Ind4.0
Master Degree in Industry 4.0
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# 1st International Conference on Business and Technological Advancement in Industrial Revolution 4.0 (ICoBTA-IR4.0)

"Industrial Revolution 4.0: Challenges for a Sustainable Future"

# ICoBTA-IR 4.0 e-Proceedings Book

3 - 4 October 2023
Riverside Majestic Hotel
Kuching, Sarawak
Malaysia

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*Industrial Revolution 4.0:*
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# PREFACE

The emergence of the Fourth Industrial Revolution in the past few decades has changed the technology, industries, and societal patterns and processes in the 21$^{st}$ century due to increasing interconnectivity and smart automation. Thus, the ERASMUS+ IND4.0 with 15 partners' consortium co-funded by the ERAMUS+ Key Action 2 Capacity Building in Higher Education aim is to provide practical solutions so as to help close the gap between industry needs/expectations and educational system outputs in relation to Industry 4.0 in the target countries. In this context, the consortium has transferred significant know-how from the European Educational System, which the partner country Institutions in Asia used to design an advanced, practical-based MSc Curriculum for Industry 4.0. This is to build the capacity of Higher Education Institutions in the partner countries, improve the level of competencies and skills offered, and address the absence of a similar programme.
A final conference, the 1$^{st}$ INTERNATIONAL CONFERENCE OF BUSINESS AND TECHNOLOGICAL ADVANCES IN INDUSTRY REVOLUTION 4.0, organised as part of the dissemination and exploitation work package, showcased all partners' contributions to its success. The theme was *Industrial Revolution 4.0: Challenges for a Sustainable Future*. The objectives were:

1. To disseminate the curriculum development of higher education in Industrial 4.0.
2. To interact and share information on the latest developments of Industry 4.0.
3. To deliberate recent innovations, trends, and concerns in theory and practice as well as practical challenges encountered, and solutions adopted in Smart Industries and the Fourth Industrial Revolution.
4. Discuss challenges imposed by cultural, legacy and socio-political factors for Industry 4.0.

The e-proceedings Book documented the 17 papers presented during the conference. The papers were all peer-reviewed. The Editorial Board would like to thank the authors of the papers, the organising committee, the scientific committee and the reviewers for their work with the conference and this book of proceedings.
This book of proceeding is only available as an e-publication and can be found at the following link: http://www.icobta.net/

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## Keynote Presentation

# INTRODUCTORY SPEECH

by

**Associate Professor Dr Margaret Chan Kit Yok**
Project Coordinator of ERASMUS+ InD4.0 on Capacity Building in Higher Education
Universiti Teknologi MARA, Sarawak Branch, Malaysia

As we are coming to the confluence of ICCMEH 2023 and ICoBTA 2023, one is coming to a close, and another is about to begin, it is indeed difficult to address this forum. The easy way out is to express my gratitude to all of you for being here to make both conferences happen.

It has been an arduous journey since we came together in 2019 as partners of the Consortiums of the ERASMUS+ Key Action 2: Capacity Building in Higher Education project on *A new Master Course in Applied Computational Fluid Dynamics* (APPLY) and *Master Degree in Industry 4.0* (InD4.0) co-funded by the ERASMUS Programme of the European Union. Time flies so fast, and we are almost at the end of our projects. Between the time we started and today, I have met great friends. I hope Kuching has met your expectations better than your imagination that we have impressed on you when we were at your countries. But this is not the forum to go down the memory lane. Both conferences are the final work task that we are meeting face-to-face throughout the 4 years project time frame – sharing best practices that we have developed not just among our member institutions but also participants from other institutions so that they can be brought into the mainstream of the output of the projects in one way or another.

Allow me a couple of minutes to express my sincere gratitude to

***The Right Honourable***
***Datuk Patinggi Dr Haji Abang Abdul Rahman Zohari bin Tun Datuk Abang Haji Openg***
***Premier of Sarawak***

for accepting our invitation to grace the occasion. As with any organising chair, it brings great significance as it is the show of his support of our work and acknowledgement of the contributions towards the aspiration of the Sarawak Government towards a digital and green economy by 2030.

Thus, a big thank you to

***The Honourable Dato Sri Professor Dr. Sim Kui Hian,***
***Deputy Premier Minister and Minister for Public Health, Housing and Local***
**Government**

for agreeing to be here with us. As UiTM's current ERASMUS+ project on the ASEAN Smart Cities Network, which started this 1 July 2023, we can connect with you.

I would also take this opportune time to express my profound thanks to Prof Dato Dr Haji Jamil, my advisor, my contemporary and my rock. His trust in me has enabled me to travel worldwide to bring UiTM globally, networking and building with academic peers. This is one of the evidence today with the presence of the international delegates.

There are many people from the international, national and local committees whom I owe tremendously to being given the honour to be on this podium and whom I cannot mention individually. You have helped put things together relentlessly and contributed towards the conferences. My apologies to all the participants for any shortcomings. It is not because of them, but it is due to my overlooking of tasks that need to be paid attention to.

To the distinguished keynote speakers, paper presenters, and panellists in the round table discussion and panel discussions, I would like to express my gratitude for all your contributions to these events to make both a success. This would not have been possible without the support of every one of you. Please rest assured that if you are here and have been chosen for the event or are volunteering to be here, there is a reason, i.e., due to your mutual passion. Your passion for a common goal helps us bring you all together and unite the energy in realising these goals – whether individually or in a group. We all need each other to fulfil our common goals, the imperatives of bridging divides, fostering collaboration and ensuring that education remains relevant, accessible, and forward-looking, and that is why it makes our resolution even stronger. These conferences should be a platform to continue to make that progress and network. We all need to keep listening and learning and, importantly, take action to meet education's changing needs and challenges in the capacity of the next generations.

To the media, I thank you for being here today because you play a very important role in the dissemination to the public of what we are doing, an obligation of the consortiums towards the ERASMUS+ Programme. To the hotel management, Thank you for providing us with a wonderful atmosphere.

To end it all, I sincerely appreciate your attention today.

# WELCOME ADDRESS

by

**Professor Dato Dr Hj Jamil Hj Hamali**
**Rector, Universiti Teknologi Mara Sarawak, Malaysia**

It is my great pleasure, with immersed pride and honour, to welcome you to this unique amalgamation of two conferences: the International Conference on Computational Methods in Engineering Health Sciences (ICCMEH) 2023 and the inaugural International Conference of Business and Technological Advances in Industry Revolution 4.0 (ICoBTA-IR4.0) 2023 in Kuching with Universiti Teknologi MARA as the host.

I wish to extend our sincere gratitude to

**The Right Honourable**
**Datuk Patinggi Dr Haji Abang Abdul Rahman Zohari bin Tun Datuk Abang Haji Openg**
**Premier of Sarawak**

for honouring us with his acceptance to officiate on these two occasions, the closing of ICCMEH 2023 and the opening of the ICobTA 2023. The right honourable premier is a man of vision, seizing new opportunities in every downturn caused by the COVID-19 pandemic. The formulation and implementation of the Sarawak Post-COVID-19 Development Strategy 2030 under his leadership are to ensure Sarawak emerging as a stronger region and embarking on a full-fledged transformation capitalising on the global megatrends. The Sarawak Government envisions that by 2030, Sarawak will be a thriving society driven by data and innovation, enjoying economic prosperity, social inclusivity, and a sustainable environment. The focus is on developing six economic sectors as drivers of growth for Sarawak, namely manufacturing, agriculture, tourism, forestry, mining, and social services, through a digital and green economy with renewable energy development. His initiative in transition towards the hydrogen economy has compelled the hydrogen modules and research programmes to be introduced at universities in Sarawak to equip future engineers to specialise in this industry.

With a very heavy schedule, he has deputised.

***The Honourable Dato Sri Professor* Dr. Sim *Kui Hian,***
Deputy Premier Minister and Minister for Public Health, Housing and Local Government.

I honour your presence despite your heavy schedule. We cannot thank you enough for gracing the events. Your support and engagement add immerse value and will make our forum a resounding success.

As mentioned earlier by ***Prof. Ir. Dr. Hj. Kamarul Arifin***, ICCMEH is a collaborative effort of the 3 higher institutions from India, Japan and Malaysia and 2 partner institutions from ERASMUS+ project APPLY in Malaysia. While we heard from ***Associate Prof Dr Margaret,*** ICobTA 2023 is an inaugural conference related to ERASMUS+ Project Industrial 4.0 in which UiTM is the project coordinator. I am proud to share with you all that UiTM Sarawak is a partner of 7 consortiums with ERASMUS+ Key Action 2 Capacity Building in the Field of Higher Education with various projects related to the digital economy since 2015. The transnational proposals were carefully made in line with the needs of all the Asian Partners' countries from the public authorities and industry perspective. The educational challenges lie in what makes them so interested in finding employees with the potential to manage broad solutions and complex ecosystems in the pursuit of the digital and green economy. UiTM Sarawak has completed two projects in Blended Learning led by Aix Marseille University, France and Food Processing and Innovation led by Universiti Teknologi Malaysia. Today, we are coming to the end of another two projects, APPLY, led by Chiang Mai University and Industrial Revolution 4.0, led by UiTM. Three more are still ongoing: Family Business Management (FAB) led by the National University of Management, Cambodia, Portable Video Conferencing Toolkits led by Danmarks Tekniseke Universitet, Denmarks and this year, we are starting with Smart City ASEAN Learning Network led by Universiti Malaya. Indeed, we have benefited tremendously in offering new Master Programmes and Professional Courses developed with the transnational effort with continuous collaboration in students and Academic staff mobility programmes and research activities.

I have spoken a lot, but before I leave this podium, I must acknowledge the support of the Sarawak Government and the ERASMUS+ Programme of the European Union, which is co-funding the projects and conferences. In addition, I would like to extend my deepest gratitude to the entire organising committee working tirelessly behind the scenes. To all of the participants, thank you for being here today. I am looking forward to the keynote address of the ***RIGHT Honourable Datuk Patinggi Dr Haji Abang Abdul Rahman Zohari Bin Tun Datuk Abang Haji Openg,*** *Premier of Sarawak* and also ***The Honourable Dato Sri Professor*** **Dr. Sim** ***Kui Hian*****,** Deputy Premier Minister.

# KEYNOTE SPEECH

by
**The Right Honourable**
**Datuk Patinggi Dr Haji Abang Abdul Rahman Zohari bin Tun Datuk Abang Haji Openg**
**Premier of Sarawak**

delivered by
**The Honourable Dato Sri Professor *Dr. Sim* Kui Hian**
***Deputy Premier* Minister**
**Minister for Public Health, Housing and Local Government**
**Sarawak**

As the Premier of Sarawak, it is both an honour and a privilege to address such a distinguished gathering of academia, researchers, industry players, policymakers and students at the confluence of two conferences co-funded by the ERASMUS+ Programme of the European Union: the official closing event of the International Conference on Computational Methods in Engineering Health Sciences 2023 and the official opening of 1st International Conference of Business and Technological Advances in Industry Revolution 4.0. The unique amalgamation of these two events, as informed by the organisers, is because UiTM is a partner of the 2 consortiums of the ERASMUS+ programme for the projects: Applied Computational Fluid Dynamics (APPLY) and Industrial Revolution 4.0 (InD4.0). I, therefore, extend a heartfelt welcome to all participants from across the globe.

With the advent of the Internet of Things (IoT), greater automation and artificial intelligence, connectivity between machines is the focus of Industry 4.0. Incorporating Computational Fluid Dynamics (CFD), an integral component of Industry 4.0 technologies, plays a pivotal role in the digital economy, significantly bolstering engineers' capacity through simulation to attain precise results in a wide array of engineering studies and design optimisations. They empower engineers to fine-tune resource allocation, minimise waste, and foster sustainability. This technology facilitates the optimisation of designs to enhance product or system performance and aids in identifying areas necessitating adjustments prior to operation and manufacturing. By synergising CFD and Industry 4.0 technologies, the industry can craft innovative solutions that set them apart, enabling them to differentiate themselves from competitors by elevating their operational efficiency, flexibility, responsiveness, and cost-effectiveness. This resonates with the Sarawak government's agenda to develop new technologies and solutions to transform into a digital and green economy for common regional prosperity. I note that the Master of Science Programmes developed under the ERASMUS+ programs concentrating on Industrial Revolution 4.0 and Master of Science on Applied Computational Fluid Dynamics (CFD) are already being offered as pilots in the Asian Higher Institution partners.

I also understand that you are here today with the two (2) final conferences as a wrap-up to your projects to share the successful execution experiences and discuss issues and ideas relating to the Fourth Industrial Revolution and its technologies synergising with CFD. I extend my sincere gratitude for choosing Kuching as the conference's destination. Kuching needs no introduction for its Malaysian hospitality and the unique diversity of the culture of the Sarawak people with the pristine flora and fauna.

I want to highlight where you are in the technological term. Kuching is the capital city of Sarawak, a region within Malaysia celebrating its 60th Independence with significant milestones towards achieving a sustainable digital and green economy in 2030. Embarking on the exciting journey of growth and transformation infused with a dynamic growth mindset embracing learning and evolution, this is the forum that can bring inspiration in seeking green solutions with a responsive education system focused on the preparation of more productive, effective, and highly skilled human resource that contribute to the productivity and development of the economy in a sustainable way.

Sarawak's big leap into the digital and green economy with the Post Covid-19 Development Strategy 2030 heralding for Kuching with Smart City Status by 2025 will benefit from the two ERASMUS projects as the objectives had been formulated to provide practical solutions to help close the gap between industry needs/ expectations and educational system outputs. The Mid Term Review of the 12th Malaysia Plan released by the Ministry of Economy on 11 September 2023 calls for the establishment of a new science technology, engineering, and mathematics (STEM) curriculum to be introduced to students to embrace the Fourth Industrial Revolution (IR4.0) aligning with the national aspiration and niche areas, IR5.0 is already advancing. That is a big education challenge.

The Sarawak government, too, aspires to seek the transformation of education to ensure a future-ready generation. Leveraging technology, we welcome pioneering initiatives to democratise education, ensuring accessibility and quality. Indeed, the overarching themes of ICCMEH and ICoBTA-IR4.0 resonate with Sarawak's endeavours, emphasising the symbiotic relationship between education and technology. We envisage a state where the confluence of education and technology acts as a catalyst for socio-economic transformation, ensuring a brighter future for our upcoming generations. Sarawak Government's commitment to these objectives is unwavering, and your conferences will serve as a legacy of our collective resolve.

I applaud UiTM Sarawak for accepting to be the host. I wish to convey my deepest gratitude to all contributors, organisers, and participants. Your dedication and passion are the lifeblood of such events, ensuring their success and impact. The Sarawak Government stands with you, not just as a supporter but as a collaborator, in our shared journey towards educational excellence. Together, we envision a brighter future and actively sculpt it.

I congratulate the successful inauguration of the International Conference on Computational Methods in Engineering Health Sciences (ICCMEH) 2023 and, therefore, officially close the conference. I am also honoured to officially open the 1st International Conference of Business and Technological Advances in Industry Revolution 4.0 (ICoBTA-IR4.0) 2023. Here's to a successful, enlightening, and productive ICoBTA-IR4.0 2023!

To the international delegates, visit Beautiful Sarawak after your hard work. Firm a lasting friendship with any local delegates to enjoy our Sarawak's hospitality.

Thank you.

# Development of Islamic Finance in Industry 4.0 Era: Challenges, Criticism and Opportunities

**Maizaitulaidawati Md Husin [1], Nor Aiza Mohd Zamil [2] and Haliyana Khalid [3]**

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## EXTENDED ABSTRACT

*Industry 4.0 represents a transformative paradigm shift in the world of manufacturing and production. Coined as the Fourth Industrial Revolution, Industry 4.0 integrates cutting-edge technologies to create a connected, intelligent, and highly automated industrial ecosystem. This revolution is marked by the fusion of digital technologies, data analytics, the Internet of Things (IoT), artificial intelligence (AI), and advanced robotics to optimise processes, enhance productivity, and redefine how products are designed, manufactured, and delivered. At its core, Industry 4.0 seeks to establish a seamless interplay between physical systems and digital technologies, enabling a level of automation and intelligence that was once deemed futuristic. The concept represents a departure from traditional manufacturing approaches, emphasising the importance of interconnected systems, real-time data exchange, and decentralised decision-making. By integrating smart sensors and devices, machinery can self-monitor, self-optimise, and communicate with other components within the production chain. Key elements of Industry 4.0 include using big data analytics to derive actionable insights, implementing cyber-physical systems that bridge the gap between the physical and digital realms, and deploying advanced technologies like machine learning and augmented reality to enhance operational efficiency. This transformation impacts manufacturing processes and extends its influence across the entire value chain, from supply chain management and logistics to customer engagement and product lifecycle management.*

*The convergence of Industry 4.0 and Islamic finance marks a transformative intersection where advanced technologies harmonise with Islamic economics and finance principles. Simultaneously, Islamic finance adheres to principles rooted in ethical and Sharia-compliant practices, emphasising risk-sharing, social justice, and economic well-being. In the context of Industry 4.0, the principles of Islamic finance provide a unique lens through which to assess the ethical implications of advanced technologies. The interconnectedness of cyber-physical systems and the intelligent automation characteristic of Industry 4.0 align with the Islamic principles of efficiency, transparency, and equitable wealth distribution. As manufacturing processes become increasingly digitised and automated, the synergy between technological advancements and Islamic finance principles offers a pathway for sustainable and socially responsible economic development.*

*Islamic finance, with its prohibiting usury (riba) and emphasis on fair and ethical transactions, encourages a financial landscape prioritising social welfare and economic justice. This alignment with ethical considerations is particularly relevant in the context of Industry 4.0, where the potential for disruptive technologies raises questions about their impact on employment, social equity, and the ethical use of data. Moreover, Industry 4.0 technologies can be harnessed to enhance the efficiency and transparency of Islamic finance operations. Blockchain, for example, can be employed to ensure the integrity of financial transactions. At the same time, AI and data analytics can streamline risk management processes and decision-making by Sharia principles. The intersection of Industry 4.0 and Islamic finance holds promise for fostering sustainable and inclusive economic growth. By leveraging the ethical foundations of Islamic finance, Industry 4.0*

*can be steered towards addressing societal challenges, reducing economic disparities, and promoting responsible innovation. This synthesis offers a unique opportunity for industries to embrace technological advancements while upholding principles that prioritise ethical, sustainable, and socially responsible business practices.*

*As Industry 4.0 gains momentum globally, industries are experiencing a paradigm shift in their approach to production, resource allocation, and business models. The potential benefits are vast, promising increased flexibility, customization, and responsiveness to market demands. However, with this revolution comes the need to carefully consider cybersecurity, data privacy, and workforce readiness to navigate the challenges posed by this unprecedented convergence of technology and industry. In essence, Industry 4.0 marks a pivotal moment in the evolution of manufacturing, propelling businesses into a new era of innovation, efficiency, and competitiveness. The objective of this paper is twofold. First, this paper examines the development of Islamic finance within the context of the Industry 4.0 era. Second, the challenges, criticism and opportunities of applying Industry 4.0 in Islamic finance are presented. This paper examined the challenges, criticisms and opportunities towards the Islamic finance industry through interviews with a sample of nine (9) chief technology/information officers of Islamic banks in Malaysia. The sample was drawn from the number of registered Islamic banks listed by the Bank Negara Malaysia. According to the Bank Negara Malaysia (2023), 17 registered Islamic banks were operating in Malaysia. Some banks were randomly contacted through email to secure permission to conduct interviews. Only 9 Islamic banks agreed to participate in the interview. Prior to the interview session, respondents were informed that their participation was anonymous and voluntary. Further, they were informed that their responses would only be used for this research. Once the respondents gave their consent, a series of questions were asked. A minimum of 55 minutes and 90 minutes were spent to complete the interview sessions. Interviews were conducted from January until July 2023.*

*This paper found that utilising advanced technologies has opened up new opportunities for the growth and expansion of Islamic finance. Digitisation and automation have enhanced the efficiency, transparency, and accessibility of Islamic financial services, facilitating smoother transactions and reducing operational costs. Smart contracts and blockchain technology have provided a secure and immutable platform for Islamic finance transactions, addressing trust and verification issues. Furthermore, Industry 4.0 technologies have enabled the development of innovative Islamic financial products and services. Fintech startups and established institutions leverage data analytics and artificial intelligence algorithms to create customised solutions for Islamic finance customers' unique needs. Robo-advisory platforms have emerged, offering automated, Shariah-compliant investment advice based on individual risk profiles.*

*This paper also found that criticism of Industry 4.0 in the Islamic finance industry primarily revolves around concerns regarding the compatibility of advanced technologies and the principles of Shariah law. Further, challenges remain in harmonising the principles of Islamic finance with the rapidly evolving technological landscape. Ensuring compliance with Shariah law, particularly in developing complex financial instruments, requires ongoing collaboration between Islamic scholars and technologists. Cybersecurity and data privacy concerns must be addressed to build trust in digital Islamic finance.*

*Overall, the development of Islamic finance in the Industry 4.0 era presents both opportunities and challenges. Despite the criticism, as technology continues to evolve, the industry must adapt and innovate to leverage the full potential of Industry 4.0 while upholding the core principles of Islamic finance. The successful integration of technology and Islamic finance has the potential to transform the industry, expand its reach, and create inclusive financial systems aligned with Islamic values.*

# Enhancing Employee Experience in Expenditure Enquiry Management of Global Service Centre Through Chatbot Implementation in Multinational Company

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**ABSTRACT**

*Enquiry management is one of the major processes in global service centre management. It addresses global employees' questions and provides support to remove obstacles in performing their day-to-day jobs and operations. The enquiry management process and tools have evolved from a manual process to a digitised process using supporting tools. It is also has evolved from guided service to self-service enquiry channels. Today, employees adopted to search for the answers themselves with tools such as knowledge-based enquiry (Frequently Asked Questions, How-to Questions, etc) and chatbot enquiry. A chatbot is a software application that aims to mimic human conversation through text or voice interactions, typically placed on an online platform. In Company X, the Travel and Expenses (T&E) department has adopted knowledge-based enquiry management as a self-service enquiry channel to resolve general & simple enquiries, with a service desk support system as a guided-service enquiry channel for complex enquiries. There are identified gaps with the current setup, as end users still go for guided-service enquiry channels when they have simple enquiries that could have been resolved self-service. Corporate faces issues transforming the enquiry management from guided service to self-service resolution. When adopting the self-service resolution, it is pertinent to ensure process efficiency, including headcount reduction, improved enquiry resolution time, and better employee satisfaction in resolving their enquiries. Implementing a chatbot could help to improve the adoption of self-service resolution further. However, corporations must execute properly to ensure successful chatbot implementation to achieve the objectives. This action research focuses on how chatbot implementation can improve the enquiry management process efficiency, which is expected to reduce the percentage of query tickets raised by end users through the guided-service support channels that self-service support channels could have addressed. The study uses mixed-method research methodology (qualitative and quantitative), collecting data in terms of the percentage of query tickets raised by end users through the guided-service support channels that could have been addressed by self-service support channels before and after the chatbot implementation, chatbot usage data after the chatbot implementation, and assess the user experience improvement in interviews.*

**Keywords:** *Chatbot; enquiry management; process improvement; self-service resolution adoption*

## INTRODUCTION

### Research Introduction

Travel and expenses (T&E) are an integral aspect of corporate work within any organisation. However, managing T&E can often be complex and time-consuming for employees, requiring meticulous scrutiny of expenses, comprehensive documentation, and adherence to the company's expenditure policies. Employees need to clearly understand which expenditures are reimbursable, as these details are crucial components of the company's quarterly and annual financial reports. The process of filing expense claims has evolved significantly, transitioning from manual submissions to nearly automated procedures, wherein employees are now required to provide supporting evidence, such as photographs or scanned documents when submitting their expense reports.

