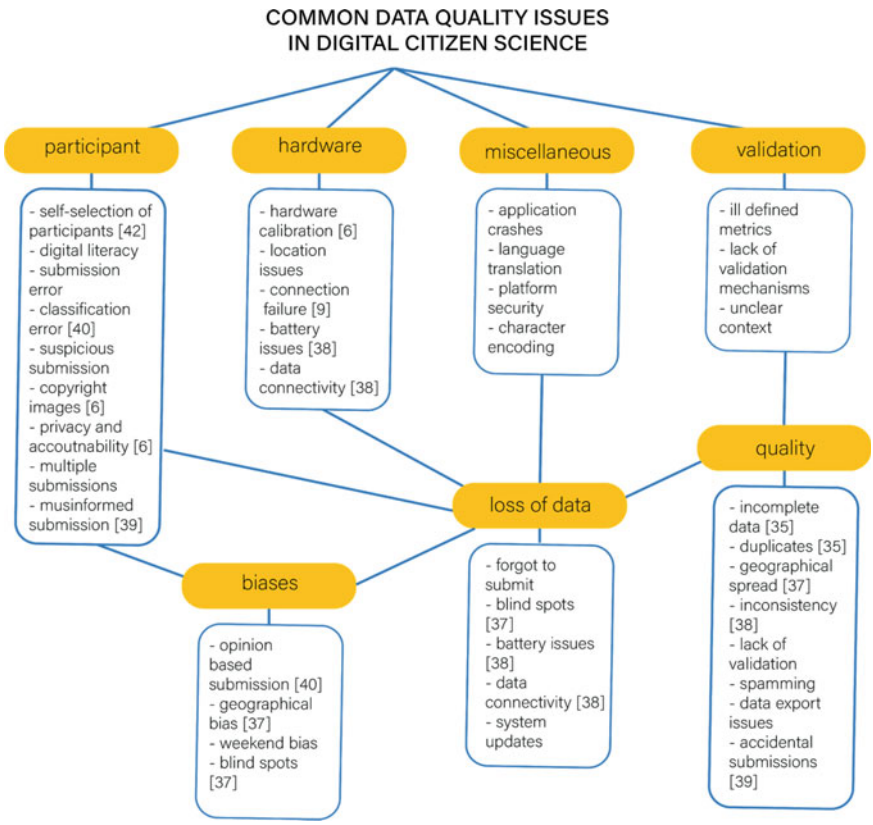


**Fig. 2** Mapping of data quality issues in various digital citizen science projects

address the issue. Resolution phase then implements the actual steps for solving the issue.

Use of methods like validation of syntaxes, checking the format of data, comparing the validity against schemas have some basic effects on improvement of data quality [41]. Using the history data and comparing with current trends can help to measure the data quality [42]. The increased complexity due to multiple data sources creates challenges, e.g., on intrinsic data quality. Use of unique and commonly agreed data representation for similar data may help in the intrinsic data quality challenges [35]. Lukyanenko et al. [43] claims that the use of social network analysis tools may also help.

## 3 Research Process

Digital citizen science has evolved a lot since its inception and is one of the fast-growing methods. As multiple people with not much formal education regarding the subject are involved, there is a high chance for error making the experiment results not useful. The main issue identified was there is a lack of systematic methods in digital citizen science to address those issues [43]. Our work suggests 64 mechanisms to advance the development of systematic methods to improve the data quality in digital citizen science projects. The research process to construct this taxonomy followed the steps in Fig. 3.

### *3.1 Phase 1: Problem Mapping*

As many as 144 research papers on various topics ranging from citizen science to data quality in citizen science were studied. 16 open source digital citizen science projects like zooniverse, eBird, and Galaxy zoo were analyzed for data quality metrics. Interviews with 11 experts in different fields like database experts, digital citizen science project organizers, and software professionals were conducted [44]. By the above-mentioned techniques, we were able to identify different issues in digital citizen science projects (see Fig. 2) and probable solutions to address these issues (see Fig. 4, Table 1).

The literature analysis included research of various scientists belonging to different eras ranging from 1980s to recent times. The main areas of search were citizen science, digital citizen science, data quality, attributes of data quality, metrics of data quality, mechanisms to improve data quality, general issues in digital citizen science projects, data quality-related issues in digital citizen science, data issues in citizen science and digital citizen science, mechanisms used to address data quality issues in general software, and mechanisms for solving data quality issues in citizen

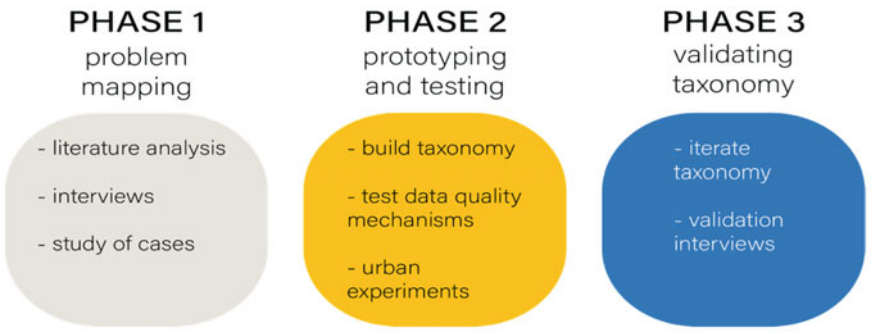


**Fig. 3** Methodology

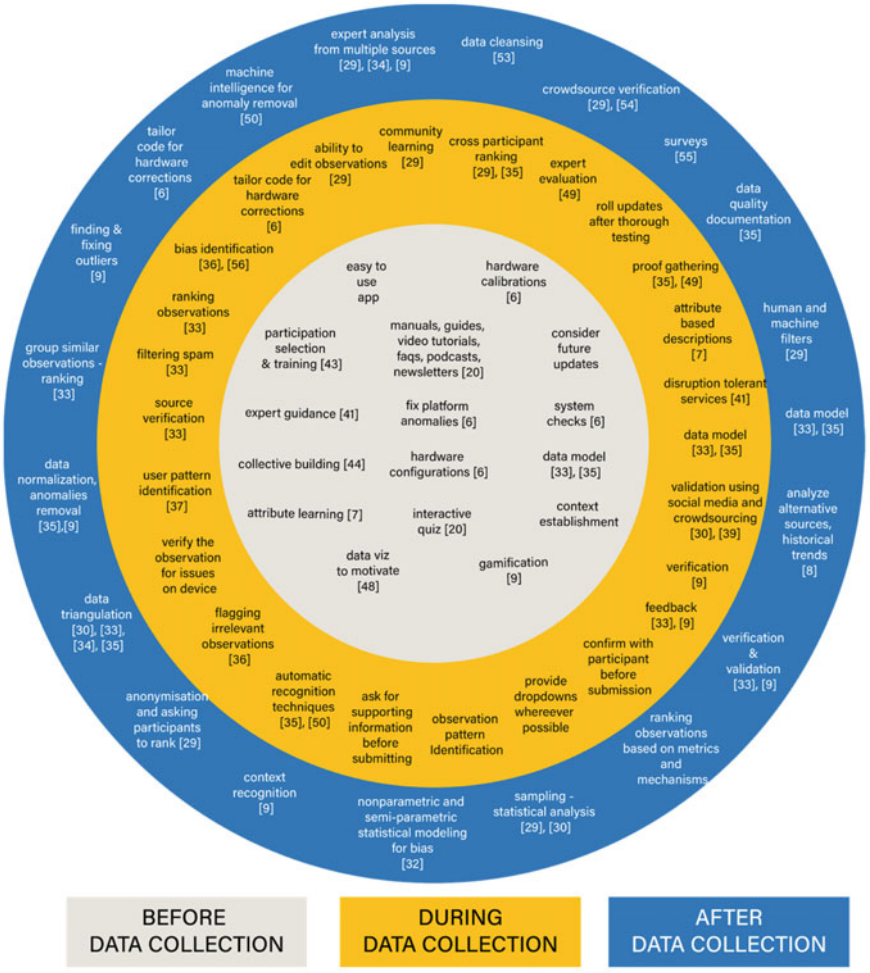


**Fig. 4** Taxonomy of data quality mechanisms for digital citizen science projects presented in chronological layers

science. This helped us identify that there is a lot of research needed in the data quality area of digital citizen science. Additionally, as there are multiple subjects like digital citizen science, software, data are involved, external experts were utilized to test the ideas. With interviews, we identified the issues and check the frequency in which the issues were faced and possible solutions to address the issues. Also, a few case studies of previous digital citizen science projects were analyzed to find some patterns of issues which they might have faced. The results helped us address some issues and realize a few more issues. Also, this phase helped us to understand how each problem affects digital citizen science data and what are the solutions available to address them.

**Table 1** Data quality issue—solution mechanisms example

| Issue | Before | During | After |
|---|---|---|---|
| Behavioral biases | Context establishment, manuals, guides, video tutorials, podcasts, newsletters, FAQs | Community learning, expert evaluation, proof gathering, validation using social media and crowdsourcing, ability to edit observations, bias identification, observation pattern identification | Multiple expert analysis, crowdsource verification, human and machine filters, analyze alternative sources, historical trends, verify and validate, rank observations based on metrics and mechanisms, statistical modeling for nonparametric and semi-parametric bias, context recognition, data triangulation |

## *3.2 Phase 2: Prototyping and Testing*

A preliminary taxonomy with a set of issues and probable solutions that help address the issues was created from information available at the end of phase 1. In order to validate the mechanisms identified, a digital citizen science platform, named anonymous, was prototyped guided by the probable solutions that were formed from phase 1. Then, from the learnings of phase 1, a preliminary taxonomy with identified issues and probable solutions was created. There were many more issues which were to be addressed and the probable solutions were to be validated. With the base taxonomy built, we wanted to validate how each mechanism would help address an issue. To test the mechanisms, a digital citizen science platform was prototyped and built. The entire process of prototyping and building included the participants and their inputs were considered in building the platform. The platform was embedded with identified probable solutions from phase 1. The platform was used for two urban experiments:

- Sensei, was a yearlong participatory sensing movement created to address environmental issues of shared interests. 240 participants were involved in this project. From which 67 used the prototype to collect observations about invasive plans, litter in forests and nice places during 3 months in 2018 [45].
- European H2020 project DOIT aimed to encourage young learners to become creative social innovators. Around 40 participating students monitored in this event [46].

During the course of the urban experiments, we were able to identify additional issues and ways to address them. The evaluation was progressive and had updates with new mechanisms included as we learnt them. This process helped us identify and create a preliminary taxonomy which was further refined in the next steps.

### *3.3 Phase 3: Validation*

With data collected in urban experiments from phase 2, a set of metrics were used to validate and check the quality of data. This helped us validate our mechanisms to a great extent. Our taxonomy was iterated to include the meaningful mechanisms from learnings after validating the data.

With the main goal of getting feedback and validating the taxonomy, updated taxonomy was presented to 11 experts in different fields ranging from people working on digital citizen science projects to database experts. The meetings lasted for around an hour each and sometimes included multiple experts. Based on the field of expert, a subset of issues and mechanisms were presented. The discussions targeted on validating if the issues could be addressed by the proposed solution or would there be a chance of creating other issues while solving the issue with identified solutions. Based on the findings, a few other mechanisms were suggested that would address the issue. The experts were satisfied with the solution presented. Finally, we refined taxonomy with 64 mechanisms which can help improve data quality issues in digital citizen science projects by the end of this phase. This taxonomy is explained in detail in the following section.

## 4 Data Quality Taxonomy for Digital Citizen Science

The lifecycle of a digital citizen science project can be divided into three steps: before, during, and after data collection. Based on this chronological order, the taxonomy of data quality mechanisms covers the ways to improve the end quality of the data, in the problem occurrence order. This taxonomy of mechanisms can inform the design of digital citizen science tools and improve the quality of its data.

In the following, the reader shall first receive the full short description of the methods, partitioned in before data collection phase mechanisms, ways to improve the quality of the data within the collection phase and to mechanisms, which can be used after the data collection has been finished and analysis is going to be started. Following the full explanation of all 64 mechanisms is a discussion and revealing of a support tool for practitioners for fast digital citizen science project design with data quality in mind. In these discussions, a lookup table from document [47] will be explained through examples of usage. But, first we present the full description of the mechanisms.

### *4.1 Mechanism from the Taxonomy for Data Quality Improvements Before Data Collection Phase*

As the first steps of pre-data collection, taxonomy guides towards a set of mechanisms that are designed to pre-empt against well-known data quality issues. These mechanisms include, e.g., hardware, participants, and data model-related matters. With the participants, the mechanisms could be training related, in case of hardware, system checks and hardware calibration, and for data model the ahead planning related to final analysis. In the following, the mechanisms important for the before the projects data collections phase will be presented. Followed by sub chapters for meaningful mechanisms for the time of the data collection, and finally mechanisms for after the data collection and for the analysis time will be presented.

**Attribute Learning**: By training the participants to understand the attributes (e.g., alien plant structures) and patterns (e.g., repetition of weather events) of the monitoring subject, makes them submit more quality observations and understand project goals [43].

**Collective Building**: By gathering the participants together and starting collaboration, they shall learn from experts and each other the goals of the project as shared interactions. Sharing of knowledge improves knowledge building collectively [48].

**Consider future updates**: By considering update path and modularity, one can minimize large scale platform changes to keep multiple participants from different backgrounds happy to stay in the project. When updating, do not deviate far from the initial look and feel, release mostly bug fixes and usability improvements.

**Context Establishment**: Digital citizen science has a specific goal. The participants need to understand the goal and context of the project. This serves to provide a purpose for the data collection, which is a crucial process to support the outcomes of the project.

**Data Model**: Analysis end result will suffer, without a proper data model. A great deal of consideration of all of the project stages is needed for a good model [49, 50].

**Data visualizations**: Like in gamification, by showing peers activity, participants can be motivated to generate more observations. Peers data can also clear the idea for proper target under monitoring and to build context knowledge [51].

**Easy to use platform**: It is suggested to design the application based on understanding the user expertise, experience and psychology [52]. Easier platform will motivate more people to use it [53]. Energy efficiency, smooth and non-blocking functioning should be considered in platform development.

**Expert Guidance**: For training of participants, multiple methods are available, e.g. expert guidance, where field experts explain for the participants the goal of the project is, participants tasks and observations they need to make [54].

**Fix Platform Anomalies**: Pre-testing the platform and fixing the bugs makes release easier. Platforms with bugs and/or temporary fixes can hinder participation rate and demotivate people, plus result in loss of observations [55].

**Gamification**: Gamification can help to motivate participants [56, 57], involving e.g. incentives for submitting more observations. But, if the implementation fails, a lot of irrelevant observations might be submitted [26].

**Guides, Manuals, Tutorials, Podcasts and Videos, Newsletter, FAQs**: With proper subject and monitoring target related background material the participants can learn the deeper knowledge about the monitoring targets and thus perform better [27].

**Hardware Calibrations**: When depending on sensors or external devices like GPS, noise, temperature, etc., the calibration needs have to be addressed for accuracy [55].

**Hardware Configuration**: Good hardware pre-configuration will make organizers and participants task easier. Misconfiguration can lead to platform crashes, valuable observation losses and resigning participants.

**Interactive Quiz**: Tool/mechanism for organizer to test if proper participants have been selected and test training effectiveness. Good quizzes will support participants' learning in different implementation forms and can help to guarantee that the participants have understood crucial data points, which might otherwise easily be missed [27].

**Participant Selection and Training**: The project can be fruitful only with proper participant selection process [58], including their subject specific knowledge analysis, a training for the goals and education of the criteria for monitoring [59].

**System Checks**: Regular system checks for maintenance and bugs collection from the participants are tools for smooth process. Including the pretest of the algorithms in the project system, specially the data handling algorithms, with multiple use case considerations, before the actual release [60].

## *4.2 Mechanisms for Data Quality Improvements in the Data Collection Phase*

Within the time of the actual digital citizen science projects data collection phase, a new set of mechanisms will be needed to improve the data quality. Mechanisms like cross participant ranking, community learning, proof gathering, etc., will help in improving the consistency, believability of data while validation, spam filtering, flagging irrelevant observations help address the issues of irrelevancy. A few other mechanisms like tailoring code for hardware devices would improve the accuracy.

**Ability to edit observations**: In case a participant was unsure of the submitted observation, but later learns more details or gets knowledgeable about a mistake made earlier; the participant needs a way to correct the observation. With editions option, participants can fix the wrongly submitted observations [41].

**Ask for supporting information before submitting**: First check that all needed data is filled properly. In case of missing data, prompting the participant to fill the

missing parts and then submit. Goal is to achieve completeness and consistency of data.

**Automatic recognition technique**: Technology to identify and tag observation with relevant information. Also useful for observations flagging and to improve the data quality [50, 61].

**Bias Identification**: Biases sources like observations submitted only weekends, submitting only to one category, submitting only from their own summer cottage area, etc., are typical digital citizen science project biases [62]. This cannot be addressed for 100% but identifying the bias sources may help to sample out the bias in analysis which improves the analysis quality [63].

**Code tailoring for hardware corrections**: Each hardware and software designs can have their own data errors and/or biases (e.g. GPS location). These can be corrected case by case, e.g., either by classifying the data against known biases or to try to fix the issues on a per device basis [55]. Participant based verification could also be used to remove hardware biases, like asking the location verification from map visualization before submitting confirmation.

**Community Learning**: Stakeholders of the project are learning from each other, like in an open library where people learn and share their knowledge. People can also look for and correct errors, making the process of learning more interesting. Can boost the amount of the observations and reduce incompleteness of the data [41].

**Confirm a summary, before submitting**: Show observation summary, before accepting the submit. Helps in error reduction and blocks spamming from accidental device activations and makes spamming more time consuming.

**Consider Attribute Descriptions**: In this method, platform designers describe the attributes shortly to improve the focusing of data collection in proper ways. Will help to save time in validating [43]. The descriptions can also help in AI-related machine learning algorithm development steps.

**Cross Participant Ranking**: If data is available to all participants, participants can give positive feedback for valid observations and negative feedback for observations with issues. Data quality will be based on feedback, which helps to identify the level of completeness and consistency [41, 50].

**Disruption Tolerant Services**: E.g. a local temporary observations storage to go around the network and other problems and to send the observation later on to the server(s). Mechanism to protect the saving of the observations [54].

**Expert Evaluation**: Method to use, both during and after the data collection. The experts shall rate and evaluate the data to remove unwanted or unqualified data [62].

**Feedback**: Feedback for the observations help participants to understand more and motivate them. Feedback can also reduce re-submission of data as it reduces participants' confusion level, which reduces duplicates [26, 49].

**Filtering Spam**: Observations at the same time, in the same location and category from the same participant usually indicate spamming. With spam protection algorithms and a notification process for the participant, the project can minimize continuation of the spamming. Similar algorithm can be used as an Attack Resistance Trust metric to filter out participants who submit fake observations [49].

**Flagging irrelevant observations**: Way for the peers to flag irrelevant observations to control low quality data. Includes a prerequisite of making the data available for peer participants. Might work better with mandatory authentication in flagging [64].

**Observation Pattern Identification**: Identifying participant related observing patterns to understand their subject related knowledge levels. E.g. repeating submission, in small areas, could be an indication for issue(s) in the area. Analyzing the pattern of observation submission could provide knowledge on the intensity of the problem(s) too.

**Proof gathering**: This phase helps in validation of data. Any possible media files or description of the observation would be helpful. It helps address timeliness, improve accuracy and also gathers the proof of events [50, 62].

**Provide predefined options**: In classification related projects, it's best to provide a presorted list of options, from where to select. Method has its limitation every now and then, but when feasible, will save a lot of post processing time and educates the participants to know the options they have as classifying targets.

**Ranking Observation**: Parameter based observations ranking (e.g., number of similar submissions, at the same time, from a specific area) can help with data validation and accuracy analysis [49]. Mechanism for both the during and after the data collection.

**Roll updates after thorough testing**: All the updates are to be tested thoroughly before release. Any small failure in the platform causes unwanted results.

**Source Verification**: Submissions without source identification can lead to unnecessary submissions and data quality issues. As a minus, full anonymization removes possibility for observation source clarifications. With verification (e.g., registration and authentication) [49], techniques like Friend of a friend (FOAF) for identity management [65] or IMEI etc. based HW information sources can be used to improve data quality.

**User Pattern Identification**: Selecting the participant from a large geographical area for geographical spread to reduce area specific biases [66]. Also, by observing the patterns of submissions (time of the day, locations, and type of submissions), tailored gamification can be introduced to improve the data quality.

**Validation using social media and crowdsourcing**: Using social media hashtags and trends, compared to the received data for quality checks. Crowdsource validation is suggested as compensation for social media analysis results. If done on real time, could help the participant to pinpoint when to improve the quality [42, 67]

**Verification**: Algorithms for observation verification. Also, e.g., a real-time mode to check is participant required to add data to achieve needed quality level [26].

**Verify observation on device**: Ways to check the format, values, etc. parameters directly on the device, before sending it to the server. Also, teaches the participant about typical input issues in the observation process, plus blocks erroneous submissions.

### *4.3 Data Quality Mechanisms from the Taxonomy After the Collection Phase*

In post-data phase, the main body of suggested approaches are mechanism to improve the quality of the data and enhance the data already in hand. These mechanisms include different sorts of analysis, verification approaches, ranking methods and methods aiming to remove anomalies in data, and plus tracking the quality of recorded observations.

**Analyze alternate sources and historical trends**: Using data from alternate sources (weather data bases, satellite images, open data archives, etc.) combined to historical trend analysis vs. the quality of data. To understand the accuracy in the data quality [25].

**Anonymized peer ranking**: Like crowdsourcing, but ranking of the data, without the participant information. Removes friend/foe etc. bias [41].

**Context recognition**: Mechanism to reduce monitoring related irrelevant data. Monitoring metrics-based irregularities cleanup improves the data quality [26].

**Crowdsourcing verification**: Crowdsourcing mechanism for data verification, including participant-based validation and public based validations [41, 68].

**Data Cleansing**: A data cleanup before analysis. E.g. looking for simple formatting and syntax errors. Combining multiple filtering tactics, usually gives best results [69].

**Data Triangulation**: Comparing data from multiple sources like satellite data, social media data, and data from other similar projects. Historical and current to be used to improve the data quality [42, 49, 50, 70].

**Data Normalization and Anomalies removal**: Data quality analysis using normalization as a method to find anomalies [26, 50].

**Data Quality Documentation**: Data quality metrics documentation and mechanisms for future reference and to any needed re-evaluating of the data quality [50].

**Expert analysis from multiple experts**: With multiple individual expert analysis, more relevant data can be found [26, 41, 70].

**Finding and fixing outliers**: When the data comes from multiple sources, specific algorithms might be needed for outlier identification. Analysis will be different than in case of a single system sourced data cases.

**Human and machine filters**: Irregularities filters can boost the understanding of the outliers etc. in the data. Can be e.g. programmed queries or humans looking for some specific data, indicating irrelevant things [41].

**Machine intelligence for anomaly removal**: AI-based methods to identify anomalies modified for digital citizen science data [61].

**Nonparametric and semi-parametric statistical biases modeling**: E.g. to identify nonlinear relationships between predictions and responses to reduce model biases [71].

**Ranking observations based on metrics and mechanisms**: Needs data quality model to work. Observations are ranked individually which when combined gives the final score for the whole data sets quality.

**Sampling—Statistical analysis**: Random sampling of the data to get generic statistical view into the data quality [41, 42].

**Surveys**: Collecting surveys from participants regarding the observations they collected to analyze accuracy in observations creation [72].

**Verification and Validation**: Verify and validate the data, before using it. Project and previous steps and mechanisms typically define the implementation [26, 49].

## 5 Discussions on Data Quality Improving Methods

Considering the previous before, during and after data collection classification of the methods in the taxonomy, non-experienced digital citizen science project planners can use the taxonomy as starting point. The full description of the methods teaches the different considerations that should/can be taken into account, related to data quality guaranteeing measures in the projects under consideration. For more experienced practitioners, approaching the solution finding using issue-based models, authors did build a lookup table to find proper methods to offer solutions to expected issues. The authors mapped issues and mechanisms for the proper phase of the project to address that specific issue. For more details on the mapping table, refer to document [47]. As an example, how to approach the issue—solution options pairing, part of the work is reproduced in Table 1 consider Behavioral biases as a case example. For example, the project developers might fear to stumble to biases, in the data they pursue to collect.

Based on the classification, it is suggested to consider context establishment and manuals, guides, video tutorials, podcasts, newsletters, and FAQs based methods before the data collection phase, basically as part of the project implementation phase. Then within the actual data collection, all the following mechanisms are some part set of them could be considered to lessen the effect of bias in time of collecting the data: Community learning, expert evaluation, proof gathering, validation using social media and crowdsourcing, ability to edit observations, Bias identification, and observation pattern identification. And finally, by considering the bias issue after the data collection, the project organizers could implement following methods to alleviate bias issues: Expert analysis from multiple experts, Crowdsource verification, human and machine filters, Analyze Alternative Sources, Historical Trends, Verification and Validation, Ranking observations based on metrics and mechanisms, nonparametric and semi-parametric statistical modeling for bias, Context recognition and Data Triangulation.

Considering digital citizen science projects data quality issues, against the mapping and current taxonomy form, following is suggested for follow up research. Cross-mapping of issues, mechanisms and implementation of the mechanisms for

ways to minimize data quality issues with a minimal set of methods. With technology development, the taxonomy should be updated accordingly to keep up with the changing societies. The updates should take into account the ways people work with data and technology and how we as society approach the management of open and closed data, and changes in political atmosphere related to digital citizen science projects-based data collections.

## 6 Conclusion

Authors identified typical issues in digital citizen science projects and created collection of mechanisms to solve these issues. Academic literature, citizen science project data, mechanisms to improve data quality and expert interviews were used to pin point data quality issues in conducted urban experiments to validate the solution mechanisms and create a taxonomy of mechanisms. Two novel contributions are made. First, a classification of 35 issues, ranging from hardware issues, loss of data, quality of data, validation issues, participant issues, acknowledge and bias issues to miscellaneous issues, from 16 digital citizen science projects. The second main contribution is the developed taxonomy of 64 mechanisms and means to improve the data quality in digital citizen science. The mechanisms are present to guide a project through the before, during and after data collection and are linked to the issues, which were mapped in this research.

As summary, digital citizen science projects are fast growing and important empirical methods for conducting scientific studies of varied nature and magnitude. However, unreliable data is encountering easily, if the stakeholders conducting the research do not consider and incorporate counter measures for data quality challenges. Our work identified a set of metrics of data quality which have higher impact in digital citizen science projects, focuses on the issues of data quality encountered in digital citizen science based on the metrics chosen and presents a set of probable solutions to address the issues determined. The metrics and mechanisms presented in this work were implemented in the sensei project that was carried out in the city of Lappeenranta and the observations received through the platforms were evaluated for validating the taxonomy. The expert discussions helped reiterate the taxonomy to its final form. Also, as data quality is multi-dimensional, there can be metrics which might affect the data quality, out of scope of our work. Thus, the taxonomy can be used as a reference for generic digital citizen science projects but may not be completely applicable to all projects.

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# Authentication Protocol for Intelligent Electronic Devices in an Edge IoT Environment with Key Agreement

**Elena Shkorkina**

**Abstract** An important condition for the functioning of systems such as mobile, vehicular, or flying ad hoc networks (MANET, VANET, VANET), the Internet of Things (IoT) and cyber-physical systems as a whole has recently become the real-time data processing and analysis. To ensure this aspect, edge computing has been invented and is being developed. The article describes the edge architecture of the IoT network and considers various models of device interaction within it. An authentication protocol with key agreement for the Internet of Things (IoT) network based on the edge computing architecture is proposed. The use of the protocol allows to authenticate intelligent electronic devices on another IoT device through the edge server (ES) and provides ensuring high resistance to various attacks. Computational load on resource-constrained devices is reduced by delegating computation to the ES. The flexibility of the protocol in terms of cryptographic algorithms allows to select them depending on the hardware characteristics of the IoT devices. An interaction phase for post-authentication management is also described.

**Keywords** Authentication · Edge computing · Internet of things

## 1 Introduction

The continuous growth of IoT network sizes, number of simultaneously working devices and their mobility requires designing and implementing more efficient methods of interaction. The processing of accumulated information of a large volume using cloud computing does not allow to work in real time due to both physical remoteness from devices and the high complexity of processing tasks. A hierarchical edge architecture is called upon to solve the described problems, in which the edge computing servers are located in physical and logical proximity to the resource-constrained intelligent electronic devices (IoT devices). However, this also entails the need to adapt the secure interaction protocols to the new architecture.

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Authentication remains the underlying security mechanism for the IoT in the new architecture. Already known solutions differ in device interaction models, network embedding level, authentication decision-making principles, composition of cryptographic algorithms and resource capacity.

In the article [1], the authors present a protocol for IoT device authentication in front of a cloud service through an edge one. It is supplemented by the functionality of determining the reliability of a device to establish its maximum access rights. The first step of the protocol involves the registration of all IoT devices by the ES and limits the use of this protocol in MANET.

The lightweight authentication protocol that provides forward secrecy for edge-based applications proposed in [2]. It based on hash chains and authenticated encryption and allows to authenticate not only an independent IoT device, but also a group. ES authentication, as well as interacting devices in front of each other, is not provided due to the use of a fully trusted server model. Similar to the protocol from work [1], initialization of all protocol nodes makes it impossible to use it in MANET.

The specificity of VANET, which consists in the heightened mobility of nodes, is considered in [3]. The proposed authentication protocol solves the problem of frequent connection when moving by introducing two phases Auth-I and Auth-II into the system. In the first, the car authenticates and generates the token. The second phase is performed when moving from the coverage area of one ES to the coverage area of another: the device provides the token, thereby proving that authentication has already passed.

Authentication methods based on the unique physical characteristics of wireless signal transmission from a device are also known (e.g., [4]). Despite the fact that these solutions reduce the load on IoT devices and are resistant to quantum cryptanalysis, and their security has not been proven. In addition, solutions cannot be called universal, as their use in 5G and 6G networks has not been sufficiently studied.

Thus, the state-of-the-art analysis has shown that the task of developing a IoT device authentication scheme through an ES, especially in ad hoc networks, is relevant. In addition, it is advisable to add steps to the authentication stage that allow to distribute keys for subsequent secure exchange between devices through the ES.

## 2 Edge Computing in IoT

### *2.1 Edge Computing Architecture and Its Features*

Edge computing architecture represents, fundamentally, a distributed hierarchical network (see Fig. 1). IoT devices interact with ES, which is located in close proximity to them (LAN/WAN). A direct interaction between devices is not supposed to be established. Edge infrastructure is connected with centralized cloud.

Described architecture has several features, which make edge computing a promising approach for use within IoT:

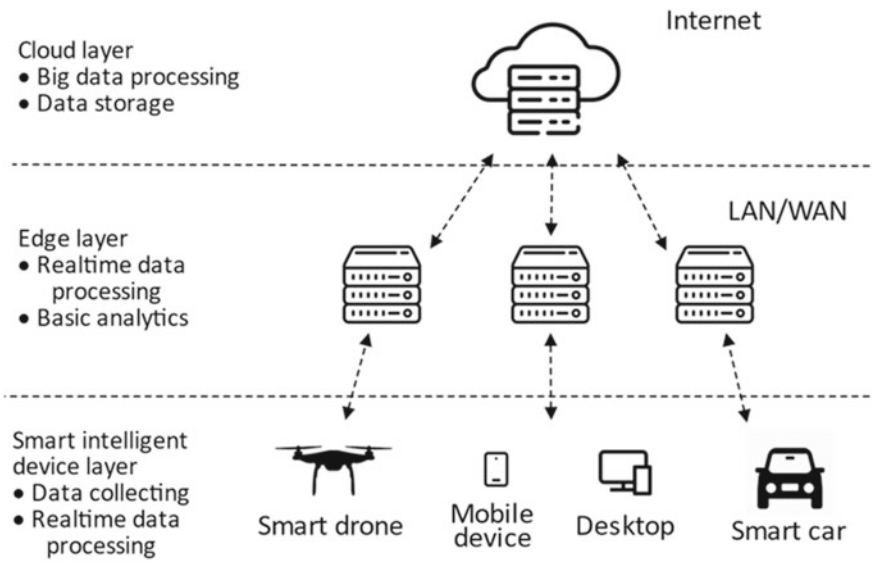


**Fig. 1** Edge computing architecture for IoT

- Hierarchy—computing resources are partially moved from datacenter to edge zone near a place where raw data is collected for their initial processing.
- Ability to make decisions—ES has significant computing resources, which allow not only preprocess data for the transferring to a cloud but make decisions as well, for instance, whether it should authenticate a device or not.
- Security multifunctionality—ES can perform functions of firewall, Intrusion Detection/Prevention System (IDS/IPS) and Data Leak Prevention (DLP) within local subnets of connected devices.
- It is combined with the 5G data transmission standard due to the use of short waves, which have poor throughput, and as a result, a short propagation range. Edge computing architecture within IoT and 5G is commonly called mobile edge computing or multi-access edge computing (MEC).
- Delegation—computational load is transferred from resource-constrained devices to the ES and cryptographic outsource protocols can be used.
- The architecture using edge computing assumes direct interaction of devices with the server, i.e., all participants are on the same local network.

## *2.2 Edge Communication Models*

In accordance with the edge architecture of the IoT network, five models of interaction between devices can be defined:

1. ES with cloud server. This method allows to transfer preprocessed data to a cloud, where it is stored and processed along with data from other edge servers. It is a classic model of interaction; thus, well-known security protocols can be used.
2. ES with SE. The data is distributed among ES. For instance, authentication tokens generated at the Auth-I step of the protocol from [3].
3. IoT device with ES. Collected data is transferred. The decision whether it should be transferred to a cloud or other IoT device is made by ES.
4. IoT device with cloud server through ES. Collected data is transferred. The decision whether it should be transferred to a cloud is made by IoT device.
5. IoT device with another IoT device through ES. Control commands, collected data or state requests are transferred.

The first and third models do not differ from classical pair models of device interaction. However, when using the third model, it should be considered that one of the parties is resource-constrained device while other might be a high mobility device if it belongs to VANET or FANET.

In the second model, the new promising approaches of authentication based on blockchain [5] or group signatures [6, 7] can be used to increase the degree of authenticity of transferred data.

The fourth and fifth models are typical for the described architecture. Despite that to be able them to efficiently use all advantages of edge computing new protocols are required. The protocol from [1] was designed to authenticate devices within the fourth model. The protocol for authentication of a control device on a dependent for the fifth model was firstly published in [8]. The new version of the protocol from [8] with key agreement is proposed in Sect. 3.1. After authentication, interaction phase is described in Sect. 3.3.

## 3 The Proposed Intelligent Electronic Devices Authentication Protocol with Key Agreement

### *3.1 The Proposed Protocol*

The notations used in the proposed authentication protocol is given in Table 1.

The protocol consists of two phases: Initialization phase and authentication with key agreement phase.

**Initialization Phase**. Before the start of ordered functioning and processing of authentication requests, the following is performed:

1. The ES receives from the trusted registration authority the signature $\mathrm{Sign}_{\mathrm{ES}}$ generated for unique data $\mathrm{ID}_{\mathrm{ES}}$ that identifies the edge server on the network. It is proposed to use $\mathrm{ID}_{\mathrm{ES}} = \mathrm{IP}_{\mathrm{out}} \| \mathrm{IP}_{\mathrm{in}} \| \mathrm{MAC}$ (the external and internal IP addresses and MAC addresses of the ES, respectively) data string.

**Table 1** Notations used in proposed authentication scheme

| Notation | Description |
|---|---|
| $\text{Dev}_1$ | Intelligent electronic device that controls, authenticated on the ES and Dev |
| ES | Edge server |
| $\text{Dev}_2$ | Intelligent electronic device being controlled, authenticates the device |
| $\oplus$ | Bitwise logical operation XOR |
| $\|v\|$ | Bit length of the value $v$ |
| $K_{\text{auth}}$ | $\text{Dev}_1$'s key for accessing the $\text{Dev}_1$ that is generated by applying a hash function to user's password pass and cryptographic salt and used as the key of the symmetric algorithm |
| $r, q$ | Random values with bit length $\|\text{Sign}_{\text{ES}}\|$, generated by ES |
| $Pk^{\text{ENC}}_{\text{Dev}_1}/Sk^{\text{ENC}}_{\text{Dev}_1}$ | $\text{Dev}_1$'s encryption asymmetric algorithm public/secret key |
| $Pk^{\text{Sign}}_{\text{Dev}_1}/Sk^{\text{Sign}}_{\text{Dev}_1}$ | $\text{Dev}_1$'s digital signature algorithm public / secret key |
| $\text{Sign}_{\text{ES}}$ | Edge server's signature value, generated by trusted registration authority |
| $E/D$ | Asymmetric encryption algorithms |
| $E^{\text{sym}}_{\text{auth}}/D^{\text{sym}}_{\text{auth}}$ | Authenticated encryption algorithms |
| $E^{\text{sym}}/D^{\text{sym}}$ | Symmetric encryption algorithms |
| $H$ | Hash function with the output length corresponding to the key $K_{\text{auth}}$ length of the $E^{\text{sym}}/D^{\text{sym}}$ algorithms |

2. Intelligent electronic devices $\text{Dev}_1$ and $\text{Dev}_2$ must obtain an access key $K_{\text{auth}}$ from a trusted registration authority or generate it using hash function $H$ with password pass and cryptographic salt salt:

$$K_{\text{auth}} = H(\text{pass} \oplus \text{salt}).$$

3. Trusted registration authority's public key and $\text{ID}_{\text{ES}}$ for $\text{Sign}_{\text{ES}}$ verification must be known to devices. Signed data $\text{ID}_{\text{ES}}$ is received by the participants during LAN/WAN connection with ES.

**Authentication with key agreement phase**. This phase is illustrated in Fig. 2.

When $\text{Dev}_1$ is in the location of the ES and needs to authenticate by $\text{Dev}_2$ with key agreement, they proceed as follows:

1. The $\text{Dev}_1$ sends own public keys $Pk^{\text{ENC}}_{\text{Dev}_1}$ and $Pk^{\text{Sign}}_{\text{Dev}_1}$ to the ES.
2. The ES:
   a. Receives $Pk^{\text{ENC}}_{\text{Dev}_1}$ and $Pk^{\text{Sign}}_{\text{Dev}_1}$.
   b. Generates random value $r$ of the same length as $\text{Sign}_{\text{ES}}$.
   c. Forms $E_{Pk^{\text{ENC}}_{\text{Dev}_1}}\left(\text{Sign}_{\text{ES}} \oplus r||r\right)$ using key $Pk^{\text{ENC}}_{\text{Dev}_1}$.
   d. Sends $E_{Pk^{\text{ENC}}_{\text{Dev}_1}}\left(\text{Sign}_{\text{ES}} \oplus r||r\right)$ to the $\text{Dev}_1$ (signed data is not sent).

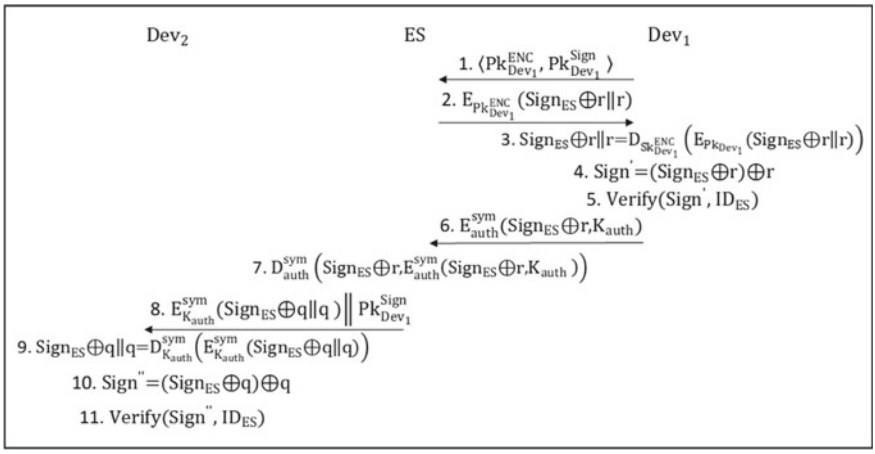


**Fig. 2** Proposed intelligent electronic device authentication with key agreement phase

3. The $\text{Dev}_1$:
   a. Receives $E_{Pk_{\text{Dev}_1}^{\text{ENC}}}\left(\text{Sign}_{\text{ES}} \oplus r||r\right)$.
   b. Gets value $\text{Sign} \oplus r||r$ by decrypting the received value $\text{Sign}_{\text{ES}} \oplus r||r = D_{Sk_{\text{Dev}_1}^{\text{ENC}}}\left(E_{Pk_{\text{Dev}_1}}\left(\text{Sign}_{\text{ES}} \oplus r||r\right)\right)$ and then gets $\text{Sign}\prime = \left(\text{Sign}_{\text{ES}} \oplus r\right) \oplus r$.
   c. Verifies the signature $\text{Verify}(\text{Sign}\prime, \text{ID}_{\text{ES}})$:
      (1) If the check is passed, then the $\text{Dev}_1$ applies the authenticated encryption algorithm to the $K_{\text{auth}}$ value using the key $\text{Sign}_{\text{ES}} \oplus r$ and sends the resulting value $E_{\text{auth}}^{\text{sym}}\left(\text{Sign}_{\text{ES}} \oplus r, \text{K}_{\text{auth}}\right)$ to the ES.
      (2) Otherwise, authentication is failed.
   d. Saves key value $\text{Sign}_{\text{ES}} \oplus r$ for the secure communication with ES.
4. The ES:
   a. Receives $E_{\text{auth}}^{\text{sym}}\left(\text{Sign}_{\text{ES}} \oplus r, K_{\text{auth}}\right)$.
   b. Decrypts the key $K_{\text{pass}}$ with a message authentication:
      (1) If the function $D_{\text{auth}}^{\text{sym}}\left(\text{Sign}_{\text{ES}} \oplus r, E_{\text{auth}}^{\text{sym}}\left(\text{Sign}_{\text{ES}} \oplus r, K_{\text{auth}}\right)\right)$ completes without error, saves key value $\text{Sign}_{\text{ES}} \oplus r$ for the secure communication with $\text{Dev}_1$, then go to step 5.
      (2) Otherwise, authentication is failed.
   c. Generates random value $q$ of the same length as $\text{Sign}_{\text{ES}}$.
   d. Encrypts $\text{Sign}_{\text{ES}} \oplus q||q$ using $K_{\text{auth}}$.
   e. Sends $E_{K_{\text{auth}}}^{\text{sym}}\left(\text{Sign}_{\text{ES}} \oplus q||q\right) Pk_{\text{Dev}_1}^{\text{Sign}}$ to the $\text{Dev}_1$.
5. The $\text{Dev}_2$:
   a. Receives $E_{K_{\text{auth}}}^{\text{sym}}\left(\text{Sign}_{\text{ES}} \oplus q||q\right) Pk_{\text{Dev}_1}^{\text{Sign}}$.
   b. Decrypts the received value using the key $K_{\text{auth}}$: $\text{Sign}_{\text{ES}} \oplus q||q = D_{K_{\text{auth}}}^{\text{sym}}\left(E_{K_{\text{auth}}}^{\text{sym}}\left(\text{Sign}_{\text{ES}} \oplus q||q\right)\right)$.

c. Forms $\text{Sign}'' = \left(\text{Sign}_{\text{ES}} \oplus q\right) \oplus q$.
d. Verifies the signature $\text{Verify}(\text{Sign}'', \text{ID}_{\text{ES}})$:
   (1) If the signature check is not passed, then a key different from $K_{\text{auth}}$ and/or a value Sign″ different from $\text{Sign}_{\text{ES}}$ was used to generate the ciphertext, and, therefore, an access to the $\text{Dev}_1$ have to be denied.
   (2) Otherwise, the $\text{Dev}_1$ authentication is considered successful, $Pk_{\text{Dev}_1}^{\text{Sign}}$ value is saved by $\text{Dev}_2$.

## 3.2 The Proposed Protocol Security

**Edge server authenticity**. Guaranteed as a result of successfully verifying the signature value $\text{Sign}_{\text{ES}}$ using the public key of the trusted party. Signed data $\text{ID}_{\text{ES}}$ is received by the participants during LAN/WAN connection with edge server. Passing the value $\text{Sign}_{\text{ES}}$ in encrypted form also minimizes the possibility of spoofing.

**Protection against known plaintext attack**. Edge server form open text for encrypting as $\text{Sign}_{\text{ES}} \oplus RVRV$ (RV is a random value of the same length as $\text{Sign}_{\text{ES}}$). Due to this, the plaintext, and as a result, the ciphertext always have different values.

**Energy-draining DDoS protection**. To transfer the access key $K_{\text{auth}}$ to the ES, the $\text{Dev}_1$ uses authenticated encryption, which provides not only confidentiality, but also the authentication. Successful execution of the algorithm $D_{\text{auth}}^{\text{sym}}$ ensures that the value received by ES was not randomly generated. As a result, only the messages generated with key values which have passed additional verification are sent to the $\text{Dev}_2$ by the ES. Thus, the risk of draining energy resources of a device (DDoS attack) is minimized.

## 3.3 Use of Agreed Keys for Secure Exchange

As a result of the implementation of the authentication protocol, a key agreement is obtained:

- The key $\text{Sign}_{\text{ES}} \oplus r$ is stored by the $\text{Dev}_1$ and the ES as a symmetric key of the authenticated encryption algorithm $E_{\text{auth}}^{\text{sym}}/D_{\text{auth}}^{\text{sym}}$.
- The key $\text{Sign}_{\text{ES}} \oplus q$ is stored by the $\text{Dev}_2$ and the ES as a symmetric key of the encryption algorithm $E^{\text{sym}}/D^{\text{sym}}$.
- The public key $Pk_{\text{Dev}_1}^{\text{Sign}}$ is stored by the $\text{Dev}_2$ for digital signature verification.

After successful authentication, $\text{Dev}_1$ needs to send command message ($M_{\text{com}}$) to $\text{Dev}_2$, participants proceed as follows (see Fig. 3):

1. The $\text{Dev}_1$:
   a. Generates command message signature $\text{Sign}_{M_{\text{com}}} = \text{Sign}\left(Sk_{\text{Dev}_1}^{\text{Sign}}, M_{\text{com}}\right)$.

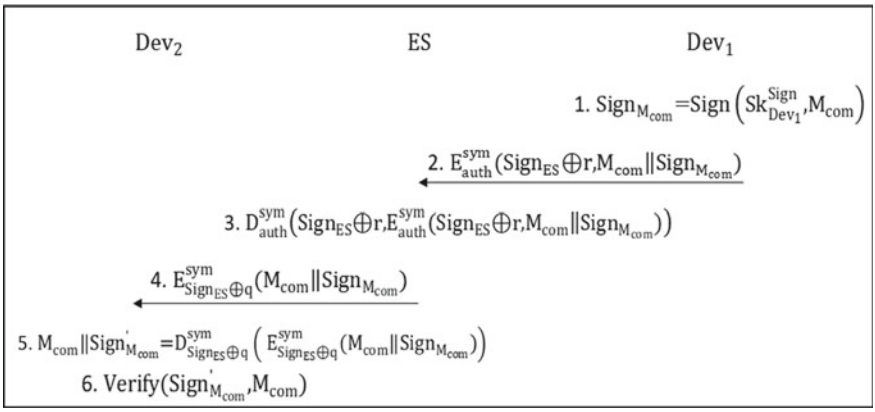


**Fig. 3** Secure transmission of control commands

b. Forms $E^{\text{sym}}_{\text{auth}}(\text{Sign}_{\text{ES}} \oplus r, M_{\text{com}}||\text{Sign}_{M_{\text{com}}})$ value applies the authenticated encryption algorithm to the $M_{\text{com}}||\text{Sign}_{M_{\text{com}}}$ open text using the key $\text{Sign}_{\text{ES}} \oplus r$.
c. Sends $E^{\text{sym}}_{\text{auth}}(\text{Sign}_{\text{ES}} \oplus r, M_{\text{com}}||\text{Sign}_{M_{\text{com}}})$ to the ES.

2. The ES:

a. Receives $E^{\text{sym}}_{\text{auth}}(\text{Sign}_{\text{ES}} \oplus r, M_{\text{com}}||\text{Sign}_{M_{\text{com}}})$.
b. Decrypts the $M_{\text{com}}||\text{Sign}_{M_{\text{com}}}$ with a message authentication:
   (1) If the function $D^{\text{sym}}_{\text{auth}}(\text{Sign}_{\text{ES}} \oplus r, E^{\text{sym}}_{\text{auth}}(\text{Sign}_{\text{ES}} \oplus r, M_{\text{com}}||\text{Sign}_{M_{\text{com}}}))$ completes without error, then go to step 2.c.
   (2) Otherwise, control error.
e. Forms and sends $E^{\text{sym}}_{\text{Sign}_{\text{ES}}\oplus q}(M_{\text{com}}||\text{Sign}_{M_{\text{com}}})$ to the $\text{Dev}_2$.

3. The $\text{Dev}_2$:

a .Receives $E^{\text{sym}}_{\text{Sign}_{\text{ES}}\oplus q}(M_{\text{com}}||\text{Sign}_{M_{\text{com}}})$.
b .Decrypts $M_{\text{com}}||\text{Sign}'_{M_{\text{com}}} = D^{\text{sym}}_{\text{Sign}_{\text{ES}}\oplus q}\left(E^{\text{sym}}_{\text{Sign}_{\text{ES}}\oplus q}(M_{\text{com}}||\text{Sign}_{M_{\text{com}}})\right)$.
c .Verifies the signature $\text{Verify}(\text{Sign}'_{M_{\text{com}}}, M_{\text{com}})$ using $Pk^{\text{Sign}}_{\text{Dev}_1}$:
   (1) If the signature check is not passed, commands are not executed.
   (2) Otherwise, the $\text{Dev}_1$ executes the commands received in the message $M_{\text{com}}$.

## *3.4 The Proposed Protocol Algorithms*

The proposed authentication protocol does not declare the use of certain cryptographic protocols and algorithms. Only types and parameters are defined. As part of the $\text{Dev}_1$ − ES interaction, a digital signature and symmetric authenticated encryption algorithms are used. As part of the ES – $\text{Dev}_1$ interaction, digital signature and

**Table 2** Summary of all the algorithms used and their requirements

| Algorithm notation | Description | Requirements for IoT device |
|---|---|---|
| $H$ | One-way hash function | Hash code length must be equal to the key $K_{\text{auth}}$ length |
| Sign() | Digital signature generation | $\text{Dev}_1$ must complete in a reasonable amount of time |
| Verify() | Digital signature verification | $\text{Dev}_1$ and $\text{Dev}_2$ must complete in a reasonable amount of time |
| $E/D$ | Asymmetric encryption/decryption | $\text{Dev}_1$ must complete $D$ in a reasonable amount of time |
| $E^{\text{sym}}_{\text{auth}}/D^{\text{sym}}_{\text{auth}}$ | Symmetric authenticated encryption/decryption with authenticity check | $\text{Dev}_1$ must complete $E^{\text{sym}}_{\text{auth}}$ in a reasonable amount of time |
| $E^{\text{sym}}/D^{\text{sym}}$ | Symmetric encryption/decryption | $\text{Dev}_1$ must complete $D^{\text{sym}}$ in a reasonable amount of time |

symmetric encryption algorithms are used. The following Table 2 gives a summary of all the algorithms and protocols used and their requirements.

## 4 Conclusion

The ability to delegate computing tasks to the edge server allows to build less resource-intensive protocols for IoT networks. In this paper, authentication protocol for intelligent electronic devices in an edge IoT environment with key agreement has been proposed. It allows to resist following types of attacks: unauthorized access to the device, substitution of the edge server, energy-draining DDoS. The protocol also allows to agree the keys for devices interaction with the edge server during the authentication process for further device management. The protocol flexibility is provided by choosing any suitable set of cryptographic algorithms for the certain computing capabilities of the devices interacting within the protocol and the bandwidth of the edge server.

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# A Channel-Based Attention Deep Semantic Segmentation Model for the Extraction of Multi-type Solar Photovoltaic Arrays from Large-Scale Orthorectified UAV RGB Imagery

**Yahya Zefri, Imane Sebari, Hicham Hajji, and Ghassane Aniba**

**Abstract** The extraction of photovoltaic (PV) arrays from remotely sensed aerial imagery is the core element in the mapping of PV sites. Moreover, it is of high utility in increasing the robustness of automatic imagery-based inspection models through reducing their searching space. The extraction can also be used reliably as a tool in assessing the generation capacity of PV installations. In this context, we leverage the channel-attention deep learning mechanism to exploit the full potential of the RGB spectrum and develop a deep semantic segmentation model for the extraction of PV arrays from very high spatial resolution imagery acquired by unmanned aerial vehicles (UAVs). We collect aerial images from four large-scale PV sites featuring multi-type PV arrays in various arrangements and backgrounds. After a photogrammetric post-acquisition workflow, we prepare a labeled big imagery dataset comprising 7319 unique 256 × 256 px tiles with a spatial resolution around 1 cm/px. Our final model relies on a hybrid LinkNet architecture embedding a squeeze-and-excitation (SE) 18-layer residual network backbone. It operates on monocrystalline, polycrystalline and thin-film surfaces, on which it achieves the state-of-the-art performance, with a mean IoU of 86.67% and F1-score of 92.20% on our test set.

**Keywords** Photovoltaics · Unmanned aerial vehicles · Photogrammetry · Deep learning · Semantic segmentation

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## 1 Introduction

The sustainability and long-term reliability of renewable energy infrastructures are major concerns within operators and investors. For solar photovoltaic (PV) installations—which hold one of the largest renewable energy market shares—PV arrays are continuously affected by various factors that degrade their performance [1]. To remedy this, regular inspection operations are required to detect and address defective modules. Thanks to their reliability and cost-effectiveness, airborne imaging techniques using unmanned aerial vehicles (UAVs) are increasingly used for this purpose, and RGB cameras—alongside thermal ones—are frequently implemented [2, 3].

RGB sensors provide high-resolution images that can be used reliably to characterize PV surfaces in search of various defect types such as cracks, delamination's, snail trails, discolorations and dust deposits [2, 4]. The RGB information makes it possible also to interpret thermal patterns more accurately, sport false hotspots and detect some defects that are not detectable through thermal imagery [4, 5].

PV arrays are installed in highly varied layouts, which makes defect detection directly from images highly challenging. Toward this issue, multiple research works [6, 7] tend to implement a prior PV extraction phase, then perform detection on the extracted areas. In this way, detection algorithms operate directly and more efficiently on modules' surfaces; false detections that may result from the background are eliminated and more computational time is gained. PV array extraction is also a key tool in mapping PV sites. Additionally, it can be used reliably as a tool in estimating the generation capacity of these sites through area computation of the extracted surfaces.

Regarding the state-of-the-art related work, Zhang et al. [8] tested an unsupervised approach for PV surfaces extraction based on k-means clustering, where the pixels were classified using 4D vectors comprising the pixels RGB and texture values. Grimaccia et al. [9] proposed an RGB to HSV color space transformation, then applied a threshold to isolate the PV arrays. Wang et al. [10] developed an object-based classification workflow where templates for PV modules were generated from geographic primitives. Souffer et al. [11] proposed a region-growing segmentation approach coupled with un unsupervised parameter optimization to create initial segments within the image. The created segments underwent manual feature engineering then were classified using random forests and support vector machines classifiers to filter non-PV and PV. In this work, we develop a fully automatic solution to extract PV arrays from very high-resolution UAV RGB imagery with the following contributions:

- We use a deep learning-based approach which—contrary to the reviewed works—involves no manual parameter tuning nor feature engineering;
- We leverage the mechanism of channel attention via its squeeze-and-excitation (SE) variant for a more efficient exploitation of the RGB radiometric information;
- In contrast to the stated works, which worked only on polycrystalline PV arrays. We address also monocrystalline and thin-film PV arrays;

- We achieve the state-of-the-art performance, with a mean IoU of 86.67% and F1-score of 92.20% on a big and highly representative collected dataset.

## 2 Methodology

### *2.1 On-Field Image Acquisition and SfM-MVS Post-Processing*

Aerial RGB images were collected from four large-scale PV installations using a UAV type DJI Phantom 4. The UAV was equipped with an integrated RGB camera of pixel pitch 2.34 μm, a focal length of 8.8 mm and a resolution of 5472 × 3648 px. Images were acquired at a flight height around 35 m, following a regular grid with a consistent overlap of 60% between images and strips. The overflown installations feature monocrystalline, polycrystalline and thin-film solar arrays in various scenarios.

The collected images of each installation underwent a three-step structure from motion—MultiView Stereo photogrammetric post-processing workflow. First, the camera parameters are recalibrated to optimized values. Next, a 3D dense point cloud reconstruction is performed for the integral site. Afterward, a digital surface model is generated and used to orthorectify then mosaic the initial images in order to obtain an extensive big image called "orthomosaic" covering the whole installation. Compared to a usual raw image, an orthorectified image offers two main advantages: (1) eliminating the distortions that result from pinhole camera imaging; and (2) making it possible to perform direct accurate distance and area measurements on the image.

### *2.2 Orthomosaic Labeling, Mask Tiling and Deep Learning-Ready Data Constitution*

In a geographic information system environment, the PV arrays in each orthomosaic were digitized using vector features with an integer-valued attribute in [0, 1, 2 and 3], corresponding, respectively, to the classes: background, monocrystalline, polycrystalline and thin-film. The vector layers were automatically rasterized on top of the initial orthomosaics to create raster masks where pixels inherited the values from the labeling attribute. The orthomosaics and masks (after being one-hot encoded) were tiled pairwise following a 256 × 256 px grid (Fig. 1) to create sub images (tiles), which in turn, underwent a 70%/20%/10% training/validation/test split. Tiles that contain no arrays were filtered out. The initially generated tiles underwent no augmentation and were directly packed into a deep learning-ready format for posterior steps.

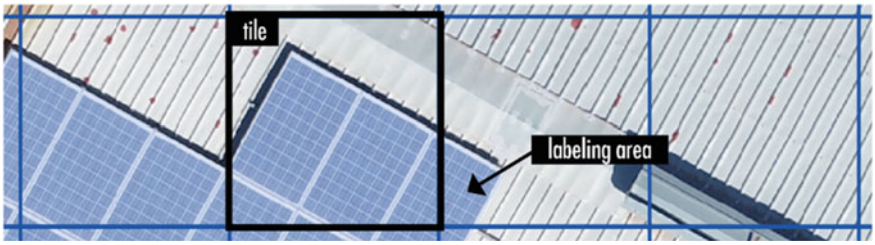


**Fig. 1** Orthomosaic labeling (blue vector polygons) and tiling (the overlaid blue regular grid)

## *2.3 Model Development*

**Architecture design**. Semantic segmentation is a pixel-wise classification where a label is assigned to each image pixel instead of an image-wise label attribution [12]. Fundamentally, a semantic segmentation model comprises two paths: (1) an encoder path whose function is feature map extraction by means of a convolutional neural network (CNN) as a backbone; and (2) a decoder path that generates the pixel-wise classification through upsampling, deconvolution or other architecture-specific procedures [13]. For the addressed task, we have chosen a LinkNet architecture. LinkNet exploits the hierarchical spatial representations generated within the encoder path more efficiently through bypassing them directly to the decoder path, which provides increased performance and computational efficiency [14]. Instead of using a vanilla encoder, we have implemented an 18, 34 and 50-layer squeeze-and-excitation (SE) residual neural networks (ResNets), denoted, respectively, as: SE-ResNet-18, SE-ResNet-34 and SE-ResNet-50. In common, the backbones provide two advantages:

- Overcoming the vanishing gradient problem, which arises in training deep neural networks because of repeated multiplications, through the implementation of identity shortcut connections within residual blocks [15].
- The use of the channel-attention mechanism via incorporating SE blocks, which enable to the network to take full advantage of the three-band radiometric information embedded in the images.

*Channel attention and the SE variant.* Attention is a mechanism that has been inspired from the human cognition. Naturally, in search of a particular detail, humans tend not to process the entirety of the received information stream; instead, they choose to focus on a part of interest which receives more attention than the others [16]. In the machine/deep learning field, attention has been proposed first within the subfield of natural language processing (NLP) [17]. Afterward, it has been transposed to computer vision via several variants among which there is channel attention and its SE variant [16]. The latter relies on SE blocks (Fig. 2) that operate as follows [18]:

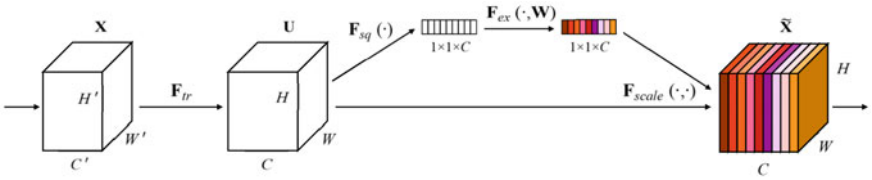


**Fig. 2** SE block [18]

- Initially, an input tensor $X$ of shape $\left(H' \times W' \times C'\right)$ undergoes a transformation $F_{\text{tr}}$ that produces a feature map $U$ of shape $(H \times W \times C)$ (where $H'$, $W'$ and $C'$ are, respectively, the tensor height, width and number of channels).
- The feature map $U$ is passed through a "*squeeze*" operation $F_{\text{sq}}$ that shrinks each channel to one numeric value, generally using a global average pooling operation.
- An "*excitation*" operation $F_{\text{ex}}$ follows, where a fully connected multi-layer perceptron processes the squeezed output to learn a weight distribution for the channels.
- The output channel-weight tensor is normalized to the unit interval, broadcasted to the shape $(H \times W \times C)$, then multiplied element-wise with the feature map $U$.

SE blocks model the intrinsic channel dependencies of a tensor, allowing an ulterior recalibration where more important weights are given to the channels to which increased attention should be paid and vice versa. SE blocks can be integrated seamlessly in existing CNN architectures with negligible added computations [16, 18].

**Model training, validation and test**. Each model was trained for 50 epochs starting with randomly initialized parameters, using the Adam optimizer, with an exponential learning rate decay schedule of 0.93 and a batch size of 32 samples. To track the learning evolution, the mean intersection-over-union (mIoU) and the F1-score were computed at the end of each epoch on the validation set. Afterward, the three models were evaluated on the held-out test set using the same metrics.

## 3 Results and Discussion

### *3.1 On-Field Image Acquisition, SfM-MVS Post-Processing and Data Preparation*

Initially, 1566 images were acquired on-field, from which four RGB orthomosaics have been produced through the SfM-MVS post-processing workflow. Figure 3

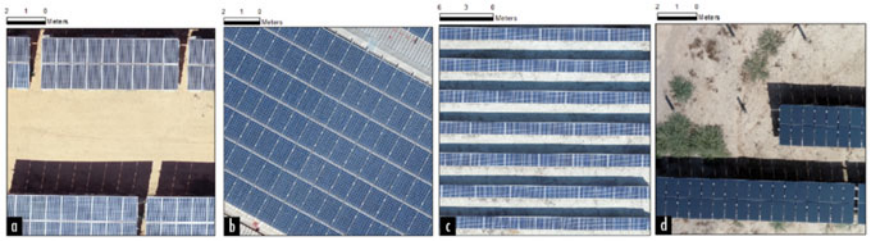

**Fig. 3** Snapshots from the obtained orthomosaics at different scales with **a** monocrystalline, **b**, **c** polycrystalline and **d** thin-film arrays containing modules under various arrangements

groups snapshots from the obtained orthomosaics at different scales. Monocrystalline, polycrystalline and thin-film arrays are featured, with four naturally different backgrounds, i.e., bare soil, bare soil/grass and an industrial factory rooftop.

The very high spatial resolution obtained (1 cm/px) enables to delineate the arrays, as well as the individual module contours conveniently. For orthomosaics (a), (b), (c) and (d), the following numbers of tiles have been generated, respectively: 2113, 664, 1714 and 2828.

## *3.2 Model Development*

Figure 4 tracks the progression of the mIoU and the F1-score for the three models, computed on the training and validation sets. The curves increase exponentially during the earlier epochs. High downward fluctuations are observed in SE-ResNet-50 compared to the two other models, and SE-ResNet-18 shows up to be the most stable model at the earlier training/validation stages.

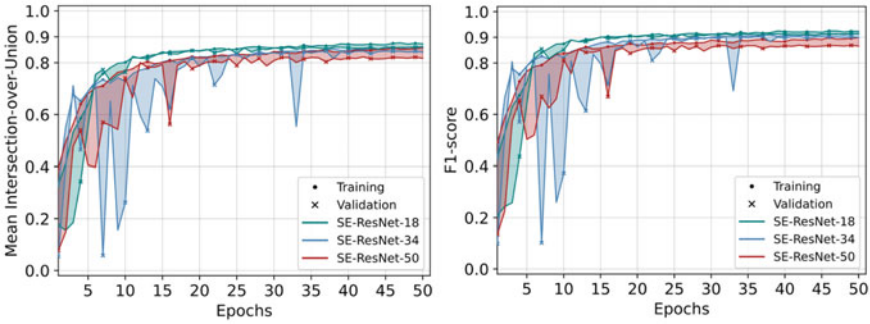


**Fig. 4** Progression of the training/validation mean intersection-over-union (mIoU) (left) and F1-score (right) along epochs with the filled generalization gaps for the three experimented models

**Table 1** The training/validation convergence (mIoU and F1-score) values and the obtained ones on the held-out evaluation test set

| | SE-ResNet-18 | SE-ResNet-34 | SE-ResNet-50 |
|---|---|---|---|
| Training (%) | 87.31, 92.33 | 85.91, 91.49 | 85.83, 89.91 |
| Validation (%) | 86.10, 91.40 | 84.05, 89.95 | 81.69, 86.59 |
| Test (%) | 86.67, 92.20 | 85.63, 91.50 | 86.19, 91.86 |

Starting from epoch 35 approximately, a general stability and convergence are observed for all the models, with SE-ResNet-18 staying at the top, followed by SE-ResNet-34 then 50. The convergence mIoU and F1-score values for the training/validation stage are summarized in Table 1. SE-ResNet-18 also has the smallest generalization gap, i.e., the difference between the training and validation curves. No underfitting or overfitting patterns were observed for any model, which means that the training of the three models has been performed optimally.

On the held-out test set, the highest performance was anew achieved be SE-ResNet-18, which scores a mIoU and F1-score of 86.67% and 92.20%, respectively (Table 1). The model was the selected as the final candidate for the addressed task. Sample thresholded ($t = 0.5$) predictions of SE-ResNet-18 applied on test tiles are shown in Fig. 5. The figure illustrates how the multi-type model predictions adhere well to the original images, with very negligible differences compared to the labeling masks. For a practical deployment, an input orthomosaic has to be tiled, then passed to the model, which will generate prediction tiles as illustrated. The latter have to be thresholded, then mosaiced to obtain at the end a whole prediction map covering the entire PV site.

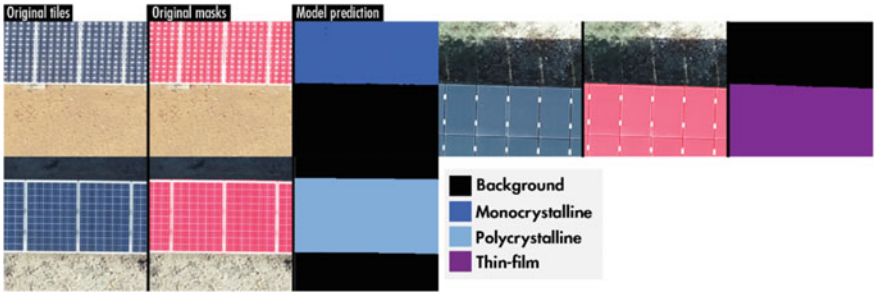


**Fig. 5** Sample thresholded model predictions (SE-ResNet-18) on multi-type PV array tiles randomly drawn images from the test set, compared to the original masks

## 4 Conclusion and Recommendations

We developed in this work a deep learning-based model for the extraction of PV arrays from very high spatial resolution orthorectified aerial RGB imagery. The model relies on a hybrid LinkNet architecture embedding a SE-ResNet-18 backbone. It involves no manual parameter tuning or feature engineering. The model can be directly applied to any input tiled RGB orthomosaic, outputting the precise contours of the extracted arrays along with recognizing their type (monocrystalline, polycrystalline and thin-film). The model also achieves the state-of-the-art performance with a mIoU and F1-score, respectively, of 86.67% and 92.20%. For future work we suggest:

- Collecting more data from additional sites to enhance the robustness, performance and generalizability of the proposed approach and model;
- Exploring additional deep semantic segmentation models namely spatial attention-based and transformer-based models;
- Addressing an instance segmentation task where, the modules are extracted individually instead of the complete array.

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# Towards an E-Psychology Solution to Support, Intervene and Educate the Control of Emotions in Infants

**Cleofe Alvites-Huamaní, John Alexander Rojas-Montero, Janio Jadán-Guerrero, and Elías Muñoz-Primero**

**Abstract** Anxiety and depression in infants are a problem that is increasing, this being a consequence of the global pandemic caused by COVID-19. The current panorama indicates that infants are possible victims of suffering from these moods at very early ages and in the worst case, it becomes the leading cause of child suicide. For this reason, it is very important to seek resources and means to mitigate the situation. The current project consisted of making a web application for the control of emotions in primary school children through modules made up of theoretical sessions that cover the management of emotions, thoughts, assertiveness, frustration, breathing, and muscle relaxation. Each module in turn has an intervention session, which consists of situations that are presented to the infants with the aim of analyzing the psychological impact that the theoretical sessions had, with the main purpose of improving or intervening the control of their emotions.

**Keywords** E-psychology · Telepsychology · Anxiety · Depression · Suicide risk

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## 1 Introduction

The COVID-19 pandemic has generated a series of changes in the various educational, professional, and business fields and with it also affectations at an emotional level, especially in people's mood. In children and adolescents, their habits and routines have changed, leading them to have emotional problems such as anger, stress, increased symptoms of anxiety, depression, and even suicidal risk [1–3].

According to what was reported by the United Nations Organization (UN) in 2020, mental illnesses have become a silent epidemic that affects people in various age ranges, highlighting those infants are the main victims of suffering anxiety and depression [3–6].

Anxiety, depression, and suicidal risk in infants is a problem that is increasing due to the situation of confinement that has been experienced since 2020. If these states of mind are exacerbated, it can become a psychopathological disorder that affects the integral development of the infant and indirectly the social context in which they live. In addition, in what is reported by organizations such as the UN and SEPEA, the current panorama indicates that minors are possible victims of suffering emotional changes due to these problems and in extreme cases, by not having control over their emotions can become the leading cause of child suicide, for this reason, it is vitally important to seek resources and means to mitigate this situation [4, 7].

According to the Spanish organization SEPEA, it mentions that the prevalence of childhood anxiety disorders ranges from 3 to 21% worldwide. Of this sector of the population, it is mentioned that around 33% meet the criteria for two or more anxiety disorders. Depression and suicidal risk are problems that are unfortunately on the rise, with an estimated 52 child suicides per month in 2020 [7], a situation that affects health in general. Health being an essential and necessary right for the whole society, considered as a priority for the 2030 agenda related to health and well-being [8], in the same perspective of guideline three of the Sustainable Development Goals (SDG) conceived at the United Nations Conference on Sustainable Development, in order to alleviate poverty, protect the planet and guarantee world peace and prosperity [9].

Currently, there are proposals that seek to mitigate this problem, one of them being "Telepsychology". This is defined as the provision of psychological services through Information and Communication Technologies (ICT), which allow the processing of information by digital means and therapies via the Internet. Therapies have shown efficacy and are becoming a complement due to increased use and accessibility [10]. In addition to this, ICTs have gained popularity in health systems and this process has greatly accelerated with the COVID-19 epidemic [11, 12], and they are considered an opportunity to approach the motivations of students and educate them for health [13], and these digital tools can have very positive effects for health management and health care [14, 15].

In this way and with the aim of generating a tool to contain the problem, a web application focused on supporting, intervening, and educating emotions in children was implemented, through modules made up of two sessions, mainly focused on three aspects: anxiety, depression, and suicide risk. The topics and materials addressed

during the development of the web application were supervised, coordinated, and verified by specialists in educational psychology. The software was developed under an agile methodology scheme, aligned to the need to have a useful tool in short production times and reduced technical documentation [16].

For what is related to the usability of the software, the ISO 9241-11 standard was taken as a basis, in which three concepts are defined and measured at a technical level: effectiveness, efficiency and satisfaction. The effectiveness as a response capacity to the requests that a user who uses a software has that is capable of interacting and specifying the foreseen objectives. The efficiency is linked to the adequate use of the resources assigned by the general project administration (time, hardware and other points selected by the planning team). Satisfaction, as a pleasant, comfortable, and useful experience of the software by the user [17].

## 2 Background

To focus this project on a line of research that supports the problem in question in a different way to what has already been done, previous studies were considered, which are described below.

*Mobile applications for anxiety*: a review in Argentina. It exposes the compilation of five applications focused on treating anxiety. Two applications were presented as simple conversation platforms (chat) with psychologists. The other three mobile applications properly discuss their features. The need to develop Argentine mobile applications for people affected by anxiety disorders is highlighted [18].

*Design of a technological application to help improve self-management of symptoms in patients with depressive mental disorders. A mobile application is developed that combines two basic functionalities*: the video game as a method of dispersion and the online social community as a space for contact with other users with similar problems. However, the project focuses exclusively on the definition of the community environment, a place where the user requirements extracted during the investigation can be explained in the form of different interactive functionalities [19].

*Remote test application*: Risks and recommendations, in which telepsychology is reflected. From a tele-assessment practice, the conditions in which the test was built, standardized, and validated are modified, and therefore it is convenient that it be accompanied by an analysis of its potential risks. In this work, the threats associated with the remote use of the test are described, and some recommendations are made to mitigate them. When a professional chooses for the remote application of a test built to be used in person, they should be aware of the risks and benefits associated with this practice, and once these have been evaluated, act accordingly [20].

*The use of technologies as a factor of socio-affective development in children and young students in northwestern Mexico.* An analysis of the relationship between the approach to the use of technologies and socio-affective development in children and young people between 6 and 18 years old is carried out. It was found that children under 12 years old continue to prefer face-to-face coexistence since they expressed

being more used to developing friendship ties in a personal way, and in this sense, they assume the use of virtual media fundamentally for recreational purposes and as a complement that does not replace direct contact with their groups of friends. In regard to young people, they showed a great capacity to establish relationships with other people, particularly with those who are of the opposite gender in the search for emotional ties as a couple and/or sexual identity [14].

*Screens, children, and confinement in a pandemic: should we limit their exposure?* Due to the pandemic situation, confinement was forced, physically away from other people and without access to recreational activities abroad; For this, it is proposed: (1) to review the information available about screens consumption in children; (2) expose the evidence that supports the current recommendations of different institutions regarding its use; (3) critically evaluate, making knowledge gaps visible, to rank them when advising families on parenting [21].

*Review of applications of Information and Communication Technologies in clinical and health psychology in childhood and adolescence.* A review of the main applications based on technologies for the treatment of different psychological disorders in childhood and adolescence, as well as in other outstanding areas of health in these ages, is addressed. The implications that this may have been analyzed and, in addition, future challenges are raised to optimize these resources and open new lines of research relevant to this topic [22].

## 3 Method

For the organization of time focused on coding this project, the agile work method called "Kanban" was used.

Kanban is a Japanese origin word formed by "Kan", whose meaning is "visual" and by the word "Ban" which means "card". Therefore, Kanban refers to visual cards. This method of organization is very simple, it can be constantly updated, with very little documentation and assume responsibilities without problem. It was decided to use this, for the limited period of seven weeks that was available [23]. The cards or tasks proposed to implement on the Kanban board were:

- Analysis of relevant technologies for the project.
- Design of the graphical interface and data repository.
- Development and programming.
- Unit and system tests.
- Synthesis of the results obtained.
- Elaboration of protocol and research article.

## *3.1 Implemented Technologies*

The application was developed to be executed in a web environment; therefore, two fundamental components were considered: the client application and the server application.

**User Application**

The HTML5 standard "HyperText Markup Language" in its version 5 was used from a basic structure and a code for the definition of content, such as text, images, videos, games, among others [24]. Together, CSS technology was used in its third version, as a graphic design language to define and create the presentation of a web page from the HTML5 standard [25]. In addition, JavaScript ECMA 6 was implemented as a programming language that runs in various web browsers and is complemented by HTML5 and CSS3 technologies, to provide interactivity and system validations for end users [26].

**Server Application**

The application was implemented in the Python programming language, known as an interpreted language whose philosophy emphasizes the readability of its open-source code that does not require a license payment for its use. It is a multi-paradigm programming language that partially supports object orientation, imperative programming and, to a lesser extent, functional programming [27]. In addition, the Flask framework with an open-source license was used, minimalist in nature and written in Python that allows creating web applications quickly and with a minimum number of code lines, based on the Werkzeug WSGI specification and the Jinja2 template engine; with functionalities to make free use of SQLite 3 for the database [28].

The unit and system tests were developed through a local server through a virtual environment through the Flask framework for Python. Additionally, a free hosting on the NO-IP platform was requested for 30 days, so that the infants had access to the software.

## *3.2 Graphic Interface*

The graphical interface generated with the characteristic of being responsive so that the infants could use the client application (Fig. 1).

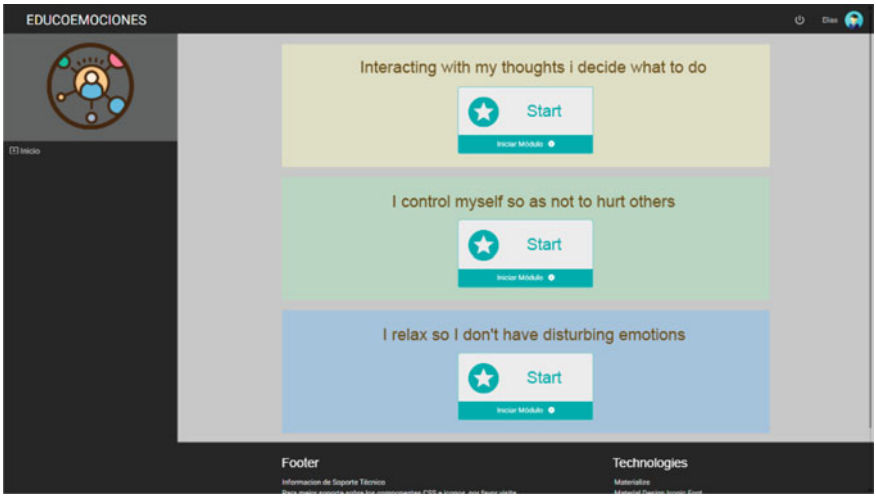



**Fig. 1** Graphic interface generated in Spanish for intervention sessions with infants

## *3.3 Technical Design*

When implementing an agile method like Kanban, only general diagrams are made. Time was focused on software development so technical documentation is only essential. The global operation of the system is shown in Fig. 2.

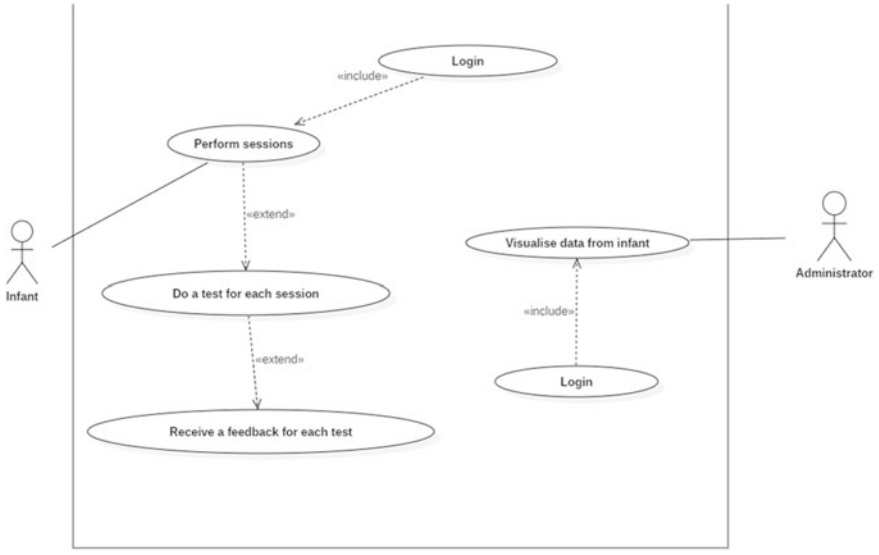



**Fig. 2** System use case diagram based on the UML standard

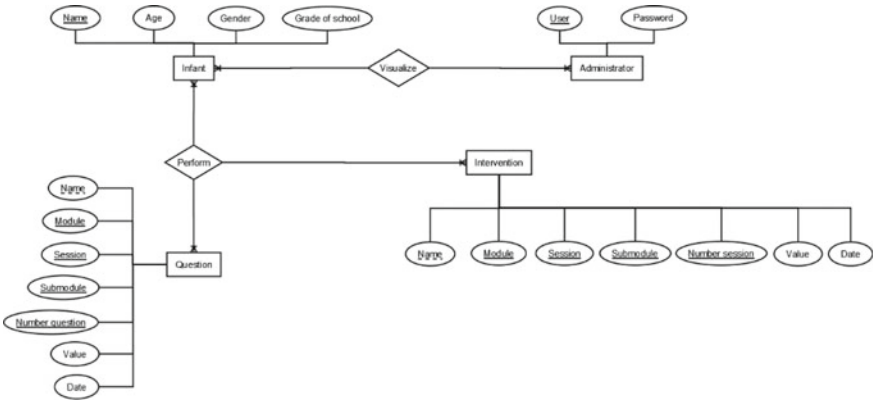



**Fig. 3** Entity relationship diagram

For the technical design focused on data persistence, it was proposed to use a relational database, for this reason Fig. 3 shows its respective entity-relationship diagram.

# 4 Results

## *4.1 Software Usability*

The impact that the software had on its first pilot was evaluated under certain headings following a standard. The items of technical usability were effectiveness, efficiency and satisfaction. These aspects were evaluated based on the ISO 9241-11: 2018 standard as follows.

**Effectiveness**

Three test sessions focused on units and systems were performed. Seven test streams were considered, and each stream was given one point as a value. Therefore, for this item the way in which it was evaluated was as follows:

$$\left[\text{Successful paths/Total paths}\right] * [100] \; = \; \%\text{Effectiveness} \tag{1}$$

At the end of the unit and system tests, the seven planned trajectories were executed correctly, therefore, an effectiveness result of 100% was obtained.

**Efficiency**

The most important points were considered by the specialists in psycho-pedagogy and psychology with their respective value for this item.

- Graphic interface for access to modules. Weighing: 15. Status: Completed. Value: 15.
- Development of Interactivity with the theoretical contents. Weighing: 15. Status: Fulfilled. Value: 15.
- Carry out questionnaires for each theoretical content. Weighing: 15. Status: Completed. Value: 15.
- Feedback for each theoretical content. Weighing: 10. Status: Completed. Value: 10.
- Intervention sessions agreed by the specialists. Weighing: 15. Status: Fulfilled. Value: 15.
- Summary of the results obtained (summarized Excel format). Weighing: 15. Status: Completed. Value: 15.
- Graphical interface for administrator access. Weighing: 15. Status: To be fulfilled. Value: 0.

The Weighing formula for efficiency item was considered as follows:

$$[\text{Accumulated value}/100] = \%\ \text{Efficiency} \tag{2}$$

Based on the previous list, the accumulated value was 85, this is due to the fact that during the seven weeks in which the project was developed, the only thing missing was the implementation of a graphical interface for administrator access. For this reason, at the end of the first pilot test in the area of efficiency, 85% was obtained.

**Satisfaction**

A survey was carried out on the infants at the end of the intervention sessions scheduled by the specialists. The results were categorized as follows:

- Good system
- Bad system
- Improvements.

The form of weighing for the item of satisfaction was carried out as follows:

$$\left[\text{Good System Answers/Total responses}\right] * [100] = \%\text{Satisfaction} \tag{3}$$

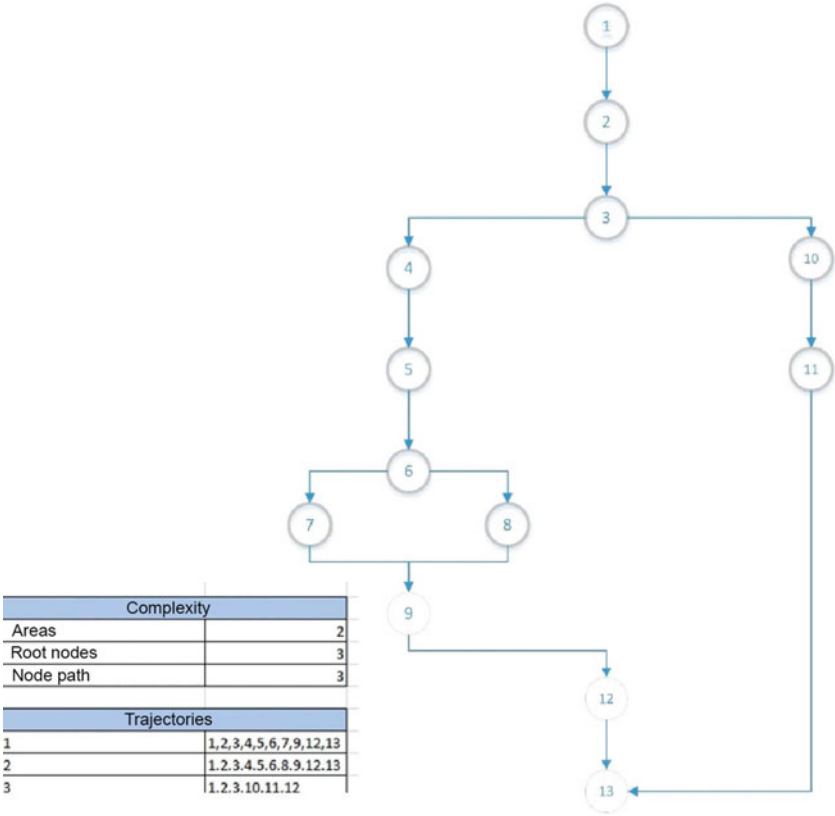
The responses obtained were a total of 9; of which the infants who thought it was a good system was 7. When performing the operation based on Eq. (3), the result in the item of satisfaction gives a total of approximately 77.77%.

## *4.2 White Box Tests*

The white box tests carried out on the web application for the usability effectiveness category were (Tables 1, 2 and 3):

**Table 1** Records in a database the information that is entered through a form [17]

| Type of test: white box: independent path |
|---|
| Object: script db.py |



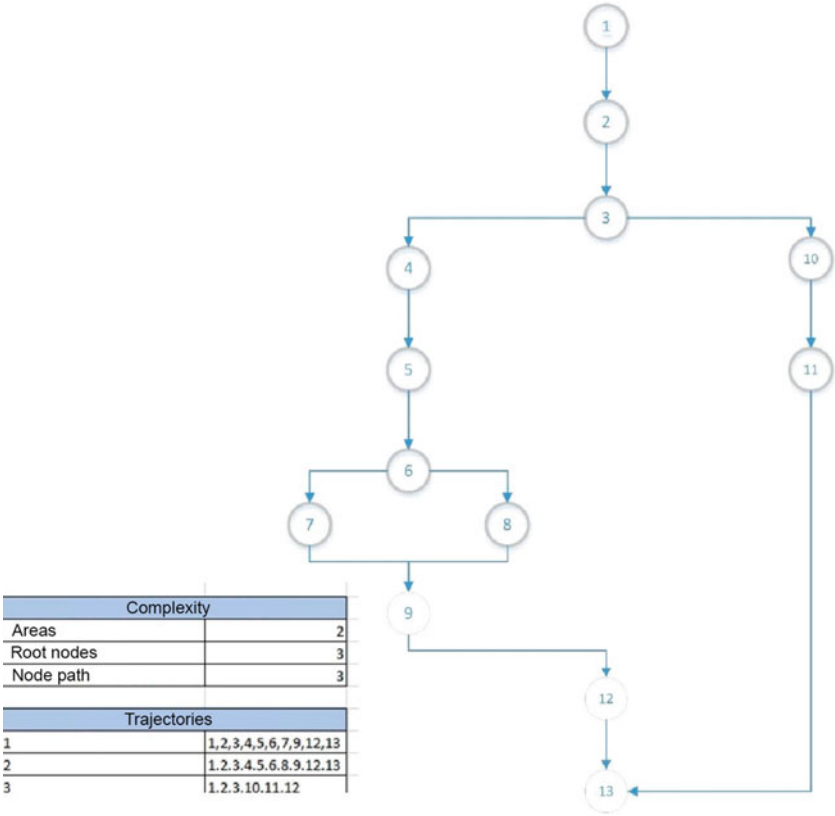

## 5 Conclusions

The web application became an alternative to support infants by allowing them to interact with their thoughts, control themselves to avoid harming others, and relax to avoid disturbing emotions. This made it possible to establish contact with a professional capable of providing feedback and guiding them on aspects related to anxiety, depression, and suicide risk.

In addition to the benefits for infants, during the process of developing the application, professionals from various areas intervened, which enriched both the intervention schemes in problems related to emotions, as well as the interdisciplinary intervention required in this type of project, with the aim to provide evidence that enables decision-making by professionals who are competent in their area and in

**Table 2** Insert an infant's responses into the system [17]

| Type of test: white box: independent path |
|---|
| Object: script db.py |



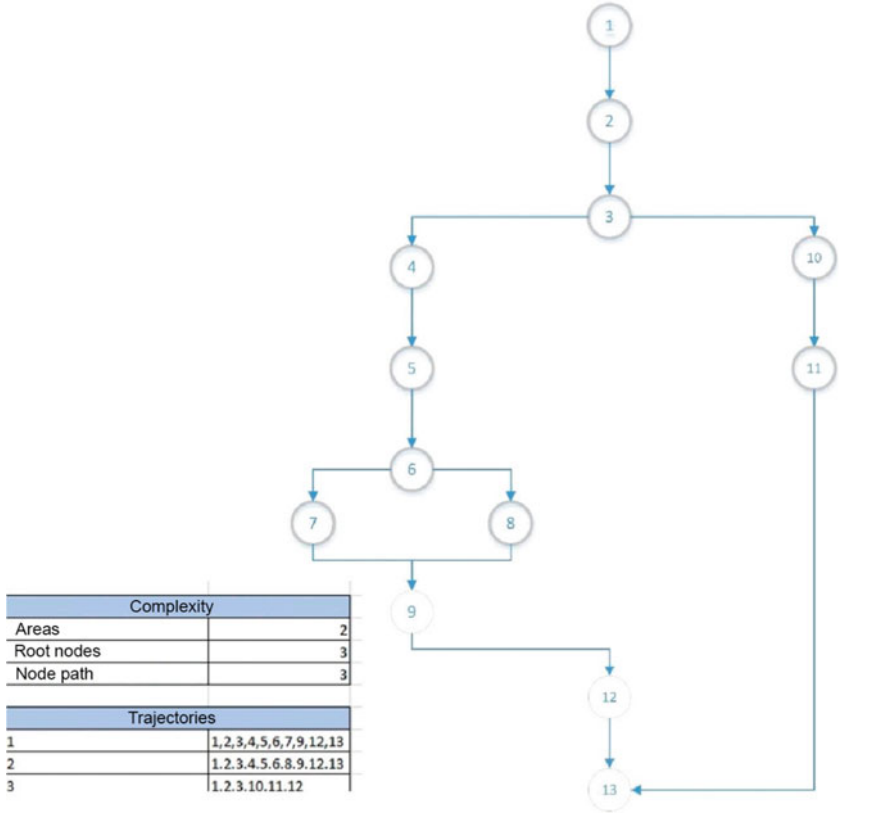

the use of ICT, in order to provide valid and ethical support, in which the familiarity they have is taken advantage of children with digital devices, which transcends being connected to entertain themselves, to take advantage of these technologies to improve their quality of life and their emotional development.

Given the pressing needs that infant have in different contexts, the agile development of applications becomes imperative to provide timely solutions to vital problems. Thus, it was necessary to consider: (a) Requirements analysis. (b) User control. (c) Response time. (d) User interactivity. (e) Statistical analysis of the system. (f) Semantic analysis of responses.

In the requirements analysis, the modules, sessions, and aspects related to the intervention were considered to guide the development of an application projected on a larger scale, which would respond to the general ideas of the project. In users'

**Table 3** Record the infants' intervention sessions [17]

| Type of test: white box: independent path |
|---|
| Object: script db.py |




control, a normalized database was designed up to its fourth form to meet the registration requirements of the application. In response time, through a host server, the adequate infrastructure was provided for the operation of the application. To address user interactivity, gamification techniques were developed with technologies such as HTML5, CSS and JavaScript, focused on providing infants with scenarios for a better understanding of their emotions.