Regardless of the specific system implemented within a corporation to oversee T&E, employees must have easy access to information on how to submit claims and what expenses are eligible for reimbursement. Navigating through extensive lists of knowledge articles related to T&E can be a source of frustration for some employees, particularly if they are unsure about the relevance of the articles or if they cannot locate answers to their T&E-related inquiries. In such cases, employees typically turn to the T&E team for assistance through available communication channels, seeking further guidance and clarification.

Introducing a conversational chatbot represents a significant advancement in addressing these challenges. This chatbot is designed to provide end users instant access to relevant articles tailored to their queries, delivering much faster responses than traditional human support through service tickets. If the top three suggestions provided by the chatbot do not align with the employee's question, the bot will prompt the employee to rephrase their inquiry, ensuring more accurate results. The chatbot aims to replicate human interaction, enabling employees to obtain support for their T&E-related questions as if they were conversing with the T&E department.

**Case Company & Problem Diagnosis**

The case company, known as "Company X" to maintain anonymity, is a global multinational enterprise with a substantial workforce. Company X operates on a model built around business service centres, encompassing various departments providing essential services to other organisational divisions. Within this structure, the Travel and Expenses (T&E) department serves a pivotal role. Company X has already integrated service desk support and ticketing tools as the primary means for end users to raise inquiries and seek assistance. Furthermore, it has implemented a Knowledge Management (KM) system and Knowledge Articles (KA), offering a knowledge-based search portal accessible to all employees across the company. These resources have been instrumental in streamlining information retrieval and problem-solving.

In the current process, end users initiate their information search by accessing the central repository within the company's knowledge search portal. They input their T&E-related keywords or questions into the search bar, which triggers the company's knowledge search system to provide a list of the top 30 search results from the repository. These results include Knowledge Article (KA) and catalogue item titles and descriptions. Users can navigate additional pages to view the next top 30 results. By default, all results are displayed without any filters applied. To enhance the user experience, the search results can be filtered based on three categories: displaying all results, showing only knowledge articles, or showcasing only service request catalogue items. The search engine utilises the user's input keywords and location as inputs, processing this information to identify articles that match the title, description, body, and metadata established during KA creation. The search engine employs semantic search techniques powered by natural language processing to identify matching keywords and arrange the search results in order of relevance. The accuracy of these results hinges on both the technical configuration of the search engine, which must interpret the user's search intent and the quality of the content within the KAs provided to the search engine for processing.

However, the limitation of the current system is that it only accepts input from the search bar and processes keywords solely from this employee input, yielding the top 30 search results. The relevance of these results can vary significantly based on the keywords entered. If the search results align with the user's request, they proceed to the respective KA to address their query. If not, users may either rephrase their search keywords, continue scrolling through results until they locate the appropriate articles, or directly contact the support team through catalogue requests. This process poses certain challenges. It inundates end users with a potentially overwhelming amount of information, risking information overload. It also relies on users' natural responses and reaction times to search results, which can vary significantly among users with different demographics and behaviours. In an era where rapid and precise information retrieval is critical to a positive user experience, the current process falls short, potentially discouraging users from conducting fact-finding missions and resorting to support ticket submissions instead. This shift away from self-service can have negative implications, as it may result from tools perceived as overly complex or unhelpful. Ultimately, it could lead users to abandon self-service channels altogether, hindering the adoption of these channels within the organisation.

### Research Questions and Objectives

This research is structured to study on the below research questions (RQ):

- RQ1: What is the current adoption rate of end users in the knowledge search portal versus the T&E service desk in Company X?
- RQ2: What can chatbot improve in end-user experience?
- RQ3: Can knowledge-based chatbot tools improve the adaptation of self-service experience in managing T&E queries?
- RQ4: What impact does chatbot have on improving end-user experience in T&E queries?

This research is conducted to achieve below research objectives (RO):

- RO1: To assess the current adoption rate of end users in the self-service and guided service channels.
- RO2: To assess the opportunity to improve end-user experience through the chatbot.
- RO3: To assess the new adoption rate of end users in the self-service channel vs the guided service channel after chatbot implementation.
- RO4: To assess the impact of chatbots in improving end-user experience in self-service channels.

**Table 1**
*Summary of Research Questions, Research Instruments and Source of Data*

| RQ | Research Method | Research Instrument | Source of Data |
|---|---|---|---|
| RQ1 | Quantitative | • Secondary Data Analysis | Primary Data<br>• Focus Group Discussion: T&E Enquiry Management Challenges & How Chatbot can Improve End User Experience in Enquiry Management<br>• Interview Session: Chatbot experience, usability & continuous improvement<br><br>Secondary Data<br>• Percentage of queries ticket raised by end users through the guided-service support channels that could have been addressed by self-service support channels. |
| RQ2 | Qualitative | • Focus Group Discussion | |
| RQ3 | Quantitative | • Secondary Data Analysis | |
| RQ4 | Qualitative | • Interview | |

## Literature Review

Chatbots have garnered significant attention as a potential game-changer in how people interact with data and online services (Brandtzaeg & Folstad, 2017). These AI-driven entities act as digital agents, serving as intuitive interfaces between users and data/service providers (Dale, 2016). Previous studies have indicated that end users highly value the swift responses offered by chatbots, particularly when compared to waiting for a human service desk response, especially during off-hours (Folstad & Skjuve, 2019). The primary motivation for users to engage with chatbots for customer service lies in their ability to effectively address simple queries, contributing to an overall positive user experience. Even occasional inaccuracies or inadequate responses from chatbots may not be detrimental to the user experience, provided an exit path to connect with human representatives is available.

Users are primarily attracted to chatbots for their ability to provide easily understandable answers and assistance in locating online self-service resources. This aligns with other studies on chatbot user experience (Telner, 2021), emphasising the importance of factors such as response time, ease of navigation, visual appeal, vocabulary, guided conversation, content quality, knowledge base, and error handling in determining overall satisfaction. To optimise user experience, it's essential to ensure that chatbot responses are specific, relevant, accurate, well-structured, concise, and employ understandable language and terminology. In a systematic review of service chatbots (Mohamad Suhaili et al., 2021), two critical components emerge as vital for chatbot success: Natural Language Processing (NLP) and Natural Language Generation (NLG). NLP facilitates the comprehension of end-user feedback, while NLG is responsible for generating appropriate responses in human-understandable language. Additionally, research on designing high-quality chatbots (Johari & Nohuddin, 2021) highlights six pre-development features, including functionality, efficiency, humanity, effectiveness, technical satisfaction, and ethics, as essential considerations.

Moreover, a study on productive chatbot design (Jassen et al., 2022) outlines a process covering preliminary considerations, use case determination, defining chatbot characteristics, constructing dialogue trees, content development and training, prototype development, acceptance testing, measuring added value, and post-implementation. These guiding principles may not apply universally to every chatbot project, but they offer valuable insights for ensuring successful implementation that caters to end users. Furthermore, understanding end-user attitudes toward chatbots is crucial. Research on chatbot taxonomy (Gkinko & Elbanna, 2022) categorises users into four types: Early quitters, Progressives, Pragmatics, and Persistents. These categories reflect varying acceptance and engagement with chatbots, from outright rejection to active cooperation.

In a prior study (Brandtzaeg & Folstad, 2017), five distinct categories emerged for why people engage with chatbots. The first category pertains to productivity, where chatbots are used for convenience, speed, and assistance in accessing information. The second category centres on entertainment, where chatting with a chatbot is fun and engaging. The third category involves social and relational purposes, with chatbots serving to alleviate loneliness or provide a sense of social interaction. The fourth category relates to the novelty of chatbots, where users are curious to explore their capabilities. Finally, the fifth category encompasses other motivations, including using chatbots to discuss sensitive topics, as they provide automatic responses when human help is unavailable or as a default method for customer support.

Engaging with a chatbot often feels like interacting with a virtual agent that mimics human responses. A study by Ruane et al. (2021) explored the ideal balance of personality traits to be injected into chatbots for user acceptance. The study applied the Five Factor Model (FFM), which includes openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism. The research delved into extraversion vs. introversion and agreeableness vs. disagreeableness language cues. Findings revealed that users perceived different personalities in different chatbots. Moreover, the perceived personality of a text-based chatbot significantly influenced user experience, with most users favouring a formal and professional tone for its directness and user-friendliness.

End-user interactions with chatbots can also impact their overall experience. Nguyen et al. (2022) investigated how different chatbot interfaces (e.g., menu-based vs. text-based) affect autonomy, cognitive effort, and user satisfaction during task completion. Results supported previous findings regarding the impact of interface types on perceived autonomy, cognitive effort, perceived competence, satisfaction in performance, and satisfaction in the system. Incorporating AI-based chatbot capabilities, such as Natural Language Processing (NLP), enhanced the user experience by providing autonomy and efficient task completion.

Another study by Haugeland et al. (2022) explored how conversation types and interaction mechanisms in chatbots for customer service affect human likeness and user experience. Four chatbot types were examined: task-led with button interaction, task-led with free-text interaction, topic-led with button interaction, and topic-led with free-text interaction. The study found that topic-led conversations strengthened the perception of anthropomorphism and hedonic quality in chatbots. Users also preferred human-like conversations for exploring specific topics, and clever use of button interactions improved the overall chatbot experience.

Several chatbot implementations have been analysed in previous studies to assess their impact on end-user experience. Kushwaha et al. (2021) investigated AI-driven chatbots in B2B enterprises and their impact on customer experience (CX). Their findings highlighted various factors influencing CX, including perceived risk, brand trustworthiness, sensory appeal, flow factors, touchpoint-specific factors, predictability, innovation, privacy, safety, transparency, and trust (PSTT). Another study by Ngai et al. (2021) focused on knowledge-based chatbots for customer service, emphasising the importance of system design and components in providing proactive and continuous system improvement. Challenges in technological and management aspects were also identified, emphasising the need for proper planning and support.

Nguyen (2019) explored knowledge-based chatbots for customer support, highlighting the close relationship between chatbots and knowledge bases. The study showed that unresolved queries could be rerouted to human agents without negatively affecting the end-user experience. Additionally, Kvale et al. (2021) conducted a customer satisfaction survey to assess user experiences with chatbots. Their research demonstrated the significant impact of problem resolution on user satisfaction, as well as the influence of the type of problem users sought help with on satisfaction levels. Zhang et al. (2021) emphasised the importance of organisational factors in the successful technology implementation of chatbots. They identified five critical factors: work and team organisation, change management, competencies and competency acquisition, organisational resources, and performance measurement. Proper team composition, effective change management, competency in AI trainers, resource availability, and performance measurement were essential for successful chatbot implementation.

Research findings have revealed various factors contributing to successful chatbot implementation and user experience. These factors include user motivations, chatbot personality traits, user interfaces, functionality, knowledge bases, problem resolution, and organisational considerations. Understanding these factors is essential for organisations that leverage chatbots effectively and enhance user satisfaction. The factors of speed, convenience, and user-friendly features are important in shaping end-user satisfaction with chatbots. Effective chatbot functionality, including response mechanisms and human-like interactions, plays a pivotal role for end users to start using and continue using a chatbot. Additionally, understanding user attitudes helps predict how different individuals will engage with chatbots as a self-service channel.

## METHODOLOGY

### Research Philosophy and Design

This action research adopts a pragmatic philosophical approach, which is rooted in practicality and seeks to determine the value, truth, and meaning in real-life situations (Legg et al., 2021). Pragmatism stands in contrast to idealism, where idealism is centred around a set of abstract ideas or high principles (Guyer et al., 2022). Pragmatism, in this context, is chosen because it aligns with the examination of real-world situations, values, truths, and meanings, which are central to this research, rather than following an idealistic theoretical path. For this study, the researcher will employ a cross-sectional case study design incorporating a mixed-methods data-gathering technique. This approach combines both primary and secondary data, as well as quantitative and qualitative data, to gather a comprehensive dataset that can validate the problem statement and assess the effectiveness of the proposed intervention strategy in addressing the identified problem. By adopting this pragmatic approach and utilising mixed-methods data collection techniques, this research aims to provide practical insights and solutions to enhance the T&E inquiry management process and improve end-user experience within the company.

## Research Instruments and Measures

The research uses secondary as quantitative data collection. The objective is to identify quantitative data concerning the current percentage of queries raised by end users through guided-service support channels that could have been effectively addressed through self-service support channels. This investigation will shed light on user behaviour trends, particularly in cases where support tickets have been raised despite the availability of knowledge articles (KAs) that end users could utilise for self-service. By analysing this quantitative data, the researcher aims to identify the impact of a knowledge-based chatbot on the new adoption rate of end users in self-service channels vs guided service channels before and after chatbot implementation.

The research uses focus group discussions (FGDs) as a vital component of qualitative data collection. The FGDs serve the purpose of understanding the challenges related to T&E inquiry management within the company and how this study can address these challenges by enhancing end-user experience and usability through a knowledge-based chatbot. The FGDs will be structured into three sections: Section A covers the background of FGD participants, Section B delves into T&E Enquiry Management Challenges, and Section C focuses on Knowledge-Based Chatbot Implementation Strategies. The following topics will guide the discussions during the FGD sessions:

**Table 2**
*Focus Group Discussion Input in Formulating of Chatbot Functionality*

| Focus Group Topics | Baseline of Discussion |
|---|---|
| Functionality<br>Interpret command accurately.<br>Flexible in interpreting knowledge.<br>Number of service available in the chatbot.<br>Sustainability.<br>Accuracy.<br>Interoperability.<br>Compliance.<br>Security. | To ensure our chatbot could achieve most favoured functionality to gain end user satisfaction by integrating with the existing backend setup. This is to make sure our current business and IT support structure to maintain the sustainability of chatbot in terms of maintainability and continuous improvement. This is also to ensure this study follow the security and compliance setup in Company X. |
| Efficiency<br>Ease of use.<br>Quick replies to vs free text.<br>Available always.<br>Accessibility.<br>Time behaviour.<br>Resource.<br>Utilisation.<br>Strong to manipulate data input by users. | To ensure our chatbot can perform much more compared to existing channels. As Company X operates as business service centres with cross time zone support, this will further support the model to have 24/7 accessibility and support. |

| | |
|---|---|
| Humanity<br>Realness of robot.<br>Create an enjoyable interaction.<br>Convey personalities.<br>Able to maintain the theme of the discussion.<br>Able to respond to specific inquiries.<br>Able to mimic human personality.<br>Able to provide correct response to user's request. | To ensure our chatbot can make it feel seamless to the end user in getting support, as in talking to almost real humans with natural language processing, just like how humans will process in giving feedback to end user questions. |
| Effectiveness<br>Construe statements and commands correctly.<br>Linguistic precision.<br>Accurate task execution.<br>Consist of vast area of knowledge.<br>Ability to solve simple task request. | To ensure our chatbot is smart enough to cater end user queries, from simple to complex combinations of queries. With global support, to also be mindful on how to manage end user language choices in asking questions, as well as searching results in the language spoken by end users. |
| Technical satisfaction<br>Ability to express feeling.<br>Provide entertainment and enjoyment to user.<br>Conveying emotional information through tones and expression. | To ensure our chatbot is engaging in providing response, able to understand end user situations and give appropriate feedback to manage end user emotion, just like how service desk humans could be empathetic in responding to questions. |
| Ethics<br>User's privacy protection.<br>Consistency.<br>Training the bot with knowledge and cultural ethics. | To ensure our chatbot follows the ethical, risk and compliance guidelines of the company, in what kind of information that could and could not be provided depending on the level of sensitivity of the information. |

*Reference: Johari and Nohuddin (2021)*

Additionally, interviews will be conducted as part of the qualitative data collection process. The interviews aim to analyse the end-user experience using the chatbot implemented for T&E inquiry management. The interview sessions will consist of Section A, which covers the background of interviewee participants, and Section B, which delves into T&E End User Experience in Using Chatbot. The following interview questions and objectives were formulated from the literature review study:

- To assess end-user usability of chatbot.
- To assess end-user information processing in getting answers to their queries.
- To assess the chatbot's capabilities in resolving end-user queries.
- To assess the chatbot interaction in resolving end-user queries.
- To assess the end user's willingness to switch to the new channel.
- To assess the end user resistance to switching to the new channel compared to an existing channel.
- To assess the end-user adaptability in switching to new technology.
- To assess the chatbot's end-to-end support in solving end-user queries.
- To assess the end user's confidence in the new technology.

## Proposed Intervention

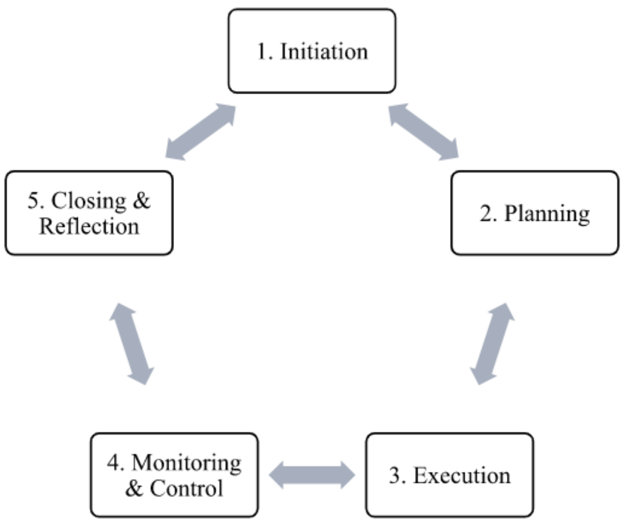
With the analysis of the current setup, it becomes evident that end users are encountering challenges in efficiently accessing the most pertinent knowledge articles for their common "How To" queries, especially those relevant to their specific work locations. The existing setup presents the top 30 search results, inundating end users with excessive information. Consequently, some end users resort to raising support tickets for "How-to" assistance even when the necessary knowledge articles are available, resulting in unnecessary delays as they await support team responses, whereas self-service could have resolved their issues.

Furthermore, a portion of users has become habituated to guided-service support, preferring to pose questions to a human agent rather than proactively searching for answers themselves. Additionally, there's a lack of clarity among end users regarding the ticket-raising process and the correct procedures for soliciting further assistance. These challenges collectively underscore the need for intervention. Implementing a knowledge-based chatbot is envisioned to significantly enhance the end-user experience. It aims to streamline and simplify information presentation, effectively addressing end-user inquiries and bridging the identified gaps.