Likewise, in the statistical analysis of the system, an algorithm was implemented to guide a general and statistical analysis for each registered infant, so that the administrators could visualize the information. In the semantic analysis of answers, an algorithm for the classification and recognition of natural language obtained in the answers to open questions made to infants was worked on.

It is necessary to continue with the development of this type of technology that provides better conditions to intervene on the effects that various populations have

been suffering, which negatively impact emotions and relationships with others, as a factor that contributes to an education that is attentive not only to knowledge, interaction, and expression, but also to the affective and emotional dimension of people.

Finally, some opportunities for improvement that have been analyzed during the application of the proposal are suggested as future work, among them, within the **Analysis of requirements**, all the modules, sessions and other aspects of intervention that are sought to be implemented can be contemplated in software on a larger scale. In the same way, in the **User Control module**, a normalized database can be designed up to its fourth or at least third form, considering the entire spectrum of application of the project in question. For **Response Time**, the software can be mounted through a host server that has the appropriate infrastructure for its operation. Also, for **Interactivity with the user**, it is recommended to develop gamification techniques through technologies such as HTML5, CSS and JavaScript so that infants show a better understanding and entertainment by the system. However, for the **Statistical analysis of the system**, an algorithm can be implemented that can perform a general and statistical analysis (for each registered infant) so that the administrators can view the information. Similarly, for the **Semantic analysis of answers**, an algorithm can be implemented that can classify and recognizing, through natural language processing or some other technique, the answers to open questions made by end users, in this case by infants.

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# SEMAFORE: Secure Mobile Field Diagnostics for Cyber-Physical Systems

**Tate Seyler and Denis Ulybyshev**

**Abstract** It is vital for Cyber-Physical systems to quickly recover after emergencies that might be caused, for example, by natural disasters or cyberattacks. In this paper, we propose a secure field diagnostics methodology for monitoring Cyber-Physical systems. Our solution relies on near-field communication technology and a mobile application that incorporates biometric fingerprinting for its fast and secure role-based authentication. For data protection, we propose an encryption schema with on-the-fly key generation, using a biometric secret. Our solution also allows operators to read and write diagnostics messages for field devices and sensors, which makes the maintenance of Cyber-Physical systems easier and reduces the probability of failures.

**Keywords** Cyber-Physical Systems · Biometric authentication · Near-field communication · On-the-fly key generation · Key management

## 1 Introduction

In Cyber-Physical Systems (CPS), it is essential to quickly recover after emergencies and failures. For example, in city infrastructures, it is vital to quickly fix power outages that might be caused by natural disasters, cyberattacks, or other reasons. In this paper, we propose a Secure Mobile Field Diagnostics for CPS (SEMAFORE) methodology. It is a framework for user-based field diagnostics that can be applied in power grids, water treatment facilities, manufacturing systems, and Internet of Things (IoT) systems. Our solution employs on-the-fly key derivation using biometric fingerprinting. SEMAFORE is specifically designed to provide persistent storage for IoT diagnostics data. This system is broken up into a front-end mobile application and a back-end server. An individual interacting with the front-end application that

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retrieves diagnostic data from the back-end server is subsequently referred to as a user of our system. To successfully perform diagnostics, one or more already deployed CPS must be available and connected to SEMAFORE's back-end server. Henceforth those CPS that interact with our system's back-end are referred to as monitored systems.

To enable diagnosis of the necessary attributes of varying IoT systems, our back-end server is able to be customized. An individual responsible for customizing our back-end server, managing one or more CPS, and connecting those CPS to our system (so that they may be considered monitored systems) is from this point forward referred to as the administrator of the affected system/systems. Section 3.1 "Customization" of the "Core Design" section covers the requirements and instructions for an administrator to customize the system and transition their CPS into a monitored system.

Field diagnostics for the purpose of this paper are simply diagnostics taken at the location of what is being diagnosed. Invocation of Near-Field Communication (NFC) technology is performed in the front-end application as a mechanism of ensuring a user's proximity. NFC technology is a fine-tuned version of Radio Frequency Identification (RFID). NFC operates on the frequency of 13.56 MHz "over a distance of up to around 20 cm. Currently, it offers data transfer rates of 106, 212, and 424 kbit/s, and higher rates are expected in the future." [1]. Embedded NFC tags are the expected target of the invocation and provide an intuitive method of interaction with monitored systems.

Key derivation is defined as deriving one or more secret keys from a secret value. By doing so during run-time as needed, the derivation is considered on-the-fly. The back-end server uses a stored biometric secret for on-the-fly key derivation. This provides a secure mechanism for passwordless authentication and authorization.

Fine-grained access control as referred to in this paper is access control allowing distinctions in access at the smallest level of a single data item rather than an entire row or other form of subset.

The novelty of our solution proposed covered in this paper is as follows:

1. Biometric-based on-the-fly symmetric key generation mechanism.
2. Fine-grained role-based access control schema.

This paper continues by covering related works in Sect. 2. It then presents the core design and implementation in Sect. 3. Afterwards in Sect. 4, evaluation results are shown for the SEMAFORE's vital metrics. In Sect. 5, we discuss possible future directions for the solution. Finally, Sect. 6 concludes the paper.

## 2 Related Work

When it comes to the integration of NFC technology, there is an abundance of cutting-edge related work. In the domain of remote data acquisition and field diagnostics, most implementations pertain to the medical field with the solid use case of medical

implants [2, 3]. In these papers, researchers have shown the usefulness of NFC due to its penetrability [3] as well as its safety and adaptability [2] in the medical field alone.

Research has been done using Android™ devices and the Android™ SDK to do more general remote monitoring of data [4]. They used NFC technology as a similar method of pre-communication to an eventually dedicated back-end server. But this form of data access lacks solid means of data encryption, authorization, and customization.

In the field of CPS, specified approaches have been taken in monitoring attributes using NFC with dedicated monitoring systems, in one case, Arduino boards [5]. Their system uses NFC shields connected to the Arduino boards. These NFC shields give the Arduino boards the ability to interface with NFC labels and other devices. Integration in this way allows for all-in-one systems for integrated NFC technology with a micro-controller and applications for Cyber-Physical Production Systems and Cyber-Physical Machine Tools.

Integration of biometric is present in specific use cases as well. Machine-to-machine communication using biometrics and NFC as steps to authenticate a user for a home security system is covered in [6]. This system uses NFC and fingerprint technology as a first and third step, respectively, for authenticating a user. The second step is a stored password. Aside from encryption of this password, data in transit is not secured. Failing authentication in this system invokes an alarm system notifying authorities of the intrusion.

On-the-fly key derivation is also a wide field with areas to improve upon. When it comes to incorporation of biometrics for key generation, one approach is to use a dedicated third-party device in order to record the biometric data and thereafter derive a key from that data [7]. Their approach has many benefits including the ability to alter the biometric verification to be more or less sensitive. A major downside when compared to our implementation is the requirement of a third-party device magnifying the cost of implementation. Combating the need for third-party devices is implemented using other metrics such as voice [8]. Most mobile devices can sufficiently collect voice data at low cost. Their key derivation solution can be seen as a similar solution using a different input, voice rather than fingerprint data.

In PROSPECD [9, 10] solution, the symmetric key is derived from three separate factors on-the-fly through a method of concatenation and hashing. Our key generation methodology uses a biometric secret to derive one of the inputs for the key derivation, and it does not involve the centralized Authentication Server, making our solution more flexible and decentralized.

## 3 Core Design

The SEMAFORE core design consists of a front-end application and a back-end server with the goal behind this design being field diagnostics of CPS.

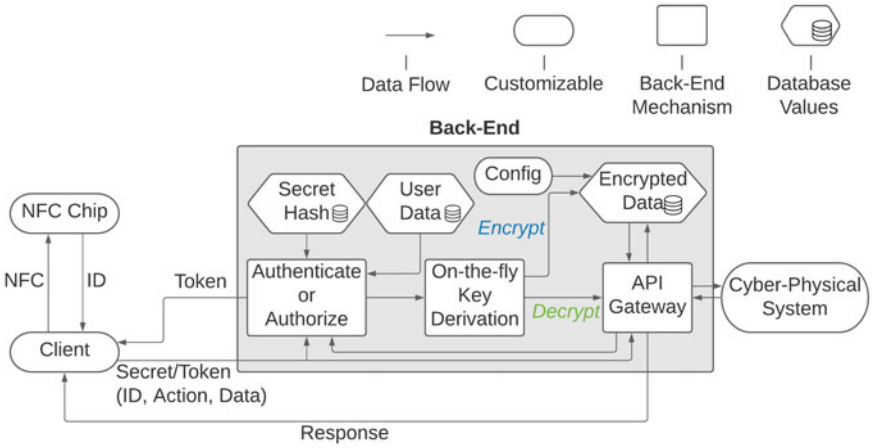



**Fig. 1** SEMAFORE system architecture

The front-end application is built with the Apache® Cordova framework. This framework allows developers to create cross-platform front-end applications. This is achieved by Cordova operating as a web viewer on the devices it is run on. Native calls are handled by Cordova to allow for features a web browser alone would not. For this use case, we are strictly focused on Android™ development, but porting the front-end over to IOS™ devices should be possible. This framework relies on the Android™ SDK for compiling and running the developed application on Android™ devices. The Android™ SDK can be obtained by downloading Android™ Studio. The front-end server gathers biometric data and hardware data using the built-in fingerprint technology and NFC technology, respectively, that the device offers.

The back-end server consists of a server and a database. PostgreSQL® was chosen as a Database Management System (DBMS) due to it being open-source and one of the fastest and feature-heavy DBMS implementations. The server is written in Node.js®. It leverages the Express library in order to create a web API that enables interfacing with the database and invoking actions for the server via requests. With this API, users are able to retrieve, store, and update data given their user credentials allow them to do so.

Figure 1 shows an overview of the SEMAFORE architecture and communication between the various components. It shows the intercommunication between key functions within the back-end server.

## *3.1 Customization*

Customization is an important part of SEMAFORE system. Database design and back-end automation via configuration files allow this customization. Key features

that the system assists in are setting up and populating a PostgreSQL® database that stores data of monitored systems and users. The goal is to make any CPS able to act as a monitored system. In order to do so successfully, there are a few steps listed below that an administrator must take.

**Setup** When it comes to setting up the DBMS, a monitored systems can have many devices of the same type occupy a single database table. Devices are considered the same type if the values recorded from them are the same. There can be any number of types of devices, space permitting, and each device of a certain type occupies a single row of the type's table. In order to give the database knowledge of these relations, a list of table names corresponding to the types and the desired attributes to be stored in each table must be provided. Currently, this configuration file is in the form of a JavaScript Object Notation (JSON) file. The data in the file represents an object with keys pertaining to types of devices that the back-end monitors and values corresponding to the specific sensor values of the device. When this configuration file is correctly populated and the back-end server is started, the required tables are automatically set up by the back-end server.

Also generated are users, roles, designations, and access tables for access control. These tables are populated via a JSON configuration file similarly to the CPS types covered previously. Derived from the data in the access control tables are helper tables that assist in the on-the-fly encryption used later. These helper tables are named "subroles", overlap, and supersession and are automatically populated. A tokens table is also created that is automatically populated when authenticating through the system. Lastly, salts and iterations configuration values a customizable to alter resulting cryptography output. More in depth detail of the usage of these tables is covered in Sect. 3.3 "Access Control".

Figure 2 shows a schema generated by the back-end resulting from a configuration file. This file includes the name of the CPS type and the measured sensor values, for example, voltages and currents.

**Connecting** Next, before an administrator can populate the database, it is important to be able to connect to it. The back-end provides a web-based API. Therefore, it can be connected to via the front-end application or a third-party tool such as Postman®. This relies heavily on the usage of HTTP verbs such as "GET", "POST", and "UPDATE". The front-end application has a built-in settings menu for specifying the endpoint for the back-end server.

**Populating and Maintaining** The first step to populating the database is specifying a user that is authorized to populate and update a monitored system's sensor values. Once created these authorized users can simply make a POST request to the back-end server with the type of device of the monitored system. The back-end server then allocates a new entry to the corresponding table and responds with the new devices's identification number. This identification number is what is written to the NFC chip as specified in Sect. 3.4 "Near-Field Communication". Now communication can be done via UPDATE commands to insert/update data to be stored in the system and GET commands in order to retrieve stored data. The UPDATE process should be

```
    Column    |          Type
--------------+------------------------
 id           | integer
 voltage      | bytea
 voltage_iv   | bytea
 current      | bytea
 current_iv   | bytea
 encryptor    | character varying(32)

Indexes:
    "smartgrid_devices_pkey"
    PRIMARY KEY, btree (id)

Foreign-key constraints:
    "fk_user"
    FOREIGN KEY (encryptor)
    REFERENCES users(name)
```

**Fig. 2** Smart grid relation schema in PostgreSQL® database

```
smartgrid=# select id,voltage,voltage_iv,encryptor from powermeter_devices;
  id  |              voltage               |             voltage_iv             | encryptor
------+------------------------------------+------------------------------------+-----------
 5574 | \x0dadcdd7a8a45928ac935494dc1688f2 | \xa036554acf6a2b1f1bd628aebe88109a | Tate
 5575 | \x4aaa78ee80bea02d31b8d1c8b435fe6d | \xb12695e30fb4a69dc76e3ce97db9f66a | Tate
 5576 | \x13a626e5de3bb37c58dda63d3b5fcd28 | \xcaab6d61bc5cbc6959993bbeb2085abe | Tate
 5577 | \x2ab4a40384b13dd431ba2d34a0e01b40 | \x3d5feb8686ff3ceb8e2d9d5929e8ca43 | Tate
 5578 | \x1f3c28b5e797046894c2acbe1516d98f | \xf8add315ae02ac7a9f3a9f766cb5811b | Tate
 5579 | \xd105cc04a60ed9aa48d547085a025798 | \x0efa44a11474690b862e736a5d187a3d | Tate
 5580 | \x90129c5895cb5f3c3f5006233812479b | \xc0f6cb0c69c53a66fb4de65233208926 | Tate
 5581 | \xb3730b72ff1ba1cf423419346b171bbf | \x18fd07d782f934fec257bda08d905225 | Tate
 5582 | \xfc2baa4b3e7b5be7fd61af15353c2103 | \x71f4e5d41ebd23fb3f7e4d0282f8814f | Tate
 5583 | \x20e50ca1d114637bba89482e97da50f0 | \x8948b218bac01a4e503c855c4cd9135e | Tate
```

**Fig. 3** Smart grid relation records with encrypted sensor values attributes

automated so that real-time values are monitored. These requests are handled by the front-end application as specified in Sect. 3.6 “User Interface”.

Figure 3 displays a smart grid relation records as stored in the database.

**Updating** Whenever a new type of device within the monitored system is desired, an administrator simply updates the configuration files by adding the new device type. After this is done, the previous steps can be repeated to achieve the monitoring of the new CPS device’s values.

If new sensor value attributes wish to be added or removed from a type, the simplest method is to rename the table corresponding to the device in PostgreSQL® to another device name. Copy the configuration for the type in the JSON type configuration file. Change old copies name to match the previously renamed value. Finally, change the new copies sensor value attributes to the new desired attributes. In this way, old data is still accessible as a separate table and new updates will be sent to the newly

updated device table. Old values can also manually be "GET" and "PUT" to the newly updated device table and the old device table removed if desired.

To secure the web-based connection between the client and the server, SSL protocol will be used.

### *3.2 Biometrics*

In order to interface with the Android™ device's fingerprint features, Fingerprint All-In-One [11], an Apache® Cordova plugin has been included in the front-end mobile application. This plugin allows not only standard fingerprint prompts but also registering a biometric secret with that fingerprint. According to the plugin's creator(s), this feature allows for "true security" in biometric authentication [11]. Without this feature, simply registering a new fingerprint via the device's settings grants the same access as the individual with the previous fingerprint had. With this feature, if another fingerprint is registered, the secret is irreversibly corrupted, rendering it unusable.

**Creation and Storage** For appropriate functionality, the secret is generated by the back-end server and then promptly registered on the front-end device. The hash of the secret is calculated by the back-end server and stored for later use.

### *3.3 Access Control*

Access control is provided in a fine-grained role-based manner. The fine-grained aspect comes from the ability to regulated access down to the individual data point being accessed.

**Cryptography** Cryptography is performed by the back-end server using the built-in cryptography library of Node.js®, called "crypto". Stored attributes of all devices are each encrypted separately with AES-256 algorithm in Cipher Block Chaining (CBC) mode. A random Initial Vector (IV) is generated for this encryption and stored in the same database as the ciphertext as shown in Fig. 3.

When it comes to hashing, values stored for comparison, such as the biometric secret are encrypted with one or more rounds of SHA256 before being stored. Hashing is also done for the derivation of the final encryption key and uses SHA256 as well but with a number of rounds separate from the comparison hashing mechanism to prevent redundancy.

**Authentication** For authentication, when prompted by the plugin, a user provides their fingerprint. Then, the biometric secret, IMEI, and user's name are sent to the back-end server. The server then computes the hashes of the biometric secret and IMEI. It then compares them with the stored values for the specific user. If a match

is determined, the server allocates a token and stores it on the back-end server. This token is then sent to the client. In order to ensure only a single session per user, if another request resulting in the generation of a new token arrives while a token is already in the system for a specific user, the new token will overwrite the prior token of the specific user with the newly generated token.

**Authorization** For authorization, when an action is performed requiring authorization, the user provides the previously provided token obtained during authentication. If the token is incorrect or has expired, the client will be asked to restart the process by re-authenticating. If the token is valid and role-based access is required, a translation occurs between users biometric secret and their role secret. The "designations" table of the PostgreSQL® database maps the translation between user and role. The table stores the name of the user, their role, and the roles key encrypted with the users biometric secret. In this way, any user is able to access their role's secret by decrypting it with their biometric secret, and the role secret is not required to be stored in a plaintext or hashed format.

**Overlap** In order to deal with a special case of roles with overlapping access to attributes, a methodology of automatically generated subroles is used. In this methodology, the system detects when a particular data value is accessible by more than one role. This detection occurs by querying the "overlap" table that contains a list of types and attributes that are accessible by more than one role. When this occurs, a sub-role is generated. This sub-role receives its own key that is derived from the concatenation and hashing of the role keys of the overlapping roles. This key is maintained in the "subroles" table. A "supersessions" table is populated similarly to the "designations" table that maps the relation between a role and sub-role. The relation also includes the sub-role key encrypted by the role key. With this, a user is able to obtain the subroles key. This sub-role key is used in place of the role key. With this method, overlapping roles can each access an data values without compromising their own role key.

**On-the-fly Key Derivation** The on-the-fly key derivation function is a lightweight function designed to derive the same key when given the same list of factor. The function is an adaptation of the NIST Special Publication on 800-132 on recommendations for password-based key derivation [12].

This function relies on randomly generated "iterations" and "salts" values stored once in a configuration file. The "iterations" value is a single numeric value that can be anywhere between 1000 and 10,000,000 per the NIST specification. For our use case, a range between 5000 and 20,000 is targeted as lower iterations increase the performance of the function. The "salts" value is an array of five randomly generated 16–32 byte values. This number is also on the lower end of the NIST specification for performance. The arrays length for our implementation is four to match the number of factors used in the key derivation. Although, our function work with any arbitrary amount of factors given a matching number of salts.

The factors used for our methodology are the hash of a role or subroles secret, the unique ID of the record being encrypted, the type and attribute of the record being encrypted, and the metadata of the access control policies.

Once provided the factors, the function starts by sorting the provided factors. After sorting the factors, each factor is then looped through and salt concatenation is performed. The nth factor is concatenated with the nth salt in the "salts" array. The resulting value is then hashed. The resulting hash is then concatenated with the salt again and hashing is repeated. This process continues for a number of times as specified by the "iterations" value. The final hashed values of each factor are then concatenated together in order, and a final hash is taken that becomes the master key and final derived key.

### *3.4 Near-Field Communication*

The incorporation of the NFC provides an intuitive means of identification and an aspect of security. The security aspect originates from the physical proximity limitations of NFC technology. In implementing the system with NFC, we reasonably assume that a party must be physically present to successfully interact with the system as a whole. This compounds a layer of physical security on top of other existing measures.

In the implementation, NFC chips are embedded in a system to be monitored. These chips store identification numbers that are retrieved upon the allocation of a new database table representing a monitored system.

In order to interface with the Android™ device's built-in NFC features, PhoneGap NFC [13], an Apache® Cordova plugin has been included in the front-end mobile application. This plugin allows the device to interact with any NFC technology device that is NDEF formattable. The NFC chips used for testing are NDEF formattable and with this plugin, the front-end is able to read and write data onto the NFC chip. For integrity, the application is also able to irreversibly set chips to read-only, disabling potential malicious actors' interference by scrambling data on the chip.

When the Android™ device is placed within proximity to the NFC chip and NFC is activated, the device retrieves the identification values from the chip, and that value is subsequently used for a "GET" request in order to retrieve the correct value from the database associated with an NFC chip.

### *3.5 Diagnostic Messages*

It is important to be able to diagnose problems after assessing the sensor values of monitored systems. To enable users of the system to diagnose issues in monitored systems, the ability to read and write diagnostic messages in the form of comments was implemented. These diagnostic messages are stored alongside the sensor values of the monitored system they pertain to.

Whenever data on a monitor system is retrieved, a log of recent comments is also sent to the system. Users can view these comments on the front-end device or in tools such as Postman®. On the front-end device, this is done through the "View

Comments" option after fingerprint authentication. Interacting with this button will open the log of the retrieved comments in a human readable form.

In order for a user to leave their own comment, an appropriate POST request is required. In the front-end device, this can be achieved after authenticating and retrieving data from a monitored system via scanning the corresponding NFC chip. If successful, the user is then able to interact with the "Add Comment" option. Interacting with this, button opens a menu that allows the user to type a message of up to 255 characters. Upon re-scanning the NFC chip, the comment is appended to the log. The name corresponding to the comment will reflect the identity of the fingerprint scanned for authentication.

## *3.6 User Interface*

Implementing the front-end with Apache® Cordova, which operates as a web viewer, allows us to rely on very useful web technologies such as Bootstrap and JQuery. The front-end user interface is implemented with Bootstrap 5, which allows for responsive mobile-friendly design. The system's implementation focuses heavily on Bootstrap's card classes and populates them using front-end JavaScript. Communication via web-based requests using HTTP verbs such as "GET", "POST", and "UPDATE" is done using the JQuery library that implements useful functions for this purpose. Requests with JQuery are meant to be quick and efficient and the front-end reflects that.

Interacting with certain features of the front-end application is locked behind authentication. A user must first authenticate with a fingerprint before the NFC communication technology is invoked. This is by-passable as anyone could write their own application for retrieving the NFC data, but is implemented for design.

A general workflow of retrieving data from the back-end server using the front-end is as follows.

**Settings** First, it is vital to ensure the correct setting are implemented on the front-end. Settings are managed in an application menu available via a drop-down at the top of the user interface. In these settings, the user must specify the details of the back-end server including IP address, port number, and TYPE. TYPE is used to validate the table type specified in the Sect. 3.1 "Customization". The user can also register their biometric secret with this menu by filling out the SECRET field and subsequently scanning their fingerprint.

**Authenticate** A user needs to authenticate, using a fingerprint and IMEI. Afterward, a request is generated and sent to the back-end server containing the biometric secret and IMEI. If the server responds with a correct session token, the front-end invokes the NFC reader technology built into the phone and activates it. If the fingerprint scanning failed or the back-end replies with an error, then an error message is shown and the user must re-scan their fingerprint to continue. The number of allowed fingerprint authentication attempts is selected depending on a particular monitored system and use case.

**Scan** After the settings are complete and the user is authenticated, the next step is to place the Android™ device in proximity to an NFC chip corresponding to a monitored system, for example, an electric cubicle with a power meter and a relay protection device. The devices interact and the identification corresponding to the device reference by the NFC chip is sent alongside the user's biometric secret for authorization. The server handles this request and responds. If authorized, diagnostic data is sent from the back-end server to the client. If authorization fails, an error is returned to the user and the user is unable to access the data until they authenticate with another fingerprint and re-scan.

## 4 Evaluation

To evaluate the SEMAFORE system performance, time metrics were taken of the encryption, decryption, key generation, and data retrieval from the PostgreSQL® database. All observations are measured in milliseconds and are represented as an average of 500 occurrences. The system configuration for conducting tests is described below. Postman® was used to automate requests for testing due to the ease of replication of similar requests.

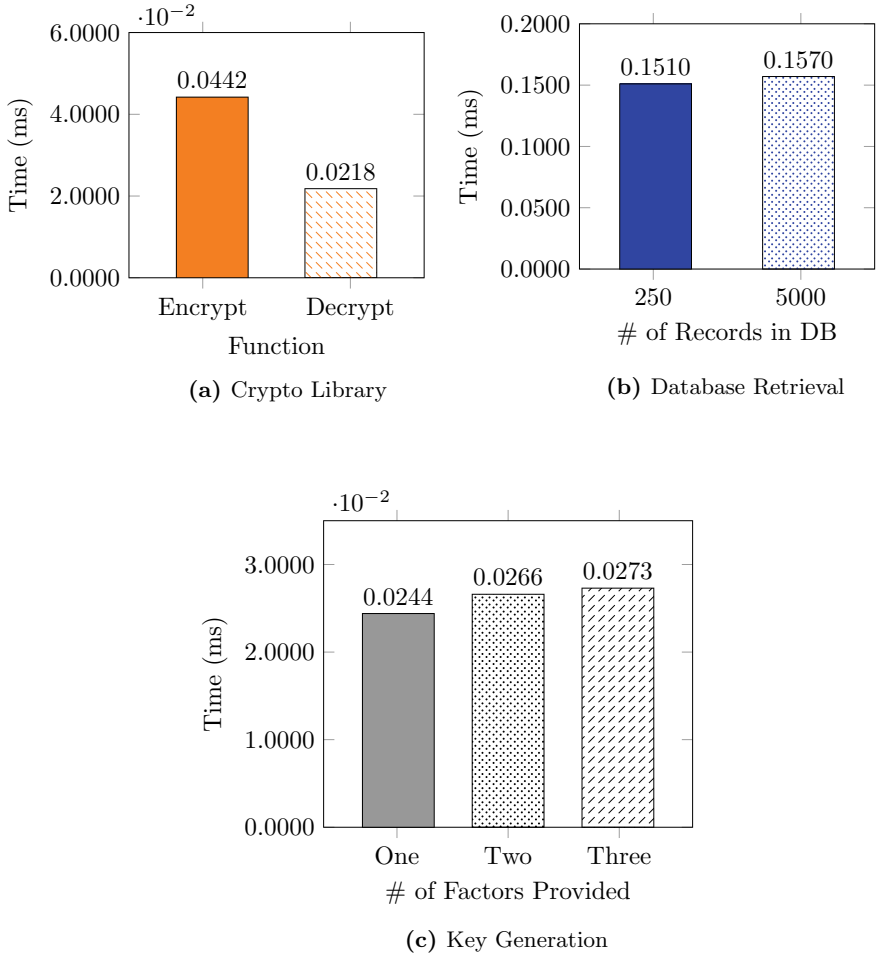
- CPU: AMD® Ryzen® 7 5800X @ 3.8 GHz; RAM 32 GB DDR4 @ 3200 MHz
- OS: Microsoft® Windows® 10 Pro, 64 Bit
- Back-end Software: Node.js®, ver. 16.13.0
- DBMS: PostgreSQL®, ver. 14.1
- HTTP Protocol Tool: Postman®, ver. 9.1.5

Figure 4a represents the time taken for AES-256 encryption and decryption of 16 bytes of data in CBC mode. 16 bytes represent one sensor value, such as voltage or current. To eliminate network delays, the data are hosted on the same machine as the data requester. This form of evaluation tests the speed of encryption and decryption of the "Crypto" library in Node.js® that we use in SEMAFORE implementation. As it can be seen from Fig. 4a, "Crypto" library provides satisfactory performance for encrypting (0.04 ms) and decrypting (0.02 ms) one analog sensor value. Encryption takes 2.03 times greater than decryption.

Figure 4b represents the time taken for one data record retrieval given the database table was populated with differing numbers of records. The size of one record is 160 bytes. The SQL query used in this test is as follows:

```
SELECT * FROM smartgrid_devices where id = 1
```

Logically, a more populated database table increases overhead in data access. This effect is shown to be minimal in testing with a change in average retrieval time of 0.006ms or 4% between 250 and 5000 records.




**(a)** Crypto Library **(b)** Database Retrieval **(c)** Key Generation

**Fig. 4** Performance evaluation graphs

Figure 4c represents time to generate a symmetric 256-bit key given one, two, and three factors being used for the on-the-fly key generation. The size of factors (inputs) is the same and equals to 16 bytes. As it can be seen, adding factors to the key derivation adds minor but observable overhead. Generating a 256-bit key with three factors adds 12 ms overhead compared to one factor. These are the lowest possible values as an iteration of 1 is used.

### *4.1 Overhead*

Overhead is the amount of delay introduced by the access control and encryption mechanisms. In order to determine the overhead introduced, a response time metric was taken. The test request accesses 3 sensor value attributes. The average response time recorded for the requests ranged from 230 to 270 ms. A baseline response time was calculated by creating within the API a test response that immediately responds. The default delay measured was roughly 30 ms. This places the overhead at a range of 200–240 ms.

## 5 Future Work

To share CPS field diagnostics data for logging and auditing purposes, containerization will be used. With containerization, the measured data attributes retrieved from the back-end server could be downloaded and stored in different formats, for example, as protected archives or as spreadsheet files, similar to PROSPECD containers [9, 10]. Our solution supports easy integration with containers as the "designation" and "supersession" tables can be distributed to allow data access without credential leakage.

## 6 Conclusions

In this paper, we presented the SEMAFORE framework for effective CPS field diagnostics and monitoring. Its password-free biometric-based authentication schema for mobile applications provides fast and secure authentication for CPS administrators and users, which is essential for field diagnostics in case of emergencies. The NFC technology ensures proximity and an intuitive method of interacting with the monitored CPS components. Using NFC technology in conjunction with the PostgreSQL,® RDBMS provides an effective mechanism to read, write, and persistently store CPS field diagnostics data. Building upon Apache® Cordova allows for a cross-platform development environment and intuitive web-based front-end libraries in Bootstrap and JQuery to become available. Customization is a core feature of SEMAFORE solution and allows integration of any CPS as long as monitoring data can be sent to the back-end API. This customization has room to be built upon and could eventually allow fast and efficient integration of this system into already operable CPS.

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# Redefining the Museum Experiences in the Virtual Age

**Janio Jadán-Guerrero, Mónica Mendoza, and Cleofe Alvites-Huamaní**

**Abstract** Technology has the potential to redefine museums, opening the opportunity of new ways to connect with visitors. In the pandemic, museums had to close their doors and in-person visits were canceled. In reaction to this reality, many museums rushed to generate digital tours of their works and collections. The creation and development of these visits were born from the need to continue with virtual visits to continue to bring the knowledge that these institutions house closer. Today a possible approach is to create hybrid experiences that utilize digital technology capable of enriching a physical visit to museums. In this context, this paper addresses three experiences developed in Ecuador: (1) The Spiral of Memory proposal developed at the National Museum of Ecuador (MUNA), (2) The Animals of Yesterday and Today proposal developed at the Smithsonian Virtual Museum and (3) Interactive Museums as Pedagogical Mediators, digital educational resources in virtual learning environments. The conclusion of these experiences led to the conclusion that museums are spaces of interaction that contain an infinity of resources that allow children to create their own stories and compositions from the observation of real facts and situations, presented through the creation of physical or virtual experiences in these cultural spaces.

**Keywords** Digital museums · Digital experiences · Virtual museums · Interactive digital exhibits · Children's museums · Interactive museums · Social and emotional learning

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## 1 Introduction

During this pandemic, the world's museums faced a crisis due to the lack of visitors and had to innovate in the digital world to reach new audiences. The transformation not only went through their pieces, objects or collections; the transformation came through an appreciative look toward the regular user of museums and the new users who approached these sites that physically had not visited them. As Mendoza [1] argues, currently this interactive dynamic between users and digital portals of museums offers a great variety that facilitated this transformation that goes hand in hand with the creation of experiences that provoke emotions [1]. According to Robinson [2] the emotion will be the next desired goal, where empathy, inclusion, diversity form a central axis of this meta-museum that is possibly available to everyone [2].

This process that goes hand in hand with the adaptability of human heritage, which is undoubtedly the vital part of any cultural center, must be accompanied by constant training because without this resource it is almost impossible to fulfill one of the primary functions of these cultural centers, as it is to be a means of communication of this digital ecosystem that took center stage and comes to redesign the priorities of mediation and interpretation where the central axis is the user.

Considering the use of these knowledge spaces should be part of the national agenda of any educational system, since their spaces are ready to be an integral part of the teaching–learning process for the benefit of the educational quality of a country. Globally, they are used with more emphasis in some countries than in others, articulating projects, alliances and partnerships and creating interesting proposals to use their physical and virtual spaces within the teaching practice at all levels. This paper aims to highlight those classroom initiatives in Ecuador that remain far from the public eye, but should be made visible for their quality, relevance and positive and innovative results that are transforming the new educational didactics.

## 2 Background

The current pandemic caused by Covid-19 motivated in most sectors the desire to adapt and transform, according to Cano [3] argues that cultural institutions must adapt along with this technological advance to allow this approach and reduce these gaps through educational innovation. On the other hand, educational processes at the national level were adapted, and managers and teachers had to create new spaces and digital content to give continuity to the education service [3].

Globally, innovative free access proposals have been developed; one of the learning spaces that has a number of digital resources that allow understanding art, culture and science through meaningful experiences is the Smithsonian Learning Lab, which shows a wide variety of resources. Another platform where visitors can find, download and share digital resources is Europeana, a digital library that allows

visitors to explore the history, art and science of the European Community from prehistoric times to the present day. Free access to the content allows teachers and students to use the resources for the benefit of their educational practice. According to Romualdo [6] it is necessary to readapt the vision of museums and audiences, through the development of new experiences that include gamification to open new spaces for reflection [6]. Gamifying is, according to Contreras and Eguia [7], "As a process in which the gamifier tries to increase the probabilities of the occurrence of different game experiences by infecting possibilities for that purpose, either through badges, points, etc." (p. 8). It also speaks of a hybridization of the physical and the virtual, working on new compositions that allow interaction with different users using a suitable language in line with the museum's proposals [7].

The initiatives that were developed through social networks as a means to reach other audiences generated interest that perhaps they did not have in their view of the museum as a space for learning, play, interaction and socialization. An example is the proposal of the Instagram page of the Tussenkunstenquarantaine, developed in the quarantine by Covid-19 in which it developed a challenge to recreate paintings with materials from the environment, some categorized it as an antidote to confinement, and undoubtedly this type of playful initiatives allow bringing art closer from a close, inclusive and fun look.

In the Ecuadorian context, it was possible to observe the development and adaptation of most museums, creating digital content for free access, organizing tours, virtual workshops and the digitization of their collections to remain close to their audiences. Other initiatives that can be highlighted are the tours organized by cultural managers such as the blog "The bricks of Quito" which is one of the first virtual communities to disseminate the heritage architecture of the city of Quito. In this pandemic went from face-to-face experiences to virtual experiences using the Google Street View tool to continue disseminating the knowledge that host routes, corners, monuments and little-known buildings, within their virtual tours we detail: Palaces of the Mariscal and Route of the Italian Architects.

Park et al. [8] argue that digital transformation has gained centrality and is framed in two elements such as the attitude of an open, collaborative look at the changes and new challenges brought by technological progress and the aptitude to continue learning and be open to new knowledge that is linked to the new forms of mediation and interpretation of collections [8]. Undoubtedly, the pandemic brought a sort of technological acceleration that democratized knowledge and allowed professionals interested in this subject to be co-creators and developers of new spaces for dialog and interaction of contents that otherwise would not have happened, where the user, the student, the child, the mother and father or the teacher are the central axes of this new social museology that will be part of this discussion.

## 3 Museum Experiences in Ecuador

Currently, museums and cultural centers must look beyond their physical accesses, the great digital opening that was made visible by the pandemic has allowed the professionals of these centers to develop their skills in online communication, social networks, data analysis, creation of new content and development of user experiences; which allowed an adequate and relevant interaction. We are realizing then that part of our personal growth also depends on the development of our digital competencies, skills that allow professionals interested in the subject to promote the achievement of significant learning, to provoke intellectual curiosity to move from the face-to-face experiences of the museum framed within a passive and unidirectional medication to the development of digital experiences. Experiences that are not only created by scholars but also by other professionals who are encouraged to collaborate in the face of the recognition that is being given to the different points of view in this emerging context.

Digital technology can make it easier for children and adolescents to exercise their right to express their opinions, promote their citizen participation and provide a channel for their freedom of expression and information. Interactive digital exhibits (IDE) with new technologies have a relatively longer dwell time than others without technology. Technological novelty is also important in maintaining children's attention or enhancing their experiences. New technologies are more engaging and can enhance children's experience and dwell time. The display screen plays an important role in children's misunderstanding and attention. In this sense, it is necessary to incorporate digital experiences that bring museum knowledge closer to children and young people to complement their life project [9].

Digital transformation does not depend only on technology but also on the people who will create and transform with it. The commitment of educational actors is fundamental, and it is there where collaborations and networks between cultural centers and centers of knowledge are born, where the formal and non-formal space takes relevance to complement the integral development of children and young people. As access to physical spaces becomes more difficult, there is a growing shift toward the use of virtual spaces for remote work, education and entertainment. However, the use of virtual spaces to support these types of services is still largely unexplored. Presence, engagement and real connection are difficult to establish through virtual exhibits [10]. The moment is opportune to transform and adapt technology to develop meaningful, fun, face-to-face and digital experiences within the digital ecosystem of museums.

The digital is an integral part of the museum according to some experts; others categorize it as a tool that allows coexisting in this digital ecosystem where empathy, inclusion, diversity come to combine these new social habits, new immersive technologies and new metaverses that are being created according to the advancement of technology. Where a metaverse is a virtual space, as defined by Checa [11], "They are fictitious constructions in which participants interact through avatars created by themselves trying to reproduce the participation or real life in a virtual metaphor

environment without the space-time limitations" [10]. But how can we bring this knowledge to the classrooms of our educational institutions?

In Ecuador the use of museums as spaces for teaching and learning is not common, there is a lack of formal articulation that allows access to the knowledge that these cultural centers house, and it is necessary to establish and strengthen partnerships between educational actors and the community. That is why we will dive into the world of fine arts; through our experience as teachers and researchers driven by the passion for teaching, we invite you to a tour where we detail our classroom and digital experiences with the museums of our city and the world.

### *3.1 The Spiral of Memory at the National Museum of Ecuador (MUNA)*

Proposal developed by the team of teachers of the innovation area of the educational center El Arca del Saber is located in the city of Quito. The protagonists were the children of the on-site holiday workshops in 2019. The creation and development of this experience stem from the need to bring the national museum closer to children, where they can appropriate the space without having to worry about the formal environment of a museum. Generally, in these spaces it is not possible to touch, move or raise your voice, here began the challenge of using this cultural space with preschool children. Supporting us in the proposal of Ruiz de Velasco and Abad [12] who says "The installation is a space of symbolic interaction, a place that gives access and sustains the symbol from its initial configuration" [12]. In such virtue it is possible to symbolize through art taking into account the object, the space, the assembly and where everything is possible, a proposal inspired by the works of great artists. Figure 1 shows The Spiral of Memory, a video that brings together a selection of 30 photographs and 40 scenes corresponding to landscapes, rituals, festivals, milestones of modernity and social struggles of the late nineteenth and early twentieth centuries in the country.

**Fig. 1** The spiral of memory at national museum of Ecuador

The Spiral of Memory is a playful and didactic piece located at the main entrance, welcoming visitors to the national museum. It was an innovative proposal of the Ecuadorian artist and curator Fabiano Kueva; the distant of this piece became close by giving life to this space, where the artist's reflection interacts and relates to the child, changing the focus of interpretation. The gaze was the protagonist along with the body to mediate this knowledge making them participate in this piece, provoking reflection, resignification, the creation of stories through the reading of images, rhythm and movement in a relational context with playfulness and the floor, which allowed us to know our country and know ourselves, imagine, look, be and feel the world between the real and the imaginary.

## *3.2 The Animals of Yesterday and Today*

An experience developed by teachers of the educational center "El Arca del Saber" located in the city of Quito was to take a tour of the National Museum of Natural History of the Smithsonian Institution. The protagonists were children from the first and second grade in virtual mode of the 2019–2020 school year. The creation and development of this experience stem from the need to continue with the tours to museums and cultural centers that due to the pandemic could no longer be visited physically and that with the great opening of the world's museums could be developed to continue bringing the knowledge housed in these institutions. Figure 2 shows the photographic evidence of the activities carried out with the children during the virtual tour of the museum.

Virtual museums are spaces for interaction that contain an infinite number of digital resources that allow children to create their own stories and compositions

**Fig. 2** Virtual tour at national museum of natural history of the Smithsonian institution

based on the observation of real events and situations. In the initial levels of education, the accompaniment of the adult in the classroom and at home is important; the adult becomes the mediator between the teacher and the child and the knowledge to be transferred, as Santibáñez [13] states, "The exploitation of the virtual museum as a didactic resource requires the programming of didactic strategies to acquire conceptual content and procedural content, as well as to develop attitudes and values" [13]. In this sense, in order to learn with the virtual museum, it was necessary to develop an articulation with the axes and areas of development and learning detailed in the 2014 early education curriculum currently in force.

This didactic proposal is in accordance with the three axes of development and learning which are: personal and social development, discovery of the natural and cultural environment and expression and communication. And within the areas of development and learning for the initial level 1: emotional and social bonding, discovery of the natural and cultural environment, manifestation of verbal and nonverbal language, for the initial level 2: coexistence, relationships with the natural and cultural environment, understanding and expression of language and artistic expression.

In virtual environments and as creators of experiences with museums to achieve a meaningful interpretation, the reading of objects and the execution of tasks must be taken into account; as observed in the evidence of the project the animals of yesterday and today, we can visualize the articulation that was achieved through the creation of concrete material, created from the children's reading of the animals they observed in the virtual tour of the museums favoring the appreciation, representation and expression of ideas, spaces, memories and emotions that represent the development of children's thinking. In this sense, the proposals presented above motivated the use of museums to bring art closer to early childhood, motivated teachers to become developers of memorable experiences for the benefit of the teaching-learning process, articulating with the education curriculum.

### *3.3 Interactive Museums as Pedagogical Mediators*

This experience describes the interactive museums as pedagogical mediators propose a fusion of knowledge and new experiences, which transport the student to a cultural environment fostering the interest of interacting, knowing and visiting museums; in this way they can renew and create new interactive and innovative experiences [14].

The virtual interactive museum consists of a website constituted as an interactive museum of Natural Sciences that functions as a pedagogical mediator to be used by teachers to work with their students, in which several strategies linked to external sites, as well as designed by the teacher, are presented. These strategies can be applied during a virtual class or sent to students for practice at home.

The site is elaborated by the introduction where the interactive museum is presented; six strategies are integrated that aim to provide mediation resources to teachers, all based on the museum activity. These strategies are: augmented reality, virtual tours, interactive games, interdisciplinary museums home experiments and student exhibitions.

By means of interactive museums, it was possible to promote a different learning dynamic and at the same time improve the student's willingness to receive new knowledge, contributing to the teaching–learning process, with the use of innovative and interactive didactic resources that are at the same time coherent with the current environment in which children grow up. It is relevant to be able to encourage teachers to apply new educational strategies supported by technology and thus enrich their teaching management, achieve better teaching results with students and seek other interrelationships. Figure 3 shows the interface of the interactive virtual museum.

On the interactive museum website visitors can find a variety of resources with augmented reality, interactive games, virtual visits to museums around the world, visits to interdisciplinary museums, home experiments and student exhibitions, resources that undoubtedly promote their application and development in classrooms in the area of natural sciences and other sciences for the benefit of the teaching-learning process.

**Fig. 3** Interface of the interactive virtual museum

## 4 Conclusions

In Ecuador and in the world there are these formal buildings that house a great visual content, ready to be used by its visitors; likewise there are museums for children that are like wellsprings of information where interaction, discovery, cocreation, experimentation and community development become central axes of this new mediation centered on the user. It is here where the creation of a didactics oriented to work "with the museum" and not "in the museum" that motivates the development of innovative physical and digital educational resources, raising the learning experiences to the level of children and young people in our country, begins.

Several authors have talked about the benefits that a visit to a museum brings; in this paper we have presented proposals developed with preschool and elementary school children, lines that we hope serve to understand that the development of life skills is not only given in the classrooms of schools, colleges and universities or institutes, that the creativity that is developed through the fine arts could give us fruits in children and young developers of disruptive innovations, questioners, curious and dreamers who are happy adults and enjoy what they choose to sustain their lives.

The proposals presented have been developed with museums, and the central axis of these proposals is the mediation and interpretation of the knowledge that teachers present to their students, articulated with the national curricula. In this sense, we see the importance of training and reflection of teachers in the use of non-formal spaces to improve the quality of education and contribute to the strengthening of the teaching–learning process.

Bringing children and young people closer to these cultural spaces is a challenge that educational leaders and teachers of all levels must share in order to move the classroom to the corridors, halls, routes, corners and monuments of our cities and the world. On the other side the cultural space must be prepared for this new meta-museum through mediations where the main actor as we have stated is the user and the satisfaction of their needs as explained in his blog Frankle [15] on Maslow's hierarchies of needs taken to another scenario such as the museum [15].

In this pyramid we find that at the base are located the needs of accessibility and security, followed by the general psychological needs, basic, major, and the highest to finish at the top of the pyramid is self-actualization. Maslow in museums allowed us to develop questions such as: is this space safe, am I going to learn in this space, is the adult accompanying my learning, what is this space, how and what am I going to learn, etc. Categories and questions that invite us to rethink our activities for the physical, cognitive, affective and social, language and sensory-motor development of children and young people as protagonists in this hybridization of spaces brought about by the Covid-19 pandemic.

It is also important that cultural centers give the opportunity to meet the artists of the collections or works presented because it will give relevance to the experience developed, and for the artist it will be a feedback of his work observed and read from the educational didactics, and it will also allow us to know situations or experiences

occurred in the production of the works, data that will enrich the experience and bring the artist closer to his audience.

The possibilities are endless to bring the world of fine arts closer to children, young people and adults, to sensitize cultural centers and directors of educational centers to articulate and produce a new way of teaching and learning with museums, through alliances and collaborations that make the use of these spaces viable and that allow a participatory and constructive dialog. Assuming positions of favorite participants and not of scholars, not only museums for children "are for children" nor museums and national galleries are for adults, in these lines have been visible experiences in national museums with children and young people will be then the emotion that we manage to find and fit in this adventure to innovate to move from the face-to-face experiences to digital experiences with the museum.

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# Auto Train Brain Increases the Variance of the Gamma Band Sample Entropy in the Left Hemisphere in Dyslexia: A Pilot Study

**Günet Eroğlu**

**Abstract** Auto Train Brain is a mobile app that improves reading speed and reading comprehension in dyslexia. The efficacy of Auto Train Brain was proven with a clinical trial. We have analyzed the long-term training effects of the Auto Train Brain on dyslexic children. We have collected QEEG data from 14 channels from 21 dyslexic children for 100 sessions and calculated the sample entropy in the gamma bands for the left posterior brain (T7, P7, and O1). Although the gamma band values fluctuate and no permanent increase in the gamma band values is detected after Auto Train Brain training at T7, P7, and O1, the variance of gamma band sample entropy increases as the neurofeedback session number increases. We have concluded that the Auto Train Brain increases the flexibility of the left brain in dyslexia.

**Keywords** Neurofeedback · Sample entropy · Auto Train Brain

## 1 Introduction

According to DSM-V, dyslexia is categorized as a subtype of specific learning [1]. Dyslexia is a neurodevelopmental diversity that affects the reading skills of children when they start school [1]. The problems emerge when the child starts school, and if the necessary interventions are not taken on time, the symptoms may last during their lifetime.

In dyslexia, neurologically, there is a weak connection or disconnection between the left anterior and the left posterior regions of the brain which manifests itself in lower reading abilities [2]. QEEG measurements display the increased slow brain waves in the left temporal region of the dyslexic brain [3]. The main affected brain regions due to this disconnection syndrome might be the left parietal occipital region related to visual processing or angular gyrus which functions as multimodal higher-order neuron groups that combine the information coming from unimodal visual and auditory neuron groups [4].

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Many theories describe this phenomenon. The most commonly accepted theories are apart from genetic disposition; there may be a brain maturation delay due to inflammation in the brain [5], which slowed down the left lateralization and development of the gray matter in the brain. It is known that elimination diets [6], special education [7], neurofeedback, and multi-sensory learning [8] are the only effective solutions to reduce the symptoms of dyslexia.

Neurofeedback is known to reduce the effects of dyslexia. The subject's EEG data are read and shown to him in real time. With operational conditioning, the subject gains more control of their brain [9] upon continuous usage. The user learns to control a specific part of the brain region, and it was shown that this phenomenon may alter and add weak connections which enable the subject to attend and learn better [10].

Dyslexic people find it difficult to learn the associations between graphemes and phonemes and learning methods with visual and auditory cues increase memory and writing abilities [11]. If more than two senses, namely visual and auditory, are involved in the learning of orthographic tokens and phonemes, learning becomes permanent, and memory is improved.

A multi-sensory method example (Orton Gillingham) decreases the reading disability of dyslexic people [12]. Some dyslexic people have problems with visual abilities, and perceptual learning may be improved with practice [13]. Problems with dyslexia may be in unimodal visual recognition parts of the cortex or mostly in the higher-order neuron hierarchies which are responsible for combining the visual and auditory signals. Dyslexic people may find it difficult to go from one modality to another. This delayed attention shifting would be reported either in visual [14–16] or in auditory modalities [17] or cross-modal attention processes [18]. Therefore, any dyslexia software should increase the abilities of visual, auditory, and cross-modal attention processes.

Auto Train Brain is an advanced solution that includes neurofeedback, multimodal learning, and special education principles [8]. Machine learning algorithms are built-in features of Auto Train Brain.

In this research, we collected data from the children with dyslexia during 100 neurofeedback sessions and determined whether there were any improvements in the gamma band sample entropy[5].

## 2 Material and Methods

### *2.1 Subjects and Experimental Data*

In this experiment, 21 dyslexic children participated providing their written consent both from themselves and from families according to the rules set by the research ethics committee. Their ages differ from 7 to 10 (15 males, 6 females). They have used Auto Train Brain (a clinically tested mobile app for applying neurofeedback

from 14 channels) many times (more than 100 times) to improve their reading speed and reading comprehension.

In the experiments, EMOTIV EPOC-X headsets are used. The EEG data were read with 2048 per secs per channel—downsampled to 128 per secs per channel. EEG data were converted to the frequency band data with EMOTIV's standard procedures. The frequency band data are binned as follows: theta (4–8 Hz), alpha (8–12 Hz), beta-1 (12–16 Hz), beta-2(1625 Hz), gamma (25–45 Hz). The artifacts were removed with a high pass filter (>100 Hz). EMOTIV app is used for the calibration of the headsets; each electrode is soaked well and ensured that EEG data are read with top quality.

The participants took the neurofeedback sessions with the bits of help of their families at home. During the neurofeedback training, each participant stayed at home and used it while sitting at a table. There was 40 cm between the subject and the mobile app as their families are instructed to do beforehand. The participants used the arrow neurofeedback interface of Auto Train Brain.

### *2.2 Subjects and Experimental Data*

All subjects used Auto Train Brain many times; their brain waves are read using EMOTIV EPOC-X from 14 channels, and visual and auditory neurofeedback is given for 30 min. After the neurofeedback session, multi-sensory alphabet learning is studied for 15 min.

At the end of each session, session average data for each frequency band were saved to the database. During the neurofeedback session, sample entropy was calculated for each frequency band data [19]. Sample entropy is the minus of the logarithmic probability which measures the similarity of two sequences. If the two sequences of m consecutive data points, that are similar to each other (within given tolerance $r$), will remain similar at the next point $(m + 1)$ in the dataset $(N)$, then the sample entropy would be higher. $N$ is the number of samples in the session data. Normally, sample entropy is calculated based on EEG data series; however, in our calculations, we have used QEEG data as we have not reached raw data from EMOTIV EPOC-X.

The feature set consists of 14 variables mapped from 14 channels. The measures are gamma band sample entropy values calculated from QEEG band power values.

## 3 Results

We have plotted a regression line (the $x$ coordinate is the session numbers, and the $y$ coordinate is the variance of gamma band sample entropy for each bin that consists of 100 sessions). The results indicate that there was an increase in the variance of gamma band sample entropy in the long run usage of the neurofeedback, but we

cannot determine any continuous improvements in the gamma band sample entropies across sessions in the long run.

We have combined the 100 consecutive and increasing order of sessions for the subjects in a bin. Then, we calculated the variance of gamma band sample entropy in each bin. There were 10 bins. We have plotted the bin number versus the variance in the gamma band sample entropy values. The variance in the gamma band sample entropy continuously increased in the left posterior regions of the brain (T7, P7, and O1) that are known to be most affected by dyslexia.

Excluding the first 30 sessions, the regression line has $R^2 = 0.78$ (Fig. 1). Including the first 30 sessions, $R^2$ for the regression line is 0.50 (Fig. 2). The slopes for the linear regression lines were positive in both cases.

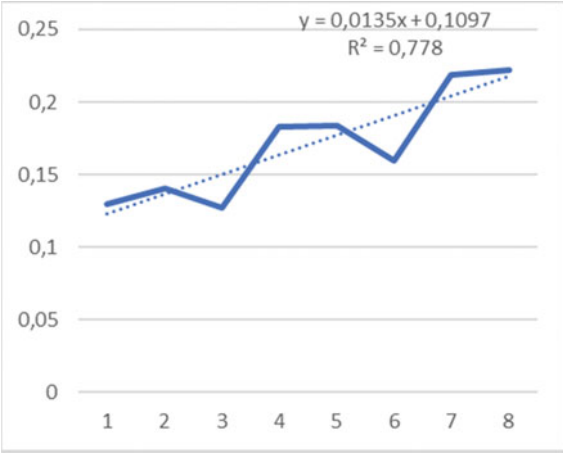


**Fig. 1** Increase in the variance of gamma band entropy after 30 sessions

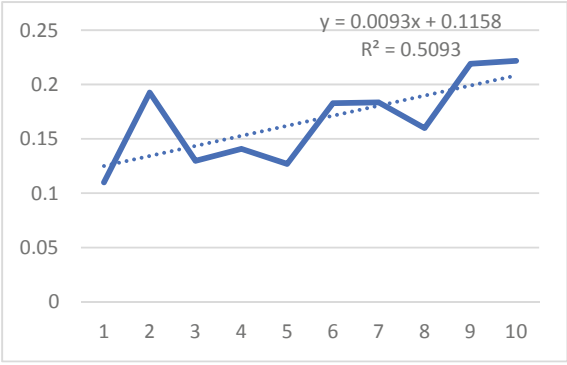


**Fig. 2** Increase in the variance of gamma band entropy after session 1

## 4 Discussion

Auto Train Brain was proven to be effective for children with dyslexia in a clinical trial beforehand. In this research, we have investigated the long-term use and positive effects of Auto Train Brain at home.

In the first 30 sessions of the usage, the variance of the sample entropy in the gamma band increases rapidly. We hypothesize that many metabolic changes take place in the brain and in the body of these children when adapting and learning neurofeedback, and the learning effort is high in the first month. After the 30 sessions, the variance of the sample entropy in the gamma band is reduced, and we hypothesize that the subjects have learned to do neurofeedback, and they spend less effort doing neurofeedback. The adaptation of the brain is very high in the first month. Another hypothesis is that the inflammation in the brain is reduced; then, the pruning and the new cell formation started in the brain. Thereafter, the variance in the gamma band entropy increases in the rest of the sessions after 30. There are 2 more pruning/adaptation phases in the rest of the sessions.

The results indicate that the human brain spends more effort in the learning phase than in the following periods. After the adaptation and learning, there is a pruning phase and learning continues with some variations included. The flexibility of the left hemisphere for dyslexic children is increased after 100 sessions of usage of Auto Train Brain. These children and families are happy to use Auto Train Brain at home. They see the positive effects in their everyday life, and they have increased their reading by at least 2 levels, especially they have increased their reading comprehension, reading speed, and self-esteem.

The limitation of this research is the number of participants. We will repeat this experiment with more dyslexic people in the future.

The other limitations of the experiment are that there is a maturation effect and the placebo effect (Fig. 3).

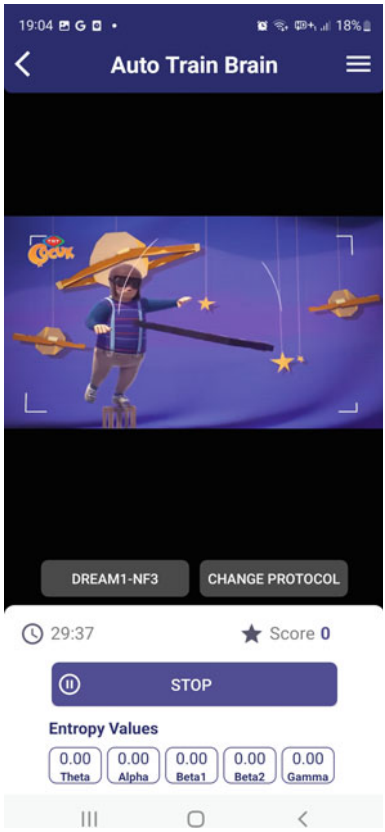


**Fig. 3** Auto Train Brain "YouTube" interface

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# Parallel Clustering Method Based on Density Peaks

**Libero Nigro and Franco Cicirelli**

**Abstract** This work develops a clustering method which is based on the identification of density peaks in the available data. The realization is characterized by its goal of carrying in parallel as many operations as it is possible and to exploit current commodity many/multi-core machines with shared memory. The algorithm is prototyped in Java using parallel streams and lambda expressions. The paper first describes the rationale underlying the design and implementation of the clustering method. Then, the tool is practically applied to several and challenging benchmark datasets, for example, admitting general not spherical clusters. The experimental results confirm efficiency and reliability of the proposed method. Finally, conclusions are drawn with an indication of on-going and future work.

**Keywords** Clustering · Quality indexes · Density peaks · Parallelism · Java · Streams

## 1 Introduction

In many application areas, from image processing, to biology, to machine learning and artificial intelligence, there exists the need to extract useful information from gathered data. It is the problem of information mining. An important and recurrent case is the clustering problem where data are to be partitioned into K groups (clusters) in such a way that within cluster data are similar each other, according to some metric, and data belonging to distinct clusters are dissimilar. Clusters are represented by prototype or centroid points, often defined as the mean of belonging points. In this paper, the dataset is supposed to be constituted by $N$ points $X = \{x_1, x_2, \ldots, x_N\}$, with

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$x_i \in R^D$, that is each point has $D$ coordinates or features, assumed numerical. The clusters are $\{C_1, C_2, \ldots, C_k\}$ where the corresponding centroids are $\{c_1, c_2, \ldots, c_K\}$.

A well-known clustering method is K-means [1] which is preferred due to its simplicity and efficiency. As a rule, K-means partitions point into clusters according to the minimal Euclidean distance to the relevant centroids. K-means favors scalability but, as many analysis papers have confirmed [2–4], it is sensitive to the centroids initialization method and tends unavoidably to converge to a local sub-optimal solution. As a consequence, K-means gets often initialized by choosing K random points in the dataset and iterated a certain number of times. The more is iterated, greater is the chance to improve the clustering solution. Another limitation of K-means concerns the fact that it can mainly handle spherical clusters.

Several more advanced clustering methods were defined to cope with the built-in weaknesses of K-means. For example, Random Swap [5] was designed with a global strategy in centroid management, which integrates K-means for fine-tuning locally a handled solution. Random swap executes a certain number of iterations. At each iteration, a centroid point is randomly selected and replaced by a randomly chosen point in the data space. The new centroid configuration (partial solution) is then improved by a few (e.g., 2) iterations of K-means, and its cost evaluated. As cost the normalized mean, sum of squared error is used:

$$nMSE = \frac{SSE}{N*D} \text{ with } SSE = \sum_{k=1}^{K} \sum_{\substack{i=1 \\ x_i \in C_k}}^{N} \|x_i - c_k\|^2$$

where $\|x_i - c_k\|$ denotes the Euclidean distance between $x_i$ and its nearest centroid $c_k$. Random swap, started with a random initialization of centroids, has demonstrated its ability to converge to solutions near optimal solution. It can work with arbitrary shaped point distributions.

Another class of more sophisticated clustering methods than K-means is inspired by the goal of preliminarily detecting density peaks [6] around each point of the data space. Density peaks are natural candidates for centroids, provided they are also chosen to be far away each other. Density peaks tend to filter out outliers and noise points. The problem is that the identification of density peaks has a high computational cost related to finding the distances among all pairs of points, which is $O\left(N^2\right)$. Such a cost is a bottleneck when analyzing non-trivial datasets. Two main techniques for searching density (mass/volume) [7] are as follows: the *cutoff* distance-based ($d_c$) and the k-nearest neighbor-based approach ($kNN$). In the first case, a $d_c$ value (radius of hyper-ball) is assumed, and point density is evaluated by counting how many points fall within the radius. In the second approach, the number (mass $k$) of nearest neighbors is assumed, and then (by average distances to neighbors), the radius (and then volume) is inferred. No method is better than the other. Franti et al., e.g., have developed heuristics for fast density estimation, based on the approximate construction of the $kNN$ graph, whose general use is clarified in [7]. In [8], an efficient divisive technique for building the $kNN$ graph was proposed. Initially, two random points are selected, and remaining data are partitioned according to nearest distance to the two

points. The splitting process continues into each group a certain number of times. Sub-graphs corresponding to splitting parts are built and combined. The solution is finally further improved by evaluating neighbors of neighbors. In the dimensionally distributed density estimation (DDDE) [9], density is inferred by sorting data, separately for each dimension (coordinate) and using a sliding window for applying the KNN and density estimation, with a cost $O(D \cdot NlogN)$.

The work described in this paper rests on the use of the $d_c$ cutoff, preliminarily estimated through a random sample of data points. The full quadratic cost of distance calculations is smoothed by using parallelism. The novel contribution proves effective in both time efficiency and clustering accuracy as demonstrated by many examples reported in the paper.

The paper is structured as follows. Section 2 reviews the basic concepts of density peaks clustering (DP). Section 3 describes the development in Java of PDP, a parallel method based on DP. Section 4 discusses the efficiency and accuracy of PDP through examples. Section 5 concludes the paper with directions of future work.

## 2 Basic Concepts of Density Peaks Clustering

The reference work on density peaks clustering (DP) is that of Rodriguez and Laio of 2014 [6], which is based on two intuitive assumptions: (1) centroids are high density points, surrounded by neighbors with lower density; (2) centroids should be far away from other points with higher density. Therefore, DP first finds density peaks to assign the role of centroids. Then, non-centroid points are clustered by propagating the label of the nearest point with higher density. Benefits of DP include: (i) its ability to handle regions of data space of arbitrary shapes, (ii) the possibility of automatically establishing the number $K$ of centroids. The disadvantage is the quadratic cost for computing all pairwise distances.

DP algorithm needs to calculate, for each point $x_i$, two quantities (see also [10]): its local density $\rho_i$ and the *delta* parameter $\delta_i$ which is the distance between $x_i$ and its nearest point with higher density. In the following, to simplify the notation, a point $x_i$ will also be referred to by its index $i$ in the dataset $X$. Such a viewpoint naturally corresponds to what happens in the implementation layer where points are selected by their indexes in the $X$ data structure (e.g., an array). The notation $d(i, j)$ represents the distance between points $i$ and $j$. According to the *cutoff kernel* $d_c$, the local density of a point $i$ is defined as the quantity:

$$\rho_i = \sum_{j=1, j!=i}^{N} \chi\left(d_{(i,j)} - d_c\right)$$

where $\chi(x) = 1$ if $x < 0$, $\chi(x) = 0$ otherwise. However, in the source code of DP, the density is actually estimated through the *Gaussian kernel*:

$$\rho_i = \sum_{j=1, j!=i}^{N} e^{-\left(\frac{d_{(i,j)}^2}{d_c^2}\right)}$$

As noted in [10], such a choice can avoid distinct points to have the same measure of local density, as it could occur with the basic cutoff kernel. The Gaussian kernel is consistently adopted also in this work.

The delta quantity $\delta_i$ denotes the minimal distance of point $i$ to a point with higher density. Formally:

$$\delta_i = \begin{cases} \max\{d_{(i,j)}, 1 \leq j \leq N, j \neq i\} \text{if}(\rho_i \geq \rho_j) \forall j \\ \min\{d_{(i,j)}, 1 \leq j \leq N, j \neq i\} \forall j : \rho_i < \rho_j \end{cases}$$

As one can see, in the case, a point has the highest density, its $\delta_i$ is set to the maximal distance of $i$ from any other point.

After the two quantities have been defined for each point, DP clustering is completed as follows. First, the centroids are established. Then, clustering is propagated from centroids to all the remaining points. It is obvious that a centroid is expected to have high values of $\rho_i$ and $\delta_i$. To automate the discover of centroids, a third quantity, *gamma*, is associated to every point: $\gamma_i = \rho_i * \delta_i$. Centroids have high values of the gamma quantity. The identification of centroids can be automated by building the so-called *decision graph* which displays $\delta$ versus $\rho$ for the various points. Candidate centroids visually emerge as points whose gamma is strictly higher than remaining points. After the definition of centroids, which are assigned of initial labels, the clustering is finished in one step. To simplify the operation, both the $\delta_i$ and the index $\Delta_i$ [10] of the nearest point to $i$ with higher density (called *big brother* in [7]) are kept with $i$. For completing the clustering, each non-centroid point is assigned the label of its big brother.

DP facilitates spotting outliers by defining a threshold $\rho_b$ such that points with a density lesser than $\rho_b$ are potential outliers or noise. $\rho_b$ qualifies as the maximum density of points in the *border region* of a cluster, which consists of points assigned to this cluster but which are within the $d_c$ radius of points of a different cluster.

## 3 PDP—Parallel Algorithm Based on Density Peaks

The PDP clustering algorithm was prototyped in Java using parallel streams and lambda expressions [11–13]. This way many operations can be executed in parallel. The algorithm is shown in Fig. 1. Many driving parameters, e.g., INIT_GT, DECISION, PARALLEL, and so forth, are user-defined in a global class which is statically imported in all the application classes.

For example, the INIT_GT is set to true when a synthetic dataset is chosen which comes with its *ground truth* (GT) centroids, which are downloaded from disk into memory. In these cases, GT were used to create specific point distributions

```
load_dataset();
if( INIT_GT ) load_gt();
long start=System.currentTimeMillis();
cutoff(); rho(); delta(); gamma();
if( DECISION ) textual_decision_graph();
else {
   clustering();
   long end=System.currentTimeMillis();
   if( PARALLEL ) System.out.println("PET="+(end-start)+" ms");
   else System.out.println("SET="+(end-start)+" ms");
   if( INIT_GT ) System.out.println("CI="+CI(centroids,gt));
   System.out.println("nMSE="+nMSE());
}
```

**Fig. 1** Outline of the PDP algorithm

in the dataset, thus determining spherical or Gaussian-based or other mixed complex shapes.

Following the loading of the dataset and possibly of GT, the first invoked method is cutoff() which hides three operations: distances(), initialize_sample(), and estimate_dc(). distances() determines and records the minimum and maximum distance among pairs of points in the dataset. The initialize_sample() creates a small random sample by selecting $SS$ points in the dataset. Sample points are then used to estimate, in parallel, the cutoff distance $d_c$. This task is accomplished by subsequent increments of local $d_c$ variables (one per sample point) initialized to minimal distance, and terminating, e.g., when the observed density around the point is greater than a given threshold (1% of the dataset size) [6]. The minimum value of local $d_c$ in sample points is chosen as the estimated $d_c$. The rho() method (see Fig. 2) computes, with the Gaussian kernel, the density of each point which gets stored in the point itself. The underlying lock/free fork/join mechanism splits the data stream into segments which are processed by separate threads which update individual points with the density estimation. No shared data are used and modified.

The delta() method first sorts the dataset by descending values of rho; then, for each point, its delta is computed by checking its preceding points, thus by increasing values of rho. Both the delta and the index of the nearest point having greater density (big brother) are stored with the point. The gamma() method sorts the dataset by descending values of the gamma = rho*delta. To preserve the identity of big brother references $\Delta_i$, the sorting operations in rho() and gamma() actually do not move points in the dataset. An indirection (array of indexes to data points) is instead used which reflects the ordering.

The algorithm in Fig. 1 can be used (see parameter DECISION) either to identify the number K of clusters or to complete the clustering with an assigned value of K. To detect K, instead of generating the visual decision graph (see, e.g., [10]), a textual print of the first K + 1 (K is set to a prospective/guessed value) data point gamma values can be generated. The number of centroids emerges by observing the position where a sudden decrease of the gamma value occurs. When K is defined,

```
Stream<DataPoint> pStream=Stream.of( dataset );
if( PARALLEL ) pStream=pStream.parallel();
pStream
  .map( p->{
    double sum=0;
    for( int j=0; j<N; ++j ) {
      if( p.getID()!=j ) {
        double d=p.distance( dataset[j] );
        sum=sum+Math.exp(-(d*d)/(dc*dc));
      }
    }
    p.setRho( sum );
    return p;
  })
  .forEach( p->{} );
```

**Fig. 2** Excerpt of the rho() method which estimates density of points by Gaussian kernel

the clustering() method will finish partitioning by assigning labels to remaining non-centroid points. The procedure propagates to every point $i$ the label of the nearest point $\Delta_i$. If still this point is without label, the procedure is recursively applied to its nearest $\Delta_i$ and so forth until necessarily a centroid is found, or a labeled point is reached. During the coming back from recursion, the label is assigned to all the traversed points.

The overall cost of PDP ([cutoff() + rho()] + [delta() + gamma()] + clustering()) $O\left(2N^2 + 2NlogN + N\right)$ remains $O\left(N^2\right)$ which is smoothed by the use of parallelism.

Some clustering indexes are, finally, computed to check the accuracy of the clustering solution. If ground truth centroids are available (INIT_GT is true), the centroid index (CI) [14] is computed, which maps the achieved solution onto GT and vice versa. The CI captures the correctness of the cluster structure by assessing that each real cluster effectively receives just one centroid. A CI = 0 mirrors a structurally correct solution. As a further measure, the nMSE cost is also shown.

## 4 Experiments

The PDP clustering algorithm was applied to some synthetic datasets [15], often used as benchmarks. Such datasets are challenging because integrate different point distributions and cluster shapes. In addition, they can be provided of ground truth centroids (GT) for the application of the CI index. PDP was able to correctly solve (final CI = 0) (almost) all the benchmark datasets reported in [4, 13]. In the following, for demonstration purposes, the datasets depicted in the figures from 3 to 7 are considered, whose parameters are collected in Table 1.

Birch datasets (Fig. 3) are composed of spherical clusters organized according to a 10 × 10 grid (Birch1) or following a sine curve (Birch2).

**Table 1** Parameters of chosen benchmark datasets

| dataset | N | D | K | GT |
|---|---|---|---|---|
| Birch1 | 100,000 | 2 | 100 | yes |
| Birch2 | 100,000 | 2 | 100 | yes |
| Skewed | 1000 | 2 | 6 | yes |
| Asymmetric | 1000 | 2 | 5 | yes |
| Spiral | 312 | 2 | 3 | no |
| Aggregation | 788 | 2 | 7 | no |

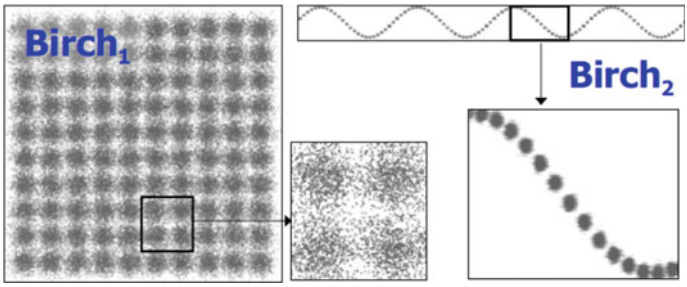


**Fig. 3** Birch1 and Birch2 datasets [15]

The skewed and asymmetric datasets of Figs. 4 and 5 are examples of 2D Gaussian clusters designed to test specifically variations in cluster size unbalance, symmetry and skewness. Spiral (Fig. 6) and aggregation (Fig. 7) datasets introduce challenging shapes of point distributions.

As one can see from Table 1, some datasets are without ground truth centroids. In these cases, first, a "*golden*" solution is derived by using the parallel random swap algorithm [13] with a "generous" number (e.g., $10^5$) of iterations; then, the centroids of the achieved solution are used *as* GT centroids.

**Fig. 4** Skewed dataset [15]

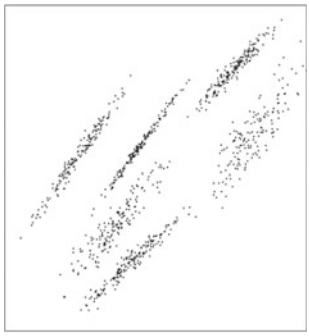

**Fig. 5** Asymmetric dataset [15]

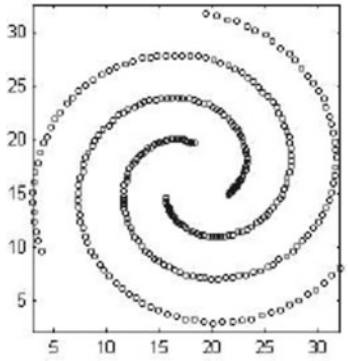


**Fig. 6** Spiral dataset [15]

## *4.1 Accuracy and Time Efficiency of PDP Clustering*

Table 2 reports the observed values of the nMSE cost and cluster index (CI) when applying PDP to the chosen benchmark datasets. The results comply with similar results documented, e.g., in [5, 13, 14].

To give an idea of the computational efficiency, five runs of the Birch2 case study were executed and the average parallel elapsed time (aPET) and the average sequential elapsed time (aSET) (PARALLEL is set to false) observed. On a Win10 Pro, Dell XPS 8940, Intel i7-10,700 (8 physical + 8 virtual cores), CPU@2.90 GHz,

**Table 2** Accuracy of PDP applied to datasets in Figs. 3, 4, 5, 6 and 7

| dataset | nMSE | CI |
|---|---|---|
| Birch1 | 5.46E8 | 0 |
| Birch2 | 2.33E6 | 0 |
| Skewed | 1.20E4 | 0 |
| Asymmetric | 6.65E3 | 0 |
| Spiral | 68.44 | 0 |
| Aggregation | 10.41 | 0 |

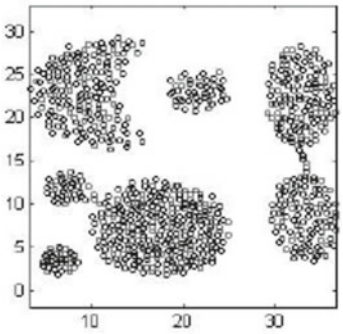


**Fig. 7** Aggregation dataset [6, 15]

32 GB Ram, Java 17, the values emerged: aPET = 64,203 ms and aSET = 540,213 ms, with an estimated speedup = aSET/aPET of 8.41.

## 5 Conclusions

This paper proposes PDP, a parallel algorithm in Java [12, 13] for clustering datasets with general cluster shapes, by fast searching of density peaks [6–10]. The experimental results confirm good execution performance and accuracy of PDP on benchmark synthetic datasets [15]. Prosecution of the work aims at optimizing PDP and particularly the performance of the prediction procedure of the cutoff $d_c$ by integrating concepts of k-nearest neighbors [7], applying PDP to other challenging datasets, and comparing performance of PDP to that of similar tools existing in the literature.

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# Assemblable Musical Device for the Development of Attention in 5-Year-Old Children

**Fernando Ibarra-Torres, Gustavo Caiza, Marcelo V. Garcia, and Valeria Barona-Pico**

**Abstract** The purpose of this research project is to analyze the process of creation of a musical arming device and its benefits for the development of the attention of 5-year-old children. The research was carried out with 300 infants and their place of residence is a sector of the city of Ambato—Ecuador. The researchers focused on the use of this type of device to promote in an interactive way the development of skills such as visual-motor coordination, auditory discrimination, attention and concentration, obeying orders and improving the recognition of sounds, the identification of percussion instruments, the recognition of the intensity of sounds and to enhance the ability to discriminate and attention continuously. In order to proceed with the creation of the device, the researchers applied a Denver II pre- and post-test to determine the requirements. The result obtained was a musical device with characteristics to interactively develop the attention of 5-year-old infants.

**Keywords** Assemblable musical device · Development of attention · Musical electronic device

## 1 Introduction

The present research aims to develop the guidelines to be considered for the elaboration of a musical device for the development of attention in 5-year-old children, a case study in the city of Ambato—Ecuador. In this work, a quantitative, analytical, prospective research was carried out in order to obtain the necessary information

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about the development of attention and thus be able to elaborate the device, which has had as general objective To develop an assemblable musical device for the development of attention in 5-year-old children, this project consists of the following chapters, the research problem, research antecedents, methodological framework, results and discussion, conclusions, recommendations, bibliography and annexes, the ENI Test (only attention battery) will be applied to measure attention in children, the difficulties that have arisen are: the SARS pandemic COV-2 that has limited the application of the proposal to safeguard the health of the population studied and the researcher.

At present, attention deficit is known as a chronic neurobiological disorder that begins in childhood and prevails until adulthood, and can be related to other accompanying symptoms, such as impulsivity, learning disorders, hyperactivity. This pathology has a high prevalence in the population, This pathology has a high prevalence world-wide that has been growing in recent years, as shown by [1], in a meta-analysis study conducted from 2007 to 2014, this work was carried out in some countries using DSM-V diagnostic criteria, and concluded that attention deficit affects 5% of schoolchildren, Another study from Spain shows a prevalence of 4.7 to 6.6%, using the same diagnostic criteria, in the United States showed higher figures of 17% and they doubt whether these results are the result of overdiagnosis, studies are showing growth in recent years so the importance of knowing how to intervene [2]. Of the 3% of children who may have attention deficit, there is a dominance of 6 to 9 in the male sex, in most cases of children with attention deficit there is no specific criterion, but studies point to a biological cause, which also influences heredity, environmental and social factors; The manifestations begin to be noticed at the age of 3 years and clinically diverse at the age of 5 years, when passing to the school stage it becomes chronic and symptomatic that will evolve as time goes by, 60% of the children will present other associated symptoms, the world-wide prevalence of adolescents of 18 years with this deficiency is between 5. 29% and they are 20 to 40% of consultations in psychiatric departments, 65 to 75% of these children already in their adult life continue to maintain symptoms of attention deficit, the ratio between boys and girls is 4:1; this psychiatric disorder is the most common that affects the neurodevelopment of the infant, and the most frequent in schoolchildren, hence the need to create an assemblable musical device for the development of attention in 5-year-old children [3].

The researchers intend to determine the influence of the musical device on the development of attention in 5-year-old children, with the purpose of improving learning in the preoperational stage (2–7), and it will be evaluated with the ENI Test (only attention battery) of the Neurosciences Institute of the University of Guadalajara 1999–2003, this subject of study is subject to the millennium objective goal 2A, which is to ensure that all children can complete a full cycle of primary education. For the researchers it is important to develop the device in order to answer the following research question: Is the assemblable musical device effective for the development of attention in 5-year-old children?

## 2 Methodology

This section analyzes and explains the method used by the researchers to carry out the research. The research was carried out in the north of the city of Ambato—Ecuador, the population consisted of 130 boys and 170 girls.

### *2.1 Inclusion Criteria Used*

The following criteria were taken into account for inclusion:

- Children 5 years old
- Male and female children
- Children who signed the informed consent form, representatives signed the informed consent form and psychomotor disorders.

### *2.2 Exclusion Criteria Used*

The following criteria were taken into account for exclusion:

- Children with anatomical damage to the pinna, hypoacusis, hypersensitivity to sound
- Children whose parents refused to sign the informed consent form.
- Children who are 4 years of age or younger, children who are 6 years of age or older

### *2.3 Collection of Information*

After the approval of the Bioethics Commission of the Technical University of Ambato of the research and innovation project, the execution of the project began. Parents were informed about the research and asked for their permission and signature of the informed consent. The following questionnaires were used to collect the information:

1. Survey form addressed to parents, containing demographic data and data related to care.
2. ENI evaluation test (attention battery only) from the Neurosciences Institute of the University of Guadalajara 1999–2003, the results of the test will be put in the notebook and in the answer booklet.
3. The test is made up of four sections: visual attention where the drawing cancelation and letter cancelation sheet is applied, as well as auditory attention where digits in progression and digits in regression are applied; once these four sections

are applied, the scores and percentiles sheet for attention is calculated and the results that the child has obtained are obtained, it is graded as follows: >75 above average, 26–75 average, 11–25 low average, 3–10 low, <2 extremely low.

### *2.4 Data Processing and Statistical Analysis*

In Table 1 we can observe the sociodemographic data of the population, to help improve the results of the research, children were randomly selected from urban and rural areas, both males and females. The male–female population is larger and a mean of 64.27 months, the urban residence presents a higher number of children.

## 3 Discussion

During the development of the research, it has been noted that attention is fundamental for learning and better cognitive development in children, today attention deficit is a disorder that is most commonly observed in infants and how it affects their social, family, educational environment which is where they have more difficulties, it is characterized by a behavior of inattention or inattention, this disorder is present from the early years but is evident much more clearly and in the educational environment; Attention deficit occurs much more in boys than in girls and is always accompanied by learning or reading and writing problems. For this reason, a musical device is used to improve attention as a pedagogical re-course and thus favor the areas of child development, as stated by [9] who proposes music as a pedagogical resource that favors cognitive, motor and language development in school-age

**Table 1** Sociodemographic data

| Features | Número | Percentage (%) |
|---|---|---|
| **Gender** | | |
| Male | 130 | 43.3 |
| Female | 170 | 56.7 |
| Total | 300 | 100.0 |
| **Residence** | | |
| Urban | 170 | 56.7 |
| Rural | 130 | 43.3 |
| Total | 300 | 100 |
| **Age in months** | Minimum | 60 |
| | Maximum | 71 |
| | Mean | 64.21 |
| | Standard deviation | 4.28 |

children, strengthening cognitive processes such as memory, attention, perception and motivation, also exposes the effect of musical expression at this age because it generates important learning spaces and contributes to the integral formation in each of the stages of development of children [10, 11].

On the other hand, there are not many studies on attention deficit alone since it is more associated with hyperactivity, autism or other pathologies, the theory on the development of attention can be obtained from web portals and books which can be found in this study, many of the researches are focused on attention deficit plus hyperactivity, Many modern parents wonder why my child does not pay attention but it is not associated with hyperactivity that is why this study seeks to identify what traits children present today to be able to say that it is an alteration in the child's attention and if this brings it from previous years or is being developed by the environment or another cause. [12] suggests that when there is an inadequate functioning of the frontal lobes it leads to clinical pictures of attention deficit; on the other hand [13] affirm that typical pictures of ADD are related to weakness in the function of frontal and sub-cortical or posterior cortical structures [1].

## 4 Results

This section presents the results found.

The research detects activities and strategies for the development of attention in 5-year-old children, through the use of the musical device. It is addressed to professionals who work with children: kindergartens, early stimulators, psycho-rehabilitators, educators, special educators.

This guide presents resources to use with the musical device and to apply musical activities to children, with the purpose of developing the important attention for learning and cognitive development. The activities are directed to the child according to the characteristics and needs of the minor, with all the ethical standards promoted by the environment, ensuring quality care.

There are many techniques and resources to improve the development of attention and learning, so this guide includes musical exercises to be used with the child.

### *4.1 Construction of the Musical Device*

Once the devices and the musical taste of the children and their preference in instruments were investigated, we came to the conclusion that when applying musical activities we should interact with the child, for this reason we chose the circular shape for the construction of the device, the moment of interaction the child and the stimulator should be facing each other, for this reason the device in circular shape gives us this advantage, so we have a wide field for its application.

In relation to music and instruments, the children prefer the following: in music they like more bass sounds than treble sounds, the instruments that most attract their attention are: bass drum, tambourine, tambourine, guitar, trumpet, piano, as the main ones; percussion instruments were chosen to emulate a bat-ria, and a piano in order to distribute the spaces within the musical circle that will be built.

**Construction procedure**

- Cut two circles with a radius of 40 cm, one for the base and one for the top.
- For the circular walls draw circles of 20 cm on boards, then cut and join them together to form a perfect circle, do this a few times until the width is 10 cm, glue and join with carpenter's glue, keep pressed to fix the parts with the help of presses until the glue dries, once dry polish the circular walls until we are at the same level. Glue with glue the walls with the circular base so that we have a wooden container. In the lid you must make four holes to place the drumheads for the drums, then you must glue another circle under the lid so that it fits when you place it on top.
- To make the circuit the piezo electrics will serve as microphone for the drumheads. To the Arduino we program in binary with what we want to realize.
- On the SD card we load the sounds to be programmed in WAV format.
- For the piano we install photocells on the cubes to be switched on.

## *4.2 Music Activities*

**Battery of Instruments**

The objective is to identify percussion instruments using the musical device. In the device we load the SD card with sounds of different percussion, wind, string, etc. instruments.

- On the green drum pads we will record the first four instruments.
- We ask the child to play the first instrument, either by hand or with the drumstick we provide so that he/she can hit it and it can be heard.
- The child will be hitting each drumhead and identifying the instrument when he/she exceeds that level we select other instruments for him/her to identify.
- Once the activity is finished, we indicate which ones the child likes the most so that he/she can play freely and have fun.
- It is estimated to generate the activity with the child approximately 15 min.

The skills to be developed are

- Visual-motor coordination, auditory discrimination, attention and concentration and obeying orders

**Recognize the Intensity of Sounds**

The objective sought by the researchers is that the infant is able to recognize the intensity of sounds.

- We loaded into the device sounds of nature, transportation, instruments, etc.
- We load in each patch a sound of high, medium and low tonality.
- Example: in one patch the sound of a motorcycle which is loud, in another patch the sound of the wind which is low pitched, the sound of a tambourine a medium pitched sound.
- In this way we play with the intensity of the sounds loading them so that the child can identify.

The skills to be developed are:

- Auditory discrimination, attention and concentration and to obey simple orders.

**Favorite instrument**

The objective is to identify the percussion instruments, for this we detail the steps to follow:

- We record percussion, string and wind instruments in the device.
- We place the instruments distributed with the intention that when the child hits a drumhead an instrument will sound and the child will say if it is a percussion instrument.
- We must be emphatic in asking him to say if it is a percussion instrument when he hits and we ask him which is his favorite instrument.
- We put a set of instruments to have a free game where he can play and unexpectedly we ask him if this is the instrument he likes.

The skills that the researchers seek to achieve are:

- Visual-motor coordination, auditory discrimination, attention and concentration and obey orders.

## 5 Conclusions

The assemblable musical device is functional and effective for the development of attention in 5-year-old children because it is colorful, the activities are focused on enhancing attention, auditory and visual memory will be used a lot, in addition to music, sounds, noises, riddles, singing, musical developers, graphic cards, the device has a range of possibilities focused on new activities according to the child's learning needs.

Through the evaluation of the ENI test, it was possible to identify that the male gender has more inattention than the female, but the range between the two genders is not very wide, with the male predominating.

During the application of the survey, a number of children were in the care of grandparents and the rest in the care of their parents, where it was observed that the children in the care of grandparents had a higher degree of inattention than those cared for by their parents. It was not possible to apply the musical device to a larger population in order to improve the attention of the children, due to the pandemic and the biosecurity norms, for this reason the post-test was not applied.

Parents were shown the importance of doing musical activities to improve children's learning, not only attention but also language, cognition, motor skills and socialization, for this reason it is important to include music in home tasks or in social games. Music is important in children who suffer from inattention because it influences to improve and enhance learning and the development of thinking.

## 6 Recommendations

For school-age children, an attention evaluation should be performed in order to focus on activities to improve attention, so that when they move to future levels they do not carry this problem and the child has a low self-esteem due to poor academic performance. Take into account risk factors that the child may bring from previous years that are triggering the lack of attention in school activities. Use the musical device to perform activities in order to improve attention in children and also do activities at home in order to support the therapy and the child will be the beneficiary.

The musical device has a guide of musical activities that can be used at home and thus maintain biosecurity due to the SARS-CoV 2 health emergency that forces the population to be confined to their homes.

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# Ethical Aspects of Work Disability Risk Prediction Using Machine Learning

**Katja Saarela, Vili Huhta-Koivisto, and Jukka K. Nurminen**

**Abstract** Our study focuses on the areas of social and economic sustainability in machine learning. The risk of work disability can be predicted with machine learning and using various data sources. Machine learning techniques appear to be a potential tool to support expert work and decision-making. We will present the five stakeholders of the work disability prediction—the employee, the employer, the occupational health care, the pension fund, and society. All these stakeholders should be taken into account when developing AI to support disability risk prediction. We will compare two methods with different data sources, occupational health care data, and pension decision register data. There is still another stakeholder, the data scientist, who is developing the machine learning algorithms. We will present five important aspects of the data processing and algorithm design phase: non-maleficence, accountability and responsibility, transparency and explainability, justice and fairness, and respect for various human rights. These aspects need to be considered when collecting data, storing it in databases, and sharing it with others.

**Keywords** Machine learning · Work disability · Ethics · Decision-making · Artificial intelligence

## 1 Introduction

Sustainability can be divided into environmental, social, and economic sustainability. Virtually, all OECD countries share the problem of too many employees leaving the labor market permanently due to disability or health problems [1]. It is in the common interest of society, the employer, the employee, and the pension fund to keep the employees healthy and able to work. When people stay able to

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work as long as possible, the dependency ratio of society remains as good as plausible, which improves economic sustainability. Our study is thus on areas of social and economic sustainability. Early interventions and treatments of work disabilities are known to be cost-effective and more effective than later treatments. Thus, it is important to identify people who are at high risk of ending up in disability pension as early as possible. Many factors predicting disability, like duration of sickness absence, diagnosis, socioeconomic status, and disability, are known from the previous cohort or multicohort studies (for example, in Finland Airaksinen et al. [2] and Salonen et al. [3], in Sweden Salonen et al. [4], and in Germany Bethge et al. [5]). Airaksinen et al. [2] found eight factors that lead to increased risk of disability pension: age, self-rated health, no. of sick absences during the previous year, socioeconomic position, chronic illness, trouble falling asleep, body mass index (BMI), and smoking. Machine learning (ML) methods are widely developed to predict certain disability types (for example, musculoskeletal diseases [6], fatigue [7], and lung function [8]), whereas Reho [9] inspects the relation between occupational health care visits and disability risk. He et al. [10] former a deep learning model to predict future blood pressure using anonymized data from physical examination centers in China. The data was numerical and consisted of several medical measurements such as blood pressure, body mass index, and hemoglobin. There are also several methods to extract temporal expressions from health records [11]. Medical texts consist of medical treatments, events, and temporal expressions, such as how often or how many times events have happened.

However, there are only a few proposed methods for the work disability risk prediction on a general level. The closest relating work comes from disease prediction, where diseases have been predicted from medical reports using natural language processing (NLP) tools (for example, Pham et al. [12]). We strive to predict whether the person has a high risk of getting a work disability for any reason, for example, diseases or a combination of them. In this study, we will first represent the stakeholder analysis. Second, we will compare two methods, our method [13], work disability risk prediction using occupational health care textual data ($M_{Health}$), and prediction using pension decision register's structural data ($M_{Pension}$) [14, 15]. Saarela et al. [16] Finally, we will discuss the ethical aspects of the algorithm development phase and have a conclusion on the results.

## 2 Stakeholder Analysis

We started our study with the stakeholder analysis, as Vakkuri et al. suggest in their ECCOLA method for ethical AI [17]. When thinking of the ethical issues of the work disability prediction using machine learning, we need to understand the five different stakeholders. First, there is an employee, who works for a company. Second, we have an employer running the company. Third, there is occupational health care, which provides services for the employees but also for the employer. Fourth, there is a pension fund that provides a pension for the employees and also services for the

employer. Finally, the society is closely connected to all other stakeholders. There is still another stakeholder, the data scientist, who is developing the machine learning algorithms. We will discuss ethical aspects for that stakeholder in the fourth chapter.