## Action Research Intervention

**Figure 1**
*Action Research Cycle on Enhancing Employee Experience in Expenditure Enquiry Management of Global Service Centre Through Chatbot Implementation in Multinational Company*


**Figure 2**
*Action Research Cycle*



## Input

### *Business Research*

The initial phase of this action research involves problem identification, which is a critical foundation for the subsequent research journey. This process commences with an initial meeting with the case company, where the research proposal is introduced and discussed. During this meeting, the primary objective is to identify and define the specific problem or challenge the research aims to address within the organisational context. This phase sets the stage for the entire research endeavour by pinpointing the areas where improvement and innovation are required.

Following the problem identification phase, a comprehensive literature review is conducted. This step entails an exhaustive examination of existing theories and prior case studies related to the research topic. By delving into the academic and practical knowledge already available, the research gains valuable insights into the broader context of the problem.

Once the literature review is complete, the research enters the information-gathering phase. This stage involves engaging in discussions and seeking confirmation from various organisational business stakeholders. These stakeholders are individuals from the T&E enquiry management team and the company's chatbot implementation team who possess relevant insights and expertise. These interactions aim to collaboratively refine the research activities, ensuring that they align with the identified problem and are designed to yield actionable outcomes.

## Transformation

### *Initiation: Data Collection and Analysis*

Pre-implementation data collection's primary focus is on problem diagnosis and strategy development. Firstly, the research performs analysis of secondary data. This is to comprehensively understand the existing situation by delving into quantitative data. This involves the examination of the current percentage of support queries raised by end users through guided-service channels, which could have been readily addressed through self-service avenues. This analysis aids in deciphering user behaviour patterns, particularly when they submit support tickets that already have corresponding knowledge articles for self-service. The insights drawn will guide improvements in information display within search results and the management of knowledge articles (KAs) to enhance their visibility as top search results.

Next, the research performs Focus Group Discussion (FGD) with stakeholders. This is to gather primary qualitative data; the research engages in focused discussions with key stakeholders involved in the implementation process. This includes team members responsible for executing the intervention. During these FGDs, the research aims to gain insights into the end-user journey, tracking their actions within the T&E service desk support and KA content management team. By understanding the current workflow and identifying potential gaps, the participants brainstormed ways in which chatbot implementation could address these challenges. Moreover, the participants strive to uncover strategies for enhancing the end-user experience, as well as pre-emptively addressing any anticipated challenges post-chatbot implementation. Participants in these FGDs are chosen via judgmental sampling based on their technical and business process backgrounds, ensuring their insights are valuable for successful implementation.

**Table 3**
*Focus Group Discussion Participants Profiling*

| No | Participant/Designation | Role in T&E Enquiry Management |
|---|---|---|
| 1 | Person A | Business process owner (BPO) in defining and overseeing T&E enquiry management process & procedures globally in Company X. Participate in project discussion planning & execution for T&E chatbot. |
| 2 | Person B | Subject Matter Expert (SME) in customer engagement for T&E, maintain the knowledge library management for the company knowledge search portal, collect end user feedback and improve enquiry management topics globally in Company X. Participate in project discussion planning & execution for T&E chatbot. |

### *Planning: Development Plan*

At this stage, the researcher collaborates closely with the chatbot implementation team to meticulously chart out the course of action for the development and deployment of the chatbot. This phase is informed by the valuable data collected during the initiation stage, which serves as the foundation for decision-making and strategy development. The team engages in in-depth discussions to outline the precise business requirements for the chatbot's functionality. This entails thoroughly examining what the chatbot needs to achieve, the problems it should address, and the specific tasks it should perform to enhance the end-user experience in the T&E enquiry management process. These discussions are critical in ensuring the chatbot aligns seamlessly with the organisation's and user's needs. Simultaneously, the team delves into the intervention strategy and evaluates the feasibility of proposed solutions. This involves a careful assessment of whether the identified strategy is not only viable but also capable of effectively addressing the identified problem. Feasibility studies help in making informed decisions about the direction the project should take. Furthermore, meticulous planning is carried out for the different stages of the project. Tasks are identified, prioritised, and scheduled in accordance with the required timeline. Resource allocation and management are also key components of this planning phase. Ensuring that the right resources, whether they are human, technological, or financial, are available when needed is crucial for the successful execution of the project.

### *Execution, Monitoring & Control: Action Implementation*

Following the meticulously aligned implementation plans forged through collaboration with business requesters and the technical project team, the chatbot implementation team proceeds to execute the project activities. This crucial phase encompasses a series of coordinated steps, beginning with the development of the chatbot itself. This involves the chatbot's design, coding, and configuration, transforming it from concept to reality. Following the development phase, rigorous testing procedures are carried out to ensure the chatbot's functionality, accuracy, and reliability. Testing is critical in guaranteeing that the chatbot operates seamlessly and delivers the intended user experience. Any issues or glitches are identified, addressed, and rectified during this phase to ensure the chatbot's effectiveness.

Simultaneously, the change management plan is put into action. This entails communicating and preparing end users and support teams for the forthcoming transition to the knowledge-based chatbot. Change management involves training, clear communication of the benefits of the chatbot to end users, and addressing any concerns or resistance that may arise during the adoption and deployment stage. Finally, the knowledge-based chatbot is ready for deployment after thorough preparation and testing. This culminates in the chatbot's go-live phase, where it becomes available to end users for real-time support and assistance for T&E enquiries. The fully operational chatbot contributes to enhanced end-user experiences in the T&E knowledge domain.

### *Closing and Reflection: Post-Implementation Data*

After implementing a chatbot, the focus shifts to evaluating the impact of the intervention on end-user experience. Key data collection methods are from the end user's behaviour towards the chatbot. The first is through the interview sessions with end users. Qualitative data is collected through interview sessions conducted with selected end users. The objective is to gauge their experiences with the chatbot, evaluate its usability, and identify opportunities for continuous improvement. These interviews help determine if end users find it easy to adapt to the chatbot technology for T&E queries, assess the quality of their experience in resolving queries via the chatbot, and pinpoint areas where further enhancements can be made. Participants for these interviews are selected through convenience sampling, prioritising accessibility.

**Table 4**
*Interview Session Participants Profiling*

| No | Participant/Designation | Role in T&E Enquiry Management |
|---|---|---|
| 1 | Person C | Employee of Company X from IT department. A casual T&E end user used T&E enquiry management to understand corporate credit card application and claim process, and how to use T&E expense system. |
| 2 | Person D | Employee of Company X from IT department. A casual T&E end user, used T&E enquiry management to claim parking ticket expense and how to use corporate credit card |

Secondly is the secondary data analysis, comparing with the baseline data collected before the intervention. This step examines quantitative data on the percentage of support queries raised through guided-service channels, which could have been resolved through self-service options. This analysis tracks whether the chatbot implementation has led to an improved adoption rate of self-service channels, reducing the percentage of queries that necessitate guided-service support.

## Output

In the short term, this study aims to assess the initial adoption of the chatbot as the first point of contact for end users seeking support for their queries, in contrast to utilising the knowledge search portal. Specifically, it will gauge the chatbot experience among a selected group of end users, seeking to understand their comfort level and willingness to adapt to the chatbot as a primary resource for T&E-related inquiries. The primary focus here is to evaluate the rate of adaptation to the chatbot in the early stages of its implementation.

In the medium term, the study evaluates the chatbot's capability to deliver the expected level of support. This involves measuring the chatbot's effectiveness in assisting end users to resolve their issues through interactive conversations. Key metrics include the chatbot's success rate in resolving queries and its impact on increasing the adoption of self-service channels while concurrently reducing the utilisation of T&E service desk tickets. This phase assesses the practicality and efficiency of the chatbot in enhancing self-service adoption.

In the long term, the ultimate objective is to witness a substantial shift in end-user behaviour. In this phase, the study envisions end users predominantly opting for the chatbot as their primary self-service channel. The knowledge search portal becomes a secondary resource, and T&E service desk tickets are reserved for exceptional cases where the chatbot or existing knowledge articles cannot address the user's query. The long-term goal is to establish the chatbot as the go-to platform for end users, marking a significant evolution in the support landscape.

## Logic Model

**The Situation**
In the current setup, the end users are not guided with the most relevant knowledge article for the most common "How To" queries applicable to their work location, as the current setup gives top 30 searches which gives end users too much information. Some end users raise tickets asking for "How To" support in the already existing KA as they could not find the correct KA, which wasted waiting time from the support team when the problem resolution could be self-service. In other cases, end users also are not sure where to raise tickets and how correctly to raise tickets to get further support.

| Inputs | Outputs | | Outcome | | |
|---|---|---|---|---|---|
| | Activities | Participation | Short Term | Mid Term | Long Term |
| 1. Percentage of queries ticket raised by end users through the guided-service support channels that could be addressed by self-service support.<br>2. Literature review theories and models<br>3. Focus group discussion on how this study could enhance end user experience & usability through chatbot.<br>4. Interview with selected end users on chatbot experience, usability & continuous improvement | 1. Problem diagnosis: Determine the current adoption rate of end user in knowledge search portal vs T&E service desk.<br>2. Determine the functionality of chatbot that could improve in end user experience.<br>3. Implementation planning, execution, and control<br>4. Data analysis of post implementation if the knowledge based chatbot tool could improve adaptation of self-service experience in managing T&E queries, and the impact of chatbot in improving end user experience in T&E queries | 1. All company users that engage with T&E department support<br>2. Target focus group discussion participants to formulate implementation plan based on the identified problem.<br>3. Target group interview to assess the impact of intervention in end user experience. | 1. User to use chatbot for their first point of contact to get support in their queries instead of going to the knowledge search portal.<br>2. Good chatbot experience<br>3. Increase in the adaptation rate to the self-service channels. | 1. Chatbot can provide expected support to end users for self-service.<br>2. Increase self-service adoption rate.<br>3. Decrease the T&E service desk tickets adoption rate. | 1. End users almost fully adopt chatbot as their primary self-service channel,<br>2. User only raise T&E service desk tickets for exception basis |

| Assumptions: | External Factors: |
|---|---|
| 1. Enough project resources from the respective team to deliver roles and responsibilities. Team members have all the required skills, no change in teams.<br>2. All relevant stakeholders will come to respective meetings for project progress. Full support from respective stakeholders for new technology adoption to ensure successful go live.<br>3. Enough project budget to support deliverables of the project.<br>4. All reports with needed fields already exist in the technical setup as secondary data to compare pre & post results. | 1. Company X is currently undergoing major global transformation.<br>2. Potential decision from company leadership on chatbot implementation, which the change may impact the implementation strategy.<br>3. Uncertainties may impact the execution and timeline of this project. |

## RESULTS AND DISCUSSIONS

### Quantitative Data Collection and Discussion

The researcher collected pre-intervention qualitative data by analysing ticket volume from the 6 months prior to the chatbot implementation month. Out of the total tickets raised, 33.87% required guided support, indicating complex inquiries that needed agent intervention. 26.12% were T&E department-initiated, while 22.50% were simple how-to queries that could have been resolved through the knowledge management portal. The remaining 17.51% were other tickets related to cross-functional resolutions, non-T&E-related topics, duplicate tickets, and more. Based on this data analysis, there is a clear opportunity to adopt self-service channels to reduce the number of general and simple ticket queries through the guided-service channel.

To conduct a meaningful analysis of post-intervention qualitative data, it is essential to collect and examine enough ticket volumes, preferably a six-month period following the implementation of the chatbot. This extended timeframe is necessary to accumulate a sufficiently substantial dataset, which is critical for conducting a thorough qualitative analysis aimed at understanding the impact of the knowledge-based chatbot on end users' adoption rates of self-service channels as compared to guided service channels before and after the chatbot's introduction. The research could not retrieve significant quantitative post-implementation information due to the time limitation in concluding the research.

### Focus Group Discussion of Chatbot Implementation Strategy

During the preliminary focus group discussion preceding the implementation of chatbot interventions, the research meticulously identified the tools employed by end users to seek support within Company X. As employees, they are granted access to the Company X knowledge search portal, a valuable resource enabling them to independently resolve their queries. For more intricate issues, end users can create support tickets, obtaining guided assistance from the T&E team. Additionally, they have the option to reach out for support via telephone. Furthermore, Company X offers various channels for end users to provide feedback regarding the service they receive. The T&E team diligently collects and analyses this invaluable feedback alongside ticket volume data, employing a collaborative tool for quantitative data collection. The analysis unveiled a significant opportunity for Company X to address 20% of straightforward inquiries via the existing self-service channel. This achievement aligns with the primary research objective: to assess the current adoption rate of the self-service channel relative to the guided-service channel represented by the T&E service desk. A reduction in this percentage would signify a higher level of user adoption for the self-service channel over the guided-service one.

Simultaneously, during the same focus group discussion, this research recognised several challenges within Company X's T&E enquiry management process. Despite possessing a knowledge library capable of handling most end users' queries through self-service, some users still prefer alternative support channels. This preference leads to unnecessary waiting times for end users when they can easily find answers. From the standpoint of the T&E team, the high volume of simple tickets adds to their workload and prolongs response times for more complex issues. This results in inefficiencies for the T&E team, as these simple queries could be resolved independently. Moreover, dealing with numerous repetitive inquiries may reduce job satisfaction for the resolution team, as they find themselves providing repetitive answers and performing tasks that don't significantly contribute value. The root of this challenge lies in end-user resistance to change and their inclination towards assisted service channels rather than self-service options. The influx of simple tickets creates a demand that exceeds Company X's limited T&E enquiry management resources, exacerbating existing challenges. Consequently, this data collection effectively fulfils the second research objective: assessing the opportunity to enhance end user experience through the implementation of a chatbot.

Guided by insights gained from the focus group discussion, Company X aims to incorporate several critical functionalities into their chatbot. This includes 24/7 availability, user-friendliness, accessibility, instant responses, multilingual support, and cognitive abilities to comprehend and accurately respond to a wide range of global or country-specific queries. Interoperability with the knowledge library for self-service and ticket creation for assisted service ensures a seamless user experience. Sustainable self-learning capabilities will enable the chatbot to continuously enhance its intelligence. Tools for analysing ways to optimize the chatbot's performance are also deemed crucial, ensuring its effectiveness evolves over time. Additionally, the chatbot must adhere to the company's policies on ethics and compliance while delivering standard customer service. While some nice-to-have features, such as cultural ethics awareness and humour, could personalise the chatbot's interactions, the primary focus is on developing a proficient virtual assistant rather than creating a virtual best friend. To gauge the success of the chatbot implementation strategies in improving end-user experience in T&E enquiry management, specific key performance indicators have been identified. Success will be defined by end users proactively choosing the chatbot as their preferred self-service channel. Additionally, the implementation will be considered successful if there is a substantial reduction in the number of service tickets that could have been easily self-resolved. Ultimately, the improved end-user experience and satisfaction with the T&E enquiry management process will testify to the chatbot's effectiveness. This data collection aligns with the fourth research objective: assessing the opportunity to enhance end-user experience through implementing a chatbot.

### Interview Session of End User Experience in Using Chatbot

In subsequent interview sessions with end users following the implementation of chatbot intervention, the research concentrated on evaluating the end-user experience when using the chatbot compared to the existing knowledge search portal. The findings indicate a positive response from end users regarding the chatbot's usability. Users reported that interactions with the chatbot were pleasant, resembling natural conversations with a person. Additionally, end users expressed satisfaction with the quantity of information provided by the chatbot and found the arrangement logical when retrieving answers. The chatbot's capabilities in resolving and assisting with end-user queries were well-received. Users appreciated the chatbot's helpfulness, interactivity, and consistent delivery of answers. Furthermore, the chatbot's non-verbal capabilities were positively acknowledged for effectively guiding end users to resolve their queries. The research revealed that end users were willing to switch to the chatbot as their new self-service channel for T&E enquiry management. Resistance to transitioning from the existing channel to the chatbot was low, as users found the chatbot easier to use compared to the knowledge search portal. Moreover, end users reported positive adaptability to the chatbot technology, finding it easy to learn. However, while the chatbot performed well in providing correct answers to simple and direct questions, there were some limitations in handling complex and specific queries. This resulted in end users expressing some uncertainty and lack of full confidence in the chatbot's ability to address more intricate issues. Overall, the data collected from the interviews successfully achieves the research objective of assessing the impact of the chatbot on improving the end-user experience in the self-service channel. The positive feedback and willingness to adopt the chatbot as the preferred self-service option indicate its potential to enhance the support system.

During the same interview sessions, the research identified several areas of improvement in the current chatbot capability implemented. Based on feedback from end users, valuable suggestions were made to enhance the chatbot's performance. Firstly, end users suggested that the chatbot should be smarter and better equipped to handle specific and complex questions. This improvement would ensure the chatbot can provide accurate and relevant responses to a wider range of queries. Secondly, it was recommended that the chatbot should be more personalised, human-like, and friendlier in its interactions. Adding a touch of personality to the chatbot's responses can enhance the overall user experience and make the interaction with the chatbot more enjoyable and engaging. Another important enhancement involves enabling the chatbot to identify situations where there are no available answers in the knowledge database for a particular question. In such cases, the chatbot should be able to seamlessly route the user to the next level of support or direct them to appropriate resources for assistance. Lastly, end users suggested that the chatbot rephrase questions to validate its understanding before providing answers. This step would ensure the chatbot interprets the user's queries accurately and delivers more precise responses. Collectively, these insightful suggestions from end users highlight the opportunities for further improving the chatbot's capabilities to enhance the end-user experience. By implementing these enhancements, the chatbot can evolve into a more efficient, effective, and user-friendly tool, providing better support and service to end users. This data collection successfully achieves the research objective of assessing the potential areas for improving the end-user experience through the chatbot's continued development and refinement.

## Reflection

The choice of participants for focus group discussions and end-user interviews was strategic. Focus group discussion participants, given their direct involvement with the topic, offered precise insights. However, the end-user interviews were limited to just two participants due to stakeholder unavailability, a constraint that hampers the comprehensiveness of the findings. To address this limitation and obtain a more holistic understanding of end-user experiences, future interviews should employ a more diverse participant selection process. This could involve considering participants' frequency of engagement with enquiry management systems and identifying users according to the types described in the literature review. This broader approach will enrich research findings with a wider array of perspectives, rendering them more robust and insightful.

In terms of research instruments, this research effectively utilised focus group discussions and interviews to grasp challenges and explore intervention strategies through qualitative data analysis. These methods yielded valuable insights. Additionally, the study also considered employing a global questionnaire to gauge end-user acceptance of the chatbot on a larger scale. However, technical complexities and limitations in survey distribution hindered this approach. Despite this setback, the focus group discussions and interviews contributed substantial qualitative data, enriching the research. Future investigations could explore alternative means of reaching a broader audience to enhance the survey's scope and validity.

The full desired chatbot functionality, unfortunately, could not be implemented due to technical constraints; the implementation team needs to prioritise the most feasible functionality and implement them in a phased approach to ensure the chatbot can achieve maximised end-user experience as possible and implement the rest of the functionality in the future enhancements. There were delays in the live chatbot's actual launch, primarily due to technical issues related to handling unrecognised user queries, even those pertaining to simple inquiries. Rigorous re-testing ensured the chatbot's efficacy in handling end-user enquiries and providing intelligent responses. There were also several challenges, including company transformation and technical delays, that have impacted the implementation timeline. The complexities of decision-making within Company X during this transformation process and the interdependencies among project teams contributed to these delays.

The data collection process was meticulously executed, aligning with the research's goals and objectives. The chosen instruments and insights from prior literature reviews ensured the collected data precisely addressed the research questions. During data analysis, the results mirrored the anticipated outcomes based on previous research, reinforcing the validity of the selected data collection methods. This congruence between expected and actual results enhances the credibility of the study's conclusions, signifying that the research is on a sound trajectory. By drawing from existing literature and employing appropriate data collection techniques, this research has laid a robust foundation for the research project, instilling confidence in its potential to contribute significantly to the field.

# CONCLUSIONS

## Research Impact on Practise

This study constitutes a significant theoretical contribution to the T&E department and the chatbot implementation team, shedding light on chatbot functionality and the factors influencing end-user adoption of this technology. It enriches our comprehension of implemented chatbot functionality, end-user experiences with the newly introduced self-service support channel, and the responses of end users as they transition to this self-service channel in comparison to existing support methods for T&E enquiry management. Notably, within the realm of chatbot implementation and end-user experiences, prior studies have predominantly adopted applied research approaches. There exists a paucity of research employing action research techniques. This study bridges this gap in the action research literature, focusing on implementing a knowledge-based chatbot to enhance end-user experiences within a company's operational processes.

In practical terms, this research has made significant contributions to Company X by elucidating the impact of chatbots on improving end-user experiences. The commitment of the T&E department to implementing intervention strategies has yielded measurable enhancements in end-user experiences within the T&E enquiry management process. Furthermore, this research has empowered Company X with invaluable insights into effective strategies for developing high-quality chatbot functionality to enhance end-user experiences in enquiry management. By improving the end-user experience with swift and seamless responses for self-resolving T&E queries, this action research has facilitated increased adoption of the self-service channel for managing T&E queries. Simultaneously, it has alleviated the T&E department's bandwidth, enabling them to focus their efforts and response times on resolving more specific and complex queries. The findings of this action research study hold the potential to offer crucial insights for real-case implementations of service chatbots, particularly for companies operating within business service centre models.

## Research Limitations and Delimitations

The research project faced a significant constraint related to the implementation timeline. Due to various factors, including company transformation and unforeseen delays, the originally planned project timeline could not be adhered to. This timeline constraint impacted the ability to implement and test the chatbot functionality as initially envisioned, and adjustments had to be made to accommodate these changes.

External factors and the ongoing company transformation necessitated a downsizing of the project team. This constraint affected the availability of resources, both human and technological, required for the successful execution of the project. The reduced team size posed challenges in terms of workload distribution and may have impacted the overall efficiency of the project/

The implementation of the desired chatbot functionality encountered technical challenges. These challenges included managing unrecognised utterances, particularly for simple queries. Overcoming these technical hurdles was crucial to ensure the chatbot could effectively handle end users' inquiries and provide intelligent responses. These technical constraints required additional time and effort to resolve.

Another constraint was the availability of post-implementation quantitative data. Due to the project timeline constraint, there was limited time for data collection after the chatbot implementation. This limitation hindered the ability to gather a robust dataset for assessing the long-term impact of the chatbot on self-service adoption and T&E service desk ticket rates.

The research relied on end-user interviews to gather qualitative data on the end-user experience with the chatbot. However, due to various constraints, including stakeholder availability and logistical challenges, the pool of end-user interviews was limited. This constraint may have resulted in a lack of comprehensive qualitative data that could encompass the diverse taxonomy of chatbot end users and their varying usage patterns in T&E enquiry management.

## Research Future Recommendations

In future research, it's essential to consider the timing of end-user interviews more strategically. As pointed out, chatbots require time to learn and improve their understanding of end-user utterances. Interviews should ideally be conducted after the chatbot has had sufficient time for self-learning and optimisation. This ensures that the chatbot is at its optimal level of intelligence capable of handling both simple and complex queries effectively. Planning interviews at the recommended period post-chatbot implementation will yield more insightful feedback and a better understanding of the chatbot's performance.

To gain a more comprehensive perspective on the end-user experience, future research should aim to include a diversified set of end users. This diversity can encompass various aspects, such as user behaviour and the frequency of engagement with T&E enquiry management. Consider incorporating the four types of chatbot user taxonomy, including Early Quitters, Progressives, Pragmatics, and Persistents, into future action research. This approach will help capture a broader range of user experiences and preferences, contributing to a more well-rounded understanding of the chatbot's impact.

To assess the end-user experience more comprehensively, consider implementing satisfaction surveys. These surveys can be designed to gather feedback from end users across different demographic factors. Since the impact of the chatbot extends to global shared service centres in a multinational company, variations in demographics may influence the user experience of the chatbot. Surveys can help identify patterns, preferences, and areas for improvement that might be specific to certain user groups.

Recognise that chatbot technology is not static; it evolves over time. Therefore, future research should include plans for continuous chatbot enhancements in subsequent cycles. End-user feedback is invaluable for identifying areas that require improvement. By incorporating end-user feedback into the development process, the chatbot's quality can be continuously enhanced. This, in turn, will lead to an improved end-user experience with the knowledge-based chatbot.

## Research Conclusion

Action research possesses the potential to catalyse profound and positive transformations within an organisation, delivering benefits to employees, end users seeking support, the T&E department responsible for managing the enquiry management process, and the whole company through long-term gains in cost efficiency and operational improvements. The successful implementation of our action research at Company X owes much to the open-mindedness and enthusiasm displayed by both the research team and the chatbot implementation team, embracing new technology for process enhancement. We recommend that other companies employing enquiry management processes, especially those grappling with high volumes of repetitive, mundane, and non-value-adding tasks, seriously contemplate the implementation of automation through knowledge-based chatbots. It is imperative for action researchers to exercise careful consideration of the implementation's limitations, particularly external factors that may exert substantial influence over the implementation's overall quality and effectiveness.

In summary, this research has made substantial progress in achieving three pivotal research objectives. Firstly, it effectively assessed the baseline adoption rates among end users, scrutinising both the self-service and guided service channels. Secondly, the study meticulously evaluated the potential for enhancing the end-user experience by integrating a chatbot. Lastly, the research rigorously examined the impact of the chatbot on elevating the end-user experience within the self-service channel. These findings signify remarkable advancements in comprehending the intricacies of the support system and underscore the promising advantages of integrating chatbot technology to streamline end-user interactions. Equipped with these accomplishments, the research is poised to embark on further investigations, leveraging the insights garnered thus far to enhance support services and more adeptly cater to the diverse needs of end users. As a research methodology, action research holds substantial promise for technology implementation researchers eager to investigate and resolve organisational problems effectively while concurrently contributing relevant scholarly knowledge.

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# Bridging Local Womenpreneurs' Knowledge and Application Toward SME Business Digitalisation

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## ABSTRACT

*Business digitalisation is a profound transformation of business involving the use of digital technologies to optimise business processes, improve business productivity, and satisfy customers' experience towards services or products offered. During the pandemic, the new business norm has urged digitalisation to take place. However, there is an existence of a knowledge gap between men and women entrepreneurs when it comes to business digitalisation. This paper aims to study women entrepreneurs' knowledge of SME business digitalisation. The significant number of women involved in SME is seen as vital to support the current mainstream agenda i.e., the Malaysia Digital Economy Blueprint (MyDIGITAL), how the local womenpreneurs are knowledgeable and applying or engaging with the digitalisation business, particularly digitalisation on their products, processes, and communications. Scarcity in research findings regarding local womenpreneurs' engagement towards business digitalisation is real. This gap has motivated such studies to be conducted immediately, especially during a pandemic. This study applied a quantitative research method to achieve the objectives. Questionnaires were conducted in data collection. The result of this study helps the relevant bodies, such as the policymaker and local government authorities to strategise better plans and programs for small- medium enterprises (SMEs) in the future.*

**Keywords:** *Womenpreneurs; Digitalization; Knowledge gap; SME; Pandemic; Quantitative method*

# Impact Analysis of CLAHE and UM-Based Image Quality Improvement on Diabetic Retinopathy Disease Classification

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## ABSTRACT

*Diabetic Retinopathy (DR) is the main cause of human visual impairment. DR will cause the patient to experience gradual blindness. In the current clinical diagnosis, routine screening of diabetics is done through fundus examination, which is the most effective way for early detection of abnormalities. Therefore, a method that can facilitate and assist doctors in identifying DR through retinal images is required to obtain accurate and precise analysis results. This study proposes a method of improving image quality using contrast-limited Adaptive Histogram Equalization (CLAHE) and Unsharp Masking (UM) combined with a deep learning-based classification algorithm of a convolutional neural network (CNN). The CLAHE and UM image results are fed into CNN. After conducting research, the test results show that the CNN model can distinguish between negative DR (normal) images and positive DR images (DR patients), and the application of image enhancement based on CLAHE and UM has better accuracy in several models than the original image. The results on the CLAHE images show that the method's average accuracy is very good, with 97.2% on ResNet-34, 94.8% on VGG-16, and 97.2% on EfficientNet-B0. The model accuracy using the UM image is 96.3% on ResNet-34, 90.5% on VGG-16, and 94.8% on EfficientNet-B0. The model performance is better when trained using CLAHE and UM images than the original image, with accuracy rates of ResNet-34, VGG-16, and EfficientNet-B0 being 96.9%, 96%, and 90%, respectively. However, the VGG-16 model achieves better accuracy on the original image at 96%, in the CLAHE image at 94.8%, and in the UM image at 90.5%. Meanwhile, the ResNet-34 and EfficientNet-B0 models achieved higher accuracy using CLAHE images, 97.2% for ResNet-34 and 97.2% for EfficientNet-B0.*

**Keywords:** *Diabetic Retinopathy; Image Enhancement; CLAHE, UM; Deep learning, CNN*

## INTRODUCTION

Diabetic retinopathy (DR) is a major cause of human visual impairment. Research by Muhammad Shoaib, et al (Farooq et al., 2022) reported that about 285 million people in the world are affected by diabetes, and one-third of them have symptoms of DR. This disease tends to attack patients aged 20 years and over. Based on epidemiological research in Europe, America, Asia, and Australia, it was also reported that the number of people with DR will continue to increase from 100.8 million in 2010 to 154.9 million in 2030, with an estimated 30% of them at risk of blindness.

Diabetes Mellitus (DM) is a disease of the endocrine system diagnosed with abnormally high blood sugar levels and has rapid development around the world. Diabetes can cause increased mortality, blindness, kidney failure, and decreased quality of life in sufferers. Many complications of

DM disease usually develop gradually and can attack the body due to DM disease, such as diabetic retinopathy (Hendriyawan & Saputro, 2021). DM has affected 463 million people worldwide, projected to increase to 700 million by 2045 (Tsiknakis et al., 2021). It is estimated that 35% of people with DR will increase with the age of people with DM (Math & Fatima, 2021).

DR begins by weakening the small capillaries in the retina area and leaking blood, which causes thickening of the tissue in the retina, swelling, and more extensive bleeding. Features of DR include microaneurysms, abnormal new blood vessels, leaking blood vessels, retinal swelling, and damaged nerve tissue (Hayati et al., 2022). DR occurs when blood glucose levels damage blood vessels in the retina. The increase in blood glucose levels causes the arteries in the retina to weaken and leak into the eye, causing blurred vision. Then, the eye can lose vision due to the weak blood vessels forming shards and flowing blood into the eye area (Kassani et al., 2019).

In current clinical diagnoses, routine screening of diabetics is done through fundus examination, which is the most effective way to detect abnormalities early. Doctors still do it manually to identify this disease, which takes time. Therefore, a method that can facilitate and assist doctors in identifying DR through retinal images is required to obtain accurate and precise analysis results. Classification and early detection of retinal disorders have always been a big and serious concern for research groups (Math & Fatima, 2021). Currently, the automatic classification of medical images through computer vision techniques has been widely carried out to help in the early detection of diseases.

Mira Hayati et al. (2022) used the contrast-limited Adaptive Histogram Equalization (CLAHE) method to improve image quality on DR images, integrated with the Deep Learning classification algorithm. In this study, the result of the Convolutional Neural Network (CNN) model was compared to the original and CLAHE images. The obtained results outperformed the best accuracy value, particularly in the image with CLAHE image quality improvement, where the accuracy value obtained was 91% for the VGG-16 model, 95% for the InceptionV3 model, and 97% for the EfficientNet model. However, the accuracy of the original image is superior to the CLAHE image in the ResNet-34 model, with an accuracy value of 95% for the original image and 84% for the CLAHE image. Thus, the CLAHE method in the image enhancement process in this study shows a fairly good accuracy value.

Research conducted by Khairul Munadi et al. (2020) deep learning (DL) method was used to see the effect of image enhancement on DL techniques in identifying Tuberculosis (TB) disease. The image quality improvement algorithm aims to improve the image's overall characteristics. Unsharp Masking (UM), High-Frequency Emphasis Filtering (HEF), and CLAHE image quality enhancement techniques were used, and they were evaluated and tested on pre-trained ResNet and EfficientNet models. In terms of accuracy, the UM method outperformed the highest accuracy value of 89.92%. Regarding area under curve (AUC), the method proposed in this study achieved competitive results with a value of 94.8%. However, the impact of image quality enhancement on classification accuracy has not been comprehensively investigated.

Therefore, this research proposes using deep learning techniques to classify two eyes classes as DR (Positive DR) or normal (Negative DR). Furthermore, CLAHE and UM image quality improvement methods will be applied to LAB colour channel variants, which will then be integrated and compared using the VGG-16, ResNet-34, and EfficientNet architectures to build classification models with the hope that the accuracy will be as accurate as previous studies or better.

## METHODOLOGY

### LAB Colour Space

The LAB colour space (Lightness, A & B) describes all visible colours to the human eye and is commonly used for vision. CIELAB is a three-dimensional colour model with the largest colourspace based on human eye colour perception. This LAB colour space consists of 3 layers: the $L^*$, $a^*$, and $b^*$

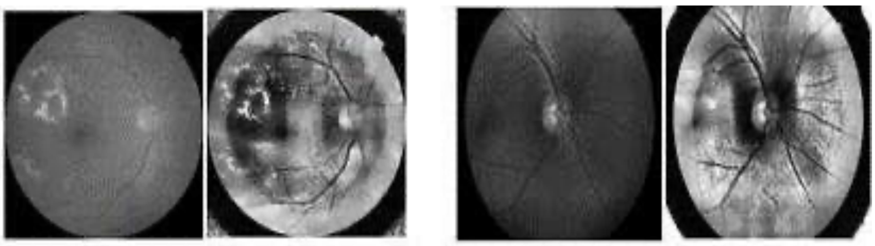
dimensions. The dimension describes the green-red colour type, where -a* (negative) indicates green and +a* (positive) indicates red. The b* dimension describes the blue-yellow colour type, where -b* (negative) indicates blue and +b* (positive) indicates yellow. The notation of $L^* = 0$ (black), and L to the asterisk operator equals 100 (white), representing reflected light that produces achromatic colours of white, grey, and black. The L dimension that describes brightness can directly reflect the illustration status of the image, which is the main quality indicator for the retinal images used in this study (Alamsyah & Pratama, 2019).

## Contrast Limited Adaptive Histogram Equalization (CLAHE)

Contrast Limited Adaptive Histogram Equalization (CLAHE) is one of the image quality improvement methods used in general image enhancement. CLAHE can overcome excessive contrast enhancement in the Adaptive Histogram Equalization (AHE) method by providing a boundary value to the histogram. This limit value is called the "Clip Limit", which states the maximum height limit of a histogram. The CLAHE principle works by increasing the contrast value in an image locally (in specific areas) such that previously invisible elements (hidden features) become visible. How to calculate the clip limit of a histogram can be defined by equation (1). β states the clip limit value, variable M states the region size, variable N states the grayscale value, α is the clip factor, which states the addition of histogram limits with a value of 1-100, and $S_{max}$ is the maximum allowed slope (Hayati et al., 2022).

**Figure 1**
*Difference of image enhanced through CLAHE and original image (Hayati et al., 2022)*

$$\beta = \frac{M}{N}\left(1 + \frac{a}{100}\left(S_{\max} - 1\right)\right) \quad (1)$$



## Unsharp masking (UM)

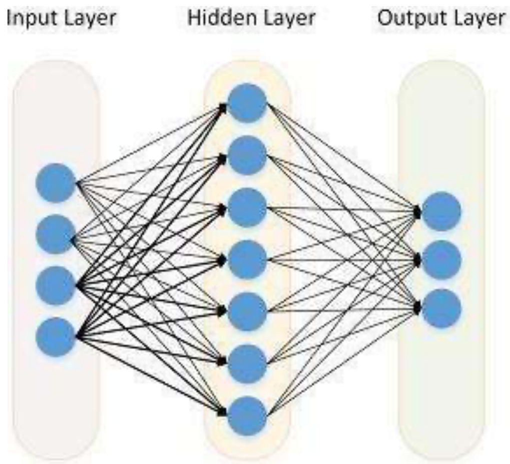
Unsharp masking (UM) is a commonly used technique in image sharpening enhancement methods. The UM technique adds a scaled and high-filtered version of the image to the original image by using a blurred or unsharp negative image to build a mask of the original image. The unsharp mask is then merged with the original positive image, resulting in a sharper image than the original image. The mathematical equation for the Unsharp Masking algorithm can be defined by equation (2), which $x(m, n)$ denotes the signal of the original image, $y(m, n)$ denotes the signal of the enhanced image, $z(m, n)$ is the enhancement operator, and $\lambda(m, n)$ is the enhancement coefficient factor that used to control the enhancement rate (Munadi et al., 2020).

$$y(m, n) = x(m, n) + \lambda(m, n) * z(m, n) \quad (2)$$

## Deep learning

Deep learning is a branch of machine learning and artificial intelligence. Deep learning uses a neural network consisting of many layers (hidden layer), which is implemented on problems with large data sets to classify commands and produce outputs. Deep learning uses the concept of a neural network that functions similarly to the human brain, allowing it to learn supervised learning or data features automatically and draw conclusions like humans when analysing logical and sequential data structures (Math & Fatima, 2021).

**Figure 2**
*Neural Network Structure (Hayati et al., 2022)*




## Convolutional Neural Network (CNN)

The Convolutional Neural Network (CNN) is a part of the Artificial Neural Network that is used in image classification and image processing. CNN is a type of Deep Neural Network, as it has a high network depth and is widely used in image data. CNN has four main layers: the convolution layer, pooling layer, activation function, and fully connected layer (Muslih & Rachmawanto, 2022).

1. Convolution Layer

The convolution layer consists of kernels that use an N-dimensional matrix to generate an output feature map for the next layer. Each data entering the convolution layer will go through a convolution process where each filter in the layer will be converted to the entire input data. The filters in this layer have length, height, and thickness according to the input data channel.

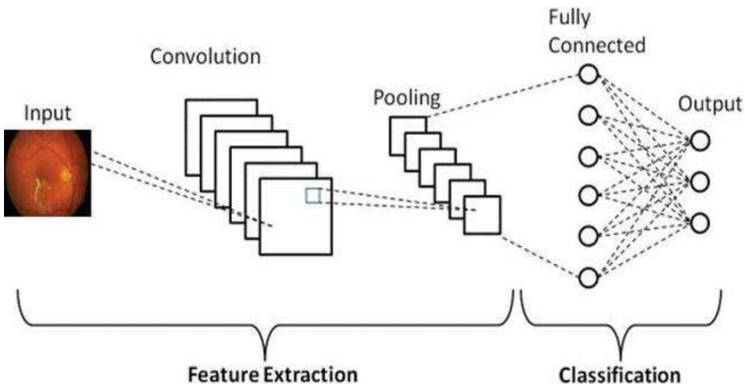
2. Pooling Layer

The Pooling layer is the next step after the convolution layer operation. The Pooling layer is used to sub-sample the feature map by taking a larger-size feature map and shrinking it to a lower-size feature map. When the feature map is shrunk, the most dominant feature is retained in each pooling step. Various pooling techniques are used in different pooling layers, such as max pooling, min pooling, and average pooling.

3. Fully Connected Layer

The fully connected layer is the last layer of the CNN. This part consists of neurons in layers fully connected in one layer with the previous layer. The fully connected layer consists of the input layer, hidden layer, and output layer.

**Figure 3**
*Neural Network Convolution Layer (Frangky Handono, Stevanus; Tri Anggraeny, Fetty, Rahmat, 2020)*

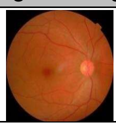
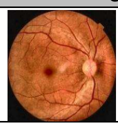
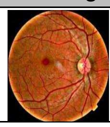
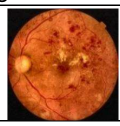



# RESULTS AND DISCUSSIONS

## Dataset Condition

The source dataset for this study was taken from APTOS 2019 (APTOS, n.d.) The dataset consists of two classes: the negative class (normal) and the positive class (DR patients). The dataset contains 3,288, with 1,799 negative and 1,489 positive class images. The entire dataset image then goes to CLAHE and UM pre-processing. Table 3.1 shows the appearance comparison of the original, CLAHE, and UM image samples.

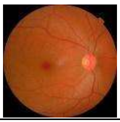
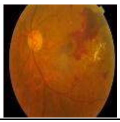
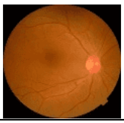
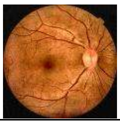
**Table 1**
*Differences in Appearance of Original Image, CLAHE Image, and UM Image*

| Original Image | CLAHE Image | UM Image |
|---|---|---|
|  |  |  |
| (a) Negative DR Image | | |
|  |  |  |
| (b) Positive DR Image | | |

### CLAHE Implementation Result

This pre-processing method compares the accuracy level between the original image and the image pre-processed with CLAHE. The original image in RGB colour space is used as the input image for the CLAHE application process, which is then transferred to LAB colour space, and the results of the CLAHE pre-process are converted back into RGB colour space. One of the goals of this study is to obtain different visual characteristics that can affect the performance of deep learning networks by using colour spaces other than RGB. The application of CLAHE in this study uses a clip limit of one window tile with default values of (8,8). After CLAHE pre-processing, the resulting image shown in **Table 2**, will become the new input for the architecture model proposed in this study.