**Employee's point of view**. It is typical to assume that all employees want to stay healthy and able to work as long as possible. When they reach the statutory retirement age, they will retain the earned old-age pension. Additionally, they need to be full members of society. They want to use their strengths, time, and skills for the society and common good. Employees have high internal motivation for work but the salary is naturally also important. There are, however, also other kinds of aspects when thinking about the meaning of work. The following quotes are our suggestions to illustrate the possible ways of thinking.

- "I have all sorts of little cramps. I could not work, but I just have to get food and a roof over my head."
- "There is so much more in life than just work! I have a lot of interesting hobbies and I also do meaningful volunteer work. I wish I had more time!"
- "I think that I have done enough of this hard physical work. I suppose that it is time for society to support me."
- "I have all sorts of little cramps but my work is so meaningful and interesting that I want to continue working despite them."

Thus, we argue that it is naïve to assume that all the people could work as long as possible if they could just be healthy enough to work. However, there are societies without any pension systems, and then, the situation is different—people must work even if they are partly or fully disabled assuming that there is work available.

**Employer's point of view**. The employer certainly wants employees to stay healthy and able to work. If an employee becomes ill and retires on disability, the employer must look for a new replacement for him. The recruitment process is typically laborious and lengthy. There is also a risk that a suitable employee will not be found. In addition, recruitment is always an expensive extra expense for the company. When a team member retires on disability, it always affects the remaining team's atmosphere. The work of the disabled person easily falls to others. It is not always even possible to hire a new person to replace an old one. There is also a risk that more people will get sick if the workload becomes too high. Companies typically take measures to prevent disabilities—there are, for example, an occupational health company, gym applications, and team days. Of course, not everything can be controlled, for example, a person can get cancer, no matter how healthy one lives. There exists plenty of work with low requirements of education or knowledge. In these situations, it is much easier to replace the employees especially when there is a lack of work, or the reputation of the employer is respectable.

**Occupational health care's point of view**. Occupational health care aims to help employees to stay healthy and able to work. They offer employees and companies a variety of services for that purpose. In addition to doctor appointments, they offer, for example, an opportunity for a conversation with a psychologist, physiotherapy, nutrition counseling, and physical exercise programs. Occupational health care tries to address situations as early as possible. Proactivity is always cheaper and more

effective than reacting when the situation has already worsened, and problems may have accumulated. However, an occupational health care company's aim is not only to take care of the employee but also to sell as many different services as possible, because that is their business. Occupational health care wants to develop new and better services for its customers and thus beat the competitors. They have the right to secondary use of health data. There have been concerns about who has the right to use this data. Should this data and these services be available for everybody in the public sector [18] or is this data owned by the occupational health care organization?

**Pension fund's point of view**. A pension fund aims to help an employer to keep employees healthy and able to work. The pension fund can identify companies with a high risk of disability and provide support to reduce this risk. They offer various services to employers, for example, through their online services. A pension fund's business is based on ensuring that as many people as possible remain healthy and able to work and retire at the earliest the statutory retirement age. On the other hand, it is also suitable for the pension fund that the retirement period is as short as possible because in that case, pension payments are at a minimum.

**The society's point of view**. It is important for society that the population remains healthy and able to work. The illness of the population brings costs to society. Early detection of diseases is a good thing, as early intervention measures and preventive health care are not only more effective but also more cost-effective. As much of the population as possible should be included in the labor force so that tax revenue can cover the care of children, the elderly, and the sick. On the other hand, health care resources are always limited. Is it possible for us to take care of everyone? Should resources direct to where there is the best chance of success? There is a discussion on who has the right the use the health data [18]. From the equality point of view, the same services should be accessible for everybody, not only for the privately owned occupational health care customers. Open Data Institute aims for organizations to collect and share data for common good to provide services for society [19]. One service could be our method, which could predict the work disability risk and provide help proactively for the persons who need it.

## 3 Methods

We developed an NLP machine learning method for disability risk prediction using occupational health care data, MHealth [13], and compared it [16] with a method using structural pension data, MPension [14, 15]. The data sources are shown in Fig. 1.

When a person is in working life, her information can be found in the company's human resources (HR) system and working time system as well as in occupational health care company's information systems. The employer knows her sick leave information, and the occupational health care company has more detailed information about the reason for the absence, such as medical reports written by a doctor. It would be useful for the prediction if this information could be combined to get

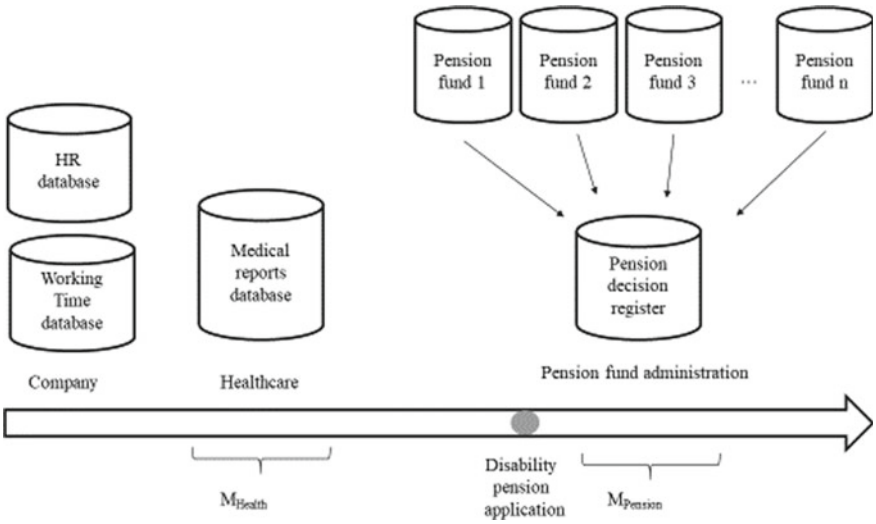


**Fig. 1** Data sources for $M_{Health}$ and $M_{Pension}$

the most comprehensive picture possible but there are legal issues that restrict this. For example, pension funds cannot get information on the insured before he has submitted his pension application. When a person becomes ill, he or she first goes on sick leave. In Finland, after a year of sick leave, a person has the opportunity to apply for a rehabilitation allowance, a fixed-term disability pension. After one year of rehabilitation support, a person can apply for a permanent disability pension. The pension fund administration receives information about the person at the stage when the first disability pension application arrives for them. At this point, a person's health is already quite poor, and often problems have accumulated.

We compared [16] two ML methods for the prediction of work disability risk. The method $M_{Health}$ [13] is an NLP model that predicts work disability risk based on medical records. There are two classification groups: no disability risk and disability risk. The model is created based on Fastai's ULMFiT using 6000 labeled Finnish medical records as training data and 3000 labeled texts for validation. Medical experts labeled texts to the risk and non-risk cases and the algorithm tried to learn the classification. The method $M_{Pension}$ [14, 15], on the other hand, tried different algorithms and utilizes structural data. Data consists of pension decision register data of 240,000 persons retired on a work disability pension and same size data set of randomly selected persons not retired on a disability pension. In this method, we knew the real disability pension decisions and the algorithm tried to predict a given decision. Results are quite similar in both methods, and work disability risk can be predicted with an accuracy of 70–80%. $M_{Health}$ and $M_{Pension}$ had quite similar results on sensitivity (79% and 76%, respectively), but methods differ on specificity (61% and 80%, respectively). This is enough to use these methods to support expert work but the

decision-maker must still be a human, and the responsibility for the decision cannot be on AI but on the expert.

## 4 Ethical Aspects in the Data Processing and Algorithm Design Phase

The data scientist, who is developing the machine learning algorithms, is another stakeholder in our case. Jobin et al. [20] have found five different aspects of ethical AI: non-maleficence, accountability and responsibility, transparency and explainability, justice and fairness, and respect for various human rights. Vakkuri et al. [17] handle also similar themes in their ECCOLA method. These aspects should be considered when collecting data, storing it in databases, and sharing it with others. We will discuss these five aspects in this chapter in the context of work disability prediction.

**Non-maleficence**. Our idea behind our machine learning model is to help people avoid work disability by providing intervention in a very early phase. Thus, our original idea is to use AI for good. On the other hand, we do not have full control over the use of the algorithm. It can also use for the classification of risk and non-risk employers in the recruitment process or when selecting who is getting treatments in medical care and who is not. In these situations, our model would be harmful to the individuals but useful for the employer and the organization that is paying the costs of the medical care. These kinds of discussions lead easily to a utilitarian worldview, where the happiness for as many as possible is maximized at the expense of the benefit of an individual.

**Accountability and responsibility**. Accountability is being responsible for your decisions or actions and being ready to explain to them when you are asked [21]. In the case of an AI system, this means its behavior and its potential impacts. Responsibility can be legal or moral. Legally, an actor is responsible for an event when a legal system is liable to penalize that actor for that event. Morally, an actor is responsible for an act, if they can be blamed for the action. Accountability [22] AI algorithms can be divided into assistive and autonomous [23]. When using our machine learning model in production, the expert in occupational health care or pension fund must be the real decision-maker and responsible for the decisions. Sensitivity and specificity for AI in work disability risk prediction are not at a suitable level. Therefore, the previously discussed algorithms can only work as an assistant to an expert.

A machine learning development is typically cyclic—preliminary results are investigated, and after, the algorithm or model is modified to better fit the real world. Thus, the machine learning algorithm is a summary of mathematics and expert intuition. In the algorithm development phase, it is important to understand that the developers of the model are responsible for that the algorithm works right and that data is not biased. We could aim for a fully automated AI where AI could do work disability pension decisions by itself. We could create a 100% sensitive AI if we put a “risk” label for all of the cases. But in that case, the specificity would have

0%. On the other hand, we could get a 100% specific algorithm by the output of "no risk" for all of the cases, but the sensitivity for that case would be 0%. If we would like to get autonomous AI, we should get at least similar results to an expert. The prediction of the work disability risk is a complex case, and very good results are not easy to achieve. However, if you compare this with the situation when we have a very specific disease to diagnose, the results are different. For example, in the detection of diabetic, retinopathy experienced clinicians had 30–40% sensitivity, 95% specificity, and 80–90% diagnosability, while the automated AI got similar or better results for all of the metrics: 87%, 91%, and 96%, respectively [24–27].

**Transparency and explainability**. Human rights are norms that protect all people everywhere from political, legal, and social abuses. Examples of human rights are the right to freedom of religion and the right to education [28]. According to human rights, people are entitled to have explanations on how decisions were made so that they can maintain genuine agency, freedom, and privacy. The general data protection regulation laws in the EU state that all people have the right to "meaningful information about the logic behind automated decisions using their data" [29, 30]. Similar discussions have also taken place in the clinical literature. It has been argued that clinicians might feel uncomfortable with black-box AI, leading to recommendations that AI should be explainable in a way that clinical users can understand it [31]. Many recent studies have been done to modify machine learning models interpretably or explainable. There are two broad aims of work on interpretability in the literature: transparency and post-hoc interpretation. Transparency addresses how a model functions internally, whereas post-hoc interpretations concern how the model behaves [32]. When the input data is simple and understandable relationships between inputs and the outputs of the model can be explained, the machine learning model is explainable. A good example of this is a linear regression model. In contrast to inherently explainable models, the data and models are too complex and high-dimensional to be easily understood and cannot be explained by a simple relationship [31]. The disability risk prediction models are a good example of this.

We have compared two different methods to predict work disability risk. $M_{Health}$ is used occupational health care data. Experts in health care labeled data and divided individuals into two (no risk–risk) clusters. Our machine learning algorithm tried to get similar results to an expert. To achieve this, we used deep learning and NLP. Our algorithm assessed each word in its context. Then, the assessment either increased or decreased the overall risk assigned to a person. The algorithm learned all the words and connections by itself, and we had no control over the learning process. This is the reason why it is not easy to explain to the patient why the algorithm showed risk or no risk. In $M_{Pension,}$ the data was not labeled, but the result was known exactly—data showed if the person had gotten the disability pension decision. Decision trees were used in $M_{Pension}$. Decision trees are arguably easier to explain than neural networks and deep learning. The decision tree is only a series of decisions with yes or no answers, such as "does he have asthma? Does he have sleeping problems?" and so on. In this case, the algorithm also learns these questions and it is not under the control of data scientists, but the methodology is easier to understand.

**Justice and fairness**. Equality means that everybody is treated the same, and each individual or group of people is given the same possibilities or resources. Equity means that everybody gets what they need to be successful [33]. Distributive justice means the extent to which society's institutions ensure that benefits and burdens are distributed among society's members in ways that are fair and just. We aim to develop an algorithm that can predict as accurately as possible the work disability risk and thus provide help for these individuals proactively. We assume that proactive help is efficient and even more cost-efficient, and thus, we should put the society's resources into that. When thinking of distributive justice, we want to use limited resources so that we maximize the benefit—healthy employers work as long as possible, pay their taxes, and use fewer societal benefits. In our ideal world, we provide service just on time—before the problems accumulate. But, how do we treat people with many problems? Is it useful to use resources on them when the probability of success is low? Is it fairer to provide the same services to everybody, when reaching equality, or is it more reasonable to seek equity and provide more services to individuals who need them most?

There is also a concern for data solidarity [18]. The law of secondary use of data gives possibilities to use health data to develop AI health services. The problem is that these services are mainly developed by private companies, whereas it would be fair that similar services would be available for everybody. The key is to establish data institutions to store health data [18] such as Findata [34] in Finland. The digital maturity of European countries to support secondary use of health data is increasing but they point to an urgent need to develop common data standards and data models [35]. Common data models and standards would also help in the development of work disability prediction algorithms.

**Respect for various human rights**. Human rights are norms that protect all people everywhere from political, legal, and social abuses. Examples of human rights are the right to freedom of religion and the right to education [28]. Privacy concerns are raised, for example, by digital records, which contain information that can be used to infer sensitive attributes (age, gender, health, or sexual orientation), preferences, or religious and political views. The right to safety is a norm protecting individuals from physical, social, and emotional harms, including accidents and malfunctions. Security means safety from malicious and intentional threats. As mentioned earlier, we aim to develop a machine learning model to find individuals who have an increased risk to get a work disability and help them proactively. That kind of algorithm needs a lot of data to function properly. We need to use anonymized data for this secondary use of data. When using anonymous data, we do not collect digital records containing sensitive information. When thinking of primary use of the data, databases consist of highly sensitive data. In the production phase of the machine learning algorithm, we add extra data for an individual—is he a high risk or no risk case. It is important to think carefully about how we are using this data. We will discuss this more in the next chapter and go through the five different points of view on that topic—employers, employees, occupational health care, pension fund, and society's perspectives.

## 5 Conclusions

To improve society's social and economic sustainability, it is important to find methods for work disability prediction to screen efficiently potential risk individuals to provide preventive help and thus avoid disability pensions. We must take into account the five stakeholders: the employee, the employer, the occupational health care, the pension fund, and society when using the algorithm in clinical use. We need to discuss topics such as patient autonomy, decision makers' responsibility in the decision-making process with a human and AI, and the private and public sector's role in health care AI. Who is the owner of the data? Are our services for everybody or only for private health care clients?

We compared two ML methods, such as $M_{Health}$ and $M_{Pension}$, for the prediction of work disability risk. The methods are good enough to be used to aid decision-making, but the responsibility for the decision must lie with the expert, not the artificial intelligence. We went also through five important aspects in the algorithm design phase: non-maleficence, accountability and responsibility, transparency and explainability, justice and fairness, and respect for various human rights. We need to consider these aspects when collecting data, storing it in databases, and sharing it with others. In addition to that, we need to take care that the learning data we are using is not biased and that the algorithm function correctly. We will concentrate on autonomy and responsibility-related issues in the following articles.

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# Awareness and Practice of Green Computing in Higher Education Institutions

**Samson Obafemi, Kayode Oyetade, and Morvyn Nyakudya**

**Abstract** Daily, latest versions of Information and Communication Technology (ICT) devices are released into the market rendering previous versions obsolete. This calls for the application of green computing to effectively manage the negative impact of these devices on the environment. This paper aims to determine the factors that influence the awareness and practice of ICTs on adoption of green computing in higher education institutions (HEI). The aim was achieved by evaluating academics and students' level of awareness of green computing as well as determine green computing practices among academics and students. The study adopted quantitative research method. A sample of 125 academics and students from the department of Information Technology, Durban University of Technology were surveyed to test the model developed by this study empirically. The findings found that awareness and practices of green computing have no influence on adoption of green computing on one hand. On the other hand, there is a significant relationship between the knowledge of green computing and the use of computing devices at home, at school, and both at home and in school. Awareness on the safe use and acceptance of environmentally friendly computing practice among staff and students of HEI is recommended by seeking ways it can be integrated into the curriculum. The findings add significant value to our understanding of awareness, practices, and adoption of green computing in HEIs.

**Keywords** Green computing · Information technology · Green use · Green awareness · Green practices

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## 1 Introduction

The proliferation of computing and mobile devices known as ICT is impacting human lives positively. Human communication, entertainment, socialization, education, commerce, leisure, transportation, and governance are all increasingly becoming dependent on one form of ICT or the other. Hence, a rise in the adoption of these technologies in all field of human endeavors. Since 2015, there has been an increase of 10% with more than 50% of the world population who are now active internet users [1]. Also, due to the emergence of Internet of Things (IoT), it has been projected that over 28 billion devices such as surveillance camera, smart phones, laptops, printers, television sets, and other wearable devices will be networked by 2020 [2].

Due to advancements in technology, many ICT devices quickly become obsolete upon the release of newer versions. Hence, a huge amount of e-waste is generated annually from discarded ICT devices, which negatively affects the sustainability of the environment [3]. However, this increase in the adoption and use of ICT has been associated with various environmental challenges such as increased: e-waste generation, power or energy consumption, and hazardous emissions [4, 5].

The pervasiveness of ICTs today calls for the introduction of green computing which incorporates the practice and study of effectively using ICT resources without impacting the environment negatively [6, 7]. With the advent of green computing, regulators, and manufacturers such as the United State of America (USA) government and Energy Star have invested enough resources to ensure the reality of green design, manufacture, usage and discarding of ICT devices.

Nevertheless, the adherence level to green use of technologies is under reported amongst ICT consumers in developing nations. The ongoing increase in the rate of adoption and use of ICT in general has considerably increased the demand for an eco-friendly approach to their usage, green computing promises exactly this. It is therefore important to know the motivation behind the level of awareness and practice of green computing among staff and students in HEI.

This paper aims to determine the factors that influences of awareness and practice of ICTs on adoption of green computing in HEI, perhaps the level of exposure of these individuals to ICT being the major tools of trade in this field will influence their level of adoption of green computing by fulfilling the following objectives: firstly, to evaluate academics and students' level of awareness of green computing. Secondly, to determine the relationship between the concept of awareness, practices, and adoption of green computing. Lastly, to test the students' knowledge of green computing by finding if there is any significant difference based on their access to computers.

## 2 Literature Review

The ongoing increase in the rate of adoption and use of ICT in general has considerably increased the demand for an eco-friendly approach to their usage, green computing promises exactly this. These are discussed in the following section.

**Green Computing**: In 1992, the USA Environmental Protection Agency (EPA) initiated the Energy Star voluntary program called the green computing concept to promote energy efficient, recyclable, and environmentally friendly design and use of ICT devices and other technologies [8, 9]. Also known as green IT or green ICT [10], it effectively and efficiently covers the study and practice of using ICT resources without affecting the environment negatively [11, 12]. The green computing concept addresses the green: design, manufacturing, use, and disposal of ICT and other related technologies [13, 14].

**Green Design**: Green design refers to adherence to green practices during the design process of ICT devices and other related technologies [15]. This aspect of green computing caters for the entire life cycle of these devices in terms of their eco-friendliness [10]. At this stage, how a device will be manufactured, used, disposed, and recycled in a way that has low or no negative effect on the environment is conceptualized and applied to all the processes involved in the life cycle of such device or technology. To achieve greener designs, many designers of ICTs also ensure that their products are designed to be power efficient, and modularized, i.e., can be disassembled into various components that can be used to refurbish or repair other devices [13, 14] to reduce energy costs and e-waste [3].

**Green Manufacturing**: Green manufacturing is an environmentally friendly way of manufacturing ICT products [7, 15]. Despite the importance of the manufacturing sector to the economy of any nation, the emitted hazardous compounds and wastes generated during manufacturing processes poses a great danger to the environment, hence the need for green manufacturing [10]. In the context of ICT devices and related technologies, green manufacturing involves manufacturing of devices such as monitors, printers, servers, networking, and communication devices under reduced energy demanding processes, reduced carbon emission, and the use of biodegradable and recyclable materials. For example, the use of mercury in liquid crystal display (LCD) to manufacture display units as opposed to organic light emitting diode (OLED) was found to be of negative impact on the environment [16].

**Green Use**: Green use refers to environmentally friendly use of ICTs [10, 15]. Users need to be aware of green computing practices to achieve improved adherence. Such practices may include reducing energy consumption by enabling the power management features on devices or switching off unused devices like monitors, printers, projectors, laptops, etc. [7, 17]. Embracing virtualization, which involves running different operating systems on a single hardware platform, hence reducing power and other resources that would have been dedicated to each of the operating systems. Also, using power smart algorithms in software development has proved to further entrench the sustainable use of software products [18].

**Green Disposal**: Globally, electronic waste termed e-waste is becoming a major concern [19]. According to Balde, et al. [20], about 42 million tons of e-waste was generated globally in the year 2014, and this is expected to rise by 20% in the year 2018. It has been suggested that green disposal practices by all stakeholders is the solution to this negative global trend [7, 21]. Green disposal is the environment friendly disposal of e-waste which involves the reuse, refurbish and recycling of ICT products to minimize e-waste and the related consequences on the environment and the users in terms of costs and health implications [7, 15].

## 3 Research Methodology

A deductive approach using the quantitative research strategy was implemented for the study. Descriptive and inferential statistics were used for data analysis.

### *3.1 Population, Methods, Sample, and Procedure*

Questionnaire is used for data collection which is structured into two sections. The first section covered the demographics of respondents. The second section cover questions on green computing awareness, practices, and adoption in the HEI. A sample size of 92 was arrived and the respondents include academics and students from the department of IT, DUT, South Africa. Quantitative data are analyzed using Statistical Package for Social Science (SPSS 27).

### *3.2 Reliability Analysis*

Reliability analysis was conducted on the constructs using Cronbach's Alpha as shown in Table 1. All the constructs had a high-reliability coefficient higher than 0.7 which indicates the questionnaire is reliable for this study and suitable for further analysis.

**Table 1** Reliability coefficient values

| Construct | Cronbach's values |
|---|---|
| Green computing awareness | 0,904 |
| Green computing practices | 0,784 |
| Green computing adoption | 0,779 |

**Table 2** Characteristics of selected sample

| A | | Percentage (%) |
|---|---|---|
| | Male | 54.84 |
| Gender | Female | 45.16 |
| | 18–25 | 69.89 |
| Age Group | 26–35 | 16.13 |
| | 36–45 | 8.60 |
| | Above 46 | 5.38 |
| | African | 75.27 |
| Ethnicity | Indian | 22.58 |
| | Colored | 1.08 |
| | White | 1.08 |
| Designation | Lecturer | 26.88 |
| | Student | 73.12 |
| | At home | 6.45 |
| Computer Access | At school | 17.20 |
| | Both | 76.34 |

## 4 Result

The results obtained from descriptive and inferential statistics from SPSS are discussed in the next section.

### *4.1 Descriptive Statistics*

From the demographic characteristics presented in Table 2, there were relatively more male participants (54.84%) compared to the female participants (45.16%). A simple majority of the participants are aged between 18 and 25 years old (69.89%) with most of them of African origins (75.27%). Most of the participants are undergraduate students (73.12) and use computers daily (92.47%). Majority of the participants have access to computers at home and at school (76.34%), and own two or more devices (86.02%).

### *4.2 Correlation Analysis*

Correlation test will be used to find the relationship between the concept of awareness and practices and green computing. In testing green computing constructs to determine the relationship between green computing awareness and practices on

**Table 3** Green computing correlations

| Construct | | Green computing awareness | Green computing practices | Green computing adoption |
|---|---|---|---|---|
| Green Computing awareness | Pearson correlation | 1 | 0.264* | 0.271** |
| | Sig. (2-tailed) | | 0.11 | 0.09 |
| Green computing practices | Pearson correlation | 0.264* | 1 | 0.275** |
| | Sig. (2-tailed) | 0.11 | | 0.008 |
| Green computing adoption | Pearson correlation | 0.271** | 0.275** | 1 |
| | Sig. (2-tailed) | 0.009 | 0.008 | |

**. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed).

green computing adoption. From Table 3, the green computing awareness ($r = 0.271$) and green computing practices (0.275) are not statistically significant ($p > 0.001$) at the 0.01 level (2-tailed) and respectively has a weak positive relationship with green computing adoption. These results revealed that the participants' green computing awareness and green computing practices has no significant influence on their adoption of green computing.

### *4.3 Anova*

The constructs were subjected to a one-way analysis of variance (ANOVA) to explore significant differences in the participant's knowledge of green computing based on their access to ICT devices.

Results from Tables 4 and 5 showed a statistical difference in student knowledge on green computing based on the mean and standard deviation of the three groups (At Home, At School, and Both). At Home ($M = 33.00$, $SD = 5.06$); At School ($M = 36.63$, $SD = 4.66$); Both ($M = 34.00$, $SD = 3.61$). There is a significant difference at $p < 0.05$ level for the three groups $F(2,92) = 3.399$, $p = 0.038$. The result suggests that the participants across all groups (At Home, At School, and Both) were the same in terms of their knowledge of green computing.

**Table 4** Green computing adoption based on student access to computer

| | Sum of squares | df | Mean square | F | Sig |
|---|---|---|---|---|---|
| Between groups | 103.092 | 2 | 51.546 | 3.399 | 0.038 |
| Within groups | 1364.736 | 90 | 15.164 | | |
| Total | 1467.828 | 92 | | | |

**Table 5** Descriptive table of student green computing adoption based on their access to computers

| | N | Mean | Std deviation | Std. error | 95% confidence interval for mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower bound | Upper bound | | |
| At home | 6 | 33.00 | 5.06 | 2.06559 | 27.6902 | 27.6902 | 27.00 | 40.00 |
| At school | 16 | 36.63 | 4.66 | 1.16503 | 34.1418 | 34.1418 | 31.00 | 47.00 |
| Both | 71 | 34.00 | 3.61 | 0.42813 | 33.1320 | 33.1320 | 28.00 | 46.00 |
| Total | 93 | 34.38 | 4.00 | 0.41419 | 33.5537 | 33.5537 | 27.00 | 47.00 |

P = <05

## 5 Discussion

The descriptive result in Table 1 shows that the gender of participants seems to be skewed towards males. However, there seems to be a fair balance between the male and female respondents overall. This could be because males tend to take more interest in using ICT devices than females. Also, the age of respondents tends to skew toward are between the ages of 18 and 25. This is because respondents are curious and excited to explore the use of ICT devices. For the inferential test, the result of the test reveal results revealed that the participants' green computing awareness and green computing practices has no significant influence on their adoption of green computing. For the ANOVA test result, findings reveal there is any significant different in the respondents' knowledge of green computing based on access to ICT. This implies that their knowledge of green computing can be explained from their use of ICT devices.

## 6 Conclusion, Recommendation, and Future Studies

The result of the study has provided more insight into green computing among academics and students at a HEI. As this paper aims to determine the influence of awareness and practice of ICTs on adoption of green computing in higher education institutions (HEI) by reviewing eco-friendly approaches, the study found that the participants had little to no insight on green computing. This limits their efficient use and disposal of technological devices. A methodical approach to create the

right awareness and practices among academics and students in HEI is necessary. Hence, an awareness of green computing from the curriculum point of view should be promoted among staff and students in HEIs especially in the context of developing countries. Also, the university should occasionally organize workshops to teach staff and students on the latest trends on green computing. In addition, universities can set-up teams to encourage procurement of eco-friendly ICTs in the university and encourage behavioral change in the usage pattern to reduce the carbon footprint of computer user in the university. Future studies should consider increasing the sample size as well as to test the significant differences between the student and staff population. In conclusion, these findings add significant value to our understanding of awareness, practices, and adoption of green computing in HEIs.

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# New Hybrid Monitoring Approach for Distributed Installations in Rural Areas

**Bala Moussa Biaye, Khalifa GAYE, and Cherif Ahmed Tidiane Aidara**

**Abstract** In rural areas that are often difficult to access, we have different types of installations (sanitary, hydraulic, solar, school, etc.). The remote monitoring of these installations poses a real problem. Local authorities often do not have enough resources to remotely monitor all installations. To facilitate the monitoring of these equipment, we have proposed hybrid monitoring in our works. However, if equipement are of the same type and have the same characteristics, we can easily classify from failed equipment the failure of other equipment pairs. We used the similarity calculation method to sort and classify similar failures of equipment pairs. An approach where each type of failure is represented by an attribute has been proposed. Algorithms were then used to represent the proposed models.

**Keywords** Hybrid monitoring · Remote monitoring · Distributed installations · Similarity calculation

## 1 Introduction

Equipments remote monitoring is a method which aims to remotely monitoring equipment in order to detect its failures. Remote monitoring is not used as an alert system but aims to adapt the treatment according to the values observed on

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the measured parameters [1]. To detect failures in equipment, it would be necessary to first go through the acquisition of measurements data. In some works, for example, those of Biaye et al. [2], measurement acquisition systems (sensors) have been installed in each equipment. These acquired measurements will undergo treatment in order to detect failures. Local communities do not have enough resources to support the cost of the sensors. In our work, we propose a hybrid method of monitoring installations. This considerably reduces the material (sensors) to be used for data acquisition, consequently the cost of remote monitoring this equipment. The proposed method relies on the symmetric quantitative similarity calculation to determine the similarity of the failures. In some works [3–6], cosines are used as a measure of similarity, but this method is more suitable for texts. In other works, on the contrary, they use the k nearest neighboring algorithm [7, 8]. In our approach, each type of failure is represented by an attribute for the failure similarity calculation. We will first present the objectives, then the failures detection methodology, and the expected results. Finally, we present the conclusion and the perspectives.

## 2 Objectives of the Works

Equipment remote monitoring is a method which aims to remotely monitoring equipment in order to detect its failures. This remote monitoring does not generally require a human presence. In our works, we use a hybrid method in order to efficiently monitor the equipment. The objective of this work is to verify the similarity of failures between the two monitoring methods. The failure similarity calculation allows us to conclude that two failures are identical if they are similar.

## 3 Our Methodology

During the functioning of an equipment, multiple failures can be reported. For the monitoring of the equipment, two methods have been proposed, namely automatic monitoring by the remote monitoring method and manual monitoring which is done through a human observer. We present in Fig. 1 the algorithm of the real-time equipment monitoring process which consists of retrieving the measurements data delivered by the measurement acquisition systems (sensors, embedded systems, Internet of things) and failures observations and then to treat them. We present algorithm of the equipment monitoring process in Fig. 1.

For data acquisition, two methods are used. The acquired data are saved in the database. The treatment consists of seeing if the acquired measurements data are within the normal functioning limits. If not, a failure is detected. Then, we calculate the similarity between the failures detected visually and those detected by the remote monitoring system according to the similarity calculation algorithm shown in Fig. 3. We use a new criterion based on a particular analysis of failure similarity calculation.

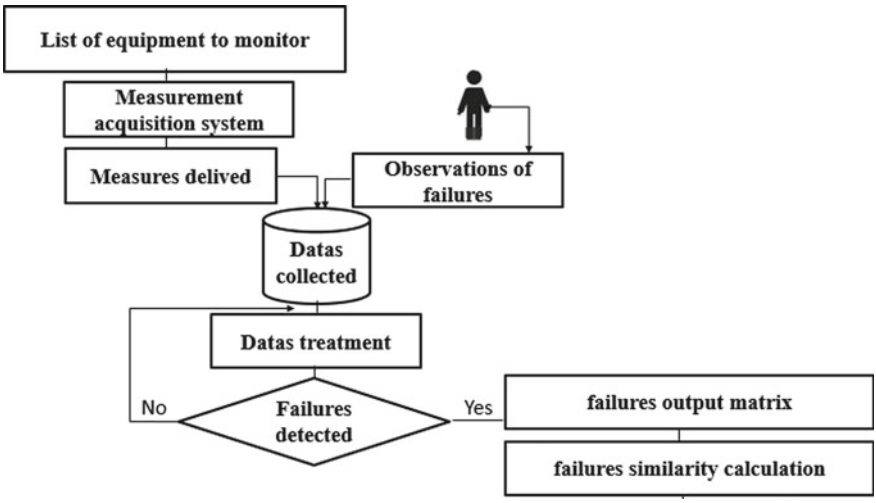


**Fig. 1** Algorithm of the equipment monitoring process using a hybrid method

We pose for the same type of equipment E1 such as dfE1a equal failure detected by the remote monitoring system and dfE1b equal failure recorded by a human operator. The objective is to be able to identify if the failures recorded by the human observer are the same as those identified by the system for the same type of equipment. If we manage to find a significant similarity of failures between the two, we can significantly reduce the sensors installed in the equipment to be monitored. This reduction in the number of sensors could help local communities to bear the cost of hybrid monitoring of installations in rural areas. The principle is based on the symmetric quantitative similarity index. The index do the ratio between the number of descriptors having the same state for the two equipment and the total number of descriptors (Fig. 2).

The average similarity in Fig. 2 is given by the following formula:

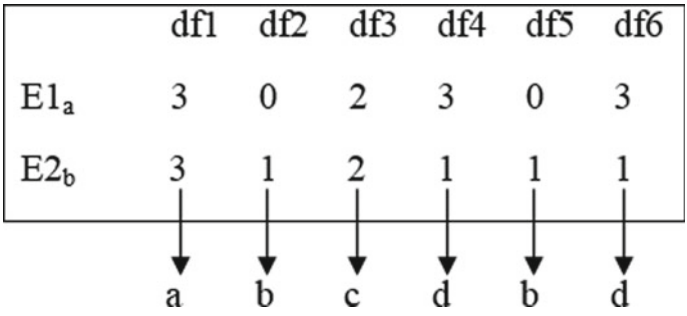


**Fig. 2** Simplified example of the quantitative similarity

**Program** : Classification by Similarity ;
**Input** :
N ← Total number of failure type ;
**Output** : Similar failure ;
**Begin**
**For** (i := 1 to N) **do**
$Sim(dfE1_a, dfE1_b) = \frac{\sum_{i=1}^{N} \Omega df_i}{N}$
If $Sim(dfE1_a, dfE1_b)$>0 then
$dfE1_a$ et $dfE1_b$ are similars ;
**End if**
**End for**
**End.**

**Fig. 3** Similarity calculation algorithm

$$\mathrm{Sim}(\mathrm{dfE1_a},\ \mathrm{dfE1_b}) = \frac{a+c}{a+b+c+d} \tag{1}$$

For our similarity calculation algorithm, we make the following hypothesis: $\Omega \mathrm{df_i} = \{\mathrm{df1}, \mathrm{df3}, \ldots \mathrm{dfn}\}$ set of descriptors having the same state, so the similarity calculation algorithm is presented in Fig. 3.

## 4 Expected Results

Our real motivation is to group together similar failures that is to say categorically close between the two types of monitoring. For each type of equipment, the failures obtained by automatic acquisition are compared with those obtained by visual acquisition. If the similarity is higher than zero, we can deduce that the concern equipment have the same types of failures. After calculation on the monitored equipment, we obtain the result of Table 1.

The calculation consists of identifying similar failures between the two types of monitoring (automatic and visual) and stores it in a variable. If there is no similarity of failures everywhere, as in Table 1, we can confirm the relevance of hybrid installations

**Table 1** Zoom on average similarity result

| Equipment | Type of failure detection | Average similarity |
|---|---|---|
| $E1_a$, $E1_b$ | Automatic, visual | 0.25 |
| $E2_a$, $E2_b$ | Automatic, visual | 0 |
| $E3_a$, $E3_b$ | Automatic, visual | 0 |
| $E4_a$, $E4_b$ | Automatic, visual | 0.42 |
| … | Automatic, visual | … |
| $En_a$, $En_b$ | Automatic, visual | 0 |

monitoring. Indeed, some failures would not be detectable by the remote monitoring system put in place.

## 5 Conclusions and Perspective

We have proposed efficient monitoring of installations using a hybrid monitoring solution (remote monitoring and visual monitoring). The application of the hybrid facility monitoring solution is a real benefit. Because not all faults can be detected by the monitoring system. The advantage that can be drawn from this hybrid monitoring is that it considerably reduces the cost of remote monitoring for certain types of equipment. But also a perfect collaboration between the organizations responsible for installing the equipment and the local communities. So that if an equipment failure, all stakeholders will be informed in time.

This interesting work has its limits. However, failures can be similar and do not have the same causes. The limits to this work open up many research perspectives, namely to determine the causes of equipment failures. In addition, determine too the complexity of the choice of the threshold value for the calculation of similarity with cosines.

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# Active Learning of Programming as a Complex Subject Applying Problem-Based Learning for Computational Thinking Development Model (CTPBL) in High School

**David Alvarado, Margarita Zambrano, César Villacís, and Fernando Galárraga**

**Abstract** The objective of this study is to stimulate the conceptual, procedural and attitudinal development of high school students who take subjects considered as complex, such as programming, applying the problem-based learning for computational thinking development model (CTPBL). The agile extreme programming (XP) methodology was applied for the design and development of the online course template from the point of view of software engineering. In addition, the ADDIE model was applied for the instructional design of the online course, from the educational point of view. As a proof of concept, a basic course on structured programming in the C/C++ language was implemented, using a template developed on the MEAN Stack Web, which was uploaded to Google's virtual classroom platform. For the evaluation of the online course, an evaluation matrix was applied from the student's perspective and a matrix of usability metrics for online courses was applied too. The results show the validation of the theoretical and practical procedure applied to the course with the CTPBL model from the technical point of view, for which the two Cearreta evaluation matrices were applied. The first matrix of Cearreta allows to analyze the performance of the students regarding the development of abilities and skills in the resolution of problems and development of projects focused on the area of programming as part of CT. The second matrix of Cearreta allows to analyze the mastery of knowledge by the teachers who teach programming subjects according to the academic curriculum that is completed in high school.

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**Keywords** Active learning · CTPBL model · Computational physics · Instructional design · Extreme programming · MEAN stack web

## 1 Introduction

IT applied to education with social responsibility has made educational institutions at all levels such as schools, colleges and universities, include them as a transversal axis in the development of digital skills. [1]. In addition, IT has allowed the design of new curricular plans where they are considered suitable for improving the teaching and learning process of students by applying them to learn to solve problems using tools and programs made on the computers [2, 3].

In the constructivist paradigm of education, active learning is being applied with all teaching and learning strategies that are based on the motivation, attention and active participation of students [4]. In this study, the problem-based learning for computational thinking development model (CTPBL) was applied, which contemplates project-based learning with the methodology Science, Technology, Engineering, Art, Mathematics (STEAM) [5].

The use of virtual laboratories, simulators and other tools at high school allow understanding and applying knowledge of subjects considered complex and abstract such as physics, chemistry, biology, environmental education, plane and space geometry, analytical geometry, calculus and programming [6–9]. These tools help self-learning and carry out an effective self-assessment, where the student is the protagonist of the teaching and learning process.

The main contribution of this study is a methodological work proposal that helps to stimulate the ability to understand and learn programming considering it a complex and interrelated subject with others, such as physics, chemistry, biology and mathematics. Consequently, our research premise to be resolved would be: To what extent does the design and development of online courses applying instructional design, extreme programming (XP) and the problem-based learning for computational thinking development model (CTPBL) with the use of free and open source compilers, allow to improve the levels of comprehension, analysis, application and synthesis that students have who take the subject of structured programming in C/C++ as a complex subject within the high school with a constructivist model?

As a proof of concept, a template was designed and developed in the MEAN Stack Web for the structured programming in C/C++ online course, for which the extreme programming (XP) methodology was applied from the point of view of software engineering. The design and development of the course from the educational point of view, such as the structuring of the contents and the curricular plan of the subject, were made based on instructional principles applying the ADDIE methodology. In addition, some learning activities were developed with the authoring tools eXe Learning, Ardora and H5P. The complete course template was uploaded on Google Classroom platform. Regarding the learning strategies of the course, the problem-based learning for computational thinking development model (CTPBL) was applied,

as well as the problem solving (PS) and programming case study (PCS) methodologies, which promotes active and collaborative learning among students. Regarding the evaluation process, a self-assessment test was applied per chapter studied and a summative evaluation was also applied that contemplates a theoretical part and another practical part. The practical part was evaluated in two ways: (a) one part corresponds to an individual practical exam applying the PS and PCS methodology; (b) another part corresponds to group work applying the problem-based learning model for the development of computational thinking (CTPBL). For the evaluation of the online course, two matrices were applied: (a) an evaluation matrix from the student's perspective; (b) an evaluation matrix from the teacher's perspective. The results show the validation of the theoretical and practical procedure applied to the online course with the CTPBL model from the technical and pedagogical point of view.

## 2 Related Work

There has been a considerable amount of related works with development of learning skills in high school students applying problem-based learning (PBL) for computational thinking development model (CTPBL), Bloom's Taxonomy, extreme programming (XP) and instructional design (ID), the state of the art of a few of them is described below. In the first study [1], they apply Bloom's Taxonomy for the learning of object-oriented programming which has been demonstrated to reinforce the comprehension levels of high school students. On study [2], they use project-based learning (PBL) for generation and transfer of computational thinking (CT) to high school students. There needs to be an improvement on the operational mechanism to put the model in practice. The study was conducted under a pedagogical lens without taking in to consideration instructional design and web-based applications, our study does. Work [3] project-based learning in higher education highlights the pedagogical value of project-based learning (PBL) as framework for teaching and learning in a collaborative and interdisciplinary manner. Several options that support learning and teaching with technology were evaluated, such as: (SAMR), (TPACK), (TIM) and DIGCOMP. To conclude, the benefits of collaboration, problem solving and learning through inquiry have been confirmed. Also, the development and accessibility of ITCs have the potential to engage the students in the PBL process. Work [4] proposes the development of online learning to improve computational thinking through the validation of the proposed model. The study concluded that the learning contents, the media and the design of the proposed model, positively impact the development of computational thinking and improve the learning experience. Work [5] deals with the concept of involving students on computational thinking methodology throughout characteristics of project-based learning (PBL). This work concludes that a project-based learning approach shows promising benefits to encourage the learning of sciences and computational thinking (CT) for students. Also including students who historically did not have access to STEM careers. The work [6] approaches the

problem regarding the low level of interest that Australian students have on STEM careers. The solution includes the use of ICT tools to generate greater levels of interest. To summarize, there substantial evidence that ICT can be used to support a greater and better implementation of these activities and learning environments. Nevertheless, this represents a challenge for Australian educators, in our study, we will discuss this problematic trough web-based design, using an intuitive template for the development and administration of online courses.

## 3 Theoretical Framework

### *3.1 Active Learning and the Constructivist Paradigm*

Active learning is a learning strategy that involves the student in the educational material of the course they are learning through the application of methodologies such as problem-based learning (PBL), case-based learning (CBL), project-based learning (PrBL), among others. The teacher can make use of countless platforms and technological tools, which allow active learning to be inserted into the learning experience of students [7].

The constructivist paradigm considers that learning is built as the student elaborates new knowledge from previous experiences [8]. Active learning is intrinsically related to constructivism in the sense that it supports the idea that learning should be active, where the student participates in learning activities instead of passively observing what the teacher explains [7]. In addition, the student builds meanings as he/she learns, so learning becomes significant in the sense that knowledge is built through experience and experience leads to practice and the creation of schemes [2].

### *3.2 CTPBL Model/Methodology*

The problem-based learning for computational thinking development model (CTPBL), proposed by [2] is a combination of the following four learning methodologies: (a) problem-based learning (PBL), which is an active learning strategy, where first the problem is presented, then the learning needs are identified, then the necessary information is sought, and finally, the problem is returned [9]; (b) project-based learning (PrBL), which is a learning strategy where students actively work, plan, implement and evaluate projects that have application in the real world beyond the classroom [10]; (c) STEAM methodology (science, technology, arts, mathematics), which is an active learning methodology focused on problem solving, through which questions are asked, objects are examined, antecedents are tracked and needs are inquired into, within of an interdisciplinary model, such as structured learning that encompasses several disciplines but does not enhance any one in particular, but rather

gives importance to the transfer of content between subjects [11]; (d) computational thinking (CT), which is a learning methodology based on the implementation of the basic concepts of computer science to solve everyday problems applied to real life and complex problems, where students also learn design strategies, problem solving, and collaborative work [12].

The CTPBL model [2] proposes seven components for computational thinking, as follows: (1) Abstraction; (2) Generalization; (3) Problem Decomposition; (4) Systematization; (5) Data Practices; (6) Analytical Modeling and Algorithms; (7) Evaluation and Improvement. This iterative model revolves around Computational Thinking (CT) and additionally contemplates six specific implementation processes corresponding to the cultivation of different dimensions of computational thinking, such as: (1) Selected items or questions; (2) Develop programs or plans; (3) Design Activity Exploration; (4) Generate solutions or works; (5) Results exchange; (6) Conducting activity evaluation.

### *3.3 Computational Physics*

According to [13], computational physics is the study, design, development and implementation of numerical methods and mathematical formulas to solve physics problems for which a scientific theory already exists. Within the history of computer science, computational physics was the first area of application of modern computers in science. According to [14], computational physics is an intermediate branch between theoretical and experimental physics since it complements theory with experimentation.

### *3.4 Instructional Design*

According to [15], instructional design (ID) is a process of planning academic results, selection of learning strategies, choice of relevant technologies, identification of educational means and measurement of student performance. This process has been used for the design, creation and publication of online courses, offline courses, modules, teaching units, lessons, chapters, learning objects or any other educational material to be used in face-to-face study modalities, distance, mixed, virtual (e-learning), b-learning and m-learning. The ADDIE model is a generic process widely used by instructional designers and business trainers [16]. This model is made up of five phases: Analysis, design, development, implementation and evaluation, where these phases are interrelated and allow their adaptation to achieve effective instruction [17].

### 3.5 Extreme Programming

According to [18], this is an agile software development methodology ideal for small or medium-sized software development workgroups whose requirements can be ambiguous or changing and consider people as a decisive factor for the success of a project. Its life cycle complies with the phases of: exploration, planning, iterations to release the ionizing product and the maintenance. The practices taken from XP focused on software coding needed for the e-Learning web app.

### 3.6 MEAN Stack Web

A web stack (solution stack, tech stack), called a web application stack or solution set, defines a component-based software package used for developing web applications (web-apps). The term stack refers to the method of stacking the components of this set of tools, that is, each tool is placed one on top of the other. A simple architecture for a web stack consists of an operating system, a web server, a database and a programming language interpreter. This set of elements ensures that the necessary information reaches the client that requests it in a web application, with the support of the server hardware and with the use of an Internet browser, which processes HTML code, style sheets (CSS) and JavaScript [19]. The MEAN Web Stack is a set of frameworks or technologies for building web applications that consists of the following base components like MongoDB, Angular (Google), Express JS and Node JS [20].

## 4 Experimental Setup

### 4.1 Development Process

The development process of the web app template for the online course was based on the XP life cycle that performs iterative and incremental tasks [17]. The research team made an incremental delivery of the product in each iteration. The experiment considered five iterations: (1) The design and development of the front-end of the web app, for which we applied the MEAN Stack Web; (2) Chapter 1 of the online programming course referring to Operators and Expressions; (3) Chapter 2 of the online programming course referring to Algorithms and Control Structures; (4) Chapter 3 of the online programming course referring to Functions; (5) Chapter 4 of the online programming course referring to Arrays. All chapters were designed applying instructional design. In these iterations, parts of the product were released, inspected and evaluated to increase functionality and improve quality compared to previous versions of the web app [21], which has been implemented by creating a

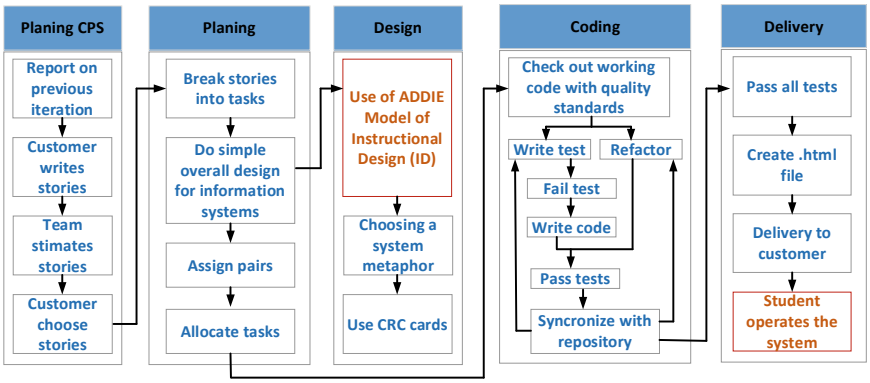


**Fig. 1** Extreme programming iterations web app

template with the web stack MEAN. Figure 1 shows the XP iterations web app model modified based on the model proposed by [22].

## *4.2 Requirements Specification*

The online course was designed, developed and implemented as a web application with the MEAN stack based on Angular to fulfill the following tasks and roles: (1) Manage Users; (2) Access the web application; (3) View academic content; (4) Download academic content; (5) Navigate between course activities; (6) Solve the evaluations and self-evaluations of the course; (7) Manage Evaluations; (8) Review the problems and solved cases of the course; (9) Solve the problems and cases proposed for the course; (10) Review the completed projects of the course; (11) Solve the projects proposed for the course.

## *4.3 Solution Architecture*

The architecture of the online course solution complies with a Client/Server architecture in three layers, which are: (a) Database (DB), which allows managing the data of the user's session; (b) API Rest Server, which allows managing the web services of the application; (c) Front-End, which works with the user interface from the code point of view, so that visual interaction with the web app is possible, intuitive and attractive (see Fig. 2).

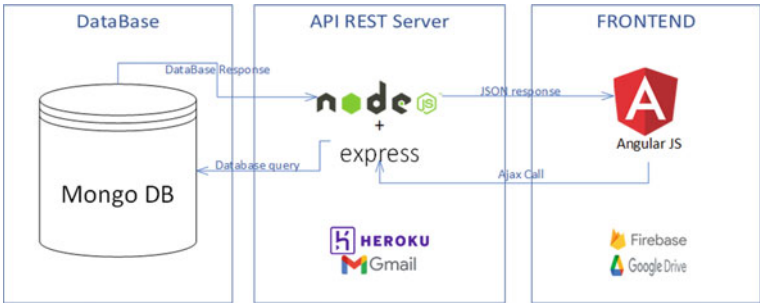


**Fig. 2** Sequence diagram of "access academic content"

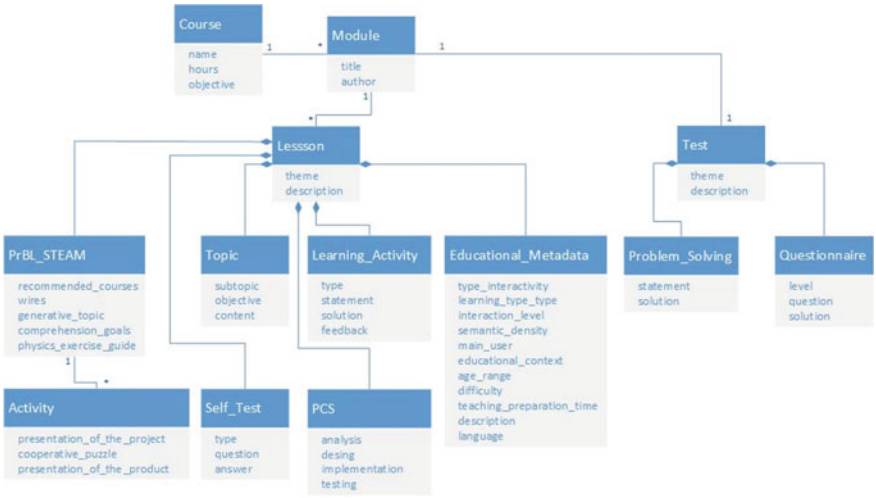


**Fig. 3** Conceptual model

## *4.4 Conceptual Design*

The conceptual model of the application has been created through classes, relationships and cardinalities specified in the principles of creating user interaction diagrams (UID). Figure 3 shows a simplified model of the web application, considering the main associated entities.

## *4.5 Navigational Model*

The navigational topology has been designed in such a way that the web application allows executing all the tasks required by students and teachers, considering the

application of the CTPBL model and the use of authoring tools such as eXe Learning, Ardora and H5P to generate small microsites that will be embedded in the online course and uploaded on the Google Classroom platform.

### *4.6 Design and Development of Educational Contents*

In the analysis phase of the ADDIE model of the instructional design process, the educational needs in the programming area have been identified, as given in Table 1.

To design the evaluation questionnaires for each didactic unit, Bloom's Taxonomy was applied, listing the specific competencies by applying the work model of [7] and the problems, cases and projects solved and proposed that they have been also designed for the online course. In the development and implementation phase, the multimedia resources of the course were selected, such as images, text, videos, text documents and presentations incorporated within the web app template with Angular and embedding the applications made with authoring tools such as eXe Learning, Ardora and H5P (see Fig. 4).

**Table 1** Educational needs in programming

| #Topics | What do recipients need to learn? | Didactic unit |
|---|---|---|
| 1 | Creation of a program in C/C++ language | Fundamentals of the C/C++ language |
| 2 | Basic structure of a program in C/C++ | |
| 3 | Data input and output functions | |
| 4 | Variables | |
| 5 | Arithmetic operators | |
| 6 | Relational operators | |
| 7 | Mathematical formulas | |
| 8 | Algorithm | Algorithms and control structures in C/C++ language |
| 9 | Sequential control structures | |
| 10 | Selection control structures | |
| 11 | Repetitive control structures or loops | |
| 12 | Function | Functions, references and pointers |
| 13 | Passing parameters by value | |
| 14 | References | |
| 15 | Pointers | |
| 16 | Mathematical functions applications | |
| 17 | Menu creation | |
| 18 | Header files | |
| 19 | One-dimensional arrays | Arrays |
| 20 | Two-dimensional arrays | |

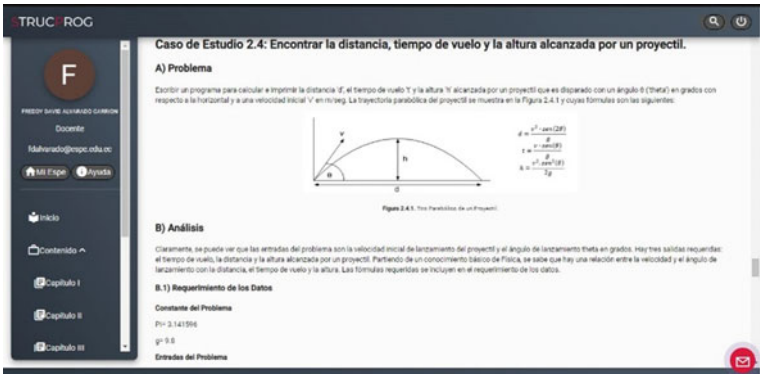


**Fig. 4** GUI of the online course

### *4.7 Implementation of a Physics/Computational Physics STEAM Project*

According to the methodological guidelines of [11] and the work templates, the specific methodological description for the designed STEAM learning project is the one presented in Fig. 5.

Next, the statement of the generalization problem of the project related to the application of vectors and forces in the plane is placed: The resultant of the forces exerted by $\overrightarrow{T_1}$ and $\overrightarrow{T_2}$ is a force $\overrightarrow{T_R}$ directed along the x-axis. Determine the tension of the forces $\overrightarrow{T_1}$ and $\overrightarrow{T_2}$, knowing that the values of the angles $\theta$ and $\alpha$ are known, as shown in Fig. 5. The formulas obtained from the resolution of the systems of equations were:

$$T_1 = \frac{-T_R \cdot \text{sen}(\varphi)}{\text{sen}(\theta) \cdot \cos(\varphi) - \cos(\theta) \cdot \text{sen}(\varphi)} \tag{1}$$

$$T_2 = \frac{T_R \cdot \text{sen}(\theta)}{\text{sen}(\theta) \cdot \cos(\varphi) - \cos(\theta) \cdot \text{sen}(\varphi)} \tag{2}$$

## 5 Experimental Results and Discussion

To validate the structured programming in C/C++ course with the CTPBL model, from the point of view of the development of computational thinking (CT), an evaluation was applied to a group of 126 high school students, as indicated below: (a) 42 10th grade students, parallel "A"; (b) 42 10th grade students, parallel "B"; (c) 42 10th grade students, parallel "C." The evaluation that was applied was based on the

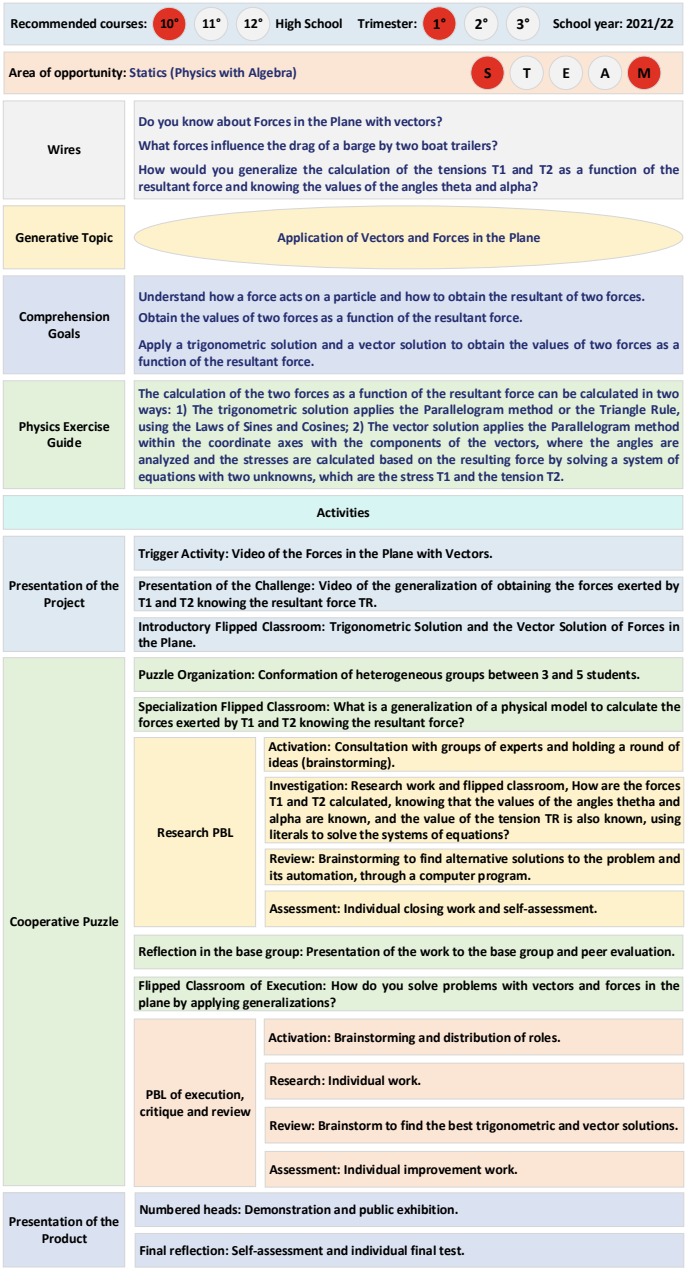


**Fig. 5** Design template of the project on the application of vectors and forces in the plane

**Table 2** Descriptive characteristics of the Cearreta questionnaire

| Programming concepts/practice—Students | | | | |
|---|---|---|---|---|
| Unit | Group 1 average | Group 2 average | Group 3 average | Total average |
| Fundamentals of the C/C++ language | 7.26 | 7.62 | 7.54 | 7.47 |
| Algorithms and control structures in C/C++ language | 6.90 | 6.46 | 6.66 | 6.67 |
| Functions, references and pointers | 7.30 | 7.56 | 7.42 | 7.43 |
| Arrays | 8.50 | 8.74 | 8.52 | 8.59 |
| Total average | 7.49 | 7.60 | 7.54 | 7.54 |

**Table 3** Descriptive characteristics of the high school teachers Cearreta questionnaire

| Computational concepts—Teachers | |
|---|---|
| Variable | Teachers average |
| Sequences | 9.60 |
| Loops | 8.00 |
| Events | 9.00 |
| Parallelism | 7.00 |
| Conditionals | 9.40 |
| Operators | 9.80 |
| Data | 7.30 |
| Total average | 8.59 |

questionnaires proposed by [23], which have been built considering the artifacts of [24] to study the development of computational thinking (CT) for students.

Table 2 presents the tabulated results of the surveys applied to the 126 of 10th grade students who are part of three groups in different parallels, where the topics with the greatest difficulty in understanding in the structured programming language in C/C++ course were: (a) the subject related to the management of control structures with an average score of 6.67; b) the subject related to the management of functions with an average of 7.43.

In addition, an evaluation survey of the same course was also applied to a professor of the physics subject and to a professor of the ICT subject related to programming languages. Table 3 presents the tabulated results of the surveys applied to these teachers.

## 6 Conclusions and Future Work

In this research, the structured programming in C/C++ language online course was designed and developed as a complex and abstract subject as part of the computational thinking that constitutes a transversal axis in the formation of the students at

the unified high school where they receive the subjects of biology, physics, chemistry, mathematics and calculus. The application of the CTPBL model in the design of the course constitutes a crucial learning strategy due to the combination of four learning models and methodologies such as PBL, PrBL, STEAM and CT, which allow learning to be active and significant where the student, in addition to acquiring relevant and updated knowledge, above all, they develop skills and cognitive abilities such as creative thinking and learn to work in a team as part of collaborative learning for the development of social skills and decision making. The evaluation tests of the online course were carried out with a group of students from the 10th year of high school, considering that the physics projects included generalizations that could be automated by applying principles of computational physics with the support of programming languages. In this project, we worked with free and open source tools such as Visual Studio Code, the OnlineGDB compiler and authoring tools such as eXe Learning, Ardora, H5P and an academic version of Google Classroom. The results show the satisfaction of the students with respect to the didactic design of the course, the organization, the contents, the learning activities and the application of the CTPBL model using the PBL methodology with problem solving (PS) and programming case studies (PCS) using the OnlineGDB compiler and also applying the STEAM methodology with PrBL and CT for the design and development of physics and computational physics projects. As future work, it is proposed to redesign the online course of structured programming in C/C++ language to include projects of computational chemistry, computational biology, computational mathematics, computational calculus, green education and computational sustainability (Society + Economy + Ecology). In addition, it is planned to design and develop new programming courses applying the CTPBL model, such as the following: (a) Object-oriented programming and visual programming; (b) video game programming for teenagers; (c) programming of robots for high school.

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# Agents for Change—Profiling South African Construction Quantity Surveyors

**Daniël Johannes Hoffman, Derick Eben Booyens, and Karl Trusler**

**Abstract** We live in a world characterised by change. Organisations and professions wanting to survive and prosper need the capacity to adapt to change. Since the first democratic election of 1994, South Africa has experienced significant change. Organisations such as the Association of South African quantity surveyors (ASAQS) also adapted. Successful strategies for change require accurate information. Adding an ASAQS membership category for construction quantity surveyors (CQS) is a current issue. Quantity surveyors (QSs) are the financial consultants of the construction industry; however, more than 17% do not work as professional consultants but are employed by contractors. These CQSs have no professional organisation serving their interests. An ASAQS membership category fills that need can strengthen the ASAQS membership base and expand the ASAQS's influence in the construction industry. The ASAQS, assisted by the University of Pretoria (UP), circulated a research questionnaire to all QSs nationally. This study compiled a profile of CQSs from the questionnaire data to assist the ASAQSs consideration of a CQS membership category. The profile of CQSs confirmed them to be relatively young (almost 55% are not older than 35 years), 83% are located in provinces with major urban economic hubs, 63% are African, but less than 10% are from Coloured, Indian or other racial groups. All CQSs have tertiary qualifications, only 25% of CQSs are not registered with the South African Council for the Quantity Surveying Profession (SACQSP), but 34% are not ASAQS members. This profile provides much-needed information guiding the ASAQSs decision on CQS membership.

**Keywords** Change · Construction · Profiling · Quantity surveyors · South Africa

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## 1 Introduction

In a dynamic world characterised by rapid and constant change, organisations and institutions need to be agile and geared to adapt to change [1]. A structured approach may be required to support change management [2], while research also supports a rapid adaptive change model [3]. Organisations and institutions will need to develop their adaptive capacity to cope with constant change [4].

Since the first democratic election in 1994, South Africa has entered an era of constant and significant change. The change affected virtually all aspects of society, including the political, legal and socio-economic environments. The construction industry and the stakeholders participating in that industry did not escape the effects of this change. The quantity surveying (QS) profession is one of the established construction industry stakeholders that need to adapt to change to ensure the profession's future success. To successfully adapt to change will require of the QS profession to be, amongst others, well informed about its members and their needs and challenges.

Quantity surveyors (QS) act as the financial consultants of the construction industry. They advise on cost and contractual matters of construction projects, which includes preparing contract documents. Through their training and experience, they often work independently as experts in a specialised area of the construction industry. In fulfilling their duties, QSs have to comply with a strict code of professional conduct. QSs are not only responsible to their employers or clients but also to the profession itself while also having full regard for the public interest. QSs must, through their conduct, uphold the dignity and reputation of the profession and are required to perform their duties competently, effectively, timely and with the best interest of their employers and clients in mind [5, 6].

In South Africa, many QSs are employed by construction companies (see Sect. 4.1, Fig. 1). The main aim of these CQSs is to act on behalf of the contractor as their employer. These quantity surveyors perform their duties as full-time employed consultants acting on behalf of the construction company. Many of these CQSs also choose not to register as professional quantity surveyors with the South African Council for the Quantity Surveying Profession [7]. The need for professional registration is not recognised or required when a QS is employed by a construction company. Many CQSs also never become members of the ASAQS [7–9].

The question has often been raised if the SACQSP and the ASAQS should not consider creating a registration category for CQSs. This study evaluates and describes the different characteristics of CQSs. A detailed profile of CQSs will assist the SACQSP and the ASAQS in considering the professional status of CQSs in South Africa.

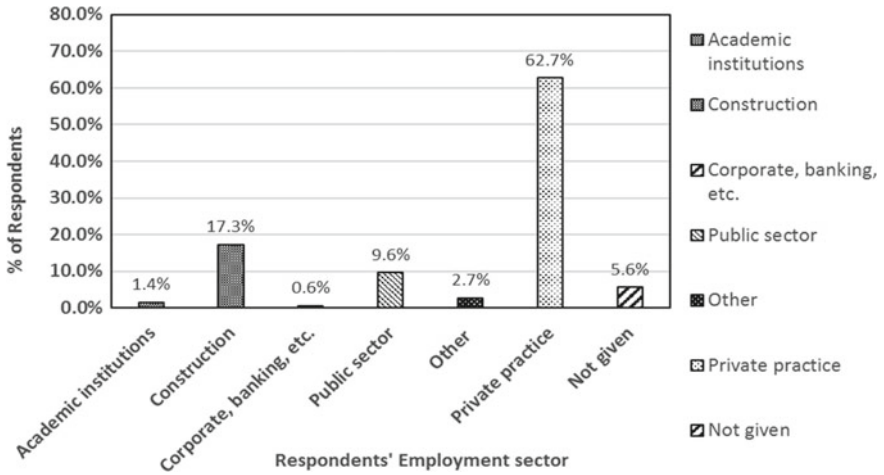


**Fig. 1** Employment sector of CQSs (*Source* Author, 2022)

## 2 South African CQS's

According to the ASAQS [9], the range of services offered by professionally registered South African QSs to their clients include:

- Estimating and cost advice during the project's different life cycle stages, including possible financial implications
- Cost planning for determining the value of money of the proposed project, both for the capital expenditure and the operational and maintenance cost.
- Advising on procurement methods (such as contracts incorporating bills of quantities, provisional bills of quantities and schedules of rates) and
- Choosing the appropriate form of contract based on the nature of the project (for example, negotiated, lump sum, managed and cost-plus contracts, packaged deals or turnkey offers)
- Project cost control, the measuring and valuing of work in progress, determining the value of variations and ensuring a fair and equitable settlement of the final cost of the project in accordance with the contract conditions
- Acting in disputes as experts in the field of costs and contracts,
- Preparing valuations and advising on the settlement of insurance claims or
- Be called as expert witnesses or act as arbitrators in court or arbitration on contract disputes.

The value of the above services offered by QSs to their clients, who are typically property developers and property owners, can benefit construction companies in a very similar manner. For that reason, many construction companies appoint full-time quantity surveyors in their employment [8, 10, 11]. The potential value gained by construction companies when employing quantity surveyors are:

- Estimating and calculating construction costs at tendering stage,

- Calculating the possible financial implications of variations ordered onto the project.
- Cost planning for determining the value of money of the proposed project based on the construction company's available resources and deployment thereof;
- Advising during the tendering process on tendering procedures with the interpretation of the tender documents prepared by the project client's quantity surveyor;
- Negotiating with and procuring material suppliers and specialist sub-contractors not only during the tendering but also during the construction stages in terms of the contract conditions;
- Project cost control during the construction stage, submitting progress claims of valued work completed on behalf of the contractor, including the possible influence of price fluctuations in terms of the applicable contract price adjustments allowed;
- Reducing building defects and re-working;
- Meeting regulatory, contractual and legal requirements;
- Determining the value of variations ordered onto the project and settling the final account fairly in collaboration with the client's quantity surveyor to prevent the declaration of possible disputes between parties in terms of the contract conditions
- Creating new client opportunities;
- Setting a benchmark to retain existing clients [10–13].

Irrespective of whether university graduates end up working for professional QS firms or construction companies, they need the following skills and traits:

Skills required:

- Talent and skill in mathematics, figures and geometry as it sets an understanding of measurement and the use of financial calculations;
- Problem-solving and logical reasoning;
- Focus and concentration, whether on the construction site or the office;
- Good literacy ability and concise communication with a good command of oral and written techniques.

Traits required:

- Work systematically and orderly;
- Be a reliable team member;
- Competency that is based on a sound knowledge of the construction process and a solid understanding of project management principles;
- Enjoy the construction industry and want to learn more about new techniques as they become available [8, 12, 13].

Towey [8] continues to elaborate on the importance of the QSs time and self-management requirements because effective time and self-management lead to good working habits and help develop a mindset of overcoming obstacles which are especially important when construction project deadlines are to be met. A competent

QS can add value to any construction company regarding quality management and implementing procedures to ensure the contractor delivers its services.

### *2.1 The Merit for the Study*

The status quo regarding the registration status and membership of the South African QS profession is that neither the SACQSP nor the ASAQS has categories to formally accommodate and recognise CQSs [6, 14]. In contrast to this situation, the Royal Institution of Chartered Surveyors (RICS) in the UK, as the largest institution of construction industry professionals in the world, offers membership categories to QSs who are not practising as professional consultants (PrQSs) such as CQSs [15].

The ASAQS can, by extending its membership categories to allow CQSs to become members, substantially add to the potential membership of the organisation. This additional membership category can bolster the impact and sphere of influence of the ASAQS. CQSs will benefit by receiving the same comprehensive professional support and representation that the ASAQS currently offers to practise QSs.

This study aims to profile CQSs to assist the ASAQS in gaining more comprehensive insight and understanding of South African QSs employed by the construction industry. The study's profile of South African CQSs includes detail on their numbers, age, gender, location, race, qualifications, SACQSP registration and ASAQS membership.

## 3 Methodology

The data for the quantitative research originated from a questionnaire distributed by the ASAQS to all South African QSs on their database. The University of Pretoria (UP) assisted the ASAQS in compiling the research instrument and analysing the data. A total of 626 QSs responded, representing approximately 14% of registered QSs in South Africa. The questionnaire focused on various aspects to describe South African QSs. These aspects include age, gender, race, contact details, qualification levels, employment status, SACQSP registration status and ASAQS membership.

The above study data was secured based on a signed agreement between the ASAQS and UP.

## 4 Findings

The data analyses from the questionnaires enabled the study to draw a fairly comprehensive profile of South African QSs. The most pertinent findings are discussed in the following sections.

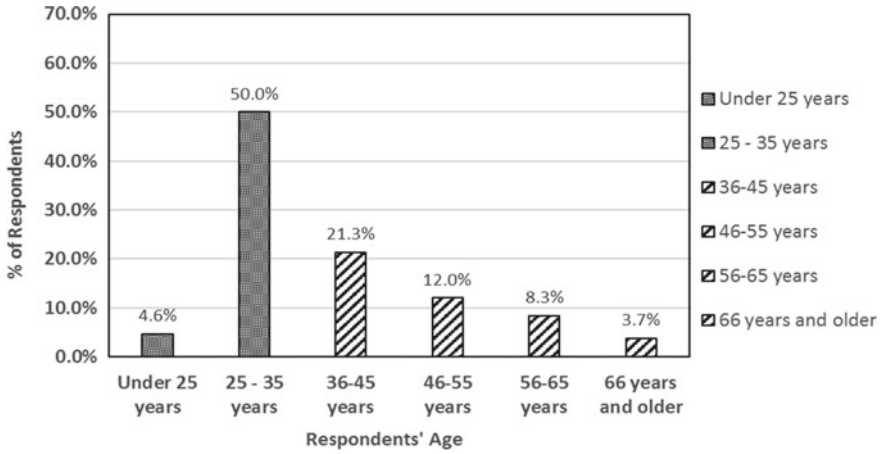


**Fig. 2** Age of CQSs (*Source* Author, 2022)

## *4.1 Construction QS Numbers*

Figure 1 confirmed that CQSs are the second largest group amongst the respondents, with 17.3% employed by construction companies. Although the majority of 62.7% of respondents confirmed to be working as professional consultants, the number of CQSs is substantial. Based on numbers alone, the ASAQS should consider more formally including these QSs in their membership structure.

## *4.2 Age and Gender*

Figure 2 confirmed that the majority of South African CQSs are relatively young—54.6% of them are not older than 35 years. The spread across the sequential age groups gradually declines, with only 12.0% of CQS older than 55 years.

Figure 3 confirms that the gender makeup of CQSs is almost identical to that of all QSs. A total of 73.1% of CQSs are male compared to 73.4% of all QSs. Likewise, a total of 26.9% of CQSs are female compared to 26.6% of all QSs.

## *4.3 Location*

Figure 4 details the spread of QSs amongst the country's nine provinces. The analysis indicates that CQSs are spread across all nine provinces but are largely concentrated in the country's major urban areas. A total of 83.4% of CQSs are from Gauteng (52.1%), the Western Cape (16.7%) and KwaZulu-Natal (14.6%). These three provinces are

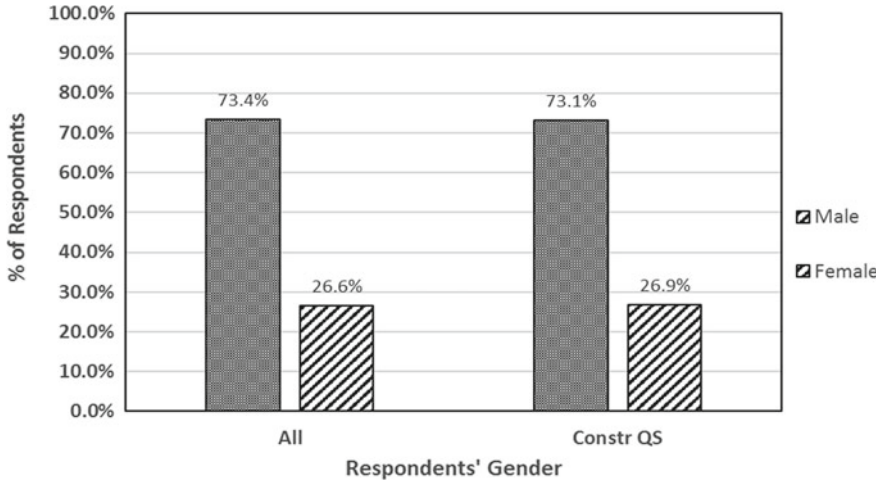


**Fig. 3** Gender of CQSs (*Source* Author, 2022)

also the country's major economic hubs, and most construction activities occur there. This finding, therefore, confirms the expectation that the location of CQSs corresponds with the areas of significant economic activity.

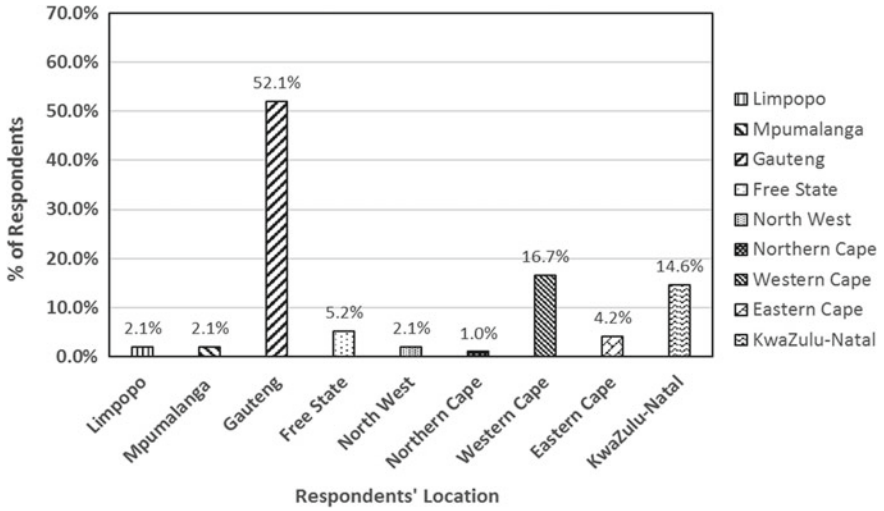


**Fig. 4** Location of CQSs (*Source* Author, 2022)

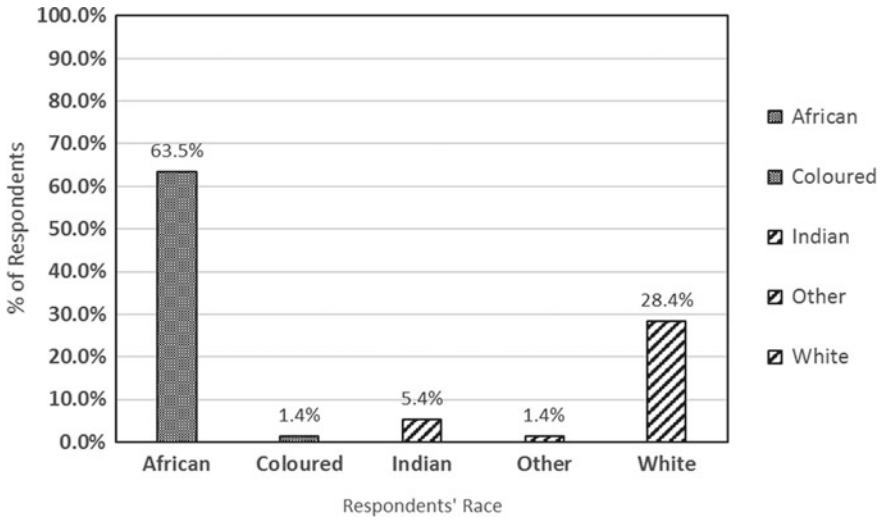


**Fig. 5** Race of CQSs (*Source* Author, 2022)

## *4.4 Race*

The racial compilation of CQSs is detailed in Fig. 5. This analysis reveals that a significant majority of 63.5% of CQSs are of African descent, while 28.4% are of European descent. Coloured, Indian and "other" racial groups only total 8.2% of CQSs.

## *4.5 Qualification Level*

All the CQSs in the study have tertiary qualifications (see Fig. 6). The majority of 56.5% of CQSs have Honours degree qualifications, with a further 16.7% who have B-degrees. A total of 18.5% have diplomas or post-graduate diplomas, while 8.3% have achieved Master's degrees.

The above finding confirms that PQSs in South Africa have achieved a not-insignificant qualification level. The finding lends some support to the argument in favour of creating an ASAQS membership category for CQSs.

## *4.6 SACQSP Registration*

The study found that a surprisingly large portion of 65.4% CQSs are registered with the SACQSP. Of these registered QSs, 27.1% have registered QS (PrQS) status, while

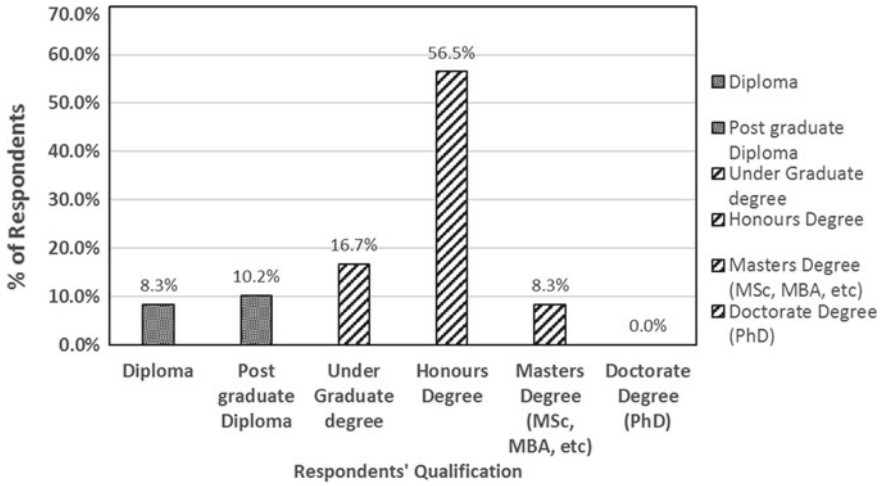


**Fig. 6** Qualification level of CQSs (*Source* Author, 2022)

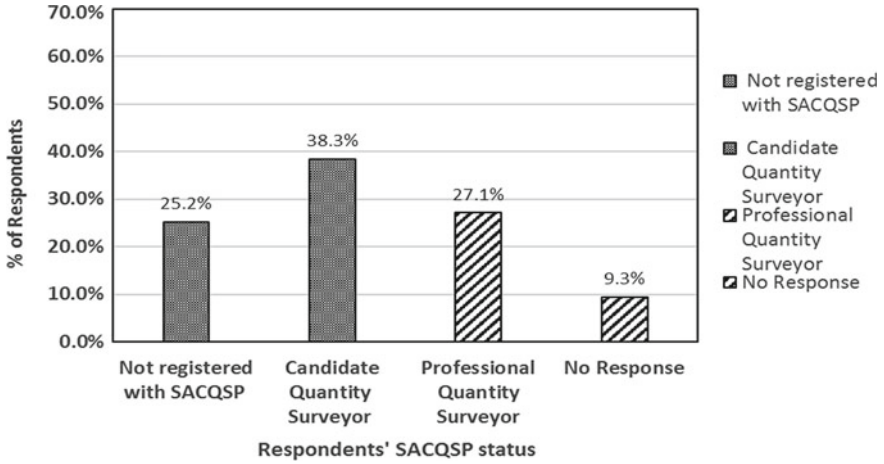


**Fig. 7** SACQSP status (*Source* Author, 2022)

38.3% are registered as candidate QSs. Figure 7 confirms that only 25.2% of CQSs have responded that they are not registered with the SACQSP.

## *4.7 ASAQS Membership*

The study found that 34.0% of CQSs are not ASAQS members. Figure 8, however, confirms that, even though the ASAQS does not currently have a specific membership

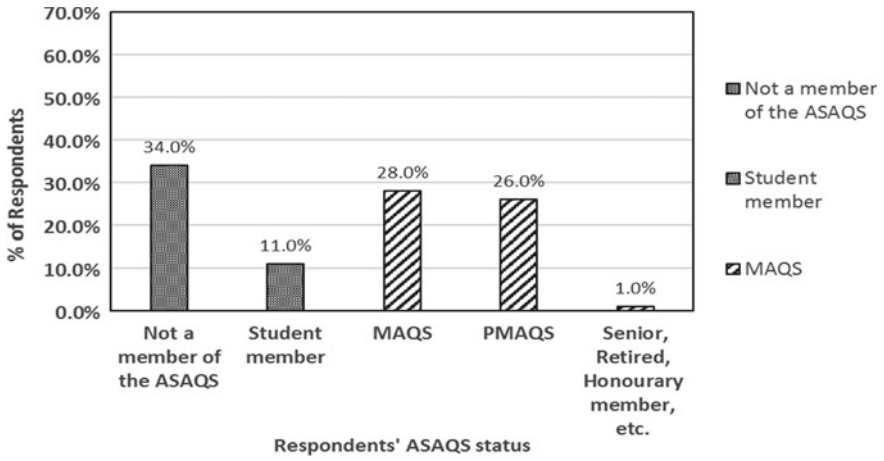


**Fig. 8** ASAQS membership (*Source* Author, 2022)

category for CQSs, 66.0% of CQSs are currently ASAQS members. However, only 26.0% of CQSs are practising members (PMAQS) of the ASAQS since the PMAQS membership category caters for consulting QSs.

## 5 Conclusions

The study made some important findings that the QS profession and specifically the ASAQS should note.

The first finding is that CQSs make up more than 17% of all QSs, making them the second largest grouping when analysed by employment sector. Therefore, the ASAQS should seriously consider including CQSs more specific in their membership category.

The second finding is that CQSs are relatively young and that most CQSs, therefore, still have many years of economic activity left where they can make a substantial contribution to the QS profession.

Thirdly, the study finds that CQSs are already located in the areas of major economic significance for the country. No significant relocation of CQSs will be required if the ASAQSs future strategies may need to include CQSs to target areas of economic activity previously unattended by or not serviced by QSs.

In the fourth instance, the study confirms that, in keeping with the general trend in the country, the majority of CQSs are of African descent. A worrying finding was that only 8.2% of CQSs are from the Coloured, Indian or other race groups. A dedicated marketing and communication campaign from the ASAQS is advised to ensure a strong and viable supply of future QSs from these sections of the South African population demographic.

The fifth finding is the high qualification level of CQSs. All CQSs have tertiary qualifications. A total of 73.2% of CQSs have academic degrees (Bachelors and Honours), while 8.3% have achieved Master's degrees. Similar to the example set by the RICS, the ASAQS and SACQSP may do well to consider membership and registration categories catering specifically for CQSs.

The sixth finding is that as many as 65.4% CQSs are registered with the SACQSP. Of these, 27.1% are registered QSs (PrQS). A CQS registration category may suit these QSs better since they are not performing actual PrQS functions in their day-to-day activities. Only 25.2% of CQSs are not registered with the SACQSP.

The seventh and last finding is that 34.0% of CQSs are not ASAQS members and that only 26.0% of CQSs are practising members (PMAQS) of the ASAQS. A new and dedicated CQS membership category by the ASAQS may be considered better to suit the needs and challenges of CQSs.

## 6 Recommendations

Based on the above findings, it is proposed that the ASAQS considers exploring CQSs in more detail. After serving the needs and interests of consulting QSs for many decades, the ASAQS is well informed of what consulting QSs require from the organisation. However, CQSs needs and interests may be quite different, and the ASAQS should inform themselves in this regard.

The study's findings also suggest that this study should be repeated every 2nd or 3rd year to keep the profession and the ASAQS informed of trends and changes amongst QSs. New, updated and accurate information about the profession and its members will be essential components of change management plans of the ASAQS to keep the organisation focused on the current and future needs of the profession.

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# Data Mining to Support Decision-Making—A Research Approach

**Jorge Duque, José Joaquim Moreira, and Joaquim Costa**

**Abstract** The digital age and the interest in the areas of knowledge development in databases and Data Mining are related to information and communication technologies that contribute to the exponential growth of science data. Data Mining is a method of extracting data from systems such as business intelligence, big data and data warehouses so that through consistent systematization is it possible to create patterns that can be moldable to answer customers. In this way, the patterns must be presented as representations of knowledge. The purpose of this article is to observe the different stages of the knowledge discovery process and analyze data using Regression and Classification models in Data Mining, to support companies in knowledge management.

**Keywords** Data mining · Knowledge discovery · Knowledge management · Decision support systems

## 1 Introduction

The process of gaining knowledge for decision-making should be a priority for organizations, to the quality information management, as well as essential for the conscious systematization of data, through patterns that can be molded to respond to the market and design patterns using Data Mining techniques, concerning the concepts that support these patterns.

To get the knowledge, the data quality must be one of the biggest concerns of the organizations. In this way, it is intended to explore techniques for Data Mining to create standards that allow automating internal quality processes.

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Globalization has contributed to increased competitiveness, and organizations are forced to constantly change and manage the large amount of data generated daily, to support decision-making.

Also, the data represent the essential source to produce information and knowledge necessary [6, 7, 22], for the maintenance of the organization's levels of competitiveness. Thus, Data Mining technologies allow companies to better train their users to analyze the information available and essential for any decision process [10, 26].

In the Data Mining phase, results can be obtained that lead to an initial understanding of the organization's experience, considering the creation of new ideas and conceptual models, as well as the reformulation of models to assist in the management of knowledge for organizations [3, 26].

The objective of this work is to contribute with a Data Mining model, which allows us to evaluate the data and lead to knowledge management, from the analysis and treatment of the received data, and to present examples of the creation of Data Mining models.

Thus, this article is structured as follows: the next section includes all the important terms for the development of the work, such as Discovery of Knowledge in Databases, Decision Support Systems, business intelligence, and Data Mining.

The third section proposes the methodological approach; the fourth section presents a conceptual model of Regression and Classification models in Data Mining, considering the process of acquiring and preparing data through ETL (Extract, Transform and Load), creating the "OLAP" (Online Analytical Processing) cube, to analysis and creation of Key Performance Indicators (KPI); finally, the last section presents the conclusions and final considerations.

## 2 State of the Art

The work developed fits into the Data Mining environment, following the emergence of new technologies such as Cloud Computing, Web Data, and Big Data Warehouse, among others in the Data Science area, for the design of patterns using techniques of Data Mining, considered knowledge, for companies to formalize strategies for decision-making.

To identify the relevant Data Mining procedures for knowledge management, a systematic review of the literature published in the last 20 years was carried out, following the process shown in Fig. 1. The decision that led to restricting the review to this period is mainly related to the fact that the Data Mining system is heavily dependent on technological support, which has evolved considerably in recent years.

In the first stage (step 1), the databases were selected to carry out the research, including the Web of Knowledge, Scopus, ScienceDirect, ResearchGate, Springer, and Google Scholar, as they bring together a very comprehensive set of references in the area, and universally recognized. The search terms to be used were also defined: "Data Mining," "Business Intelligence," "Data Knowledge Extraction,"

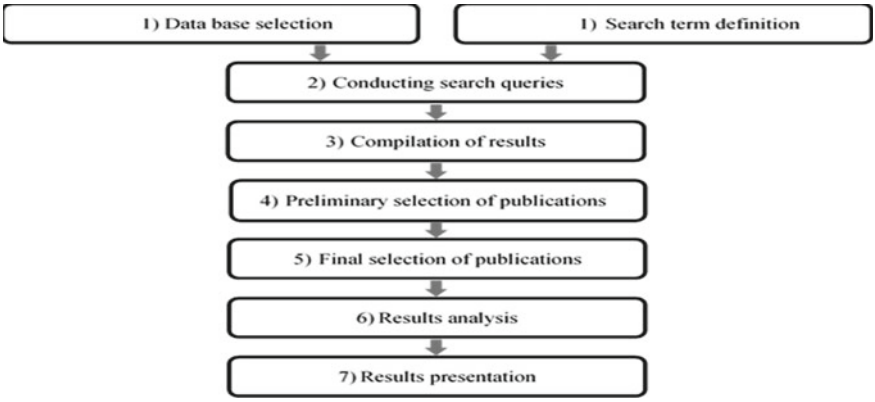


**Fig. 1** Investigation method

"ETL," "Integration Services," "Data Warehouse," "Analysis Services," "Online Analytical Processing (OLAP)," and "Knowledge Discovery in Databases (KDD)."

In the second stage (stage 2), several searches were carried out, with the expressions and respective translations in English. The research carried out resulted in several publications that, once compiled (step 3), were analyzed concerning the title, abstract, and keywords (step 4).

When it was not possible to identify the relevance of the publication for the study only through the initial reading, a full reading was carried out (step 5).

Finally, from the full reading of the articles, those that presented methodologies and procedures for extracting data for the Regression and Classification models in Data Mining were identified, which were then analyzed (step 6) and presented (step 7).

The process of discovering knowledge in a database, in addition to being iterative, is also interactive, as it requires user participation whenever decision-making is necessary [20]. Thus, "Discovery of Knowledge in Database" is composed of five main phases (Fig. 2): Selection, Preprocessing, Transformation, Data Mining, and Evaluation/Interpretation.