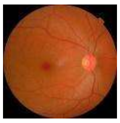
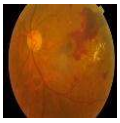
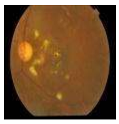
**Table 2**
*Difference between Original Image and CLAHE Image*

| Negative DR | | Positive DR | |
|---|---|---|---|
| Original Image | CLAHE Image | Original Image | CLAHE Image |
|  |  |  |  |
| (a) | | (b) | |
|  |  |  |  |
| (c) | | (d) | |

## UM Implementation Results

This method uses a smoothed positive image from the original image, which is then combined with a negative image to produce a sharper image than the original (Munadi et al., 2020). After UM pre-processing, the resulting image becomes clearer with an increase in the sharpness of the image edges, making the details of objects in the eye appear more real. Furthermore, the texture of the blood vessels and disease spots on the retina of the eye, as well as blood clots in the positive image (DR patient), appear clearer with a higher contrast level than the image without enhancement as shown in Table 3. This enhanced image is used as the new input for the architecture model proposed in this study.

**Table 3**
*Differences between Original Image and UM Image*

| Negative DR | | Positive DR | |
|---|---|---|---|
| Original Image | UM Image | Original Image | UM Image |
|  |  |  |  |
| (a) | | (b) | |
|  |  |  |  |
| (c) | | (d) | |

## System Training Results

The dataset used comprises three types of datasets: original images, CLAHE images, and UM images. Then, each dataset is divided into three parts: 70% for training data, 20% for validation data, and 10% for test data, as shown in Table 4. Before carrying out the training process, the first stage is to design the classification model system with the ResNet-34, VGG-16, and Efficient Net architectures and set their parameter as shown in Table 5. The training process of the three models for each dataset yields evaluation parameters such as training time, training accuracy & loss accuracy, and validation accuracy and loss, as shown in **Table 6-8.**

**Table 4**
*Details of Image Sharing*

| Data Type | Positive DR | Negative DR |
|---|---|---|
| Training Data | 1.040 | 1.259 |
| Validation Data | 297 | 362 |
| Test Data | 149 | 178 |
| **Total** | 1.489 | 1.799 |

**Table 5**
*Parameters Used in the Training Process*

| Parameters | ResNet-34 | VGG-16 | Efficient Net |
|---|---|---|---|
| Epoch | 50 | 50 | 50 |
| Batch Size | 2 | 2 | 2 |
| Loss Function | Cross-entropy | Cross-entropy | Cross-entropy |
| Optimizer | SGD | SGD | SGD |
| Momentum Optimizer | 0.9 | 0.9 | 0.9 |
| Learning rate optimizer | 0.001 | 0.00001 | 0.01 |

**Table 6**
*Accuracy and Validation Results on Original Image Training*

| Architecture | Train Time | Train Acc | Train Loss | Val Acc | Val Loss |
|---|---|---|---|---|---|
| ResNet-34 | 79 minutes 16 seconds | 0.9922 | 0.0303 | 0.9772 | 0.0620 |
| VGG-16 | 85 minutes 54 seconds | 0.9613 | 0.1067 | 0.9712 | 0.0762 |
| EfficientNet- B0 | 102minutes 4 seconds | 0.9548 | 0.1128 | 0.9363 | 0.0303 |

**Table 7**
*Accuracy and Validation Results on CLAHE Image Training*

| Architecture | TrainTime | Train Acc | Train Loss | Val Acc | Val Loss |
|---|---|---|---|---|---|
| ResNet-34 | 60 minutes 49 seco nds | 0.9974 | 0.0128 | 0.9863 | 0.371 |
| VGG-16 | 86 minutes 22 seconds | 0.9482 | 0.1323 | 0.9727 | 0.783 |
| EfficientNet-B0 | 96 minutes 15 seconds | 0.9839 | 0.0421 | 0.9848 | 0.0587 |

**Table 8**
*Accuracy and Validation Results on UM Image Training*

| Architecture | Train Time | Train Acc | Train Loss | Val Acc | Val Loss |
|---|---|---|---|---|---|
| ResNet-34 | 57 minutes 38 seconds | 0.9957 | 0.0169 | 0.9848 | 0.0329 |
| VGG-16 | 72 minutes 59 seconds | 0.9610 | 0.0990 | 0.9712 | 0.882 |
| EfficientNet- B0 | 74minutes 17 seconds | 0.9853 | 0.0466 | 0.9788 | 0.0596 |

## System Testing Results

It is shown that the pre-trained model is good enough to predict new data on the original image, CLAHE image, and UM image from negative and positive images. In the original image data, the ResNet-34 architecture achieved an accuracy value of 97%, then VGG-16 achieved an accuracy value of 96%, and EfficientNet-B0 of 90%. In the CLAHE image, the ResNet-34 architecture achieved an accuracy value of 97.2%, VGG-16 achieved an accuracy value of 94.8%, and EfficientNet-B0 was 97.2%. In the UM image, the ResNet-34 architecture achieved an accuracy value of 96.3%, VGG-16 achieved an accuracy value of 90.5%, and EfficientNet-B0 of 94.8%.

The testing accuracy value, as shown in Table 9. shows the ability of the model to predict almost all test data with good prediction results. In this study, the three models with the parameters used were able to provide good performance and performance.

**Table 9**
*Model Test Data Accuracy Results*

| Architecture | Original Image Accuracy | CLAHE Image Accuracy | UM Image Accuracy |
|---|---|---|---|
| ResNet-34 | 0,969 | **0,972** | 0,963 |
| VGG-16 | 0,960 | 0,948 | 0,905 |
| EfficientNet-B( | 0,905 | **0,972** | 0,948 |

**Table 10**
*Comparison of Model Testing Results on Negative Image Classes*

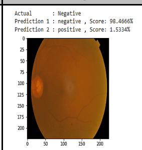
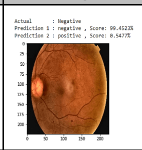
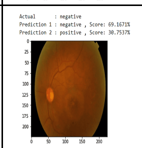
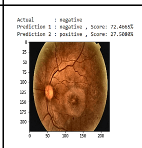
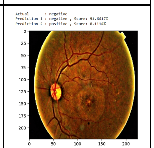
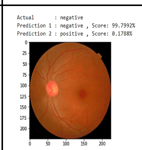
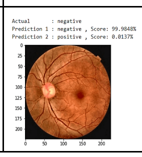
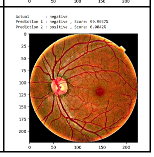
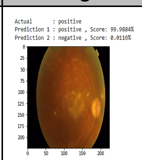
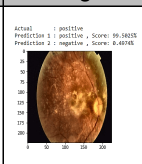
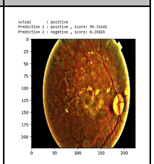
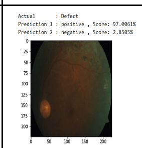
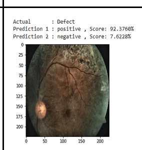
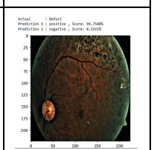
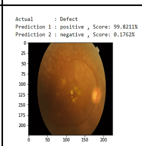
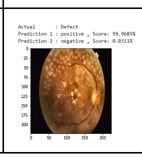
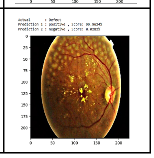
| Architecture | Negative DR | | |
|---|---|---|---|
| | Original Image | CLAHE Image | UM Image |
| ResNet-34 |  |  |  |
| VGG-16 |  |  |  |
| EfficientNet-B0 |  |  |  |

**Table 11**
*Comparison of Model Testing Results on Positive Image Classes*

| Architecture | Positive DR | | |
|---|---|---|---|
| | Original Image | CLAHE Image | UM Image |
| ResNet-34 |  |  |  |
| VGG-16 |  |  |  |
| EfficientNet-B0 |  |  |  |

## CONCLUSION

The model's performance trained using the application of CLAHE and UM demonstrates the superiority of utilising the EfficientNet-B0 architecture. This is proven by the visual graph of the CLAHE image data, which shows an improvement in the EfficientNet-B0 architecture. ResNet-34 provides optimal values for all three datasets: the original image data, CLAHE images, and UM images. Based on the visuals and accuracy obtained from the research, it is evident that image data with the application of CLAHE and UM methods outperforms the original image data. This is demonstrated by applying the CLAHE and UM methods, where positive and negative image data characteristics appear much clearer than the original image data.

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# A Framework for Non-Homogeneous Data Generation in Federated Machine Learning

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**ABSTRACT**

*A potential technique for training Machine Learning (ML) models on large amounts of decentralised data from many entities is federated learning (FL). However, FL cannot guarantee independent and identically distributed (IID) data, unlike centralised ML (CL). To describe the functioning of FL, it is therefore essential to measure the amount of IID data among the decentralised data. Regrettably, federated data is not as widely available as centralised data, which makes it more challenging to simulate real-world scenarios. This work presents various techniques to produce a measured degree of IID data by splitting centralised data into multiple nodes. We present the distances used to measure the extent of IID data spread throughout the decentralised data. Additionally, we put into practice partitioning techniques according to client distribution. Our suggestions are all contained in a framework that runs on Python. It makes it easier to compare the findings of CL and FL research. It makes it easier to conduct FL research by enabling the methodical and controlled partitioning of centralised datasets. Considering the skew in the labels' distribution, that split can be made. We experimented with the ECG arrhythmia detection sector to illustrate our suggested methodology. The findings demonstrate that our method can produce federated datasets appropriate for training models across several nodes and offer precise measurements of the non-homogeneity of client distributions.*

**Keywords:** *Federated Learning; Artificial Intelligence; Machine Learning; non-homogeneous clients; federated data*

## INTRODUCTION

Remarkable machine learning (ML) services have emerged in the last few years (Bohr & Memarzadeh, 2020; Krittanawong, 2018), trained on an enormous amount of publicly available data (centralised ML, or CL). Certain pertinent situations do, however, occur when data is reasonable and private; for example, financial or health data are typically safeguarded and challenging to share. An EU regulation known as the GDPR (Phillips, 2018) restricts data flow between companies and nations and establishes stringent guidelines for handling sensitive data. It is said that having such stringent regulations will encourage the development of data silos. Protecting data privacy in ML is essential to safeguard sensitive information, maintain trust, adhere to legal requirements, and prevent biases, ensuring responsible and ethical AI development.

Federated Learning (FL) (McMahan et al., 2017) runs an ML algorithm across a federation of nodes, each contributing a dataset to calculate a shared model. This method is effective in running ML algorithms across a federation of nodes. FL preserves privacy by enabling model training on decentralised client devices, localising sensitive data, and only sharing model updates. Differential privacy and secure aggregation techniques protect individual data while improving the model's performance. However, FL is difficult because data is not spread identically or independently across numerous places (IID). This raises the question of whether FL can perform as well as CL.

To solve the lack of FL datasets, this work uses metrics to assess data distribution non-homogeneity between FL nodes. It creates federated datasets from centralized ones with controlled non-homogeneous properties. Furthermore, the suggested metrics and division strategies are implemented inside an adaptable framework that generates FL datasets from any centralized one. Regarding the construction of federated datasets, a method for partitioning CL via label distribution was proposed by (T. Lin et al., 2020) and (Hsieh et al., 2020). In addition, (Li et al., 2022) have developed a suitable approach for the feature skew (Ma et al., 2022) in which the features are altered by summing Gaussian Noise.

## METHODOLOGY

We consider values that quantify the degree of non-uniformity between two or more clients. First, there is the one revealed by the similarity measure (Nielsen, 2019) that compares two probability distributions. Second, a metric for gauging the difference in probability distributions between the two is put forth (Goussakov, 2020). The fact that the suggested distances are restricted between 0 and 1, where 1 denotes completely different distributions and 0 indicates identical distributions, is one of its advantages. They also meet the triangular inequality. The techniques presented by (Hsieh et al., 2020) and (J. Lin, 2016; T. Lin et al., 2020) are applied to generate artificial partitions of a centralised dataset, considering the label skew partition.

Using the Physionet 2020 competition integrating six varied datasets (Perez Alday et al., 2021), we consider high-quality 12-lead electrocardiography (ECG) data from several health facilities with different ECG recording devices to categorise different cardiac abnormalities. We chose a Deep Neural Network (DNN) and a Long-Short Term Memory (LSTM) model (Murat et al., 2020) as the competition's highest-achieving model (Hong et al., 2022).

## RESULTS AND DISCUSSIONS

This experiment shows how to divide the dataset according to the distribution of the labels. In the sequel, we analyse multiple clients and use varying degrees of α to adjust the label skewness of the resulting partition. Initially, we merge all the partitions into a centralised dataset. We utilise the distances to calculate the degree of similarity between the distributions of the various clients for each resulting division. We focus on assessing the case with four clients' performances.

**Figure 1**
*Performance of the DNN and LSTM models for CL and FL.*

After applying the framework with the resulting partitions, we measure the performance of the two models for the CL and FL versions. The performance attained for the resulting divisions based on the measured distance is shown in Figure 1 using the F1-score. Observe that the achieved performance decreases with increasing non-homogeneity.

## CONCLUSION

To simplify comparisons between CL and FL research, the experiments in this study showed how effective the framework is at creating decentralised datasets from a centralised dataset. The outcomes demonstrated that the instrument was able to provide consistent datasets with varying levels of variability via a quantifiable and controlled degree of non-homogeneity, even exhibiting performance that was comparable to FL instances found in real life. We have used the centralised dataset for our tests. By reducing the parameter α, the strategies enabled us to increase the distance between divisions. Additionally, the FL's performance in terms of the F1-Score decreases when the label skewness rises. Regarding the F1-Score, the performance of the CL and FL are nearly equal when there is no skewness.

## ACKNOWLEDGMENTS

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# Development and Implementation of Smart IoT-Based Aquascape Monitoring System

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## ABSTRACT

*Aquascaping, the intricate art of creating appealing underwater landscapes, demands an extensive understanding of aquatic ecosystems and detailed maintenance. The application of technology, specifically the Internet of Things and artificial intelligence, has begun to significantly influence this field, enabling precise, real-time monitoring and control of vital parameters like temperature, pH, feeding and lighting. This paper presents the design and implementation of a Smart IoT-Based Aquascape Monitoring System that leverages IoT technology to enhance the efficiency and sustainability of aquascaping. The system incorporates an ESP32 microcontroller and various sensors and employs the Blynk platform for data display and user interaction. The proof-of-concept was tested in an aquascape setup, successfully automating several maintenance aspects such as temperature regulation, pH level monitoring, and fish feeding. This innovative technology integration aims to make the rewarding yet demanding hobby of aquascaping more accessible and manageable.*

**Keywords:** *Aquascaping, IoT; Sensors; ESP32 microcontroller*

## INTRODUCTION

Aquascaping is an artful arrangement of aquatic plants, rocks, wood, and substrates that aims to create an engaging underwater ecosystem within an aquarium. In this context, every element, both biotic and abiotic, plays a pivotal role in the overall aesthetic appeal as well as the chemical and biological balance essential for the sustenance of the aquatic life housed within. The intricate process of aquascaping requires a blend of patience and proficiency. Despite its challenges, it is a hobby that offers considerable benefits. It contributes positively to mental health by offering a soothing retreat, but when pursued passionately, it can also evolve into a profitable venture. The primary objective of aquascaping extends beyond creating an aesthetically pleasing aquatic landscape. It also encompasses various technical considerations such as substrate selection, water quality maintenance, plant and fish care, ornamentation, and an ongoing commitment to overall upkeep. Contrary to conventional fish tanks, aquascapes place a heightened emphasis on the depiction of diverse flora and the panorama it creates. This distinction necessitates special attention to plant care, making aquascapes a unique blend of art and science (Hetami et al., 2023). Despite the aesthetic appeal and mental health benefits that this hobby offers, it comes with its own set of challenges. Maintaining the health and balance of these miniaturised ecosystems requires constant vigilance and can be labour–intensive. Variables such as water quality, temperature, pH levels, and feeding schedules require continuous monitoring to ensure a thriving environment. In response to these challenges, the study presents the development and implementation of a smart Internet of Things (IoT)-based aquascape monitoring system.

Incorporating advanced technologies and data analytics into aquascaping practices heralds the advent of smart aquascaping. This innovative approach to aquaculture enhances its efficiency, sustainability, and productivity by leveraging the power of modern digital tools. At the heart of smart aquascaping is integrating technologies such as sensors, artificial intelligence (AI), and the Internet of Things (IoT). The IoT functions as a digital nexus that enables communication among various devices. This interconnectedness, integral to the IoT structure, promotes the smooth exchange of data and coordination of tasks across different elements of an aquascape setup (Rastegari et al., 2023). The amalgamation of these technologies within aquascaping cultivates a more accurate, data-informed methodology for handling and optimising aquascape conditions. This system aims to automate several facets of aquascape maintenance, such as monitoring temperature and pH levels, controlling lighting, and managing fish feeding.

This paper is organised into four sections. Section 2 will encompass a review of the literature pertaining to related work. Section 3 will delve into the methodology used, while Section 4 will be dedicated to discussing the results. The study will be concluded in Section 5.

## REVIEW OF RELATED WORK

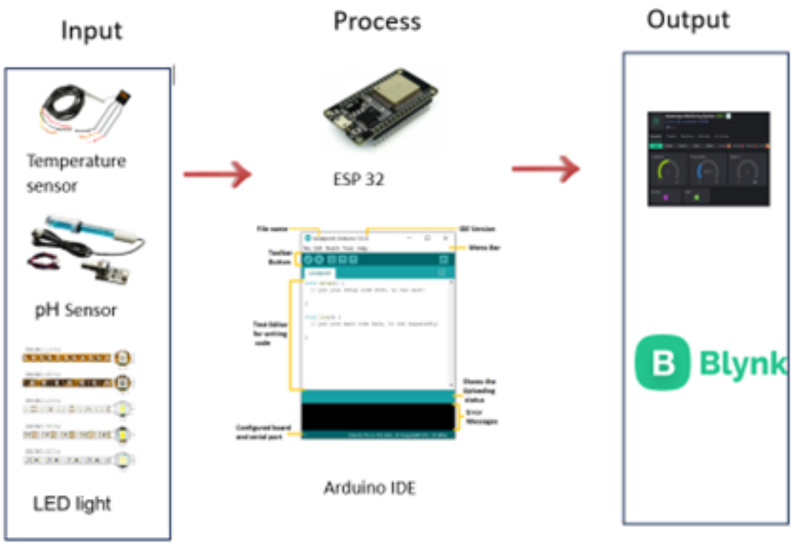
The aquascaping, the art of creating aesthetically pleasing underwater landscapes, requires a comprehensive understanding of the aquatic ecosystem. It involves monitoring and controlling numerous variables to maintain the health and balance of the system. Recently, technology has played a significant role in this field, particularly using the Internet of Things (IoT) and artificial intelligence (AI). Aquatic environment monitoring has seen the successful application of IoT technologies. Real-time data provided by wireless sensor networks allow for proactive management of crucial parameters, such as temperature, pH, dissolved oxygen, and ammonia levels. In addition, AI and machine learning have been used to predict water quality parameters and analyse fish behaviour, among other applications. Machine vision, for instance, can aid in fish detection, species classification, and feeding behaviour analysis. Blockchain technology has also found its way into the aquaculture industry, enhancing traceability in the fishery supply chain(Dilli Kumar V et al., 2023; Khudoyberdiev et al., 2023; Zhang & Gui, 2023). The application of intelligent systems, particularly those leveraging Internet of Things (IoT) technology, has significantly increased. Such research initiatives aim to assist users in sustaining ideal environmental conditions within their plant aquariums (Hutabarat et al., 2022). The research of Akhter and colleagues (Akhter et al., 2021) explores the crucial water parameters for fish farming, such as temperature, pH, nitrate, phosphate, calcium, magnesium, and dissolved oxygen, and review the existing sensors designed to measure these parameters. The researchers underscore that many current sensors are costly, necessitate enhancements in sensitivity and power requirements, require improved compatibility with IoT technology, and need to sustain continuous field usage. They suggest implementing a cost-effective system, employing both commercially available and custom-built sensors, which they deemed economical and efficient for field applications in fish farming. Petkovski et al. (2021) delve into examining IoT-based systems specifically designed for aquaculture. The researchers pose five research queries to identify the sensor types in use, the varieties of single-board computers utilised, the data transport protocols in place, the cloud-based platforms applied in aquaculture, and the advantages of employing IoT. Their findings reveal the usage of seventeen distinct types of sensors, with temperature, pH, and dissolved oxygen sensors emerging as the most prevalent. Raspberry Pi, Arduino, and ESP were the most frequently utilised single-board computers. Despite providing an overview of the sensor types, the authors did not delve into details such as the manufacturing process, sensor models, or cost considerations associated with these sensors.

Despite the progress made, there remains a noticeable absence of comprehensive, user-friendly IoT solutions tailored for the maintenance and monitoring of aquascapes. Many of the current systems are geared towards larger-scale applications such as marine aquaculture or commercial fish farming, which may not account for the unique considerations that come with aquascaping, including the need to delicately balance various parameters to preserve the aesthetic integrity of the setup. This study introduces the design and execution of an IoT-based aquascape monitoring system that quantifies critical parameters such as pH, temperature, and food incorporates automated controls for feeding fish and managing light conditions. This system, specifically designed for aquascaping, fills a noticeable void in the research by offering a comprehensive, cost-effective, and user-friendly solution for aquascape upkeep and monitoring. This integration of IoT technology with the unique needs of aquascaping paves the way for the exploration of innovative, custom-made solutions within this field, thereby making this enriching hobby more accessible and manageable.