According to Oded et al. [18], the five main stages are defined as:

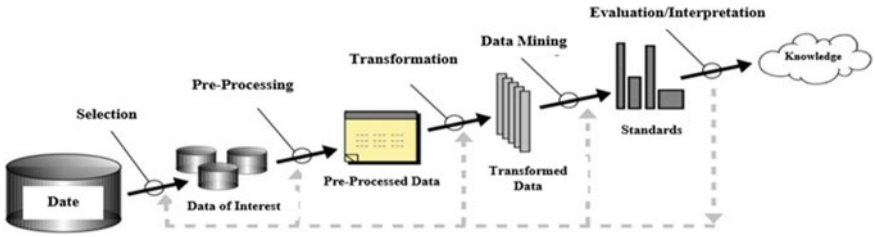


**Fig. 2** Process of discovery of knowledge in database (adapted from [8])

- Selection: Definition of objectives as well as the selection of data for the knowledge discovery process (the entire process for building the models is defined at this stage);
- Preprocessing: Improve data reliability, i.e., data are filtered and cleaned to make them consistent.
- Transformation: Develop the best data models, to obtain quality information (data with low quality is subject to transformation methods/techniques to generate useful data);
- Data Mining: Definition of the choices according to the objectives defined in the previous steps (the specific models and search patterns to be used are selected to achieve the best possible results);
- Evaluation/Interpretation: Outline the end of the knowledge discovery process in databases or readjust the patterns to repeat the process (reliability is determinant for the model's acceptance process).

According to Fayyad et al. [9], the process of knowledge discovery in databases to identify valid, new, potentially useful, and understandable patterns from existing data, is non-trivial.

The Decision Support Systems have evolved permanently, with the automation of manual systems that allow the creation of strategic organizational value, with the use of Regression models and Classification in Data Mining [15].

The success of organizations lies in making strategic decisions in real-time, using technology like Business Intelligence (BI). BI is a *framework* that combines architectures, data storage, analytical tools, computer applications, and methodologies that transform data into useful and relevant information for decision support, enhancing business success [7, 10, 13, 16, 23, 26]. BI is the meeting point between business, management, and technology, allowing aggregated and structured information, based on a large volume of data from various software solutions, to develop performance indicators and dashboards with real-time information, enhance knowledge of customers, train employees of organizations, executives, managers, and analysts, to make quality decisions in real-time, to obtain efficiency and effectiveness gains, knowing the behavior of customers, analyzing the past, observing the present, predict the future of the business and ability to anticipate the competition [3, 5, 10, 11, 26]. BI systems make it possible to improve the availability and quality of information [2, 17, 21], with resources to Data Warehouses, which are repositories of organizational information, OLAP data analytical processing systems, and Data Mining mechanisms. That is, the former provide a multidimensional analysis of the data, and the latter is used for knowledge extraction, identifying patterns, and predictive models in the data.

The phenomenon of Data Mining is the trend in the discovery and data-driven decision-making. Data mining is the process of extracting knowledge from a large set of observed data, to define the unsuspected relationship and patterns in the data, presenting it in an innovative, understandable, and useful way for users [1].

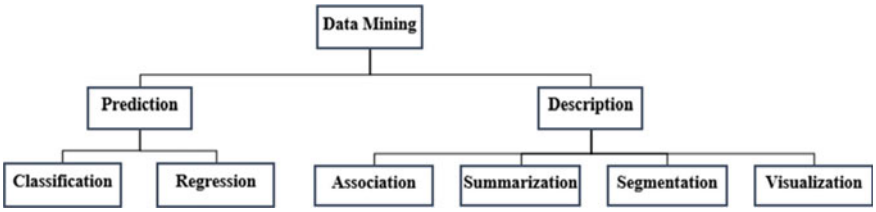


**Fig. 3** Data *mining* categories and subcategories (adapted from [19])

The presence of Data Mining is crucial for organizations, considering that deep analysis is essential to define the value of the pattern found, making it useful and relevant [14].

Data Mining objectives can be divided into two broad categories, which are divided into subcategories according to the purpose of their use, as can be seen in Fig. 3.

Figure 3 allows the identification of the Forecast category, consisting of Classification and Regression, as well as the Description category, consisting of Association, Summarization, Segmentation, and Visualization. Since Classification is the process of assigning classes to objects according to their characteristics [4, 19]; Regression allows setting a value for a variable, such as predicting the probability of a person surviving a disease based on the results of diagnostic tests [19]; the Association determines the data that tend to compete in the same transaction, for example, placing products together in a supermarket cart, market basket analysis [19]; Summarization is the most evolved method, it derives from summary rules, visualization techniques, and discovery of relationships between variables, applied to data analysis and automatic report generation [8]; Segmentation or Clustering allows a heterogeneous division of a population into several homogeneous segments, with data grouped according to similarity [19]; in Visualization, Data Mining results are presented through graphs and diagrams, allowing the representation of patterns and trends.

## 3 Methodology

The methodology adopted in the work is Design Science Research (DSR) for problem-solving. According to Hevner et al. [12], this methodology allows the production of innovative artifacts and responds to organizational problems.

After its construction, the evaluation takes place. The objective is to provide new knowledge within the scope of scientific evidence. The key pieces to understanding the problem are the engineered artifacts. Through its construction and application, it is possible to know and understand the difficulty of the problem and define a solution.

For the application of this methodology to be successful, it is essential to analyze its procedure from the identification of the problem to the result, that is, until the work is completed.

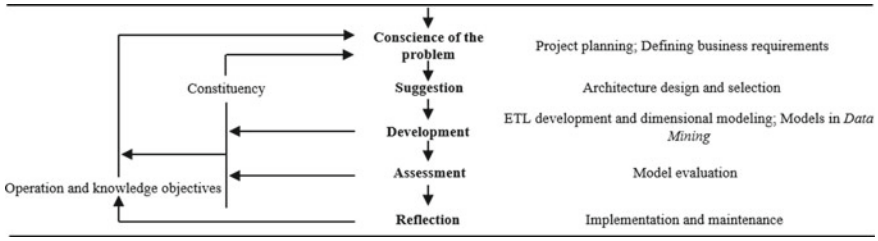


**Fig. 4** Design *science research* model applied to this work

Figure 4 outlines the application of the DSR to be applied in the development of Data Mining in which the five phases of the proposed process cycle are followed.

The first stage consists of planning the work, with the tasks being continuous and controlled, to ensure compliance with the plan, define the objectives, and ensure that the selected requirements guarantee the success of the development of the work.

It follows the integration of various data storage technologies, in association with the design of the system architecture to satisfy the needs of the business. The next step is development, with dimensional modeling with the data to be divided into measurement facts.

Relational models can be instantiated in relational databases, multidimensional models, OLAP cubes, and Data Mining models. It is critical to ensure ease of use from the user's perspective and fast query performance. In the transformation process through ETL, data is extracted from the source, cleaning and conformity transformations are carried out, as well as dimensional modeling, as well as the design of models in Data Mining.

The evaluation of the model should be taken as a reference in the data analysis process and in the presentation of the results, guaranteeing a good perception of them. The life cycle converges in the implementation, bringing together the technological solutions and data handling. The maintenance phase is very important throughout the process. In all work, all limitations and risks must be guaranteed, whose objective of the organization is the acceptance of business to support the decision-making process.

## 4 Conceptual Model of Regression and Classification Models in Data Mining

The main objective is to present the conceptual model in Data Mining, from the data source—Data Source, the cleaning and formatting of the data, the KPI's relevant to the analysis, and the visualization rules in the creation of visual reports, allowing the creation of Regression and Classification models in Data Mining.

**Table 1** Development tools [24, 25]

| Experimentation context | Data exploration |
|---|---|
| MS SQL *server management studio–database engine* | MS excel |
| MS SQL *server management studio–analysis services* | MS excel and power query |
| *Visual studio–integration services project* | |
| *Visual studio*–multidimensional and *data mining* project | |

Table 1 presents the tools that serve as examples to be used in the development of the model, which are grouped by the context of experimentation and extraction and exploration of the data.

**Task organization**. In Table 2, we can observe the bases for the acquisition of knowledge and development of a solution, thus divided into two components (step 1): the acquisition of knowledge with the collection of data from the dataset in CSV format (Comma-separated values), organized in the MS Excel and Power Query environment, follows the design of the data warehouse architecture in MSSQL Server Management Studio. In stages 2, 3, and 4, the development of the solution takes place, with the preparation of data through the ETL process in Visual Studio–Integration Services Project, and data integration in the Data Warehouse, creating a favorable environment for the design of the analysis, through Visual Studio–Multidimensional Project and Analysis Services Data Mining, report generator, OLAP cube, design of models of classification algorithms, Regression, Association, Summarization, Segmentation, and Visualization, in Data Mining.

**Working environment**. This topic discusses the technologies, tools, and languages used, describing what they are, what they are for and how they fit into each phase of the model, according to the structure presented in Table 2.

1. Analysis of data and requirements through a proof of concept from dataset.
2. Modeling the data warehouse, design and implementation of ETL processes (Dimensions and Facts).
3. Analysis services multidimensional Project (OLAP Cube).
4. Multidimensional and Data Mining design for Data Mining models).

**Table 2** Tasks of the project stages

| Knowledge acquisition | Development of the solution |
|---|---|
| • Data collection and study<br>• Problem classification<br>• Solution design<br>• Selection and aggregation of research data | • Data preparation<br>• ETL process<br>• Creation of the OLAP cube<br>• Models in *data mining* |

Applications, infrastructures, tools, and technologies are briefly described below and bring strategic benefits to organizations, allowing them to support business decisions and forecasts.

The technologies used to design the data knowledge extraction model for Data Mining: SQL Server Integration Services (SSIS) and SQL Server Analysis Services (SSAS) from Microsoft SQL Server. Microsoft Excel and Power Query are used as tools for the construction of data mapping tables). As languages, they have presented: SQL Server language for the construction of tables, views, stored procedures, and jobs of data sources, and Visual Studio for the construction of ETL, OLAP Cube, and Data Mining.

**Regression and Classification models in Data Mining**. Data Mining performs procedures for analysis and exploration of volumes of data from specialized techniques and algorithms to discover patterns, predictions, associations, and others. Based on the acquired knowledge, it is possible to carry out new strategies for the business, understand the needs and behavior of consumers, predict the organization's financial performance, and mitigate future risks. Data Mining allows automation in the discovery of information. However, further human analysis is needed on where and in what way this knowledge can be applied.

In this context, we characterize the importance of Classification and Regression models in Data Mining, through the presentation of the algorithms that constitute them. That is classification algorithms that predict one or more discrete variables, based on other attributes of the dataset, and regression algorithms, that predict one or more continuous numeric variables, such as profit or loss, based on the other attributes of the dataset.

Algorithms such as Decision Tree, Naive Bayes, Clustering, and Neural Network are some of the examples of algorithms to consider in the Regression and Classification models in Data Mining, which we present below.

- The Decision Tree algorithm is a classification algorithm that works for predictive modeling. Supports both discrete and continuous attribute prediction. In the case of discrete attributes, the algorithm makes predictions based on the relationships between input columns in a dataset. This one uses the values, known as states, of columns to predict the states of a column that we define as predictable. Specifically, the algorithm identifies the input columns that are correlated with the predictable column. For example, in a scenario where you want to predict the tendency of customers to buy a bicycle, if 9 out of 10 young customers buy a bicycle, but only 2 out of 10 older customers do the same, the algorithm infers that age is a good indicator for the purchase of bicycles. The Decision Tree makes predictions based on this trend to obtain a specific result.
- The Naive Bayes algorithm, being a classification algorithm, is less computationally intensive than other algorithms. It allows you to quickly generate mining models to discover relationships between input columns and predictable columns, perform initial data exploration, and then apply the results to create additional mining models with other algorithms that are computationally intensive and more accurate.

- The Clustering algorithm provides two methods for creating clusters and assigning data points to clusters. The first, the K-means algorithm, is a rigid clustering method. This means that a data point can belong to only one cluster and that a single probability is calculated for the membership of each data point in that cluster. The second method, Expectation–Maximization (EM), is a flexible clustering method. That is, a data point always belongs to multiple clusters and a probability is calculated for each data point and cluster combination.
- The Neural Network algorithm is an implementation of the popular and adaptable Neural Network architecture for machine learning. The algorithm works by testing each possible state of the input attribute with each possible state of the predictable attribute and calculating probabilities for each combination based on the training data. Allows you to use probabilities for Classification or Regression tasks to predict an outcome based on some input attributes. A neural network can also be used for association analysis. The number of networks contained in a single mining model depends on the number of states (or attribute values) in the input columns, as well as the number of predictable columns that the mining model uses and the number of states in those columns.

In this context, an algorithm in Data Mining is a set of heuristics and calculations that create a model based on the data. To create a model, the algorithm first analyzes the data we provide and looks for specific types of patterns or trends. The algorithm uses the results from the various iterations to define the optimal parameters to create the mining model. Parameters are applied across the entire dataset to extract actionable patterns and detailed statistics.

## 5 Discussion and Conclusion

After characterizing the various phases of the work, some conclusions and results can be considered. The first coincides with the importance of Data Mining to support data knowledge management for organizations. The data stored in different sources must be extracted and exploited from systems that allow the conscious systematization of data, creating patterns that can be molded to respond to the market, as well as designing patterns using Data Mining techniques, allowing for automation and internal quality processes. In this sense, the importance of the state of the art must be recognized, allowing the study and characterization of platforms, applications, and systems, for the process of discovering knowledge in databases.

The research methodology phase contextualizes the development structure of the aligned work, intending to be achieved, through the creation of the artifact, from the extraction and exploration of the relevant data that serve the Business Intelligence system, which represents a lot for the models of Regression and Classification in Data Mining.

As demonstrated by the DSR methodology, it allows for finding a plausible solution to the problem. After analyzing the problem and by this methodology, the solution found was the creation of a cataloging typology, which makes it possible to identify how and which data extraction and exploration tools best suit the requirements of users, as well as for the determination of Regression and Classification algorithms in Data Mining.

Thus, the algorithms presented and which can be applied from an interactive and multidimensional environment, contribute to improving the decision process, in the scope of data science with Data Mining applied to knowledge management.

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# Sustainability of Digital Transformation (DX), Institutional Research (IR), and Information and Communication Technology (ICT) in Higher Education Based on Eduinformatics

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**Abstract** We proposed a novel concept for the sustainability of digital transformation (DX), institutional research (IR), and information and communication technology (ICT) in university reform based on Eduinformatics in this paper. DX was proposed in 2004 by Prof. E. Stolterman and Prof. AC Fors. The concept behind DX is to digitize human behavior and create new value. Eduinformatics is a new interdisciplinary field that includes informatics and education. Eduinformatics analyze data of students and develop novel analytical methods. In this paper, we assess the method of obtaining sustainability in DX, IR, and ICT to perform university reform. To obtain the answer of this research question, we show some practical examples. From these examples, we proposed a new matrix of feasibility and sustainability and

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concluded that Eduinformatics and Significant Other Groups (SOGs) are the keys to obtain sustainability in DX, IR, and ICT to improve the quality in higher education.

**Keywords** Digital transform (DX) · Institutional research (IR) · Eduinformatics · Information and communication technology (ICT)

# 1 Introduction

## *1.1 Sustainability of Digital Transformation*

The concept of digital transformation (DX) was proposed by Prof. E. Stolterman and Prof. AC Fors in 2004 [1]. The idea behind DX is not just to replace analog data with digital data; in their paper, the authors said that the penetration of information technology (IT) will change people's lives for the better in every way. Thus, the essential concept of DX is to digitize human behavior and create new value. In Japan, the Ministry of Economy, Trade and Industry (METI) reported the promotion of digital transformation in industry in 2018 [2].

This shows that DX in Japan started faster in industry fields compared to education fields. Similar to DX, Japanese Cabinet Office in the fifth Science and Technology Basic Plan constructed novel concept called "Society 5.0" in 2016 [3]. Society 5.0 is the concept of the next stage of society [3]. Society 1.0, 2.0, 3.0, and 4.0 are the hunting, agricultural, industrial, and information society, respectively.

The concept of Sustainable Development Goals (SDGs) was proposed during the United Nations Summit, 2015 [4]. The aims behind SDGs connect easily with the concept of Society 5.0. Incidentally, Japan Business Federation proposed the new concept "Society 5.0 for SDGs" [5] (Fig. 1).

## *1.2 Eduinformatics*

Let us now introduce the new field of Eduinformatics. Eduinformatics is a novel interdisciplinary field that includes informatics and education [6]. Eduinformatics analyze

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**Fig. 1** Society 5.0 for SDGs (from [5])

data in the educational fields, for example university, and develop new analytical methods [7] (Fig. 2).

Specifically, we introduced the idea of applying information and communication technology (ICT) on Eduinformatics [8], and the importance of Eduinformatics in the age of ICT, in the fifth International Conference on Smart Trends in Systems, Security and Sustainability which was in congress last year [9]. Additionally, we proposed a new concept of DX, institutional research (IR), and ICT in higher education based on Eduinformatics [10].

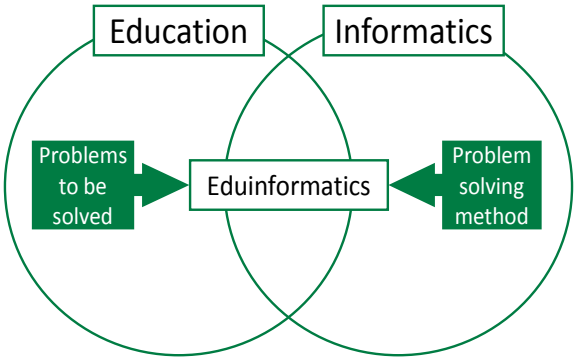


**Fig. 2** Visualization of Eduinformatics (from [7])

### *1.3 Research Question*

In this research, we set the following research question: how do we obtain sustainability in DX, IR, and ICT for university reform? Firstly, we show some examples of practice from a Japanese university, which show good suggestions of recent Eduinformatics. And we understand that Eduinformatics is the key to obtain sustainability in DX, IR, and ICT, to further promote university reform. In the last section, we suggest a novel concept of sustainability for the application of DX, IR, and ICT on Eduinformatics in higher education.

## 2 Practical Examples for Sustainability of DX, IR, and ICT in Higher Education Based on Eduinformatics

How does sustainability in higher education improve its quality? The answer depends on the layers found in higher education. Fortunately, the United Nations Educational, Scientific and Cultural Organization (UNESCO) proposed the "three layers of learning analytics" in a report on learning analytics in 2012 [11] (Fig. 3). The following are the definitions of the three layers of analytics from [11].

Using these three layers, we proposed new methods of comparing student data in IR [12]. We defined so called as primary data and secondary data. Primary data is origin of secondary data. Secondary data is constructed from primary data or secondary data or both primary data and secondary data.

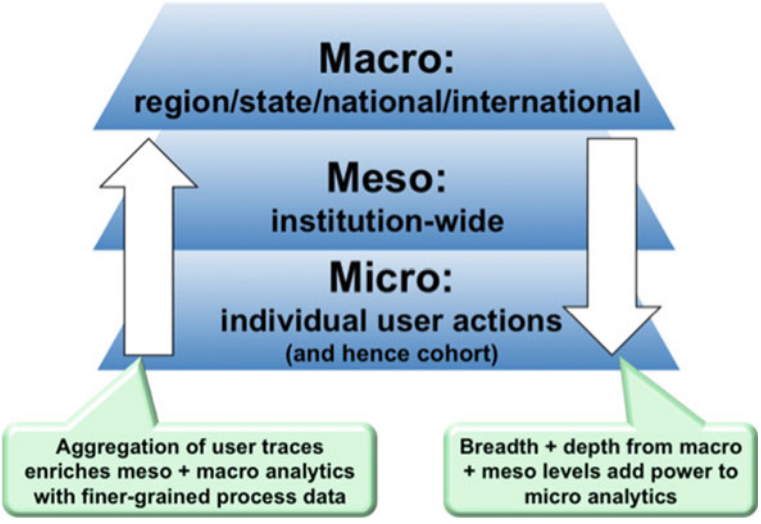


**Fig. 3** Layers of learning analytics from UNESCO IITE (from [11])

Additionally, we reported the "Sustainability of Equal Evaluations Among Teachers of First-Year Students in Higher Education" in 2019 [13], obtaining the best paper award of IEEE/IIAI International Congress on Applied Information Technology (IEEE/IIAI AIT 2019). The research examined the sustainability of the higher education assessments at Kobe Tokiwa University in Japan, where a new first-year education program had begun in 2017. The results showed that equal evaluations were sustainable for teachers of first-year education students.

Moreover, we proposed a new concept for university reform in Eduinformatics called the Significant Other Groups (SOGs) [14]. Kobe Tokiwa University was established in 2008 in Japan. The result of the first university reform construct novel competency-based curricula in 2017 [15]. We assessed the curricula that constructed the first university reform [16], the result of which shows that Tokiwa's competency needs to be rebuilt [16]. SOGs are supposed to implement university reform [14], and as described in Sect. 1.2, we concluded that Eduinformatics is the key to connecting DX, IR, and ICT in higher education [10].

## 3 Results and Discussion

When we contemplate sustainability, we also have to refer to replicability. Replicability is very important issue. In 2016 Prof. Baker reported that more than seventy percent of researchers could not reproduce another scientist's experiments, and more than half have failed to reproduce their own experiments (reproducibility) [17]. This is not only research files but also institutional research (IR). It is especially important to use replicability analysis rather than ad hoc analysis [18, 19], as most IR departments include both faculty and staff. In Fig. 4, we show the matrix of feasibility and sustainability.

The first and fourth quadrant are high, or easy, in terms of sustainability. This means that we can obtain the same result, i.e., there is replicability. The second and third quadrant are low, or difficult, in sustainability. This means that it is difficult to obtain the same result, i.e., there is no replicability. The first and second quadrant are high, or easy, in feasibility. This means that we can easily achieve results. Conversely, the third and fourth quadrant are low, or difficult, in feasibility. This means that we cannot easily achieve results.

In our past research, we referred to this sustainability in IR research. In the title "New visualization of competency-based education (CBE) in higher education institutional research (IR)", we analyzed our data using only RStudio. Generally, to analyze IR data, a combination of Perl and R language is used along with z-shell script, awk script, and sed script. In the case of the second quadrant, while I am able to achieve the results, the faculty or staff members find it difficult to achieve replicability. Thus, sustainability is low or difficult for other faculty or staff. This may be due to my use of multiple languages or scripts. Therefore, we decided to use only R language to analyze IR data in the research.

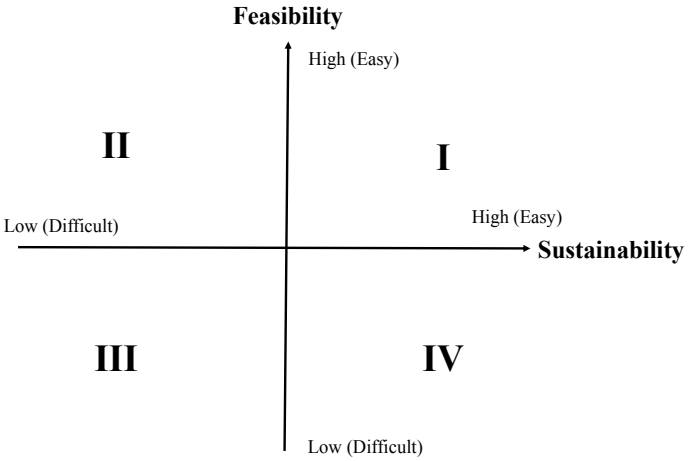


**Fig. 4** Matrix of feasibility and sustainability

To obtain the result immediately, usually, we select the second quadrant. In other words, we can choose the least time consuming route, except to achieve replicability and sustainability. However, for replicability and sustainability, we have to select the first quadrant or the fourth quadrant. To choose from the second quadrant to the first quadrant, you have to immediately select first quadrant. However, it is usually difficult to select the first quadrant instead of the fourth quadrant.

Data analysis normally begins in the third quadrant. In the third quadrant, it is difficult to obtain the results easily, and achieve sustainability or replicability. People may use some tools to easily obtain the results, proceeding to move from the third quadrant to the second quadrant. As described above, people usually move from the second quadrant to the fourth quadrant.

When people move from the fourth quadrant to the first quadrant, we propose the use of DX. However, during the third quadrant, the second quadrant and the fourth quadrant, data have to change from analog to digital data to be analyzed easily using a computer. In the last part of this paper, we propose a novel concept based on Eduinformatics for sustainability in higher education (Fig. 5).

## 4 Conclusion

In this article, we have solved our research question, which was on obtaining sustainability in DX, IR, and ICT to promote university reform. One of the answers is both SOGs and Eduinformatics. As described examples in Sect. 2, we find that Eduinformatics and SOGs are the keys to obtain sustainability in DX, IR, and ICT to improve the quality in higher education.

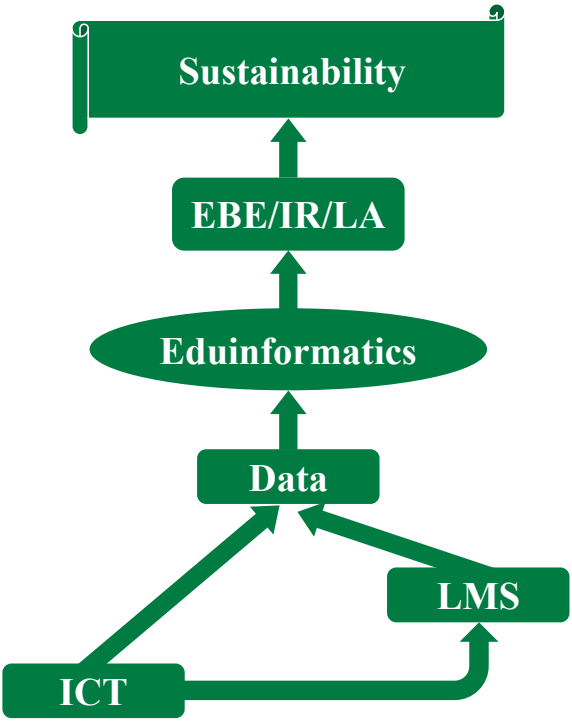


**Fig. 5** Using of Eduinformatics in higher education

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# Digital Platform for Monitoring and Comprehensive Support of Children with Autism Spectrum Disorders

**I. Nigmatullina, S. Sheymardanov, and M. Abramskiy**

**Abstract** Based on recent breakthroughs in medical, pedagogical, and psychological research, Kazan Federal University is undertaking a project to build a scientifically based model of comprehensive assistance for children with autism spectrum disorders (ASD). The findings of recent research underline the necessity to develop and deploy novel remote support models for children with ASD and their families, as well as technology targeted at boosting educational quality. This determined the need to develop a digital platform in order to increase the success of the socialisation of children by increasing the amount of time for specialists to corrective work with children, informing clients about the effectiveness of the educational process and reducing the time to collect information and prepare individual child development programmes, as well as family support programmes. The paper proposes an algorithm for the operation of a digital platform for an online monitoring system as well as full assistance for children with ASD who use intelligent services. The developers of the online system were guided by the ideas of inclusivity, justice, and accessibility whilst creating the concept. Regardless of position, income, living situations, or other considerations, all services and resources established in the online system enable children with ASD and their families, caregivers, professionals, and students with equitable access.

**Keywords** Autism spectrum disorders · Digital monitoring platform · Remote support · Preschool age

## 1 Introduction

The importance of developing a comprehensive support system for children with ASD, as well as the need for a set of measures to develop and implement innovative

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remote support models for children with ASD and their families, as well as technologies to improve the quality of their education, is confirmed by the findings of recent systematic reviews and monitoring.

Autism affects around one out of every 100 children worldwide [1]. Autism affects one out of every 44 children, according to statistics issued by the US Centres for Disease Control in December 2021, with males being 4.2 times more likely than girls [2]. According to statistics collected by the administrative authorities of the constituent bodies of the Russian Federation that carry out public administration in the field of education in 2020, the total number of persons with ASD receiving education was 32,899, up 42% from 2019 [3].

The degree of developmental disorders in children with ASD varies substantially, making the construction of universal standards of care for all children in this target group extremely difficult. ASD comes in a variety of forms, ranging from the most severe, which needs lifetime care, to the mildest, which allows for practically total recovery and full participation in society. All of these youngsters, however, share a common deficiency in the area of social interaction, which expresses itself in varying degrees.

Modern systematic reviews and studies emphasise the urgent need to develop innovative remote support models for children with ASD and their families, which maximise the effectiveness of available educational and information resources, and contribute to widespread and timely access to the system of accompanying children with ASD parents (legal representatives), educators, and other professionals [4–8].

The analysis of the works backs up our findings, indicating that in the case of ASD, a quick start to correction and socialising is critical [9–11]. With early identification of children at risk for ASD, early start of correction and socialisation, and creation of a system of continuous comprehensive support, up to 60% of children with ASD (according to modern diagnostic criteria) have the ability to achieve a high-functioning level, which implies the possibility of a full life in society without or with little accompaniment. In this case, not only the individual with ASD, but also his parents, are able to resume full participation in society. In the absence of early diagnosis, treatment, and maintenance, ASD can become a lifelong debilitating disease.

Modern research describes the existence of significant barriers to access to many services for accompanying children with ASD: the high cost of intensive care programmes; limitations associated with the low throughput of the educational system and the exclusion of families living in rural and remote areas; parents' language barriers and limited accessibility (due to parents' work schedules and other childcare needs) to educational services; closure of access to educational services due to COVID-19 containment measures [13–15].

The most successful support system for people with autism can be implemented in a full combination of three types of unique competencies: parents, professionals and the state using online monitoring systems and comprehensive support for children with autism spectrum disorders, including intelligent services, according to a study of the best foreign and domestic experience. We utilised the findings of a research on the usefulness of virtual teaching techniques for children with ASD and their parents

to learn the fundamentals of constructing an online system for collecting, analysing, and interpreting data on children with ASD [15, 16]. These studies emphasise the importance of developing and evaluating alternative management methods that are more resource efficient than standard treatments and can be accessible quickly when ASD is detected. Parental and human resource participation, as well as the use of virtual education techniques, are all promising breakthroughs.

A rapid increase in virtual interventions in response to COVID-19 was discovered in systematic reviews, underlining the need for more research into the comparative outcomes of face-to-face and distant integrated support [17, 18].

As a result of the creation of online technologies, the process of accompanying and training project participants will become more inclusive, accessible, and equitable.

The goal of this study was to offer an algorithm for establishing a digital platform for an online monitoring system and complete assistance for children with autism spectrum disorders, based on the most recent medical, pedagogical, and psychological research and the use of intelligent services.

The importance of this concept stems from the social order's ability to execute duties connected to guaranteeing equitable educational opportunities for children with ASD by creating an effective tool. This tool allows the user to access information about the newest autism research and successful technology for dealing with children with ASD more rapidly, collect statistical data more quickly, and see the outcomes of the work. It is aimed to increase the effectiveness of ASD children's schooling and socialising, raising parental awareness and expanding learning options for families through the use of digital educational courses.

## 2 Materials and Methods

A comparison of modern research on this topic was carried out in the study. Design, modelling, and visualisation approaches were utilised to create a digital platform for electronic recording of data from children with ASD and the outcomes of medical, psychological, and pedagogical work.

The initiative was created using technologies that allow for more sustained education of participants in the process of accompanying children with ASD.

The digital platform was created with WordPress, a content management system that allows administrators to control the site's structure through a customised administration interface.

All project participants' data is stored in cloud systems, together with the outcomes of medical, psychological, and pedagogical work, templates for personalised child development programmes, and advice for parents and professionals. The dashboard reflects the visualisation of all data. Educators may use visual analytics to create customised child development programmes.

In 2023, it is planned to develop a mobile version of the online system in order to make project participants' training more accessible, by allowing more families to participate in the education process, including those who live in remote areas of the

country and do not have access to full-time education, as well as support professionals and students by providing new opportunities for teaching and learning, including in families where traditional education is not available.

Parents, children with autism spectrum disorders, correctional and educational specialists, and students are amongst the participants in the study. Each group has its own sector on the platform.

For parents raising children with a suspected or diagnosed autism spectrum disorder, online templates of screening tests to detect the first signs of autism for different age groups are presented (M-CHAT—a modified autism screening test for young children from 1.5 to 2. 5 years; CARS, the Early Childhood Autism Diagnostic Scale from 2 to 6 years; ASSQ, a questionnaire for identifying signs of autism in children and adolescents from 6 to 16 years; ESP-IR, a questionnaire for gathering baseline information about a child's health and mental development to better identify signs of distortion characteristic of autistic development; ATEC, a test for assessing the effectiveness of autism treatment).

When the first signs of autism are found, this type of work will allow parents to be tested at a convenient time and to contact specialists (information about them is provided on the online site) in a timely manner to provide qualified assistance to the kid.

For specialists, online templates of diagnostic protocols with the proven effectiveness of the functional capabilities of children with ASD (VB-MAPP—diagnostics of assessment of speech skills and social interaction), templates of criteria for the automated compilation of individual development programmes for each child and recommendations for parents have been developed. Individual programmes are compiled automatically using the "artificial intelligence" technology. These programmes are placed in the offices of specialists and parents, which allows not only all specialists working with the child to engage in this programme, but also parents at home to continue working with the child, online to see the individual achievements of children.

The online system contains digital educational courses developed on the free Stepik online platform to teach parents, professionals and students planning to work with this category of children, methods with proven effectiveness. This form of training allows raising the awareness of the project participants, attracting those categories of parents and professionals who do not have the opportunity to receive full-time training.

The dashboard shows the visual results of the job in the form of graphs and charts. On one screen, managers, experts, and parents could view all of the critical information about the child's unique accomplishments, the success of specialists' work, and the efficacy of the execution of correctional and developmental work programmes.

The mobile version of the online system will allow a larger number of professionals and families with children with ASD to participate in the educational process, particularly those in remote regions of the nation.

Proposed solutions for the use of active information and communication techniques for a sustainable system of lifelong learning employing e-learning, m-learning

(mobile), u-learning (ubiquitous), and s-learning (smart) technologies. This approach makes it possible to expand the availability of education for all types of project participants 24 h a day, raise project participant awareness, and attract parents and professionals who are unable to attend full-time training.

All programmes are located in the personal account of specialists, parents, and students, allowing not only all experts working with the kid to participate in this programme, but also parents at home to continue working with the child, as well as online viewing of individual child achievements.

Working together on an open, unified worldwide research coordination platform will enable researchers from all over the globe to undertake cooperative research focussed at enhancing the quality of education and the length of time children with ASD, their parents, and experts receive lifelong education.

## 3 Algorithm for Developing a Digital Platform for Monitoring and Comprehensive Support of Children with Autism Spectrum Disorders

Since 2019, Kazan Federal University has begun work on the implementation of a global project to create the International Centre for the Study of Autism, accumulating the international experience of researchers in the field of medicine, pedagogy and psychology. The project is aimed to develop and implement of new technologies with proven effectiveness in working with children with ASD in order to make society more inclusive, to identify the talents of people with autism, to provide opportunities for them to reach their potential, to help them develop their strengths. To this end, an online monitoring and comprehensive support system for children with autism spectrum disorders have been developed for specialists, parents, researchers, students, based on the latest medical, pedagogical and psychological research using intelligent services.

The digital platform is represented by individual cases of children, parents, professionals and researchers in the form of templates to fill out. The developers paid special attention to cases of children, including information about the child, reporting on the dynamics of his development and the effectiveness of working with him, templates for individual child development programmes and recommendations for parents (legal representatives) and specialists. The project work includes three stages.

At the first stage, a team of Kazan Federal University's IT specialists selected and modernised a system for data entry and analysis to meet the project objectives. The university researchers dealing with the problem of studying autism have developed criteria for the selection of existing diagnostic methods with proven effectiveness. At the second stage, diagnostic tools for the online system were developed, based on technologies with proven effectiveness, electronic data entry forms were created; algorithms for analysing the received data; templates for conclusions and recommendations. Currently, the third stage is being implemented, at which the online system

is being tested in the Kindergarten of Kazan Federal University for children with ASD.

The presented algorithm for working of the online system allows managers to generate reports on the effectiveness of the correction and education, on the results of the work of each specialist, on the achievements of each child, in a short time, without the involvement of specialists.

The digital platform for collecting and analysing data on accompanying children with autism spectrum disorders includes 6 sections, which provides information about the project, information for parents, information for researchers; volunteers and philanthropists. Separately, 6 sections are presented with information about the history and current state of knowledge of autism spectrum disorders and comorbid disorders, about ongoing social projects supported at the state level, about scientific projects supported by Kazan Federal University and project partners.

With the help of non-formal and informal learning forms in open digital educational courses, parents and specialists are simultaneously trained at a time convenient for them in the methods of applied analysis of learning and the methods of the emotional-semantic approach, which are used by specialists in an educational organisation when teaching children with ASD. This approach allows you to select common methods for teaching children, which increases the effectiveness of the formation of social and academic skills.

To ensure the effectiveness of educational activities, the method of Applied Behaviour Analysis is used, which allows reducing the level of behavioural disorders in children with ASD.

On the digital platform, there are online screening tests for detecting the first signs of autism, as well as access to an advanced training courses hosted on educational platforms.

## 4 Conclusions

The implementation of the system in the educational market will increase the speed of information retrieval, methods of working with children with ASD; quickly collect statistical data; visualise the results of work; improve the efficiency of socialisation of children with ASD; draw public attention to the problem of autistic disorders. An analysis of the educational market showed that there are competitors, there are many of them, but they are narrowly focussed, or they offer to buy printed versions of methods. Our project covers a wider range of users.

In the structure of Kazan Federal University, the first kindergarten for children with ASD was created, where this system will be used. Potential consumers are government agencies, heads of state and non-profit educational organisations, resource and rehabilitation centres, parents who are interested in improving the quality of educational services.

In 2023, it is planned to develop a mobile version of the online system in order to make the training of project participants more accessible.

The necessary specialists are included in the project participants. Competent and experienced employees supervise the various stages in the course of the project, which will effectively carry out the planned work plan. Each of the team members has its own strengths—IT technologies, pedagogy, and medicine. There is also an opportunity to attract highly qualified young professionals in various fields such as copyright and patent law, marketing and science.

The advantages of the digital platform are as follows.

Technical effect. The proposed project makes it possible to achieve a new technical result for each child with autism, create an electronic case with the results of his examinations carried out by specialists, clarify his diagnosis, draw up an individual development programme, starting from an early age and improve the quality of life as children as well as parents.

Educational effect. The created digital platform makes it possible to collect data not only within the framework of one technology but also to apply medical, psychological, and pedagogical methods for diagnosing and correcting disorders.

Scientific effect. It will increase the efficiency of the research process, due to a detailed and in-depth analysis of the information received and work with the necessary parameters.

Economic effect. Using the automatic reporting function based on artificial intelligence technology, specialists will be able to quickly implement collecting data through the report configurator. It will save up to 86% of working time.

Sustainability of results and impact will be ensured through the following measures:

- development of a mobile version of the digital platform, which will attract more professionals and families raising children with ASD, including those located in remote parts of the country;
- further development of digital educational courses and video library that includes video lectures by world-class researchers.

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# Application of Deep Convolutional Neural Networks MobileNetV2 and Xception for Detecting Cardiac Arrhythmia

**Tachanat Akarajaka, Komgrit Leksakul, Chichana Suedumrong, and Nivit Charoenchai**

**Abstract** Cardiac Arrhythmia has grouped into cardiovascular disease, and it occurs when the electrical signals that coordinate the heart's beats didn't work properly. Moreover, it can cause the body to have abnormalities ranging from mild to death. Cardiac Arrhythmia is among the leading death rate in the world. It can occur from several reasons such as sleep deprivation, eating fatty foods, and lack of exercise. From the structure of the heart system, it was found that there are 4 functional electrical pathways, e.g., SA node, AV node, bundle branches, and Purkinje fiber. These electrical signals can be read by EKG. In this experiment, 10,000 images of EKG from PhysioBank ATM were used and divided into 4 classes as abnormal SA + AV node, abnormal bundle branches, abnormal Purkinje fiber, and normal condition to train and compare the result of using two CNN models: transfer learning MobileNetV2 model and transfer learning Xception model. Then, these models were used to detect Cardiac Arrhythmia. As a result, the transfer learning MobileNetV2 model has an accuracy of 98.58%. Besides, the transfer learning Xception model coved an accuracy of 94.51%. It can be concluded that the transfer learning MobileNetV2 has higher accuracy than the transfer learning Xception at 4.34%.

**Keywords** Cardiac Arrhythmia · EKG · Deep learning · Convolutional neural network · Transfer learning · MobileNetV2 · Xception

## 1 Introduction

Cardiac Arrhythmia has several causes, such as lack of sleep, frequent intake of fatty foods, and not exercising [1]. Cardiovascular disease remains the leading cause of death in the world [2, 3]. At present, there are attempts to classify widespread disorders of Cardiac Arrhythmia [4, 5]. For example, the health of the blood vessels may further customize or categorize the classification of new risks [6]. In a classification of the risks, there are several important parameters such as data age, data size, data type,

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and data color [7] using data from cardiovascular system registrations based on electronic health records [8]. The classification of Cardiac Arrhythmia requires a variety of parts such as a malfunction of the SA node, the part of the heart that generates the electrocardiogram. AV node works with SA node to receive electrical waves and then send them forward. Bundle branches are the portions that transmit electrocardiogram pulses to the lower part of the heart. The lower part of the heart, also known as the Purkinje fiber, receives an electrocardiogram for sudden contraction caused by blood release to the rest of the body [2, 9–11]. The electrical voltage data obtained from the functioning of the Cardiac Arrhythmia inside the heart are displayed in a graph called an electrocardiograph (EKG) [12]. When the malfunction happened, it takes 24–72 h to find out what's wrong [13]. On the other hand, if we retrieve the EKG data from an electronic medical repository which can be found quickly and cheaply, the abnormality can be screened beforehand [14]. In this research, we demonstrate the classification of disorders of Cardiac Arrhythmia in the heart using a CNN. It has been used for many years for different types of classification, including the automatic classification of heart-related diseases [18]. A CNN is a collection of machine learning that composes multi-layer computational which has an algorithm that learns the appropriate predictive features based on a sample. Recently, CNN is a special type of deep learning technique that is optimized for image processing. It has been used to create high-precision algorithms for diagnosing diseases such as skin cancer [19] and diabetic retinopathy [20] from accurate medical imaging. The Xception model type was used by [21]. The model was developed for the classification of heart disease with a test accuracy of 90.7%, using a dataset of over 2 million images and separated into 1,000 classes [21]. The Xception model could classify images with high accuracy under an uncomplicated structure [22]. Besides, the transfer learning model, modified and used by Simonyan (2013) for cardiac classification, was developed with a test accuracy of 97.2%, using a dataset of over 20,000 images and split into 10 classes [23]. Moreover, the transfer learning Xception model was used by Ting [24] to predict cardiology from a dataset of 12,000 retinal fundus photographs and divided the prediction into 8 classes, compared to the VGG-16 model. The transfer learning Xception model was tested with an accuracy of 98.50% and the VGG-16 model with an accuracy of 78.95% [24]. Applying the transfer learning model to different models can improve both the accuracy and computational speed of the experiments [25]. In this research, CNN in transfer learning Xception and transfer learning MobileNetV2 for the classification of abnormalities in 4 types of Cardiac Arrhythmia and EKG data were used to classify the image from the PhysioBank ATM database.

## 2 Convolutional Neural Network

CNN is created to mimic the human brain works. Many researchers claimed that CNN is excellent in working for image recognition. This neural network is a multilayer perception neural network. CNN was introduced by Roy Chowdhury [26], which is the back-propagation method. It returns the error value to adjust the error

weight to an appropriate value. Later, Krizhevsky conducted an experiment with CNN by simulating human vision. The simulation of human vision began by looking at each subset and linking each subset together to provide a complete interest image [27]. After this capability of CNN was reported, CNN was initially popular, especially in pattern recognition. CNN was reported that it could operate faster and with higher accuracy than other methods. CNN has many features to use because it works based on weight adjustments to reduce faulty function methods and back-propagation approaches [30]. Convolutional filters using feature maps weights have been specified; the workflow starts by importing data to the input section and processing with filters in the convolution layer to adjust the loss. It sends the data to the activation function in the form of rectified linear unit (ReLU) for processing and then sends the data to the pooling layer for further processing, and the result will be sent to the layer fully connected processing is performed before the results are sent to the output layer and its structure. Convolutional neural network architecture is show in Fig. 1.

Kappa score is a statistical measure coefficient used to measure the consistency of the data between the two models used in the experiment, the transfer learning MobileNetV2 model, and the transfer learning Xception model. And the maximum display value is 1.0, which means that the 2 models used in the experiment were all consistent. And the lowest is 0.0, meaning that the 2 models used in the experiment are not consistent at all. And the calculations in this section will be in Eqs. (1)–(5).

$$E = 1 - \frac{\Sigma_{ij} W_{ij} O_{ij}}{\Sigma_{ij} W_{ij} E_{ij}} \tag{1}$$

$$W_{i,j} = \frac{(i-j)^2}{(N-1)^2} \tag{2}$$

$$E_{ij} = n \times P\left(Y = i \text{ and } \hat{Y} = j\right) n \times P(Y = i) \times P\left(\hat{Y} = j\right) = n \times \frac{r_i}{n} \times \frac{c_j}{n} \tag{3}$$

$$r_i = \Sigma_{i=i} O_{ij} \tag{4}$$

$$c_i = \Sigma_{j=j} O_{ij} \tag{5}$$

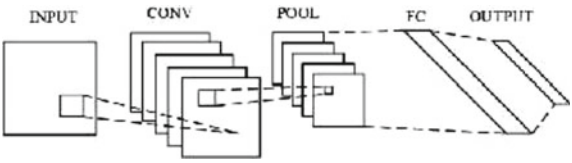


**Fig. 1** Architecture of convolutional neural network

## 3 Data Training

An EKG, or Electrocardiogram, is an electrical pulse generated by the heart to pump the blood supply to nourish the body. An EKG that we are interested in is divided into four parts. These are the SA node, AV node, bundle branches, and Purkinje fiber. And then, the system working is SA node, and AV node serves to create an electrocardiogram together and transmit the electrocardiogram to the bundle branches to distribute the electricity to Purkinje fiber to make a sudden contraction to pump the blood supply to the body. The data used are an image format with a size of 128 × 128 pixels taken from PhysioBank ATM. Training has to divide into 4 classes, i.e., abnormal SA + AV node, abnormal bundle branches, abnormal Purkinje fiber, and normal conditions as follows.

1. Abnormal SA + AV node is anomalies detected at the point of origin of the electrocardiogram, as in Fig. 2.
2. Abnormal bundle branches are anomalies detected that occur in the center of the heart and are the part that sends the electrocardiogram to the lower part of the heart as in Fig. 3.
3. Purkinje fiber is anomalies detected in the lower heart that contracts suddenly and supplies blood throughout the body as in Fig. 4.
4. Normal condition as in Fig. 5.

In case of an abnormality occurs at any point in the blood pump system, it may cause ischemic heart disease and may cause symptoms such as chest tightness, vomiting, palpitations, and blackouts. For the EKG, we divide it into 3 parts. The first part is SA + AV node which is the first part of the wave. Anomalies that can be observed from the first wave are lower than the normal condition. The second is the bundle branches; it is the inheritance of the SA + AV node, and anomalies can be observed at the end of the SA + AV node upper than the normal conditions. The last part, Purkinje fiber, is a part, and an abnormality can be observed if the point is higher than normal condition it is abnormal.

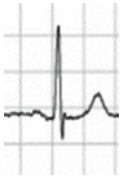

**Fig. 2** Shows an example of a pattern of abnormal SA + AV node

**Fig. 3** Shows an example of a pattern of abnormal bundle branches

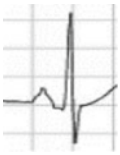

**Fig. 4** Shows an example of a pattern of abnormal Purkinje fiber

**Fig. 5** Shows an example of a pattern of a normal condition

## 4 Method

The method for this experiment is as follows.

1. Collect 4 types of electrocardiogram (EKG) samples from PhysioBank ATM, namely abnormal SA + AV node, abnormal bundle branches, abnormal Purkinje fiber, and normal condition by classification, each of 2500 images, a totally of 10,000 images.
2. Filtering of damaged images and eliminating samples as in Fig. 6.
3. Adapt the image data to 128 * 128 pixels and reduce unwanted data by adjusting it to black and white.
4. Design and develop both CNN architectures; transfer learning Xception and MobileNetV2 model by pulling out the fully connected layer instead of the dense layer for training data. The information on CNN architectures is in (Table 1).
5. The experimental data have used a dataset from PhysioBank ATM, with 10,000 images and is divided into 4 types of abnormal SA + AV node, abnormal bundle branches, abnormal Purkinje fiber, and normal condition, then, divided into 70% for training and 30% for test set.
6. Filtering the number of images to prevent overfitting and to cut off the images that are unusable. The final image is 9500 which is classified, and the ratio of the training set and validation set is shown in Fig. 7.

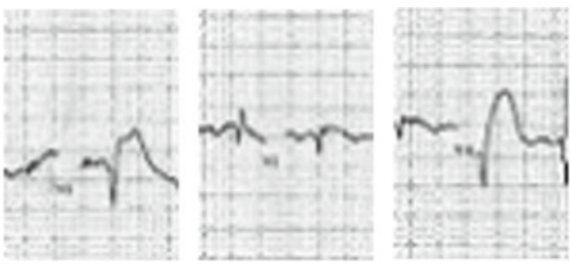

**Fig. 6** Filtering the damaged image

**Table 1** Information of the transfer learning MobileNetV2 and Xception models

| Layer | Dimension (pixel) | Layer | Dimension (pixel) |
|---|---|---|---|
| Input (1) | 3 × 128 × 128 | Dropout 6 (4) | 400 |
| Model (2) | MobileNetV2, Xception | Dense 2 (5) | 200 |
| Dense 1 (3) | 400 | Output (6) | 4 |

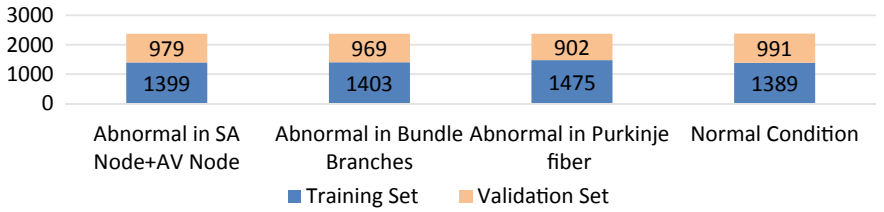


**Fig. 7** Number of training sets and the validation set

To build and train a transfer learning model for Cardiac Arrhythmia detection, that used Keras and Tensorflow are backend library tools. Training procedures are as follows:

1. Input training data 100 rounds of 9507 images from the training set.
2. Evaluating loss value of each round using images from validation set.
3. Using test set results, to compare 2 models with Kappa score.

## 5 Transfer Learning MobileNetV2 and Xception Models

Transfer learning MobileNetV2 is a simple structure and relatively small size. It supports mobile processing and a few parameters to calculate. Making processing faster. Learning transfer Xception has a simple structure. And this experiment uses depthwise separable convolutions, which are layer-by-layer computations up to the final layer. An overview of the two structures is shown in Fig. 8.

From Fig. 8, structure overview of transfer learning MobileNetV2 and Xception. The two models have different parts, which are the central part of the structure, and that part is the part used for processing to find the results. In processing, the cross-entropy loss is adjusting transfer learning MobileNetV2 to use ReLU in activation function and transfer learning Xception use sigmoid in activation function and set learning rate = 0.01 same as two models. Then, the result is transfer learning MobileNetV2. Gave a cross-entropy loss at 0.2461, and transfer learning Xception gave a cross-entropy loss at 0.2867. When we compared the cross-entropy of two models, we found transfer learning MobileNetV2 gave the lowest cross-entropy loss.

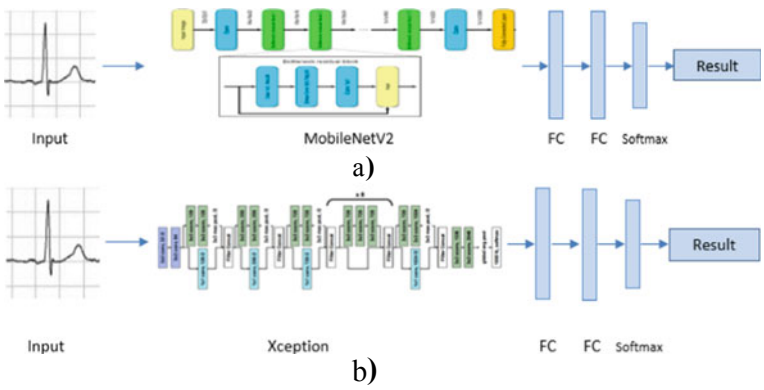


**Fig. 8** Structure overview of the transfer learning MobileNetV2 (**a**). And Xception (**b**). Models

**Table 2** Comparison of the severity classification results of two models

| Model | % Accuracy | Kappa score | Cross-entropy loss |
|---|---|---|---|
| MobileNetV2 | 98.58 | 0.2791 | 0.2461 |
| Xception | 94.51 | 0.2695 | 0.2867 |

## 6 Results

Results of the experiment, transfer learning MobileNetV2 model used ReLU in the activation function and set the learning rate as 0.01, the percentage of accuracy, the kappa score, and the cross-entropy loss for transfer learning MobileNetV2 is 98.58%, 0.2791, and 0.2461, respectively. Later, the transfer learning Xception model used sigmoid in the activation function and set the learning rate as 0.01, the percentage of accuracy, the kappa score, and cross-entropy loss for transfer learning Xception is 94.51%, 0.2695, and 0.2867, respectively. The comparison of the result of the classification of Cardiac Arrhythmia by transfer learning MobileNetV2 and Xception models is in (Table 2).

## 7 Discussion

Based on the results of the two models, the results of transfer learning MobileNetV2 provided 98.58% accuracy and transfer learning Xception with 94.51% accuracy. It was found that the difference between transfer learning MobileNetV2, and transfer learning Xception was 4.07%. Therefore, the transfer learning MobileNetV2 model should be more suitable in the development of the applications for detecting Cardiac Arrhythmia. The current EKG of the patient can be scanned and put into the app; then,

it would be rapidly analyzed. Consequently, preliminary diagnosis, patient warning, or abnormal detection can be sounded more rapidly than the present.

## 8 Conclusion

In this research, two CNN models to classify the type of Cardiac Arrhythmia, the transfer learning MobileNetV2, and the transfer learning Xception model were studied. Images of the EKG dataset from PhysioBank ATM according to 4 types of data are abnormal SA + AV node, abnormal bundle branches, abnormal Purkinje fiber, and normal conditions were trained by both CNN models, transfer learning MobileNetV2 model, and Xception model. Based on the experimental results, the transfer learning MobileNetV2 model achieved higher accuracy than the transfer learning Xception model, along with, a better Kappa score, and a better cross-entropy loss. Moreover, the model of this research may be extended to other medical applications even for the classification of disorders occurring in different parts of the body. In this research, we found getting a better result from the transfer learning MobileNetV2 model. The model can be used in medicine and save time and money on the diagnosis. On the other hand, it may be expensive to develop, and it may be difficult to understand for older medics.

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# Showing the Impact of Data Augmentation on Model's Decisions Using Integrated Gradients

**Ingrid Hrga and Marina Ivašić-Kos**

**Abstract** Deep neural network-based systems are increasingly performing tasks that can significantly impact various aspects of human life, such as medical diagnosis or financial risk assessment. Therefore, it is important to understand their decision-making process in order to determine whether those decisions may have been biased. Among the many factors that can influence a model's decision is that of a data augmentation strategy. In this paper, we analyze how various augmentation techniques affect the image area that the model takes into account when classifying images. We use Integrated Gradients as a method to calculate the attribution of model's output to its input features. Integrated Gradients results are clustered to determine the strategies the model uses to decide on the label, and to uncover possible changes in decision-making strategy due to the application of a particular augmentation. The results show that even when the accuracy is fairly uniform among the models, there may be a significant difference between the areas of the image to which they give more importance, as a consequence of the applied augmentation.

**Keywords** XAI · Integrated gradients · Data augmentation

## 1 Introduction

With the continuous improvement of deep neural models, their application in various real-world systems is becoming even more frequent. Such systems can increasingly be found in critical domains on tasks that significantly impact various aspects of human life, such as medical diagnosis or financial risk assessment [1]. For models usually considered as black-boxes, scientists have sought to find ways to understand their decision-making process better.

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Despite exhibiting very good performance on a number of tasks [2], one major drawback of deep models is the lack of transparency and interpretability, especially since the performance on standard metrics alone cannot compensate the insufficient understanding of deep models. Difficulties with deep models arise from their architectural sophistication, with processing units arranged in a very large number of layers. As a result, it is very difficult to associate a particular aspect of an input with the resulting output, which could be crucial in determining whether or not such decisions may have been biased [3].

In recent years, researchers have intensified their efforts to develop various methods and approaches that collectively fall into a special subfield of machine learning called Explainable AI (XAI). The goal of XAI is to provide a theoretical basis and tools in order to make the whole process of building a model, learning representations and of decision-making transparent and understandable to humans, especially to the end-users [3]. There are already numerous papers proposing methods to explain the decision-making process of a model [4–6], and finding the right way to evaluate those methods [7]. However, much less emphasis is put on analyzing how the decisions at different stages of the machine learning process, especially choices prior to training, affect the model's attributions. For example, one such decision is related to the choice of a data augmentation strategy.

Data augmentation has become an often indispensable approach to increase a dataset in order to improve the generalization ability of a network. The authors in [8] investigated the differences in classification results from various image augmentation techniques applied when training convolutional neural networks (ConvNets). However, better results on a standard metric do not necessarily mean that the model takes into account the right parts of the image [9].

In this paper, we continue the work of [8] and take a step further by analyzing how the augmentation techniques applied to training images affect where the network "looks" when making a classification decision. We first investigate the generalization capability of networks trained on augmented images. Then, we use Integrated Gradients to calculate the attribution of the model's output to its input features. Finally, Integrated Gradients results are clustered to determine the strategies the model uses to decide on the label, and uncover the possible decision-making strategy changes due to the application of a particular augmentation technique.

The paper is structured as follows: after the introductory part, in the second section we outline some of the most commonly used methods for explaining ConvNets. In parallel, we provide an overview of the related work. The third section presents the methods employed in our research and the experimental setup. The results of network generalization, attribution, and clustering are presented in the fourth section. In the last, fifth section, we conclude and propose guidelines for future work.

## 2 Background and Related Work

Of the large number of methods that can be categorized under the XAI umbrella (a more detailed presentation can be found in [3]), the most popular choices for explaining ConvNets are the so-called post-hoc methods. Post-hoc methods are applied to an already trained model to discover the relationships that the model has learned between the input features and the output [3]. Among them, the attribution methods are particularly aimed at discovering the contribution of an individual input's features to the model's decisions. Simple attribution methods involve perturbing the values of input features and measuring the resulting change in the output. Although such methods are easy to implement, they can be computationally inefficient [4]. More sophisticated are gradient-based methods. Simonyan et al. [10] were the first to propose a class saliency map to visualize model's attributions. They used the gradient of the output with respect to the input image, with a larger gradient magnitude representing a more relevant feature. A disadvantage of the approach is that it produces noisy saliency maps. In contrast, Guided Backpropagation [11] and Deconvolution [12] propagate through the layers only non-negative gradients. Nonetheless, they still fail to avoid the problem of saturation, which could lead to zero gradients even if there's a change in the input [4].

To eliminate such shortcomings, one group of authors suggested that the explanations of the model on a particular input should be based on a comparison with a baseline. DeepLIFT (Deep Learning Important FeaTures) [4] addresses the saturation problem by calculating the contribution scores of each neuron in terms of a "difference-from-reference" activation, where a reference represents some neutral input, chosen for a particular problem and by taking into account specific domain knowledge. Layer-Wise Relevance Propagation (LRP) [5] decomposes the output of a layered feed-forward model into a sum of feature relevance scores, quantifying the contribution of every input to the final prediction. The total relevance is propagated backwards through the layers starting from the network's output. All the relevance received in a layer is redistributed to the neurons in subsequent layers so that the global conservation property holds.

However, the authors in [6] found that most attribution methods violate at least one of the two key desirable criteria: sensitivity and implementation invariance. For instance, gradients don't satisfy the sensitivity axiom, while DeepLIFT and LRP do not satisfy the implementation invariance axiom. So instead, the authors proposed Integrated Gradients as an attribution method to overcome such shortcomings. Integrated Gradients explain the model's decisions on a specific input by computing and aggregating the gradients along a straight path from an input to the baseline, which should be an informationless input (e.g., a fully black image). Another benefit is that the method provides more fine-grained explanations that do not favor positive scores like some other attribution methods [3].

Our work additionally relies on the results of the following papers. In [13] the authors analyze images of human faces by considering the choices made during different stages of the ML process, such as the choice of model's architecture,

initialization technique or image preprocessing. Additionally, the authors use LRP to generate the model's explanations. In [9] the authors cluster the LRP explanations to uncover different strategies that the model uses when making a decision. Finally, in [14] the authors propose using the model's robustness to augmentation as a generalization metric. In contrast, our work focuses on comparing different augmentation techniques and their effects on the model's explanations obtained with Integrated Gradients.

## 3 Methods and Experimental Setup

### *3.1 Dataset, Classification Models and Augmentation Techniques*

To be consistent with the previous research, we use the same dataset, augmentations and classification models as in [8]. The models are based on a pre-trained MobileNet v3 [15] and fine-tuned (from now on referred to as FT) on the CelebA [16] dataset or used as feature extractors (FE) for two different binary classification tasks. For the first, easier task, the attribute "Mouth Slightly Open" (MSO) was chosen as a target to represent an objective one because it has a clear representation in the image. The attribute "Attractive" (ATT) was chosen for the second task because attractiveness is highly subjective, making the task much more challenging. The models were trained on subsets of 1 K, 10 K and 50 K training images, with five different augmentation techniques (simple affine transformations (AFs), more aggressive affine transformations (AF), information dropping (CUT), Mixup [17] (MIX), RandAugment [18] (RND)) and without augmentations (NOAUG), shown in Fig. 1. Among the 19,962 test images, we randomly selected 1000 to use in our further experiments.

### *3.2 Classification and Generalization*

As proposed in [14], in order to assess the generalization capability of models trained using a particular augmentation technique, we subjected them to testing

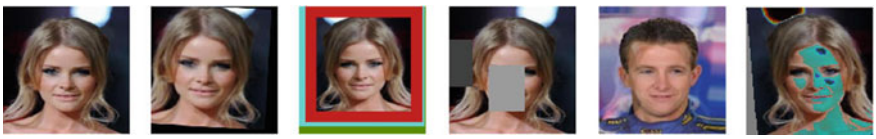

**Fig. 1** Augmentations used in experiments [8]. From left to right: no augmentation, simple affine transformations, more aggressive affine transformations, information dropping, Mixup [17], RandAugment [18]

on augmented test images so that each model was tested using each augmentation technique.

### 3.3 Generating Explanations with Integrated Gradients

We generated explanations in the form of Integrated Gradients, which can be calculated according to the following equation [6]:

$$IG_i(x) = \left(x_i - x_i^{'}\right) \times \int_{\alpha=0}^{1} \frac{\partial F\left(x' + \alpha \times \left(x - x'\right)\right)}{\partial x_i} \, \mathrm{d}\alpha \tag{1}$$

where $x$ represents an input, $x'$ a baseline, $\partial F(x)/\partial x_i$ is the gradient of $F(x)$, $i$ is the dimension, and $\alpha$ is the scaling coefficient. Computing the integral of Integrated Gradients can be approximated [6] as in:

$$IG_i(x) \approx \left(x_i - x_i^{'}\right) \times \sum_{k=1}^{\mathrm{m}} \frac{\partial F\left(x' + \frac{k}{m} \times \left(x - x'\right)\right)}{\partial x_i} \times \frac{1}{m} \tag{2}$$

where $m$ represents the number of approximation steps. For the Gauss–Legendre integration method we used 50 steps. As a baseline, we chose a black image, obtained by multiplying the input with 0. In our experiments we used the Captum library [19] for PyTorch [20].

### 3.4 Clustering Explanations

For each combination of the target attribute, training method, dataset size and augmentation technique we clustered images showing the explanations obtained by Integrated Gradients. The aim was to determine the differences in importance that was assigned to image pixels, which could result from the applied augmentation technique. As a clustering algorithm we used k-means, for which we empirically selected 8 clusters.

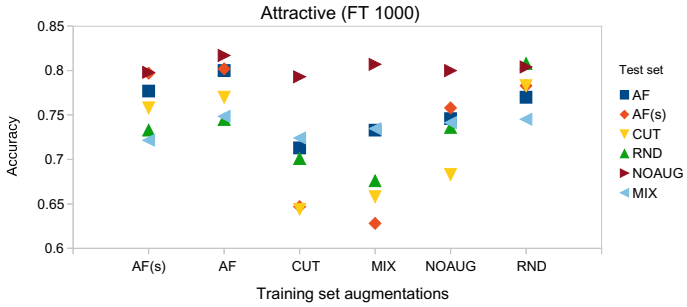


**Fig. 2** Comparison of accuracy scores for models trained and tested on augmented images or images without any augmentation applied. The figure shows models with "Attractive" as the target attribute and fine-tuned on a subset of 1 K images

# 4 Results

## *4.1 Generalization*

Figure 2 shows part of the results for which the greatest differences in accuracy were observed. Almost all models achieved better results when tested on non-augmented than on augmented images. Only models trained with AF(s) or AF augmentations, which are quite similar, showed slightly better results when tested on AF(s) augmented images. In general, larger differences can be observed between fine-tuned models trained on the smallest set, especially when using MIX or without any augmentation. As the number of training examples increases, the results become more uniform. On average, models with MSO as a target attribute and augmented with CUT showed the most consistent results on all tested augmentations. At the same time, the largest difference was recorded for NOAUG models.

Similar behavior was observed in the case of ATT as a target attribute, where on average, the smallest differences were observed for models trained with RND augmentation. Overall, test images augmented with MIX proved the most challenging, even for models trained with this type of augmentation.

## *4.2 Explanations and Clustering*

Figure 3 shows an example of explanations produced with Integrated Gradients. There is a noticeable difference in attributions depending on the applied method of image augmentation during training. The differences are not only in the strength but also in the image areas that the model takes into account. For example, some models put more emphasis on the face, while others put more emphasis on the background. The AF(s) model shows the greatest indecision in assigning importance to particular

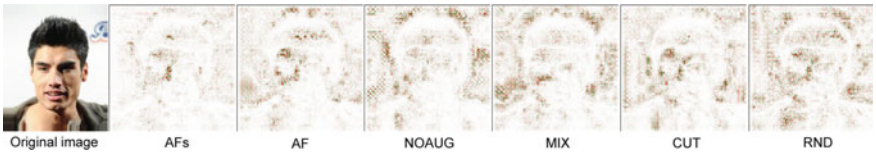


**Fig. 3** Original image and explanations produced with Integrated Gradients for the attribute "Attractive" and with fine-tuning on a training dataset size of 1 K images

image areas. Models with AF(s) augmented images generally achieved the worst classification results.

Figure 4 shows cluster centers for MSO with fine-tuning and 10 K training samples. For this combination, the classification results are fairly uniform with respect to augmentations applied to training images. However, it can be seen that differences exist concerning which aspects of inputs were most relevant when making a prediction. In the case of NOAUG the focus is mainly on the whole face with considerable importance given to the background, while in the case of AF the model is more focused (in as many as 5 of 8 clusters) on the lower part of the face where the mouth is located, and with significantly less reliance on the background. This difference cannot be observed from the classification results alone.

In contrast, the classification results for models with ATT as a target and fine-tuned on 1 K examples indicate clear differences between the individual augmentation techniques. However, if looking at the attributions, this difference is not obvious. The focus is mainly on the cheeks, forehead, nose and lower part of the chin, with different levels of attention focused on the background. Since it is more difficult to estimate which part of the image should be given more importance with the ATT attribute, we calculated the Jaccard index between the ATT and the remaining attributes in the dataset. It turned out that the mentioned parts can be related to those in the top 10 by similarity to ATT, as shown in Table 1.

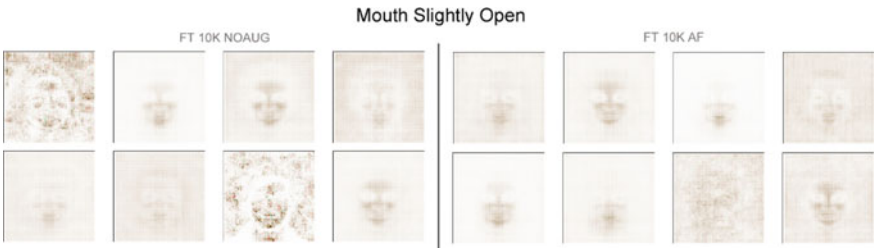


**Fig. 4** Cluster centers for models with "Mouth Slightly Open" as target and fine-tuned on 10 K training samples. Left: with no augmentation applied to training images. Right: with AF augmentation applied

**Table 1** Jaccard index for the 10 attributes that have the largest overlap with Attractive

| Attribute | Jaccard index | Attribute | Jaccard index |
|---|---|---|---|
| Young | 0.5920 | HighCheekbones | 0.3869 |
| WearingLipstick | 0.5831 | WavyHair | 0.3467 |
| HeavyMakeup | 0.5388 | MouthSlightlyOpen | 0.3417 |
| NoBeard | 0.5282 | ArchedEyebrows | 0.3291 |
| Smiling | 0.3991 | PointyNose | 0.3213 |

## 5 Conclusion

In this paper, we analyzed the influence of selected image augmentations on model explanations. We first investigated the generalization ability of individual models by testing them on augmented images. The results showed that more complex augmentation techniques (such as RandAugment) applied to training images yielded more robust models. We then generated model explanations using Integrated Gradients and clustered them to uncover various attribution strategies that the models used to classify images. The results showed that even when accuracy is fairly uniform among models, there can be a significant difference in which parts of the image were key to a particular decision. Such a difference may be due to the chosen augmentation technique. We intend to expand this research to object detection models and more complex images, showing more diverse scenes, in our future work.

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# Development of a Computer System for the Documentary Process in the Management Process at the Wissen LP Academy

**Luisa Paola Jorqueda Vasquez, Luciana Victoria Jurado, Jesus Lagos Morón, Mario Reynaldo Medina Ramos, and José Antonio Ogosi Auqui**

**Abstract** Academic management is based on being able to facilitate and improve the different processes in the institutions, in order to have a successful process, but many of these do not have an adequate documentary procedure that accompanies it at the time of carrying out the present processes, that is why with these antecedents a computer system was raised and developed that allows us to improve the management process in the documentary process to at the time of this being required, the system that was developed helped to improve this process thus reducing the established response time of each query that was had with the client. For the development of the computer system, the RUP methodology was used, in addition to the use of MySQL for data storage and Visual Basic for the realization of the system. On this, it was possible to observe the decrease in time in the response that was had with the client when looking for any type of procedure.

**Keywords** Computer system · Academic management · Documentary processing

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# 1 Introduction

The following scientific article deals with the implementation of a computer system for the documentary process in the management process at the Wissen LP academy in the district of Ica; due to ineffective documentation procedures in the research area [1].

The implemented system will improve the processing of documents through the computer system, reduce the time of search and attention, and increase the number of files managed by the lack of services it performs due to the accumulation of queues, complemented by its actions without any control [2].

To develop this system, it is necessary to face the problem of defining the requirements and characteristics that the proposed system must have, starting with the types of documents such as letters, requirements, memoranda, and files [3].

Know the función of the people who integrate this field by observing their activities to obtain better managerial information in the improvement of their management through the proposed system [4].

This system is implemented in order to improve its procedures in the public sector body due to the large number of users served, refer to concepts related to care and delay in registration, which are related to the image risk of the organization [5].

The advance of today's technology has changed dramatically, showing us how completely simplified document management improves workflow and thus allows entities to gain momentum for real change and improvement [6].

# 2 Definition of Terms

## *2.1 Computer System*

It is understood by an automated system of storage, processing, and retrieval of data, which takes advantage of the tools of computing and electronics to carry out its complex series of processes and operations [7].

## *2.2 Documentary Procedure*

It is defined as a set of processes that allow organizations to have control of the physical location and current and past status of the documentation that arrives and is generated within them, in order to better manage their flows and diligence [8].

### *2.3 Management*

Is to assume and carry out the responsibilities on a process, this can be business or personal, which includes: Concern for the disposition of the resources and structures necessary for it to have a role in trade [9].

### *2.4 Process*

It is a set of mutually related activities that when interacting together turn the input elements into results [10].

### *2.5 Academy*

The academy is a professional, artistic, technical, or practical teaching establishment [11].

### *2.6 Development*

It means growth, increase, reinforcement, progress, development, or evolution of something. Designates the action and effect of developing or developing [12].

## 3 Methodology

The software development methodology that will be used in this project will be rational unified process (RUP) since it gives us a different approach to being the one that helps us improve productivity as a group; it also ensures an effective development of the software within the time established for said project, in addition to the costs and is the one that can best be adapted to any project [13].

### *3.1 Prototype Development*

For the development of this document processing system, we are using PHP and JavaScript. This system will have multiple functions [14].

The first of these will be new procedure, where a form will appear in which we will add the different data of the document [15].

Then, it will give us a follow-up number for later, and in the section of consultation procedure, we can keep informed about our document [16].

There will also be a section to print a ticket, where you will provide us with the information, a QR code which will be attached to the tracking number. In the login section, we will have several users such as administrator, parts desk, and human resources. Each user will have exclusive functions corresponding to their work [17].

The administrator user will be provided with the total management of the system, in addition you will be able to observe the different drop-down menus that are users, areas, type of document, procedures, employees [18]. The parts table user will have the function of deriving, observing the follow-up, and finalizing the documents. Finally, the human resources user will have the task of accepting, deriving, or rejecting the procedure [19].

### *3.2 Mocking Bot*

It is a mobile app and/or program prototyping tool designed to help quickly prototype mobile or Web apps, and be able to share and discuss them with other team members in a timely manner [20].

As a tool focused on prototyping mobile or Web apps, in addition to cloud storage and real-time previews on your mobile device or system, Mocking Bot also offers a variety of gestures, page flip effects, and themes [21].

### *3.3 Architectural Design*

**PHP**: is a general-purpose programming language that is especially adapted to Web development. It was initially created by Danish–Canadian programmer Rasmus Lerdorf in 1994. Currently, the php reference implementation is produced by The PHP Group [22].

**XAMPP**: is a free software package, consisting mainly of the MySQL database management system, the Apache Web server and the interpreters for PHP and Perl scripting languages. The nombre is actually an acronym: X, Apache, MariaDB/MySQL, PHP, Perl [23].

**MySql**: is a relational database management system developed under dual license: General Public License/Commercial License by Oracle Corporation and is considered as the database [22].

**RUP**: The unified rational process or RUP is a software development process developed by the company rational software, currently owned by IBM model design [24].

**Fig. 1** Main interface

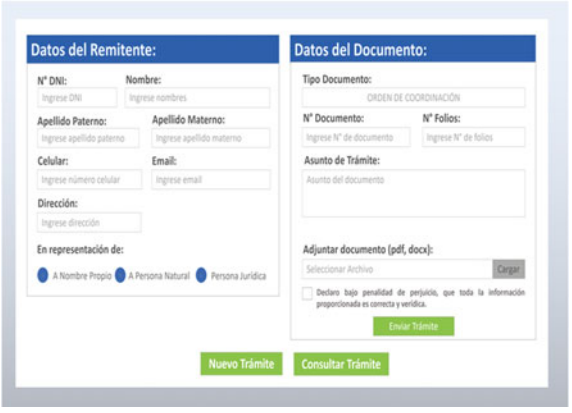


**Fig. 2** Enter the information of the document to be made

### *3.4 Prototypes*

See Figs. 1, 2, 3, 4, 5 and 6.

## 4 Results

After finishing the implementation of the system, it is of vital importance to be able to check the satisfaction of the client with respect to its implementation that is why in the company 59 responses were collected from the workers, and based on this, graphs were made to be able to complement the interpretation of the results obtained.

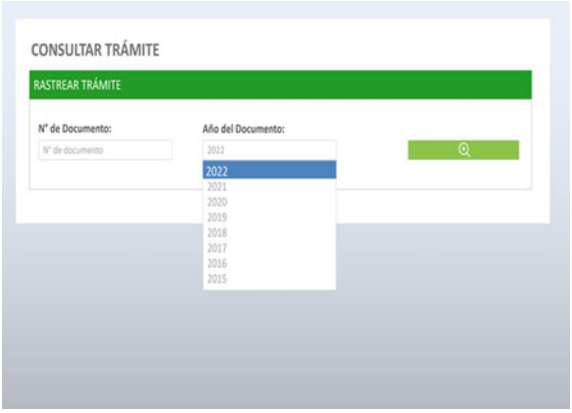


**Fig. 3** Follow-up of the procedure

**Fig. 4** Track procedure

Figure 7 shows that 90% of respondents are satisfied with the implementation of the system. On the other hand, in Fig. 8, it is shown that 98% agree that the system streamlines the processes requested by the company. And in turn, in Fig. 9, it indicates that 100% of employees agree that the system reduces the waiting time to the customer.

**Fig. 5** System startup

**Fig. 6** User maintenance

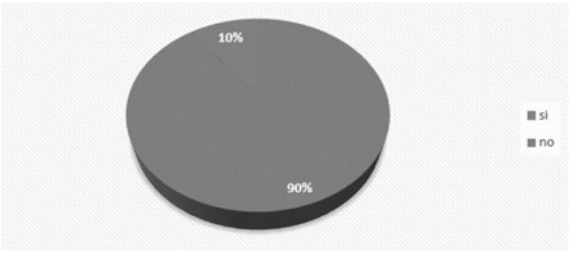


**Fig. 7** Are you satisfied with the implementation of the system?

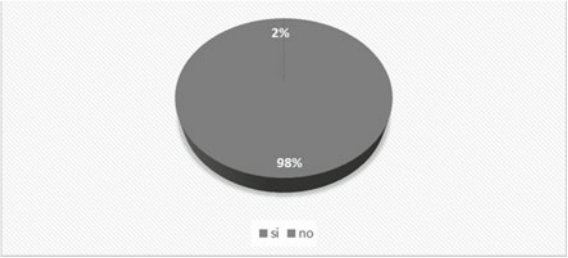


**Fig. 8** Does this system streamline the processes requested in the company?

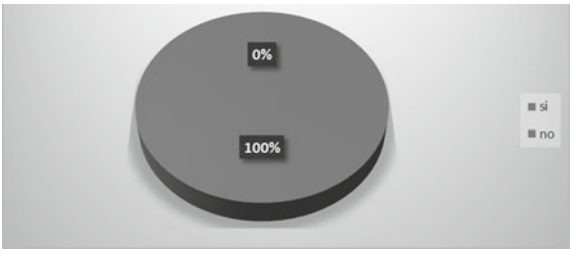


**Fig. 9** Does the system reduce waiting time for the customer?

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# Impact of Digital Marketing on Budamaki Company

**Victor Hugo Guadalupe Mori, José Antonio Ogosi Auqui, David Hugo Obando Pacheco, and Jorge Cano Chuqui**

**Abstract** Currently, companies have the obligation to acquire new technologies to automate their processes, activities and functions, so that they can guarantee an efficient service. In this article, we present a proposal to implement a web system to improve the digital marketing of the Budamaki Company, thus fulfilling one of its objectives such as developing high quality products and acceptance for its customers. So we opted for the development of a web page for greater interaction with your customers.

**Keywords** Marketing · Digital marketing · Web application

## 1 Introduction

The concept of digital marketing was first used in the 1990s, although at the time, it was primarily about advertising to customers. However, during the 2000s and 2010s, with the emergence of new social and mobile tools, the concept expanded and was transformed from a technique oriented to advertising for users, to a concept of creating an experience that interacts with them [1].

The digital revolution has changed the way consumers perceive business strategies. From the era of learning about the day's events in the morning newspaper to

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instant gratification with social media updates, people's perception has been shaped by a technology-based bubble, whose access is limited to a digital platform [2].

Digital marketing has become an essential tool to compete in the market. Since we are all unintentionally immersed in the digital age, its use is the most efficient tool to reach potential consumers [3].

Within the business world, marketing plays a fundamental role. As a philosophical principle of the business, it can be defined as a management process for the identification, anticipation and satisfaction of the needs of the client in a profitable way for the organization or company [4].

In this order, Uribe et al. [5] point out that the essential objective of marketing is none other than the optimization of the relationship between companies and customers and the maximization of their mutual satisfaction.

Based on these principles and depending on the needs of the consumer, organizations have adapted to changes and orientation models have evolved. Thus, in the mid-1980s, there was definitely a change in trends when there was a greater concern about competition and the way products were marketed. Subsequently, the model was chosen that concentrates a greater effort on analyzing the needs of customers to offer them the product that best suits them. In this new century, the leading organizations will be those that, in addition to satisfying the needs of the client, consider the environment as an integral part of the marketing process. Within the models: Artisanal, Production, Sales, Marketing and Social Marketing, the last of them is considered an orientation based on strategic planning and a greater long-term vision [6].

The main functions of the marketing activity [6], are: Research; Innovation and creation of new products and services; Determination of prices; Intermediation or distribution of tourism services; Communication; Internal marketing, and Planning.

In this research, we will be based on the study of the impact of digital marketing in the Budamaki Company, this company is not digitized, this leads to it not having a marketing process on social networks or any web site, thus being the only method of marketing its advertising brochures, because of this the Budamaki Company is not very crowded; therefore, it does not generate many sales.

The importance and impact of digital marketing that it has on companies is significantly exponential, since it indirectly manages to increase the sales of the company or organization in such a way that over time the management of the sales process is increasingly evolving. Likewise, the implementation of a web system or any technological tool is considerably remarkable, since it brings with it various benefits, according to Bricio et al. [7]. "In general terms, it is a tool capable of organizing, collecting accurate information and optimizing processes with practicality and agility within companies, organizations or enterprises," consequently, this makes web systems an essential and vital tool in companies to develop their processes in an efficient way. Based on this scenario, the country has been growing exponentially around the technological field, consequently, according to Andrade [8], "in a study focused on market statistics, 57% of online purchases made in Peru are through the company's web site, likewise Peru invoiced more than 2 billion US dollars in online

sales in 2019, and it had been expected that for by the end of 2021, Peruvians make 3 of their 6 purchases online."

According to [9], "companies seek to maximize their competitive advantages, this is caused by technological development and is complemented by the organizational effort that companies make to add value to their products or services" mentioning the previous quote, highlights the immediate need for the importance and impact of digital marketing that allows the Budamaki Company to align its priorities in terms of optimizing its processes, thereby improving its interaction with the customer through a digital tool which will achieve an effective sale and customer service. The implementation of this tool is fundamental, since it will allow to solve immediately and feasibly the management of sales, quality of service, purchase process, warehouse, etc.

## 2 Methodology

This section describes the process that was carried out in order to investigate the problem and select the technology that will be used to solve the issue raised, thus obtaining to identify the impact of digital marketing in the Budamaki Company.

### *2.1 Definition of Terms*

**Web System**: Web systems are hosted on a server on the Internet or on an Intranet (local network). Its appearance is very similar to web pages that we normally see, but in reality, web systems have very powerful functionalities that provide answers to particular cases. Web systems can be used in any web browser (Chrome, Firefox, Internet Explorer, etc.) regardless of the operating system.

**Web Page**: A web page is an electronic document or information adapted for the World Wide Web (WWW) that is usually part of a web site. Its main feature is the hyperlinks of a page, this being the foundation of the WWW.

**Database**: A database is a collection of related files that allows the management of the information of some company. Each of these files can be viewed as a collection of records and each record is composed of a collection of fields. Each of the fields in each record allows you to carry information about some attribute of a real-world entity.

**Python Programming Language**: It is an interpreted programming language, multiparadigm and multiplatform, used mainly in Big Data, Artificial Intelligence (AI), Data Science, testing frameworks and web development. This makes it a high-end general-purpose language, due to its extensive library, the collection of which offers a wide range of facilities.

**MySQL**: It is a database management system widely used today for the reason that it provides you with speed, possibility of working on different platforms, multiple table formats for every need, security, great stability and simple administration.

**SQL**: It is a standard language for accessing and manipulating databases, and it allows you to execute queries in a database, retrieve data from a database, insert records into a database, update records in a database and delete records from a database, among others.

**XAMPP**: It is an independent server based on free software, it is a completely free and easy to install Apache distribution that contains MariaDB, PHP and Perl. The XAMPP installation package has been designed to be incredibly easy to install and use.

**Visual Studio Code**: It is a powerful source code editor for Windows, Linux and macOS, developed by the Microsoft brand.

**Responsive Design**: Adaptive or responsive design is a method that allows you to modify the visualization of the web design for the different devices that exist. "Responsive web design is focused so that a web page can be viewed on any operating system and browser, for any screen size and connection speed, those are the three fundamental pillars of responsive web design."

**Framework**: It is a structure that contains different tools which allow the programmer that facility to create a software. This system is configurable and you can create applications according to your requirements in an easy and fast way, due to its components, it is used by many programmers.

**Cascade Style Sheets**: Cascading style sheets or CSS are style-handling formats that contribute to the design and accuracy when building a system in a web environment. HTML is quite limited when it comes to controlling the appearance or distributing the multimedia elements, so it is necessary to fill these gaps using patches with embedded languages such as cascading style sheets.

**Bootstrap**: It is a framework that contains several templates with embedded designs, in order to assign styles to buttons, menu tables among others (Garcia 2016). It is based on CS3 and Javascript, contains different design elements that facilitate web development making it more efficient and considerably agile.

## *2.2 System Architecture*

**Efficiency**. System response time.

**Safety**. Have a correct data warehouse. The information will only be viewed by authorized personnel.

**Reliability**. Where a product operates flawlessly.

**Maintainability**. Modified effectively and efficiently.

### *2.3 Technical Design*

At this point our design will be developed in the corresponding client-server relationship that is considered a distributed architecture because the server and the client are distributed in different computers.

### *2.4 Database Architecture*

The use of MySQL has benefit in terms of the development of a web page since being open source does not present any generating savings to the company on the other hand, it is considered high performance making high-speed transactions or a high-volume web site with service to one billion queries a day.

### *2.5 Prototype Development*

The elaboration of a prototype will allow to quickly define the sections that each of the pages of a site will have, so that the information can be hierarchized and the content blocks defined.

It is also considered as the navigable sketch, which will allow to create a visual reference of the structure of the web page, defining in detail the visual distribution content, thus organizing the information at the page level.

In the final phase, the navigable prototype of the entire web site will be made, where the entire navigation structure will be displayed, as well as the complete design.

## 3 Results

In relation to the use that the world population makes of technology, digital marketing has become an increasingly attractive alternative of commercialization, based on the use of technological resources and digital media for the development of strategies based on the establishment of direct communication with the client, in order to achieve the sale of products or services, the positioning of brands or loyalty to them [8].

Digital marketing is part of a commercial strategy that aims to increase the sales figures of a company, and according to this, some organizations decide to outsource all or some of the aspects involved in its development. Thus, there are organizations that decide to manage the entire process, from the management of their information and communication technologies (ICT) to the final contact with the client, through the use of human resources specialized in this type of tasks; while others decide

to outsource all stages, leaving the commercial responsibility of their companies in the hands of specialized suppliers [10]. In any case, decision-making must take into account all the responsibilities inherent with each style of work, knowing that the final objective results in an improvement in communication, interaction with customers and in the increase in sales figures of their products or services [11].

Likewise, the tools and techniques useful for digital marketing are very varied and their use will depend on the needs and resources available for investment by the interested company. The following stand out:

- Web page
- Online stores
- Search engine optimization (SEO)
- Search engine marketing (SEM)
- Content marketing
- Social media
- Email marketing

Based on the above, it is worth noting that digital marketing techniques and tools not only have to do with the publication of attractive content for potential customers, but also their usefulness depends on the ability of the organization to develop quantitative and qualitative analysis of the data associated with the consumption behavior of its customers, and in this way, to be able to create and carry out really effective commercial strategies for the sales interests of the company.

Entering the context at the national level, year after year, we have seen how the country has been growing at a technological level, this as a result of the influence thanks to digitalization in companies or small businesses, because of this, in a study carried out in 2021, indicates that more than 70% of Peruvians have access to the Internet, like-wise, most of these are focused on the capital (Lima).

Based on the above, the following graph shows the percentage of horgares with Internet access in all cities in Peru (Fig. 1).

### *3.1 Benefits of Using Digital Marketing in Companies*

The Internet represents an element of great advantage for Colombian companies, because it offers a window to the world that facilitates a better interaction with customers, as well as knowing characteristics, news and trends of the market in which it operates and by the same means make itself known with the investment of less resources of time and capital [12]. In this way, the Internet allows SMEs to position themselves in the market on a par with large companies, offering their products and services in a more effective way and facilitating their access to markets that were once inaccessible (Cepeda Palacio et al. 2017).

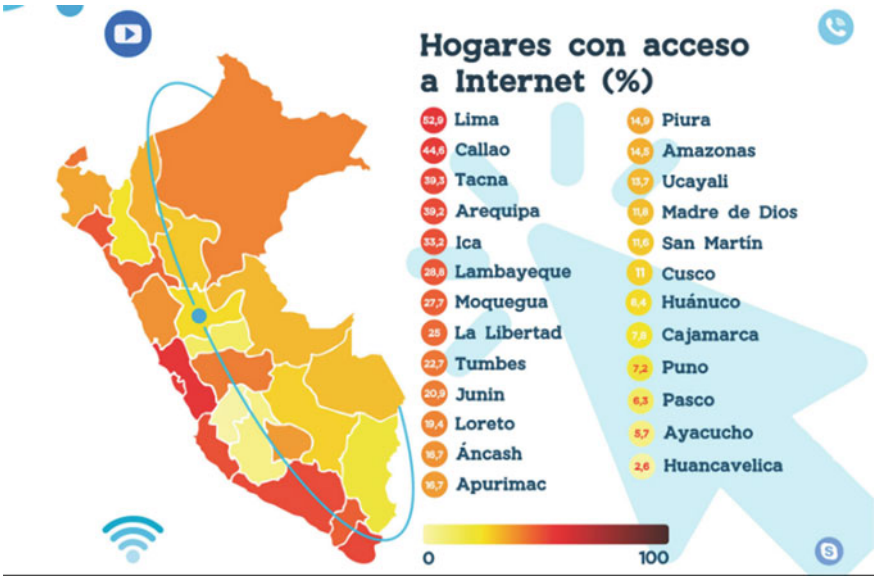


**Fig. 1** Map of the cities of Peru in homes with internet access

### *3.2 Commercial Processes*

Hand in hand with the above, the commercial processes developed with the support of the Internet achieve a greater sale of products and a better interaction with customers and suppliers, through the use of specialized tools for Customer Relationship Management (CRM), which in turn optimize commercial attention and offer greater accessibility and availability of information flows [13]. Additionally, another of the benefits obtained from the incorporation of digital marketing in commercial strategies is innovation, taking into consideration that its main input is the acquisition and generation of knowledge developed from various sources of information.

## 4 Conclusions

The implementation and development of a web application for the improvement of the digital marketing in the Budamaki Company will allow it to become a more recognized company which will generate greater income to the company.

That of a client/server system of web type will allow to adapt to updates of new versions of the developed system, on the other hand, the system offers portability toward the various brands of operating systems.

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# Industry 4.0: Implementation of Technologies in Medical Manufacturing Companies

**Victor Hugo Guadalupe Mori, José Antonio Ogosi Auqui, Jimmy Aurelio Rosales Huamani, and José Luis Arenas Ñiquin**

**Abstract** The term Tic's, in this context, refers to the information systems that infer in the data process, allowing its easy access and distribution, thanks to automation through databases and storing in trusted servers, this also refers to the media such as the use of digital marketing through social networks, advertising through advertisements on television or radio stations, for which it is widely used by companies that want to grow, allowing them to have a better image and better quality of their services In a business context, information systems generally serve the purposes of any other system, such as: data processing, entity data storage, reporting and other types of data summary tools. However, in the era of digital transformation, the use of information systems, especially those related to management, plays an important role in ensuring the technological integration of all operations. Service management gives the company access to the right knowledge to make quick and accurate decisions.