## METHODOLOGY

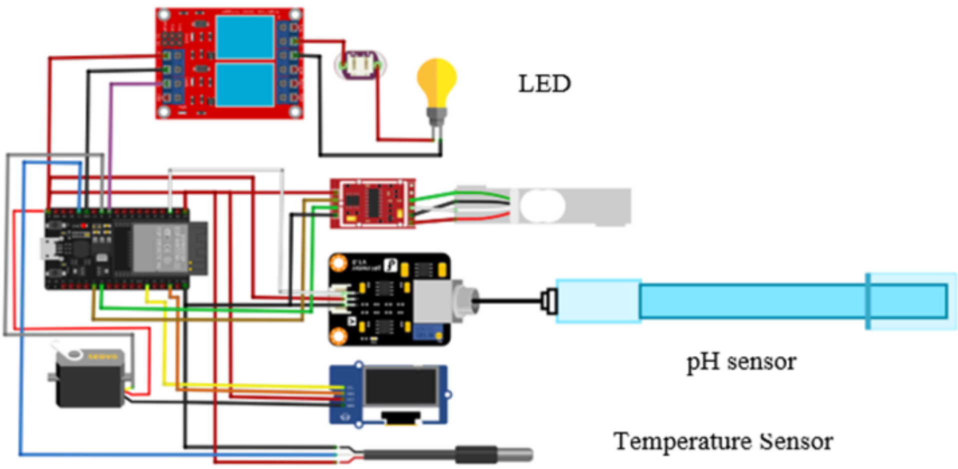
The overall methodology for developing and implementing the smart IoT-based aquascape Monitoring System is visualised in Figure 1.

**Figure 1**
*Block Diagram of Smart IoT-Based Aquascape Monitoring System*




The fundamental component of the system is a collection of sensors designed to monitor a range of parameters essential for maintaining a thriving aquascape. Included in this sensor suite are a pH sensor for the assessment of water acidity, a temperature sensor for tracking the thermal state of the water, a load cell sensor in conjunction with an HX711 Module for gauging weight, and a servo motor to regulate the feeding of fish. The sensory data collected is conveyed to an ESP32 microcontroller, an economical system-on-a-chip microcontroller fortified with integrated Wi-Fi and dual-mode Bluetooth capabilities. This primary function is to interpret and process the data produced by the sensors. Additionally, it governs the relay and OLED display, as well as handles the communication with the Blynk server. After data processing, the ESP32 microcontroller communicates the information to the Blynk server via Wi-Fi. The Blynk server serves as a cloud-based platform tailored for IoT applications, enabling remote supervision and management of the system. It offers a user-friendly interface where real-time sensor data is exhibited, thus ensuring continual monitoring of aquascape conditions. Access to the system's user interface is provided through the Blynk app, operable via a smartphone or computer. This app grants users real-time updates on the aquascape status, including metrics such as pH level, temperature, and weight. In addition, it empowers users to remotely command the servo motor for fish feeding, control the relay, and observe real-time readings on the OLED display.

**Figure 2**
*Creation of the diagram using the fritzing tool*

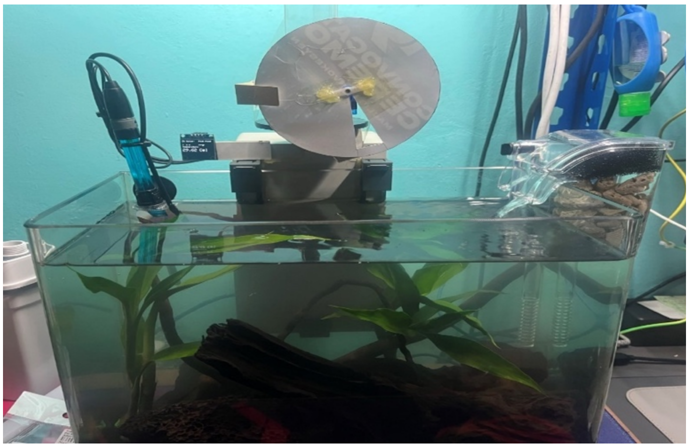



The schematic illustration of the proposed system's hardware is presented in Figure 2. The microcontroller, which acts as the heart of the system, is tasked with processing the signals it receives from the sensor module. Alongside this, a microcomputer is employed to prepare the sensor readings for onward transmission to the Blynk server platform. The sensor module comprises a temperature sensor and a pH sensor, while the system's lighting is controlled through LED lights.

## RESULTS AND DISCUSSIONS

The prototype of a smart IoT-Based Aquascape Monitoring System is illustrated in Figure 3. For this project, a hands-on, proof-of-concept assessment was conducted within an aquascape environment, presenting a concrete example of the custom-built circuit developed for this research. The initiation of system evaluation involved the loading and running the Arduino IDE's file codes on the ESP32 microcontroller. The aquascape habitat was equipped with critical components, such as pH and temperature sensors, to sustain an ideal environment for aquatic life. LEDs were integrated as a light source to mimic the required lighting conditions, promoting the growth and survival of the organisms within the aquascape.

**Figure 1**
*Prototype for Smart IoT-Based Aquascape Monitoring System*



## Temperature Monitoring

Maintaining a balanced aquatic environment necessitates consistent water temperature monitoring, as shown in **Table 1**. The sensor was tested for accuracy by immersing it in water at varying temperatures. The readings of sensors were then compared with those of a digital thermometer. The system showed a high level of precision, with sensor readings closely aligning with the thermometer readings, regardless of the temperature of the water.

**Table 1**
*Monitoring the Temperature of Water*

| Activities | Expected Result | Actual results |
|---|---|---|
| Soak temperature sensor in hot water | The temperature reading same as the thermometer reading. | Were as expected |
| Soak temperature sensor in cold water | The temperature reading same as the thermometer reading. | Were as expected |

## PH Monitoring

The pH sensor of a smart IoT-based aquascape monitoring system was evaluated next in Table 2. The sensor was immersed in water with known pH values obtained by using pH powder. Although the sensor provided less accurate readings due to its lower quality, it could still provide a reasonable estimate of the water's pH level.

**Table 2**
*Monitoring the pH of Water*

| Activities | Expected Result | Actual results |
|---|---|---|
| Soak the pH sensor in water with a reading pH of 9.18. | The pH reading same as the brewing water. | Less accurate reading due to low-quality sensor. |
| Soak the pH sensor in water with a reading pH of 4.01. | The pH reading same as the brewing water | Less accurate reading due to low-quality sensor. |

## Auto-Feeding

The auto-feeding mechanism of the system, controlled by a servo motor, was also tested, as depicted in Table 3. The motor was programmed to rotate and release a controlled amount of food into the aquarium at specific times. The mechanism functioned as expected, consistently releasing food at the designated times.

**Table 3**
*Auto Feeding Testing*

| Activities | Expected Result | Actual results |
|---|---|---|
| Set a certain timer to start feeding. | The Servo motor starts to rotate when the time comes. | Were as expected |

## Quantity of Food Given

The system was designed to display the remaining amount of fish food on an OLED display depicted in Table 4. This feature was tested by reducing the amount of food in the container and observing the weight displayed. In most cases, the display showed the correct weight. However, when the amount of food was reduced by 2 grams from an initial 50 grams, the display still showed 50 grams. This minor discrepancy could be due to the sensitivity of the weight measurement mechanism.

**Table 4**
*Testing Quantity of Food*

| Activities | Expected Result | Actual results |
|---|---|---|
| Set a certain timer to give start feeding. reducing the amount of fish food by 2 grams out of 50 grams. | The food weight displayed is 48 grams | The display is still 50 grams after reducing 2 grams of the food. |
| Set a certain timer to give start feeding. reducing the amount of fish food by 3 grams out of 50 grams. | The food weight displayed is 47 grams | Were as expected |

## Automation Light

The system's automated lighting feature was tested by programming the relay to turn the light on for specific durations, as shown in **Table 5**. The light was successfully turned on for the designated durations, ranging from 50 seconds to 1 hour, demonstrating the reliability of the system's automated lighting control.

**Table 5**
*Testing Light Automation*

| Activities | Expected Result | Actual results |
|---|---|---|
| Set a certain timer to light up for 50 seconds. | Light will light up for 50 seconds. | Were as expected |
| Set a certain timer to light up for 60 seconds. | Light will light up for 60 seconds. | Were as expected |
| Set a certain timer to light up for 1 hour. | Light will light up for 1 hour. | Were as expected |

## User Interface

The system's user interface was designed for straightforward navigation and easy access. Real-time sensor readings, including temperature, pH value, and the remaining quantity of food, are displayed on both the Blynk mobile application, as shown in **Figure 4**, and the Blynk website, as shown in Figure 5.

**Figure 4**
*Blynk Mobile Application*

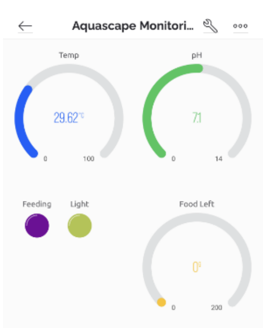
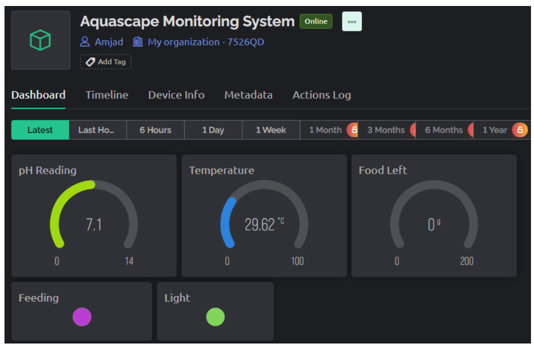



**Figure 5**
*Blynk Website*




Additionally, the interface provides indicators for the feeding and lighting status of the aquascape. To ensure seamless monitoring, the system not only empowers aquascape owners to supervise their setup locally via an OLED display but also remotely through the Blynk application. This feature greatly enhances the convenience of managing the aquascape, allowing owners to keep tabs on their setup from any location with internet access.

## CONCLUSION AND FUTURE WORK

The successful deployment of a smart IoT-based aquascape monitoring system signifies a notable convergence of technology, science, and aesthetics, streamlining the upkeep of thriving aquascapes. The system provides an optimal environment for aquatic life, equipped with sensors to monitor water acidity, temperature, and remaining fish food. Key features include automated feeding and lighting mechanisms operating on pre-set schedules, eliminating manual intervention. The user-friendly interface displays real-time sensor data, and its integration with the Blynk app allows remote control and monitoring, enhancing user experience. This innovation represents a significant advancement in aquascaping and broader aquaculture applications. Future work includes expanding usage to commercial enterprises and incorporating machine learning for predictive maintenance.

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# Preliminary Results of a Deep Learning Model for Classifying Watermelon Sweetness Through Field-Spot Detection

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## ABSTRACT

*Watermelon is a popular fruit commodity due to its pleasant and refreshing taste. A ripe and sweet watermelon is recognised using human senses by inspecting its weight, the sound produced by tapping its bottom, and its visual characteristics, such as the field spot and colour. A field spot on a watermelon indicates that the fruit has had sufficient time to mature while on the vine. However, these traditional methods are considered subjective and less efficient because disparities exist in evaluating each specimen. Thus, this study aims to build a deep-learning model to classify the ripeness and sweetness of watermelons based on field-spot appearance. Four convolutional neural networks, EfficientNet B4, EfficientNet B7, ResNet-50, and ShuffleNet V2, were implemented in this study. This study also proposes a novel dataset of watermelons as a baseline for ripeness and sweetness classification to implement a deep-learning model. The results reveal that EfficientNet B4 outperformed other architectures with an accuracy of 92.22%. Under the testing procedure, the confusion matrices demonstrate that EfficientNet B4ss produced the best performance among the algorithms.*

**Keywords:** *Field spot; watermelon sweetness level; deep learning, melon dataset; classification model*

## INTRODUCTION

Belonging to the Cucurbitaceae family, watermelon (*Citrulus lanatus*) is one of the most crucial seasonal horticultural commodities cultivated worldwide (Saediman et al., 2020). These exotic fruits are grown in tropical and subtropical areas. Watermelon contains high nutrients and is a good source of vitamins such as B, C, E, calcium, iron, and zinc, which are beneficial for human health (Theurkar et al., 2023). Several studies have demonstrated that watermelon is medicinal because it effectively decreases blood pressure, cholesterol, cancer, diabetes, cardiovascular disorders, and obesity (Lum et al., 2019; Dube et al., 2021; Karimi et al., 2023).

Watermelon also has commercial and economic value, contributing to an annual production of over 100 million tons (Bantis et al., 2019; Helilusiatiningsih, 2022). It holds a broad market share, ranging from traditional to modern markets. The Food and Agricultural Organization of the United Nations reported that a total area of 3.2 million hectares was used for watermelon cultivation, resulting in a global production of 103 million tons in 2018 (Manivannan et al., 2020). Over 80% of global watermelon production originates from Asia (Dube et al., 2021). The refreshing taste, high water content, and attractive red, yellow, and pink colours increase watermelon consumption. From 2014 to 2018, watermelon consumption in Indonesia increased by 6.14% (Isharthani et al., 2020), indicating that the public widely consumes watermelon and that the market is highly competitive. The watermelon must meet domestic and international market standards to enhance this competitiveness and be accepted widely by consumers, commonly indicated by its sweetness.

Based on interviews conducted at various fruit markets in Banda Aceh, within the watermelon agrotourism of Aceh Besar, and at the UPTD Balai Benih Hortikultura, Tanaman Pangan, and Tanaman Perkebunan in Banda Aceh, the ripeness and sweetness of watermelons are assessed through a visual examination of their field-spot appearance and weight and by tapping them to gauge the sound. Nevertheless, this visual assessment of watermelon ripeness is prone to subjectivity due to the variations in interpretation among individuals.

Furthermore, the traditional method of categorising watermelon quality is not standardised. According to the Indonesian National Standard, watermelon sweetness is indicated by the total dissolved solids in the fruit flesh, called the Brix value or degree Brix, which is >8% (Badan Standarisasi Indonesia, 2009). However, measuring the Brix value in the fruit requires the flesh to be sliced, making this process invasive and potentially damaging (Jaywant et al., 2022).

Many existing studies have been conducted to identify the ripeness and sweetness of various fruits, such as melon, apple, strawberry, pineapple, and watermelon. In 2019, Jie et al. developed a watermelon ripeness detection method with visible and near-infrared images of watermelon as the object. They demonstrated an analysis method for spectral characteristics in detecting ripening watermelons. The results revealed that the corrected intensity ratio between $peak_1$ and $peak_2$ has a sophisticated predictive ability with a classification-level accuracy of 88.1%. In 2020, Albert-Weiß proposed an acoustic resonance-based model combined with a deep learning model for classifying ripe and overripe watermelons. This study demonstrates that this classification model trained on acoustic information achieves an impressive accuracy of 96%. In 2020, Nazulan et al. also investigated sweetness detection and classification using a machine-learning algorithm. The watermelon's colour, field spot, and shape were detected using the K-means clustering method with 84.62% accuracy. However, the dataset used in their work is considered too small, at only 15 images.

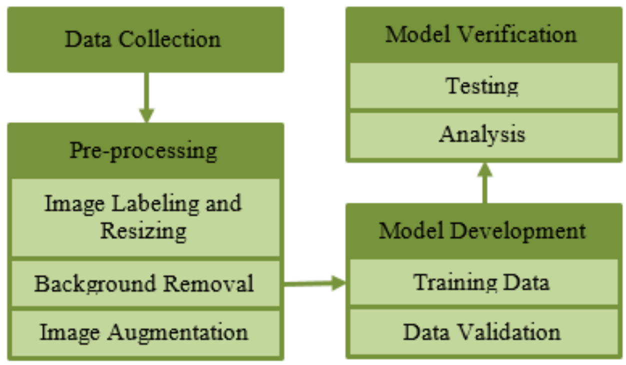
By adopting the most recent methods and technology, more studies must be conducted on quality detection regarding the ripeness and sweetness of agricultural commodities, such as watermelons. This study proposes a novel approach to assess the sweetness of watermelons based on their field spots by employing deep learning techniques to recognise the potency of deep learning in data-driven applications and computer vision tasks (Ganatra et al., 2021). The watermelons are grouped into two classes: sweet and nonsweet watermelons. The Jamaican F1 watermelon variety was chosen for this purpose, as this variety is the predominant watermelon cultivated in Indonesia. The study employs three distinct deep learning architectures: EfficientNet B4, EfficientNet B7, ResNet-50, and ShuffleNet V2.

EfficientNet is an architecture with exceptional performance, attaining the top-1 position in recognising images within the ImageNet dataset (Tan et al., 2019). In addition, ResNet-50 is a distinctive and widely renowned architecture for image classification, demonstrating impressive proficiency in pattern recognition (Theckedath et al., 2020; Tian et al., 2019). Moreover, ShuffleNet is an architecture designed for computational efficiency, achieved through point group convolution techniques and channel randomisation, reducing the required computational operations. Therefore, ShuffleNet delivers strong performance on a smaller scale (Jin et al., 2022).

## METHODOLOGY

The procedure of this work consists of four stages: data collection, preprocessing, model development, and model verification, as illustrated in Figure **1**.

**Figure 1**
*Research procedure for watermelon field-spot detection.*

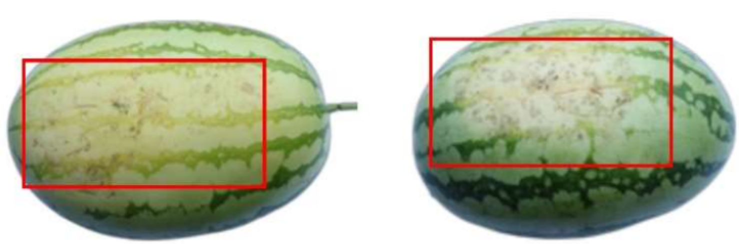



### Characteristics of a Ripe Watermelon

According to the field findings from the interviews, there are many ways to determine the ripeness of a watermelon. One is tapping the watermelon's lower part and listening to the sound. A watermelon with a deeper sound is a ripe watermelon. Another method is determining the watermelon's weight (Kato, 1997). The last is by examining the field spot of the watermelon. A watermelon with a larger field spot with a yellowish colour indicates that it has had enough growing period as long as it is on the vine. In contrast, the watermelon with a smaller spot or a white colour indicates that the watermelon is not ripe, as presented in

Figure **2**. This work focuses on determining the sweetness and ripeness of watermelon based on its field spot. Moreover, a sensory evaluation was conducted on the watermelon to provide the classification guidelines for its sweetness level, and the sweetness standards emerged based on the Indonesian National Standard using the Brix value. A sweet watermelon has a Brix level of >8%, and the nonsweet class has a Brix value of ≤8% (Badan Standarisasi Indonesia, 2009).

**Figure 2**
*Field-spot area of a watermelon: sweet watermelon (left) and nonsweet watermelon (right).*



### Data Collection Setup

The images were taken shortly after watermelon harvesting. The dataset was gathered under natural lighting from the sun. The images were taken at a distance of 30 cm between the lens and the watermelon using a Canon EOS M10 with a focal length of 16 and an aperture of f/3.5. Six sides of the watermelon were captured: front, back, right, left, top, and bottom. The image dimensions are 5184x3456 pixels. Figure 3 depicts the image-gathering setup for the watermelon dataset. The original collected data comprises 150 images.

**Figure 3**
*Setup for gathering data for the dataset.*


## Data Preprocessing

After all data were collected, the preprocessing stage was conducted. The stage was divided into four processes: image labelling and resizing, background removal, oversampling, and image augmentation. The preprocessing started with image labelling. Each image was labelled as either sweet or nonsweet, based on the Brix value of the melon measured using a refractometer after the images were taken. The labelling process resulted in 90 sweet watermelons and 60 nonsweet watermelons. Subsequently, each image was rescaled to a fixed dimension of 244x244 pixels.

Moreover, the background of the resized images was removed using the Python library rembg. The tools employ a machine learning algorithm trained on an extensive collection of images, enabling precise detection and distinction of the foreground object from the background (Fan et al., 2022). "Rembg" is an abbreviation for "remove background," describing its primary functionality. The library uses the U-2-Net framework, a deep-learning model for salient object detection. It leverages the power of a convolutional neural network (CNN) to analyse image pixels and categorise them as either foreground or background (Liang, 2022). Figure 4 presents an image whose background was removed using rembg.