**Keywords** Easy access and distribution · Automation · Technological integration

## 1 Introduction

The concept of "Industry 4.0" appeared in Germany in early 2010, coined by a multidisciplinary group of specialists convened by the German government to design a program to improve the productivity of the manufacturing industry; The term was

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first introduced at the Hannover Messe in 2011 and quickly gained popularity. Josefa et al. [1] that means that machines work independently or in conjunction with humans to produce customer-centric manufacturing that works to keep up at all times. Rather, the machine is an independent instance that can collect, analyze and advise on data. This is made possible by the introduction of self-optimization, self-awareness and self-adaptation in the industry, which allows manufacturers to communicate with computers, not just operate machines [2]. The industrial sector is considered an engine of innovation, growth and social stability; however, competition is becoming increasingly intense. Customers demand high quality, customized products with shorter production time. So, only those companies that manage to achieve customized products and reduce production time, through maximum efficiency in their plants, will be able to remain competitive [3]. Similarly, the manufacturing industry is facing major challenges today, such as, globalization, competition increasingly.

The fourth industrial revolution is the digitalization phase of the manufacturing sector, driven by increased data, computing power and connectivity. While many of today's converging technologies already existed, albeit in their infancy and lacking the robustness they provide today, the difference with the past is how they come together to create significant breakthroughs [4].

It was established with a concept that emphasizes some basic design principles of Industry 4.0. These principles are as follows: Efficiency and productivity, integration, flexibility and adaptability, decentralization, personalization, virtualization, safety and security, it's global, ubiquitous, collaboration, modular, operational robust and reliable, real-time information The leading decision-making that needs to be processed and optimized and created is service-oriented, balancing the work and personal life of the worker, motivating his continuous professional development, and finally. Be autonomous and intelligent [5].

## 2 Definition of Terms

TiC: All of these are technological tools and solutions that allow you to organize and efficiently process information and communication of any type of person, company or organization in an efficient and agile way.

Industry 4.0: Combining advanced manufacturing and operational technologies with intelligent technologies, we promise a new revolution in integrating organizations, people and property.

Manufacturing: It is a work organization system that focuses on improving the production system. It is based on eliminating activities that do not add value to the process or to the customer [6].

## 3 Methodology

At present, the demand for services through ICTs (Information and Communication Technologies) is greater, which is why companies choose to introduce these services in their logistics, allowing them to streamline processes effectively with a minimum margin of error, thus have more autonomy to manage its operations, interact with suppliers and customers, and compete in the market with others who have not yet done so, thus allowing the increase of production or clients, for which the scope of these services can be expanded [7].

### *3.1 Research Objective*

The healthcare industry is currently dominant in many European countries, but it is also dominant around the world. Manufacturing in Slovakia and the Czech Republic in particular contributes significantly to the state's GDP [8]. The technology of the Fourth Industrial Revolution has given this segment an unprecedented dimension and is taking a leap forward. These two countries have the highest per capita production [9]. In our research, we decided to evaluate the fitness and progress of companies in the implementation of technology and automation elements of the Fourth Industrial Revolution. Studies with a similar approach at this level have not yet been documented, so we believe this study will be useful for what we apply to the healthcare industry [10]. The goal of our work is to identify the level of technology usage within Industry 4.0, focusing on automation support in samples from Slovak and Czech companies in the healthcare sector. The survey also used questions about implementing automation, providing IT services, network failures, or industry 4.0 support technologies [11].

Based on our personal experience and observations in the field of automobiles, we have made two hypotheses based on theoretical knowledge, technical and current articles on this subject. For ease of validation, the results show the average utilization of individual automation elements in classes of various enterprise sizes. The sample was divided by company size in terms of employee numbers (micro/small, medium, large). The various question items were qualified on a scale of 1: not done yet, 2: simple implementation, 3: medium implementation, 4: high/high implementation [12].

**Assumption 1** Bots and software devices are the most popular elements of automated production in the health industry.

**Assumption 2** Large manufacturers implement automation elements at a higher level than SMEs.

### 3.2 Sample and Methods

The quantitative–qualitative documentary methodology will be used, for which information from different sources will be recorded, to later analyze and write them up in this work [13].

To understand in more detail the method we are going to take (Baena 1985) observes a technique consisting of selecting and collecting information by reading and critically reviewing documents, opinions and bibliographic data from libraries, press library, resource and information center [14].

Therefore, the literature referred to above has been obtained from information media and analyzed for the collection of data and its introduction in the present work, thus fulfilling the purpose of being able to support the research, which has a relationship with the qualitative variable research [15].

For the veracity of the information collected, a series of surveys to companies that have TiC's tools are carried out by means of a form, in order to later analyze the results and write them up, with the purpose of informing the readers about how TiC's changed the work processes [16].

For which the technological tool Google Forms will be used, which allows to make dynamic surveys, of easy understanding to be able to distribute in a free way to the candidates who will fill it [17].

### 3.3 Research Sample and Data Collection

To collect data, we conduct a survey using a secret quiz that allows companies to freely express themselves. The quiz is designed to help detect a more comprehensive picture of the Peruvian medical device regional manufacturing industry of Lima, while preserving the know-how aspects of these companies. For data collection, we chose to use an electronic questionnaire. To formulate the questions, we used theoretical evaluation of the study. We looked at companies in the medical device manufacturing sector operating in Surco, with a focus on manufacturing. For research purposes, we have divided them into three groups: small, medium and large companies. The questionnaire was sent to about 5 selected companies operating in Lima. We have chosen companies like Ajaime Rojas. The survey was addressed to operational managers or technical director. A total of 18 participants completed the test correctly [18].

For the purposes of the study, the companies were grouped by size, age and core business life cycle. Results of the distribution of samples are shown in Table 1. Most of the respondents were representatives of large enterprises (1), three micro and small enterprises. Most of the companies surveyed have been on the market for over 15 years and are currently in the growth stage of their life cycle. These companies believe that they are well suited to apply the concept of Industry 4.0. A comprehensive analysis of the market and external and internal conditions, Supplier

**Table 1** Table of survey of the 5 companies of medical technology

| Variable | Category | Quantity |
|---|---|---|
| Size | Micro/Litte | 1 |
| | Medium | 3 |
| | Big | 1 |
| | Total | 5 |
| Year | Lower than 5 years | 2 |
| | 5–15 | 2 |
| | Upper than 5 years | 1 |
| | Total | 5 |
| Life of cycle | Establishment | 2 |
| | Growth phase | 1 |
| | Stabilization | 2 |
| | Critical phase | 0 |

network and technical staff, and independent research are basic requirements for success in conditions [19].

## 4 Results and Discussion

### *4.1 The Level of Automation Implementation*

We used the next chart, 1—no automated production introduced, 2—significant utilization level, 3—medium utilization level, 4—higher automation level.

Figure 1 shows that only 13% of organizations reported the least or no use of automation assets. About the same number of companies (33% and 42%) showed primary or intermediate level implementations, and 12% chose advanced degree responses.

As expected, the adoption of autonomous technology was the normal reaction of micro or SMEs during the stabilization phase that had been on the market for 5–15 years [20].

By industry category, highest/advanced level of use of automation was reported by the organization that manufactures medical devices.

### *4.2 Advantages of Industry 4.0*

We have identified the following benefits: increased production efficiency and cost reduction, digitize paper documents, eliminate errors and problems, improved

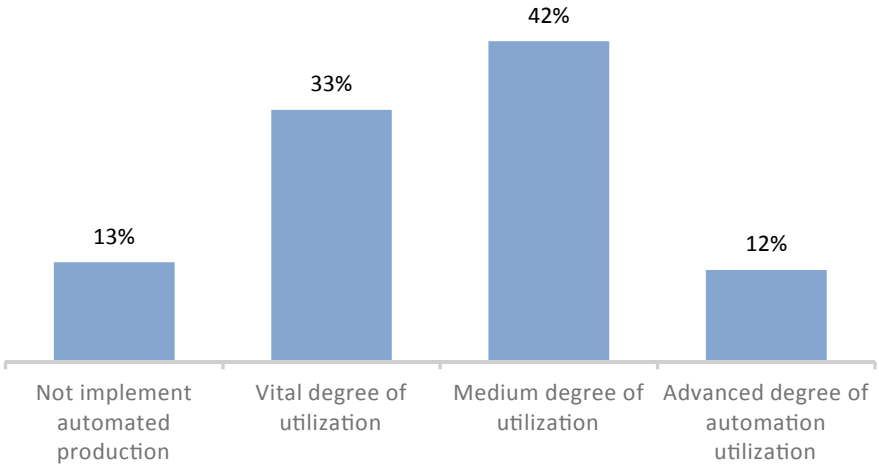


**Fig. 1** The degree of implementation of automation elements

product quality, simplified manufacturing processes, tracking tool predicts downtime and overviews the current state of production and, ultimately, increased stability and defense at work [21].

In the picture 2, we see accumulated results for all business surveyed. The attributes that were most appreciated (on a scale of 4 and 3) were the following categories: increased production efficiency, cost savings, optimized product quality and simplified production process [22]. Attributes as error suppression, a tool to track and digitize paper documents also dominate the positive impact (mainly on a scale of 3 and 2). On a scale of 1 and 2 ratings, attributes such as increase stability, defense in the workplace and prevention of error suppression prevailed [23].

Benefits such as improved production efficiency, cost reduction, digitization of paper documents, elimination of errors and malfunctions, improved product quality, simplified production process, tracking tools, downtime forecast, overview of current production status, etc. [24], are finally confirmed to make work more stable and defensive (Fig. 2).

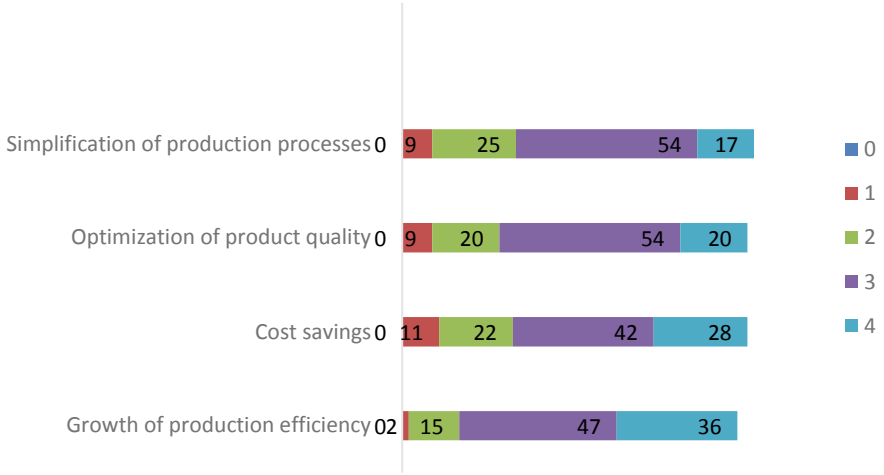


**Fig. 2** Advantages in realizing automatic production

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# The Potentials of Deep Learning Techniques for the Classification of SARS-CoV-2 Variants Based on Genomic Sequence Information

**Marion Adebiyi, Miracle Nmesomachi Enwere, Timothy Adeliyi, Abiodun Okunola, and Ayodele Adebiyi**

**Abstract** Genetic mutations give rise to a quasispecies of drug/vaccine-resistant and virulent organisms. These organisms are classified as strains or variants depending on the extent of their phenotypic manifestation. Thus, there is a thin dichotomy between SARS-CoV-2 strains and their associated variants. This paper sought to comprehensively review the successes achieved in the classification of SARS-CoV-2 strains based on genomic sequences (GSs) using deep learning architectures, thereby stimulating further research on the variants identified recently. Selective screening and analysis of research articles centered on deep learning architectures employed for SARS-CoV-2 detection based on GS information were carried out. This incorporated the use of relevant key/search terms and logical/Boolean operators to scan through the Scopus repository. To provide a foundation for future investigations on the classification of SARS-CoV-2 strains, meticulous analysis of the three key aspects, such

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as abstract, methodology, and conclusion, was implemented. Despite the high level of intra-species similarity, this article presents new studies that use deep learning technology to detect SARS-CoV-2 strains on the premise of the primary sequence of nucleotides in their genome. Manually searching through specific genes for mutations to identify variants after sequencing can be very laborious. This is where the use of computational acumen comes into play. Deep learning, an offshoot of machine learning, has been utilized in various literature to tackle such problems. Rapid identification of SARS-CoV-2 variant after sequencing aids quick response by clinicians to administer relevant drugs and save lives. Also, governments utilize this information to map out strategies for the timely containment of the spread of an identified variant with elevated virulence. The deep learning models reported in this paper show the remarkable predictive results achieved in identifying SARS-CoV-2 strains. However, no work has been done on the identification of recent variants reported globally.

**Keywords** Deep learning · Recurrent neural networks (RNNs) · Long short-term memory networks (LSTM) · SARS-CoV-2 · Omicron variant

## 1 Introduction

Since its discovery in the Chinese capital of Hubei province (Wuhan) in 2019, the severe acute respiratory syndrome coronavirus 2 SARS-CoV-2 has been directly linked to the death of millions of people around the world. As of December 2021, the number of cases recorded hit a devastating 282,800,017 cases with 5,414,213 deaths reported globally. In Nigeria, 240,387 cases and 3030 deaths have been recorded as of December 30, 2021 [1]. Coronaviruses (CoVs) are taxonomically classified as belonging to the Coronaviridae family, Nidovirales order, and genus Coronavirus. The most common cause of infections of the gastrointestinal and respiratory tract is these viruses. CoVs are uni-stranded ribonucleic acid (RNA) viruses that are positive sensed. CoVs exist in a quadri-genera strata as Alphacoronavirus, Betacoronavirus, Gammacoronavirus, and Deltacoronavirus [2].

The genome of CoVs span 26.4-kilobase pairs (kbps) to 31.7 kbps in length, with G-C contents ranging 32–43%. Coronaviruses that infect humans include HCoV-229E, HCoV-HKU1, MERS-CoV, HCoV-OC43, HCoV-NL63, and SARS-CoV [3]. It is interesting to note that there is over 50% and 79% genome sequence similarity of SARS-CoV-2 with the MERS-CoV and SAR-CoV, respectively [4]. The proliferation of the coronavirus with time creates evolutionary pressure which selects those variants with elevated virulence (faster rate of completion of infection cycle and increased reproduction rate) compared to others [5].

Mutations are the building blocks of evolution. Three kinds of mutations have been elucidated in the CoV metamorphosis, and they are base substitution, insertion, and deletion. Furthermore, the identified base substitutions are subdivided into nonsense, missense, silent, and frameshift [6]. These mutations are crucial in the generation of pathogenic CoV strains and variations. A notable feature of RNA viruses is their high

rate of mutation during replication, often known as copying errors, which result in evolutionary fit populations that survive adverse environmental conditions as well as a disproportionately higher number of physiologically impaired mutants that do not thrive. This characteristic has been implicated as one of the major factors frustrating efforts in research geared toward chemotherapeutic and/or vaccine design.

CoVs express the enzyme, RNA-dependent RNA polymerase which is responsible for synthesizing daughter RNA strands from parent RNA (template) during replication. The mechanism of action of this enzyme proceeds with low replication fidelity (that is, high copying error) which is partially mitigated by the 3′–5′ exonuclease proofreading activity of the non-structural protein (nsp14) [7]. This is the major reason why SARS-CoV-2 exhibits a low rate of mutation at a slower rate of about one in every two weeks, which tallies with $1.1 \times 10^{-3}$ substitutions per site per year [5]. Emergent mutations in the SARS-CoV-2 genome have facilitated the development of morphs exhibit heightened rate of infection and produce an outbreak of illness in humans, thereby increasing the virulence of the strain.

In the scientific world, the dichotomy between the definition of variants and strains lies within a thin line of partition. Although both variants and strains differ from the wild type CoV, strains have a more pronounced phenotype (such as antigenicity, transmissibility, or virulence) and are thus evolutionarily distant. The World Health Organization (WHO) has come up with an initiative that classifies SARS-CoV-2 variants as variant of interest (VOI) and variant of concern (VOC) in order to prioritize activities focused at tracking the spread of certain variants that present high virulence, increasing research in these areas, and raising worldwide awareness about a potential pandemic (VOC) [8]. The pioneer VOC is SARS-CoV-2, B.1.617.2 (Delta) variant. It was first identified in Maharashtra late in 2020 and spreading throughout India, displacing previously known lineages like B.1.617.1 (Kappa) and B.1.1.7 (Alpha)1 [9]. Furthermore, on the 26th of November 2021, the WHO announced the appearing of a novel SARS-CoV-2 VOC known as Omicron (formerly known as B.1.1.529), which was found to be on the rise in practically all of provinces in South Africa (SA), specifically Gauteng [1]. The fast rise of cases, recorded in SA, has put WHO and worldwide institutions of health painstakingly alert, especially among the younger age groups.

The primary nucleotide sequence of SARS-CoV-2 is determined using next-generation sequencing (NGS) technology [9]. Through this means, searching through highly conserved regions such as the ORF1ab and N genes, variants can be identified manually. It is worthy of note that the recent advances in high throughput sequencing have sped up the rate at which several SAR-CoV-2 sequences are submitted to databanks (most of which are publicly accessible). This has led to the rise of big data in the scientific world and an urgent need to make sense of this data. In literature, the recurrent neural networks (which represent a subgroup of deep learning) have been applied by bioinformaticians for the efficient identification of CoV strains. The availability of sequential data in repositories have been used to train models that carry out the classification/identification process. This approach is promising and could be preferred above utilization of molecular methods for the purpose of identification.

This review paper therefore examines some of the shortcomings of utilizing of molecular methods for identification of sequence-similar SARS-CoV-2 variants and then reports the progress made in the classification of CoV strains through the use of deep learning algorithms in literature. An imminent lacuna in variant detection for further studies globally has also been revealed in this work.

## 2 Mutation Drives Evolution

(Gene) mutation refers to the alteration of the nucleotide sequence of deoxyribonucleic acid (DNA) [10]. It is the fundamental driving for evolution is mutation. Typically, organisms evolve to morphs that physiologically adapt effectively to adverse environmental conditions. This facilitates the process of natural selection which conserves only fit populations of a species and ensures their perpetuation over time. In essence, mutation accounts for intra-species differences and the ability of a species of an organism to thrive in a specific geographical location [11]. It is worthy of note that mutations occur spontaneously, and as such, not all mutations are advantageous to any organism under consideration. Some mutations give rise to organisms that adapt effectively to rapidly changing ecosystem, others to organisms that are less potent than the immediate population, and others do not even present any phenotypic manifestation at all. There have been reports that undesirable mutations always exceed beneficial mutations irrespective of the mutation rate (high or low), and biological entities vary markedly in their mutation rate per nucleotide (approximately eight orders of magnitude) [11].

## 3 Techniques in Molecular Biology for Identifying SARS-CoV-2 Variants

In Africa and most parts of the world, the molecular techniques for detecting SARS-CoV-2 variations are reverse transcription-quantitative real-time polymerase reaction (RT-qPCR) and nucleic acid sequencing [12]. The RT-qPCR is a hybrid technique that involves an RT-PCR procedure for synthesizing complementary DNA (cDNA) from extracted viral RNA. This is then followed by qPCR which measures the amplicon (amount of genes amplified) in real-time as facilitated by a quencher and reporter probe. For the identification of SARS-CoV-2 variants, primers are designed that selectively target the ORF1ab and N genes of the variant under consideration [3]. One of the major disadvantages of the RT-qPCR is that it does not detect variants based on the sequence information of the whole genome of the organism.

The efficacy of the RT-qPCR approach has been queried by [13], who found a 17.8% negative rate in moderate cases and an 11.1% negative rate in severe cases when sputum samples were used. In severe and mild cases, the RT-qPCR

approach demonstrated negative rates of 26.7% and 27.0%, respectively, when used on nasopharyngeal and throat samples. Furthermore, when applied to throat swabs in severe and mild cases, this approach yielded an alarming negative rate of 40.0% and 38.7%, respectively. Lopez-Rincon et al. [3] opine that the heterogeneity that ensues from subtle mutations in genomic sequence within and across species may be responsible for the false-negative results obtained. These mutations make variants of the SARS-CoV-2 genetically similar and as such difficult to detect.

Next-generation sequencing (NGS) tops the chart as the predominantly used technique for sequencing a viral genome. Nucleotide sequencing simply entails the process of figuring out the order and arrangement of nucleotides in the primary sequence of a target genetic material. Usually, a sequence alignment is carried out on the sequenced sample while searching through major repositories/databases such as the GenBank using the basic local alignment search tool (BLAST) available on the National Center for Biotechnology Information (NCBI) to identify the lineage or variant of SARS-CoV-2 sequenced. However, a multiplicity of applications of deep learning for predictions involving genomic sequences (GS) has been reported in the literature. These models take nucleotide sequences as input and extract relevant features on their own.

## 4 Deep Learning Techniques for Classification

Deep learning techniques are subsets of machine learning architectures that have seen a multi-varied application toward the analysis of biological data [14]. This has facilitated bioinformatics research over the years. To differentiate SARS-CoV-2 from other CoVs, a machine learning technique based on genomic signal information was introduced. This involves the use of the GS available in the NCBI GENBAND to maximize disease detection accuracy within a short time frame [15]. Before incorporating into a classifier, features such as discrete Fourier transformation (DFT) and discrete cosine transformation (DCT) are extracted. One of the major advantages of deep learning over machine learning is the fact that deep learning architectures extract features automatically.

The BLAST technique is the gold standard for nucleotide sequence-based classification of SARS-CoV-2 sequences. However, [16] showed that the COVID-DeepPredictor outperforms the NCBI's nucleotide BLAST algorithm using an technique devoid of alignment steps. The COVID-DeepPredictor was designed with long short-term memory network (LSTM) model as the underlying algorithm and applied as a discriminatory tool to distinguish between GS of SARS-CoV-1, SARS-CoV-2, MERS-CoV, Ebola, Dengue, and Influenza without sequence alignment. On the validation dataset, the model outperformed random forests (RF), linear discriminant analysis (LDA), and gradient boosting (GB) algorithm, with a prediction accuracy of 100%. The accuracy of the test dataset is reported to range from 99.51 to 99.94%. In comparison with the nucleotide BLAST, the runtime of the COVID-DeepPredictor fares better.

Deif et al. [17] implemented the LSTM and gated recurrent unit-based (GRU) bidirectional recurrent neural network (BRNN) as an alignment-free technique for differentiating SARS-CoV-2 from other strains of the family, Coronaviridae. The GRU-BRNN proved to be the best performing algorithm possessing overall classification accuracy of 96.8% above LSTM-BRNN with an overall classification accuracy of 95.8%. It is worth noting that when the SGD optimizer and an ideal number of unit cells of 80 were used in both models according to [17], the optimum hyperparameters that gave the maximum degree of performance for the two models were generated.

Another amazing work reported by [18] shows the implementation of convolutional neural network (CNN)-Bi-LSTM for classifying GS as SARS-CoV-2 or otherwise. Furthermore, the model was able to classify whether or not nucleotide information about a genome contained a putative regulatory motif. The experiment's findings elucidated that the proposed CNN-Bi-LSTM model attained 99.95% accuracy of classification, a 100.00% area under curve receiver operating characteristic (AUC ROC), 99.97% specificity, and 99.97% sensitivity, with Cohen's Kappa and Mathews correlation coefficient (MCC) of 0.9978 and 0.9978, respectively, for distinguishing SARS-CoV-2 among Coronaviruses.

Rani et al. [19] applied a multimodal system which composed of the COVID-Screen-Net and 'GenomeSimilarityPredictor' elucidated by [20]. GenomeSimilarityPredictor was used to predict the correlation of the genomes of SARS-CoV-2 with those of other viruses (SARS-CoV, Human Immunodeficiency Virus, MERS-CoV, and Human T-cell Leukemia Virus), as well as the classification of genomic data into infected and non-infected classes (based on Covid-19 infection status). COVID-Screen-Net, on the other hand, was modeled after the work given in [20] for classifying chest radiographs into healthy, bacterial pneumonia, and SARS-CoV-2. These two networks act in tandem: The GenomeSimilarityPredictor is called when GS is sent into the multimodal system, while the COVID-Screen-Net is called when chest radiographs are fed into the model. The model's SARS-CoV-2 genome detection had a sensitivity of 95.47%, while the screening of chest radiographs for SARS-CoV-2, non-COVID pneumonia, and healthy had a sensitivity of 99.27%. The GenomeSimilarityPredictor, which is a system consisting of an embedding layer for preprocessing and computation of scores for each GS on the premise of the position and frequency of nucleotides in the primary sequence; three convolutional neural network (CNN) layers that carry out feature extraction protocol on the output of the embedding layer; three bi-LSTM layers that train the model; and three Global Max Pooling (GMP) layers that calculate scores for each genomic sequence based.

## 5 Conclusion

The survival of species has always been predicated on their ability to evolve. Such evolution is predicated on the rate of mutation. The SARS-CoV-2 that has depleted the global human population is no exception. Identifying the exact variant equips

clinicians to know the best line of treatment for patients and helps governments to set up structures for preventing the spread of variants with increased virulence. The key to identifying these evolved variants and strains lies in their genomic sequence information. The findings reported in this paper provide evidence for multiple deep learning architectures that have been employed for quick detection of SARS-CoV-2 strains using genomic sequence information. This elucidates the crucial relevance of bioinformatics in biological data analysis. However, more research is needed to refine the reported algorithms and construct extremely sensitive deep learning architectures for SARS-CoV-2 variant detection.

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# Smart Traffic Handling Algorithm Using Aggregated Channel Feature

**Wania Tahir, Raja Asif Wagan, and Bushra Naeem**

**Abstract** Traffic management is a subject of improvement all over the world, may it be the emerging or developed countries. Road safety and vehicle management requires continuous improvement mechanisms to ensure the safety of public. With the widespread growth of vehicles and thus the traffic, road coercions as well as threats to life have increased, making the management of traffic as a daunting task. A mismanaged traffic administration lead to rising road accidents, overcrowding of traffic movement, merger of distinct vehicles into prohibited lanes, and numerous additional coercions that could be menacing for life. In this paper, aggregated channel feature (ACF) algorithm is applied to track the vehicles. Further, the algorithm is enhanced for the traffic flow management with the use of classifications of various groups of transportation, enabling the road management infrastructure to identify the nonvehicle versus vehicle and further recognize vehicles according to the type of vehicle, size of vehicle, and status of vehicle as emergency or non-emergency vehicle. This helps building up of congestion as well as avoiding coercion. The proposed implementation of ACF to the road traffic for smart cities has detected true positive rate of 80, 89%, has detected true positive rate of 69 and 79% having nonvehicle detected with assigned priority.

**Keywords** Smart traffic · Congestion · Emergency · Aggregated Channel Feature (ACF)

## 1 Introduction

Traffic congestion is a common issue in major cities, and it becomes even worse in the event of an emergency situations such as a flood, fire, ambulance, or other natural disaster. Traffic bottleneck occurs when the demand surpasses the existing road capacity. Countries around the world looking forward to implement smart "traffic

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management system" the recent advancement in wireless sensors networks and low-cost power consumption sensors have bolstered the system towards creating "an effective and efficient system for intelligent traffic management". The initiation of internet of thing and high accessibility of cloud resources are facilitating us creating tool that can automate the smart transportation system and can augment utilization of prevailing infrastructure. The general fact is that number of traffic and the population from rural to urban areas is bursting day by day. As the number of vehicles, necessity of vehicle controlling streets, motorways highways are gruesome issue within limited resources for under developing countries. The developing countries have another issue of pollution which is result of excessive amount of increasing traffic. Literature review has comprehensively discussed the interests of authors toward the smart traffic. This paper will provide algorithm which will Priority to traffic by considering the numerous factors. This thesis will provide solution toward priority of vehicles and non-vehicles in order to curb the congestion and provide solution for infrastructure development. The initiation of internet of thing and high accessibility of cloud resources are facilitating us creating tool that can automate the smart transportation system and can augment utilization of prevailing infrastructure. Traffic bottleneck occurs when the demand surpasses the existing road capacity. Countries around the world looking forward to implement smart "traffic management system" the recent advancement in wireless sensors networks and low-cost power consumption sensors have bolstered the system toward creating "an effective and efficient smart traffic management system". Local consultants might use traffic monitoring to keep an eye on the flow of traffic in their neighborhood or on a specific street. Emergency detection is a critical component of the "Intelligent Traffic Handling System," and the method for it is presented. The situation of road traffic must be captured (Fig. 1).

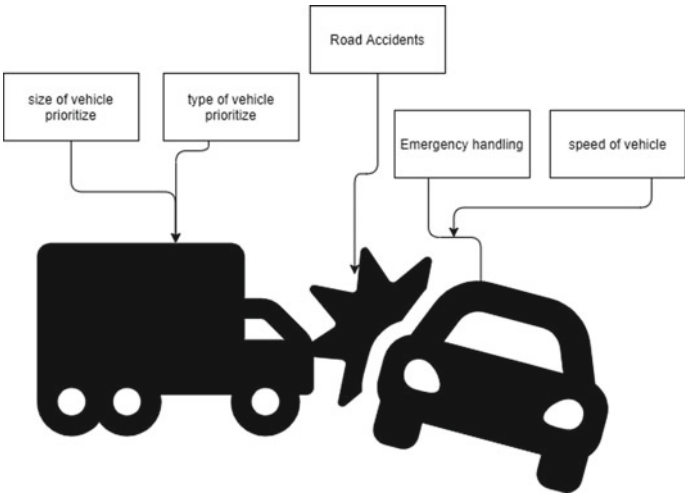


**Fig. 1** Factors behind prioritizing the vehicle at smart city

In smart municipalities around the creation, smart transportation management system is deployed to curb the traffic concerns. “Smart traffic management system”, examines road stream of traffic moves in actual spell mode also recommend driver to opt for most optimized direction for traffic with assistance of Google map embedded in proposed system. It also enables grabbing the traffic recording notifying the up-to-date transportation incidences to appropriate participants, so long as traffic data for disconnected examination, signal control, display sign, warning and essential message and emergency situation updates. Smart transportation management system is inclusive and compound scheme to project, build and implement. “Effective and efficient smart traffic management system based on IoT” not only manages the traffic density but also perform numerous tasks like emergency situation handling, signals recognition, symbols detection, incident management, crash avoidance and safety, shortest route optimization and road jam scenarios. It must provide previous warnings for transportation approaching hazardous turns, rail crossing, work zones, groups, and restricted overpass and off ramps.

## 2 Literature Review

A well-managed conveyance makes the traffic and transportation safer. Outlook for the selection and calculation of best possible routes which depends on the patterns of traffic utilization, classification of vehicle, emergency, and for the level of hail different Machine Learning Algorithms [1, 22] can be used in his work has provided beneficial results in for of reducing the time to wait during logjam with the exact calculation for an alternate route. All these techniques and algorithm makes the system efficient and effective in congested situations. Many authors have worked on an algorithm for prioritizing the dynamic traffic as a result of rampant progress in the populace. Some pieces of related literature have worked on duration of the green lights and provided an algorithm for the dynamic duration of green lights with the emergency management of vehicles. The change is the duration of traffic is managed through control algorithm by determining the length of traffic by calculation distance formula with the juncture to the emergency means of transportation. The author considered the wireless sensors network for input source [2]. With all these benefits, there are numerous risks involved in intelligent transportation. Intelligent transportation is all about combination of interconnected services and devices. These interconnected devices make it imperative for the developer to protect the sensitive and private data. The data privacy has gained a supreme significance and the developer need to ensure that it is not available to public. Reference [24] has discussed traffic signs detection by using feature detection method. The proposed study focused on mechanism of feature detection of traffic signs (Fig. 2).

**Fig. 2** Intelligent traffic and urban transport [3]

## 3 Methodology

In the proposed algorithm, one of the major tasks is to identify the type of vehicles and assign the priority to the vehicles and non-vehicles. Early detection of vehicle works as a core part in smart traffic management system. This paper relates the vehicle tracking and detection techniques based on a variety of constraints. The first stage is to extract images that are sensitive to data faults and portray a robust response to a noisy image. The proposed technique first detects motion from an image, then extracts the image and generates a blob using the ACF and point tracker algorithms. The detail of prioritizing the cars is discussed in the following section. In this section design, the steps involved in the algorithm to detect vehicle and semantic segmentation are explained.

### *3.1 Aggregated Channel Feature*

For the detection of vehicle of different categories, ACF detector is simulated in MATLAB. It calculates several feature channels and then computes these channels. The boosted tree is used to train aggregated channels to distinguish between the backdrop and the objects. ACF computes multi scale aggregated features using a sliding window approach and the approximation technique. AdaBoost is employed to train the detectors. In order to detect vehicles, it employs cutting-edge detection precision.

### *3.2 Prioritized Intelligent Road Management Technique by Using ACF*

The intelligent traffic system utilizes four aspects to make the transport intelligent:

- Detection of traffic
- Assigning significance to transportation according to category
- Highlights the separate lanes for non-vehicles
- Emergence detections and to recommend and substitute routes to adjacent vehicles.

Once the data has been properly put into the frame, the following step is to choose an algorithm to recognize and track the vehicle, for which ACF and point tracker are utilized. The data is then trained for priority after detection and tracking, which is the main contribution of this work. Gaussian smoothing is used to remove noise from an image and convert it to greyscale in order to prepare it for further processing. In vehicle detection and tracking, ACF algorithm provided a variation of channel feature that extracted the values of pixels directly in the extended channel without computation of the rectangular sum at different scale and locations. ACF algorithm has the provided the richer representation of image, acceleration of detected speed, and more precise localization of detected vehicles in the image. Then the aggregated channel features were extracted from the region of interest [4] and the transportation were detected using the "ACF vehicle detector [2]" than according to study in order to make the system intelligent bounding boxes are assigned to vehicles according to category and prompted with priority according to the type of vehicle.

### *3.3 Algorithm for Proposed Technique*

The algorithm is designed with the following parameters:

Input.

$V_t$: General Transport indicator

$P_d$: person detection

T: Movement follower

F: Video sequence from Frame at a t time

P: ACF algorithm

$V_C$: Assigned bounding boxes according to category of vehicles and non-vehicles

P: Assigning Priority to Vehicles and non-vehicles

E: Emergency handler

Output:

$V_d$: distinguished vehicle and non-vehicle

$V_c$: detected category of vehicles and assigned bounding boxes with priority prompt.

$A_d$: Accident detected as Emergency handler

Algorithms processing:
$V_d \leftarrow \{\}$
$BBox_G \leftarrow$ {detections by $V_t$ in F}
ROIp ← get region of interest ROI(T)
$BBox_S$ + - recognition by $V_t$ in ROIp
$BBox_T$ + - predicted location of P by T in F
if $BBox_S \neq \{\}$ then
if bbox coincides with $BBox_G$: bbox ϵ BBoxG
Update T
$\{V_t\} \leftarrow$ update $V_t$ (bbox)
$V_d \leftarrow$ associated bounding box of "bbox "U BBoxs
else if, $BBox_T$ coincides with BBoxs then
Bring up-to-date T
$V_d \leftarrow$ associated bounding box of $BBoX_T$ U $BBox_S$
end if
end if

$BBox_S$ is bounding box of specific vehicle and non-vehicle, equivalent bounding boxes is represented as $BBox_T$. This is how proposed technique detects, categorizes and prioritize the traffic.

## 4 Results

All the vehicles and non-vehicles are given as data by video, due to trees and fencing the vehicles of incoming sides are not properly detected by using ACF Algorithm. The results of this dataset show out of 42 vehicles true positive rate of classification were 54 of total vehicles and out of 42 non vehicles false positive was 12. Due to ongoing an outgoing traffic algorithm could not get the result of other side of the road. There are some static vehicles beyond another road side did not detect, but when those vehicles which are in front of camera were detected and prioritized as they started moving. In previous dataset non-vehicles were no depicted, here the representation of detection of non-vehicle and transfer priority (Figs. 3, 4; Table 1).

## 5 Conclusion

In this work, a method is proposed for detecting, classifying, and ordering vehicles based on their category, size, and kind, as well as non-vehicles and people on the road, in real-time display. Aggregated channel feature is implemented to check the authenticity of tracking algorithms. ACF followed trained detector function to detect the vehicles, but according to implemented algorithm priority is assigned to every vehicle and non-vehicle. Point tracker algorithm has more accuracy as compare to ACF because it detects the vehicle till last point. Accident detection is added for

**Fig. 3** Non prioritized vehicles versus is prioritized vehicles

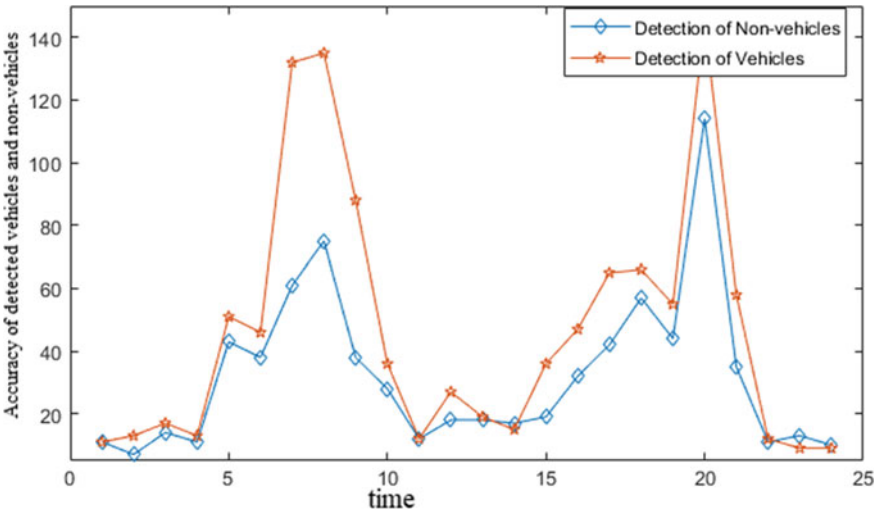


**Fig. 4** Detected vehicles and non-vehicles using proposed algorithm

handling the emergency situation by using both algorithms, an alternative route is successfully suggested to neighboring transports.

**Table 1** Result compiled from experiment by using ACF algorithm

| Heading level | No. of vehicles | True positive (detected vehicle) | Rate of true positive (%) | False positive undetected vehicles | Rate of false positive (%) |
|---|---|---|---|---|---|
| Result of Dataset1 Without assigning Priority | 15 | 12 | 80 | 3 | 20 |
| Result of Dataset II Without assigning Priority | 19 | 17 | 89 | 2 | 11 |
| Result of Dataset III With assigned Priority | 42 | 29 | 69 | 13 | 31 |
| Result of Dataset IV With assigned Priority | 54 | 42 | 78 | 12 | 22 |

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# Estimating Nodes' Number in a Nanonetwork Using Two Algorithms

**Athraa Juhi Jani**

**Abstract** A nanomachine has the ability to proceed simple functions, as an example: computing, sensing, actuating and/or data sorting. However, if there are more nanomachines, it is possible to achieve more complex functions through communication and information sharing. Thus, a nanonetwork would be formed through the communicating and sharing information among few nanomachines. We consider in this paper a model of $N$ nanomachines which are located in two-dimensional environment, communicating between each other via diffusion to form a nanonetwork. The model aims to estimate the number of nanomachines in the nanonetwork, i.e., $N$. This paper presents two algorithms for the estimation. The first proposed algorithm is based on quorum sensing mechanism. Where, quorum sensing represents a biological mechanism which is utilized to enable the synchronization of bacteria population. While the second algorithm; we employed a counting algorithm in beeping model to estimate our nanonetwork size. Beeping model is a group of nodes that are communicating through multiple-access channel, where the communication concept of beeping and listing to the channel is similar to the one in diffusion-based molecular communication.

**Keywords** Nanomachines · Nanonetworks · Diffusion · Quorum sensing · Beeping model · Bio-inspired network

## 1 Introduction

A nanomachine is the basic operating unit in any nanosystem. At a nanolevel, these nanomachines have the ability to carry out a specific task including data sorting, communication, computation and/or sensing. The interaction between these nano machines forms a nanonetwork expanding the capabilities and applications of single nanomachines by enabling them to execute more complex tasks in a distributed manner [1]. There are different communication mechanisms used to form a nanonetwork.

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One of the examples is carbon nanotubes which can be used to connect nanomachines (where data transmission occurs through modulated current flow). Other examples are the possibility of using electromagnetic waves, acoustic waves for communication, or it possible that nanomachines can mimic natural biological systems using molecular communications. Molecular communication has been explored in many studies, where at nanoscale, essentially molecules are utilized for encoding, transmitting and receiving information [2, 3]. Molecular communication is counted as one of the propitious methods to observe the interaction among nanomachines. Basically, the inspiration of using molecular communication came from the observation of biological systems in which molecules are used to mediate the communication. Molecules in nanonetworks are acting as information carriers, causing biochemical reactions on the receiving side [4, 5]. There are various molecular communication techniques that can be used according to the distance between the sender and the receiver nanomachines. In this paper, the adopted communication technique is diffusion. Where, the communication channel between the sender and receiver nanomachines is envisioned to be a molecular channel [6–8].

*Previous Work*: In any network, the estimation of nodes' number can be considered as important task to achieve many substantial protocols and it can be used for network analysis. Thus, proposing an algorithm to estimate the network size efficiently can be challenging [9]. Network size is a global parameter of great necessity to many structured p2p systems. There is a possibility to use the network size to tune the rates of topology maintenance. In addition, it is possible to utilize the estimation of the network size parameter for load-balancing objectives. Furthermore, it would be useful to choose a level for setting the outgoing links, and it can be employed for designing algorithms where knowing the network's size would help in implementing their procedures [10]. Probably, all the applications of network's size estimation discussed above can be used in conventional networks. However, as far as we understand, in nanonetworks, the most suitable application is the last one, i.e., using the network size parameter to help in designing new algorithms which depend on estimating network's size. In peer-to-peer networks, there are many proposed algorithms to estimate the number of nodes. However, the main two techniques which should be distinct are: Gossip-based aggregation and random walk-based approaches [11].

*Related work*: If we compare systems at the nanoscale to microsystems, it is possible to find that it have different functionalities and different environment rule. Thus, different approaches are needed for system design, problems specification, and that could result in proposing different algorithms which are suitable for nanosystems. Many research papers are focusing on investigating the communication among living cells, taking in considerations that the scale of nanomachines could be close to the living cells' scale. Quorum sensing [12–14] is a process which represents an example of signaling communication among bacteria. Bacteria usually use quorum sensing for estimating their population density in the environment. Thus, basically that could be done through utilizing the estimation of the concentration of a certain molecule to estimate their population. However, in [15, 16], the process of quorum sensing has been proposed to be employed for signal amplification and to be used to synchronize nanonodes in a nanonetwork. The authors in [17] have derived the nodes

density estimation through investigating the application probabilistic flooding in the network, and via analysis and simulations, the authors have employed molecular communication in a synchronous transmission-based network. Then in [18], they were inspired by quorum sensing to propose a scheme to be applied in nanonetworks known as distributed density estimation. In [9, 19], the problem of size estimation in a one-hop beeping network has been addressed. The aim of this paper is to count nanomachines' number in an nanonetwork, using two algorithms. The first algorithm is proposed based on a bio-inspired mechanism. The second one is adopted by a counting algorithm from a beeping network in [19].

## 2 System Model

The considered system in this paper is a nanonetwork with $N$ nanomachines (nodes) in two-dimensional environment. These nanomachines are communicating through diffusing molecules, i.e., messages (information) among the nanomachines are encoded as molecules. In this model, it is assumed that nanomachines are distributed in a local range; thus, if a nanomachine diffuses all other nanomachines can receive some molecules. When a nanomachine diffuses a unit $u$ of molecules, these molecules will be propagated through the medium. These diffused molecules are assumed to follow Brownian motion in their spreading in the medium. The following function [20] is used to find the molecular concentration at the receiver nanomachines after a transmitter nanomachine had diffuse a unit $u$ of molecules.

$$u(t) = u * \frac{1}{(4\pi Dt)^{\frac{2}{3}}} * \exp\left(\frac{-d^2}{4Dt}\right) \tag{1}$$

To clarify the symbols in the above function, where, time is signified as $t$, the distance between the transmitter nanomachine and any receiving point is denoted by $d$, and the diffusion coefficient of the medium is $D$. In this model, the considered signaling type is On-Off Keying modulation. In such a way that if a nanomachine diffuses a unit $u$ of molecules, then that signifies 1 in case the sensed molecules by the receiving point have aggregate above or equal to threshold $\tau$. While in the case that there are no diffused molecules (and/or sensed molecules by the receiving points are less than $tau$) that would signify 0.

## 3 Quorum Sensing

In biology, in order for a group of bacteria to be synchronized, there is a particular type of molecules which would be released by each bacterium at a constant rate. Eventually, that type of molecules' concentration increases in the environment proportionally to the bacterial population. Thus, through detecting the concentra-

tion of a certain molecule, bacteria can sense the density of their population in the environment [14, 15]. The proposed algorithm in this paper to find the number of nanomachines in a nanonetwork is inspired by this mechanism which is used by bacteria. To elaborate the explanation of quorum sensing, if we consider a group of $X$ nodes that are deployed in a specific environment. Each one of these $X$ nodes would emit certain molecules in a fixed rate. Consequently, that constant emission of these molecules would increase their concentration in environment. Thus, when the molecular concentration reaches a particular threshold, these nodes are able of reacting [15, 16].

### *3.1 Estimate Number of Nodes Using Quorum Sensing*

In order to employ the quorum sensing mechanism to find the nanomachines' number, we need to derive the mathematical expression which finds $N$ from the proportional value of the following two things: the molecular concentration in the environment and the emission rate ($Q$) of that specific type of molecules (here, it is assumed to be autoinducer).

**Algorithm 1** Estimate N in Nanonetworks using QS

$h \leftarrow$ threshold to get Quorum Sensing
$i \leftarrow 0$
$t_i \leftarrow$ time slot $i$
$Q \leftarrow$ amount of autoinducer emitted by a nanomachine at each $t_i$
$C(t_i) \leftarrow$ sensed autoinducers concentration in environment at $t_i$
$N \leftarrow$ Number of nanomachines
**while** $C(t_i) <= h$ **do**
  Compute $C(t_i)$ using Equation (1).
  $i \leftarrow i + 1$
**end while**
**Quorum Sensing is reached**
$i \leftarrow i + 1$
Compute $C(t_i)$ using Equation (1), (to know the current concentration after reaching quorum sensing)
**while** $C(t_i) > C(t_{(i-1)})$ **do**
  Compute $C(t_i)$ using Equation (1).
  $i \leftarrow i + 1$
**end while**
$j \leftarrow$ total $i$
$N \leftarrow C(t_j)/Q$

Using this mathematical expression, it is possible to set formally the dependence between the nanomachines density and molecular concentration in the environment. The algorithm depends on determining the value of $h$ which represents the threshold for reaching quorum sensing. Furthermore, it is possible to pre-define the amount of autoinducer (or any other type of specified molecule emitted by these nanomachines)

diffused by the nanomachines, which represents $Q$. It is important to compute the concentration of autoinducer (or any used molecule) in the environment, that should be done using Equation (1) where the value of $Q$ is used instead of $u$ in Equation (1). In Algorithm 1, $(t_i)$ represents the time slot $i$, thus, $C(t_i)$ represents the autoinducer's (or any other used molecule) concentration in the environment at time slot $i$. Before reaching to quorum sensing, Algorithm 1, checks if the molecular concentration of autoinducer (or any used molecule) $C(t_0)$ in the environment at time slot $t_0$ is less or equals $h$. If the molecular concentration $C(t_0)$ is less than $h$, the same process is repeated during the next time slot(s), until the value of $C(t_i)$ is higher that $h$, which indicates that quorum sensing is approached by the nanonetwork's nodes. When the quorum sensing is reached, $C(t_i)$ is computed again, i.e., the process of computing autoinducer concentration in environment using Eq. (1), to specify the current concentration. This process is continued as long as the concentration of autoinducer at $t_i$ is greater than its concentration at $t_{(i-1)}$. The total amount of autoinducer concentration computed throughout the time interval $(t_0, t_i)$. Where this total concentration is represented as $C(t_i)$. In order to estimate the number of nodes $N$, $C(t_i)$ is divided by $Q$ which represents the amount of autoinducer emitted by a nanomachine at each $t_i$. Thus, it is possible to think that the required time to estimate the number of nanomachines, according to Algorithm (1) depends on both $Q$ and the total amount of autoinducer concentration $C(t_i)$. However, the algorithm didn't take in consideration the residual molecular concentration (i.e., the none received molecules) in the environment at each time slot. Time to estimate the number of nanomachines is inversely proportional to the amount of $Q$ and eventually to the size of the nanonetwork.

## 4 Beeping Model

The beeping model is a distributed system consists of number of nodes, communicating capabilities of each node in this model is to beep or listen to the beeps of other nodes. When a node beeps, it would not be able to find out if there are other nodes beeping simultaneously. When a node listen, it can distinguish between silence or that at least one node beeping, nevertheless, it cannot detect if there is one or many nodes beeping [9, 19]. The communication concept of beeping and listing is the same in diffusion-based molecular communication.In molecular communication systems, the process of diffusing and sensing can correspond to beeping and listening in beeping model. Thus, nanomachines in our model have the same communication capabilities in beeping model; therefore, we are motivated to adopt an algorithm from such systems.

### *4.1 Estimate Number of Nodes Based on Beeping Model*

We adopt an algorithm that has been described in [19] to count the number of nodes in a beeping model. The algorithm's main concept is that nanomachines would diffuse molecules alone as frequent as possible to increase the chances that their molecules

sensed and become counted. The algorithm is consisted of three slots, during the First Slot, the none counted nanomachines diffuse unit $u$ of molecules with a certain probability. In case these nanomachines diffused alone, then they would re-diffuse in the Second Slot in order to notify the rest nanomachines, so that they can be counted. During Third Slot, it is time for all the none counted nanomachines to diffuse. In case, no nanomachine diffused during the Third Slot, that could indicate that every nanomachine has been counted, and the algorithm would terminate. To raise the opportunity that a nanomachine diffuses alone during the First Slot, the algorithm uses an adoptive probability $1/j$. Where that can be accomplished through raising the probability (i.e., reducing $j$)in case no nanomachine diffuses, and to reduce the probability (i.e., raising $j$) in case, there are more than one nanomachine diffusing molecules. Algorithm (2) shows the details, where the phase can be considered as detected if it is repeated until termination.

**Algorithm 2** Estimate N in Nanonetworks based on Beeping model

```
counted ← false
finish ← false
Integer j ← 2
Integer size ← 1
repeat
  Switch Slot
  Case1
  if count=false then
    diffuse with probability 1/j
  end if
  Case2
  if Only me diffused during the first slot then
    diffuse
    counted ← true
  end if
  Case3
  if counted = false then
    diffuse
  end if
  End of phase:
  if a nonomachine diffused in Second Slot then
    size = size + 1
  end if
  if no one diffused in Third Slot then
    finish ← true
  end if
  if no one diffuse during First Slot then
    if j > 2 then
      j ← j − 1
    else
      if more than one diffused during First Slot then
        j ← j + 1
      end if
    end if
  end if
until finish = true
```

The authors in [19] state that the algorithm steps forward each time a nanomachine diffuses alone during the phase's first slot. The probability that this occurs can be determined by the value of $j$ and the number of nanomachines $n'$ that are still competing in this phase. If the value of $j$ is too large, that could possibly mean no nanomachine will diffuse during the first slot. While, if the value of $j$ is too small, then it is likely that many nanomachines would diffuse during the first slot. The main point which the algorithm attempts to maintain is that the probability of success is maximum when $j = n'$.

## 5 Conclusions

We proposed two algorithms to estimate the number of nanomachines in a diffusion-based nanonetwork. The proposed algorithms are based on different techniques. The first algorithm is based on the concept of quorum sensing, which represents a biological process that bacteria use to sense their population. Bacteria could determine if it has the proper number of population to launch an attack through detecting the level of a certain type of molecules in the environment. The same idea employed in the first algorithm, by checking the concentration of a certain type of molecules in the environment and if it has reached to a certain threshold. The total amount of its concentration is divided by the amount of molecular concentration diffused by each nanomachine to estimate the number of these nanomachines. However, the algorithm didn't take in consideration the residual molecular concentration (i.e., the none received molecules) in the environment at each time slot. Thus, the sensed molecular concentration would be an approximate to the actual values. Beeping model is a group of nodes that are communicating through multiple-access channel, where the communication concept of beeping and listing to the channel is similar to the one in diffusion-based molecular communication. Thus, the second algorithm to estimate our nanonetwork size is based on a counting algorithm in beeping model. The algorithm is consisted of three slots, during the First Slot, the none counted nanomachines diffuse unit $u$ of molecules with a certain probability. To raise the opportunity that a nanomachine diffuses alone during the First Slot, the algorithm uses an adoptive probability $1/j$. If the value of $j$ is too large, that could possibly mean no nanomachine will diffuse during the first slot. While, if the value of $j$ is too small, then it is likely that many nanomachines would diffuse during the first slot. The main point which the algorithm attempts to maintain is that the probability of success is maximum when $j = n'$, where $n'$ represents the number of nanomachines.

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# Digitization Techniques for the Representation of Genomic Sequences in LSTM-Based Models

**Marion Adebiyi, Miracle Nmesomachi Enwere, Abenego Shekari, Ayodele Adebiyi, and Francis B. Osang**

**Abstract** Deep learning (DL) is an actively growing domain of machine learning owing to the proliferation of big data in multifaceted fields of study. Widespread in literature, there are multiple reports on the implementation of long short-term memory network (LSTM)-based models in the field of bioinformatics for the analysis of the vast amount of genomic data. Genomic data is quintessentially a contiguous stretch of unspaced characters that correspond to the nucleotides adenine (A), guanine (G), cytosine (C), and thymine (T) known as deoxyribonucleic acid (DNA). The DNA sequence must be converted to formats readable by LSTM algorithms run on computers, a process known as digitization. This paper aims to uncover and elucidate the various techniques for digitization in studies that apply LSTM for predictive and classification problems as it relates genomics. We hope this paper would serve as

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a template for assessing pre-processing techniques for suitability in future studies involving deep learning.

**Keywords** Deep learning (DL) · Recurrent neural network (RNN) · Long short-term memory (LSTM) network · Genomics · Pre-processing · Feature extraction · Digitization

## 1 Introduction

The genetic information of all life forms is encoded either as a sequence of deoxyribonucleotides or ribonucleotides to yield the polymers, deoxyribonucleic acid (DNA), and ribonucleic acids (RNA), respectively [1]. The DNA in its two-dimensional representation is a double stranded biomolecule consisting of nitrogenous bases, adenine ($A$), guanine ($G$), cytosine ($C$), and guanine ($G$), which stacked within a backbone composed of phosphate group and a deoxyribofuranose (5-carbon closed ring ribose sugar) [2]. RNA is different from DNA in the sense that it is single stranded, possesses uracil instead of thymine and contains a ribofuranose. Genomic sequences are usually given as the primary sequence of nucleotides written from the 5' to 3' direction. Thus, a genomic sequence $J$ of length $n$ is represented mathematically as $J = (J_1, J_2, J_3, \ldots, J_n)$ where $J_i = \{A, C, T, G\}$.

The explosion of data in the biological sciences due to advances in high throughput sequencing technologies have led to an era of 'big' data. In this era, biological (genomic) data is churned out faster than it is being analysed [3]. Thus, there is a growing need to make sense out of this vast data to extract information that would guide clinical decisions and government policies. Deep learning (DL) is a branch of machine learning that is well suited to analyse copious amounts of data. The timely emergence of algorithms that employ multiple layers of a neural network (deep learning) has made it famous in the scientific world for analysis of biological data. The DL algorithms have shown to outperform maximally in terms of prediction accuracy [4]. Deep learning models are, however, well suited for a multiplicity of functions such as (but not limited to) speech recognition, text sequence prediction, image, and natural language processing [5]. One special type of DL is recurrent neural networks (RNNs) which is well suited for effectively analysing time-series data and other sequential data [6]. It is an extension to feed-forward networks, designed to allow the processing of sequences of variable-length (or even infinite-length). It is employed in natural language processing for speech recognition. Long short-term memory (LSTM) and gated recurrent units (GRUs) represent a fraction of the popular recurrent architectures reported in literature [6]. LSTM-based models are however commonly used for various forms of predictive analysis and classification problems involving genomic sequences. As a natural language processing tool, the inputs fed into LSTM-based models are always converted to a sentence made up of words of length $k$. The process of converting a sequence of nucleotides into computer readable formats is known as digitization.

This study seeks to extract and explain the various digitization techniques employed by various authors. To the best of our understanding, this is the first time such a review would be done. We envisage that the information in this paper would yield better understanding of LSTM applications, spur up more research into better digitization protocols, and equip future bioinformaticians with an arsenal of techniques for pre-processing.

## 2 LSTM Networks

Long short-term memory networks (LSTMs) are unique types of RNN that are designed to overcome the long-term dependency limitation of traditional RNNs. Typical of members of the RNN family, LSTMs consist of a chain of repeating modules. A distinguishing feature of LSTMs is the presence of four neural network layers within each repeating monomer in the chain, 3 sigmoid $\sigma$ layers known as forget gate, input gate and output gate, respectively, depending on their location and a tanh layer [7]. The basic architecture of an LSTM is shown in Fig. 1.

### *2.1 The Principle Behind LSTM*

The primary feature of LSTMs is the **cell state**, that is, the horizontal line seen at the top of Fig. 2. The cell state connects the output of the previous time stamp, $C_{t-1}$, to the output at the next, $C_t$ with some transient modifications in between. The modifications are implemented only when necessary, and as such, information may pass through a module unaltered [8].

One of the ways that LSTMs can circumvent the long-term dependency problem is through their ability to add (remember) or remove (forget) information to the cell state as carefully regulated by structures known as **gates**. Gates literally allow information (or manage passage of information) through the cell state. A pointwise multiplication operation and a sigmoid $\sigma$ neural network layer makes up a gate. The

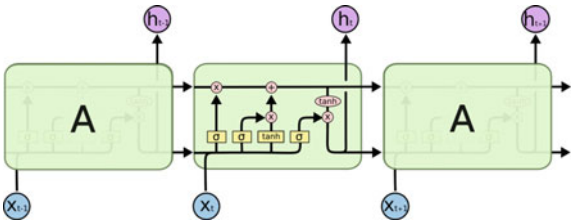


**Fig. 1** LSTM functional structure. The four functions within each repeating monomeric module are illustrated as 3 sigmoid, $\sigma$, functions and 1 hyperbolic tangent, tanh, function [7]

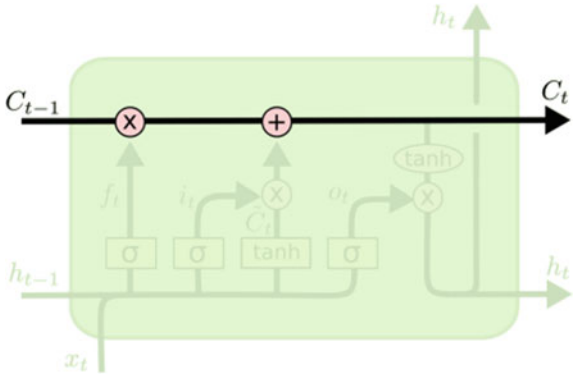


**Fig. 2** Cell state of an LSTM is shown as the arrow line from $C_{t-1}$ to $C_t$ with pointwise operations in between [7]

sigmoid layer yields outputs within a crisp set [0,1] where the value 0 implies that the corresponding information is forgotten while a value of 1 leaves the corresponding incoming information unaltered. An LSTM possesses three of these gates known as the forget gate, input gate, and output gate [7].

## 3 Digitization Techniques

### *3.1 Codon Indexing*

Khan et al. [9] report the use of a recurrent neural network-based long short-term memory (LSTM) for the prediction of the mutation rate of SARS-CoV-2 from whole genomic sequence. The effectiveness of this model is as presented by the root mean square error (RMSE) of 0.06 in testing and 0.04 in training. The authors in [9] utilized a digitization method known as codon indexing. This protocol represents the genomic sequence of each strain considered in the study as a sequence of indices (numbers) which are designated by a model that translates codons into unique 64 words as shown in Fig. 3. In this case, uracil in the standard biological genetic code was substituted with thymine, since DNA sequences were involved in the analysis and not RNA.

Mohamed et al. [2] developed a hybrid method known as the LSTM recurrent neural network and pre-processed genomic sequence data of Newcastle Disease Virus (NDV) and H1N1 of influenza A virus as text data for the prediction of next generation sequence. The model obtained a 98.9% accuracy when applied to influenza virus data set and an accuracy of 96.9% with NDV data set. The digitization technique employed by [2] involves an approach similar to the $k$-mer model, where $k = 3$. Firstly, the DNA sequence of a given species was converted into a sentence containing words of length 3. Each word in the sentence comprised of three nucleotides. Tokenization of each genomic sequence ensued which is characterized by representation of each

| | T | C | A | G | |
|---|---|---|---|---|---|
| T | 1. TTT | 5. TCT | 9. TAT | 13. TGT | T |
| | 2. TTC | 6. TCC | 10. TAC | 14. TGC | C |
| | 3. TTA | 7. TCA | 11. TAA | 15. TGA | A |
| | 4. TTG | 8. TCG | 12. TAG | 16. TGG | G |
| C | 17. CTT | 21. CCT | 25. CAT | 29. CGT | T |
| | 18. CTC | 22. CCC | 26. CAC | 30. CGC | C |
| | 19. CTA | 23. CCA | 27. CAA | 31. CGA | A |
| | 20. CTG | 24. CCG | 28. CAG | 32. CGG | G |
| A | 33. ATT | 37. ACT | 41. AAT | 45. AGT | T |
| | 34. ATC | 38. ACC | 42. AAC | 46. AGC | C |
| | 35. ATA | 39. ACA | 43. AAA | 47. AGA | A |
| | 36. ATG | 40. ACG | 44. AAG | 48. AGG | G |
| G | 49. GTT | 53. GCT | 57. GAT | 61. GGT | T |
| | 50. GTC | 54. GCC | 58. GAC | 62. GGC | C |
| | 51. GTA | 55. GCA | 59. GAA | 63. GGA | A |
| | 52. GTG | 56. GCG | 60. GAG | 64. GGG | G |

**Fig. 3** Digitization by indexing [9]

codon based on a dictionary of 64 words that typify the genetic code similar to codon indexing of [9]. The genetic code translation in this case yields unique numbers per codon present in the genome. The last step of digitization as carried out by [2] involved a padding phase which adds columns of zeros in order to make the sequences under consideration to be of equal length. This process is shown in Fig. 4.

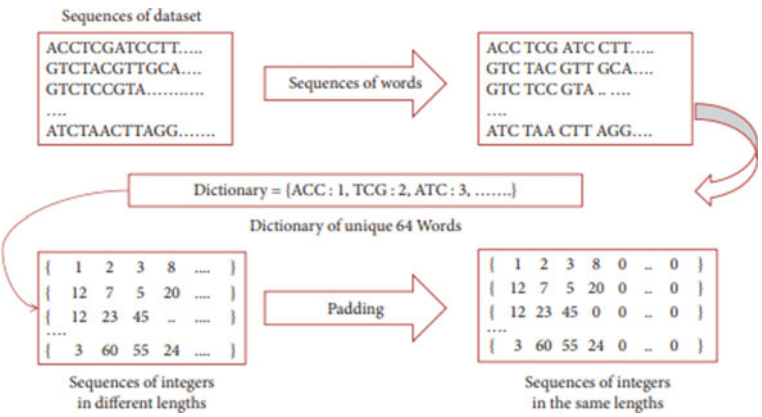


**Fig. 4** Digitization by indexing as proposed by [2]

### 3.2 *k-mer Embeddings and Bag of Words*

Deif et al. [10] compared the two subcategories of bidirectional RNN (LSTM and gated recurrent unit, GRU) for classification of coronaviruses, acute respiratory infection, and common cold viruses based on their genomic sequence. In this work, GRU was found to outperform LSTM for distinguishing closely related viral genomic sequences with an accuracy of 96.8%. The digitization phase was characterized by three steps. The first involved labelling of each genomic data corresponding to a virus as 0, 1, 2, 3, and 4. In second step, the genomic sequence of each virus considered was represented in computer readable forms through a *k*-mer technique. For a given DNA sequence D, the contiguous sequence is split into overlapping *k*-mers, where $k = 4$ using a sliding window with stride *w*. The window moves from the left-most nucleotide in the current *k*-mer towards the right by skipping the first nucleotide of the previous *k*-mer. The authors in [10] declared their preference of the *k*-mer technique over one-hot encoding as informed by several literature with respect to its capacity to reduce the time complexity and memory requirement of the latter. The third stage of digitization involved using a word2vec algorithm to map each 4-mer to a d-dimensional vector space. To produce a distributed representation of words to be fed as input to the bidirectional LSTM (BLSTM) and BGRU, Continuous Bag-of-Words (CBOW) was employed (Fig. 5).

A unique application of LSTM was reported in a recent work by [11]. A COVID-DeepPredictor was designed based on the LSTM model and applied as a discriminatory tool to distinguish between genomic sequences of SARS-CoV-1, SARS-CoV-1, MERS-CoV, Ebola, Dengue, and Influenza without sequence alignment. A 100% prediction accuracy was achieved. The *k*-mer technique was used to make a Bag-of-Descriptors (BoDs) for the generation of Bag-of-Unique-Descriptors (BoUDs) as vocabulary. The embedded representation was then used to denote each viral sequence.

Ching Liang and Sakakibara [12] developed a hybrid framework that combines CNN and LSTM to predict how to partition a de Bruijn graph for better exploitation of sequence information and to differentiate genomes of different species in each metagenomics sample. The framework adopted a *k*-mer (where $k = 6$) embedding approach. The hexanucleotides values range between 1 to 4096 for AAAAAA to TTTTTT, respectively, where a substitution of a single base in the 6-pb sliding

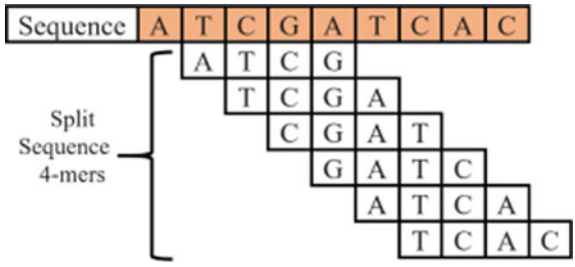


**Fig. 5** *k*-mer model showing a sliding window that iterates over overlaps of quadri-nucleotides [10]

window from the 5' to 3' direction will result to a change in the representation value (Example, AAAAAG = 2). This enables better exploitation of the metagenomics sequence information. The model has an accuracy of 55.6%.

### *3.3 One-Hot Vector Encoding*

The one-hot system of encoding is an effective and simple feature representation approach used to classify DNA sequences base on the nucleotide composition along the DNA sequences. In the one-hot encoding system, the four nucleotide of a DNA, adenine (*A*), cytosine (*C*), guanine (*G*), and thymine (*T*) are represented as (1, 0, 0, 0), (0, 1, 0, 0), (0, 0, 1, 0), and (0, 0, 0, 1), respectively [13].

One striking trend in literature is the use of one-hot vector encoding whenever there is a hybrid of convolutional neural networks (CNN) and LSTM. The work of [14] is no exception. Whata and Chimedza [14] proposed a convolutional neural network (CNN)-BLSTM for the prediction of DNA binding motifs and classification of SARS-CoV-2 amongst other members of the Coronaviridae family. As a common trend in studies that utilize a CNN layer for feature extraction, the (CNN)-BLSTM model proposed by [14] applied one-hot vector encoding for the representation of the text sequences in CNN readable format.

Quang and Xie [15] proposed a hybrid convolutional and recurrent neural network (DanQ) model for the prediction of DNA function. The model is a combination of a novel hybrid of convolutional and a bi-directional long short-term memory recurrent neural network to predict the function of non-coding DNA region. The model uses a one-hot coding scheme to encode the genomic sequences into a 4-bit row matrix by the convolution layer producing an output matrix. The size of the output's matrix is reduced by the max-pooling layer, and the outputs are feds into the hybrid bi-LSTM. The bi-LSTM considers the orientation and spatial distances between the motifs, reducing the dimensionality and feeding the output into a fully connected rectified layer unit. The output is transformed by this layer via a sigmoid nonlinear transformation [15].

Kuang and Wang [16] developed a hybrid CNN and LSTM network to predict RNA recognition pattern to enable identification of long non-coding (lncRNA) binding to a protein that regulates 3D genome organization and gene expression. The model uses one-hot spot coding scheme where the input sequences are converted to a $4 \times 20$ binary matrix by the convolution layer. The max-pooling layer help reduces the dimensionality, and the bi-LSTM layer is used to model the dependencies amongst motifs learned by the pooling layer in a bidirectional manner. The develop model have an accuracy of 77.7%, sensitivity of 73.3%, and specificity of 81.7%.

## 4 Conclusion

In this review, we have been able to point out some of the digitization techniques for processing genomic data in text format usable by LSTM-based models. These techniques include the codon indexing, one-hot vector encoding, and *k*-mer embeddings and Bag of Words. It was observed that almost all literatures that incorporated CNN as a feature extracting model in an LSTM hybrid made use of the one-hot vector encoding technique for feature extraction. This may be because such a representation meets the requirement of a 1– or 2-dimensional array of numbers suitable for training CNN models. Further research has to be carried out to test the time complexity, memory, and computational requirement of each digitization technique.

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# On Accountable and Distributed Audit of Outsourced Data

**Amit Kumar Dwivedi, Naveen Kumar, and Manik Lal Das**

**Abstract** Strong accountability identifies the misbehaving entity's activities and protects the honest entity from false accusations. This paper proposes a strong, accountable, and distributed auditing scheme for outsourced data in public cloud setup. A proof-based solution with fine-grained read-write access is used to address strong accountability and auditing of data services. A comparative analysis with similar work is carried out.

**Keywords** Accountability · Distributed audit · Distributed cloud

## 1 Introduction

In a data outsourcing model, data is stored to a third-party storage service provider by the data owner (DO). The data storage service is provided by the Cloud Service Provider (CSP). For efficiency reasons, direct access to the outsourced data is allowed by the authorized users avoiding any possibility of bottleneck at DO. As outsourced data is accessed directly without involvement of the CSP and DO could be untrusted, the security of its outsourced data poses a serious concern to the DO.

One way to address these security concerns is that the entities involved must be accountable for their assigned tasks. Accountability [15] is a state that ensures answerability. An accountable entity is legally responsible for its assigned duties [13]. Accountability is of two types: weak and strong. Auditability is a weak form of accountability. It only enables the auditor to detect any security violation [12]. Many

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schemes address weak forms of accountability. Some of them use centralized auditing [2] where either the DO or a trusted third-party audits the data. These schemes need significant computation costs at the auditor and failure of auditor halts the process. Far et al. [4] propose a distributed auditing scheme using blockchain to audit online transactions. Hao et al. [9] proposed a distributed data auditing mechanism where auditing task is distributed among auditor groups. The audit is successful using the consensus algorithm among group leaders. The use of consensus algorithm incurs delay in integrity audit. In a recent work [8], another distributed auditing scheme was proposed where the readers are the auditors for their authorized data files. They detect the data integrity violation during file read operation and report it to the DO. The above schemes only address detection of integrity violations, whereas it is not sufficient [12], and the DO needs an accountable auditing mechanism that provides proof of violations against integrity violators [6]. Furthermore, the auditors may ignore or delay the auditing process for efficiency reasons without getting noticed by the DO [8]. Strong accountability provides proof of violation and makes the entities answerable [12]. This work considers strong form of accountability such that the CSP [10] and the users including auditors must be answerable for their data practices. In the case of any security violation, the violating party must be liable for bearing the consequences. The following are the main contributions of this work.

- The scheme provides an accountable and distributed auditing scheme, where authorized readers act as the auditors, and a proof-based solution is used to address the accountability of the system entities.
- The accountability of the auditors is addressed to ensure timely detection and alert the data integrity failure reports to the DO.
- A comparison of the proposed scheme is carried out with the related schemes.
- The scheme is analyzed and implemented in AWS cloud instances, and the results show its practicality with strong auditing features.

## 2 The Proposed Accountable Distributed Auditing Scheme

Typically, three parties are present in the data outsourcing scenario [7, 11] the DO, the CSP, and the end users. The owner of outsourced data is the DO, which defines the fine-grained data access policy for the authorized users. It can delete, read, or write an outsourced record. CSP is a third-party organization that provides data storage-as-a-service to the DO. Upon receiving a read or write request, the CSP authenticates the user and fulfills the access request. The DO registers the end users and distributes access credentials to them that they will use to read and/or write the data files directly to the server.

**Assumptions and security requirements**: This work assumes the data files are encrypted before being outsourced to ensure confidentiality, and the decryption keys are received by authorized users through the DO. The read operation is frequent and the auditing task is distributed among the authorized readers. We assume partially

trusted users as they may delay or ignore the assigned task. Malicious-but-cautious CSP [1] is assumed here that may be involved in active attacks on data, but cautious about any provable trace against it. It may collude with external users and allow unauthorized modification to the outsourced data for mutual interests. Therefore, data integrity protection is an essential requirement but is not sufficient. Provable piece of evidence is necessary to enhance the confidence of the DO. Therefore, accountability is a necessary requirement to enhance trust among the system entities. We consider accountability of the following system entities.

- **Writer** is accountable for uploading correct and genuine data. It cannot deny if fake data is uploaded at the CSP on its behalf.
- **CSP** is accountable for allowing only authorized modification to the outsourced data. It cannot deny its involvement in any unauthorized data modification since the CSP maintains the storage entirely.
- **Auditors** are accountable for auditing and timely sending the correct $FR$s to the DO.

**Accountable write**: A data record was prepared by a writer and later communicated to the CSP. The CSP verifies the record structure upon authenticating the writer and uploads it to the server. To address the accountability requirement, the message in communication must contain a commitment to be verified later. A writer is accountable for what it is uploading in the outsourced store, including the correct formation of the record. To this extent, the record structure in [8] must be modified that contains the writer's commitment message. It is assumed that each party $p$ is assigned a public key and private key pair $\{PU_p, PR_p\}$. The record structure contains the record id ($ID$) of version ($V$) and encrypted file $E(K, X)$. $E()$ is symmetric encryption function, $X$ is the data file, $K$ is the symmetric encryption key shared between all authorized users including the DO. Furthermore, it contains a signed hash $\{H(ID||V||E(K, X))\}PR_W$, where $H()$ is secure hash function, $\|$ is a bit-wise concatenation operator, and $PR_W$ is private key of its writer $W$.

Compared to the earlier record structure, a signed hash is used, replacing the earlier authentication code $AC$. The hash is computed and signed by the writer using its private key. Signed hash is used for writer's authentication and outsourced data integrity verification. It is also a proof or a commitment message that makes the writer accountable for his written record.

**Auditing writer's accountability**: A writer is accountable for creating the correct record and its content. A writer may casually compute the data record and dispatch it to the CSP. Therefore, the CSP will verify the record before uploading it at the server, as it has to provide proof of the successful upload of the data record to the writer. If incorrect record structure is received, the write operation fails and is acknowledged the writer. Otherwise, the data record is published. Note that the content of the record cannot be verified as it is encrypted. The signed hash $WSH$ works as a proof of written record and is stored with the record. The audit of the outsourced record is done in the following two phases.

*Phase I-Distributed audit* In this scheme (shown in Fig. 1), the read authorized users are the auditors who audit the authorized data files upon read access. Fine-

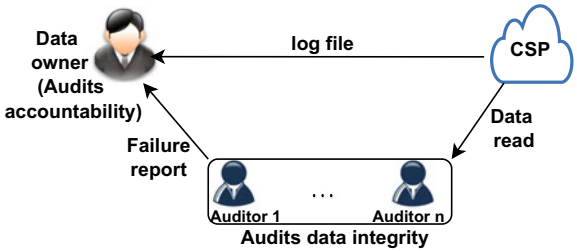


**Fig. 1** Accountable and distributed auditing

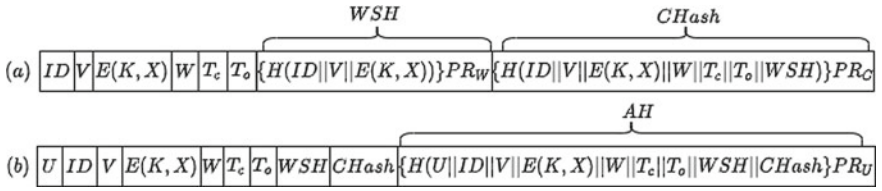


**Fig. 2** **a** Data record received by the auditor, **b** Structure of $FR$

grained access is considered in this work. Upon read access, if an auditor detects an integrity violation, it shares a corresponding failure report ($FR$) to the DO. The structure of the $FR$ is shown in Fig. 2b.

The procedure of auditing a record by an auditor is as follows. An auditor receives the authorized data record $(R < ID, V, E(K, X), W, T_c, T_o, WSH, CHash >)$ containing a data record id $ID$, version $V$, encrypted data file $E(K, X)$, writer's id $W$, current timestamp $T_c$, the timestamp when the data record was stored at the CSP $T_o$, $WSH$, and $CHash$. Upon receiving $R$, the auditor decrypts $CHash$, computes $CH \leftarrow H(ID \| V \| E(K, X) \| W \| T_c \| T_o \| WSH)$ and verifies both of them. If verification fails, i.e., the data record received from the CSP is incorrect, the auditor re-initiates the data access request. If verification succeeds, the auditor computes $AuditorHash \leftarrow H(ID \| V \| E(K, X)$, decrypts the $WSH$, and computes $Y \leftarrow D(K, E(K, X))$. If the $AuditorHash$ and $WSH$ are same or $Y$ is correct then there is no data integrity violation. Else, either record structure or data is received incorrect. On incorrect data received, the auditor computes a signed hash $AH$ (see Fig. 2b) for the received data record and constructs the $FR$. It will store the audit report $AR \leftarrow \{ID, V, T_c, CHash\}$ locally which may be needed by the DO during $FR$s verification later. The $FR$ will be sent by the auditor to the DO for further processing. If the decryption of the data file results in bogus data, it concludes that the writer has uploaded it as the $WSH$ was signed by the writer.

*Phase II-Verifying failure reports*: In this phase, the DO verifies the $FR$s sent by the auditors. If DO confirms the integrity failure, it may take appropriate actions against the violating party. Else, the $FR$ is dropped. The $FR$s verification process is as follows.

The DO receives a $FR$ containing auditor's id $U$, record id $ID$, version $V$, encrypted data file $E(K, X)$, writer's id $W$, data record access timestamp $T_c$, data upload timestamp $T_o$, the writer's signed hash $WSH$, a cloud signed hash $CHash$ and an auditor's signed hash $AH$. $AH$ works as proof by the auditor for the claim it has made in the $FR$. The DO verifies the $FR$ by decrypting $AH$. If integrity verification succeeds, the DO computes $CHash1 \leftarrow \{H(ID \| V \| E(K, X) \| W \| T_c \| T_o \| WSH)\}$, decrypts $CHash$, and compare them. If both are the same, it decrypts $WSH$ as $WriterHash$ and computes $DH \leftarrow \{H(ID \| V \| E(K, X))\}$ to verify the proof of data record sent by the writer to the CSP. If $WriterHash$ is the same as $DH$ (i.e., the proof produced by the writer is correct, the DO concludes that there is no integrity violation and decrypts the encrypted data file $E(K, X)$ using $K$ into $Y'$. If $Y'$ is unintelligent message, it confirms the content failure. Else, the data record is correct. Since the signatures are unforgeable, the CSP and the writer cannot deny what they uploaded and communicated.

**CSP's accountability**: The CSP is accountable for allowing fine-grained data access by the authorized readers and for any unauthorized modification to the outsourced data. An accountable CSP improves the DO's trust on it. Since the data is secret and is kept with the untrusted CSP, the CSP's accountability must be frequently audited. The accountability verification process of the CSP is described using two steps: Step 1 describes how an auditor verifies a data record's integrity and Step 2 re-verifies the $FR$s at the DO. The auditors will verify the outsourced data in a distributed fashion as each auditor will verify their authorized data records during data read operation. The auditor receives $R < ID, V, E(K, X), W, T_c, T_o, WSH, CHash >$. Upon successfully verifying the CSP's signature, the auditor verifies the writer's signed message $WSH$. If both are different (i.e., $AuditorHash! = WriterHash$, it concludes the unauthorized modification of the outsourced data record. This is impossible without the involvement of CSP, as it is found different than what was written by the writer. As the CSP has provided signed proof $CHash$, it can be verified. In this case, a respective $FR$ is computed and sent to the DO. It re-verifies the $FR$, and if the claim is found correct, appropriate action against the CSP is taken. During the re-verification process in Step 2, if an integrity violation has occurred, it must be caught by the DO using the above two steps.

**Auditor's accountability**: An auditor is accountable for two aspects. Firstly, sending correct ($FR$s) to the DO avoids wasting resources. Secondly, the auditor may ignore or delay the audit process for efficiency reasons. Meanwhile, the infection may be spread over a large horizon. Therefore, the auditor must be accountable for timely auditing of the data files.

If an audit failure is detected, the auditor computes $AH$, adds to $FR$, and conveys it to the DO. The DO verifies $AH$ and the proof of the data record produced by the CSP. Successful verification verifies the content. If the proofs sent by the CSP and the writer are correct, it confirms no violation. The auditor cannot deny it due to the signed $AH$ in $FR$. The auditor may ignore the audit process. To address this, we suggest a log-based solution, where a log is created at the server for each data access. The log file contains the user's id $U$, accessed file id $ID$, version $V$, access type $R/W$, and access timestamp $T_c$. To verify the auditor's accountability, the DO

accesses the CSP's public log file $L_f$. The $L_f$ is signed and published by the CSP after every fixed interval. Knowing the corrupted data record in $FR$, the DO verifies the auditors, including those who have recently accessed the given data record. Upon receiving $L_f$ and $FR$, the DO verifies the $FR$ and finds the respective record $r$ in $L_f$ to verify the other auditors who have recently accessed the same data record. If they accessed the record and did not report it to the DO, action may be taken against the auditor(s).

## 3 Experimental Results

We consider a computer with ubuntu acts as the DO, and an ubuntu instance hosted on AWS acts as the CSP. This scheme is implemented in Python.

*Computation cost at the auditor*: The auditing of a data record is performed whenever an auditor accesses it from the cloud in comparison with the traditional auditing schemes, where the auditor plans, access a group of files, and audited them. Computational cost at the auditor is measured for varying file sizes, i.e., 100, 500 KB, and 1 MB. The experiment is performed on 100, 300, 500, 700, and 1000 files considering varying file sizes. We have considered varying audit failure rates of 1, 2, and 5% of the total audited data records at a time. The result is shown in Fig. 3. Here, the computation cost for 5% $FR$s is nearly the same as 1% and 2% $FR$s. The auditing cost is linearly growing with the data files. Since the file size changes 5 times from 100 KB to 500 KB, the difference in the computation cost is higher when compared to the 1 MB files.

*FRs verification cost at the DO*: Upon detecting an audit failure, each auditor sends the respective $FR$ to the DO which is then verified. In this experiment, a local machine acts as a DO with the same configuration as above. The cost is computed for 200, 400, 600, 800, and 1000 $FR$s considering varying file sizes of 100 KB, 500 KB, and 1 MB. The cost of $FR$ verification is shown in the Fig. 3b. It is shown, as the number of failures enhances, its verification cost increases linearly.

## 4 Performance Evaluation and Discussion

This section compares and analyzes the proposed scheme with the existing schemes. In Table 2, the detailed comparison is given, and abbreviations and notations used in Table 2 are described in Table 1.

The proposed scheme is deterministic as each data record is accessed with equal probability which gives more confidence to the auditor in the verification process. The accountability of the CSP, auditors and the writers is verified by the DO which increases the computation cost as compared with [8]. However, as compared to DSwCCC and PbA schemes, the computation cost is less as the DO is only verify the audit $FR$s. Also, the audit failures are significantly less to all the data files.

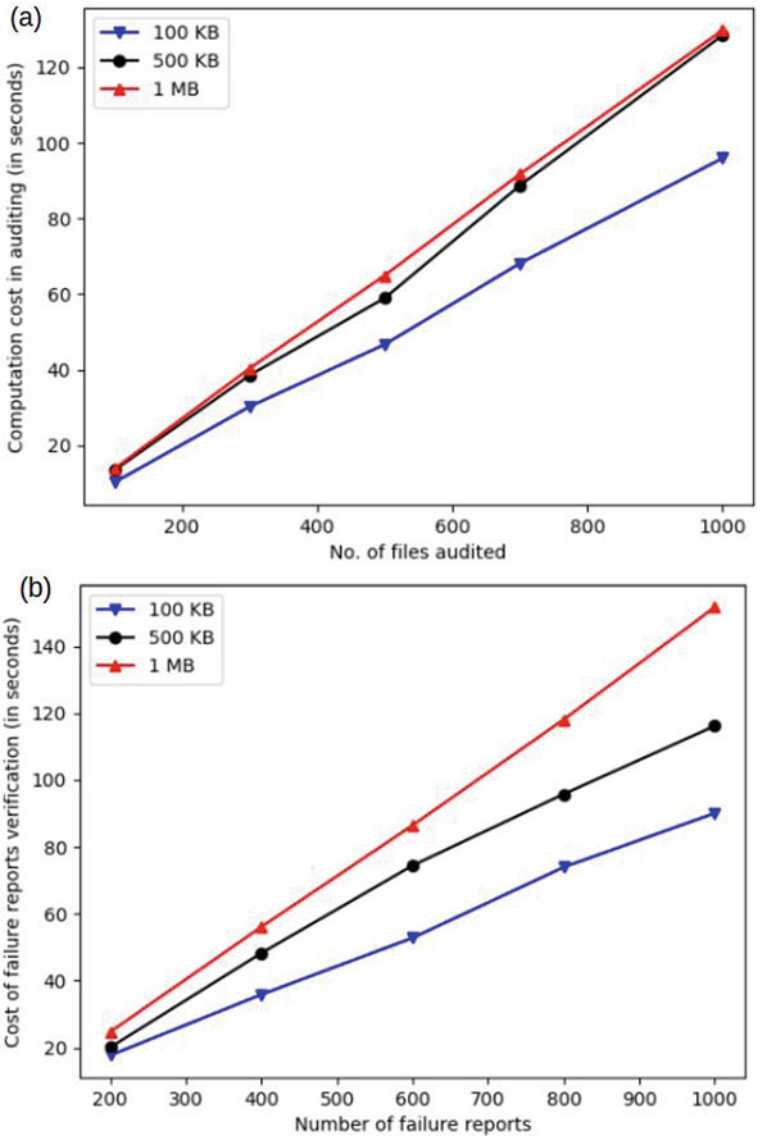


**Fig. 3** Computation cost: **a** auditing at auditor and **b** $FR$ verification at DO

**Table 1** Abbreviations and notations used in the comparison table

| Abbrev./ Notations | Description | Abbrev./ Notation | Description | Abbrev./ Notation | Description | Abbrev./ Notation | Description |
|---|---|---|---|---|---|---|---|
| DSwCCC | Deterministic scheme with constant comm. cost | PSRLS | Probabilistic scheme with reduced local storage | PSDD | Probabilistic scheme for dynamic data | PbA | Priority-based auditing |
| $t$ | Number of pre-computed challenges | $c$ | Number of files/blocks in a challenge | $\#X$ | No. of times operation $X$ executes | $k$ | No. of $FR$s received by DO at audit |
| $Mul$ | Multiplication operation | $Div$ | Division operation | $K/K'$ | Symm./Asymm. key | $n$ | Number of files |
| $\#A_F$ | No. of auditors asked by DO for audit report | $D/D'$ | Symmetric Asymmetric decryption | $Add$ | Addition operation | R/W | Read/Write operation |
| | | | | DS | Deterministic scheme | $RG$ | Random number generation |

**Table 2** Comparison of the schemes

| Properties↓ \ Scheme → | DSwCCC [5] | PSRLS [2] | PSDD [3] | PbA [14] | Existing DS [8] | Proposed DS |
|---|---|---|---|---|---|---|
| Proof Type | Deterministic | Probabilistic | Probabilistic | Probabilistic | Deterministic | Deterministic |
| Computation cost at the DO | $n(RG + 2 * Add) + 1Mul + H$ | $c * (D' + H + Div)$ | $c * D$ | $(\#R + \#W)D' + (2 * n - 1)H$ | $k * H$ | $k * \{3H + 3D' + D + \#A_F * 2(D' + H) + \mathcal{O}(\lvert log \rvert)\}$ |
| Communication cost between CSP and DO | $2 * \lvert Digest \rvert$ | $2 * \lvert Digest \rvert$ | $2 * \lvert Digest \rvert$ | $\#W * \lvert F \rvert$ | $k * (\lvert F \rvert + \lvert Digest \rvert)$ | Nil |
| Communication cost between user and DO | NA | NA | NA | $(\#R+\#W) * (\lvert A \rvert + \lvert Digest \rvert)$ | $k * (2 * \lvert ID \rvert + \lvert V \rvert)$ | $\lvert F \rvert + \lvert Digest \rvert$ |
| Storage at auditor | $n * \lvert Digest \rvert$ | $3 * \lvert K' \rvert + \lvert \#c \rvert$ | $3 * \lvert K \rvert$ | $(\#R+\#W) * (\lvert A \rvert + \lvert Digest \rvert)$ | $2 * \lvert K \rvert$ | $\lvert K \rvert + \lvert \#AR \rvert$ |
| Additional Storage at CSP during audit | $n * \lvert Digest \rvert$ | $n * \lvert Digest \rvert$ | $t * \lvert Digest \rvert$ | NA | NA | NA |
| Cryptosystem | Asymmetric | Asymmetric | Symmetric | Asymmetric | Symmetric | Asymmetric/ Symmetric |
| Dynamic Data Support | No | No | Yes | Yes | Yes | Yes |
| Decentralized Audit | No | No | No | No | Yes | Yes |
| Audit type | Agressive | Aggressive | Aggressive | Aggressive | Lazy | Lazy |
| Accountable scheme | No | No | No | No | No | Yes |

Therefore, as compared to DSwCCC [5], PSRLS [2], and PbA [14], there is no significant change in the computation cost.

In verification of a $FR$, the DO searches in the log file for the auditors who have earlier read the same data record. The searching cost of the auditor (i.e., $\mathcal{O}(|logp|)$) depends on the number of records ($P$) in the log file. The communication cost between the DO and the CSP is nil. The communication cost between the auditor and the DO increases as the auditor sends the $FR$s to the DO. With each auditor and $FR$, only one file is sent to the DO. The storage require at the auditor is less than the DSwCCC, PSRLS, and PbA schemes but increases with respect to [8] as the auditor stores audit report for each integrity $FR$.

## 5 Conclusions and Future Work

Auditing of outsourced data in public cloud is essential requirement that enhances the business goals. Participating entities involved in auditing must be accountable as per the agreed terms. This work proposed a strong accountable distributed auditing scheme that uses a proof-based solution with fine-grained read-write access to the data as well as services. The scheme is implemented in AWS cloud instance, and the performance result shows its efficiency and practicality. Furthermore, the access control issues such as credential leakage can be explored.

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# Predicting the Workload in Debt Collections to Improve the Efficiency of Manpower Planning

**Pornpimol Chaiwuttisak**

**Abstract** This research aimed to predict volume workloads in debt collections and compare the accuracy of forecasting methods. Three forecasting methods were considered in the study: the SARIMA model, the random forest model, and long short-term memory. The data used in this study were a time series of a daily debt collection volume workload due 1, 5, 10, 15, 20, and 25 in the used car loan corporation. They were divided into 2 datasets. The first dataset containing the past data from June 2020 to October 2020 was used for selecting the most suitable model, and the second dataset containing the past data from November 2020 to December 2020 was used for comparing the prediction accuracy of each forecasting model in terms of mean absolute percentage error (MAPE). Consequently, the lowest MAPE achieved by LSTM for different due dates was 6.79%, 6.24%, 7.08%, 10.88%, 12.45%, 10.17%, respectively, while the MAPE achieved by random forest was 11.72%, 11.27%, 8.94%, 11.92%, 13.91%, 16.67%, respectively, and the MAPE achieved by SARIMA was 23.35%, 32.87%, 32.58%, 30.07%, 33.93%, 27.31%, respectively. It indicates that the LSTM model was the most accurate to forecast the daily debt collection volume workload of the field debt collector in advance of the future. The predicted workload can be used as a piece of supporting information for adequate workforce planning of the corporation's used car loan.

**Keywords** Box–Jenkins method · Debt collection volume workload · Deep learning · Machine learning · Time series analysis

## 1 Introduction

Banks have an important role in driving the national economy of the country. They act as a financial intermediary that collects deposit money from savers and lends to borrowers who have a legal obligation to make payments to the bank over time. At present, several banks and financial institutions are offering more varieties of loans.

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A second-hand car loan is a loan that has been paying attention to people who want to buy a car.

When a loan agreement with a bank occurs, the borrower is a debtor, and the financial institution has a legal creditor status. However, financial institutions will collect debts in order to receive debts or loans released back. The operation starts with warning the debtor before the payment due date. When the debtor does not pay the debt according to the agreed time, debt collection officers need to take action in order to receive the payment of the debt. There may be considerations in order for the debt collection process to be successful. That is the way for creditors to receive their debts in full as quickly as possible and in a legitimate and lawful manner.

A debt collection department of a bank is responsible for debt collection from customers who request a loan service for the purchase of second-hand cars from dealers who are representatives through the process of debt collection. The process starts with the preparation of a warning letter for late payment and negotiating debt restructuring, such as preparing a letter of acceptance or promissory note in the event that a new debt repayment condition is agreed upon that differs from the original debt. In the event that the debtor defaults on payment and cannot be contacted, there will be officials to expedite the debt in the field to negotiate debt collection with the debtor.

Planning and allocating the workload of the debt collection officers in the field can help to increase the efficiency in tracking the debt collection of the debt collector. Therefore, the research aims to create models to daily forecast the workload of the debt collectors in the field. Three different methods: SARIMA, random forest, and long short-term memory are employed. The accuracy of those forecasting models can be compared by considering on mean absolute percentage error (MAPE).

## 2 Literature Reviews

### *2.1 Seasonal Autoregressive Integrated Moving Average (SARIMA)*

A seasonal autoregressive integrated moving average (SARIMA) model is one approach of the Box–Jenkins approach [1] for forecasting the seasonal time series data. It can extend from the ARIMA model by adding the seasonal component. The SARIMA is the model that transforms non-stationary time series into stationary time series by differencing. The SARIMA can be expressed in Eq. 1.

$$\phi_P(B)\Phi_P(B^S)(1-B)^d(1-B^S)^D y_t = \theta_q(B)\Theta_Q(B^S)\varepsilon_t \tag{1}$$

where $\phi$ and $\theta$ are parameters of the autoregressive and moving average, whereas $\Phi$ and $\Theta$ are parameters of the seasonal autoregressive and seasonal moving average, respectively. Consequently, $p$, $d$, and $q$ are the order of non-seasonal autoregressive, a

degree of non-seasonal differencing, and the order of non-seasonal moving average, respectively. $P$, $D$, and $Q$ are the order of the seasonal autoregressive, a degree of seasonal differencing, and the order of seasonal moving average, respectively. $S$ is the length of the seasonal pattern; $y_t$ is the predicted variable, and $\varepsilon_t$ is a random error at time $t$.

## 2.2 Random Forest

Random forest (RF) is a technique of supervised learning algorithm based upon tree modeling. It is one of the models known as ensemble learning where the principle is to train the same model, several times on the same dataset. The different portions of the data are selected to train in each epoch, and then take the decision of those models to vote on which class is the most chosen shown in Fig. 1. The advantage of this approach is that it provides accurate forecasting results and overcomes the problem of over-fitting.

## 2.3 Long Short-Term Memory

The long short-term memory (LSTM) is an algorithm developed on the recurrent neural network (RNN) architecture for solving the vanishing gradient problem by redesigning the cell function to be able to store the state of the calculation [2]. There are three segments known as gates of an LSTM cell. The first segment is forget gate; the second segment is the input gate, and the last segment is the output gate shown in Fig. 2.

The LSTM has the hidden state of the previous timestamp represented by $H(t-1)$ and the hidden state of the current timestamp represented by $H(t)$. Furthermore, the LSTM also has a cell state represented by $C(t-1)$ and $C(t)$ for previous and current timestamps, respectively. The hidden state is called as short-term memory, while the cell state is called as long-term memory.

Kane et al. [3] studied the H5N1 avian influenza outbreaks prediction by applying ARIMA and random forest (RF) time series models. The comparison of ARIMA and RF model showed that RF model was better than the ARIMA model. Moreover, it also found that the RF model was effective to predict H5N1 outbreaks in Egypt.

Peng et al. [4] studied monthly tide prediction based on random forest (RF) algorithm and the new phase space reconstruction theory. Furthermore, the Cao method and mutual information function method were used for phase space reconstruction. The parameters of the RF model were considered to analyze the monthly tide data of the Pingshan Hydrological Station of Jinsha River Basin. The RF was compared to the neural network (BPnet) model and the support vector machine (SVM) model. The study found that the RF model is the most effective in prediction.

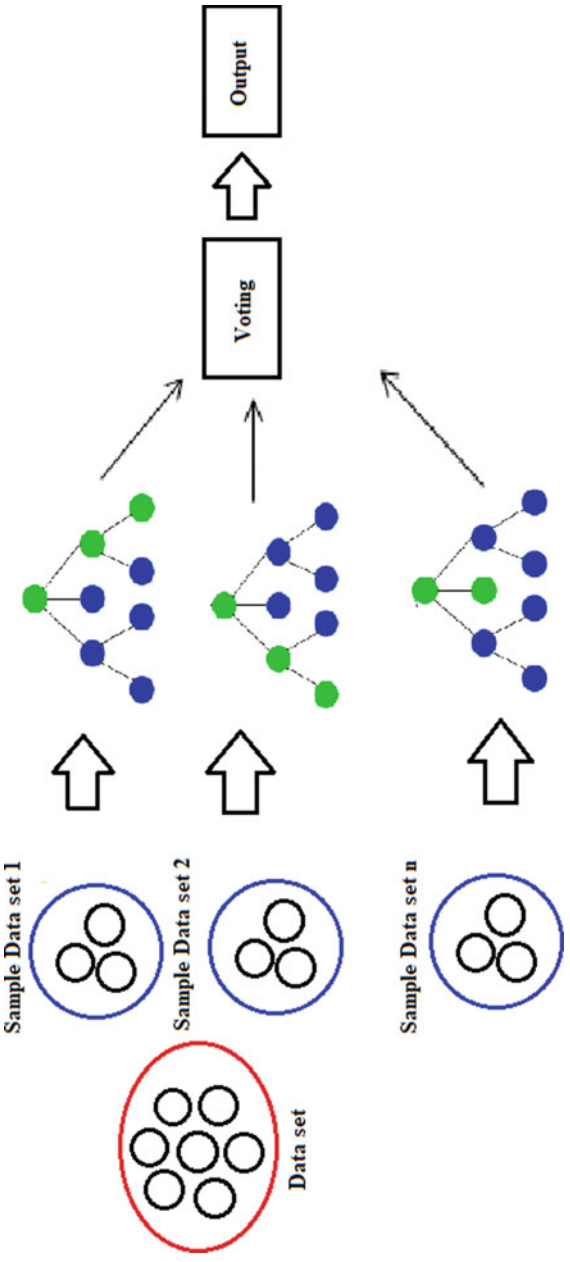


**Fig. 1** Random forest architecture

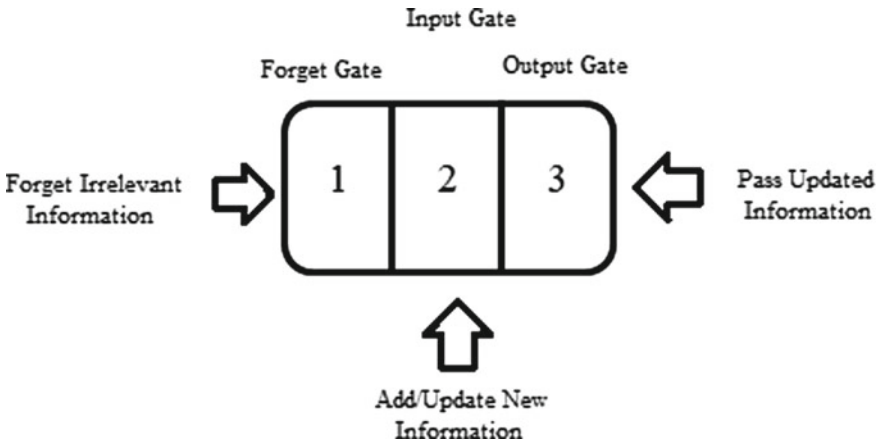


**Fig. 2** LSTM architecture

Abdoli et al. [5] studied comparison of the accuracy of the forecasting model based on the LSTM and ARIMA for the permanent volatile time series. It applied daily data of the Tehran Stock Exchange (TSE) for the past 10 years to make predictions for the next two months. The study found that the LSTM method outperformed the ARIMA method with predictive errors of 3 periods for 20 days is 3.22, 2.73, 25.76% for the ARIMA method, and 9.32, 3.84, 46.95% for the ARIMA method.

Siami-Namini et al. [6] study a comparison between ARIMA and LSTM in time series forecasting and examine whether LSTM is better than traditional forecasting methods. It used monthly financial time series or stock market data from the Yahoo website from January 1985 to August 2018. The studies have shown that the LSTM method outperformed ARIMA methods, whose RMSE values using rolling ARIMA and rolling LSTM were 511.481 and 64.213, respectively.

## 3 Research Methodology

Data used to forecast the workload of the field debt accelerators for a used car loan agency are secondary data collected from the customer agreement details. It is time series data from June 2020 to December 2020. Data from June 2020 to October 2020 are used as the training dataset for building the forecast models in various methods and data from November 2020 to December 2020 as a test dataset for evaluating the forecast results of the different models.

Figure 3 shows the time plot of the daily workload of debt collection officers by using the augmented Dickey–Fuller test (ADF) statistical test. It is found that the data are not stable. Moreover, the amount of debt collection workload of debt collectors is clearly seasonal. Therefore, it is necessary to eliminate seasonal variations. In this research, the seasonal difference method is used. As a result, the stability of this data

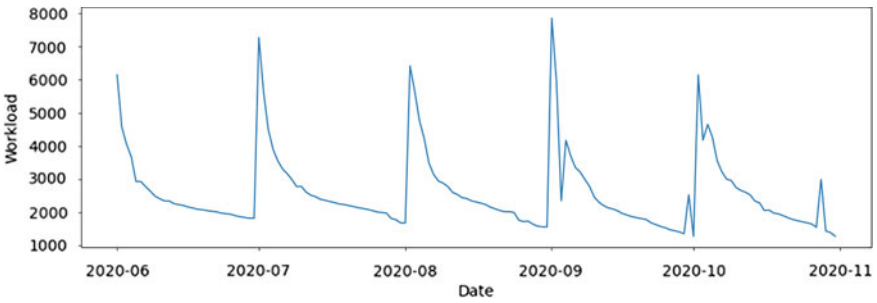


**Fig. 3** Time series plot of the amount of daily workload in debt collection of debt collection officers for the payment due on 1st date

**Table 1** Testing the stability of the workload data in debt collection of field debt collectors at the date of payment 1st, 5th, 10th, 15th, 20th, 25th

| Payment due date | *P*-value |
|---|---|
| 1 | 0.000000009 |
| 5 | 0.000000155 |
| 10 | 0.000008572 |
| 15 | 0.000002492 |
| 20 | 0.000004519 |
| 25 | 0.000014728 |

is tested with the datasets at a significance level of 0.05 shown in Table 1. In this study, the hyperparameter is tuned by the random search method to find the boundary suitable restriction. The number of an epoch is in the range from 1 to 100, and the number of neurons starts from 100 to 4000.

From Figs. 4 and 5, when taking the 1st difference of the seasonal variation, the ACF and PACF values declined sharply to zero. It shows that the time series is constant.

The mean absolute percentage error (MAPE) is considered to compare the performance of forecast models. Namely, the model with the lowest MAPE value is selected to be the model for prediction.

## 4 Result

It is found that the data showed seasonal variations every 30 days, Therefore, $s = 30$ is determined to build the appropriate model. The suitable model is considered at the lowest AIC value.

As Table 3, it was found that $p = 1$, $d = 0$, $q = 0$ and $P = 0$, $D = 1$, $Q = 1$ provide the lowest AIC value (shown in Table 2) for the payment due of 1st date.

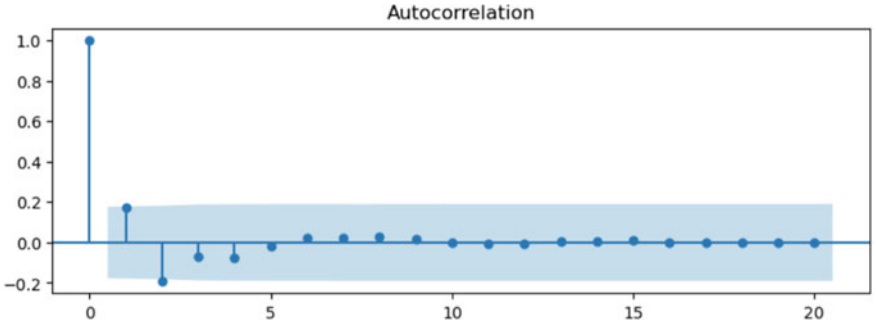


**Fig. 4** Autocorrelation function (ACF) value of the 1st seasonal difference for the payment due of 1st date

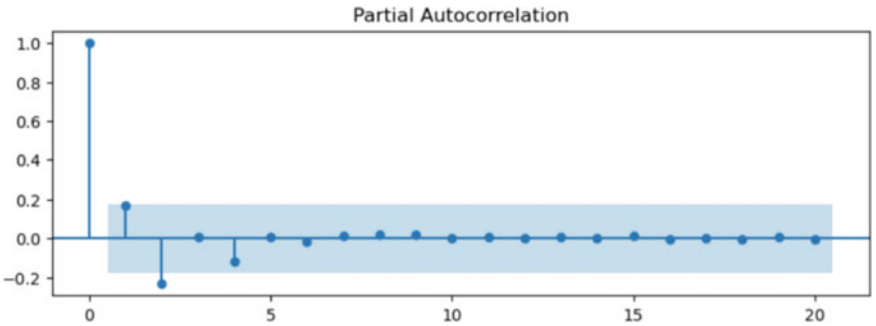


**Fig. 5** Partial autocorrelation function (PACF) value of the 1st seasonal difference for the payment due of 1st date

The optimal parameters for other payment due dates were shown in Tables 4, 5, 6, 7 and 8.

Table 9 compares the MAPE of three forecast models for the amount of workload in debt collection of field debt collectors. It was found that the LSTM was a suitable model to predict the amount of workload in debt collection for the payment due date of 1st, 5th, 10th, 15th, 20th, and 25th which yielded the following MAPE of 6.79, 6.24, 7.08, 10.88, 12.45, and 10.17, respectively. The LSTM has been used as a guide or additional information in the planning of future debt collection work for field debt collectors.

The forecast of the amount of workload in the debt collection process of the field debt collectors is shown in Table 10. When considering the manpower rate according to the forecast amount of workload on every payment date, the company's staff manpower will be allocated suitable for debt collection of 239 field debt collectors in one month closing period.

**Table 2** AIC value of ARIMA ($p$, $d$, $q$) SARIMA ($P$, $D$, $Q$) for the payment due on 1st date

| ARIMA$(p, d, q)$SARIMA$(P, D, Q)_s$ | AIC |
|---|---|
| ARIMA(0, 0, 0)SARIMA$(0, 0, 0)_{30}$ | 2845.664 |
| ARIMA(0, 0, 0)SARIMA$(0, 0, 1)_{30}$ | 2178.319 |
| ARIMA(0, 0, 0)SARIMA$(0, 0, 2)_{30}$ | 1608.121 |
| ARIMA(0, 0, 0)SARIMA$(0, 1, 0)_{30}$ | 2033.939 |
| ARIMA(0, 0, 0)SARIMA$(0, 1, 1)_{30}$ | 1528.862 |
| ARIMA(1, 0, 0)SARIMA$(0, 1, 1)_{30}$ | 1527.852 |
| … | … |
| ARIMA(0, 1, 0)SARIMA$(0, 0, 1)_{30}$ | 2015.562 |
| ARIMA(0, 1, 0)SARIMA$(0, 0, 2)_{30}$ | 1538.189 |
| ARIMA(0, 1, 0)SARIMA$(0, 1, 0)_{30}$ | 2079.978 |
| ARIMA(0, 1, 0)SARIMA$(0, 2, 1)_{30}$ | 2702.607 |
| ARIMA(0, 1, 0)SARIMA$(1, 0, 0)_{30}$ | 2035.453 |
| ARIMA(0, 1, 0)SARIMA$(1, 0, 1)_{30}$ | 2017.286 |

**Table 3** Parameters of SARIMA model for the payment due on 1st date

| Model | Parameter | | | | | |
|---|---|---|---|---|---|---|
| | $p$ | $d$ | $q$ | $P$ | $D$ | $Q$ |
| ARIMA$(p, d, q)$SARIMA$(P, D, Q)_s$ | 1 | 0 | 0 | 0 | 1 | 1 |

**Table 4** Parameters of SARIMA model for the payment due on 5th date

| Model | Parameter | | | | | |
|---|---|---|---|---|---|---|
| | $p$ | $d$ | $q$ | $P$ | $D$ | $Q$ |
| ARIMA$(p, d, q)$SARIMA$(P, D, Q)_s$ | 0 | 1 | 1 | 0 | 1 | 1 |

**Table 5** Parameters of SARIMA model for the payment due on 10th date

| Model | Parameter | | | | | |
|---|---|---|---|---|---|---|
| | $p$ | $d$ | $q$ | $P$ | $D$ | $Q$ |
| ARIMA$(p, d, q)$SARIMA$(P, D, Q)_s$ | 0 | 0 | 1 | 1 | 1 | 1 |

**Table 6** Parameters of SARIMA model for the payment due on 15th date

| Model | Parameter | | | | | |
|---|---|---|---|---|---|---|
| | $p$ | $d$ | $q$ | $P$ | $D$ | $Q$ |
| ARIMA$(p, d, q)$SARIMA$(P, D, Q)_s$ | 0 | 0 | 0 | 1 | 1 | 1 |

**Table 7** Parameters of SARIMA model for the payment due on 20th date

| Model | Parameter | | | | | |
|---|---|---|---|---|---|---|
| | $p$ | $d$ | $q$ | $P$ | $D$ | $Q$ |
| ARIMA$(p, d, q)$SARIMA$(P, D, Q)_s$ | 1 | 1 | 0 | 0 | 1 | 1 |

**Table 8** Parameters of SARIMA model for the payment due on 25th date

| Model | Parameter | | | | | |
|---|---|---|---|---|---|---|
| | $p$ | $d$ | $q$ | $P$ | $D$ | $Q$ |
| ARIMA$(p, d, q)$SARIMA$(P, D, Q)_s$ | 0 | 1 | 1 | 0 | 1 | 0 |

**Table 9** Comparison result of the three forecasting methods for the amount of workload in debt collection of field debt collectors in the payment due date of 1st, 5th, 10th, 15th, 20th, 25th

| Payment due date | MAPE | | |
|---|---|---|---|
| | SARIMA | Random forest | LSTM |
| 1 | 23.35 | 11.72 | 6.79 |
| 5 | 32.87 | 11.27 | 6.24 |
| 10 | 32.58 | 8.94 | 7.08 |
| 15 | 30.07 | 11.92 | 10.88 |
| 20 | 33.93 | 13.91 | 12.45 |
| 25 | 27.31 | 16.67 | 10.17 |

**Table 10** Forecast of workloads in debt collection on the different payment due dates

| Payment due date | Amount of workload in debt collection of the field debt collector |
|---|---|
| 1 | 6510 |
| 5 | 15,700 |
| 10 | 16,500 |
| 15 | 12,600 |
| 20 | 5400 |
| 25 | 3000 |

## 5 Conclusion

The objective of this research was to study a suitable model for forecasting the workload in debt collection of field debt collectors to use the model as a guide for decision-making in manpower planning. Therefore, the researcher studied and selected the most suitable model for forecasting the amount of debt collection workload of field debt collectors by comparing the accuracy of the forecast values. The mean absolute percentage error (MAPE) is used to compare the performance of the SARIMA model, random forest, and LSTM model. The LSTM model is outstanding with the lowest MAPE value. In the future study, it will include other techniques

such as gated recurrent unit (GRU) which may provide in more accurate forecasting results.

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# Artificial Intelligence: Benefits, Application, Ethical Issues, and Organizational Responses

**Khalda Ali, Maram Alzaidi, Dimah Al-Fraihat, and Amir M. Elamir**

**Abstract** Artificial intelligence (AI) ethics is a hotly debated subject. Increasingly, both service providers and users face ethical dilemmas. To ensure that the development, deployment, and usage of AI are all morally permissible, various initiatives have been launched. For the most part, it's not clear how AI-enabled businesses deal with these ethical challenges. Our paper identified four main ethical issues of AI (i.e. "Ubiquitous surveillance, social engineering, transhumanism, machine learning issues, and metaphysical issues"). It also identified two main mitigation strategies (i.e. "Policy-level mitigation, corporate governance of AI ethics"). Many people, including those working in AI-related organisations and academia can benefit from these findings, but policymakers grappling with how to best handle ethical concerns generated by AI may find them most useful.

**Keywords** Artificial intelligence · Ethical concerns · Organisational responses

## 1 Introduction

Ethics are still a hot topic when it comes to artificial intelligence (AI). Since AI is becoming increasingly widespread, particularly machine learning and big data analytics-based AI technologies, ethical considerations have emerged as a major issue. Even though the idea of AI dates back to the 1950s and ethical questions about AI have been talked about for decades, civil society, policymakers, and the media have only recently started to pay attention to this topic. The twin forecasts to the US President on the subject (2016) may be a good indicator of how much more people are thinking about it. The reason for this growing interest is that these technologies

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are getting better and better at doing things that utilized to be done by individuals. Games traditionally associated with human intelligence are now being easily beaten by these machines, but they are also getting close to or passing human levels in a wide range of tasks, such as recognizing faces, diagnosing cancer cells, and making sure that organizational or societal processes run as smoothly as possible. The fact that we know AI can do things gives us reason to believe that further technological advancement result in big shifts in how we live.

It's not uncommon to read articles in the media about the ethical implications of artificial intelligence (AI), which helps to promote related research but also raises concerns that it could undermine it: these articles often imply that the issues under discussion are predictions of future technology and that we already know what's ethical and how to get there. Thus, the media concentrates on risk, security, and the forecast of impact [1]. The end result is a discussion of technical issues that focus on how to achieve a target outcome. There is a lot of "ethics washing" going on in the present discussions in policy and industry, where the label "ethical" is really just the new "green". Problems in AI ethics must be ones where we don't know what the proper course of action should be. It's not an issue in ethics to lose a job, steal, or kill with AI; it's a challenge to decide when these actions are acceptable.

Two recent studies of the use of artificial intelligence in service delivery have provided important theoretical insights for evaluating the advancement of these technologies into front line services context [2]. However, none of these otherwise outstanding assessments addresses ethical considerations related to AI. According to Belanche et al. [3], when introducing service robots, service managers should think about ethical considerations, which are not addressed in our paradigm. Some ethical difficulties are unique to the service industry, such as "the military and sexual use of robots" [4]. One recent assessment of service robotics raises ethical problems as potential research topics in four categories: "privacy, dehumanization, social deprivation, and disempowerment". However, even here, these potential ethical concerns are identified but not discussed. Thus, this study seeks to address seven ethical concerns (i.e. "Ubiquitous surveillance, social engineering, transhumanism, machine learning issues, and metaphysical issues"). This paper offers contributions to the field of ethics in the field of AI by exploring the different ethical concerns of AI and how organisation response to them.

## 2 Literature Review

### *2.1 Opening the "Black Box": What is AI?*

Research into artificial intelligence (AI) has been around for a long time. In 1956, Dartmouth College developed the phrase "artificial intelligence" to describe an emerging academic field that brought together specialists in brain physiology, formal logic analysts, and computer engineers [5]. It has been described as (1) the capacity

of machines to perform tasks with human-like intelligence, and (2) the capacity of machines to act rationally (i.e. as intelligent agents) by monitoring their surroundings and adjusting their behaviour accordingly to achieve predetermined ends [6].

AI research has gone through many ups and downs as it has grown. In the late 1950s, people first got excited about computers because they could build programmes that could prove some mathematical theorems or play simple games like checkers [7]. After the initial excitement died down, there was a period of disappointment. For example, in the field of machine translation, where AI systems were supposed to be as smart or smarter than humans, they failed miserably [8]. This was partly because computer technology wasn't very good at the time, and partly because there wasn't a good way to map and include contextual knowledge. Many people think that the "AI winter" that followed, which was marked by less money and interest in AI research, only ended in the late 1990s, despite occasional bursts of optimism about AI.

There are a lot of technical terms used in the current discussion about AI ethics. These often talk about what the technology can do, like "AI system is a machine-based system that can, for a given set of human-defend objectives, make predictions, recommendations, or decisions influencing real or virtual environments" [9]. Because AI is meant to mimic some aspect of human or animal ("natural") intelligence, the very definition of AI is murky and up for debate because it implicitly or explicitly refers to humans (or other animals) as a reference point. The distinction between natural and artificial intelligence is further blurred by this. Additionally, it begs the philosophical and ethical question of what, if anything, fundamentally differentiates robots from humans [10]. This work is not concerned with the definition of artificial intelligence, although it is evident that the definition influences or even dictates which AI-related ethical dilemmas qualify as such.

## *2.2 Artificial Intelligence and Its Benefits*

The majority of AI ethics studies are largely concerned with negative outcomes (see Table 1). A. However, it is equally essential to recognise the benefits that AI can provide. Since AI is a general purpose technology, predicting where exactly it will be used is impossible. However, the vast majority of its potential applications will likely have positive results.

The underlying ability of artificial intelligence to rapidly process massive volumes of data and the accompanying ability to optimise decisions have various benefits. The ability to analyse massive data sets fosters the development of insights that are impossible for humans to achieve on their own [11], consequently, there has been encouraging progress in science and knowledge generation across many disciplines, often leading to unexpected results. The option of optimising operations and enhancing efficiency is a further advantage. This results in economic benefits, including increased productivity and wealth creation in society, as well as assistance for sectors of the economy other than the AI industry [12]. These efficiency gains have the potential

**Table 1** Extant academic research on impact of AI

| Article | Key point(s), as relevant to this paper | Domain |
|---|---|---|
| Boyd (2016) | Showed that the Facebook "emotional contagion" study resulted in ethical discussions regarding manipulation of social media content | Marketing/business |
| Carmon et al. (2019) | Suggested that AI's personalized recommendations may have much commercial benefits, they may cause discomfort, as some customers may perceive such recommendations as loss of autonomous choice | Marketing/business/retail |
| Davenport et al. (2020) | Examined the broad impact of AI on marketing | Marketing |
| Edwards et al. (2014) | Showed that (some) Twitterbots may be perceived as credible, competent and attractive as humans | Computer science |
| Huang and Rust (2018) | Proposed that lower forms of AI will be good at routine tasks in simple, rule bound contexts, where the focus is on efficiency. The higher forms pf AI (yet not in place) may be good at developing context-based intelligence, at being creative as regards solutions and at being able to empathize (with customers) | Marketing/business |
| Kaplan and Haenlein (2019) | Defined AI and distinguished between ANI and AGI | Marketing/business |
| Luo et al. (2019) | Showed cases wherein customers preferred human service agents versus bots | Marketing/business |
| Mende et al. (2019) | Showed that interactions with humanoid service robots may trigger discomfort, with downstream consequences | Marketing/business |
| Qiu and Benbasat (2009) | Showed that anthropomorphizing bots enhances social presence, enhances shoppers' trust in the bots and increases shoppers' bot usage intentions as a decision aid | Computer science |
| Rai (2020) | Examined the tradeoff between AI explainability versus AI predictive accuracy | Marketing/business |
| Shankar (2018) | Examined how AI may reshape retailing[a] | Retailing |
| Syam and Sharma (2018) | Examined how AI may impact the sales function | Marketing/business |

(continued)

**Table 1** (continued)

| Article | Key point(s), as relevant to this paper | Domain |
|---|---|---|
| Wang and Kosinski (2018) | Used AI to examine facial features and predict customers' sexual orientations | Marketing/business |

for immediate impact by reducing the negative effects of wasteful production on the environment. There are further positive AI-enabled futures beyond this.

As part of the "United Nations' Sustainable Development Goals" (SDGs) of 2015, AI can contribute to various facets of sustainability, including environmental sustainability [13]. Thus, these SDGs, which are seen as the current consensus of humanity about morally desirable results, typically serve as the yardstick to test whether AI can attain morally desirable goals, or whether AI can be "good" [14]. The EU's HLEG (2019) emphasises the connection between AI and the SDGs and discusses it in depth in [15]. Much of what follows is devoted to discussing the unethical ramifications of artificial intelligence. Ethical considerations must be taken into account while developing and implementing mitigation mechanisms for such ethical difficulties; however, it is crucial to keep in mind that any strategy to managing AI must also preserve the balance between its good and negative repercussions.

## 3 AI Applications

Modern society is heavily reliant on AI. Furthermore, it is expected to expand in scope over the next few years. There are many examples of this (health care, information technology, manufacturing, etc.). So, the one we have now is capable of a wide range of tasks, including treating patients and putting together components for vehicle building (Fig. 1). Because of this, it is possible to improve people's living and working conditions.

### *3.1 Smart Home*

Since the dawn of the "Internet of Things" (IoT), the concept of a "smart home" has been around. In the smart home, the objective is to monitor, manage, optimise, remote access, and totally automate the home environment, minimising human labour. For a smart home application to work, the Internet of Things must be in place. A smart home built on the Internet of Things makes use of both local storage and processing devices (like a gateway or hub) and cloud infrastructure. Informatics performance is expected to rise dramatically as the size of the study environment grows.

Smart grid may be considered as an extension of the smart home [16]. The primary objective of smart homes is to reduce energy consumption by factoring

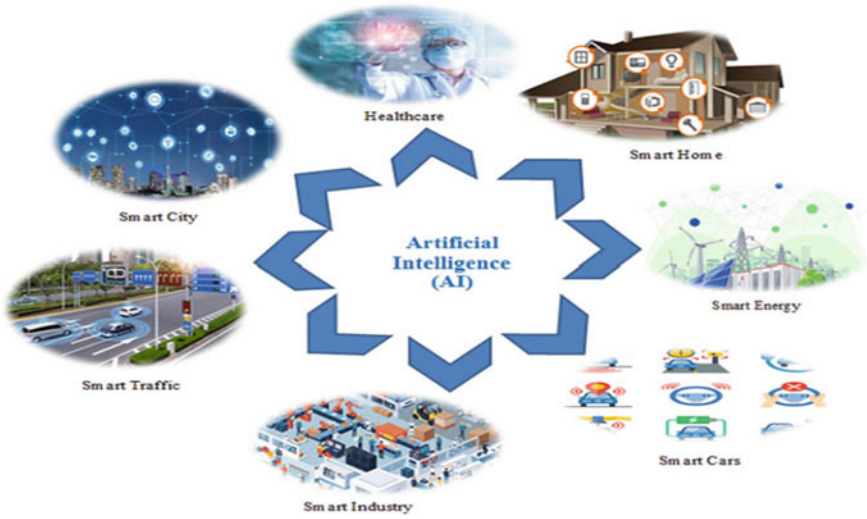


**Fig. 1** Applications of artificial intelligence

in usage patterns, occupancy levels, and even weather conditions outside the home [17]. As part of the smart home application's monitoring systems and intelligent HVAC ("heating and ventilation and air conditioning"), as well as the ability to customise an environment based on a user's profile, there are several key components (Fig. 2). High levels of security, dependability, and interoperability, as well as a strong ability to react to a wireless environment with different dangers, are all important considerations for the smart home.

## *3.2 Aviation*

AI is used to analyse flight data in aircraft simulators. Computers can determine the best possible outcomes in wars involving aircraft [18]. The location, magnitude, speed, and strength of forces and counterforces can also be factored into computer-generated strategies. During a battle, pilots can obtain computer-assisted assistance in the air. Programs using artificial intelligence may sort information and provide a pilot only the best feasible manoeuvres, while also eliminating manoeuvres that a human could never do. So that computer-simulated pilots may be employed for data collection, it is important to have a number of planes. Future air traffic controllers can also be trained using computer-simulated pilots [19].

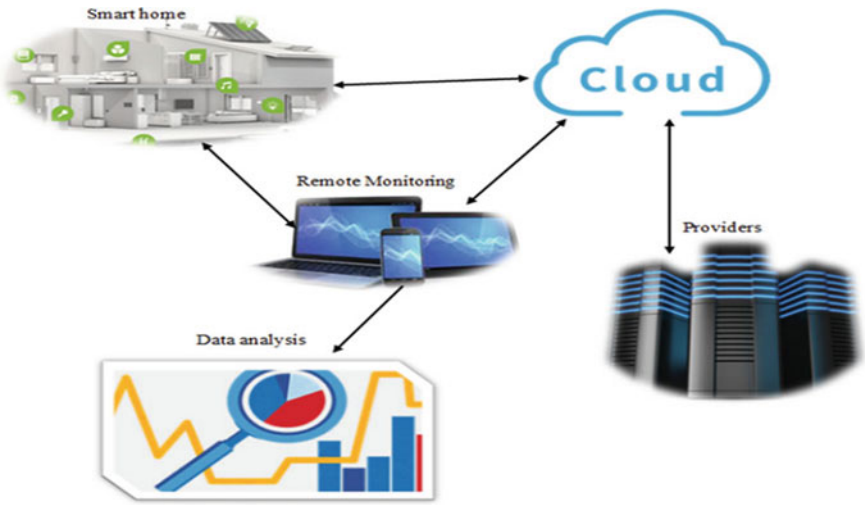


**Fig. 2** Essential elements of the smart home

### *3.3 Smart City*

Many nations, such as Germany, the USA, UK, Italy, Saudi Arabia, China, and India, have already launched their smart city project plans [20]. A city built on the IoT can improve in many ways, including sanitation, transportation, administration, governance, infrastructure, monitoring, and control. This is shown in Fig. 3. High scalability, dependability, availability, and security are among the most important factors in developing a smart city that is built on the Internet of Things. Moreover, RFID, Zigbee, Bluetooth, Wi-Fi, and 5G are only few of the technologies that could be used in the future.

### *3.4 Computer Science*

For the most difficult computer problems, AI researchers have developed a wide range of techniques. Furthermore, many of their innovations have been incorporated into more general computer systems and are no longer seen as being part of artificial intelligence (AI). This includes, according to Ligeza and Antoni [21], data structures and functional programming lists, as well as time-sharing and interactive interpreters, rapid development environments, and symbolic programming. Soon, AI will be able to replicate itself. For instance, in November of 2017, the AutoML team at Google is working on optimising their system for use with ImageNet and creating new neural network topologies. This is the first time in ImageNet history that Google claims NASNet has outperformed all previously reported results.

**Fig. 3** IoT based smart cities

## *3.5 Hospitals and Medicine*

IoT-driven healthcare applications are predicted to become widely used by 2025 and to account for the majority of the global IoT market [22]. The Internet of Things can effectively administer all types of health care. To diagnose illnesses, offer preventative care, and adapt treatments based on AI, however, the healthcare industry needs a new Internet of Things (IoT) paradigm. Consequently, the Internet of Things can help pharmaceutical businesses discover and design new pharmaceuticals by analysing collected IoT data. There are numerous stakeholders in health care who stand to gain from the implementation of IoT, including medical professionals, support workers, patients, hospitals, medical insurance providers, and the pharmaceutical industry (Fig. 4). Smartwatches, shoes, garments, and wristbands, among other IoT-based medical gadgets, can monitor a patient's vital signs from a distance.

**Fig. 4** Healthcare based IoT

### *3.6 IoT Automotive*

90% of worldwide car sales are expected to be either highly automated or totally automated by the year 2040 [23]. Some of the most prominent firms working in this route include Tesla (Google), BMW/Ferrari, Uber, etc. Developing remote and autonomous linked cars (often referred to as autonomous or driverless vehicles or robots) will be made possible in the near future thanks to the IoT and cloud computing working together. More than 200 sensors can now be found in a single car [24]. For IoT-ready automobiles, this is a crucial requirement. Bluetooth, Zigbee, DSRC, Wi-Fi, and 4G cellular technology are some of the fundamental technologies enabling vehicle communications [25].

## 4 Ethical Issues of AI

Different interrelated discourses deal with AI ethical issues. Ethical questions about computers and digital technology have been discussed in academic circles for decades [26]. Seminal thinkers such as Norbert Wiener [27] have influenced this debate. In addition, policymakers are hard at work. As a result, governmental and parliamentary entities produce policy texts that reflect this (i.e. "House of Commons Science and Technology Committee 2016; Executive Office of the President 2016a; European Parliament 2017; House of Lords 2018"). These articles generally discuss AI policy in broad terms, with an emphasis on the ethical considerations that must be taken

into account. If it's deemed necessary, the public sector can also prioritise ethics or request reports on the topic (HLEG on AI 2019). There are three distinct streams of discourse in the media, each of which is influenced by both the academic and policy discourses. Based on an extensive review of the previous studies in AI, our paper discusses seven ethical issues of AI (i.e. "Ubiquitous surveillance, social engineering, transhumanism, machine learning issues, and metaphysical issues".

### *4.1 Ubiquitous Surveillance*

Our digital devices, as well as satellites and drones, are all being used to spy on us, and this is the new normal. Surveillance capitalism has been dubbed this [28]. This web of surveillance has been built over time by a variety of different groups including the government, military, universities, and corporations working together [29]. We've come a long way since the days of CCTV, two-way mirrors, and concealed cameras [30]. Even if the reduction of crime and the ability to target advertising to those most likely to be interested in receiving timely information are two of the numerous advantages of this kind of monitoring, it raises ethical questions. A subset of these consumer entanglements is highlighted in the following examples.

It's no secret that video poker machines (also known as "pokies" in Australia) are the primary source of gambling revenue in both the USA and Australia. The low stakes in video poker allow players to play for longer before losing everything they've earned or more. Video poker establishments like casinos profit from having high numbers of machines and a small number of required service staff. However, they gain an advantage by being able to create a dependence on the machines. Facial recognition technology is already available in more advanced machines, allowing gaming companies to track their customers as they move from machine to machine and even casino to casino. Reprogramming the machine to conform to a player's preferred style of play, such as a lot of small victories or few big wins, is possible. Even while they can't legally alter the playout odds, they can alter the distribution of wins to keep players engaged for longer [28]. Although we may disagree about the negative effects of gambling, we can all agree that clandestine surveillance is a threat to human rights to freedom, dignity, and anonymity or privacy [31]. The proliferation of IoT devices and conversational digital gadgets and interfaces like Apple's "Siri" makes it nearly impossible to avoid anthropomorphizing these digital objects, Amazon's Alexa, Microsoft's Cortana, and Google Home in our homes". In addition to listening to us, the devices record our conversations and send them to Amazon, Apple, and Google [21]. In addition, Amazon is contemplating sending transcripts to third-party app developers [16]. Additionally, this raises questions about privacy and whether authorities can request such recordings for evidence in criminal cases [11]. Convenient as these technologies may be, Obeidat [32] argues that we must put our faith in the companies producing them rather than in ourselves. Conversational digital assistants frighten some users who fear being monitored by the devices [30].

### *4.2 Social Engineering Applications of AI*

Social engineering is one of the things that omnipresent surveillance may make easier. My flight from Yinchuan (China) to Beijing was scheduled for May 2018. A picture of my face with fine red lines surrounding it appeared on one of the airport's flight information screens as I approached it to confirm where I was supposed to go. Russell Belk's name appeared on the screen in a matter of seconds. Gate yy, zz:zz o'clock, is the departure time for your Air China flight #xxx to Beijing. My scanned passport and travel information were linked to face recognition, and the system reminded me of the information I was likely to be looking for as I approached the screen. In order to build a more trustworthy society, China has implemented sophisticated facial recognition technology. People and corporations can both receive a three-digit "social credit" score that indicates how good of a citizen they are under this system [19]. For the time being, it's only being tested in a handful of Chinese cities, but it's likely to become necessary across the country soon. Does everyone follow the rules of etiquette when it comes to queuing, walking, stopping their cars in crosswalks, smoking, and playing loud music?—Records of when they pay their bills and taxes, how much time they spend playing video games, how much they drink, what they post online, who they are friends with, and so on and so forth are all fair game [7].

Buying a lot of diapers (as a proxy for being a good parent), posting supportive messages about the communist government and economy, reading preferred newspapers, donating blood, donating to charity, and serving in the military are all proven ways to boost one's social credit score. Those with excellent social credit can take advantage of a variety of privileges, including the freedom to travel, the ability to rent apartments and bicycles without a security deposit, higher rankings on online dating sites, the ability to bypass lines in hospitals, lower energy costs, better exchange rates, access to VIP check-in areas at airports and train stations, and more [25]. People with lower social credit scores have a harder time getting things like plane and train tickets, insurance, visas, hotel and restaurant reservations, and even some jobs. A "deadbeat map" can show their whereabouts to everyone within 500 m of them who is on a public blacklist and so functions as a naming and shaming tool [11]. A number of people have compared China's social credit system to the Black Mirror episode "Nosedive", in which a smartphone app allows people to rate others in real time, with the scores determining their employment opportunities, ability to participate in social life, and even their ability to remain out of prison. A digital debtor's prison has been described as China's social credit system [28]. Over one billion of India's 1.3 billion citizens have been enrolled in an ambitious biometric identification system [20]. It consists of a 12-digit identification number, as well as fingerprints and an iris scan. Having a bank account, enrolling in school, paying taxes, and receiving government benefits were all part of the initial motivation for enrolment. Rural agencies and retailers have access to battery-powered fingerprint and iris scanners. When it comes to those who are poor or disadvantaged, the programme has fallen into challenges and injustices such as fingerprints worn away by a life of labour and eyes too foggy to scan and those with leprosy, which has resulted in

famine for some non-enrolled impoverished people [10]. It's also been accused of creating a surveillance state without flaws [21]. A second ethical issue arises as a result of this.

## 5 Transhumanism

Service robots and artificial intelligence could be used to improve the quality of life rather than to end it, which is the focus here. Some transhumanists hope that one day we'll be able to download our minds into a machine and live forever [18]. A networked computer's faster processing speed and extensive resources could assist an uploaded consciousness as well. If a robot could provide a new body to house a human's intellect and personality, it might be the ultimate service a robot could provide. Many people are worried that this technology would only benefit the wealthy and powerful, that a conscious machine will no longer be considered human, and that it will usher in a new era of super-intelligent robots that will have little use for "mere humans".

The fact that the benefits of transhumanism could only be enjoyed by the wealthy suggests that the gap between the rich and the poor could widen even further if people were able to take advantage of these advancements in their quest to become physically and mentally superior. A substantial market for genetic, pharmacological, and surgical services might be generated by the promise of possible immortality. However, there are numerous hurdles for these enterprises participating in transhumanism's first steps [17]. Transhumanism's whole objective is heavily dependent on technological advancements. The uploading of a human mind and consciousness into a computer or AI robot, for example, is unlikely to ever be achieved. Micro-assemblers, or nanotechnology, for cell repair is even more of a theoretical possibility. In the event that suitable life-extension technologies are not developed in time, some transhumanists have already had their bodies cryogenically frozen. Nonetheless, progress is being made in the area of life-extension advancements that are smaller in scope.

### *5.1 Machine Learning Issues*

One group of AI techniques is tailored to problems that arise from machine learning, and these are the ones that have contributed to recent breakthroughs in AI and are therefore at the forefront of the discussion. Traditional areas of AI, such as facial recognition, natural language processing, and self-driving cars, have seen exciting breakthroughs made possible by machine learning techniques thanks to advances in computing power and the availability of large amounts of data (AI) [8]. Using neural networks and large data analytics to train computers to make decisions raises questions about ethics. Personal or unrepresentative data in big training data sets are

particularly problematic [25]. Another issue with these methods is their opacity, their status as a "black box", which makes it difficult to determine how an AI works exactly. Data control, transparency, and reliability are three major areas of concern when it comes to machine learning. Data protection and confidentiality issues, especially for personally identifiable information, as well as data security and integrity concerns are at the forefront of the debate surrounding data control. Since AI relies on enormous data sets that may contain personal data, these issues become more important as they give rise to new vulnerabilities and methods for linking and identifying persons inside those data sets, none of them are particularly new or AI specific [24].

The reliability of the system and its outputs is the second group of concerns linked to machine learning. Worries about data quality and accuracy are at the root of the problem. The quality of the underlying data sets impacts the quality of the outputs of contemporary machine learning techniques, which may draw inferences from massive data sets. A good example of this type of system is an artificial intelligence (AI) system used to diagnose radiological data. Currently, only a few systems have the high levels of reliability required for clinical application that these systems require [10]. In addition, this is related to gender-biased machine learning, in which AI is trained using a large portion of the data set that does not accurately represent the gender composition of the population. Algorithms trained on data sets dominated by men run the danger of producing AI systems with erroneous or unreliable results. The historical, multi-layered bias in the field of computer science is explored in the chapter "The Myth of Meritocracy" (in terms of students, practitioners, publishing authors, perceptions in the media, etc.). The models that are created by machine learning using such data may be skewed [21].

Concerns about machine learning's lack of openness round out the third and final group [29]. There are concerns that the lack of openness in these systems, which is inherently ethically problematic, may also generate or at least disguise additional flaws. These potential biases have been extensively discussed in the current literature and may originate either in the data sets themselves (reflecting the earlier concern about data quality) or in the algorithms used to analyse them [13]. Concerns regarding accountability and liability for the repercussions of AI system use are exacerbated by the lack of transparency.

## *5.2 Metaphysical Issues*

The final group of concerns are known as metaphysical. For a long time, these issues have been broached in the framework of AI philosophy and larger discourses such as science fiction. The crux of the concern is that AI threatens to radically alter the nature of both itself and humans in ways that are morally troubling. The term "universal AI" (as opposed to the "narrow or specific AI that we experience in practise") has been coined to describe the anticipated development of such worries, which are not typically associated with current AI techniques such as machine learning, neural networks, etc. It is unclear whether or not specialised AI will eventually

lead to the creation of general AI. Having a different moral standing, Batubara [29] discusses the possibility of robots becoming sentient at least to some degree. If artificial intelligence (AI) were capable of improving itself, this could have far-reaching consequences, including the possibility of an exponential growth in AI capability, also known as "superintelligence" [19]. Human cultures could be profoundly altered, making this issue ethically relevant even if the outcome is unknown at this point, whether machines be good or bad towards humans. The most pressing metaphysical difficulties may be those that arise from the use of current and future technologies. Examples of the close coupling between humans and AI include implantable and wearable technologies, as well as the general pervasiveness of machines, such as the ubiquitous mobile phones most of us carry. Ethical considerations must be taken into account when it comes to how tight integration of humans and robots alters human nature.

## 6 Mitigation Strategies

Ouchchiy et al. [33] identified 106 alternative techniques, although this section only provides examples of the most frequently cited ones. Again, there are a plethora of possible classifications and groupings. Here, we begin by looking at mitigation techniques at the federal level, followed by recommendations for corporate governance, which are then outlined in the following sections.

### *6.1 Policy-Level Mitigation*

The ideals that guide the development, implementation, and use of technologies are well established at both the regional and international policy levels. Regulating/legislating and establishing institutions are two examples of policy-level activity. First and foremost, regulation pertaining to data privacy is relevant to at least some aspects of AI. Though GDPR 2016 is the most well known, there are other privacy-protecting laws that can be used to AI in the European Union. In addition, AI poses problems about accountability, responsibility, and culpability because of the apparent or real autonomy of systems [14]. Intellectual property law is another important consideration, as it dictates to a significant extent who owns data, how it can be utilised, and what business models are considered legitimate when organisations employ AI. As a result, the importance of human rights legislation was recognised.

Legislation and regulation are just one of the many ways in which policymakers might achieve their goals. As AI systems become more prevalent, there will be a need for a wide range of laws to ensure that the data necessary for their growth may be accessed by future AI users and creators [28]. Economic policies, such as taxation and social assistance, must also address issues of equity and fairness. Finally, regulatory entities can be used to implement policies and enforce legislation. This has sparked

discussions about whether the current set of regulators is adequate, whether sectoral regulators need to take on new regulatory roles to accommodate AI, or whether entirely new sets of regulators are required.

## *6.2 Corporate Governance of AI Ethics*

Policy and legislative measures, as well as specialised guidance methods, all affect how organisations will respond to the ethics of AI, a topic on which this article focuses. A company's role is not limited to being a passive recipient of rules or standards. There is a lot they can do on their own to assist shape policy and practise. The Partnership on AI ("https://www.partnershiponai.org/") and the Big Data Value Association ("http://www.bdva.eu/") are two examples of organisations that can collaborate on this issue. The environment in which businesses operate can be actively shaped, but corporations can handle AI ethics on their own as well. The principles of IT corporate governance, for instance, can be put into practise by them (ISO 2008). Information governance and data governance aren't necessarily focused on ethical considerations [15]. There are a number of additional relevant organisational processes. It is possible that the ethics of AI could pose a threat to the success of an organisation. Risk management (ISO 2010) solutions have been proposed as a suitable approach of dealing with such challenges by including ethics of AI [31]. Organizations do impact analyses as a part of their risk management procedures. A data protection impact assessment [30] is mandated by the GDPR and should be included into data protection procedures. An environmental impact assessment [17], a socio-economic evaluation [23], a moral impact assessment, or a social impact assessment may be more sensitive to the specific effects of AI use. Ethical and social considerations are a priority for many businesses in a variety of ways. Incorporating a CSR strategy into an organization's overall plan is a tried-and-true method [31]. In fact, it has been argued that responsible innovation can be fostered through the integration of technological and innovative activities into corporate social responsibility [12].

Finally, organisations can integrate and emphasise human rights. United Nations (United States of America 2011). It has been claimed that enhancing and incorporating human rights into organisations may be a suitable strategy to solve ethical challenges related to AI because of its potential impact on human rights. The World Economic Forum (2019) and the Council of Europe both advocate this strategy (2019). Implementation guidelines have been developed by the BSR global non-profit organisation [31].

## 7 Conclusion

This paper aims to provide meaningful insights into AI and its applications. We defined AI and its main benefits in general. We also identified the main ethical issues related to AI and how organisation response to these ethical issues. Readers who want to dip their toes into this topic will find references to the most recent research interspersed throughout the article.

Other service sectors, such as social media, dating and hook-up apps as well as the use of bots, robot-surgeons and pilots (such as Matthews' 2006), and the displacement of humans and their occupations by the use of AI and robotic technology are not addressed in this study. Humanoid machines (robots) are part of the discussion, but machine-humans are not (cyborgs). By discussing transhuman, I've jumped over the cyborg, which is perhaps the ultimate conclusion of cyborg modifications. However, because humans and robots may one day outperform each other, they also raise ethical questions. It is our opinion that these findings are significant and relevant to the literature on the ethics of artificial intelligence. Our research fills a glaring vacuum in AI research, which results from a lack of focus on specific application domains. A greater knowledge of how AI is viewed and how it effects current society is possible because of the insights offered here, despite the different strategies to improve the research, have been presented. AI's influence must be evaluated in the light of ethical and human rights considerations. In many circumstances, AI poses ethical issues that may be dealt with easily, but in many others, fundamental trade-offs must be made. The ethics of AI debate revolves upon the nature of these trade-offs, how they are perceived, and how they are dealt with. However, political, legal, and professional discourses are all intertwined. All of this must be based on solid theoretical foundations and empirical evidence. The authors of this research believe that this study offer contributions to artificial intelligence (AI) in companies and, in turn, a more socially acceptable application of these technologies.

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# Model for the Organization of a Cyber-Physical Production System

**Miglena Temelkova**

**Abstract** The present article studies and analyzes the nature and specific characteristics of the cyber-physical production systems, and on that basis, it generates a model for their organization. Following research and critical analysis of the definitions of the concepts "production system" and "cyber-physical system," there is specified the definition of the concept "cyber-physical production system." There is an analysis of the structure of a cyber-physical production system made in the course of research, which is the scientific-and-methodological basis of the model for the organization of the cyber-physical production systems generated with the present article for the first time in research literature. This is the first scientific research, which studies and analyzes the purpose, functions and content of the structural organizational elements of a cyber-physical production system, as well as the relational dependences and mutual determination between them. The study also points out the organizational, management, software and programming methods, tools and approaches, which ensure each of the structural elements of a cyber-physical production system. Outlined is problems unsolved by science, which are related to the topic, as well as the debating issues and the results, which are product of the present research work. Some conclusions on the topic are synthesized.

**Keywords** Cyber-physical production system · Production system · Organization

## 1 Introduction

### *1.1 The Importance of the Cyber-Physical Systems for Contemporary Production*

The term cyber-physical system usually refers to systems of collaborating computational elements that control physical entities, generally using feedback from sensors they monitor. A cyber-physical system is characterized by a physical asset, such as

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a machine, and its digital twin; basically, a software model that mimics the behavior of the physical asset [16].

According to other authors, a cyber-physical system is comprised of mutually connected computer devices, which collaborate in interaction in maintaining the connection with the surrounding physical world and its running processes; it provides and uses in real-time access to data and processes data accessible through Internet.

The cyber-physical system provides flawless integration between the computational models and the physical components, while at the same time, offering operational compatibility and sustainability [17].

The cyber-physical system has a 5-level architecture, and therefore, it is assumed in literature that its structure is founded on the «5C» Model—connection, conversion, cyber, cognition, and configuration [15].

This shows that a cyber-physical system comprises the cycle from gathering raw data from the real-life production environment, through a multilevel analysis and sending signals to real-life physical assets for carrying out physical operations in a specific temporal and spatial and physical aspect, to taking management decisions relevant to the reality and creating sustainable value.

The presented definitions provide grounds to make the following generalization: The cyber-physical system provides an opportunity to connect into a network resources, information, objects, and people. It binds together into a unity the real-life physical world with the digital one, while it is based on and integrates in itself the elements of the ecosystem "machine–human," and it is based as well on the blockchain technologies, where it interacts with the physical reality through the large bulks of data stored by it and their assessment. On the basis of the global Internet network, the cyber-physical system provides an opportunity not only to identify objects, production processes, capacities and organizational-production problems, but also to localize them in real time. Moreover, it enables the permanent monitoring and management of the entire production and management process in a business organization by facilitating covering and closing the full cycle of the transformation process from the order to the delivery of a finished product.

The importance of the cyber-physical system for contemporary production finds its expression in the purposeful, and set as a goal, impact on the basic elements of the production ecosystem—its input, its transformation processes converting resources into products, and its output.

Via the cyber-physical system, the hierarchical structural dependencies of the real-life production process are multiplied in a specific software model based on connectivity and multilayer complex analysis. Thus, the cyber-physical system facilitates the designing in a digital environment of an authentic spatial and temporal structure of production, as well as for stimulating the typical for it transformation processes.

The information about the magnitude, nature and intensity of the production cycles in the cyber-physical system is a basis of raw data, subject to monitoring, research and strategic analysis. Thus, on the basis of the incoming data drawn from the information bulk, the controlling commands from the software model are sent to the physical elements of the production ecosystem.

## *1.2 Studying the Concept of Cyber-Physical System*

The integration of the cyber-physical system model into the production ecosystem undoubtedly leads to an efficient and effective production process, based on resource and capacitive optimality.

The research into various literary sources points out that the definition of the concept of cyber-physical production system is not unambiguous to date.

According to some authors [3], cyber-production is a transformational system, which translates the data from a certain physical system into another cyber-system, which is predictable and prescribes a set of operations for achieving sustainable development. On this basis, the cyber-physical production system has the task to reveal and decipher the essence of occurring or already occurred problems and based on the integration between large bulks of industrial data and analysis implemented with the help of artificial intelligence, provide decision taking options. Therefore, it is defined also as integration of embedded computers and networks, which monitor and control the physical processes, using feedback chains [4].

Quite often, the cyber-physical production system is defined also as a combination between real-life physical and virtual objects and processes for processing information through open, partially global and all the time interconnected information networks [5]. This means that it is of the type of smart systems, which include both hardware and software and efficiently integrated physical components, which interact with each other in order to reflect the changes in the real-life environment.

The evolution from the automated production to its cyber version, assumingly, is a way from a systematic methodology, which allows the production operations to be successfully integrated with the functional objectives of a business organization by using wireless communication, toolset and technologies for forecasting [2] to a specific cyber-physical production model, which represents a complex and densely filled with information system, based on technologies, analysis of large data bulks, artificial intelligence, blockchain networks, knowledge about managing the business units and production operations [1]. At the same time, the cyber-physical production system has at its disposal two domains—physical space, where the real-life production process is implemented, and cyber-space, which is a kind of a model (double) of the real-life physical production.

According to some researchers [1], the cyber-physical production system consists of two basic functional components:

- Sophisticated interrelated sensor systems, which can be realized mostly through the Internet of Things;
- Data management and smart analytical capabilities, which turn the raw data into forecasting and prescribing operations.

In respect to the structure of the cyber-physical production system, some of the studies point out that it consists of autonomous and cooperative elements and subsystems, which start interacting in a specifically determined way, according to the particular situation, on each production level (strategic, operational, process-related, and

situational). The elements and subsystems of the cyber-physical production system cover its overall structure from the processes, through the machines and technologies, to the production and logistic networks.

A relevant conclusion can be made on this basis, that the cyber-physical production system is an appropriate instrument for the simultaneous introduction of mass personalization and personalization of the production paradigm and is based on the implementation of the cyber-physical system and the Internet of Things into production.

Other definitions relate the cyber-physical production system to the latest developments of computer science, the information and communication technologies and the production management, where its elements can gather and process data, exercise self-control in respect to certain tasks and interact with the human resources through interface.

On this basis, the main purpose of the cyber-physical production system is related to the possibility to maintain the communication between people, machines, and products.

## *1.3 Unresolved and Debating Issues in Research Literature*

The following unresolved and debating issues in research literature can be drawn on the background of the carried out literary review and analysis of the concepts "cyber-physical system" and "cyber-physical production system":

- the nature and specific characteristics of the cyber-physical production system have not been studied in sufficient depth;
- there is no analysis made of the similarities and differences between the concepts "production system," "cyber-physical system" and "cyber-physical production system;"
- the subsystems and the structure of a cyber-physical production system have not been studied in depth;
- there are no written research works on this topic concerning restructuring of the real-life production system into a cyber-physical production system;
- it is not clear what are the effects and the surplus value of cyber-production;
- there is no unequivocal opinion concerning what kind of social disturbances will result from the mass restructuring of the real-life production system into a cyber-physical production system.

All that requires that the object of study and analysis in the present article should be the main principles of the cyber-production organization, and the subject of study generating a model for the organization of a cyber-physical production system. It is through that particular model that that the further research of the nature, structure, elements, and subsystems of the cyber-physical production system could be facilitated, as well as mediate the algorithm for restructuring the physical production system into a cyber-physical one.

The article is aimed at presenting a summarized model for the organizational order of a cyber-physical production system together with the typical for its organizational structure relations and dependencies.

The tasks of the scientific research are: critical literary review of basic concepts related to the topic, analysis of the structure of the cyber-physical production system, and synthesis of a model for the organization of a cyber-physical production system.

The contribution of the present study is expressed not only in the study, upgrading and refinement of concepts such as "production system," "cyber-physical system," and "cyber-physical production system," but also in the presentation of a qualitatively new model of organization of cyber-physical production system.

A novelty for theory and practice is the linking of production processes and needs with the capabilities of cyber-physical system and their integration into a single and comprehensive model with relevant architecture, connections, and functional conditions and dependencies. For the first time in the scientific literature, a structural model of a cyber-physical production system is defined and its elements and main functional planes are highlighted, together with their adjacent relationships, process interdependencies, tools, and resources.

## 2 Methodology of the Research

### *2.1 Defining the Concept "Production System"*

The concept "system" can be determined as an aggregation of interrelated elements and interactions between them and their characteristics, integrated in one single unity, where each of the elements has its contribution to the characteristics of the whole entity. On the background of this definition, the great challenge nowadays in defining the concept "cyber-physical production system" is the lack of sufficient amount of research papers on this problematic issue. This requires that the definition of the concept should be based on what has already been achieved by science, namely the definition of the concept "production system."

There are three main definitions for a production system prevailing in research literature:

- production as production system;
- production system as a part of an enterprise;
- production organization as a production system.

The authors [6, 7, 11, 13, 14] define production as a part of a business organization, determined by a material and cash flow and subjected to the rational formation and organization of production through the activities: supply of elemental factors, their transformation, and realization of a finished final product.

**Fig. 1** Structure of the production system in a business organization (adaptation of the author)

At the same time, the production system is determined as an organizational unity [6–9], having the task to bring the production process in line with the relevant organizational principles (forms), in view of achieving the best possible impact on the economic effect development (Fig. 1).

The production system is the arrangement in space of the workplaces in the production process, as well as the structuring of the production times and the time organization principle. The space and time principle lay out the organizational forms in the production system.

The production system links the rationality of the economic action with the obtained at the output higher value than the one at the input.

For the purposes of the present article, production system shall mean a unity of interrelated and mutually determined subsystems, methodology and toolset, which, on the basis of production process automation, objectivize the nature of the production operations in view of achieving the strategic organizational goals. In structural respect, the production system is based on the principles of the systematic approach and consists mainly of two subsystems (managing and managed transforming). The fundamentals of the managing subsystem are the main management functions, and it includes in its structure the subsystems for planning, for forecasting, for organizing and for controlling. The managed subsystem is related to the transformational process and turning resources into finished products, where it is most often structured into production and servicing subsystems.

On the background of the summarization made of the nature of the "production system" concept, a conclusion is reached that the traditional physical production has based its activity on the real-life (physical) production system; however, the already emerged new economic needs of the global environment, prompted by the started Fourth Indus- trial Revolution, and the intensive digitalization of the economy related to it require the implementation into the production activity of the principles of the cyber-physical system and upgrading the production system to a cyber-physical production system. Thus, over the recent years, in research literature stands out also the issue of upgrading the definition of the concept "production system," and defining a fundamentally new concept "cyber-physical production system."

In spite of the emergence of the term "cyber-production" as early as at the beginning of twenty-first century, even until today there is no consensus in science in

respect to the definition of the concept "cyber-physical production system." That requires focusing the research on further specifying the definition of that concept and synthesizing its major characteristics, which are essentially different from concepts such as "production system" and "cyber-physical system."

## 2.2 *Specifying the Definition of the Concept "Cyber-Physical Production System"*

On the basis of the carried out review of the definitions for "production system," "cyber-physical system," and "cyber-physical production system," for the purposes of the present analysis, "cyber-physical production system" shall mean:

- a concept, where most often there is an interaction between physical components, blockchain networks, robotized systems, and models based on artificial intelligence and sensor technologies;
- an innovative kind of ecosystem of the type "human–machine and cyber-device," which has its real-life physical manifestation, but also its virtual duplicate, corresponding to the real-life production system in its structure, organization, resource provision, and goal setting and strategy;
- a system of a large amount of physical objects, services, and processes, on the one hand, and a system of sensors, gathering data from the physical world, models and algorithms integrating various scenarios with various manifested conditions of the environment and interrelated cyber-devices, on the other hand, unified in a single entity in view of performing certain physical and cyber-production tasks under certain prerequisites;
- a robotized model, which is capable, via an accurately described and simulated by machines algorithm, to analyze and assess the surrounding environment and undertake actions enhancing the possibility to achieve certain goals;
- a production process based on technologies relying on sensors, which through abstract symbols try to reproduce human thinking on hierarchical and logical level, or which imitate human brain through neurons and neural networks, organized in layers, connected with each other via simulated lines, where those neural networks have the capacity to upgrade the acquired knowledge by accumulating experience and growing.

The synthesis of the said definitions shows that the cyber-physical production system is a digital virtual and physical production model, connecting the real-life production process and its informational flow with a simulated, identical to the real-life one, virtual production replica model, integrating an information base, analysis of large bulks of data, artificial intelligence, blockchain networks, strategic and production management, which is also planning, organizing, coordinating and controlling the work of machines, facilities, technologies, sensor devices, robots, and production capacities, representing an integral part of real-life production.

## 2.3 *Analysis of the Structure of a Cyber-Physical Production System*

The upgrading of the classical production system to a cyber-physical production system requires studying:

- the essential characteristics of the two major subsystems of the cyber-physical production system—the physical production system and the cyber-production system;
- the cyber-physical components, which connect and coordinate the two subsystems and make the real-life technological chains adaptive;
- the designed socio-mechatronic subsystems, whereby the loading on the human resources in the digital business organizations is determined;
- the autonomy of certain elements of the production system;
- the components of a cyber-physical production system enabling the work in an emergency mode or the restart after registering a critical situation.

The research shows [10] that the main components of a cyber-physical production system are:

- the Internet of Things;
- the Internet of Services;
- cloud computing.

The Internet of Things can be defined as a connection between the physical and the digital world, where based on an interaction with the global network, smart devices and technologies connect with each other and are remotely operated.

The Internet of Services is a connection between the physical and the digital world, where based on an interaction with the global network, providers and clients connect with each other, while the resource flows are remotely managed.

Cloud computing is a specific provision on the Internet of an order for resources and data processing. It is an important tool for the provision of services in gathering and processing data via the Internet and creates communication for the automation systems with borders of the production system beyond the traditional ones.

At the same time, the cyber-physical production system consists of two fundamental systems, the real-life (physical) production system and the cyber-production system, which is a kind of a double of the physical one. The connections between those two systems are realized through the Internet of Things and the Internet of Services, while the virtual model is built through the approach of cloud computing. Thereby, a model of the production infrastructure is generated, enabling the supply of a wide range of cyber-resources, such as computer network, server, data storage systems, applications and services, which can be deployed quickly and with minimum efforts.

On the basis of analysis of the "5C" architecture of the cyber-physical system, analogically, the main architectural elements of the cyber-physical production system are synthesized. In view of achieving an architecture relevant to the cyber-physical

production system, the typical for the cyber-physical system structure has been upgraded and enriched, in respect to the content and functions, by the author of the present article, with the typical structural characteristics and requirements of the production system. Thus, the cyber-physical system consists of a six-level architecture (Fig. 2):

- a production system, consisting of its two main subsystems—transforming and managing ones, where the physical production process takes place in a particular temporal and spatial aspect;
- an intelligent sensor system, designated for gathering data from the real-life production environment through sensors, controlling devices, technologies, and management systems, which through the Internet of Things maintain the connection both with the real-life physical environment, and with the virtual one through the relation "sensor/device/technology, management system server;"
- an information system, where the machine signals gathered by the intelligent sensor system are transformed into semantically meaningful information, while the emphasis in that system is on the self-improvement of the intelligent sensor technologies, which acquire the primary data and turn it into a cognitive information resource, which they supply to the next higher architectural level of the cyber-physical production system;
- a cyber-system, operating as a central information center, consisting of a network of cyber-devices, which store a large information bulk for different periods of time and with different situational variables, which they analyze through specific, program-set in them methodologies, algorithms, models and tools in view of upgrading the primary information with analytical one by applying frames and

**Fig. 2** Six-level architecture of the cyber-physical production system (developed by the author)

artificial intelligence, and generating on this basis alternative options for choosing strategic and operational steps from the cyber-physical production system;

- a smart system generating in-depth knowledge about the physical production system based on expert systems, whereby a certain decision is analyzed and informationally provided on the basis of the individual primary information, gathered by the intelligent sensor system and turned into semantically meaningful one by the information system and the registered options for choice through comparative-analytical activities/events in the cyber-system of the cyber-physical production system;
- a managing and feedback system, which implements the solution chosen by the smart system and configures the feedback from the cyber-space to the physical production space, while, at the same time, it implements a wide range of controlling tools in view of the self-improvement, self-upgrading, and self-configuring of the cyber-physical production system with another similar version of a scenario.

The described six fundamental architectural elements of a cyber-physical production system are not only mutually connected and determined, but each of them enters the field of another one, while, at the same time, they preserve their functional and structural unity and integrity. In the meanwhile, the information flows are sent from a system to a system, where the main task of the managing and feedback system is the improvement of the efficiency of the real-life production system on the basis of the work of the intelligent sensor, information, cyber and smart systems. Thus, the cycle is closed and a specific production-informational smart circle is differentiated, which characterizes the functional scope of the cyber-physical production system.

## 3 Synthesis of a Model for the Organization of a Cyber-Physical Production System

The cyber-physical production system maintains the information exchange between human resources, machines, and products, where its systems, evident from Fig. 2, gather data and process information, and they are based on previous expert experience and are self- improving, self-learning, and communicate with the people via interfaces.

There no papers elaborated in research literature to date concerning the organizational modeling of a cyber-physical production system. The present research is an attempt not only to generate the structure of a cyber-physical production system, but also to define the resources, which are necessary for each of its structural elements—toolset, technologies, hardware, and software.

As it has been already clarified in paragraph 2.3 of the present article, the cyber-physical production system has six main structural subsystems, forming its backbone—production, intelligent sensor, information, cyber, smart and managing and feedback systems. From the perspective of the structure of the cyber-physical production system itself, they function as subsystems; however, examining each of them

as a separate structural element, on the basis of the main principles of the systematic approach, would define them as systems. These particular six systems have their specific designation in the unity of the cyber-physical production system, and they have their own resources, which provide them with their main content and functionality (Fig. 3).

The production system is the place in space where the elemental and provisional production factors combine physically in a specific temporal aspect. Elements of the production system are the production resources—people, finance, production areas, capacities, raw materials, fuels, materials, technologies, innovations, facilities, devices, automated systems, etc. A core structural element of the production system is the production capacities, which can be completely, or incompletely, or optimally loaded in terms of capacity. That determines the extent to which they are used, as well as the possibilities for efficiency of the entire production process.

The intelligent sensor system is a network of sensors, smart detectors and systems, which gather information about the work of the production system—about the loading of the capacity, the service ability, fitness and capabilities of its production capacities, about its resource provision, about its resource consumption in producing one unit of a product of a certain type, about the time duration of the operations, and the entire production cycle. The intelligent sensor system transmits the gathered primary data to the information system.

The information system transforms the data received through the intelligent sensor system from the production system and converts them into information recognizable for the cyber-devices. This specific transformation of the primary database into semantically meaningful one takes place by binding the data about the work

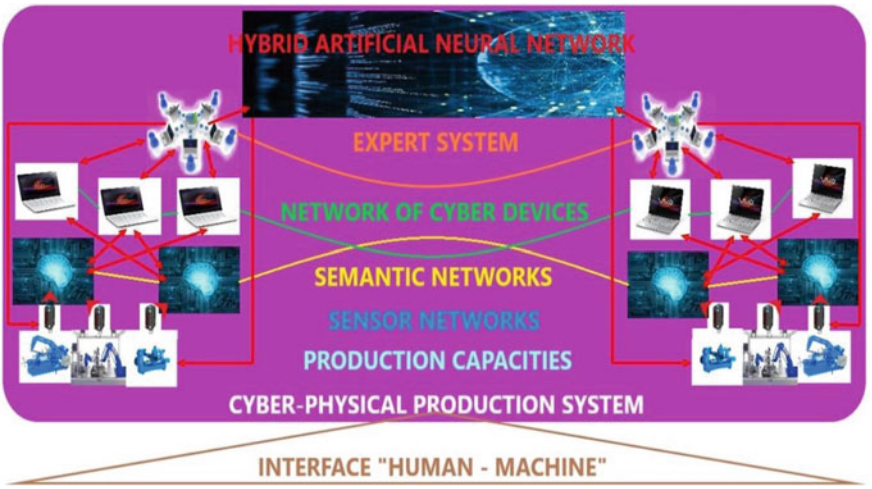


**Fig. 3** Model for organization of the cyber-physical production system (developed by the author)

and capacity loading of the production system with the links between them. Therefore, it could be generalized that the information received concerning the qualitative and quantitative results from the production process is presented through a network of nodes and arches connecting them (a semantic network). There are conclusions formed exactly on the basis of the relations between the different information indicators.

Within the information system of a cyber-physical production system, the transformation of the indicators received from the production system into data suitable for the generation of analyses by cyber-machines can be realized through the two methods typical for the semantic networks:

- method of searching cross-section, where the trend of development of the production process is searched between two indicators at one and the same point in the production system, however at a different time interval. As a result, there are new nodes reached, and the search stops when certain target indicators are reached, or when the potential of the two semantic networks is exhausted;
- method of inheritance, if a certain indicator value in the production system is searched, then upon reaching it, the value is explicitly extracted; however, if the value of a certain indicator is not set, then by way of relations between the nodes, an indicator value is reached, which is set or reached for the same indicator, in the same point in space, however at another time interval.

The cyber-system is a network of cyber devices, which carry out certain analyses in view of creating alternative options for strategic and operational choice in the behavior of the cyber-physical production system. There is a two-way connection between the information and the cyber-systems, and if necessary, the cyber-system may request additional information from the information system.

The cyber-system is based on presenting and using knowledge through frames (structural presentation of knowledge based on the option of the human brain to generate cognition around a particular concept), whereby information is provided about what would happen next, and possibly, what to do if the foreseen event occurs or does not occur [12]. The knowledge about the objects, functions, processes, logistic, and value chains, which objectively run in the production system, can be presented as stereotypical system-related sequences of certain processes, which get activated with the presence of certain prerequisites, called scenarios.

The scenarios for the development of the cyber-physical production system in a particular direction are a type of frames based on analogies and summarized descriptions of objects, functions, processes, and chains. They allow the information about the structural components of the production process not to be obtained repeatedly, but to use synthesized simulative models, which would upgrade and enrich themselves only with the acquired specific or additional information.

At the same time, the presentation and use of knowledge through frames result in the combination of factual and algorithmic data. The factual data forms a static declarative structure, while the additional data determines the procedural nature of the frame. The main tasks of applying frames in the cyber-system are comparing the

available information with the preliminary set one and drawing logical conclusions on the basis of analysis.

The smart system of a cyber-physical production system integrates the added value of the expert systems, which are computer programs presenting knowledge and making logical conclusions on the basis of available information from a certain field in view of solving typical tasks from that field or getting appropriate advice [12]. The application of expert systems in a cyber-physical production system is intended for taking a decision, which would be adequate to the realities of the environment, while involving minimum risk.

The expert systems model the algorithm, whereby conclusions and summarizations are made, and hence, solutions in the smart system of a cyber-physical production system. They apply heuristic and approximate methods and generate prompt and precise solutions of authentic production cases, while being able to adjust, upgrade, and further improve an already made decision, i.e., they use self-knowledge and self-improvement on the basis of experience.

If necessary, in view of taking an efficient decision, the smart system may request additional information from the intelligent sensor system. In such a situation, the information received from sensors, intelligent detectors, and systems is forwarded again along the chain of systems, forming the backbone of the cyber-physical production system.

The hybrid artificial neural network fills in content and functional aspect the managing and feedback system. It is based on:

- fuzzy logic: An instrument capable of solving complex problems such as the management of complex technological production capacities, the methodology of which is based on the managing impact of a particular controlling system, expressed not through mathematical equations, but via linguistic rules;
- probability theory: An estimation whether and how certain processes will be realized if a certain process or processes function in a certain way;
- systems of production rules, which include authenticity factors: A conclusion with a certain level of authenticity with cumulative presence of some assumptions and additional conditions.

The hybrid artificial neural network integrates in itself the impact of a certain number of input neurons, which represent certain independent from each other factors, on the one hand, and the possibility to teach the model of the hybrid artificial neural network on the other. That makes the hybrid artificial neural network a precise forecasting tool with a wide range of possibilities in respect to solving a number of production and management issues.

The hybrid artificial neural network demonstrates smart behavior and includes two components: database for the solution taken by the smart system and a programming system, generating smart behavior.

The main task of the hybrid artificial neural network in the managing and feedback system of a cyber-physical production system is putting into action in the real-life production system the decision taken by the smart system. On this basis, all

the elements of the production system get a signal for certain behavior in view of implementing the taken production and management decision.

## 4 Results and Debating Issues

### *4.1 Results*

The generated model for the organization of a cyber-physical production system mediates the information about the existing structural dependencies, conditionalities, and relations between the different physical and virtual objects and processes, representing in their unity a cyber-physical production system. The major advantages of the model, on this basis, are related to:

- covering the entire structural cycle of a cyber-physical production system;
- integrating in a single system of hardware and software, and physical components, which interact with each other in view of reflecting the changes in the real-life environment;
- connecting monitoring and control of the physical processes through feedback chains;
- setting in the cyber-physical production system of a solid analytical instrument, provided with appropriate hardware and adequate software and software products, based on artificial intelligence and neural networks;
- achieving efficient flexibility and adaptability of the production process through self-configuration, self-maintenance, and self-organization of the entire cyber-physical production system;
- outlining the possibilities for optimization of the production cycle.

### *4.2 Debating Issues*

Among the debating issues, which also prompt the further research by the author, are both the advantages and disadvantages of the proposed in the separate systems, comprising the structural organization of a cyber-physical production system, toolset, technologies, hardware, and software. It can be summarized, on this basis, that:

- a major advantage of the semantic networks is their simplicity, visualization, and accuracy in presenting the indicators of the production process and their connections, while a disadvantage of the semantic networks is the problematic presentation of random poly-variant connections and the insufficiently clear semantics;
- the strengths of the frames are the database modularity and hierarchy, while their objectivity of expressive power and semantics is their weakness;

- a substantial advantage of the expert systems is the integration of a large set of knowledge, tactics, methods, and tools for taking a well-grounded decision, while their "bottleneck" is the slow rate and inefficiency of the process of creating expert systems [12].

## 5 Conclusion

Integrating the physical and virtual production process in real time and under real-life spatial conditions highlights in the organization of a cyber-physical production system the unlimitedness of the virtual production image in terms of time and space. On this basis, its self-organization, self-maintenance, and self-improvement results both from the lack of temporal and spatial limitation of the virtual models, and from the option for an adequate response to the changed conditions of the environment by integrating various methods and tools for modifying the production process.

The elaborated model for the organization of a cyber-physical production system contributes to the transition from machine-based decision making to a decision based on evidence and experience. Stepping on a smart analysis of the multi-dimensionally related and mutually determined systems, correlations and cause-and-effect relationships in a cyber-physical production system, the model leads to overcoming the "bottlenecks" in the production process at the stage before they actually occur. At the same time, modeling the organization of a cyber-physical production system contributes through its network structure and data rich environment to the sustainable transition from conventional machine learning to learning on the basis of artificial intelligence and smart machine management. Thus, the model renders clarity, transparency and efficiency in the further scientific research of the cyber-physical production system and provides certain operational independence and autonomy of the future development of the theory about the cyber-physical production system.

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# A Deep Convolution Network-Based Pneumonia Identification from Thoracic X-Ray Imagery Scans

**Kamal Upreti, Prateet Mishra, Manish Maheshwari, Prashant Vats, Aisha Dhankar, Reenu Batra, Saneh Lata Yadav, Tanvi Chawla, and Jayant Bhardwaj**

**Abstract** Pneumonia is an infectious ailment which affects the respiratory system and is caused by microbes that infect the human by affecting their lung air sacs and fill them with fluid. Using chest X-ray is the most popular approach for detecting pneumonia, and the results must be calculated and examined by medical experts. The inconvenient way of detecting pneumonia results in a loss of human life owing to incorrect approach and treatment. With the advancement of computer and information technology, developing an autonomous system that can help in the diagnosis and prevention of pneumonia is now viable, especially if the patient is in a place where the medical facilities and expert doctors are limited. In order to solve this challenge, this project uses deep learning technologies. The neural network was customized to accomplish the difficult task of detecting diseases such as pneumonia in order to aid medical experts in their diagnosis and treatment options. CNN applies a filter to a photo in order to extract data from a chest X-ray. The above-mentioned goal was achieved using Python programming language, as well as deep learning and neural network methodologies.

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**Keywords** Recognition of pneumonia · X-ray component · Thoracic · Deep CNN · Chest X-rays · Rectified linear function

## 1 Introduction

Pneumonia is a dangerous lung illness and is of three types—bacterial, viral, or fungal. It affects a large number of people worldwide each year (about 4 million fatalities). However, if discovered and treated early, it is a manageable disease. Chest X-ray scanning is one of the best techniques for detecting pneumonia, concerning the World Health Organization (WHO). X-rays of the chest are usually inspected by medical professionals [1]; therefore, it requires specialist expertise. Not only this, but it is also time-consuming and costly. Furthermore, interpreting chest X-rays remains a difficult task for an expert due to their complexity. Early detection of pneumonia can assist to save children's lives. Convolutional neural network models are shown in this research to diagnose defective lungs accurately from X-rays. This can be used to treat pneumonia by medical specialists in the actual world. This model quickly distinguishes between normal and pneumonia chest X-ray pictures, allowing for early identification of pneumonia [2]. A specified number of permutations of Conv2D, dropouts, and dense layers needed to be trained to achieve the best outcomes. This was carried out by evaluating the model after each iteration. Thus, the life of that patient would be jeopardized. To avoid this, models should have high recall and good accuracies [3]. Now, the next section looks at the study that has been done in this sector so far. Then, Sect. 3 explains the proposed approach, including the model architecture, flowchart, and methodology to develop the proposed CNN model. The experiments and outcomes are presented in Sect. 4. The last section concludes the paper with a brief conclusion and the prospective scope of this study project was also given. At the end of the paper, there is a citation of all the references used.

## 2 Related Work

Identification of this disease from chest X-rays is an issue that has existed for a long time, with the main constraint being a lack of data available. Conventional deep learning techniques have been thoroughly investigated. Chandra et al. [4] identified eight statistical characteristics from the segmented regions of lungs from the dataset containing chest X-rays, which were utilized to classify them. Logistic Regression, Multiple-layered perceptron (MLP), Random Forest, Sequential minimalistic optimization (SMO), and classification via regression, were the five different classifiers that were used to achieve the desired goal. They tested their method on 412 samples and found that the MLP classifier had a 95.39% accuracy. In 185 schizophrenia patients, Kuo et al. [5] employed 11 characteristics to diagnose this disease. They compared the results of these attributes in a variety of classification and regression

models. They used a decision tree model to attain the greatest accuracy rate, 94.5%. Yue et al. [6] employed six characteristics for the identification of pneumonia in 52 patients' chest CT scan images, with the highest accuracy rate being 97%. These strategies, however, cannot be generalized and were only tested on limited datasets. Unlike machine learning algorithms, that require feature extraction and selection for classification, deep learning approaches automatically extract and identify relevant and informative characteristics by using convolution and filters on the training dataset. This is why they are more suitable for image data categorization [4]. Wang and Xia used a modified ResNet architecture to propose a deep transfer learning approach to detect numerous thoracic illnesses, pneumonia being one of them, using chest radiography [7, 8]. Their model named ChestNet was tested against three other deep learning models. To reach this result, they used a powerful computer configuration and 20 h of training in the CAFFE framework (Jia et al. 2014) [9].

## 3 Proposed Work

The CNN model was built from the ground up and trained on the dataset containing chest X-Rays and scans. The model was created using the Keras neural network framework and the backend was of TensorFlow. The input dataset contains 5318 training images and 764 images for testing purpose. Each image is categorized as either normal or pneumonia. 25 Epochs were used to train the model with the batch sizes being 32 and 1 for training and testing, respectively (Fig. 1).