**Figure 4**
*Background removal example using rembg.*

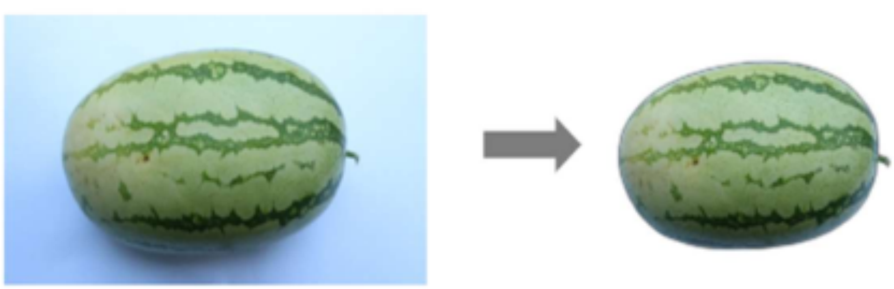


Image augmentation was performed to resolve the unbalanced data in each class. The process was conducted in each class to increase the number of data to vary the data. The augmentation process was performed by implementing the Python library imgaug. The diversity of the dataset can effectively be increased by using imaging, leading to better model performance and improved generalisation of unseen data (Garg et al., 2020). This library provides several augmentation techniques, such as flipping, rotating Gaussian blur, and random translation. The augmentation techniques used horizontal flipping, vertical flipping, 15$^{o}$ rotation, random translation, and Gaussian blur (

**Figure 5**). **Table 1** lists the total of the augmented dataset, which is 900 images divided into 450 data points for each class.

**Table 1**
*Collected Dataset and After Preprocessing*

| Class | Original Data | Augmented Data | Total Data |
|---|---|---|---|
| Sweet | 90 | 360 | 450 |
| Nonsweet | 60 | 390 | 450 |
| **Total** | 150 | 750 | 900 |

**Figure 5**
*Augmented image example: (a) original data, (b) flipping horizontal, (c) flipping vertical, (d) 15º rotation, (e) random translation, and (f) Gaussian blur.*

(a) (b) (c) (d) (e) (f)

After the datasets are augmented, they are split into training, validation, and testing data at a ratio of 7:2:1 for both classes, sweet and nonsweet watermelon. The training data are employed to train the deep learning models, whereas the validation data validates classification performance during the training process for overfitting prevention. The testing data aim to evaluate the classification performance of the chosen models. Table 2 exhibits the distribution of datasets used for the model development and verification stages.

**Table 2**
*Distribution of the Augmented Watermelon Dataset*

| Dataset | Sweet | Not Sweet | Total |
|---|---|---|---|
| **Training** | 315 | 315 | 630 |
| **Validation** | 90 | 90 | 180 |
| **Testing** | 45 | 45 | 90 |
| **Total** | 450 | 450 | **900** |

## Model Development

The second stage is model development, divided into training and validation steps. The training model was performed on 630 images, comprising 315 images for each category, sweet and nonsweet watermelons. Model hyperparameters were adjusted to determine the best combination for optimal performance. Table 3 lists the parameter set. In this case, the same optimiser, number of epochs, and batch size were used as parameters. The fine-tuning learning rates were set to $10^{-3}$, $10^{-4}$, and $10^{-5}$ to examine how quickly the model adapted to the problem. A too-low learning rate value could lead to a lengthy training process, whereas a too-large learning rate value could result in an unstable training process (Basodi et al., 2020). The validation process was performed to validate model performance during neural network training and prevent overfitting (Febriana et al., 2022). The process was conducted on 180 data (Table 2).

**Table 3**
*Parameter Set for Watermelon Field-Spot Detection*

| Parameters | EfficientNet B4 | EfficientNet B7 | ResNet-50 | ShuffleNet V2 |
|---|---|---|---|---|
| **Optimizer** | Adam | Adam | Adam | Adam |
| **Epoch** | 200 | 200 | 200 | 200 |
| **Batch Size** | 16 | 16 | 16 | 16 |
| **Learning Rate** | 10-3 | 10-3 | 10-3 | 10-3 |
| | 10-4 | 10-4 | 10-4 | 10-4 |
| | 10-5 | 10-5 | 10-5 | 10-5 |

### Model Verification

This stage was conducted on the testing dataset and aims to verify the trained model obtained in the previous process. The number of images is 90 for sweet and nonsweet watermelon. This stage also examines model performance regarding accuracy, precision, recall, and F1-score using the confusion matrix. The matrices also provide prediction scores for sweet and nonsweet watermelon.

## RESULTS AND DISCUSSION

Table 4 presents the training results for the four architectures: EfficientNet B4, EfficientNet B7, ResNet-50, and ShuffleNet V2, employing three hyperparameter values, $10^{-3}$, $10^{-4}$, and $10^{-5}$. The data in the table reveal that the EfficientNet B4 model with a learning rate of $10^{-3}$ produced the highest accuracy of 96.03% and training loss of 35.48%. As the learning rate diminished to $10^{-4}$ and $10^{-5}$, the training accuracy of the EfficientNet B4 model also decreased, followed by an increased training loss. A similar pattern emerged with EfficientNet B7, ResNet-50, and ShuffleNet V2, where setting the learning rate to a lower value produced greater training accuracy. Nevertheless, as the learning rate decreased further, a decline in training accuracy and a rise in training loss ensued. However, EfficientNet B7 demonstrated distinct behaviour, where reducing the learning rate to $10^{-5}$ led to a significant decline in training accuracy from 93.32% to 74.3% and an escalation in training loss from 39.14% to 66.98%. Moreover, EfficientNet B4 outperformed the other algorithms, followed by EfficientNet B7. Despite its different behaviour, ShuffleNet V2 obtained superior training accuracy compared to ResNet-50. Notably, the learning rate of $10^{-3}$ displayed inferior results compared to those of $10^{-4}$ and $10^{-5}$.

Figure 6, Figure **7**,

**Figure 8**, and

**Figure 9** illustrate the graphical representation of the model performance on both the training and validation datasets. The learning curves are presented for each model with a learning rate of $10^{-3}$, $10^{-4}$, and $10^{-5}$ in each figure in parts (a), (b), and (c), respectively. As observed in the figures (left), each architecture's training and validation accuracy increases progressively with each epoch, indicating that the models are learning the pattern gradually in the training data. However, using a learning rate of $10^{-5}$ in EfficientNet B7 led to underfitting, as the validation accuracy is higher than the training accuracy between epochs 25 and 100. Underfitting also occurred in EfficientNet B4 and ShuffleNet V2 when both architectures set the learning hyperparameter to $10^{-5}$.

With a learning rate of $10^{-3}$, the training and validation loss for EfficientNet B4 and B7 decreased (Figures 6 and 7), leading to convergence. However, a small gap exists between the training and validation loss for these models. A decline in convergence was produced for EfficientNet B4 and B7 by setting the learning rate to $10^{-4}$, although small fluctuations appear in the curves. Tuning the hyperparameter to a lower value at $10^{-5}$ presents a slower decline, differing from the more significant decreases in the curves for the learning rates of $10^{-3}$ and $10^{-4}$, which start early and progress steadily.

**Table 4**
*Results of Each Architecture*

| Architectures | Learning Rate | Training Accuracy | Training Loss |
|---|---|---|---|
| **EfficientNet B4** | $10^{-3}$ | 0,9603 | 0,3548 |
| | $10^{-4}$ | 0,9231 | 0,3989 |
| | $10^{-5}$ | 0,8459 | 0,5067 |
| **EfficientNet B7** | $10^{-3}$ | 0,9536 | 0,3602 |
| | $10^{-4}$ | 0,9332 | 0,3914 |
| | $10^{-5}$ | 0.7430 | 0.6698 |
| **ResNet-50** | $10^{-3}$ | 0.9170 | 0.3951 |
| | $10^{-4}$ | 0.8878 | 0.4305 |
| | $10^{-5}$ | 0.8258 | 0.5130 |
| **ShuffleNet V2** | $10^{-3}$ | 0.8987 | 0.3054 |
| | $10^{-4}$ | 0.8445 | 0.5296 |
| | $10^{-5}$ | 0.7701 | 0.6688 |

For ResNet-50 in

Figure **8**, training and validation loss run parallelly, approaching convergence. Regarding training and validation accuracy and loss, a substantial fluctuation occurs in ResNet-50 using learning rates of $10^{-3}$ and $10^{-4}$. A lower learning rate improves training and validation accuracy in the EfficientNet B4 and B7 models.

The curve produced using a learning rate of $10^{-3}$ in

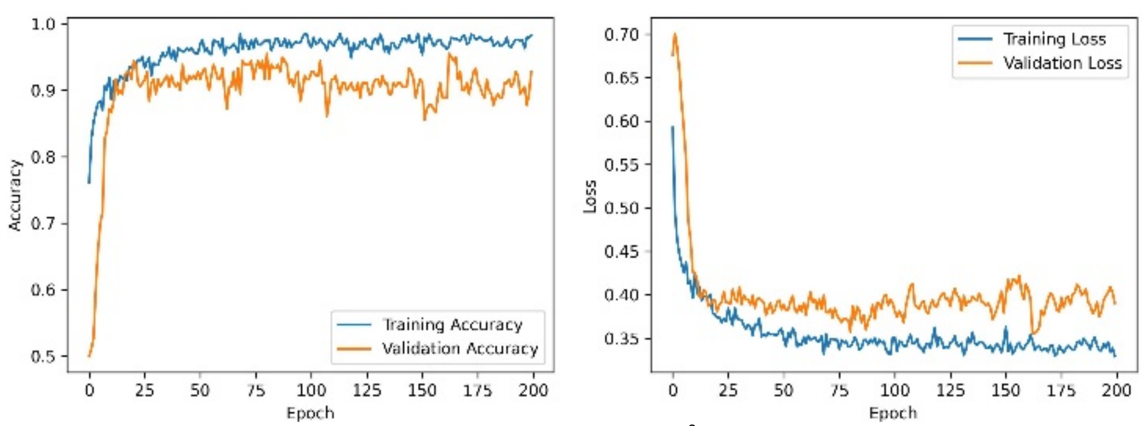
**Figure 9**
*Learning curves of the ShuffleNet V2 model*(a) experiences a significant decrease starting from epoch 0 and decreasing gradually closer to convergence. In contrast, tuning the learning rate to a lower value influenced the model performance for ShuffleNet V2. The training and validation loss tend to decline with learning rates of $10^{-4}$ and $10^{-5}$; however, convergence was not achieved by epoch 200, implying a challenge for the

model to learn unseen data effectively. In summary, the learning curves reveal that a learning rate of $10^{-4}$ demonstrates the most favourable performance on the training and validation data, particularly for EfficientNet B7.

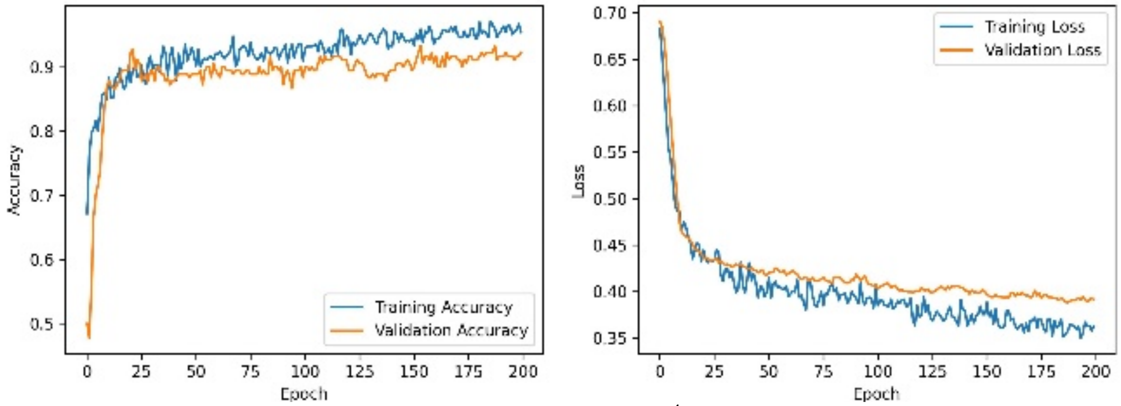
Figure 10 presents the confusion matrices of the models using EfficientNet B4, EfficientNet B7, ResNet-50, and ShuffleNet V2 testing with a learning rate of $10^{-4}$ on 90 watermelon images. In the first confusion matrix (a), the EfficientNet B4 model yields the best prediction. The model correctly predicted 45.6% of the sweet and 46.7% of the nonsweet watermelon images. Only seven images were classified in the incorrect class. The second-best prediction was yielded by EfficientNet B7, where 40 sweet images were accurately predicted, and eight sweet watermelon images were incorrectly detected as nonsweet watermelons. The ResNet-50 model also demonstrates an increasingly incorrect prediction compared to EfficientNet B7, where six images were misidentified as the sweet class, and eight were incorrectly identified as a nonsweet class. In contrast, the confusion matrix of the ShuffleNet V2 model represents an increased number of inaccurate predictions of both classes, with 5% and 8.9% incorrect predictions for the sweet and nonsweet classes, respectively.

**Table 5** exhibits the testing outcomes of the models employing the hyperparameter value of $10^{-4}$. As the table indicates, these four models have achieved high accuracy, precision, recall, and F1 scores. The highest accuracy was achieved by EfficientNet B4, indicating that the model performed exceptionally well in predicting watermelon sweetness. The recall for this model also reached a value of 93.33%, indicating the ability of the model to capture all instances of the positive class (sweet/ripened watermelon). Good performance was also achieved by EfficientNet B4, ResNet-50, and ShuffleNet V2, with accuracy in the range of 81.11% to 85.56%.

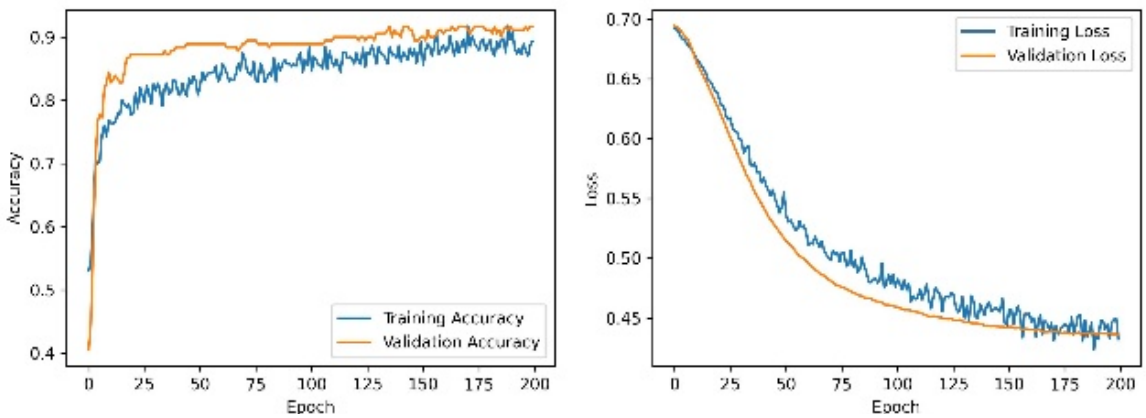
**Figure 6**
Learning curves of the EfficientNet B4 model.




(a) Learning rate: $10^{-3}$

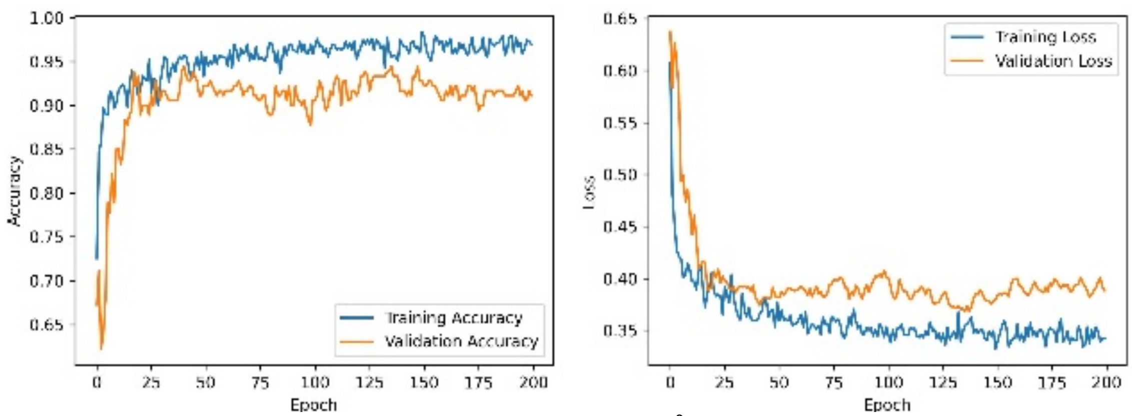



(b) Learning rate: $10^{-4}$

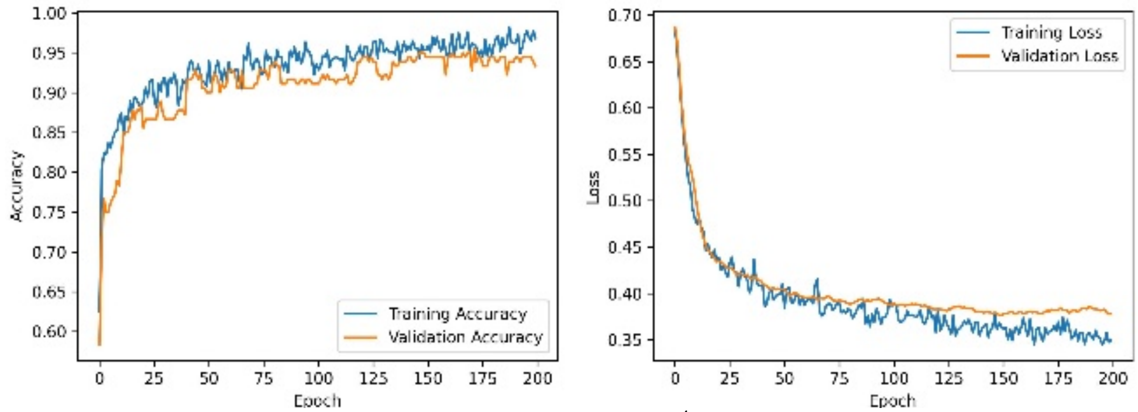



(c) Learning rate: $10^{-5}$

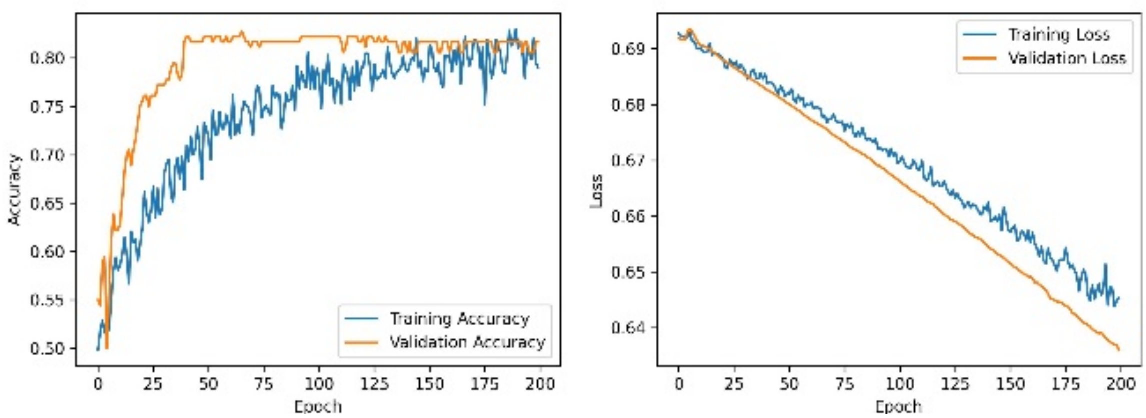
**Figure 7**
*Learning curves of the EfficientNet B7 model.*