It is not a pre-defined model like AlexNet, VGG16, VGG19, GoogleNet, etc., but a custom-built deep CNN model. Because it possesses many layers, i.e., convolutional layers, pooling layers, flatten layers, and dense layers. CNN is best suited for an object, face, and image identification [10]. Our customized model has 5 Conv2D layers, with max-pooling layers following each Conv2D layer. The primary part of the CNN model is the Conv2D layer. It is then followed by an Artificial Neural Network (ANN) that consists of two hidden layers and one output layer with a single neuron for classification. Our input X-rays are applied as a vector of $3 \times 3$ convolutions in all the convolutional layers wherein each is followed by 2D max-pooling [11]. After passing through Conv2D and pooling layers, the input image undergoes flattening which helps in reducing the computational cost of the incoming image by flattening it into a column. This is subsequently fed into the dense layer/fully linked layer. In this, each layer extracts and selects features, and based on these features, a prediction is generated by the network [12, 13], known as forwarding propagation. This proposed model has two activation functions: ReLU and sigmoid activation function. The rectified linear function is a nonlinear function that gives zero and one as results. When the input is negative, it gives zero and produces one as an output when it is positive [14, 15]. This activation function increases nonlinearity in our custom-built model. The final dense layer that collects all of the previous layers' output uses the sigmoid activation function because binary classification output was required. After this loss function (metric measuring how well a neural network model performs)

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 298, 298, 16)      448

 max_pooling2d (MaxPooling2D  (None, 149, 149, 16)     0
 )

 conv2d_1 (Conv2D)           (None, 147, 147, 32)      4640

 max_pooling2d_1 (MaxPooling  (None, 73, 73, 32)       0
 2D)

 conv2d_2 (Conv2D)           (None, 71, 71, 64)        18496

 max_pooling2d_2 (MaxPooling  (None, 35, 35, 64)       0
 2D)

 conv2d_3 (Conv2D)           (None, 33, 33, 128)       73856

 max_pooling2d_3 (MaxPooling  (None, 16, 16, 128)      0
 2D)

 conv2d_4 (Conv2D)           (None, 14, 14, 128)       147584

 max_pooling2d_4 (MaxPooling  (None, 7, 7, 128)        0
 2D)

 flatten (Flatten)           (None, 6272)              0

 dense (Dense)               (None, 256)               1605888

 dense_1 (Dense)             (None, 512)               131584

 dense_2 (Dense)             (None, 1)                 513

=================================================================
Total params: 1,983,009
Trainable params: 1,983,009
Non-trainable params: 0
_________________________________________________________________
```

**Fig. 1** CNN model layer

is calculated using the binary cross-entropy function, the model uses the Adam optimization algorithm (Fig. 2).

## 4 Experimental Results and Discussion

The suggested dataset for evaluating predictive accuracy comes from the Kaggle competing and contains a total of 578,782 X-ray pictures. The dataset is also split

**Table 1** Trainable parameter using CNN classifier model

| S. No. | Models | Trainable parameters |
|---|---|---|
| 1 | VGG16 | 124,363,435 |
| 2 | Res-50 | 23,568,565 |
| 3 | Xception | 20,564,425 |
| 4 | DenseNet121 | 6,944,532 |
| 5 | Our model | 324,821 |
| 6 | MobileNet | 3,268,345 |

into 3 folders (training, testing, and validation) with nested folders for each picture classification (Pneumonia/Normal). Patients between one and five years old provided all lung X-ray pictures (posterolateral). To demonstrate the adaptability of various models, the total sample was subdivided into three folders, supplied with training verification, and evaluated 75, 15, and 24% of the time—as performed by Baltruschat et al. [16]. The accuracy score which came out to be 96.76 was used as a performance measure to assess the effectiveness of our CNN classifier model. Figure 3 is used to show Examples taken from the database of (a) normal patients and (b) pneumonia cases. Loss graphs were examined along with the confusion matrix of the model. Table 1 is used to the show trainable parameter using the CNN classifier model. Figure 6 is used to show original and improved photos are compared, (a) original picture samples and (b) improved image instances. Vertebrae also have distinct edges as shown in Fig. 3a, b. The given Figs. 5 and 6 depict the training and testing accuracy, and also the training and testing loss, acquired during the training process for 100 epochs utilizing our developed framework and 50 epochs with another forecasting model to the other figure's larger set of parameters. The trained and verification reliability are all above 95%, and the training and testing losses have both been less than 0.025, indicating that the model we suggested has the opportunity to attain good results. Additionally, throughout training, the accuracy rate and training loss appear to be reducing. As a consequence, after developing the last epoch, the best design was kept. Table 2 gives the performances of several algorithms with enabling higher 224 and transfer functions BCE summarized on our proposed CNN model (Figs. 4 and 7).

## 5 Conclusions

Pneumonia causes a significant number of losses of human lives all over the world, 15% of the world's kids die because of pneumonia. To reduce this number, early identification and treatment of this disease are required. But the scarcity of professionals who can identify pneumonia in patients in remote areas makes it difficult to overcome this issue. Hence, in such places, our proposed model can be used efficiently by medical specialists for the early diagnosis of pneumonia in patients. Another advantage is that a huge number of chest X-rays can be analyzed in less time to generate

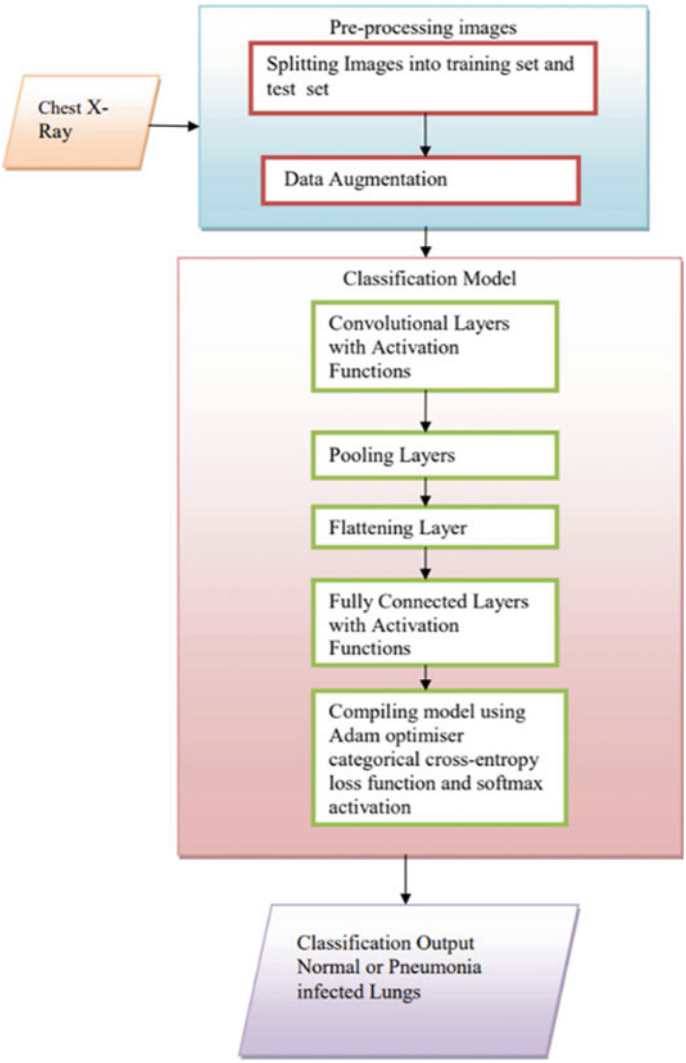


**Fig. 2** Flowchart for the proposed model for pneumonia detection using CNN Ta

extremely precise diagnostic results [17]. Our model with five convolutional layers showed a classification accuracy of 96.76% which is also higher than most of the models such as ResNet, GoogleNet, and VGG16. This allows healthcare systems to deliver more efficient patient care and thus resulting in lower death rates.

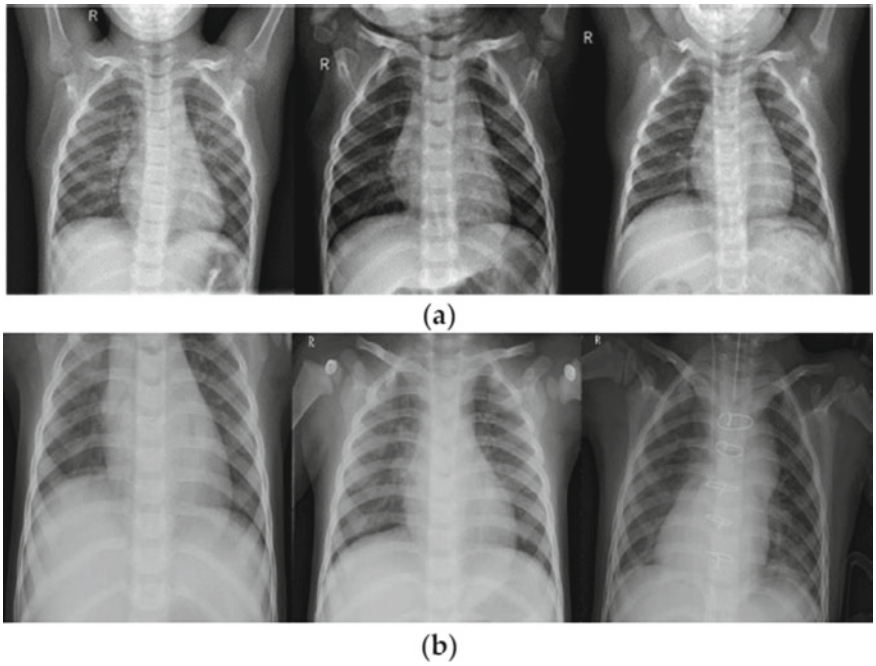


**Fig. 3** To show examples taken from the database of **a** normal patients and **b** pneumonia cases

```
Epoch 1/25
41/41 [==============================] - 651s 16s/step - loss: 0.5660 - accuracy: 0.7422 - val_loss: 1.0347 - val_accuracy: 0.5000
Epoch 2/25
41/41 [==============================] - 540s 13s/step - loss: 0.3498 - accuracy: 0.8570 - val_loss: 0.6448 - val_accuracy: 0.7500
Epoch 3/25
41/41 [==============================] - 540s 13s/step - loss: 0.2332 - accuracy: 0.9062 - val_loss: 0.5956 - val_accuracy: 0.7500
Epoch 4/25
41/41 [==============================] - 538s 13s/step - loss: 0.2226 - accuracy: 0.9090 - val_loss: 0.7649 - val_accuracy: 0.7500
Epoch 5/25
41/41 [==============================] - 537s 13s/step - loss: 0.1835 - accuracy: 0.9284 - val_loss: 0.6888 - val_accuracy: 0.6875
Epoch 6/25
41/41 [==============================] - 538s 13s/step - loss: 0.1674 - accuracy: 0.9376 - val_loss: 0.6434 - val_accuracy: 0.6875
Epoch 7/25
41/41 [==============================] - 537s 13s/step - loss: 0.1563 - accuracy: 0.9378 - val_loss: 1.5984 - val_accuracy: 0.6250
Epoch 8/25
41/41 [==============================] - 536s 13s/step - loss: 0.1587 - accuracy: 0.9393 - val_loss: 1.9638 - val_accuracy: 0.5625
Epoch 9/25
41/41 [==============================] - 535s 13s/step - loss: 0.1593 - accuracy: 0.9387 - val_loss: 1.0450 - val_accuracy: 0.5625
Epoch 10/25
41/41 [==============================] - 537s 13s/step - loss: 0.1313 - accuracy: 0.9487 - val_loss: 0.5174 - val_accuracy: 0.6250
Epoch 11/25
41/41 [==============================] - 538s 13s/step - loss: 0.1305 - accuracy: 0.9498 - val_loss: 1.1753 - val_accuracy: 0.6250
Epoch 12/25
41/41 [==============================] - 535s 13s/step - loss: 0.1185 - accuracy: 0.9563 - val_loss: 1.0080 - val_accuracy: 0.6250
Epoch 13/25
41/41 [==============================] - 532s 13s/step - loss: 0.1163 - accuracy: 0.9590 - val_loss: 0.3770 - val_accuracy: 0.7500
Epoch 14/25
41/41 [==============================] - 535s 13s/step - loss: 0.1195 - accuracy: 0.9577 - val_loss: 1.1546 - val_accuracy: 0.5625
Epoch 15/25
41/41 [==============================] - 531s 13s/step - loss: 0.1110 - accuracy: 0.9594 - val_loss: 0.7660 - val_accuracy: 0.6250
Epoch 16/25
41/41 [==============================] - 538s 13s/step - loss: 0.1042 - accuracy: 0.9602 - val_loss: 1.0391 - val_accuracy: 0.6250
Epoch 17/25
41/41 [==============================] - 535s 13s/step - loss: 0.1012 - accuracy: 0.9651 - val_loss: 1.7562 - val_accuracy: 0.6250
Epoch 18/25
41/41 [==============================] - 534s 13s/step - loss: 0.0964 - accuracy: 0.9642 - val_loss: 0.8384 - val_accuracy: 0.5625
Epoch 19/25
41/41 [==============================] - 534s 13s/step - loss: 0.1010 - accuracy: 0.9630 - val_loss: 0.8874 - val_accuracy: 0.6250
Epoch 20/25
41/41 [==============================] - 532s 13s/step - loss: 0.1037 - accuracy: 0.9609 - val_loss: 0.7061 - val_accuracy: 0.6250
Epoch 21/25
41/41 [==============================] - 532s 13s/step - loss: 0.0861 - accuracy: 0.9665 - val_loss: 0.7062 - val_accuracy: 0.6250
Epoch 22/25
41/41 [==============================] - 530s 13s/step - loss: 0.0916 - accuracy: 0.9671 - val_loss: 0.2541 - val_accuracy: 0.8125
Epoch 23/25
41/41 [==============================] - 533s 13s/step - loss: 0.0903 - accuracy: 0.9671 - val_loss: 0.8602 - val_accuracy: 0.6875
Epoch 24/25
41/41 [==============================] - 533s 13s/step - loss: 0.0803 - accuracy: 0.9701 - val_loss: 1.6991 - val_accuracy: 0.5625
Epoch 25/25
41/41 [==============================] - 533s 13s/step - loss: 0.0860 - accuracy: 0.9676 - val_loss: 0.2532 - val_accuracy: 0.8125
```

**Fig. 4** To show model accuracy of the proposed architectural framework for detection of pneumonia in lungs using CNN

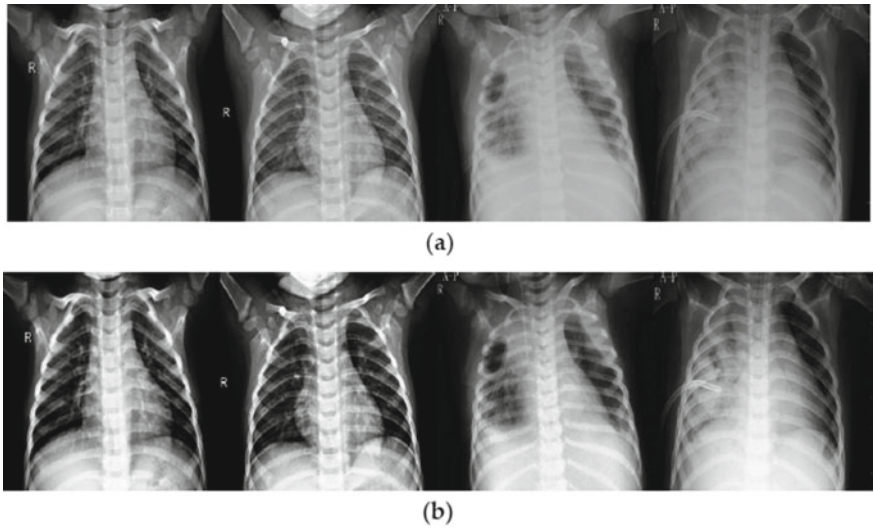

**Fig. 5** Original and improved photos are compared. **a** Original picture samples and **b** improved image instances

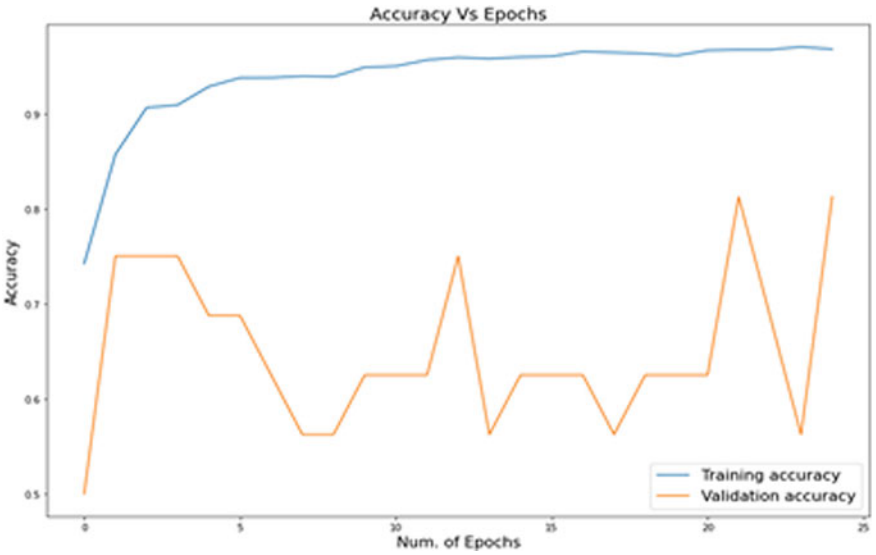


**Fig. 6** Accuracy versus epochs

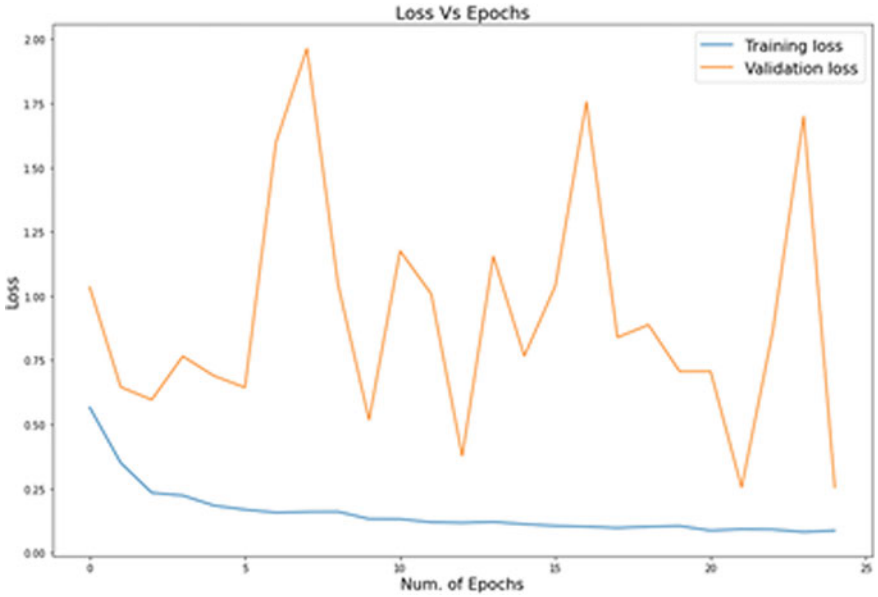


**Fig. 7** Loss versus epochs

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# Earthquake Monitoring with MEMS Sensors

**Vasileios Konstantakos, Ioannis Sofianidis, Konstantinos Kozalakis, Kostas Siozios, Stylianos Siskos, and Theodore Laopoulos**

**Abstract** Earthquake monitoring is a crucial process for human safety. Existing monitoring instruments present a high level of accuracy, along with increased size and cost because of the mechanical sensing elements they rely on. This work proposes an implementation of an earthquake monitoring device either for continuous or for non-continuous monitoring, which combines the recent advances in portable instrumentation systems along with the latest MEMS sensors. The focus is on creating a modern measuring node with improved characteristics, like high accuracy, smart and adaptive functionality, reduced energy consumption, as well as small size and cost. This system is used in a case study, targeting the evaluation and safety of school buildings, demonstrating high-quality characteristics on the acquired earthquake data.

**Keywords** Earthquake monitoring · IoT design · MEMS sensors · Accelerometer · Low power · Instrumentation

## 1 Introduction

Earthquake monitoring has always been a significant process for public safety. The existing measuring principle relies on a highly accurate internal mechanical design, which offers improved performance characteristics, but also leads to devices with increased size, weight, cost, and energy needs. Such devices have been utilized in existing earthquake monitoring networks, covering mostly key locations, providing high-quality measurements, like high signal-to-noise ratio and a frequency range starting below 1 Hz. A wired power supply is common, and in sparse cases, large batteries provide a more portable nature with energy independence of a few days. Furthermore, such instruments usually do not support added functionality like data processing and environmental variables monitoring.

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At the same time, there is advanced progress in instrumentation system design, with improved functionality, size, weight, cost, and energy characteristics. Modern sensor technology provides commercial MEMS sensors suitable for earthquake monitoring, supporting high resolution, high signal-to-noise ratio, and proper frequency ranges. Thus, the evolution of earthquake monitoring instrumentation toward lower size, weight, and energy consumption is mandatory. Moreover, additional smart functionality may be added; the cost may be greatly minimized, and in some cases, partial or total energy independence is possible by energy harvesting techniques. All the above may lead to higher integration of such systems in everyday life.

This paper presents the development of a MEMS-based earthquake instrumentation system able to record earthquake phenomena in a continuous or in a non-continuous basis. This system is used in a specific case study, targeting the evaluation and safety of school buildings. The reduced size and cost will prove important for implementing large networks of such devices. The measurements may be used either for earthquake detection or for the structural integrity evaluation of school buildings.

## 2 Previous Work

The current literature describes the progress in earthquake monitoring. Many high-quality instruments exist already with proven high acquisition accuracy and quality, but with the disadvantages already mentioned, like high cost, size, and energy consumption [1]. These systems consist of a highly important internal mechanical sensor, and at the same time, they tend to verify the lack of optimal usage of modern technology. Proper skepticism is discussed [2]. Also, some preliminary design steps on building modern instrumentation nodes toward this direction are illustrated [3].

At the same time, MEMS technology creates an attraction in integrating the mechanical designs that provide high-quality data for earthquake monitoring. This is an easy task, and MEMS designers are working toward this direction with promising results [4, 5]. Comparisons have been made between available MEMS sensors [6]. As earthquake phenomena are small, easy to lose in noise, and slow in frequency [7], the profile of earthquake recording is a lot different than the usage profile of typical MEMS sensors, like on smartphones, by being more demanding in accuracy, noise, and frequency range. In some cases, large-scale implementation approaches with MEMS are presented [8] and even by utilizing common smartphones [9]. Also, more recent sensor network designs toward earthquake monitoring are proposed [10].

At the same time, IoT system design shows an extensive development by combining modern sensors with the latest advances in instrumentation systems [11]. Energy harvesting techniques may contribute to the optimization of the energy behavior of such systems [12]. In some cases, the harvesting logic specializes to the operating conditions of an earthquake monitoring device, as in the case where a large range of indoor or outdoor lighting is mostly available as a harvesting energy source [13].

The proposed approach takes these recent advances into consideration for developing a modern earthquake monitoring device that uses MEMS sensors on its basis. The following sections will provide: (i) the architecture, (ii) the implementation of the proposed implementation, and (iii) experimental results, as acquired from both the laboratory and the field installation on a school building.

## 3 System Architecture

Earthquake monitoring may be utilized either in a continuous or in a non-continuous logic. Normally, earthquake monitoring runs in a continuous basis. The acquired time series are highly sensitive to time errors, like drifts even for a few microseconds. Thus, a GPS device is required for accurate timing information. Also, there are considerable energy demands if all parts of a system operate continuously that create challenges if there is a need for portability.

Alternatively, a non-continuous operation may be utilized, like for running post-earthquake evaluation processes. This is an easier operation mode with less data throughput, less strict time tolerances, and a reduced operating time leading to a fully portable logic. If, for example, a school is under evaluation, then placing a moderate number of measuring devices throughout the school area may provide useful on-demand data of the behavior of the building during or after an earthquake event.

The proposed architecture is created in a common logic for both the above different operations. Functionality may be enabled or disabled according to each specific configuration of the proposed measuring device, either based on the setup stage of the network (installation locations, access to wired/wireless Internet, access to a wired power supply, etc.) or based on the real-time operation (enabling/disabling devices according to available battery level, communication status, etc.).

The system's architecture appears in Fig. 1. The key device is the accelerograph, with the measuring node at its core. The measuring node relies on the ultra-low power microcontroller MSP430FR5969, with 8 MHz clock. Two MEMS sensors are used as an optimal trade-off between quality and power consumption. ADXL355 is focused on data acquisition, while ADXL362 is used only for triggering. During the continuous mode, ADXL362 is not needed. Should the system measure on demand, then ADXL362 will be able to wake-up the system from sleep by detecting local motion events with a consumption of only 3 μA average supply current in comparison to the 200 μA that ADXL355 consumes. The sampling rate is set to 200 Hz.

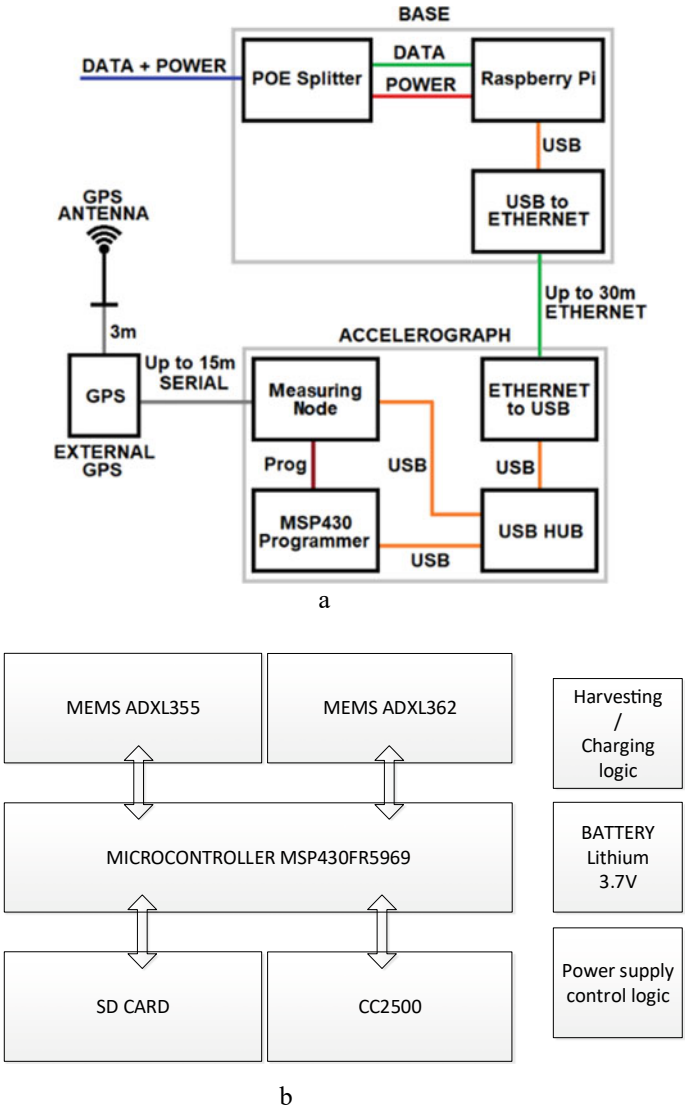


**Fig. 1** System architecture **a** of the complete system, **b** of the accelerograph

The measuring node also contains an SD card, wired communication toward a Raspberry Pi, and a wireless communication module for proprietary communication with a remote device. The SD card is used either for backup reasons or as an alternative local storage if communication is inoperable by any means. The system also contains a programmer module for remote firmware update.

The complete system may be usually powered by a nearby power plug or by power-over-Ethernet logic. In the continuous mode with all modules active, the wired power supply constitutes the energy consumption of least importance. In the non-continuous mode, only, the core measuring node is operating. The energy consumption is now vital, so this node is designed accordingly. In a mixed situation, where continuous operation is in need and a wired source is unavailable, then additional batteries may be used, which should however be replaced every several days. In any case, the reduced energy consumption of the proposed device in comparison with the existing earthquake instrument, along with the energy harvesting support, even in continuous operation, makes the battery replacement cycle less frequent.

## 4 Implementation

The final implementation, as created for operating on a school building, appears in Fig. 2.

A major difficulty is the timing instability due to temperature variations affecting the microcontroller's internal clock. Thus, a GPS module is unavoidable, as in all existing earthquake monitoring devices, and an important development step is the control of this module. The rather small operating clock of the system (8 MHz–125 ns period) creates challenges in achieving time inaccuracies of a few microseconds. The GPS module provides an accurate 1 s square signal (PPS signal) that is read by the

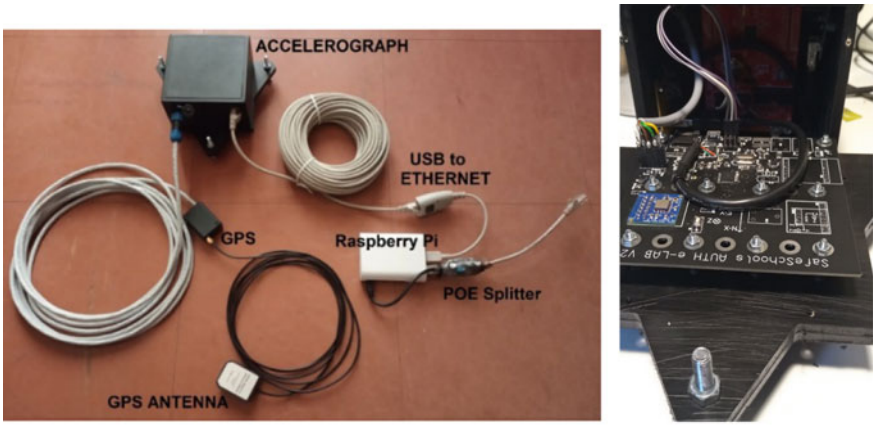


**Fig. 2** Implementation of **a** the complete system, **b** the accelerograph

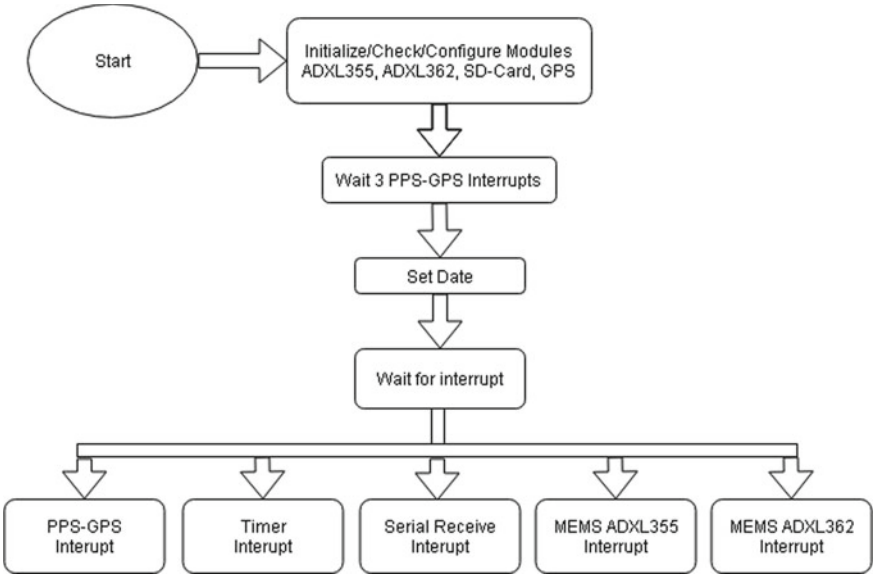


**Fig. 3** Main flow of the microcontroller's code

timers of the microcontroller. An algorithm is implemented, so that an internal time reference is constructed and maintained as accurately as possible with the help of the GPS module. A developed measurement process of the time error between the GPS time and the constructed internal time indicated error values below 3 μs, which is 3 orders of magnitude smaller than the sampling rate (200 Hz–5 ms).

Further work was needed for the SD card usage, for the serial communication with a Raspberry Pi, and for other minor functionality. The microcontroller algorithm was purely interrupt driven, and a combination of low power modes was used, with average current consumption as low as 500 nA. The main flow of the implemented code appears in Fig. 3.

The recording process presented so far is vital in both continuous and non-continuous modes of operation. The non-continuous operation uses additional rules when it is not recording. The system now is mostly powered by a battery; it has some simplified start/stop logic for the sampling functionality and utilizes proper circuitry for charging the battery either from a wired source or from an energy harvesting source. A preliminary evaluation of the energy behavior on a submodule basis is recorded through measurements and appears in Table 1, as average current consumption values.

The system can sleep with a minimum average current consumption of 25 μA (92.5 μW in 3.7 V), with 2 possible wake-up triggers, (a) either by the ADXL362 motion detection, (b) or by the wireless CC2500 module, through a remote wake-on radio mode. The CC2500 is configured to wake-up for a small percentage time window of 5% over a 2 s repeating cycle, leading to an average current consumption

**Table 1** Average current consumption per submodule

| Module | Idle state | Acquisition state |
|---|---|---|
| Microcontroller | 500 nA | 1 mA |
| ADXL355 | 0 | 200 μA |
| ADXL362 | 3 μA | 3 μA |
| CC2500 | 20 μA | 5 mA |
| SD card | 0 | 40 mA |
| GPS | 0 | 50 mA |
| Total | 25 μA | 97 mA |

**Table 2** Harvesting gain based on light intensity

| Light intensity (LUX) | Available power (μW) |
|---|---|
| 60[a] | 3.3 |
| 220[a] | 79.8 |
| 500[a] | 463.3 |
| 5000[b] | 2000 |
| 60,000[b] | 37,100 |
| 120,000[b] | 74,000 |

[a] Indoor light
[b] Outdoor light

of 20 μA. If it detects an incoming packet within this small active window, it may remain active. This leads to a wireless wake-up logic with minimum consumption, at the dispense of a 2 s delay, applicable when the earthquake network requests on-demand all devices to start recording. The acquisition state, where a full speed acquisition occurs with a local SD saving, leads to an average current consumption of 97 mA (358.9 mW in 3.7 V). All other states, like data transmission and configuration, are characterized by an average current consumption in between of these 2 states. At the same time, energy harvesting logic is applied to both indoor and outdoor light sources. A presentation of the harvesting technique appears in [13], as developed by the same research team. The performance of this technique is summarized in Table 2, based on a photovoltaic panel of 73 × 94 mm, at different indoor and outdoor lighting conditions.

The combination of Tables 1 and 2 may lead to different energy independence estimations, according to the operating conditions of each device. Although the small photovoltaic panel may not provide energy independence to the continuous operation, a larger panel will be able to. On the other hand, the non-continuous operation may become energy independent by both indoor and outdoor lighting conditions.

The measuring node creates accelerometer data that should be integrated properly to the seismological network. This means that they should be processed and uploaded to a seismological server in the proper format, which is miniSeed packets [14]. This functionality occurs in a Raspberry Pi, with Python code. Besides data handling, this device acts as the gateway device between the accelerograph and the outside world and is configured prioritizing robustness and proper operation evaluation.

## 5 Experimental Process

For the evaluation of the proposed system, several measurement sets were held in a comparison logic between the proposed system and a commercial earthquake monitoring device (Guralp). Initially, simulated earthquake events were recorded with increased quality in laboratorial conditions produced by a vibrating table device. Furthermore, noise levels were acquired presenting an expected behavior, meaning an ideal behavior for the commercial instrument, a good behavior for ADXL355, and a poor behavior for ADXL362. Both the above evaluation processes appear in Fig. 4.

Finally, the developed system was installed in a school building alongside a reference instrument (Guralp), verifying its robust operation. Eventually, an earthquake was recorded of size 6R (distance 100 km, depth of focus 8 km), as it appears on Fig. 5. The comparison between the two instruments indicated a very good performance of the implemented system with slightly increased noise, mostly on $Z$ axis (MEMS sensor limitation). On the frequency plane, the results were equally good, with some noticeable difference on frequencies equal to or smaller than 1 Hz. The final behavior is highly related to the specific MEMS sensor selection and can be improved in the future by mostly selecting alternative further developed MEMS sensors.

## 6 Conclusions

An earthquake monitoring device is studied and implemented by combining modern instrumentation guidelines along with MEMS sensors. The implemented system supports a variety of operation modes and energy needs. The development process had challenges on the accuracy of the internal time. The acquired data were characterized by an increased quality, indicating that the implemented system can withstand as a possible replacement of the existing earthquake monitoring instruments.

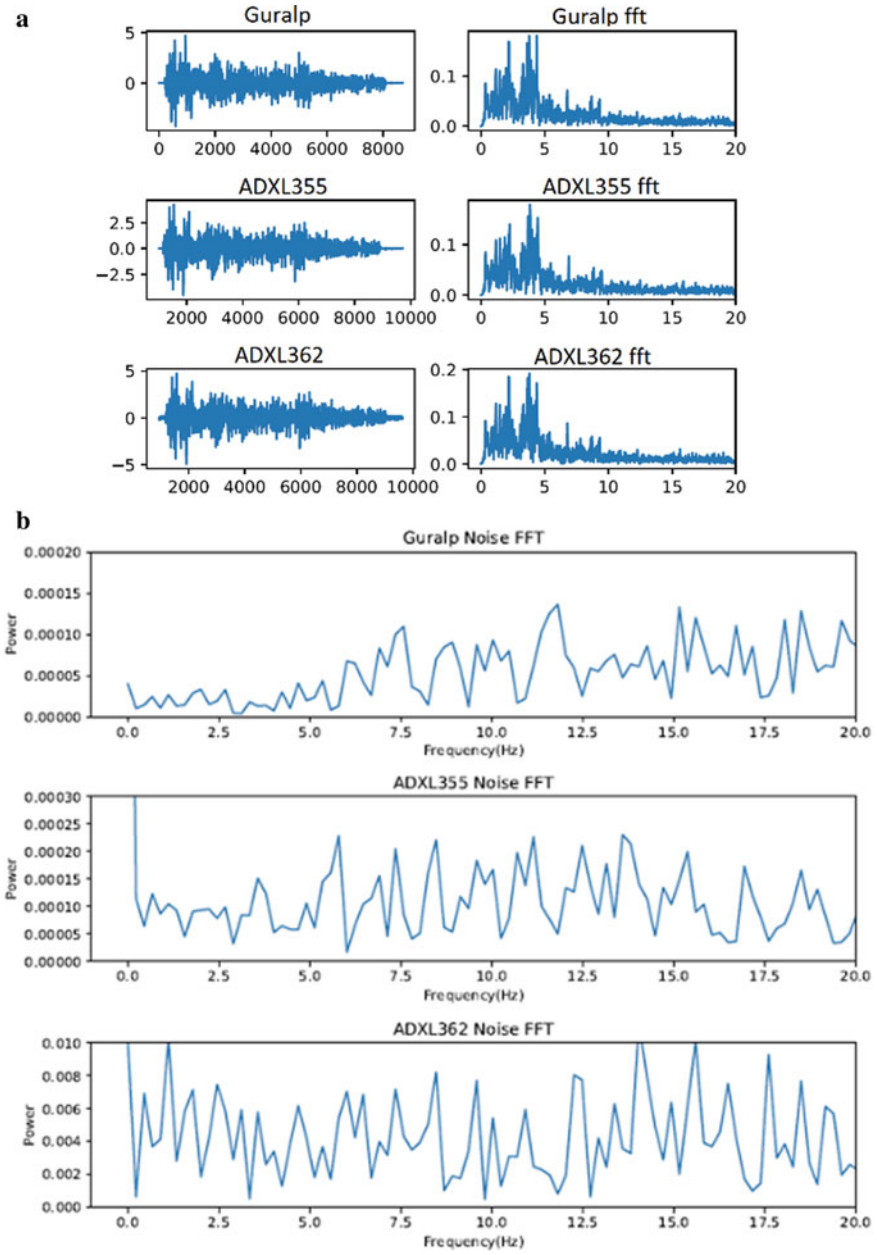


**Fig. 4** Evaluation of the proposed system, **a** recording of a simulated reference earthquake (El Centro), **b** recorded noise levels

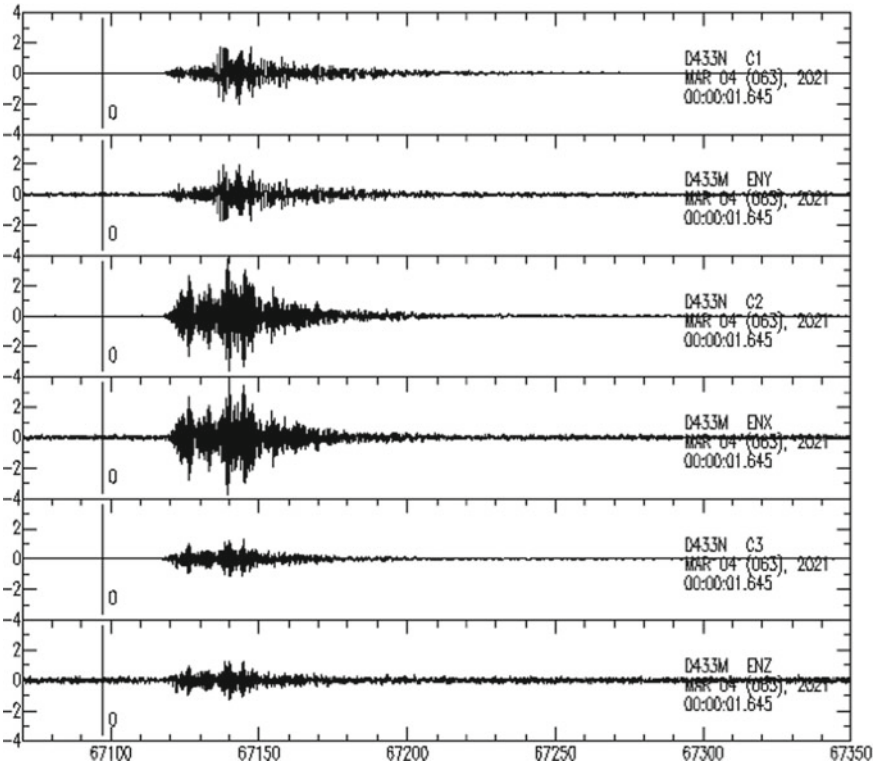


**Fig. 5** Recorded earthquake on the school building, D433N: Guralp, D433M: the implemented system, C1 parallel to *Y*, C2 parallel to *X*, C3 parallel to *Z*

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# Self-supervised Learning Approach to Local Trajectory Planning for Mobile Robots Using Optimization of Trajectories

**Juan Escobar-Naranjo and Marcelo V. Garcia**

**Abstract** In Industry 4.0, various control methods have been developed for autonomous navigation of robots. Some investigations are based on the use of SLAMs or routing systems for route tracking, but there are some limitations when it comes to obstacle avoidance and real-time parameter changes. Current work shows an algorithm based on the use of DQN and reinforcement learning. The model maximizes rewards and extracts information about the robot's position and obstacles within the simulated environment as the robot performs its actions. A series of experiments have been conducted to build the algorithm, and the results show that the robot learns through exploration and uses the knowledge gained in the previous scenarios. Using a simulated environment, the DQN network computes complex functions due to randomness, resulting in better learning performance than other control methods.

**Keywords** Reinforcement learning · Robotics · Obstacle avoidance

## 1 Introduction

Today's industry faces the challenge of adapting to technological advances through innovation and investment in the development of efficient equipment and work methods. Over the past decade, there has been a major industrial transformation known as Industry 4.0 (see [1, 2]) that focuses on the automation of manufacturing processes, real-time data sharing through the cloud, interconnecting cyber-physical systems, and developing control algorithms based on machine learning, leading to the creation of intelligent, flexible, and dynamic factories [3]. By implementing autonomous systems, sensors, and actuators, manufacturers can meet higher quality standards, reduce costs, eliminate downtime, and become more competitive [4]. Nowadays, the pro-

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ductive process is based on data analysis, and new predictive tools significantly reduce risk leading to better decision-making [5]. The use of machine learning-based systems, through statistical methods, enables the analysis and optimization of algorithms designed based on previous results and is presented as a new model for creating regression-based control systems [6]. This work presents the design of a control system based on DQN and reinforcement learning using the most appropriate optimization algorithm for error mitigation. The programming language used for the model is Python because the existing documentation on the Keras library application is large enough to enable the optimal development of the model and the training. The ROS API allows easy communication due to the interoperability between the controller nodes and the simulated environment through commands that send messages with the speed, position, and odometry of the mobile robot.

This article is structured as follows: Sect. 2 presents material and methods. Section 3 consists of results. Discussion is presented in Sect. 4. Finally, Sect. 5 details the conclusions.

## 2 Material and Methods

This section describes the actions to be developed for the control system for mobile robot obstacle avoidance. The objective is to identify, establish and analyze the information available to understand the difficulty, this allows the reader to systematically evaluate and criticize the validity of a study.

### *2.1 State of the Robot*

This includes information about the results of the previous interactions between the agent and the environment, the neural network works with representations of the state to compute an output. Turtlebot3 burger has a 2D laser distance sensor called Lidar or LDS, which is capable of sampling 360 °C and detecting objects located between 120 and 3500 mm, and it is mounted on a rotating head, which allows adjusting the size of the samples; in Gazebo, the value of 11 lidar points is used, mainly to simplify the training and therefore the complexity and dimension of the same; however, with this value, an optimal measurement and location of the obstacles within the simulated scenario are carried out.

$$\text{State} = \text{LDS}(11\text{values}) + \text{Distance}(1) + \text{Angle}(1) \tag{1}$$

The 11 sensor values are transmitted through ROS, that is, they are published in a topic from a node, and the size of the state is defined in 13 where 11 are from the sensor and 2 more are defined through the angle defined between the rotation of the

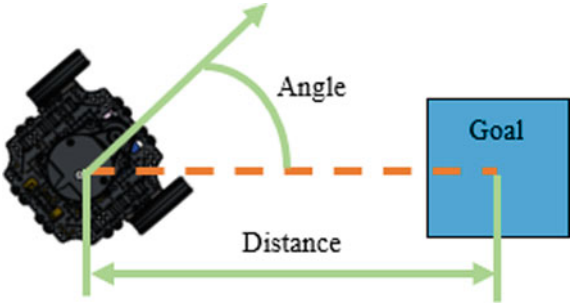


**Fig. 1** Angle calculation

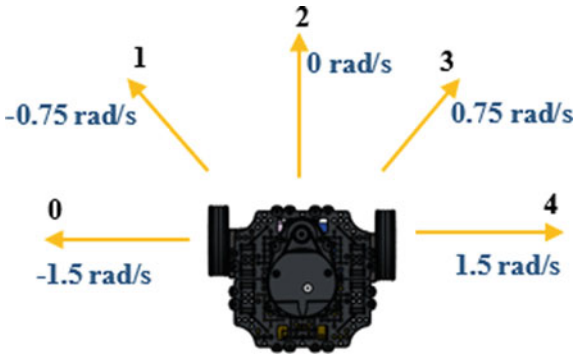


**Fig. 2** Actions of the Turtlebot3 burger

robot and the distance to the target as seen in Figs. 1, 2 and in Eq. 1. To calculate the angle, it is necessary to determine the odometry, which is the position of the robot with respect to its reference frame.

## *2.2 Action of the DQN Agent*

It is called as the action performed by the robot while interacting with the environment and it is determined as the output of the last layer of the neural network. Turtlebot3 burger has five actions to generate its movement based on the type of state. In addition, the robot always has a linear speed of 0.15 m/s so its angular speed is determined in based on the action as presented in Fig. 2.

## *2.3 Reward of the DQN Agent*

This is defined as the feedback that the agent receives from the environment after performing an action. For the development of the reward function, the robot will receive the maximum positive reward when it reaches the goal, and in the same way,

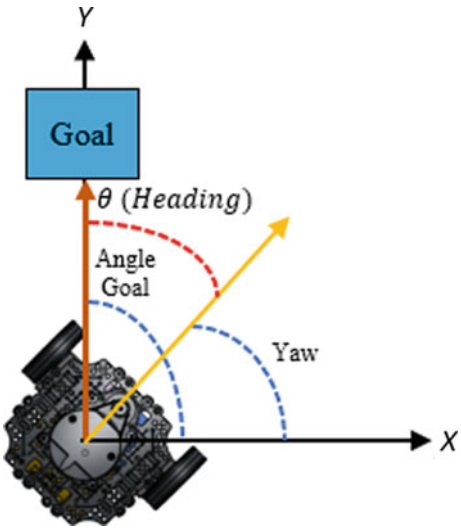


**Fig. 3** Representation of heading between the robot and the goal

it will receive the maximum negative value when it collides with any of the obstacles. Finally, the reward $R$ for the actions of the Turtlebot3 burger mobile robot comprises the multiplication between the reward of the distance $R_d$ and the orientation $R_\theta$ as shown in Eq. 2.

$$R = R_d \cdot R_\theta \tag{2}$$

## 2.4 Heading Reward

Heading is defined as the angle between the robot and the goal as shown in Fig. 3, when this value is small, it means that the orientation of the robot is close to being aligned with the goal, and in this case, the agent receives a positive reward; however, when this value increases, it means that it is in the opposite direction, which is why it tends to move away, in this case, a negative reward is obtained.

The heading reward is presented in Eq. 3 and considers two parameters, the angle and the number of actions that the mobile robot has. The objective of this reward is to indicate to the agent when an action was correct, for which the equation considers the angle $\theta$ must be in radians, and this implies that when dividing the number of actions by this value, the reward is greater when the angle is found closer to zero degrees and less as the angle is greater.

$$R_\theta = 5/\theta \tag{3}$$

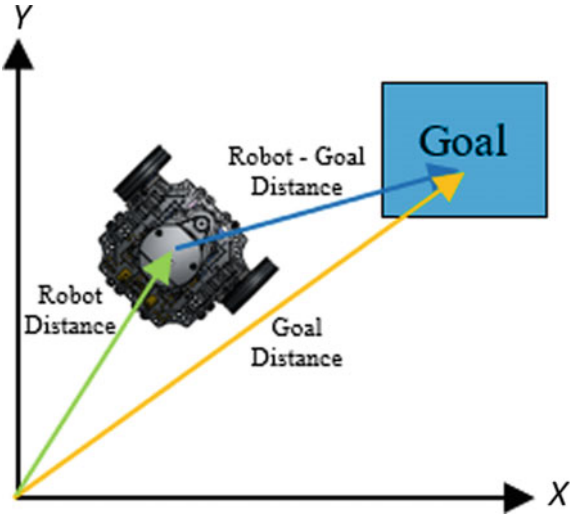


**Fig. 4** Representation of distances of the robot and the goal

## *2.5 Linear Reward*

For this, it is necessary to calculate the distance rate $D_{\mathrm{R}}$, which considers the current distance $D_{\mathrm{c}}$ and the absolute distance $D_{\mathrm{a}}$. The current distance is defined as the space between the robot and the goal; this value varies continuously depending on the movement of the robot and the new position of the goal once it has been reached in the previous training, for its calculation, it is required to analyze trigonometrically from the distances of the goal and the robot referenced from the main plane of Gazebo, as presented in Fig. 4. The absolute distance is described as the space from the start of the Gazebo reference frame to the goal but just when a training scenario starts.

The calculation for the distance rate is presented in Eq. 4. It is used because as the robot gets closer to the goal, the result of the reward is greater; however, when it gets too far away, the score is reduced to one.

$$R_{\mathrm{d}} = 2^{(D_{\mathrm{a}}/D_{\mathrm{c}})} \tag{4}$$

Finally, the reward function for the network is presented in Fig. 5, three conditions are defined for the system, which will allow an adequate automatic control of the robot's route to the goal.

$$R = \begin{cases} 200, & \text{if goal is reached} \\ -100, & \text{if collision occurs} \\ R_d \cdot R_\theta, & \text{else} \end{cases} \tag{5}$$

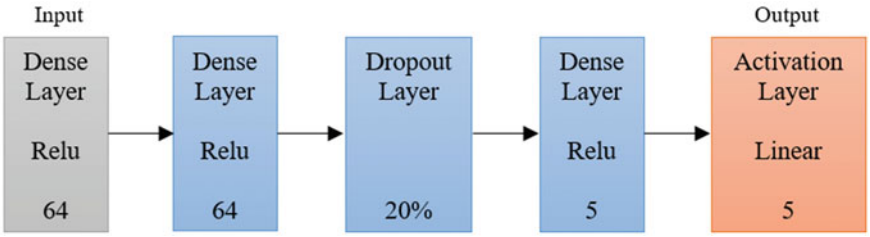


**Fig. 5** Q network

## *2.6 ROS System*

For the proposed implementation of the case study, a four-node ROS system is developed; this will allow the simulated Turtlebot3 burger mobile robot to be controlled through a reinforcement learning system based on DQN, and the exchange of messages of the nodes is based on the publication and subscription to different topics.

## *2.7 Network Structure*

The network model is sequential and its first layer is used for reading the information, it is called Dense, which indicates that the neurons are connected to each other; to avoid the problem of saturation of negative values or very long positives, the hidden layers and the initial one are activated by means of Rectified Linear Unit (ReLU), in addition, a Dropout layer was used that allows to avoid overfitting by randomly establishing the 20% of input units in each step of the training, finally, the last one was used linear Activation layer, as shown in Fig. 5.

The input layer consists of 64 neurons and 13 inputs corresponding to the size of the state, previously defined in Sect. 2.1, while the output layer has 5 neurons due to the number of actions established in Sect. 2.2, in addition, the activation of this is linear because it is a regression and not a classification.

## *2.8 Experiment Setup*

Based on the available data and the type of network used, the mean square error (MSE) loss function is established for the compilation of the model, and it is used in simulated and real systems and works in regressions where it is better to use the descending gradient method than least squares because it can find more optimal solutions in less time. This function is used because it is considered one of the most efficient and is applicable in simple and complex models, within this, the predictions

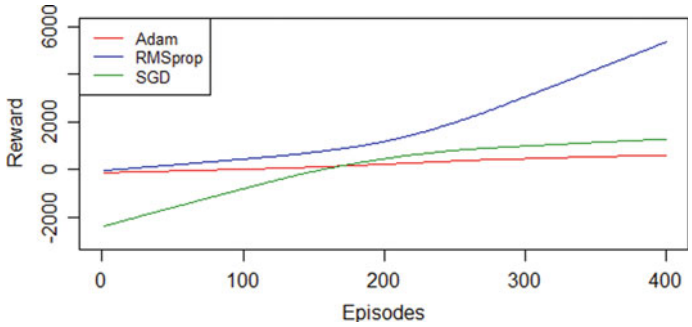


**Fig. 6** Comparison between the optimizers Adam, RMSprop, and SGD

that are very far from the real value are penalized compared to the less deviated. The experiment was configured for three different optimization algorithms based on the previously established loss function and the inferred gradient calculation.

## 3 Results

The optimization algorithm that presented the best results was RMSprop, based on its use, the robot found the goal more frequently and avoided obstacles better than the other optimizers, and the trend is growing and the reward reaches very high values, indicating that the network is functional because the algorithm is learning.

From the DQN network based on RL, the data of the reward obtained with the different optimizers were collected, as presented in Fig. 6, a smoothing based on least squares with additional weighted adjustments was considered for the representation of the trends.

## 4 Discussion

The control algorithm was simulated in a three-dimensional environment using the mobile robot Turtlebot3 burger; after 400 executions of the network training where the robot had to seek the goal avoiding obstacles, it was possible to measure the level of reward that it obtained by each action executed. During the training, the positions of the goal are generated randomly, only avoiding coinciding with parts of the arena. At the beginning of the training, the robot collides with obstacles frequently and rarely reaches the goal, after several episodes, the agent learns how to interact with the environment in an appropriate way, making the robot autonomously define its trajectory and avoid colliding so that it reaches the goal based on positive scores, and the experimentation validates the effectiveness of the model.

## 5 Conclusions

The control algorithm based on DQN and reinforcement learning works within the system as a ROS node, which is responsible for controlling the angular velocity of the differential tires through actions. The developed architecture uses open source components, giving rise to the interoperability between the agent and the environment, allowing the communication of messages through the publication and subscription to topics, mainly sending those components necessary for the model, such as actions, states, and rewards.

The experimentation allows to correct the configuration parameters of the model; this allows an optimal and adequate functioning of the structure of the neural network, and the most appropriate optimization function for the control system was the calculation of the regression through RMSProp and the loss function MSE, through its application, the robot avoided obstacles and pursued the goal with greater precision, which considerably improved its reward level, a growing trend was obtained, which validates the operation of the algorithm due the time spent on trajectories is greatly reduced.

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# Social and Technological Impact of the Simple Taxation Regime on Business Formalization in Colombia in Post-pandemic Times

**Jasleidy Astrid Prada Segura**

**Abstract** The purpose of the simple regime is to reduce tax burdens, optimize cash flow, and promote entrepreneurship and new technologies to formalize companies in post-pandemic times, guaranteeing economic reactivation and the challenges imposed by technological advances. The objective of this article is to determine the factors of the new simple taxation regime, and its influence on the creation and formalization of companies in post-pandemic times, as well as on the development of entrepreneurship through new technologies in Colombia, by means of a mixed research according to its data source, with a triangular approach that brings together the documentary review and the application of surveys as an instrument of information collection, the main sample is chosen, the merchants of the locality of Engativá in the Quirigüa neighborhood of the city of Bogotá. According to the results obtained, some of the merchants interviewed are unaware of the benefits they would have by joining the simple regime; they have not been formalized for fear of the costs that may arise, such as taxes and the time they may spend for the completion of procedures. In addition to the above, it should be noted that one of the requirements to belong to this regime is electronic invoicing, but many have not yet done so because it implies costs that they have not considered, and they have not been able to recover economically after the COVID-19 quarantine.

**Keywords** Benefits · Economic revival · Entrepreneurship · Post-pandemic · Small business

## 1 Introduction

The present research focuses on determining the social and technological impact of the simple tax regime on business formalization in Colombia in post-pandemic times, taking as a reference that throughout the last thirty years Colombia has gone through different tax reforms, authors such as Granger et al. [1], make a historical

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review of tax reforms, in which they highlight how most of them have been approved, in a deceleration phase and some in phases of economic expansion, without ignoring that the COVID-19 pandemic significantly affected the development and growth of organizations, leading small entrepreneurs to bankruptcy.

That is why this topic is developed not only in the taxation of the new regime, but also in how it is linked to technological and digital means, for example, the presentation of ELECTRONIC INVOICING AND THE SIMPLE TAXATION REGIME. With a single receipt, the payment of up to six taxes is anticipated, which is done in the virtual platform of the NATIONAL TAX AND CUSTOMS DIRECTORATE-DIAN, which contributes to saving time in the completion of procedures and reduces transactional costs. Not knowing that in many cases entrepreneurs do not have access to technology.

Currently, the country is in the process of transition to electronic invoicing, but how does the new regime affect it? The answer to this question is that electronic invoicing is a transition that has been implemented gradually in Colombia since its model was adopted through Decree 2242 of 2015. Initially, the DIAN determined some taxpayers who were obliged and invited some companies to carry out the process voluntarily, but finally determined that all persons responsible for vat would be obliged to invoice electronically, and established deadlines that have been moving, but which are expected to culminate in October this year. Now, the RST, to which both individuals and legal entities belong, is also obliged to issue electronic invoicing in accordance with the established deadlines.

This research aims to identify how the new simple taxation regime influences the creation and formalization of companies, taking into account that in Colombia entrepreneurship has become one of the main strategies in socioeconomic development, and that at the same time, as pointed out by Matiz and Naranjo [2], it is one of the barriers to business promotion and development due to the difficult access to financial resources to carry out a project. A mixed research methodology with a triangular approach is used in which a documentary review and the application of surveys in the city of Bogota are used to measure the impact of the high tax burden in Colombia. In addition, different referents of tax, accounting, business technology platforms, entrepreneurship, and statistical aspects are discussed, to measure the possibilities of entrepreneurship and business creation despite the tax burden, including a report of events of the Chamber of Commerce in which a simple, equitable, efficient, and stable tax system is proposed, aimed at combating tax evasion and tax avoidance [3].

Once the measurement instruments have been used, the results obtained from the surveys of the microentrepreneurs located in Engativá, Quirigüa neighborhood in the city of Bogotá are shown graphically. Subsequently, the opinions of the microentrepreneurs and the different entities that regulate the tax regime in Colombia are compared, and finally, the result is shown according to the research process carried out on entrepreneurship in Colombia.

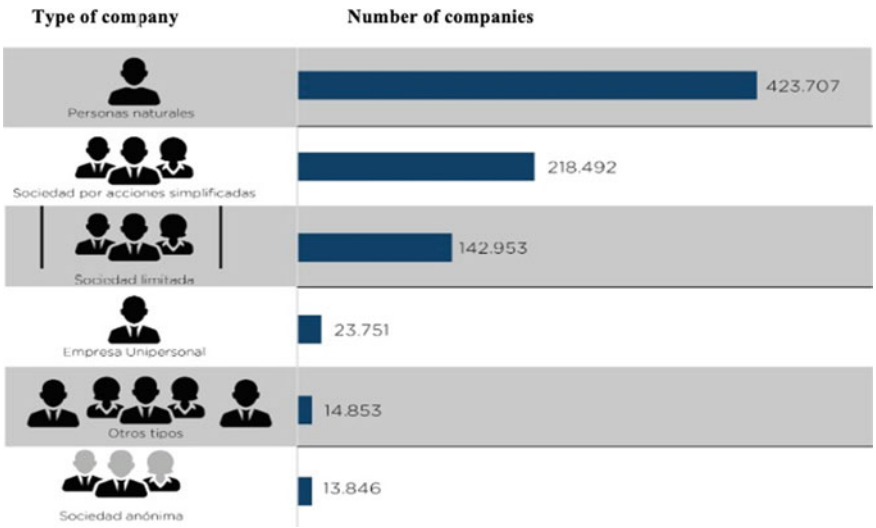


**Fig. 1** Total number of companies with active registration in Bogotá. *Source* ODEB, Bogota Chamber of Commerce

## 2 Methodology

To develop the research, a mixed approach methodology was used, with a descriptive scope, gathering information to argue the current situation of SMEs, having as references the books by R. Hernández, C. Sampieri-Mendoza, and W. F. Seiem de Castro [4].

The collection instruments used were the surveys, based on the data provided by the Chamber of Commerce of Bogotá [5] where it is established that 97.5% of the 100% of the registered companies correspond to microenterprises, and that Engativá occupies the third place in the list with 63,722 (9.7%), the largest number of registered commercial establishments. The surveys were conducted among a population of thirty microentrepreneurs from the 123 neighborhoods of the locality, taking the average to establish the number of merchants in Quirigüa, resulting in 196 microenterprises. The sample of 28 surveys was conducted with a confidence level of 95% and a margin of error of 5%, which measures the impact of the tax burden on this population (Figs. 1 and 2).

## 3 Theoretical Framework

The simple taxation regime (RTS) is an optional model launched in 2019; it is a tax that is declared annually, but for which bimonthly advances must be made. Its purpose is to reduce formal and substantial burdens on taxpayers, boost formality,

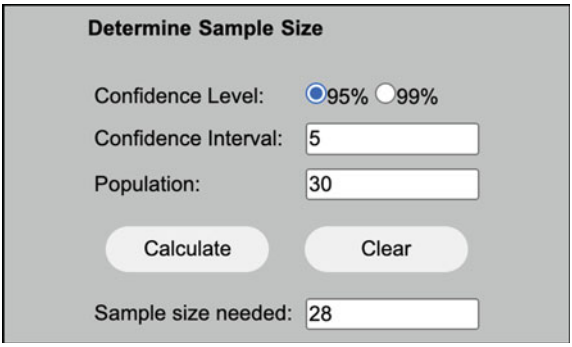


**Fig. 2** Sample size calculation. *Source* Sample size calculator. https://bit.ly/2loCgcT

and facilitate compliance with tax obligations. One of the benefits of the RTS is the integration of six taxes in a single return: simple tax, income tax, occasional profit tax, industry and commerce tax, national consumption tax, firefighter surtax, and the tax on notices and boards [6].

This tax regime has not met the DIAN's expectations because it did not obtain the number of taxpayer registrations it expected due to the lack of dissemination and guidance to traders; additionally, it is limited to a single economic activity of the self-employed. In the same line, one of the requirements to join the RTS is that in the previous taxable year gross income, ordinary or extraordinary, of less than 80,000 UVT has been obtained. For Moncayo [7], this regime does not favor the micro-business because it does not correspond to the income it may receive; on the other hand, the wrong message is sent that formalizing is obliged to keep accounting, and this in turn represents additional expenses.

How is the RST composed, the main actors and what is its impact on business creation?

To determine how the RTS influences business formalization and entrepreneurship in Colombia, we identified that Article 66 of Law 2010 of 2019 details all the considerations, conditions, and decrees of the unified tax, which was implemented by OECD recommendations to reduce informality, which came into force as of August 1, 2019, and which aims to alleviate the tax burdens of taxpayers, whether resident individuals or national legal entities. However, for Arenas [8], its impact has not been as expected, given that its conditions do not allow a wide coverage.

Which replaces the mono tax, the RST is indicated for small stores, micro- and mini-markets, and hairdressers; commerce and telecommunications; professional services and restaurants and transportation since companies with revenues from $48 million to $2700 million will be able to do so, which would impact about 500,000 companies [9]. It is important to know that this change from single tax to simple regime was influenced by the OECD's suggestion to increase the eligibility of the periodic economic benefits program and reform the labor markets to reduce informality and increase labor demand, on the other hand, the OECD [10] states that the main origin of this change is that the state seeks that many people are obliged to

declare so that there is no tax evasion, in order to voluntarily accept the form of taxation.

According to data from Confecámaras [11], 75,275 new companies were created in 2019, of which 75.7% correspond to natural persons, to which it is argued that Colombian businessmen and entrepreneurs are formalizing to gain presence and opportunities, and that this is the result of the efforts and investment made by the chambers of commerce in counseling and support programs in order to provide innovation and management tools so that companies can grow despite the costs involved.

An initiative led by the EAN University and ASEC points out that the five most important actions that President Duque should focus on are taxation, financing, increasing public budgets for entrepreneurship, access to markets and red tape. For Sergio Zuluaga, executive director of ASEC, taxation percentages, supplier payment policies, financing schemes, and access to markets are unsustainable for entrepreneurs in stabilization and growth stages, which is why it is necessary for the government to generate knowledge and relevant data to facilitate decision-making in the public and private sectors (Paragraph 1). It is of utmost importance to know the types of tax obligations that must be faced when creating a company [12]. The first thing that must be clear is that according to the economic activity exercised by the entrepreneur will be its obligations. Likewise, they must consider the district taxes, which must also be considered when creating a new company.

According to the DIAN, the simple taxation regime (RST) must be contemplated by new entrepreneurs. The main purpose of this regime is to promote formality in Colombia and, aware of the difficulties and challenges that the costs of formality imply for an entrepreneur in its entry dimension, the Government recently made available to entrepreneurs a tax regime that reduces compliance costs and provides a more competitive environment that will allow them to focus their resources on the growth of their business (paragraphs 1 and 2). An entrepreneur in Colombia, with this new regime, has rates from 1.8% with which it will be able to pay up to five taxes. It also has lower personnel hiring costs due to the possibility of deducting the pensions paid to its employees; it may also be exempted from the payment of parafiscal contributions; it has tax discounts for electronic transactions and will not be subject to high compliance costs to the extent that it can pay national and municipal taxes with a single form (paragraph 7). This shows that the new tax regime is focused on breaking schemes and reducing business informality.

### *3.1 How Taxation Affects Small Businesses at the Time of Formalization*

When analyzing the regulation, it could be said that the RTS does not benefit small entrepreneurs; since according to Actualícese [13], the following can be observed: The subjects enrolled in the simple regime will no longer have to continue reporting

their taxable net worth since in this they will not have to calculate the presumptive income nor their taxable base will be inflated with items such as "special net income for omitted assets or nonexistent liabilities," or "net income by equity comparison." These special items, which are only mentioned in articles 188, 236 and 239 of the ET, will only continue to appear in the returns of those who continue to be taxed under the ordinary regime of the Tax Statute.

However, the rule of Article 434 A, Penal Code, mentions that it can only be applied to taxpayers who continue to be taxed under the ordinary regime. Here, it would be benefiting those evaders who have wanted to hide their wealth and who can now freely go out and show it without this meaning that they must now pay for their recognition because the DIAN could not do anything about it, and on the contrary, it clearly generated a big loophole for white collar evaders. Consequently, the real scenario faced by current and new entrepreneurs to stay in the market, as pointed out by Forero et al. [14], is that income tax is the most burdensome for companies, representing on average 29.9% of the total taxes paid, the rest of the taxes include, among others, industry and commerce taxes, stamp tax, valorization payments, tourism tax, and non-discountable VAT. This does not include administrative expenses, such as salaries, social benefits, and operating expenses. All this tax burden can reach up to 117.9% of their profits and is a fundamental factor in explaining the high levels of business informality in Colombia.

## 4 Results and Discussion

### *4.1 Results*

When conducting the surveys, specific questions were asked, which are shown in the Fig. 3.

Out of seven microenterprises, only, four are registered with the Chamber of Commerce; the employees are not hired through payroll; the payments are up to date, and they do not pay social security contributions; in addition, we found that only two microenterprises handle electronic invoicing. In addition, we can deduce the following:

- Traders are not aware of the benefits of belonging to the simple taxation regime.
- The obligations of those who belong to this regime are not clear since they are not informed or have not been advised because for them it implies costs that have not been budgeted.
- Respondents are generally employees and not the owners of the establishments.
- They are not familiar with the simple taxation regime, and, in fact, many cannot say with certainty whether they are liable for VAT.
- Of the stores where it was not possible to interview the owner, the employees indicated that their payments were up to date and that they had no social security payments, i.e., 100% informal employment.

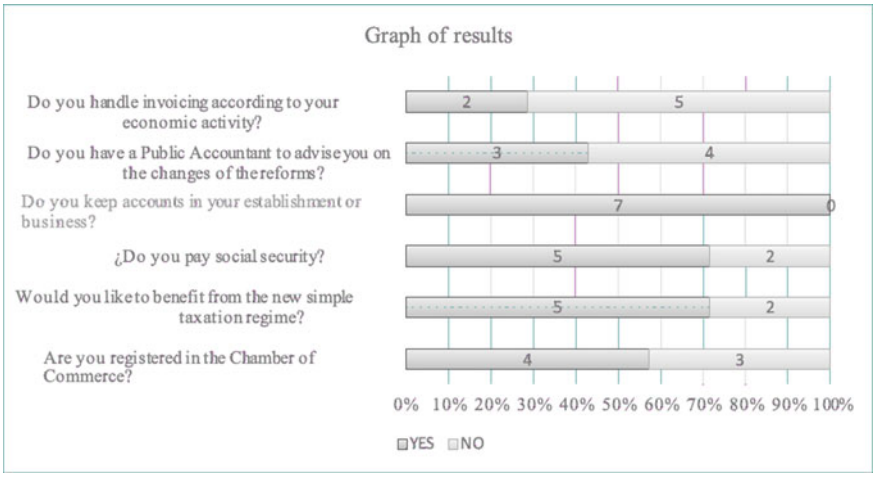


**Fig. 3** Graph of results

## 5 Discussion

The RTS requires electronic invoicing, which is considered an important step toward legality and business formalization. To this end, it is essential to train small businesses in group 1, which are small grocers, minimarkets, and hairdressers, since for them there is not much difference between an invoice made through accounting software, which in this case is a POS system, and electronic invoicing.

Additionally, many do not handle paper invoices or, at least, not the one that has the legal requirements, i.e., the sales invoice. Although it is true that many of the businesses that already have an invoice will find the process a little less traumatic, those that do not have a cash register machine must not only invest in the software or invoicing package, which varies according to the invoicing of the business, but they must also invest in equipment to be able to prepare it: computer and printer. Many merchants are not able to make this investment because, as mentioned, we are talking about neighborhood businesses that must completely change the way they are working since they have been living from their businesses, which are usually family businesses, for many years.

Now, let's review the progress that has been made with this new simple regime. According to the DIAN, as of May 12, [6], only, 515 merchants had registered, and the previous figure for the next three years is 500,000 [15], a not very encouraging figure due to the lack of knowledge and uncertainty of the merchants, as well as the paperwork it generates. Another factor that puts this sector in check is the electronic invoicing process that new entrepreneurs must implement, where many claim that it is quite wasteful due to the little knowledge and management, they have in computer systems. Hence, the importance of socializing in a clear and simplified manner what this new regime consists of and to seek strategies aimed at preparing a safe and

positive route that promotes the formalization and creation of companies to generate formal employment that contributes to the economic development of the country.

But, not everyone thinks that this new regime is favorable for business formalization; many traders, including those who make up the group of shopkeepers, wonder: is it convenient to be part of this new group of taxpayers? For many, it is better to continue in informality and not have to think about tax burdens and additional expenses that they had not contemplated and that will be directly reflected in their profits, which makes this law not as simple as it seems [16].

Finally, the state seeks to reduce informality and achieve a better and greater participation in the form of taxation, generating benefits such as deducting 0.5% of the sales received through debit and credit cards, and 100% of the contributions made to the pension funds of employees, among others [17]. And for small businesses, this transition is not a business, since many of them did not pay any taxes, and now, they are going to pay five, that is, a "combo," apart from the investment in equipment, and even the hiring of a public accountant to help them with the preparation of the declaration, and to keep the accounting, because all these changes require a management and registration of the commercial operations carried out by the businesses [18].

Undoubtedly, many of the measures adopted in the simple regime are good for entrepreneurs who move from the ordinary regime; for SMEs that have had processes of change and that have not found it easy the issue of electronic invoicing, the DIAN offers its platform free invoicing DIAN [19], an initiative launched on June 28, 2018, so that small entrepreneurs can comply with electronic invoicing, as indicated in Decree 2242 of 2015. It is important to remember that this is a process, and its implementation will take time. Additionally, the world is facing this technological revolution, which will force entrepreneurs and professionals in all areas to become more technician. We CPAs have a benefit by working in a mobile way, having the information, and accessing it from anywhere through the cloud; undoubtedly, this has changed the way companies work; on the other hand, it facilitates the realization of reports with updated data, as indicated by Auditool [20].

## 6 Conclusions

The simple tax regime seeks formalization and compliance with tax obligations by facilitating them since only one payment is made, saving time and money [21]. On the other hand, we can see that people are not aware of the simple regime or its benefits, or the deadlines that were available to be part of them.

In addition, several of the commercial establishments we visited only handle the RUT, but they do not have a registration in the chamber of commerce, either because of ignorance or because it represents more expenses and less profit for their business [7]. Some merchants think that the state does not provide the guarantees to last in time; since the tax burden is very high because, in fact, Colombia is one of the countries with the highest tax burden in Latin America.

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# Detection of COVID-19 from X-Ray Images Using Machine Learning Models

**Md. Masrul Sakib, Meem Karim, Aftab Miraj Swachchha, and Maheen Islam**

**Abstract** Corona virus disease (COVID-19) is one of the deadliest scourge mankind have ever seen. It's a highly infectious influenza virus which may transmit from one person to another without causing any symptoms. In compliance with WHO (World Health Organization) data, corona virus (COVID-19) was first found in China in 2019 and has spread swiftly to individuals in other countries, with an estimated total of 349,641,119 cases (till 25 January) globally. As counter measures to this condition, screening afflicted people is mandatory which requires time and is also costly. Radiological scanning is a plausible measure for achieving this. In this case, the chest X-Ray is the most at hand and cost-effective alternative. In this work, we present a Deep CNN (Convolutional Neural Network) based method for perceiving COVID-19 infected people by analyzing chest X-Ray images. Here, four pre-trained CNN models (AlexNet, VGG16, InceptionV3, and EfficientNetB4) are suggested to analyze chest X-ray radiographs. Among these models, EfficientNetB4 gives us the highest accuracy to detect COVID-19.

**Keywords** Covid-19 · Chest X-ray · CNN · EfficientNetB4

## 1 Introduction

The corona virus disease outbreak of 2019 (COVID-19) is having an increasingly negative influence on public health along with worldwide well-being. The virus initially was discovered in December 2018 in Wuhan, Hubei, China. Then the World Health Organization (WHO) proceeded to declare it an epidemic on March 11, 2020 [1]. Corona virus (COVID-19) causes an infectious sickness that results in severe acute respiratory syndrome (SARS-CoV-2). Corona viruses are non-segmented positive-sense RNA viruses that belong to the CoV family of the Nidovirales order. CoVs produce crown-shaped peplomers that are 80–160 nm with a positive polarity of 27–32 kb, as well as a high rate of pleomorphism along with mutation. COVID-19

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has infected 356,289,546 individuals globally, killing 5,625,137 people, according to the World Health Organization (WHO). According to data, CoV has been treated in roughly 282,569,077 individuals (January 25, 2022) [2].

A common way of diagnosing pneumonia is through chest radiography (X-ray) [3]. The major approaches for COVID-19 detection are polymerase chain reaction (RT-PCR) as well as sequencing gene for respiratory or blood samples. Other studies have found that COVID-19 demonstrates pathologies that are comparable to those observed in pneumonic disease, with chest pathologies obvious in medical pictures. There are a good number of studies that investigate the relationship between chest CT and RT-PCR. Also, some studies are focused on the relationship between the chest X-ray images and RT-PCR. The commonly prevalent result in these images is the typical opacities or attenuation, with ground glass opacity accounting for roughly 57% of the time. Even though expert radiologists can recognize the patterns detected in those pictures, this diagnosis technique is impracticable given the insufficient financial resources available at medical facilities with inadequacy as well as the growing number of patients. Recent Artificial Intelligence (AI) research, particularly the Deep Learning methods, illustrates how the machine learning algorithms performed well when applied to medical imagery [4].

Radiological imaging such as X-rays along with computed tomography (CT) scans, are considered as essential tools for diagnosing COVID-19. A simple and rapid treatment is Chest imaging that is highlighted in some literature as an initial tool while it comes to epidemic screening. CT scan pictures show a high sensitivity in identifying and detecting COVID-19 instances when compared to RT-PCR, but a low specificity. This suggests that CT scans are more accurate for COVID-19 instances but less accurate for non-viral pneumonia cases. A study of patients' diagnoses in Wuhan, China, found that in 14 percent of the images, consolidation, and ground-glass opacities (GGO) were not totally visible in CT scan imaging, implying that 14% of the conclusive cases of COVID-19 have been misdiagnosed as not infected based on the analysis of their CT scan tests. Only 12 of the 18 individuals with COVID-19 had GGO along with consolidation, indicating that there was no consolidation or illness. COVID-19 was difficult, if not impossible, to identify in many cases despite the existence of consolidation prior to the introduction of GGO. All these instances revealed a flaw in the use of CT scans to diagnose COVID-19.

Even though chest CT scans are effective at confirming and analyzing COVID-19-related lung damage, there are some drawbacks as well. Notwithstanding the WHO's guideline, chest CT scan report normal in some individuals in the earlier phase of the disease, making CT scan alone a poor predictor of disease progression. The CT scan's limited specificity can make it difficult to discover non-COVID-19 instances. Furthermore, the radiation from CT scanners might pose complications for infected who need many CT scans through the course of their illness. Traditional diagnostic examinations are far more bounded and costly than X-ray scanning. Because it is not necessary to transport an X-ray digital image from the access point to the analysis point, diagnostic procedure may be finished extremely swiftly. For medical sorting of infected people, chest radiography is both fast and convenient. Dissimilar to CT scans, X-ray imaging needs cheaper and more available equipment, making considerable

cost reduction. In addition, mobile CXR equipment may be installed in separate rooms to avoid the contamination associated with their usage in hospitals [5].

The goal of this study was to create adequate prediction models that could diagnose suspected patients' chest X-ray pictures. Those prediction models were created using deep learning techniques. A huge dataset is required to create such high-efficiency prediction models. However, only a small portion of chest X-ray pictures of COVID-19-infected individuals are publicly available. The notion of transfer learning can help in this case. A few deep learning models already have been pre-trained on huge datasets. They can use what they have learnt to address the COVID-19 detection problem with minimal datasets. These models can gently modify individual weights depending on the X-ray report and generate reasonable forecasts since they already know so many elements of numerous images [6].

The COVID-19 identification challenge drive us to investigate the compatibility of pre-trained deep learning models. In our study, four different well-known pretrained deep learning models were specifically trained to identify COVID-19 to achieve this aim. The following are some of the most significant contributions of this study: (i) The efficacy of different states of pre-trained CNNs for identifying COVID-19 disease from chest X-ray images was evaluated. (ii) A huge group of CNN architectures were utilized to categorize respiratory illnesses, by separating X-rays among healthy persons and COVID-19 patients along with by sorting pneumonia patients from corona virus infected people.

## 2 Related Works

Medical diagnosis has created in depth use of computer vision. It's convenient in medical specialties which needs visual examinations, like dermatology. Computer vision is a technique for determining if a skin abnormality is forecasting skin cancer. It's also used to search for abnormalities inside a body, notably in blood vessels, joints, and tissues. It's applied in ophthalmology for identifying disorders such as diabetic retinopathy, which can help people avoid going blind. It's also had a lot of success in operations and treatments. Computed tomography scans (CT scans), magnetic resonance imaging (MRI), ultrasound, positron emission tomography scans (PET scans), and chest X-Ray (CXR) pictures are all used in computer vision systems.

The LeNet-5 was the first CNN to give a common "architectural template" with two convolutional layers along with three fully linked layers. Since then, new designs have been developed that employ identical concept of attaching more convolutions along with pooling layers, culminating in one or more completely linked ones [7]. Singh et al. created a COVID-19-infected convolutional neural network (CNN) model using CT scan images. A CT scan is being used to test if it can detect the COVID-19 viral invasion in human lungs. Yan and colleagues developed a self-supervised multitasking AI model to detect COVID-19 virus in human lungs using CT scan images that had an accuracy of 89% [8]. In the years that followed, researchers added more complexity to the networks by incorporating many strategies inside

the layers of the networks, in addition to making them deeper. Inception-v1 uses "Inception" modules to create a "network inside a network," and it has 22 layers in all. The successor to the previous network, Inception-v3, has a similar design and was one of the earlier networks that utilized batch normalization [7]. CNN architectures have been the most often utilized method in this regard. The authors looked at two CNN architectures: one based on the ResNet-23 design and another using a location attention mechanism in the fully connected layer. This design classified COIVD-19, Influenza-A-viral-pneumonia, and infection-unrelated into three categories with a total accuracy of 86.7%. The backbone network employed by Zhang et al. was a ResNet-18 CNN design. They combined this design with two additional heads: a classification head and an anomaly detection head, both of which provide scores for recognizing anomalous pictures (COVID-19). They detected COVID-19 cases with a 96% accuracy rate and non-COVID-19 cases with a 70.65% accuracy rate [9]. The authors conducted research of covid-19 on people who were isolated in Rawalpindi's BBH medical unit. Using a chest X-ray dataset, the scientists developed a CNN-based system for assessing pneumonia. For transferring learning on CNN, they employed two distinct models (VGG16 and InceptionV3). They went on to use SVM to improve their findings. The authors discussed the use of a deep anomaly detection algorithm for accurate COVID-19 patient screening. They obtained 100 chest X-ray pictures, with 70 people testing positive for COVID-19. Finally, they spoke about how COVID-19 affects humans. They looked at a dataset of 101 COVID-19-infected pneumonia patients [10]. On 3-class categorization, the maximum accuracy was 93.48%. For lung area segmentation in CT images, the authors employed UNet architecture, while for classification, they used a bespoke CNN architecture. Aside from these studies, the authors attempted to detect COVID-19 instances using cough samples obtained by a smart-phone app. The study's main goal was comparing the clinical state of COVID-19 and pneumonia to CT images [9]. COVID-19 is a viral illness that not only affects persons but also a country, according to all the viewpoints and recommended work presented by many researchers. They reviewed several methods for early detection of COVID-19 patients. On a gathered dataset of chest X-ray pictures, we used four models (AlexNet, VGG16, InceptionV3, and EfficientNetB4).

## 3 Problem Domain

The study's ultimate purpose is to see how effective automated COVID-19 recognition from chest x-ray pictures is utilizing an empirical evaluation of classification enhancing methodologies. Three types of x-ray datasets were used in this investigation. The following are the linked objectives for this study:

- Using a chest x-ray to provide a reliable foundation for COVID-19 categorization.
- Compare and evaluate the models' performance using performance measures.

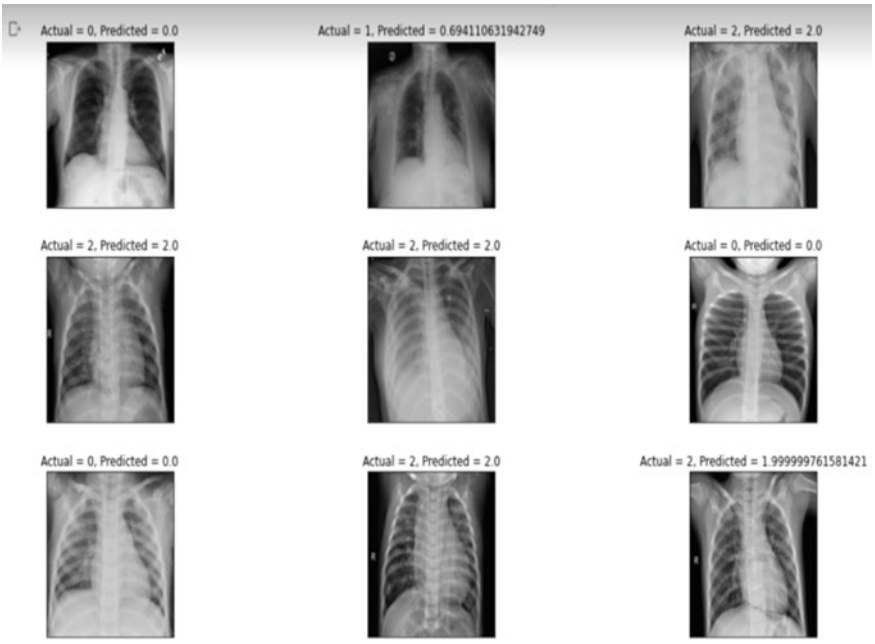


**Fig. 1** The X-ray images of chest

## 4 Materials and Methods

### *4.1 Datasets*

COVID-19 X-ray pictures may be found in numerous publicly accessible databases. Some samples are shown in Fig. 1. The dataset is collected from the Kaggle repository. Also, other data are collected from Google and from several hospitals and doctors. We have collected total data 7316. We are working with these numbers of data. From all the dataset we took three classes Covid positive, Covid negative, and Viral pneumonia. From all these datasets, we took the total of covid negative images are 3008 and covid positive images are also 3008 and viral pneumonia images are 1300.

### *4.2 Data Normalization*

A pixel-value representation of pictures is essential for training a machine learning classifier. Pixel values range from 0 to 255 in a digital picture. The photos' pixel value-wise representations are re-scaled among 0 and 1 in order that this machine learning model may efficiently function with the inputs. This normalization function

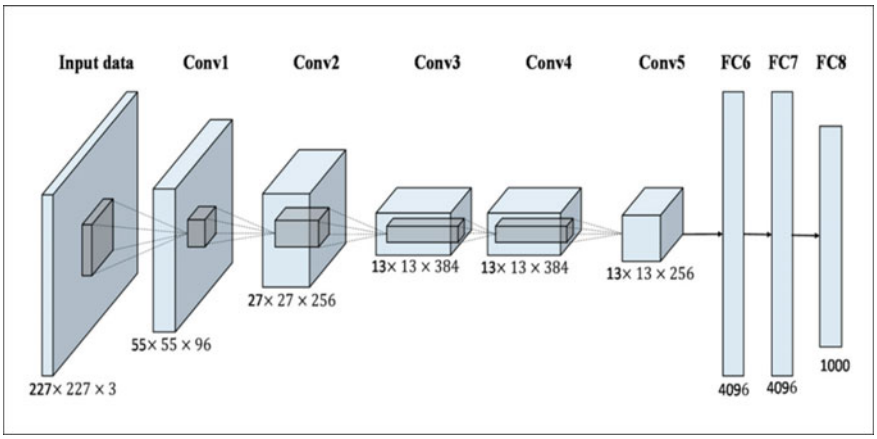


**Fig. 2** AlexNet architecture

has been used to both test and training datasets. A camera's photographs come in a variety of sizes. However, fixed-size pictures should be sent to the deep learning architecture.

## *4.3 AlexNet*

The AlexNet network holds five layers of convolution for image containment determination and three fully dedicated layers for image layout. The photographs with dimensions of 227 × 227 × 3 are used as input to this model. There are three primary tasks in organizing image highlight extraction that is two-layer specific convolution, ReLU activation and further pooling [11]. Figure 2 describes the architecture of the AlexNet Model.

## *4.4 Vgg16*

VGG16 model outperformed AlexNet architecture by substitution of huge kernel-sized filters (11 and 5 in the 1st and 2nd convolutional layers, respectively) with numerous 3 × 3 kernel-sized filters one after the other. A fixed-size 224 by 224 RGB picture is fed into the convnets during training. The picture is processed through a convolutional (conv.) layer stack using filters with a very tiny receptive field: 3 × 3. It is more complex, with more non-linearities and fewer parameters. Following a stack of convolutional layers (which have varying depths in different designs), there are three fully-connected (FC) layers [12]. Figure 3 describes the architecture of the VGG16 Model.

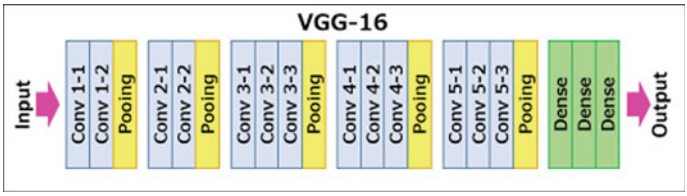


**Fig. 3** VGG16 architecture

## *4.5 Inception V3*

InceptionV3 is one of the changed adaptations of the origin family, which made a few enhancements including Label Smoothing, Factorized 7 × 7 convolutions, and for proliferating mark data on lower down the organization, there is a utilization of an assistant characterization. As well with respect to the layers in the side-head, bunch standardization is utilized. Inception v3 includes 42 layers in total and a reduced error rate than previous versions [13]. Figure 4 describes the architecture of the InceptionV3 Model.

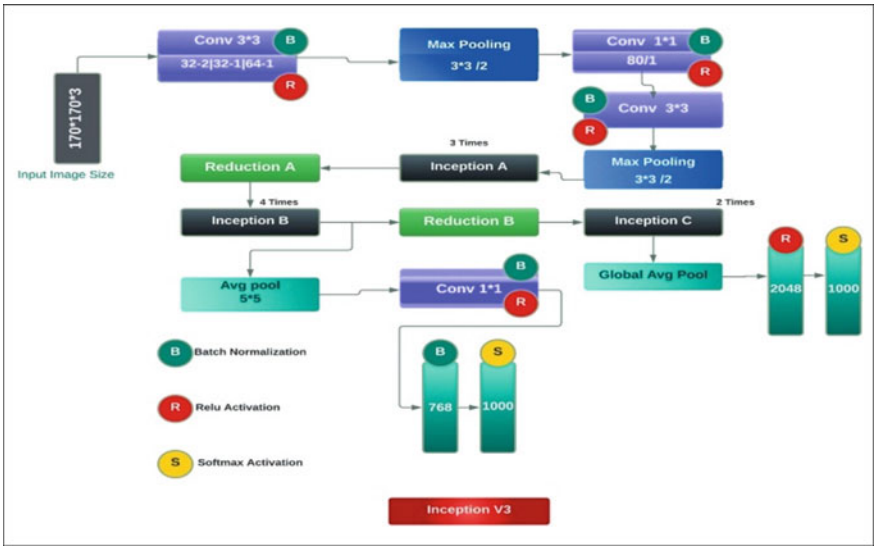


**Fig. 4** InceptionV3 architecture

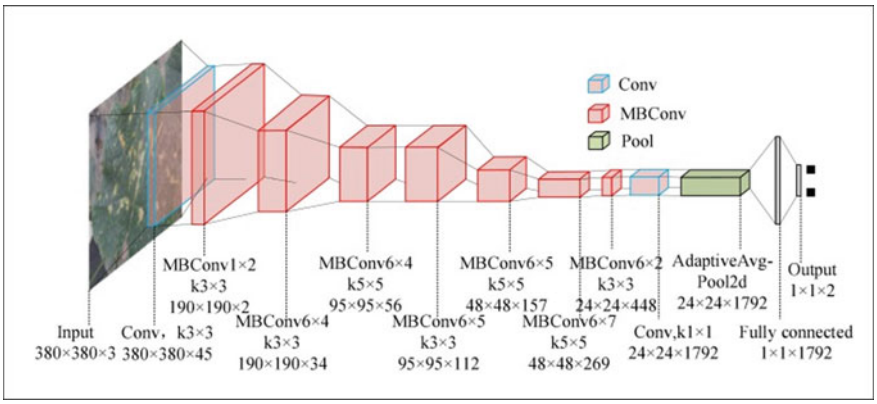


**Fig. 5** EfficientNetB4 architecture

## *4.6 EfficientNetB4*

Every one of the CNN designs has a few remarkable qualities. Efficient Nets are a group of picture characterization models that accomplished cutting edge exactness yet being a significant degree more modest and quicker than other profound learning models [6]. It is impelled by ResNet and MobileNet, what's more scaling up or down to legitimize better exactness. This is a complex exhibiting structure. EfficientNet is one of the most effective models for picture grouping. In this research, we used pre-organized EfficientNetB4 version for COVID-19 for recognizing reason. Figure 5 describes the architecture of the EfficientNetB4 Model.

## *4.7 Performance Metrics*

The metrics utilized for evaluating the proposed techniques' performance are accuracy, recall (sensitivity), and F1-score, which are measured as follows:

$$\text{Accuracy} : \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}} \tag{1}$$

$$\text{Precision} : \frac{\text{TP}}{\text{TP} + \text{FP}} \tag{2}$$

$$\text{Recall} : \frac{\text{TP}}{\text{TP} + \text{FN}} \tag{3}$$

$$\text{F} - 1\text{score} : \frac{2}{\frac{1}{\text{Precision}} + \frac{1}{\text{Recall}}} \tag{4}$$

Accuracy, Precision, Recall (Sensitivity), F1-score, and Specificity are the performance measures that have been used. The networks' categorization performance was then presented using the macro-average findings. The term "accuracy" refers to how nicely a class algorithm can distinguish among the classes in a test set. The percent of efficiently expected labels to the overall quantity of labels (each predicted and real) is referred to as accuracy. The accuracy of the model in differentiating the three classes on this observe is called overall accuracy (covid positive, viral pneumonia, and covid negative). Precision is defined as the share of anticipated accurate labels to the sum number of real labels, while we define recall as the share of anticipated accurate labels to the sum number of predicted labels. Another term for recall (true positive rate). Furthermore, the F1 score is the harmonic mean of Precision and Recall, and Specificity (true negative rate) is the fraction of genuine negatives properly detected.

## 5 Experimental Evalution

The efficacy of different state-of-the-art pre-trained convolutional neural networks for detecting COVID-19 illness from chest X-ray pictures was investigated in this study. AlexNet, VGG16, Inception V3, and EficientNetB4 were among the existing deep learning classifiers used.

Precision, recall (sensitivity), F1-Score, and overall model accuracy were used to evaluate the findings for each class (viral pneumonia, covid negative, and covid positive) as shown in Table 2. The EfficientNetB4 and VGG16 appear to have the highest classification accuracy of 97% and 94%, respectively, according to the findings. The accuracy of the AlexNet and Inception V3 model was about 90%. In addition, the four models' confusion matrices are given in Fig. 10.

For the covid positive class, EfficientNetB4 and VGG16 models had sensitivity of 99% and 98%, respectively. In other words, by using the EfficientNetB4 and VGG16 models, verified COVID-19 affected person would be correctly recognized as 'COVID-19 positive' 99% and 98%, respectively. The other two models AlexNet and Inception V3 model were also quite good (Table 1).

## 6 Result and Discussion

In this section, we present and analyze the obtained result. In a pandemic situation like this, an alternate technique of preventing the spread of the SARS-Cov-2 virus is critical. The models presented in this study can aid radiologists in distinguishing between radiologic pictures collected from suspected patients by offering a second viewpoint. This can cut down on the time it takes to test a patient utilizing RT-PCR kits and acquire laboratory findings in a timely manner.

Training and testing accuracy and loss graph for each model are shown in Figs. 6, 7, 8 and 9.

**Table 1** Overall performance acquired from exceptional pre-trained CNN models

| Model | Labels | Precision | Recall | F1-score | Overall accuracy |
|---|---|---|---|---|---|
| Alexnet | Viral pneumonia | 0.94 | 0.88 | 0.91 | 0.9052 |
| | Covidnegative | 0.90 | 0.90 | 0.90 | |
| | Covidpositive | 0.90 | 0.92 | 0.91 | |
| VGG16 | Viral pneumonia | 0.94 | 0.96 | 0.95 | 0.9413 |
| | Covidnegative | 0.98 | 0.90 | 0.93 | |
| | Covidpositive | 0.91 | 0.98 | 0.94 | |
| Inception V3 | Viral pneumonia | 0.87 | 0.97 | 0.92 | 0.9221 |
| | Covidnegative | 0.97 | 0.88 | 0.93 | |
| | Covidpositive | 0.97 | 0.89 | 0.92 | |
| Efficient-Net B4 | Viral pneumonia | 0.97 | 0.99 | 0.98 | 0.9768 |
| | Covidnegative | 0.99 | 0.96 | 0.97 | |
| | Covidpositive | 0.96 | 0.99 | 0.98 | |

**Table 2** Parameters used for training the models:

| Performance measures | AlexNet | VGG16 | Inception V3 | EfficientNetB4 |
|---|---|---|---|---|
| Batch size | 55 | 150 | 55 | – |
| Optimizer | Adam | Adam | Adam | Adam |
| Activation function | Softmax | Softmax | Softmax | Softmax |
| Training accuracy | 0.9211 | 0.9923 | 0.9769 | 0.9894 |
| Testing accuracy | 0.9052 | 0.9344 | 0.9221 | 0.9624 |
| Validation accuracy | 0.9052 | 0.9413 | 0.9221 | 0.9768 |

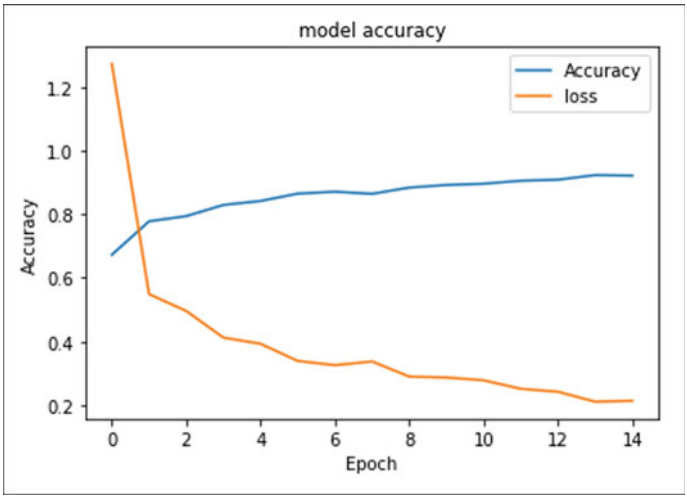


**Fig. 6** Training and testing accuracy and loss graph for AlexNet

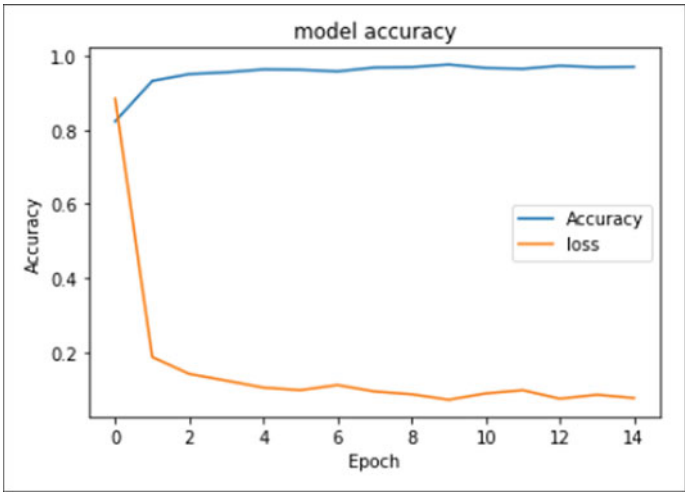


**Fig. 7** Training and testing accuracy and loss graph for VGG16

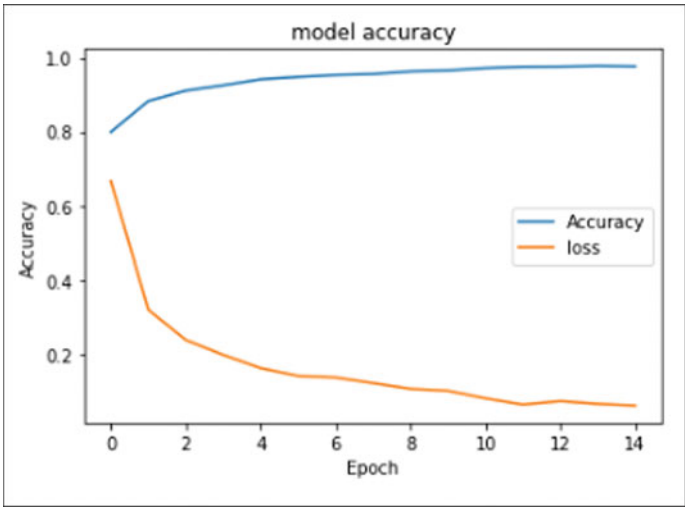


**Fig. 8** Training and testing accuracy and loss graph for inception V3

A machine learning word that denotes how many passes the machine learning algorithm has made across the full training dataset is called an epoch. Here, for 15 epochs, all the models were trained. In X-axis, there is showing accuracy and in Y-axis there's an epoch. In each model, it is showing an accuracy and loss graph in terms of epoch. By these graphs, we can see how the model accuracy is increasing with the increasing epoch.

Parameters that are used in this work are given Table 2.

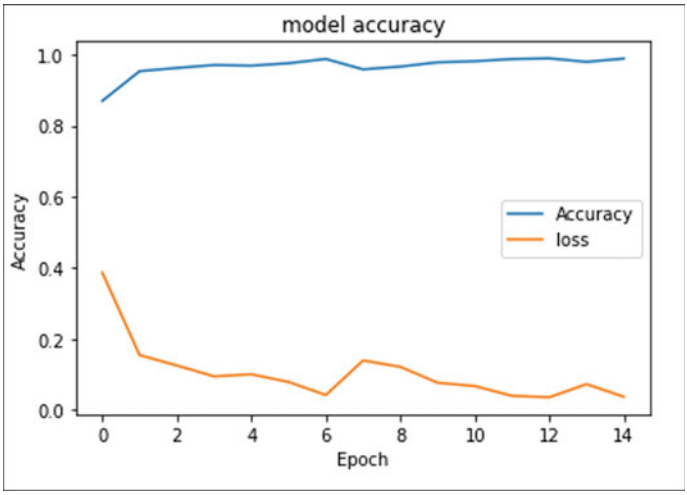


**Fig. 9** Training and testing accuracy and loss graph for EfficientNetB4

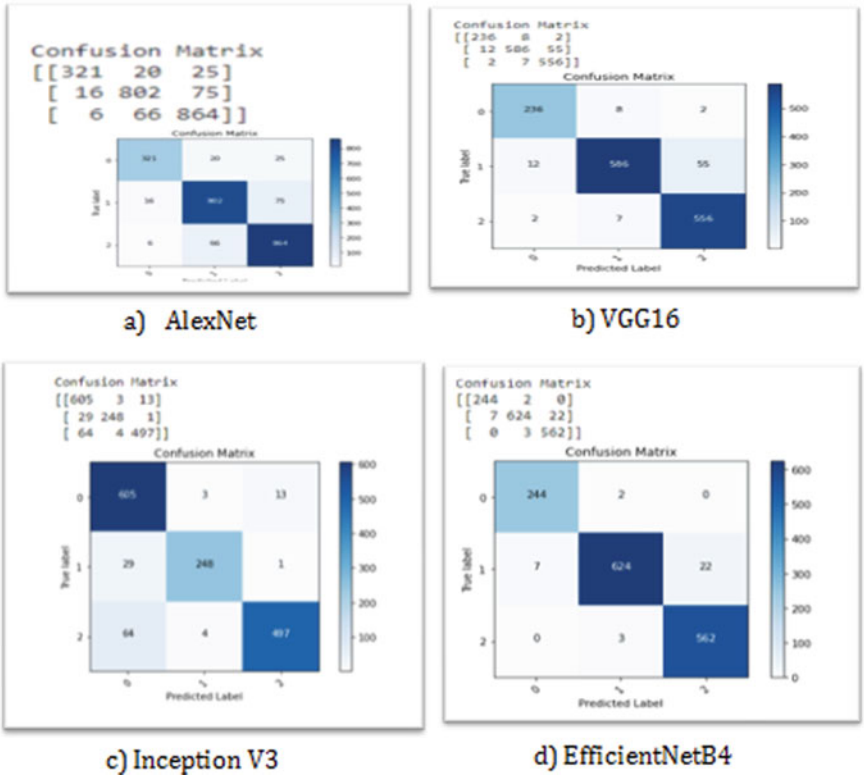


**Fig. 10** Confusion Matrix of deep learning models

### *6.1 Confusion Matrix*

In this part we are showing the confusion matrix for each model. These matrices are showing the prediction between labels, how much accuracy they are showing based on the testing datasets.

## 7 Discussion

According to the findings, advised CNN and pre-trained CNN models have a vast impact at the automated identity and extraction of vital characteristics from chest x-ray photos associated with COVID detection. Cohen et al. studied COVID-19 radiology pictures from loads of re-assets to broaden a correct model for diagnosing this viral infection. For a few of the investigate included in this parcel of the article, Cohen et al. COVID-19 picture information was utilized, whereas for others, as COVID-19 negative, photographs were procured from other publicly available sources. Kermany et al. and Ozuturk et al. presented DarkCovidNet for detecting COVID-19 using chest x-ray pictures, found that it classified Normal and COVID-19 with an accuracy of 98.08% and Normal, COVID-19, and Pneumonia with an accuracy of 87.0%. Hemdan et al. have suggested COVIDX-Net for diagnosing COVID-19 using x-ray pictures. They obtained 90 percent accuracy by using 25 positive COVID-19 and 25 normal pictures. Wang et al., on the contrary, created COVID-Net, a deep learning network for COVID-19 identification. Using a pattern of 16,756 radiographic pictures from several open-supply sources, they were able to achieve an accuracy of 92.4%. Ioannis et al. applied the notion of knowledge transmission with a goal comparable to COVID-Net's. In their investigation, they employed 224 verified COVID-19, 700 pneumonia, and 504 normal radiological pictures, achieving a binary class performance of 98.75% and a multi-class classification performance of 93.48%.

Although the number of classification categories increased, the CNN-based model's performance accuracy decreased. To create a system, Sethy et al. integrated DL and ML approaches. They employed the ResNet50 model to obtain picture characteristics and SMV as a classifier in their research. They got 95.38% accuracy out of 50 photos. Several researchers employed computed tomography pictures to train their CNN-primarily based totally models, however their models were less accurate than those trained using X-ray images [14].

From Fig. 11, we can see that among our four models, EfficientNetB4 provides the highest accuracy. Also, our models can attain higher accuracy than the state-of-the-art works described in the Discussion Section.

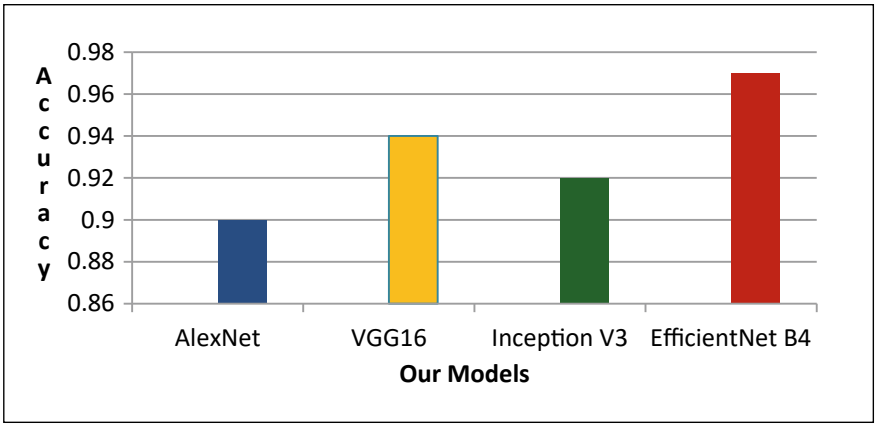


**Fig. 11** Accuracy comparison between our models

## 8 Conclusion

Because of its highly infectious nature, the COVID-19 infection poses a threat to billions of individuals. According to the World Health Organization, the number of infected persons and deaths is steadily rising. Infected people's lungs get inflamed because of the viral infection. As a result, using a chest x-ray for detecting those inflames is one of the options. The study presented and used four well-known Convolution Neural Networks for the categorization of X-ray pictures from Covid positive, Viral pneumonia and Covid negative. Convolution Neural Networks can analyze respiratory clutters with higher precision, according to research findings, albeit a significant number of sample pictures must be gathered. Among four models we can see that EfficientNetB4 is giving us the best result. The excellent sensitivity, specificity, and accuracy of the COVID class indicate that these models can accurately detect positive and or negative COVID-19 instances. As the findings demonstrate, there are various performance measures to consider when choosing the best successful model for this categorization assignment. Finally, without a clinical diagnosis, these procedures should not be employed.

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# Evaluation of Single-Stage, Two-Stage, and Anchor-Free Object Recognition Methods for UAV Detection

**Rashed Khamis Al Romaihi, Abdelhak Belhi, and Rachid Hadjidj**

**Abstract** Drones and Unmanned Aerial Vehicles (UAVs) are one of the cheapest and most difficult to counter aerial vehicles inducing security and safety concerns in many sectors. Recent events suggest that traditional detection technologies such as radar are not effective for detecting these vehicles despite the huge investments from countries suffering from various drone attacks. Current technologies often rely on data such as images to detect and locate drones in the sky using advanced AI-based approaches. Given these challenges, the global aim of this research is to evaluate the effectiveness of various deep learning-based object detection methods on the task of visually detecting airborne drones from camera feeds. We mostly compare single-stage, two-stage, and anchor-free object recognition methods in terms of recognition performance and speed. As per the data, we use as a common benchmark; the Anti-UAV dataset presented at the ICCV 2021 conference. From the results, we see that anchor-free models perform better compared to the other methods.

**Keywords** Object detection · Deep learning · Evaluation · Drones · UAV

## 1 Introduction

Drones or UAVs are becoming mainstream thanks to the increased performance and reduced costs of their manufacturing. Drones are being used nowadays for a variety of purposes serving a plethora of objectives. They have a wide range of beneficial commercial and private uses, but unfortunately, introduce concerns related to privacy and illegitimate uses such as perpetrating attacks.

Drones' development is at its maximum pace and many researchers and companies are dedicating their efforts to developing sophisticated drones either for civilian or

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military purposes. Researchers are often tasked with developing approaches for the detection and tracking of these objects as countermeasures. In the past, the focus was given to radar-based and frequency-based systems using various types of sensors. These technologies are proven to work with traditional airborne vehicles such as airplanes. However, UAVs are known to be small, have low-level flight operations and made mostly with nonmetallic materials no current radar can easily detect compared to other flying vehicles such as fixed-wing planes, fighter jets, training jets, and civilian jets. Some of the developed detection technologies also tend to yield a lot of false positive results, often confusing birds with drones.

Other issues related to drone detection technology arise such as the lack of skilled and experienced professionals in this field that can use current technologies to detect drones. This is mainly because the topic is fairly new, and a lot of already used techniques are still in the developing phases, adding to that the stealth capabilities of new drones make it very challenging to keep detection methods in pace with drones' capabilities development.

Aiming at addressing these issues, through this paper, we leverage recent deep learning-based techniques for object detection as well as a UAV dataset to see the effectiveness of the former techniques for drone detection tasks. The models we use will be retrained using transfer learning to ensure the best accuracy possible. We also compare the performance of the models in terms of precision, focusing mostly on single-stage, two-stage, and anchor-free object detection methods (see Fig. 1).

The remainder of this paper is organized as follows. In Sect. 2, we present some works related to AI-based drone detection focusing mostly on methods that use computer vision. In Sect. 3, we present the methodology of our evaluation focusing on the used development framework, the dataset collection and preprocessing, as well as the test and evaluation methodology. In Sect. 4, we outline the results of the evaluation and discuss the results. In the end, in Sect. 5, we draw our conclusion and give some perspectives for future work.

**Fig. 1** Drone detection

## 2 Related Work

Accurately detecting objects inside an image is one of the most important tasks in computer vision. Objects are often detected following the recognition of certain visual features in the image. These features make it possible to classify found objects into different often pre-defined classes. A bounding box is often drawn around each detected object.

As we are focusing on detecting drones and UAVs, most of the existing legacy approaches use technologies such as RADAR or LIDAR, sound features, and electromagnetic frequencies used for communication and imaging. RADAR, the most used technology for detection in aviation, has some difficulties in being effectively implemented for drone detection as drones often fly at low speeds which makes it difficult to take advantage of the doppler effect those radars rely on. Additionally, drones are made with non-reflective materials that do not reflect electromagnetic waves. Sound has also been one of the most used technologies for drone detection as usually drones come with a specific sound signature. However, sound cannot be effective in noisy environments such as airports and cities. As per the imaging-based approach, the principle is fairly simple. Using a video feed from a camera pointed to the sky, trying to spot drones using object detection algorithms. Tracking is also possible once the drone has been spotted. Vision has been considered the best in terms of precision and feedback, but still presents some challenges as highlighted by some researchers for accurately detecting drones and differentiating between drones and birds for instance.

Since the focus of our paper is on detection, we do not cover methods that address tracking. Most vision-based approaches work with the same principle, and modern approaches rely on deep neural networks such as Deep CNNs for accurately detecting objects. However, the small size of drones introduces new challenges.

In [1], the authors presented the Anti-UAV dataset. This dataset is used to test and validate our approach. Authors in [2] presented an approach based on Yolo for drone detection. In [3], the authors presented a challenge named VisDrone [4] with a large-scale dataset for object detection and tracking. Unfortunately, we were not able to use the dataset for our work as it is not available for download. The authors in [5] presented a single-stage approach based on the Yolov2 network for detecting whether a drone is loaded or unloaded. In [6], the authors evaluated the detection performance of using a system based on sound and imagery. The authors in [7] addressed the problem of detecting drones in real-time with high accuracy using a segmentation approach where they detect birds and separate drones from the background.

In our work, we mostly focus on 3 different types of deep learning-based object detection approaches, namely: single-stage, two-stage, and anchor-free. In the following, we will briefly explain these types of approaches and give examples (see Fig. 2):

**Single-stage**: These approaches directly perform object detection and estimate bounding boxes without having to create region proposals (candidate regions).

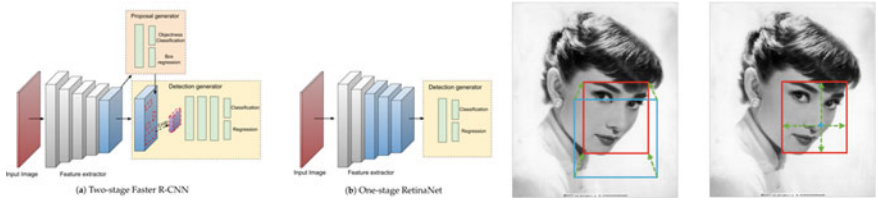


**Fig. 2** On the left the difference between two-stage and one-stage methods and on the right **a** given an anchor, the anchor-based method offsets the box (ground truth in red) from an anchor (box in blue) whereas anchor-free methods, **b** directly estimate the distance from a point to the boundaries of the box [8, 9]

**Two-stages**: Use methods such as selective search to create region proposals for methods such as R-CNN of Fast R-CNN or by a Region Proposal Network for the Faster R-CNN method.

**Anchor-free**: These methods directly determine values corresponding to the size and position of an object inside an image using a determined point.

## 3 Methodology

The goal of our investigation is to see which object detection methodology works better with drone images. We mainly intend to compare most relevant deep learning-based methods focusing on single-stage, two-stage, and anchor-free object recognition methods. As per the data, we use the Anti-UAV dataset published within the Anti-UAV challenge of the ICCV 2021 conference and available for download on the conference website. In the following, we describe the used dataset and explain the implementation of our evaluation framework which relies on transfer learning.

Our methodology consists of the following steps:

- Data collection and preparation
- Choice of models and their implementation
- Evaluation or recognition of performance of each model and comparison of results.

After the design of our approach for the implementation, we selected the MMdetection [10] opensource library. The library is based on PyTorch [11] purposefully built to develop object detection approaches. It comes with a Model Zoo that regroups major deep learning-based object recognition models and offers a wide variety of possibilities for hyperparameter tweaking, training monitoring, and evaluations with a wide range of metrics. The library offers support for custom datasets converted to the COCO dataset format.

In the following, we describe the dataset collection and preprocessing steps as well as the design principles of our framework.

### *3.1 Data Collection and Preprocessing*

Using deep learning as a backbone for object detection involves the need for annotated datasets. This means that we need datasets for drone images in the sky with annotation or "bounding box" coordinates inside the image. Very few datasets actually exist with this criterion. For our case, we selected the Anti-UAV dataset. The dataset is a video dataset that is fully annotated the videos show animated images of drones, and the annotations report the presence of the drone in the current frame as well as its position if it exists with a bounding box. The dataset is not originally in the COCO format. We had to transform the annotation to the COCO Dataset format so that we can use it with the MMDetetection library. Figure 3 shows a sample from the dataset as well as a snippet of the COCO style annotations. Table 1 reports some dataset metadata.

### *3.2 Test and Evaluation Framework*

Our test and evaluation framework is built with the MMDetection library. We selected five different deep learning-based detection approaches for our evaluation. The first step involves the training of the models using a transfer learning scheme where we reuse a pre-trained model on the Anti-UAV dataset. We split the data into 70% for training and 30% for testing and trained each model for 12 more epochs. For each model, we needed to create a configuration file to specify the different hyperparameters and the dataset to use. Most of the hyperparameters were kept to the default setting present in the Model Zoo except for the learning rate, number of classes (which affects the network architecture) as well as the number of epochs.

In the following, we briefly present the models we use for our tests:

**RetinaNet Model (One-stage)**

RetinaNet is a single-stage composed of a network considered as the backbone, and two subnetworks: the first one performs the object classification in a convolutional fashion and the second one performs the regression of the bounding boxes.

**YOLOv3 Model (Two stages)**

The 'You Only Look Once' is one of the most used approaches in object recognition. It relies on a custom CNN named darknet. The V3 network uses a unique network to process the image. Similar to earlier versions, it divides the images into smaller grids and predicts bounding boxes. It was proven that darknet53 with 53 convolutional layers performs better than ResNets.

**Faster R-CNN Model (Two stages)**

Faster R-CNN introduces the Region Proposal Network with Fast R-R-CNN. The RPN shares the features with the main object detection network, thus optimizing the region proposal task. The RPN is trained to create region proposals.

```
{
  "info":{
    "year":2020,
    "version":1,
    "description":"Anti UAV dataset",
    "url":"https://anti-uav.github.io/dataset/",
    "date_created":"2021-02-08"
  },
  "licenses":[
    {
      "id":1,
      "name":"GPL 2",
      "url":"https://www.gnu.org/licenses/old-licenses/gpl-2.0.en.html"
    }
  ],
  "images":[
    {
      "id":149479,
      "file_name":"20190925_133630_1_4_IR_0.jpg",
      "license":1,
      "width":640,
      "height":512
```


**Fig. 3** Dataset sample and metadata

**Table 1** Dataset facts

| Dataset facts | |
|---|---|
| Total number of videos | 100 |
| Total number of images | 186,494 |
| Types of images | RGB—IR |
| Number of UAV model types | 6 |
| Number of classes | 1 |

**FCOS Model (Anchor-free)**

FCOS is an anchor-free object detection method. It avoids, through the elimination of anchor boxes, all the related computations such as overlaps. It also eliminates all computations related to the hyperparameters of anchor boxes.

**Reppoints Model (Anchor-free)**

Point Set Representation for object detection proposes a new approach to represent by point sets instead of bounding boxes enabling semantically aligned feature extraction.

## 4 Results and Discussion

To test and evaluate our framework we used the Anti-UAV dataset. The detection tests were undertaken on the Google Colab platform where we ensured that all running instances had similar physical hardware (mainly focusing on the GPU). As per the software libraries, we used the MM detection library version 2.25.0 with PyTorch 1.12, CUDA 11.5 and Python 3.7. The GPU we used is the Nvidia Tesla T4 GPU with 16 GB or VRAM. From our results, it turned out that FCOS is the best model for the used dataset in terms of precision according to the Intersection over Union (IoU) loss results. This loss only works when the predicted bounding boxes overlap with the ground truth box. RepPoints came Second which confirms that Anchor-Free detectors are better in our use case. It is worth noting that with our setup, the Faster R-CNN network was the slowest to train with almost 1 day per epoch with an average of 3 h for the other networks. Table 2 reports on the evaluation results.

From these results, we can conclude that anchor-free models are better for the Anti-UAV dataset, but we cannot confirm this for the overall drone detection task due to the lack of datasets.

## 5 Conclusion

Drones are ever-increasing in numbers and present huge security implications and risks. Through this work, we discussed the fact that deep learning-based detection for drones using computer vision is possible and can be used with satisfactory accuracy. We presented an evaluation of the performance of several deep learning-based object detection methods focusing on single-stage and two-stage anchor-based methods as well as anchor-free methods. From our tests on the Anti-UAV dataset, we saw that anchor-free detectors such as FCOS and RepPoints yield better results compared to their anchor-based counterparts. However, tests on other datasets are still required to confirm this observation. In the future, we aim at testing with other datasets as well as experimenting with other approaches for AI-based drone detection such as the use of acoustics and thermal imaging as data sources.

**Table 2** Evaluation results

| Model | $AP_F$ | $AP_{0.5}$ | $AP_{0.75}$ | $AP_S$ | $AP_M$ | $AP_L$ | $AR_F$ | $AR_{0.75}$ | $AR_{0.5}$ | $AR_S$ | $AR_M$ | $AR_L$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yolov3 | 0.266 | 0.622 | 0.147 | 0.000 | 0.272 | 0.236 | 0.434 | 0.434 | 0.434 | 0.000 | 0.435 | 0.260 |
| Faster_R-CNN | 0.448 | 0.925 | 0.430 | 0.273 | 0.597 | 1.000 | 0.500 | 0.500 | 0.500 | 0.306 | 0.662 | 1.000 |
| RetinaNet | 0.392 | 0.923 | 0.228 | 0.000 | 0.394 | 0.382 | 0.534 | 0.534 | 0.534 | 0.000 | 0.534 | 0.420 |
| RepPoints | **0.482** | 0.851 | 0.558 | 0.000 | 0.486 | 0.462 | 0.571 | 0.571 | 0.571 | 0.000 | 0.572 | 0.460 |
| FCOS | **0.536** | 0.871 | 0.648 | 0.000 | 0.540 | 0.430 | 0.635 | 0.635 | 0.635 | 0.000 | 0.636 | 0.500 |

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# A Concept for Restructuring the Production Systems into Cyber-Physical Production Systems

**Miglena Temelkova**

**Abstract** Under the conditions of Industry 4.0, the restructuring of the real-life production systems into cyber-physical production systems requires the rationalization and systematization of the specialized knowledge into a concept of interrelated and interdependent notions, definitions, principles, functional dependencies, and structural elements. The analytical arrangement in a conceptual system of fundamental knowledge, tools and practices in respect to the process of restructuring the production systems into cyber-physical ones contributes to the more comprehensive understanding of that process and to focusing scientific thought on specific problems and scientific bottlenecks. The present study generates for the first time in the scientific literature a concept of the restructuring of traditional production systems in innovative cyber-physical production systems. The analysis examines the specific boundaries, elements, and scope of the restructuring process and defines the main relational dependencies between the constituent functional planes of production systems in the course of their transformation and upgrading to cyber-physical production systems.

**Keywords** Restructuring · Production system · Cyber-physical production system

## 1 Introduction

In contemporary science, a concept is comprehended as a single and integral system of interrelated and mutually complementary structural perceptions, explanations, interpretations and notions, whereby providing clarity on certain objects, phenomena or processes. In a concept, the results from the theoretical and empirical research and the achievements in business practice are purposefully integrated and synthesized in a comprehensive and analytical system of notions, definitions, tools, methodology, functions, organizational-and-management resources, tactical techniques, goals, and

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objectives. The concept keeps in a structural-and-organizational order the accumulated knowledge, skills, experience, practice, and registered exceptions in the area of a particular thematic field.

Synthesizing a concept for restructuring the production systems into cyber-physical production systems is required due to a shortage of scientific research and elaborations under this topic, as well as due to the need of systematization of the available to date fragmentary definitions, theoretical fundamentals and practical-applied models. Moreover, there is a huge gap in research literature not only in respect to the definition of the process of restructuring the cyber-physical production systems, but also concerning the qualitative determining of the notion "cyber-physical production system". Therefore, the present concept is related to the need of:

- defining the notion "restructuring the production systems into cyber-physical production systems";
- theoretical research of the fundamental restructuring activities;
- determining the borderlines, elements and scope of restructuring the production systems into cyber-physical production systems.

On the background of the defined needs of theoretical filling of the gaps in the scientific doctrine, the concept for the restructuring of the production systems into cyber-physical production systems is based on:

- the analysis of numerous definitions of the notions "production system", "cyber-physical production system", "restructuring";
- the synthesis of definitions serving the concept;
- studying and determining the borderlines, components and functions of the restructuring process;
- the analysis of the production system elements, which are subject to restructuring to cyber-physical production systems;
- studying and outlining the typical characteristics of the specific types of restructuring.

The concept for the restructuring of the production systems into cyber-physical production systems represents a management system for target-adaptive management, built on the basis of the unity between the production process, artificial intelligence, technologies, smart systems, planning, control, information provision of the management and processes.

Object of study in the present article are fundamental notions, knowledge and practices in the field of restructuring the production systems into cyber-physical production systems.

Subject of analysis is restructuring the production systems into cyber-physical production systems.

The goal of the research work is synthesizing the conceptual fundamentals for restructuring the production systems into cyber-physical production systems.

The restrictions result from:

- there are no production differences outlined, typical for the various sectors of the economy;
- the restructuring efficiency role is not studied;
- there is no comparison made between the surplus value from the work of the production systems and from the work of the cyber-physical production systems.

## 2 Methodology of the Research: Theoretical Review of the Main Concepts Under This Topic

On the basis of studying the definitions of the notion "production system" [1, 12, 13, 17, 23, 27–29], it can be summarized that the production system:

- is a spatial arrangement of the workplaces in the production process, as well as structuring the production times and the time-based organizational principle. The spatial and temporal principles lay out the organizational forms in the production system;
- relates the rationality of the economic action with the value obtained at the output, which is higher than the one that has entered at the input.

The "cyber-physical production system" has not yet been researched in depth. Nevertheless, there are some individual publications [2, 11, 19, 24], where this concept is defined. On the basis of the carried out theoretical review of those research works, it can be summarized that this is a comparatively new term, which definition is still not definitive and standardized. Generally speaking, in larger terms, the cyber-physical production system can be defined as a cyber system and a real-life physical system connected with each other in a real-life production environment within a single and integral system.

The concept "restructuring" has been studied in research literature [5–7, 21], however, that has been done primarily from the perspective of an organization in general. There is no available definition of the process of restructuring the production systems into cyber-physical production systems. The definition of the process of restructuring the production systems is also generally quite scarce. This requires, on the basis of analysis and synthesis, the definition of an entirely new concept for research literature, which should comprise that process as much comprehensively and accurately as possible. On the background of the studied sources, a well-grounded conclusion can be drawn that restructuring the production systems into cyber-physical production systems is a long-term process, focused on a comprehensive and simultaneous fundamental reorganization of production through:

- improvement of old processes and introduction of entirely new process chains;
- technological upgrading of existing structural elements or incorporating new architectural levels into the organizational-and-structural unity of production;

- further improvement of the used work methods, mechanisms and approaches or the implementation into the production process of innovative, highly technological tools and methodological operational and strategic approaches.

# 3 Conceptual Fundamentals of Restructuring the Production Systems into Cyber-Physical Production Systems

## *3.1 Synthesis of Definitions of the Notions "Production System" and "Cyber-Physical Production System", Determining the Fundamental Basis of the Concept*

On the basis of a systematic critical theoretical review of the most commonly used in research literature definitions of the notions "production system" and "cyber-physical production system", the determinations of those notions are further specified and upgraded, and they become a working fundament of the concept for restructuring the production systems into cyber-physical production systems.

The present concept for restructuring the production systems into cyber-physical production systems is based on the further specified and enriched definitions of the studied and analyzed notions. In this respect:

- The production system is a specific unity of interrelated and interdependent subsystems, methodology and toolset, which on the basis of automation of the production process, objectivize the nature of the production operations in view of achieving the strategic organizational goals and the operational production assignments. In a structural respect, the production system is based on the principles of the systematic approach, and is generally comprised of two subsystems (managing and managed-transforming one).
- The cyber-physical production system is a digital virtual-and-physical production model based on the elemental fundaments of the ecosystems "machine - human" and "blockchain networks" connecting the real-life production process and its information flows with a simulated, identical with the real one, virtual production model integrating information basis, analysis and evaluation of large bulks of data, artificial intelligence, the Internet of things, the Internet of services, cloud computing, strategic and production management, and a planning, organizing and coordinating one, which controls the work of machines, facilities, technologies, sensor devices, robots, production capacities, representing an integral part of the real-life production.

### *3.2 Synthesis of the Definition of the Concept "Restructuring of the Production Systems into Cyber-Physical Production Systems", Determining the Fundamental Basis of the Concept*

Restructuring the production systems into cyber-physical production systems is a radical reorganization (fundamental change), prompted by the development of Industry 4.0. This reorganizaton is provoked by the evolution of the additive production, of the additive materials, of the nanotechnologies, of the robotics, of the photonics, of the micro- and nano-electronics, of the information-and-technological systems, of the cloud technologies, of the Internet of things, of the blockchain networks, of the mechatronics and of the artificial intelligence. The restructuring of the production systems into cyber-physical production systems is a long-term targeted process, aimed at synergy, efficiency and optimality of production, comprising the entire organization-and-structural and management unity of production as a system. In this line of thought, the process of restructuring the production systems into cyber-physical production systems should be strategically set as a goal and planned for the long term [5]. At the same time, however, it will also affect the operational planes in a business organization-production, production indicators, and parameters.

According to some sources [5], the restructuring with economic entities, applying smart management, is based on the dissipative concept for change (considering the organization and the environment as a single unity) and creates an order of a higher degree. Adopting that definition, a conclusion can be drawn by analogy that the restructuring of the production systems into cyber-physical production systems is also based on the dissipative concept for change, however, on a micro-level (production). In that sense, both production and environment should be analyzed as a single systematic dissipative structure, which content is entirely filled with the transformational process and its management. The activities in the production systems, restructuring them into cyber-physical production systems, should be based on a two-way, sustainable and incessant relation between the production process and environment. This requires that the restructuring of the production systems into cyber-physical production systems should maintain the permanent status of dynamic equilibrium between the production and the micro-factors, and should be focused on achieving the strategic and operational organizational goals.

As a result of studying various theoretical research works, the analysis of definitions, the synthesis of determinations, and the application of analogy as a tool for argumentation, the cognitive nature of restructuring the production systems into cyber-physical production systems can be brought forward. On this basis, it is defined as a planned, comprehensive, long-term, sustainable reforming change of the production process structure, running from the top to the bottom, and determining its fundamental architectural and organizational-and-management reorganization. It is evident that restructuring the production systems into cyber-physical production systems means a purposefully planned radical structural change on an

operational level, however, directly determined and determining the strategic organizational benchmarks—connected in a two-way mode with them in a relational dependence.

### *3.3 Synthesis of the Fundamental Restructuring Activities*

The research of the literary sources on a business organization level indicates that, generally, there is restructuring when:

- an old business unit is closed, and, subsequently, a new one is established;
- an operating business organization is reconstructed and/or modernized;
- there is streamlining of the management systems that is carried out, as a result of the on-going dynamic changing of the conditions where a particular business structure is functioning.

By and large, literature [26] determines that the restructuring of the production systems can be done in various forms:

- dividing and creating economically competitive units, taking into account the technological dependence within each of them;
- adapting the activities subject to termination to the new economic conditions;
- restoring some activities;
- liquidating the non-viable production systems.

Other authors [10, 25] assume that restructuring is closing the non-profitable production lines and sectors, as well as optimizing the production structures and separating the accompanying and auxiliary production lines into separate companies.

The aforementioned restructuring activities concern primarily the business units in general, and not production as an independent system. In this relation, there is a need for analytical drawing of parallel between the restructuring activities on a macro level (business organization) and the restructuring activities on a micro level (production system). At the same time, a synthesis is also required on the basis of analogy of specific restructuring activities based on the already defined concepts "production system", "cyber-physical production system", and "restructuring the production systems into cyber-physical production systems". Although the reorganizing activities in restructuring the production systems into cyber-physical production systems are aimed at achieving efficiency, optimality and synergy, they are accompanied by a high risk, and should be focused on:

- further improvement of the system of the existing production processes or introduction of entirely new system-bound process production chains;
- technological transformation of the production structure or upgrading it with innovative and new structural subsystems;
- modernizing the work methods, mechanisms and approaches or implementing innovative, highly technological tools.

It is evident that the defined specific restructuring activities determine either the creation of a new production structure, different (by content, scope, and philosophy) to the current one, or upgrading the existing production structure with new processes, or the radical transformation of the existing organizational-and-structural and management production unity.

## *3.4 Determining the Borderlines, Elements and Scope of Restructuring the Production Systems into Cyber-Physical Production Systems*

The cyber-physical production systems are technologies containing computational and physical capacities combined with the possibility for interaction between human and machine, and between cyber devices and blockchain networks. The restructuring of the production systems into cyber-physical production systems requires first of all changes in the structure of the production systems, which is related to implementing in them elements from the technology of the cyber-physical production systems. In other words, restructuring of the production systems (they are physical) to cyber-physical production systems (they integrate a physical component—machines, tools, and a virtual component-a simulation model, data analysis, etc., within the production context), is related to upgrading and involving the real-life production process with new virtual structural elements. Moreover—restructuring of the production systems into cyber-physical production systems, transforms the production systems into subsystems, they form the overall architecture of the new cyber-physical production systems. Thus, the production systems, which comprise a managing and a managed subsystem, should be integrated in new, much more complex systems of subsystems of autonomous and cooperative elements, which connect with each other depending on the situation at all the production levels—from processes through machines to production and logistic networks, whereby procuring the processes of decision-making in real time, and responding to unforeseen conditions and changes occurring in the course of time.

The range of restructuring of the production systems into cyber-physical production systems result from the nature of the concepts of the production systems and of the cyber-physical production systems and from the nature of their architecture. The main borderline issues come from the fact, that the cyber-physical production systems have two main subsystems—a physical and a cyber one, which are, themselves, also subjected to the principles of the systematic approach, and integrate in a systematic unity and interdependence a number of complex relations.

The production systems with their two major subsystems (managing and managed one) are restructured to a subsystem of the cyber-physical production systems and become a part of their physical subsystems, which preserve the autonomy of a part of the structural elements of the real-life production systems. At the same time, the production systems (already as subsystems) become a part of the physical subsystems

of the cyber-physical production systems and are involved in relations and dependencies from the subsystems, forming the cyber subsystems of the cyber-physical production systems.

The elements of restructuring of the production systems into cyber-physical production systems issue from the structure of the two systems. The real-life production subsystem, where the physical production process takes place in a particular temporal and spatial aspect, should be integrated and upgraded with new structural elements, such as:

- a subsystem for automated gathering of data from the real-life production environment;
- a subsystem, where the gathered production machine signals are transformed into semantically rationalized information;
- a subsystem functioning as a central information centre of a network of cyber devices, which store a large information bulk;
- a subsystem based on expert systems, whereby a particular decision is analyzed and informationally supported;
- a subsystem, which implements the chosen decision and configures the feedback from the cyber space to the physical production system.

The scope of restructuring is determined by the specificity of the cyber-physical components, which connect and coordinate the physical and the cyber subsystems, and make the real-life technological chains adaptive, as well as by the designed socio-mechatronic subsystems, whereby the loading on the cyber-physical production systems is determined, and also by the components facilitating work in emergency mode, or the restart after registering a critical situation. In this line of thought, the scope of restructuring of the production systems into cyber-physical production systems depends entirely on the initial data gathering, its analysis and the creation of the final value.

## 4 Conclusion

Based on the literature review of a number of authors [3, 4, 8, 9, 14–16, 18, 20], this article defines for the first time in the scientific literature the main characteristics of the concept of the restructuring of production systems in cyber-physical production systems. A well-grounded conclusion can be drawn as a result of the present study, that the restructuring of the production systems to cyber-physical production systems is aimed at ultimately attaining an open and flexible system of simply isolated subsystems with complex interactions between them, comprised autonomous and joint elements, including physical elements (robots, metalworking machines, etc.), cyber elements and people, who can be related or independent from each other, depending on the various situations. It is on this particular basis that the conceptual fundamentals of restructuring the production systems into cyber-physical production systems take into account the relationship between the subsystems, the impact, which should

take place on all the levels of the production life cycle—from the processes to the logistics. The concept takes into consideration that the cyber-physical production systems are adaptive under unforeseen conditions and are capable of autonomously taking decisions or solving cognitive tasks.

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# Impact Assessment of 'ICT Practices' on 'Supply Chain Management Performance' in Automotive Industry in India

**Jagdeep Singh, Shivoham Singh, Mamta Kumari, and Surendra Kumar Vyas**

**Abstract** In the era of COVID-19, most of the business declined and a huge loss of jobs due to no demand and automobile sector is not the exception. Nearly 7.5% of India's GDP comes from the car industry, and supply chain is one of the key factors in a firm's overall value creation. The efficient and effective supply chain is dependent on information and communication technologies (ICTs) at present, and hence, it implies that ICT is spine of SCM. The major objective of the study was to draw conclusions on how information and communications technology practices affect supply chain management performance in the Indian auto-sector. The outcomes state that ICT practices have high correlation and direct impact on SCM performance, however, it does not have much impact on operational performance. The research also suggested that better and more effective ICT practices result better supply chain performance. The limitation of the research was the respondents' voluntary cooperation, and the ICT practices are limited to supply chain operational performance in various departments and functions only and not the applications in any vehicles.

**Keywords** ICT · ICT practices · SCM · SCM performance · Auto industry

**Paper Type**: Research Paper

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## 1 Introduction

Automobile sector in India has a good portfolio, however, commercial vehicle production is lagging behind as it compares globally. Senior leadership in automobile sector should focus on commercial vehicle (CV) demand and production side. To keep up with the rivalry in the international car industry, more funding and collaboration are required. In any event, India's automobile sector has already eclipsed the US to become the world's fourth-largest maker of cars. Technology is one of the biggest facilitators to automobile supply chain management where ICT plays a vital role in streamlining the processes, reducing the lead times, collaborating with cross functional teams and organizations, live data and information sharing, improving visibility, bringing operational efficiency and transparency, helping in strategic supply chain decision-making, enhancing the overall supply chains performances [1] at all levels, and more. Firms are focusing on intensification of their ICT practices which make supply chain more robust and responsive. As a result, SCM becomes more competitive, efficient and effective, and finally, improves overall supply chain management performance. According to [2], ICT is typically viewed as a supply chain facilitator, lowering inventory levels, cutting lead times, and fostering a culture of collaboration with suppliers and dealers [3]. Told that information and communication technology is a vital facilitator for boosting the car ecosystem at many points along the value chain, it has been claimed that integrating it might be costly and time-consuming. In a nutshell, applications of information and communications technology (ICT) have enormous potential to enhance performance across the board in society and the economy. Multiple gaps in supply chain management were discovered during the researcher's literature reviews and fieldwork (during 2015–2017), including uneven processes, longer lead times, a lack of collaborations, issues with data and information sharing, visibility, operational inefficiency, a lack of transparency, etc. The ICT practices are thought to include these gaps. The effectiveness of supply chain management depends on these ICT techniques [1]. As stated in the research paper's title, the goal of the study was established taking into account these shortcomings.

## 2 Indian 'Auto-Sector'

One of the main sectors in India is the automotive sector (automobiles and auto-components). In order for growth to be sustainable, a well-developed transportation system is needed; hence, India must concentrate on developing its infrastructure. The Indian economy's fabric includes a significant presence for the automobile industry. India has established itself as one of the key markets for global hybrid and electronic vehicle manufacturers, and this is already the scenario I n the automobile sector. Four categories make up the automobile industry as two-wheelers, three-wheelers,

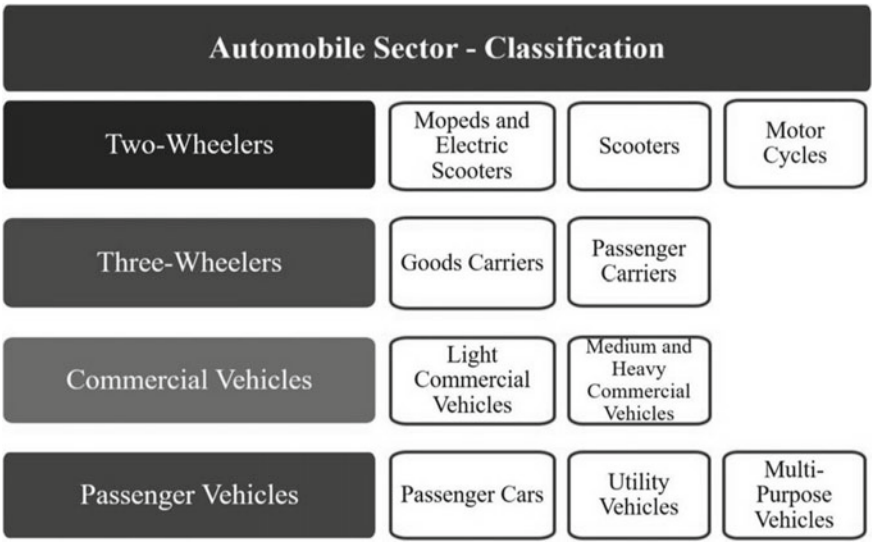


**Fig. 1** Automobile sector classification (Adapted from [4])

passenger cars, and commercial vehicles. Figure 1 displays a thorough categorization of the automotive industry.

According to (SIAM 2020), India stands at fourth position in passenger vehicles with 4.06 mn units of production, and at seventh position in commercial vehicles with 1.06 mn units of production, annually, however, USA stands at first position with 8.51 units, China at second position with 4.27 units, and Mexico at third position with 2.52 units, annually.

NTTDATA [5] reported that while the automotive industry is undoubtedly at a point where connectivity, autopilot vehicles, and power train electrification are essential elements, there are other factors—such as supply chain automation, new competitors, price pressure, and internationalization—that form the foundation of the automotive ecosystem. Current ultra-complex global supply chain networks require a high degree of automation and transparency due to the numerous difficulties in the automotive industry's supply chain (GSCNs). Original equipment manufacturers (OEMs) and suppliers must achieve a consistent, cross-company integration of processes, and application. NTTDATA [5] Revealed that 3D printing tech will be the biggest thing in the automobile sector sooner or later. Its contribution will be enormous once t is adopted, and hence, everyone is thing and waiting for mass applications in all economies whether developing or developed. The tooling is prepared and used for 10–20 years today may be the out of date due to fast changing expectations from customers in terms of new look and design which could be supported by ultra-modern technologies in the very near future. This may help to boost the automobile industry, however, it was growing at a CAGR 17% in the last few years except last two years [6]. It was shown that increased competition among manufacturing companies has

resulted in a 20% increase in productivity year over year in the vehicle industry. This demonstrates the intensity of the effort, as well as the fact that this rise in productivity is among the highest in the manufacturing sector. As a result of India's high-quality technical talents, big pool of trained people resources, strategic location in conjunction with powerful development patterns in the economy, and massive investments by global firms, the country's automotive sector is predicted to reach new heights (Rune 2008). One of the most significant advantages of manufacturing in India is the easy availability of management and engineering skills, as well as the low cost of labor. The cost of labor per hour in India is very low, averaging between 7 and 10% of the cost of labor in wealthy nations. Although this expense should be considered, it should also be considered if India can still keep its cost leadership [7].

## 3 Supply Chain Management

The systematic and strategic coordination of routine business activities by three or more parties who are directly involved in the upstream and downstream flows of goods or services, information, and/or finances from the point of origin to the final consumer is known as supply chain management [8]. The center of supply chain management is to integrate three basic functions of supply chain as CRM, internal SCM, and SRM along with to understand the even flow administration of funds, information and goods among the cross functional teams, and organizations throughout the supply chain pipeline so that desired values could be ensured and delivered to the end consumers [9]. It was found that there were gaps in concurrence and implementation of the ICT practices which needed a large amount attention on collaboration and integration of supply chain functions to bring efficiency and effectiveness [9, 10]. Recommended the integration and coordinate among the supply chains within or outside organizations as and when necessary and it was also told that supply chain is superior due to supplier/purchase management and logistics/transport management. Levary [11] advocated for supply chain integration to help stakeholders reduce inventory levels by lowering the bullwhip impact and cycle time, as well as boost efficiency and quality to acceptable levels across supply chains. The research emphasized the need of effective SCM methods in recognizing and eliminating disruptions in India's automobile sector Kottala [12].

## 4 Information and Communication Technology and Its Roles

According to [13], ICT has emerged as the cornerstone of each and every sector of any economy, in every country, on every continent. ICT lowers transaction costs and, as a result, increases overall productivity. It provides instantaneous connectivity, whether it be visible or audible. It also improves the efficiency of the system,

as well as clearness and correctness during the entire system [13, 14]. The positive and notable impact on GDP that investment in the ICT sector has on the economy has been demonstrated, and this optimistic impact is applicable to both rich and developing countries [15]. Told that ICT impacts human life in many ways and hence global 'economy and society' is undergoing a basic transformation towards the 'knowledge society.' It includes products that hold, retrieve, alter, send, or receive data electronically. Businesses often use ICT connectivity. ICTs are divided into two types: conventional and modern. Traditional ICTs employ PC-based technology at home and business, whereas modern telecommunication technologies transmit data electronically. CRM, SRM, ICT, and others like handheld computers in warehouses, etc. Many vehicle manufacturers have gaps in agreement and acceptance of ICTs, although they are eager to embrace in the near future. The use of enterprise applications may increase information exchange, process management of the business, and organization's overall effectiveness [16]. Concluded that the ICT cuts the cost, improves communication (two ways) to the customer, instant feedback brings flexibility, improves efficiency, and reduces operational costs and many more. According to [17], ICT is said to have three main functional roles: decision support, collaboration, and transaction execution.

## 5 ICT Practices, Applications, and Supply Chain Management

A number of ICT practices are available and used in the automobile and other manufacturing sectors such as RFID and barcode and scanners, mobile computer, various software such as ERP, SCM, TMS, WMS, and DSS, etc., telecom devices such as mobile phones, landline phones, and fax, etc., world wide web, website, emails, etc., smart factory and warehouse, automated picking and put away, GPS system, integration mechanism such as EDI, and more [18] Discovered that the supply chain's operational performance is positively impacted by the appropriate usage of ICT. However, the impacts and impressions of the ICT adoption may not always prompt and the length and interval might differ according to ICT used. It was also found during the research that the use of ICT impacts the bottom line of the organization such as profits and margins and market share. This performance comes primarily incomprehensibly by the enhancement of internal (within the organizations like cross functional teams SCM, operation, accounting and finance, taxation, HR, sales and marketing, etc.) as well as external (outside organizations like suppliers, customers, and any other stake holders) communication including operational performance [18]. According to a report by PwC in 2013, applications of ICT are very wide nowadays and supply chain management is the area where ICT has been meaningfully implemented and ok tested for the last many years in running the flow of goods between start and end points. The use of information and communications technology has already improved real-time monitoring of commodity movement. These systems

allow for the accurate tracking of things from the source to the distributor, then to the salesperson, and finally to the end customer. It has been proven that these systems can limit theft, identify route tampering, track equipment, reduce manufacturing delays, and improves product and personnel security among other things. According to [19], According to the results of the World Bank's survey, the usage of information and communications technology (ICT) results in faster revenue growth, increased productivity, and quicker jobs growth [20]. Worked on the effects of North America's ICT boom (US). The results show that 'influence of computerization on productivity growth is positive and significant.' [21], asserts that the most significant benefit of information and communications technology is the access to information to a large number of people and the reduction of manufacturing costs as a result of enhanced efficiency. Rooney [22] stated that knowledge can be created, exchanged, and made broadly accessible, and that anybody might contribute and share information across national boundaries. It increases transparency while also lowering prices. Though information and communication technology has a robust influence in most of the industries, however, the tourism is one of those industries that are extremely rational to information and communication technology [23]. Volpato [24] It was discovered that a unique restructuring has begun in the entire sector, aiming to redeploy parts supply chains from production through automobile assembly and final delivery. Only ICT allows this. However, insufficient organizational capacity and poor customer–supplier interactions cannot be solved solely by ICT. Many researchers advise that ICT must be used in logistics and supply chains for better results. Gunasekaran [25] Told that ICT improves quality of logistics companies, service quality which helps to gain competitiveness Bhandari [26]. Has informed that IT halts the analysis and gives information when required, but supply chain management describes the network of firms that are linked to one another via the use of information and communication technology in some way. Information and communication technology applications are used in SCM to make the supply chain more transparent [27]. Investing in information systems, according to the results of the investigation, is helping banks expand market share while also lowering operational costs, improving customer service, and facilitating the introduction of new goods and services. A study conducted by Fasanghari [28] examined the impact of information technology on supply chain management and discovered that it is much greater than previously thought. This is because information technology facilitates inter-organizational communication, which in turn reduces cycle times and fosters collaboration. IT also gives organizations with the opportunity to grow their markets globally, as well as the ability to improve teamwork and customer relationship management [29]. Suggested to consider using ICT as a prerequisite for sustainable management of today's complex supply chains. ICT shortens cycle times, improves supply chain dexterity, increases productivity, and delivers items at the right time. SCM is tailored to stress the long-term benefit of all partners in the supply chain through collaboration and information sharing. This underpins the relevance of IT in SCM, which is exacerbated by order fluctuation Tippins [30], Yu [31]. Simchi-levi [32] proposed the goals of using IT in logistics and supply chains as information accessibility, reliability, and visibility, a single point of contact for data, choices depending on supply chain information and partnerships

[33]. The concept of information technology as an organizational capability was developed, and an empirical investigation into the relationship between IT capability and firm performance was conducted, with the findings indicating that firms with high information technology capability outperform their counterparts. It was argued that information technology development serve as a catalyst or facilitator in the design and management of supply chains. The use of information and communications technology has a considerable influence on supply chain integration and performance. The use of information and communications technology for supply chain management improves communication, process flow, and decision-making, saving the cost, increased competitiveness, and improved inventory visibility. Inventory control is one of the processes in SCM that is characterized by SD. The introduction of a new parameter, such as ICT capability, has a significant impact on the situation and results in the creation of new positive feedback loops [34]. The influence of ICT on the SCM process of inventory control was investigated using CLD. This is true for all supply chain management processes, including planning and implementation [35].

## 6 Research Gaps Identified During the Literature Review

Research gaps identified in the proposed field of investigation are as follows:

- There is a gap between awareness level and adoption level in supply chain management practices [36, 37].
- Gap found in customer relationships between manufacturer and the dealers and customers [9, 36].
- Found a gap between awareness and adoption of ICTs [38, 39].
- Issues of maintaining and sustaining low inventory levels across the supply chains [2, 11].
- Issues of inventory visibility [35] and flexibility across the supply chains [16, 32, 37].
- Found issues in collaboration and information sharing at right time [9, 32, 37].

## 7 Research Methodology

### *7.1 Research Design*

The research design or process flow of the study is summarized as illustrated in Fig. 2: In this study, a descriptive and analytic technique was used to examine the information and communication technology practices in the Indian automotive industry. The research has established who (automotive enterprises in India), what (ICT practices), when (2015–2020), why (found gaps), and how in order to be understood (interview schedule).

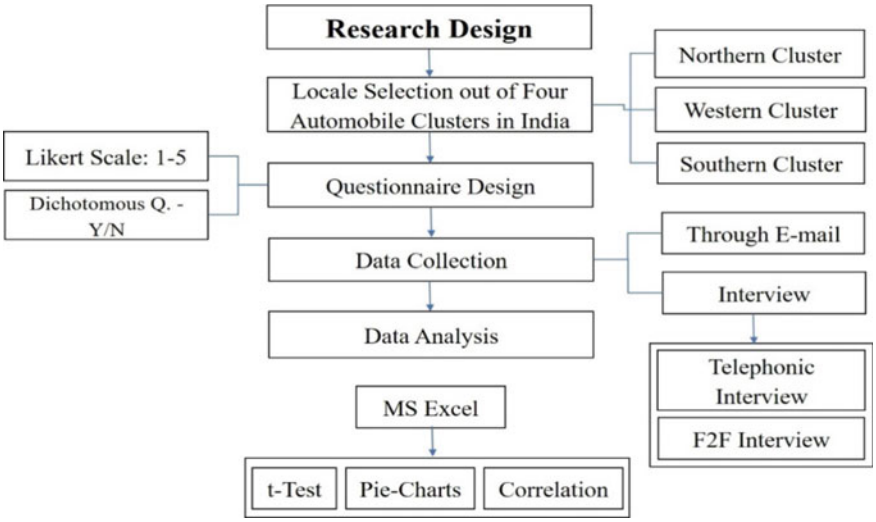


**Fig. 2** Process flow of the study

## *7.2 Locale of the Study*

The location of the research was chosen based on an examination of the information available on Wikipedia. The research was carried out for the benefit of vehicle original equipment manufacturers (OEMs) and factories in India. The Southern, Western, and Northern Clusters of automobile OEM firms/factories in India were chosen for the study because they represent more than 95% of the overall production in terms of vehicles and value, as shown in Fig. 3, and thus represent the majority of the total production.

## *7.3 Collection of Data*

### Sampling Methods

Random sampling was the sampling technique utilized for this study, and it was selected based on the data analysis (as indicated in the bar chart) and also for convenience as most businesses focused on the first three clusters and avoided the fourth.

### Analysis before the Collection of Data

The three main clusters of vehicle OEMs contained a total of 137 production facilities, although only 119 facilities were covered by the study's purview. The factories that build automobiles that have two wheels (motorcycles and scooters), three

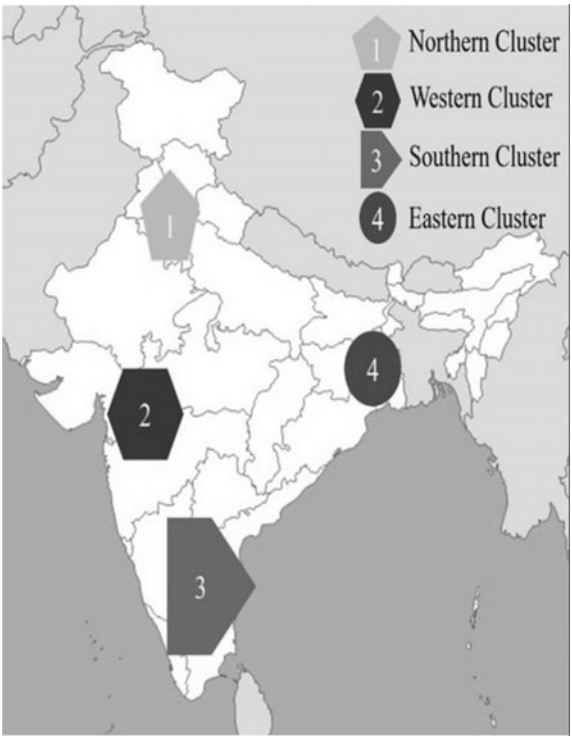


**Fig. 3** Automobile clusters in India

wheels (auto rickshaws and loaders), four wheels (loaders, light commercial vehicles, passenger cars, and tractors), and heavy vehicles (buses and trucks). The bar chart and pie chart below display the production units included in the scope as well as the distribution of assembly plants per cluster. A full list of manufacturing units was collected from Wikipedia as the data source.

Figure 4 shows the breakup of assembly plants in all clusters. About 98% assembly plants fall under west, north, and south clusters, and hence, only these three clusters were selected for the research.

### Data Collection

Primary data were gathered using a well-designed study questionnaire, scheduled in-person and telephone interviews, as well as email exchanges. Out of a total of 119 assembly plants, 92 responses were received, and 80 of those were usable. Figure 5 demonstrates that the overall response rate was good.

Figure 6 demonstrates that 77% of the total responses were received, and 87% of those could be used and further examined.

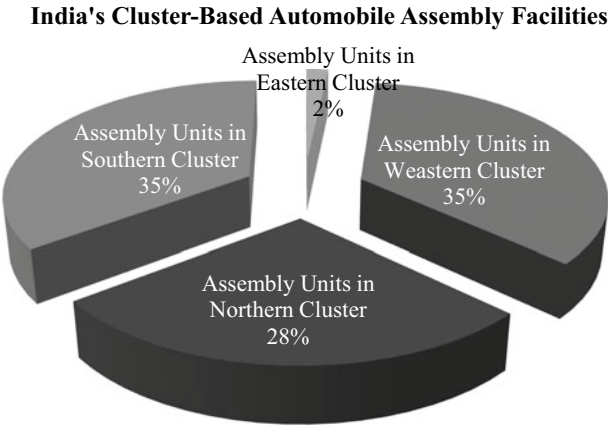


**Fig. 4** Indian automobile assembly and manufacturing facilities organized by cluster (*Source* Wikipedia—A Secondary Data Source)

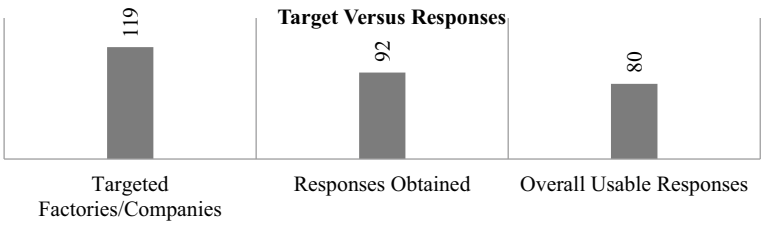


**Fig. 5** Company targeted versus responses obtained (*Source* Primary Data Analysis)

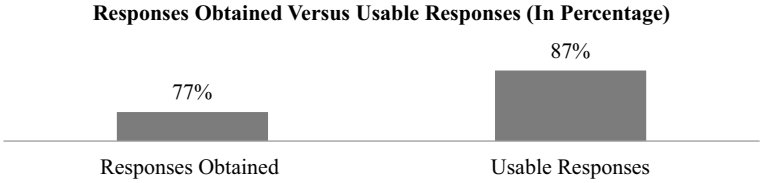


**Fig. 6** Obtained versus usable responses (*Source* Primary Data Analysis)

## *7.4 Analysis of the Data*

In order to examine the data, Microsoft Excel was used. The researchers studied the available data to estimate the impact of information and communication technology (ICT) practices on supply chain management performance.

## 8 Results Discussion

Any data set needs to be evaluated since it influences decisions. The end result of the analysis is to draw a conclusion, either positive or negative. The final result and its commentary are the primary subjects of the technical report. This chapter's goal is to present a statistically-based summary of the collected data in graphical, tabular, and/or other suitable visual representations. This study sought to examine the variations in ICT activity expectations (agreement) and perceptions (adoption) and how these impact SCM performance. Software, hardware, integration tools (IT), and communication tools and techniques (CTT) are four factors in ICT operations which are considered to analyze the impacts. All of these characteristics are linked to supply chain management success. The results were presented in the following headings:

8.1. Analysis of yes/no type questions
8.2. Model of research (RM)
8.3. Hypotheses testing
8.4. Data reliability test, t-test, and correlation in data analysis.

### *8.1 Analysis of Yes/No Type Questions*

In Fig. 7, question number 1 and 2 show that ERP and other supply chain and transport related software's like SCM, TMS brings efficiency in supply chain management system as most of the supply chain professionals agreed the same (~97% respondents were in favor). In Fig. 8, question 3 shows that WMS is also an important software for inventory management and warehouse operations management which brings operational efficiency in overall warehouse operations majority of the professionals harmonize the same (~91% respondents were in favor). In the fourth and last question in Fig. 8 shows that majority (~86%) of the supply chain professionals do not understand the role of blockchain in SCM and this is the upcoming area where SCM professionals have to polish their knowledge and be ready for future challenges.

### *8.2 Representation of Study Model*

A study model was developed based on the literature review and hypothesis, as illustrated in Fig. 8. The impact of ICT practices on supply chain management performance has been demonstrated. The correlation was used to statistically test this concept.

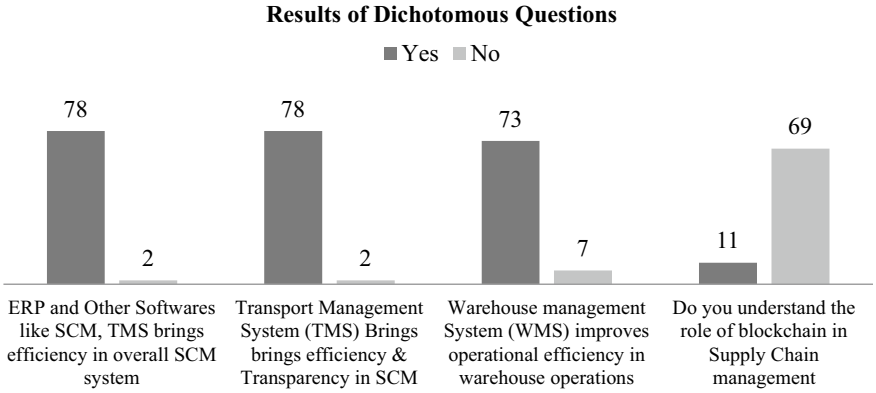


**Fig. 7** Results of dichotomous questions

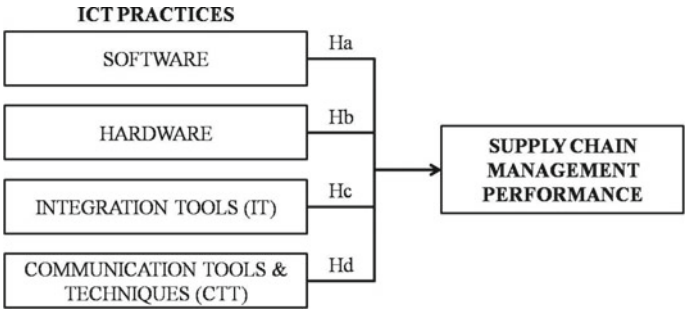


**Fig. 8** Study model: impact of ICT practices on SCM performance

## *8.3 Testing of Hypothesis*

**The following is a list of the proposed study's hypotheses**:

$H_0$ = Null hypothesis, $H_1$ = Alternate hypothesis (Table 1).

## *8.4 Data Reliability Test, t-Test, and Correlation in Data Analysis*

### 8.4.1 Data Reliability Test

According to [22], in 1951, Lee Cronbach created the Cronbach's alpha (also known as the coefficient alpha) as a metric of data reliability or internal consistency. Reliability is another name for consistency. Multiple-question surveys using the

**Table 1** Hypotheses of the proposed research

| |
|---|
| $H_0$a: software has no impact on SCM performance |
| $H_1$a: software has impact on SCM performance |
| $H_0$b: hardware has no impact on SCM performance |
| $H_1$b: hardware has impact on SCM performance |
| $H_0$c: integration tools (IT) has no impact on SCM performance |
| $H_1$c: integration tools (IT) has impact on SCM performance |
| $H_0$d: communication tools and techniques (CTT) have no impact on SCM performance |
| $H_1$d: cmmunication tools and techniques (CTT) has impact on SCM performance |

**Table 2** Cronbach's alpha value and the data reliability (internal consistency) level

| $\alpha$ | Data reliability |
|---|---|
| $\alpha > 0.9$ | Outstanding |
| $0.9 > \alpha > 0.8$ | Good |
| $0.8 > \alpha > 0.7$ | Acceptable |
| $0.7 > \alpha > 0.6$ | Questionable |
| $0.6 > \alpha > 0.5$ | Poor |
| $0.5 > \alpha$ | Unacceptable |

Likert scale have their reliability tested using Cronbach's alpha. Conscientiousness, neurotic, and transparency are examples of latent traits, or attributes that are neither apparent nor measured. These are incredibly challenging to quantify in real life. A statistic called Cronbach's alpha shows how closely a set of test items are connected. The Cronbach's formula is as follows:

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

In the above formula, $N$ demotes the number of items, $\bar{c}$ denotes the average covariance between item-pairs, and $\bar{v}$ shows the average variance.

The range of data reliability has been shown in Table 2.

According to Table 2, the final estimated value of $\alpha$ is 0.842, which falls in the range of 0.8 and 0.9, signifying that the data's reliability is good. As a result, the data proved reliable for future investigation.

### 8.4.2 T-Test

The P value has been displayed as 0.000 in all circumstances in Table 3 as shown below because it goes beyond 3 decimal places.

**Table 3** Final outcome of t-test

| Variables | p-value | Significance level | Status of null-hypothesis | Final findings on hypothesis |
|---|---|---|---|---|
| Software | 0.000 | 0.01 | Rejected $H_0$a | The alternative hypothesis ($H_1$a), according to which software has an impact on SCM performance, is accepted |
| Hardware | 0.000 | 0.01 | Rejected $H_0$b | The alternative hypothesis ($H_1$b), which states that hardware has an impact on SCM performance, is accepted |
| IT | 0.000 | 0.01 | Rejected $H_0$c | The alternative hypothesis ($H_1$c), according to which Information Integration (IT) has an impact on SCM performance, is accepted |
| CTT | 0.000 | 0.01 | Rejected $H_0$d | The alternative hypothesis ($H_1$d), which states that communication tools and techniques (CTT) have an impact on SCM performance, is accepted |

Decision at 95% and 99% significance level, the p value should be less than 0.05 and 0.01, respectively. It suggests that there is substantial evidence against the null hypothesis. Based on the aforementioned findings, the alternative hypotheses ($H_1$a, $H_1$b, $H_1$c, and $H_1$d) were accepted while the null hypothesis ($H_0$a, $H_0$b, $H_0$c, and $H_0$d) got rejected

It demonstrates the close relationship between the sample and the population. In other words, there is a clear link between the effectiveness of supply chain management and ICT practices (software, hardware, IT, and CTT).

### 8.4.3 Correlation

Correlation results have shown in Table 4, and these results are explained as below: ICT practices (software's, hardware's, IT, and CTT) have a significant (strong) association with supply chain management performance. The result says that if any of the input variables change, the output will change. The supply chain's performance would be high if all types of ICT techniques were employed. Because the association is substantial, it can be argued that ICT practices boost supply chain performance.

**Table 4** Final results of correlation according to the study model

| | |
|---|---|
| Correlation of software on SCM performance | 0.89 |
| Correlation of hardware on SCM performance | 0.77 |
| Correlation of integration tools (IT) on SCM performance | 0.54 |
| Correlation of communication tools and techniques (CTT) on SCM performance | 0.86 |

The model has likewise demonstrated the same outcome as before. As a consequence of the correlation data, the model proved to be correct.

## 9 Summary

The automobile industry has recognized the potential of information and communications technology techniques, which may assist to improve the performance of supply chain management. With each passing year, the scope and responsibilities of supply chain management (SCM) have increased. It is now responsible for everything from purchasing to warehouse operations to transportation and distribution as well as producing and delivering the product to ultimate consumers. The research discovered discrepancies between agreement and acceptance in ICT practices, which had an influence on SCM performance. As a result, the study's aim was extended to 'impact evaluation of ICT practices on SCM performance in the automobile industry in India.' Based on the problem statement and gaps identified, the ICT activities were classified into four categories: software, hardware, integration tools (IT), and communication tools and techniques (CTT). ERP, SCM, TMS, and WMS, among other things; RFID Tags, PC, mobile computers, barcode scanners, among other things; EDI system, among other things; and website, email, mobile and landline phone, Fax, virtual meetings technology such as Google meet, Zoom, and so on. The research was conducted out in three of India's most important automobile clusters. All of the information was gathered using a well-designed and organized questionnaire, which was administered in person and over the phone in addition to email exchanges with participants. A variety of data analysis methods were employed, including research models, dichotomous question analysis, hypothesis testing, and ultimately data examination utilizing the correlation and t-test in Microsoft Excel, among other methods. The fundamental finding of the study is that in all cases of information and communication technology (ICT) practices, p-values are less than 0.000 in the t-test, according to the findings. It indicates that the p-values are less than 0.05 (at the 95% level of significance), and as a consequence, the alternate hypotheses have been accepted, whereas the null hypothesis had been rejected in all the scenarios. When it comes to all four factors, the association between ICT practices and SCM performance is comparatively extremely strong. According to Table-4, this suggests that the values of the correlation are more than 0.5 in each of the four cases. As a result, it can be concluded that the effectiveness of SCM is influenced by information and communication technology practices. The overall findings affirmed and confirmed that there is a direct relationship between information and communications technology practices and supply chain performance. The findings have demonstrated that the model is valid.

## 10 Conclusion

In the automobile industry, information and communications technologies (ICTs) are critical to the performance and long-term viability of supply chain management. Because ICT practices in manufacturing organizations are nearly identical to those in other sectors, the findings may be applicable to other manufacturing industries as well. The research made it abundantly evident that ICT practices have a significant influence on the performance of supply chain management. A mix of software and hardware is necessary in the competitive era as these bring efficiency, reliability, transparency, and competitiveness in overall supply chain management ecosystem. System and process integrations are also desired for paperless supply chain transactions and to improve visibility in the system for parts/materials, documents, or any other type of desired information. Normally, required communication tools and techniques are already available to most of the organizations and that is a positive point for automobile industry, however, it is to be taught to previous generation people to optimize the use. Use of ICTs also bring flexibility and help in change management especially in automobile manufacturing environment.

The study demonstrates that improved ICT practices lead to improved supply chain performance, and each organization's bottom line wins from improved SCM performance as it boosts overall profit and client satisfaction.

## 11 Managerial Implications

The research clearly shows the positive impacts of information and communication technologies (ICTs) on supply chain management performance. The necessity of ICTs may vary company to company and sector to sector depending on the complexity of the supply chain operation. The company may brainstorm with their cross functional teams and organizations at all level from physical material handler to the middle and senior management teams. First understand the current state of operation and the problems and jot down all possible suggestions from everyone. In case, company is lacking in terms of ICTs over their competitors, try to adopt required ICTs for better supply chain management performance. In case, ERP system and other ICT tools are already available and still facing challenges, discuss with IT experts along with the suggestions from cross functional teams for best possible solutions. Quick and easy solution could be low-code tech, any business process management app which may quickly integrate with existing ERP and other ICTs for quick and low cost solution. The research recommends using ICTs at optimal level for maximum operational benefits.

## 12 Suggestions for Future Researchers

This research was performed on automobile supply chain; however, the same kind of researches could be performed in auto component industry or any other manufacturing industry to understand the gaps and provide the best possible suggestions for the respective benefits in information and communication technology perspective.

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# An Experimental Study of Machine Learning Algorithms for Predicting Start-Up Success

**Ajai Mishra, Dharm Singh Jat, and Durgesh Kumar Mishra**

**Abstract** In recent years, our data storage and processing abilities have been enhanced significantly. Machine learning (ML) has become able to capture and analyze huge data without human interference. In this context, the ML techniques will also be used for measuring, predicting, and recommending the consequences of start-up success. Therefore, first, we studied some essential contributions which employ the ML models for business success. Next, a system architecture has been demonstrated that will be able to predict the success of a start-up and also recommend the key insights. Further, we proposed and implemented a start-up success prediction model. In this modeling, we initially used four supervised learning algorithms, namely support vector machine (SVM), k-nearest neighbor (KNN), Naïve Bayes, and logistic regression. In addition, two unsupervised algorithms such as k-means and fuzzy c-means (FCM) are implemented. During experiments, we have found these models are able to provide only 58% of classification accuracy. Therefore, we have proposed to use convolutional neural network (CNN) for training and prediction. In this context, we have crafted three variants of CNN models for experimental study. According to obtained results, we found the first model provides only 48% classification accuracy, the second model provides (69%) accuracy, and the third model provides higher accuracy (74%). Thus, we found promising to work with the CNN and Crunchbase datasets. Therefore, in near future, we proposed to design a CNN model with the feature engineering processes.

**Keywords** Machine learning · Recommendation system · Business data analytics · Algorithm design · Support system · Handholding of start-ups

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## 1 Introduction

Start-up India is a program (January 2016) by our Indian government, to develop and strengthen the business ecosystem. This ecosystem will help the start-ups in their business growth, supporting the economy, and providing employment opportunities, to skilled workers. Also, the Government is empowering start-ups by involving technological innovation and design. However, in business, not all start-ups have got success, some of them failed, due to diverse business conditions. Therefore, we proposed an intelligent model using ML techniques to provide hand holding, invigilation, and business decision support models as a recommendation system to improve the chances of success.

This paper is investigating different ML algorithms to design a better start-up success prediction model. Thus, a review of ML techniques and start-up success prediction model has been carried out. The aim is to predict the success of a business venture accurately in terms of success or failure. These insights will help the business administrators to improve their performance. The utilization of such kind of model is essential for industry and start-up growth. The main reason is that India is a growing country, and the continuous failure of new start-ups has led to financial loss in the country's financial growth. On the other hand, the start-ups are creating new job opportunities and implementing new business ideas. In order to make a sustainable environment for start-ups, to grow and can contribute to the economy, we need to support them by providing ML tools.

Thus, we need to study the ML framework for the start-up using ML. Therefore, the next section provides a study based on start-up success and the ML model. Next, a prediction model is intended to design, which provides feedback to the business start-ups in terms of failure or success. The model has been evaluated in the next part of the paper. Finally, the paper discusses the conclusion, and a future extension of the work has been suggested.

## 2 Literature Review

Start-up success and failure are influenced by various parameters and planning stages. In recent years, a number of studies have been carried out in order to understand the business ecosystem and its influencing parameters. In some datasets, these attributes are organized and provided in the public domain like Kaggle. In addition, some researchers are also tried to develop start-up success and failure prediction models based on machine learning and artificial intelligence techniques. This section provides a review of some essential and noteworthy contributions. Table 1 provides a summary of the collected literature for review. The table consists of the role of ML in start-up applications and what work has been contributed to the research article. The table is subdivided into three sub-sections. The first section provides the contribution based on the start-up success prediction model for a different purpose. Section two

shows the articles where the ML techniques are employed to predict venture capital funding-based applications. And finally, the last section includes the articles which are predicting the start-up's success and failure based on different other activities or external sources of information.

## 3 Proposed Work

Based on the influence and motivations, we proposed a predictive ML technique and a recommendation model. This model is used to understand the key needs of a business and recommend the appropriate insights to do action. This model is promising to provide support to the business, during different business complexities. The proposed model start-up success prediction and recommendation model are demonstrated in Fig. 1. The proposed model will be used for two tasks. First, predicting the start-up success in the early stages by evaluation of company data. Second, provides the trends on improvement required. And third is recommendation. In this context, we need a machine learning function such that which accept the parameter $x$ and predict the consequences in terms of success or failure. This function can be described as

$$y = f(x) \tag{1}$$

where the $y$ is a set of consequences {success, failure}, $x$ is a set of features such that $x = \{x_1, x_2, \ldots, x_n\}$, and $n$ is the number start-up properties or features considered, therefore,

$$\{\text{Success, Failure}\} = f(x_1, x_2, \ldots, x_n) \tag{2}$$

In this equation, $f$ is the ML algorithm, which is trained on samples and uses the parameters to predict the consequences. Figure 1 demonstrates the overview of the proposed model. That shows how the Crunchbase dataset is prepared by collecting the information from the different sectors of companies and start-ups. In this dataset, the different parameters of start-up attributes and sectors have been organized. The dataset consists of very essential attributes such as funding, activities, promotions, employment, subsidy, and many more. Based on this data, we employ the ML algorithms to capture the required insights. In this model, we are expecting two consequences from the machine learning algorithms:

1. Prediction of start-up performance in terms of success and failure
2. Recommending the attributes which need attention.

Therefore, in this process, we first provide a comparative performance study among different ML algorithms. The requirement for this is demonstrated in Fig. 2. This model accepts the Crunchbase dataset. The data pre-processing is utilized first which is an essential part of ML models, which is used to prepare the data for

**Table 1** Literature summary

| References | Working domain | Work done |
|---|---|---|
| [1] | Using Crunchbase dataset, ML-based techniques have been developing for predicting the business success or failure | Considered data leakage problem. Involve SVM, logistic regression, and gradient boosting model. Provides results in terms of accuracy (57%), precision (34%), and F-score (43%) |
| [2] | Predict start-up success or failure. Identify whether a company has secured funding or working to secure. Investigating web-based start-up success prediction models | Data of start-up ecosystem based on business and employment. Train multiple ML models to demonstrate how companies' popularity on Web yields in their performance |
| [3] | Start-up success prediction depends on different stages. Predict success based on funding amount, occurrence, and time | Used Crunchbase and Tech Crunch datasets. The data mining methods were used, namely random forest, ADTrees, and Bayesian networks. Accu racy described by ROC, precision, and recall |
| [4] | Investigating conditions of developing a technology start-up using current and future conditions | Examples of AeroMobile and eSense are considered. Analyzes data according to sectors. Finding shows IT start-ups are focused on sales. A system for start-ups with VC. Evaluate company's success and revise measurement systems |
| [5] | Utilize text and non-text information to foresee future of companies. Consider employment growth, return, subsidy, geographical, and ownerships | Considering business centric definitions to fore- cast. Only including variables obtained from texts. Finding shows the use of employment growth with the use of BPS and founder attributes improve the model accuracy |
| [6] | A methodology to an unstructured database. Analysis carried out for a large document database | Performed descriptive statistical analysis which demonstrates the lack of business development strategy is the key issue of start-up failure |

(continued)

**Table 1** (continued)

| References | Working domain | Work done |
|---|---|---|
| [7] | Introducing a business success diagnosis system, which is able to diagnose, predict, and recommend | Correlation analysis and hybrid NB and J48 classifier has used. ***Prediction and recommendation system will helpful for business success and entrepreneurial enhancements*** |
| *Venture capital financing* | | |
| [8] | Crunchbase is a dataset of start-up and VC financing. Implemented ML model CapitalVX used for prediction of start-ups success | Predict start-up will exit with IPO, acquisition, fail, or remain private. A number of features are used Performance shows 80–89% accuracy. VC/PE firms can use ML for evaluating companies |
| [9] | Raising funds are a key element of success. Collecting the geographical data of angel | Tracking companies which are raising funds and social engagement. ***Social media engagement is correlated to crowdfunding***. Used decision tree, SVM, KNN, for predicting fund raising. Solving class imbalance issue to 84% accurate prediction |
| [10] | Making efforts to identify key facts that are essential for capturing the investments | They questioned with 40 founders. Then compared financial and business level factors. Demonstrate differences among investor's point of view and founders for success |
| [11] | Putting resources into beginning phase is hard when no information is free. Investors depend on a hunch to arrive at a choice | Assist financial backers in choosing organizations with a higher achievement. Assembled research with examination on 600,000 organizations. They found 21 elements might help financial backers |

(continued)

**Table 1** (continued)

| References | Working domain | Work done |
|---|---|---|
| [12] | A neural organization and NLP to deal with anticipating crowdfunding utilizing message, discourse, and video metadata in 20,188 crowdfunding efforts | Semantic styles in crowdfunding expect to trigger favor on comprehensiveness for achieving objectives. There is uncertainty during design and development of a product which affect purchasing. Positive psychology is salient, and funding preferences are decided based on investor's taste |
| *External activity-based prediction* | | |
| [13] | Online media can forecast about future occasions. Show that web- based authenticity is a proportion of social appreciation | Used 187,000 tweets from 253 endeavors. They can segregate bombed adventures up to 76%. Add to the conversation on the significance of ML in business research |
| [14] | Analyze and find presentation of ways to deal with results of con- test: scores from judges, straight-forward models, and ML | Track down (i) strategy scores are uncorrelated with endurance, work, deals, or benefits; (ii) effective attributes like sex, age, capacity, and business area; (iii) ML techniques do not offer upgrades |
| [15] | How data science can add to developing exploration in financial matters. ML permits making proportion of advancement keeping Italian law for helping new firms | Investigate effect of creativity. Train seven ML algorithms to perceive firms on 2013 firm. Apply model on the 2008 dataset and foresee which firms would have been marked as creative |
| [16] | Invigorate achievement of R&D coordinated effort by SMEs, fostered a technique for suggesting kinds of associations that are ideal | Applied ML and discriminate for firms that will accomplish high fulfillment with R&D accomplices. Utilized information that had not been remembered. Model exhibits remarkable exactness 91% |

(continued)

**Table 1** (continued)

| References | Working domain | Work done |
|---|---|---|
| [17] | Recognize variables on Twitter for formation of new businesses, and new companies | Latent Dirichlet allocation (LDA) was utilized, and sentiment analysis was performed with SVM to partition start-up subjects |
| [18] | Business in ideal area; fulfillment level of clients and augments benefit. Propose an application that utilizes ML to appraise area | Gathers highlights for a business and learns. Proposes bunches of local areas. The subsequent stage groups regions as indicated by these assessed highlights by utilizing a progressive tree |
| [19] | Ventures show distinctive development in executing ML methods. Audit the condition of reception of ML in ventures | ML advancements are being taken on in ventures; SMEs are battling in contrast with bigger endeavors. The SMEs neglect to apply ML innovations because of lacking ML information |

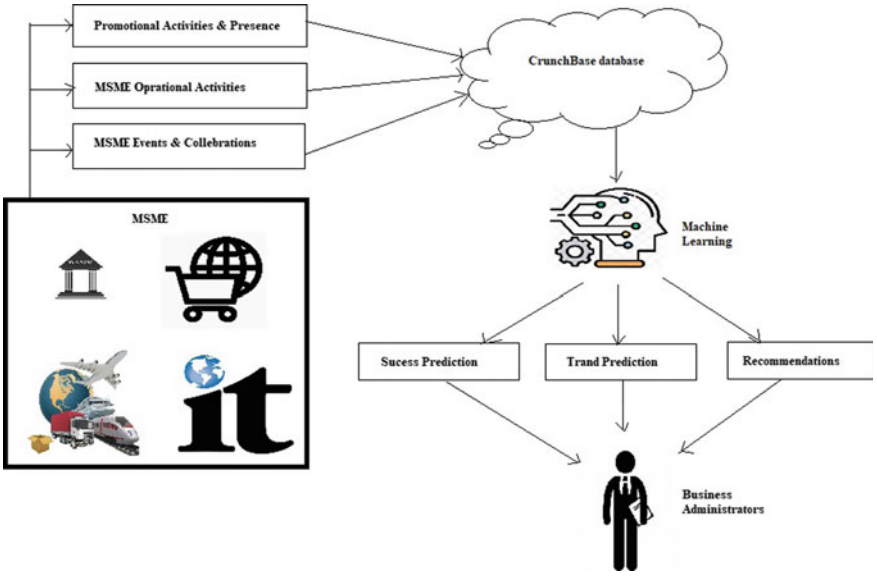


**Fig. 1** Proposed system architecture

utilization with the ML algorithms. In this context, the cleansing operations are utilized for refining data.

The data pre-processing also includes the normalization for scaling of the input data samples. Thus, we use the min-max normalization as

$$\text{norm value} = \frac{\text{value} - \min}{ax - \min} \tag{3}$$

In addition, we also filled the missing and null values by replacing them using 0. After that, we utilized the five popular machine learning algorithms for comparing them. Here, we utilized logistics regression, k-nearest neighbor (KNN), Naïve Bayes, and support vector machine (SVM). These algorithms are supervised learning algorithms, thus we have also utilized the unsupervised learning algorithm also. Therefore, we include the fuzzy c-means (FCM) and k-means clustering algorithm. All

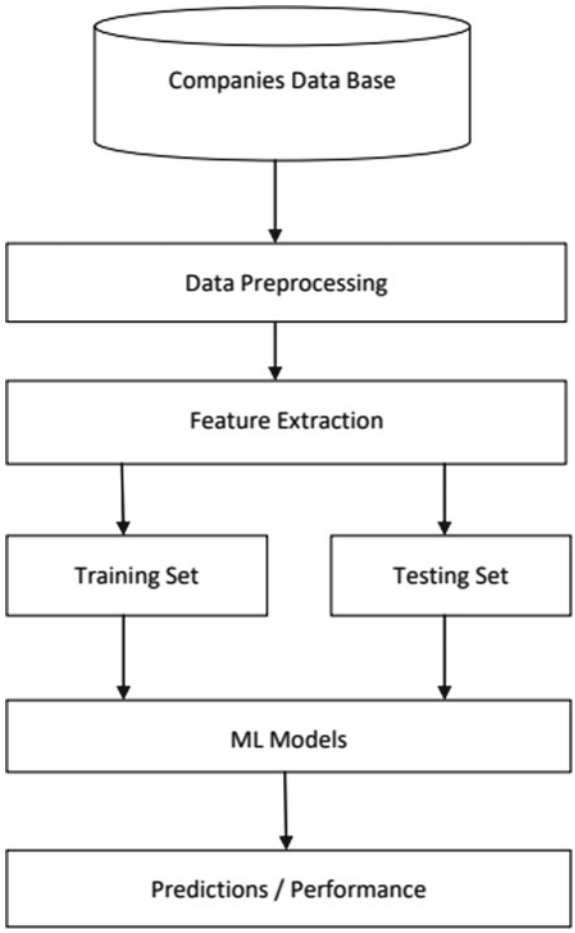


**Fig. 2** Proposed ML component for predicting the start-up success

these algorithms have been trained on the Crunchbase dataset on the training and testing split of 70–30. The performance of the implemented algorithm has been measured and reported in Table 2, and Fig. 3. Here, the performance of the models is provided in terms of precision, recall, and F-score. These parameters are measured for both the class's success and failure. In addition, the mean accuracy of the algorithms is also measured. Figure 3 demonstrates the graphical representation of the measured results. Figure 3a demonstrates the precision of the models for both the class labels. Similarly, Fig. 3b, c shows the performance in terms of recall and F-score. The blue bars show the classification performance for class 0, and the red line shows the performance of class 1. On the other hand, the accuracy of the model is described in Fig. 3d.

According to the obtained performance and demonstrated classification reports, we can say the model FCM, SVM, and logistic regression techniques are trying to learn only one sample and provide the classification results for only one class label.

On the other hand, KNN, k-means, and Naïve Bayes learn and work on either the training samples' success or failure. According to the final observation in terms of accuracy, we have found the maximum accuracy achieved by the system is 58%. That is produced by SVM, FCM, and logistic regression. That is very fewer as compared to expected or required accuracy. Therefore, we proposed to work with the other machine learning technique. Thus, we have implemented three different convolutional neural network (CNN) models for learning and classification tasks. These models are configured in the following manner:

1. **Model 1**: This CNN model consists of one input layer built with the ReLU activation function, and the next layer is a hidden layer, which is configured with ReLU activation function. Here, a total of five hidden layers are used. Finally, the output layer is given which is made with the softmax activation function.
2. **Model 2**: This model is configured with a min–max scalar and a similar configuration as described for model 1.
3. **Model 3**: This model is configured with one input, five hidden, and one output layer. The input and hidden layers are configured with the sigmoid activation function and the output layer with the softmax.

The performance of these three models is also measured and reported in next section.

**Table 2** Performance of different ML algorithms for Crunchbase dataset

| Logistic regression | | | KNN | | Naïve Bayes | | FCM | | K-means | | SVM | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| Precision | 0.58 | 0.00 | 0.74 | 0.43 | 0.74 | 0.43 | 0.58 | 0.00 | 0.59 | 0.50 | 0.58 | 0.00 |
| Recall | 1.00 | 0.00 | 0.10 | 0.95 | 0.10 | 0.95 | 1.00 | 0.00 | 0.99 | 0.01 | 1.00 | 0.00 |
| F1-score | 0.74 | 0.00 | 0.18 | 0.59 | 0.18 | 0.59 | 0.74 | 0.00 | 0.74 | 0.02 | 0.74 | 0.00 |
| Accuracy | 0.58 | | 0.45 | | 0.45 | | 0.58 | | 0.58 | | 0.58 | |

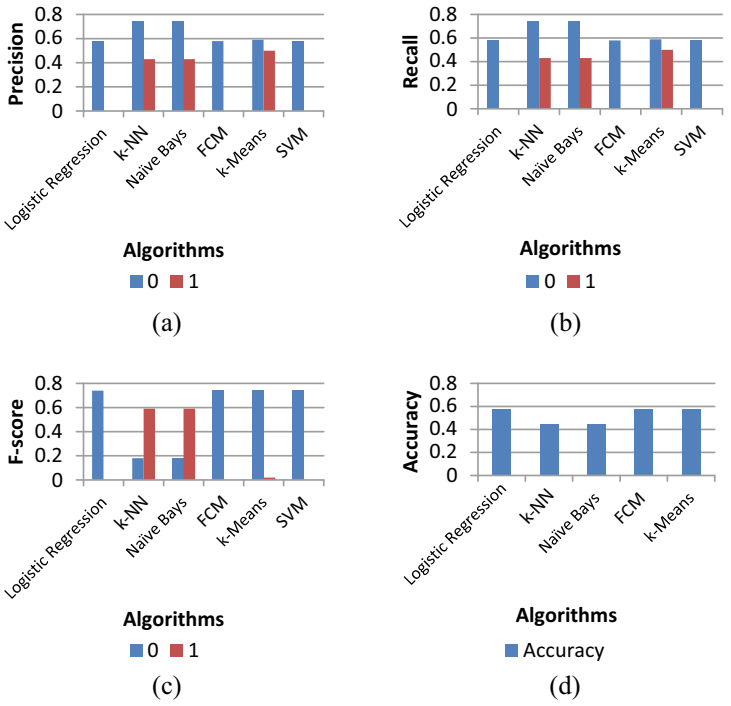


**Fig. 3** Shows the performance of the supervised and unsupervised learning algorithms in terms of **a** precision, **b** recall, **c** F-score, and **d** accuracy

## 4 Results Analysis

The performance of the implemented three CNN models which are prepared for predicting the start-up success or failure is evaluated in this section. The performance in terms of precision, recall, F-score, and accuracy is given in Table 3. Here, the precision, recall, and F-score are measured based on the class labels. Additionally, the accuracy is measured in combined form. According to the obtained results, as shown in Table 3, we found that model configuration 3 provides a higher accurate classification. Model 3 provides up to 0.74 accuracies.

In addition, performance based on the individual epoch is demonstrated in Fig. 4. Figure 4a shows the training accuracy of the entire three models, and Fig. 4b shows the validation accuracy of the model. Next, Fig. 4c shows the training loss, and Fig. 4d shows the validation loss of the model. The loss is a heuristic function, which provides the directions for enhancing the training of the network. According to the obtained performance, the accuracy of the training for model 1 is not much impressive and provides very poor learning also validation performance. On the other hand, the performance of model 2 and model 3 provides enhanced accuracy with an increasing amount of epoch cycles. Among them, model 3 enhances accuracy suddenly, but

**Table 3** Performance of CNN-based start-up success prediction models

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 0 | 1 | 0 | 1 |
| Precision | 0.0 | 0.41 | 0.69 | 0.68 | 0.72 | 0.78 |
| Recall | 0.0 | 0.98 | 0.84 | 0.47 | 0.90 | 0.52 |
| F1-score | 0.0 | 0.58 | 0.76 | 0.56 | 0.80 | 0.62 |
| Accuracy | 0.41 | | 0.69 | | 0.74 | |

model 2 provides a small number of changes. From the overall performance, we can say that model 3 provides higher accurate results and promising for enhancement by regulating different trainable parameters. Therefore using this experimental analysis, we can say the CNN-based architectures can provide better learning and classification performance.

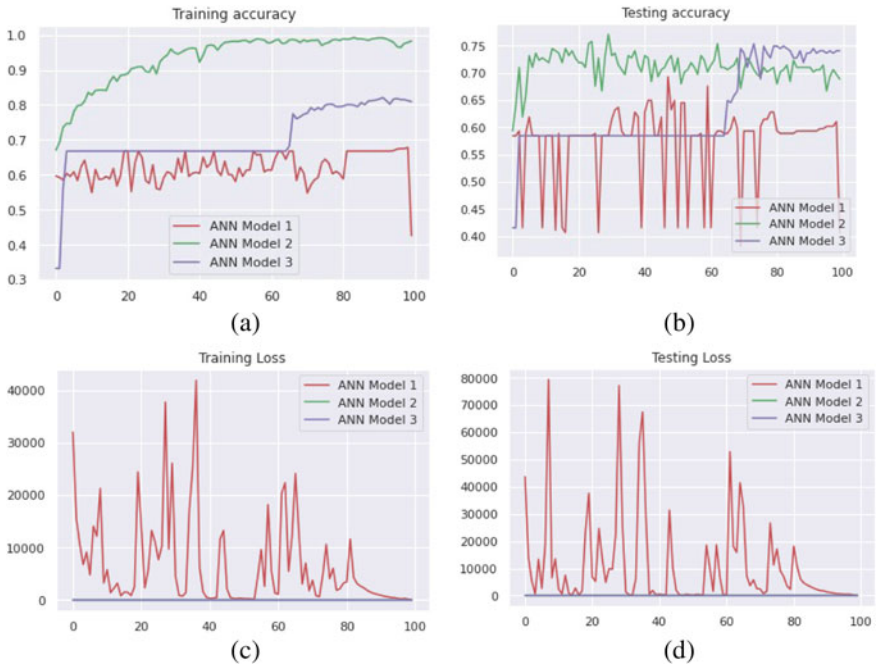


**Fig. 4** Shows performance of the implemented models based on epoch cycles in terms of **a** accuracy, **b** validation accuracy, **c** training loss, and **d** validation loss

## 5 Conclusion and Future Work

Machine learning techniques are being used in various business activities. That improves the working, process, and productivity. That also reduces human efforts and errors and improves the sustainability and growth of the business. However, business sustainability is a great challenge worldwide because of global business challenges such as COVID-19 and war fares. In addition, various other local and global events are influencing the conditions of business and increasing the risk of investment. In order to minimize the risk and understand the key influencing factors of a successful start-up, we can utilize the power of ML. Thus in this paper, we provide a review of the recent research work. That provides understanding and utilization of ML is start-ups success. Next, we proposed a start-up success prediction model. This model has utilizing four supervised learning and two unsupervised learning algorithms. Based on their performance evaluation, we have found that the maximum accuracy of the system is just 58%. Therefore, we make a trial with the CNN model and crafted three variants of CNN architecture for predicting start-up success.

For the performance obtained from this experimental study, we have used the Crunchbase dataset. Additionally, the performance for training and validation has been measured. The obtained performance of the designed models demonstrates promising consequences and we found 74% maximum classification accuracy. Thus in near future, we proposed designing an enhanced version of the start-up success prediction model by involving more techniques of ML and feature engineering.

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