(a) Learning rate: $10^{-3}$



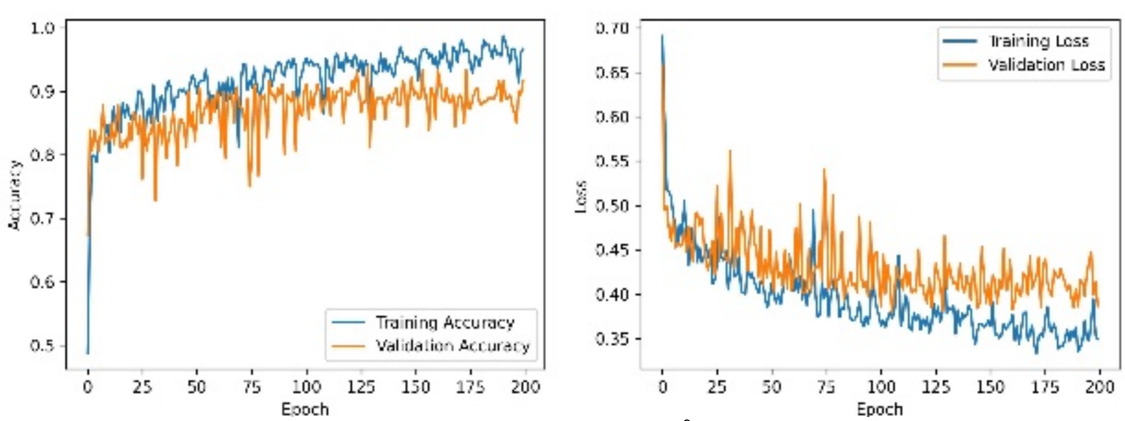

(b) Learning rate: $10^{-4}$



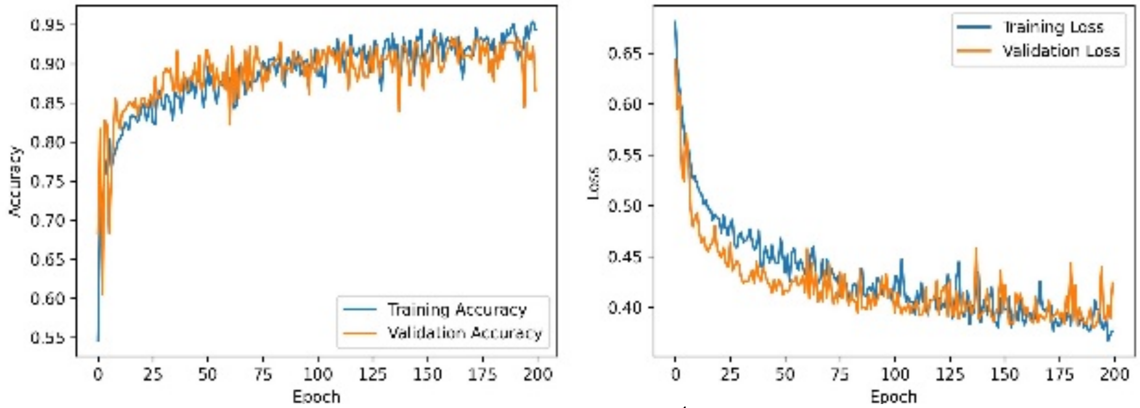

(c) Learning rate: $10^{-5}$

**Figure 8**

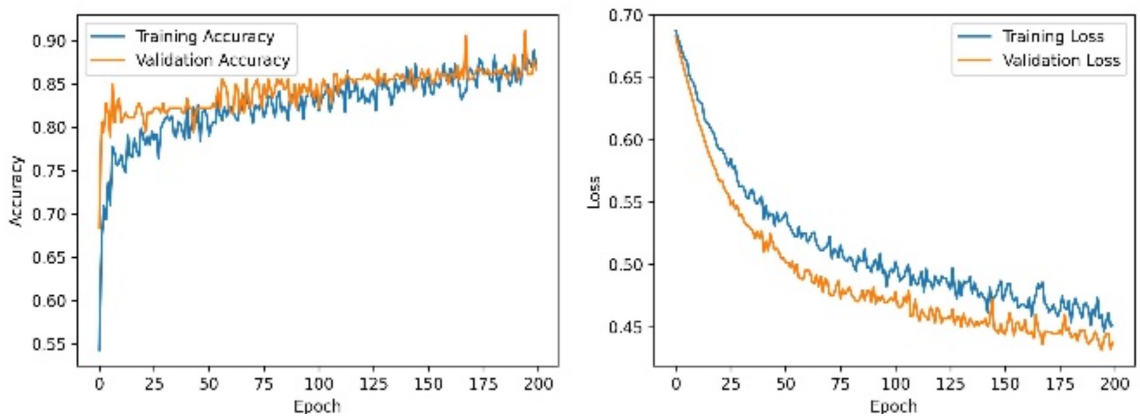
*Learning curves of the ResNet-50 model.*




(a) Learning rate: $10^{-3}$

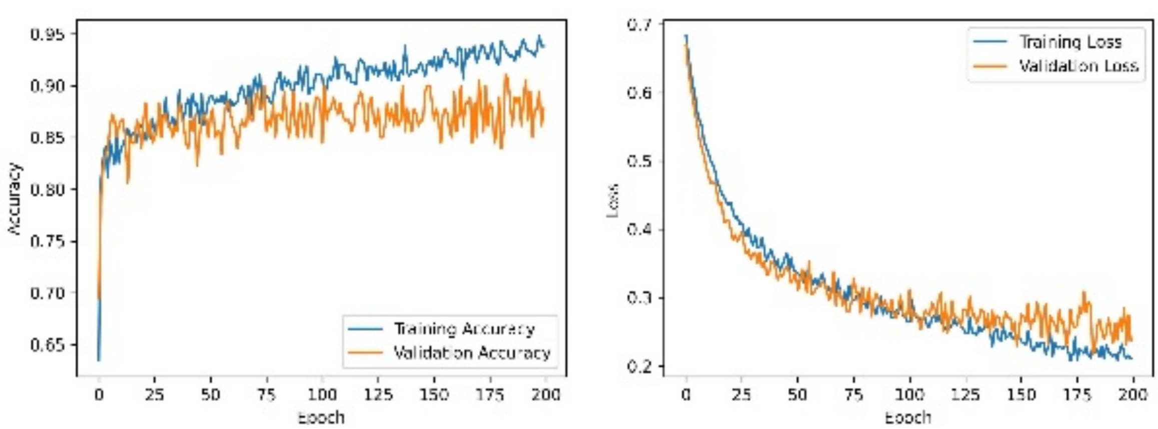



(b) Learning rate: $10^{-4}$

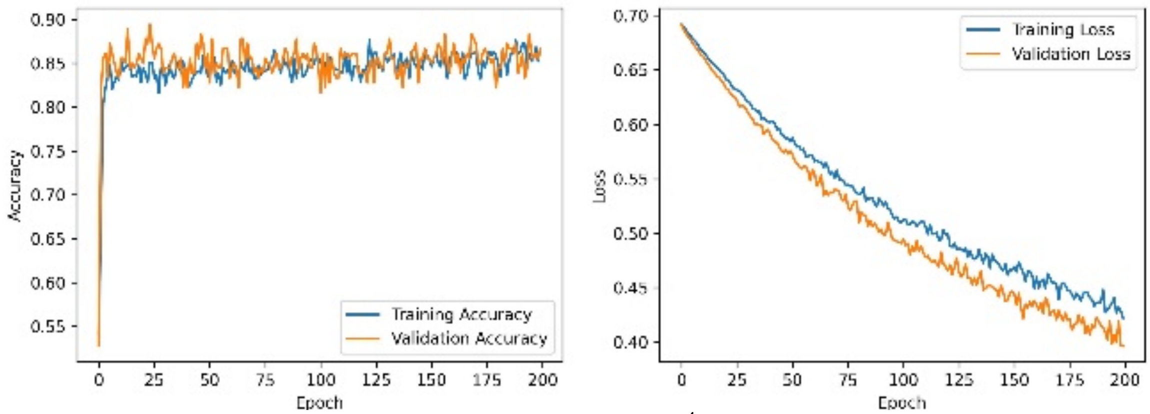



(c) Learning rate: $10^{-5}$

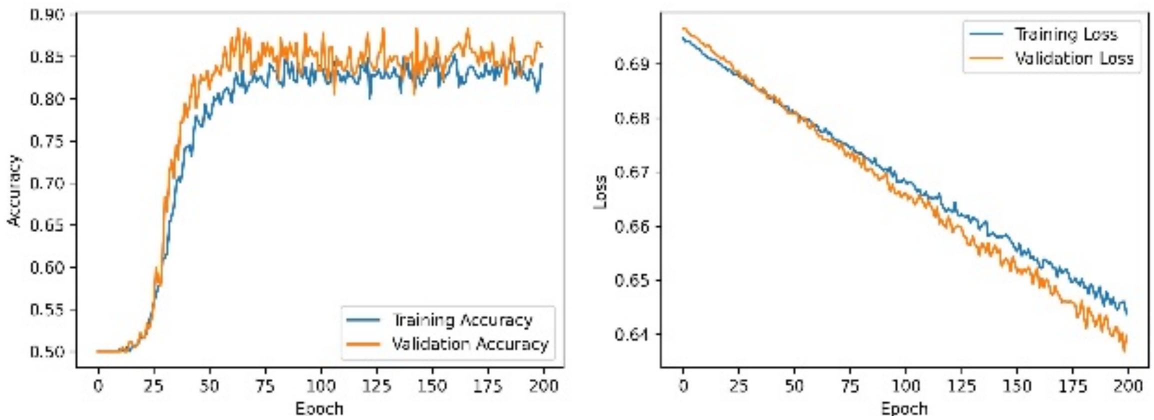
**Figure 9**
*Learning curves of the ShuffleNet V2 model.*



(a) Learning rate: $10^{-3}$




(b) Learning rate: $10^{-4}$




(c) Learning rate: $10^{-5}$

**Table 5**
*Results for Each Architecture with a Learning Rate of $10^{-4}$*

| Architecture | Accuracy | Precision | Recall | F1-Score |
|---|---|---|---|---|
| **EfficientNet B4** | 0,9222 | 0,9130 | 0,9333 | 0,9231 |
| **EfficientNet B7** | 0,8556 | 0,8810 | 0,8222 | 0,8506 |
| **ResNet-50** | 0,8333 | 0,8409 | 0,8222 | 0,8315 |
| **ShuffleNet V2** | 0,8111 | 0,8181 | 0,8 | 0,8090 |

**Figure 10**
*Confusion matrices for each architecture, employing a learning rate of $10^{-4}$.*

| | | | |
|---|---|---|---|
| Predicted Label | Sweet | **41** 45,6% | **4** 4,4% |
| | Not Sweet | **3** 3,3% | **42** 46,7% |
| Efficient-Net B4 | | Sweet | Not Sweet |
| | | True Label | |

(a) EfficientNet B4

| | | | |
|---|---|---|---|
| Predicted Label | Sweet | **40** 44,4% | **5** 5,6% |
| | Not Sweet | **8** 8,9% | **37** 41,1% |
| Efficient-Net B7 | | Sweet | Not Sweet |
| | | True Label | |

(b) EfficientNet B7

| | | | |
|---|---|---|---|
| Predicted Label | Sweet | **39** 43,3% | **6** 6,7% |
| | Not Sweet | **8** 8,9% | **37** 41,1% |
| ResNet-50 | | Sweet | Not Sweet |
| | | True Label | |

(c) ResNet-50

| | | | |
|---|---|---|---|
| Predicted Label | Sweet | **37** 41,1% | **8** 8,9% |
| | Not Sweet | **9** 5% | **36** 40% |
| ShuffleNet V2 | | Sweet | Not Sweet |
| | | True Label | |

(d) ShuffleNet V2

## CONCLUSION

This study proposed a novel deep-learning model for detecting the sweetness of watermelon based on the physical appearance of the field spot. The degree of sweetness is categorised into two groups: sweet and nonsweet. A preliminary evaluation was conducted using four robust CNN frameworks: EfficientNet B4, EfficientNet B7, ResNet-50, and ShuffleNet V2. The evaluation revealed that the EfficientNet B4 model outperformed the other algorithms with an accuracy of 92.22%. This outcome is also supported by the confusion matrix results, indicating that EfficientNet B7 predicts results with a minimal error of 7.7%. Nevertheless, further experiments should be conducted by tuning the hyperparameters, such as the batch size, learning rates, number of epochs, and optimiser, to determine the best combination for each algorithm. Furthermore, transfer learning and pretrained model experiments should be conducted to leverage existing knowledge and achieve better performance.

## ACKNOWLEDGMENT

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# LEEAF: Olive Leaf Infection Detection Using Artificial Intelligence

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**ABSTRACT**

*Olive trees, which civilisations have cultivated for thousands of years, offer a compelling case study of disease diagnosis on plant leaves. These venerable trees are susceptible to various diseases, but diagnosing them is far from straightforward. The symptoms of diseases affecting olive leaves can vary extensively between olive trees and even within individual leaves on the same tree. This inherent complexity, combined with the olive groves' vulnerability to pathogens like aculus olearius and olive peacock spot, has impeded the development of robust and effective disease detection algorithms. The LEEAF framework has been developed to confront this multifaceted challenge head-on. Our approach amalgamates cutting-edge deep learning techniques, drawing upon convolutional neural network (CNN) models and vision transformer models while harnessing the power of cloud computing through AWS Recognition to create a system that can accurately detect and classify diseases commonly affecting olive leaves. LEEAF is structured in a* three-tiered fashion, comprising the Cloud, Edge, and Far Edge layers that work in unison to share *information and data, including but not limited to olive tree images, weather forecasts, and ML predictions. Each layer possesses distinct capabilities in processing power, data storage resources, and power reserves, enabling them to excel at different process stages. This holistic approach empowers LEEAF to identify trees suffering from infection or infestation accurately. Meticulously labelled datasets that encompassed over 2000 instances of olive leaves in various conditions were used to experiment with different ML models and operations. Our multi-tiered approach offered scalability and efficient infrastructure usage, yielding highly promising results. The models developed by LEEAF demonstrated remarkable accuracy, achieving approximately 99.6% for multiclass classification, showing the potential of deep learning models in tackling the intricate and nuanced challenges presented by olive leaf disease detection.*

**Keywords:** *UAVs, machine learning; olive pests and diseases; diagnosis, smart farming*

## INTRODUCTION

In the ever-evolving landscape of agricultural research, applying deep learning techniques for disease detection has emerged as a prominent and imperative area of study, particularly in recent years. This surge in interest is driven by the potential for deep learning methods to revolutionise how we identify and mitigate plant diseases (Cruz et al., 2017). Despite the significant progress made in this field, it is not without its challenges, chief among them being the vast diversity of plant species and their unique regional characteristics. Traditional agriculture is being transformed by the Fourth Industrial Revolution, with Smart Farming and IoT solutions revolutionising the sector (Kalyani & Collier, 2021; O'Grady et al., 2019). Plant diseases, like Bactrocera Oleae and Aculus olearius, pose a significant challenge, causing substantial yield losses. LEEAF addresses these using UAVs and advanced technology to detect and diagnose olive leaf pests and diseases, enabling timely and sustainable treatments. UAVs effectively capture crop and leaf images, monitor crop health, and boost agricultural productivity (Uddin et al., 2021). End-user applications simplify UAV device control and image review, providing easy access to vital information. In the context of LEEAF, we leverage cutting-edge technology to empower farmers with insights for efficient olive grove inspection, regardless of the grove's size or location, marking a significant advancement in agriculture.

State-of-the-art ML technologies like **Transfer Learning (TL)** are used to develop LEEAF. **TL** involves leveraging knowledge from one pre-trained model to improve performance on related tasks. We can achieve impressive results by utilising pre-trained models as a starting point and fine-tuning specific parts for the new task, especially when the available data is limited. Additionally, on top of the use of TL, other technologies can be useful for exploring the domain of leaf classification and disease identification. Convolutional Neural Networks (CNNs) are potent deep learning models tailored for computer vision tasks (Harakannanavar et al., 2022). They excel at automatically extracting meaningful features from visual data, proving vital in numerous applications like image classification, object detection, image segmentation, and image generation. Residual Neural Network (ResNet) is a highly regarded CNN architecture. It was originally trained on the ImageNet dataset, making it adept at learning intricate image representations. Its pre-trained layers can be used for transfer learning, achieving remarkable performance with limited annotated data. Very Deep Convolutional Network (VGG), another notable CNN architecture, also benefits from ImageNet training. Leveraging its pre-trained weights and features extends its applicability to new tasks, particularly in data-scarce scenarios. DenseNet121, a variant of DenseNet, features dense connections between layers, enhancing feature reuse and gradient flow. This architecture performs well with limited data, efficiently transferring knowledge. MobileNetV2 is tailored for resource-constrained environments. It uses depth-wise separable convolutions to reduce computations and parameters while maintaining high accuracy, making it ideal for mobile and embedded devices. On the domain of leaf segmentation in images containing more than one leaf, the "You Only Look Once" (YOLO) framework stands out for its remarkable speed, bypassing intricate pipelines. It is an excellent choice for real-time processing, simplifying the development of custom models.

## METHODOLOGY AND RESULTS

LEEAF uses two base pillars for its AI operations: the leaf extraction and classification models (Alshammari et al., 2022). The first one receives the raw images collected and extracts from them each leaf that can be identified. This operation uses a YOLO-based ML model that has proven easy to train and reliable enough to use under any conditions. The second one uses an ML model based on the ResNet50 or VGG19, which has proven to be among the best-performing models we have identified and the AWS Recognition cloud service.

### Leaf Extraction

This YOLO-based ML model outputs a set of bounding boxes and segmentation masks that describe the location of each detected object in the images provided as input. To evaluate how the different sizes of YOLO base models can affect the performance of our system, we tested with all 5 YOLO base model sizes. We found that the medium ones guaranteed the best performance. This can be attributed to many reasons, but we mainly believe that smaller models are not elaborate enough to differentiate between leaves, tree branches, and ground vegetation. In comparison, larger models can differentiate between more than one class (i.e., detecting people, cards, and bikes) instead. The score of each model is presented in Table 1. For the evaluation of each model, we used the same set of input images we collected from our on-field experiments and labelled using the TrainYOLO online tool.

**Table 1**
*Scores on the leaf detection on the test dataset for the different YOLO-based models*

| Base Model Size | Nano | Small | Medium | Large | Extra Large |
|---|---|---|---|---|---|
| Precision | 0.751 | 0.643 | 0.742 | 0.505 | 0.411 |

### Leaf Classification

To classify the extracted leaves, we need to judge whether they are healthy or unhealthy and the pathogen that has affected them. Our experiments tested only two pathogens, aculus orealus and peacock spot. The images we used for training and evaluating our dataset were from the Olive Leaf dataset available online. As mentioned, we focused on two ML models that have proven more accurate in the results: ResNet50 and VGG19. ResNet-50 is a deep neural network architecture known for its excellent performance in image classification tasks (Ksibi et al., 2022). VGG19 is a 19-layer-deep convolutional neural network that can, on its own, classify images into 1000 object categories. These networks are re-trained to produce results in our application domain, classifying the provided images into one of our three categories. Our cloud-based AWS Recognition tool was trained and evaluated with the same dataset. Overall, we used 980 train and test images to evaluate these models.

All three options performed quite well, reaching an accuracy score of over 98%, showing they all can be considered equally capable. In more detail, the VGG19 achieved the lowest accuracy with 98,2%, followed by ResNet50 with 99.3%, and finally, Recognition with 99.6%. As we cannot interfere with the training procedure of Recognition, we can assume that the generated model results from an optimisation done by the AWS backend to provide us with the best possible option. The other two can be further fine-tuned by tweaking their training parameters to reach even better scores.

The main drawback of using AWS's tool is that its execution needs to happen in the cloud and cannot be transferred to our hardware (e.g., an edge device or a mobile phone). This is important in AI and ML applications to avoid sharing personal data and transferring large volumes of data from the on-site infrastructure to the cloud services (Kalyani & Collier, 2021). While ResNet50 and VGG19 do not achieve the best performance possible, their use is preferred in Edge-Based application environments.

## CONCLUSION

The integration of computer vision technologies with drones offers an exciting avenue to transform the identification of leaf infections in olive trees. By leveraging the capabilities of computer vision algorithms and aerial monitoring, agricultural professionals and researchers can access valuable information about the well-being of olive tree orchards. They can detect infections early on and enact precise measures for efficient disease management. With ongoing technological advancements, the future promises substantial opportunities to enhance olive tree health and ensure the sustainability of olive production.

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# Image Detection Using YOLOv7 Algorithm to Detect the Moulted Crabs

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## ABSTRACT

*Edible crab commercial exploration is expanding quickly on a global scale. Crab production in Malaysia from both aquaculture and fishing was about 16,074 tonnes last year. Soft-shell crab is one of the most valuable marketing formats. To produce high-quality soft-shell crabs, they are harvested by removing them from the water within 2-3 hours after they have been moulted to stop the shell from hardening. Thus, local soft-shell crab farming could not further develop a large-scale production to meet the market demands due to the dependence on labour-intensive and high mortality rate of crabs. These expenditures increase the impact of any expansion of intense culturing. A harmless, quick, and automatic approach to identifying moulting is a significant development in soft-shell crab farming and marketing. This study investigates the pivotal role of image preprocessing using the YOLOv7 algorithm to identify the moulted crabs in developing an IoT-embedded video and real-time monitoring system. One hundred twenty images dataset of crabs in the containers were acquired using an Internet Protocol (IP) wireless camera at a crab farm. The dataset is labelled and split into an appropriate ratio, where a significant percentage of the data was used for training the model, and the remaining was to validate its performance. The result of the system shows an average Intersection over Union (IoU) of 53.75%, average Precision of 96.67%, Recall of 50.41%, and mean Average Precision (mAP) of 62.50%. In conclusion, the findings of this study validated that YoLov7 is an efficient algorithm with high accuracy in monitoring the crab moulting processes for a soft-shell crab' farm. The study is currently working on improving its Recall and mAP.*

**Keywords***: Soft shell crab; Image detection; YOLOv7, IoT; Real-time monitoring*

# Measuring Leaf Area Using AutoCAD

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## ABSTRACT

*Leaf area can be determined by regression equitation, grid count method, gravimetric method, planimeter or image processing-based algorithm method. In this paper, AutoCAD was applied to measure the leaf area of oil palm. The image of the leaf was acquired using a printer scanner and stored in JPEG format. The image was uploaded to the AutoCAD 2014 software. The actual length of the biggest width of the leaf was measured first to be used for the reference length in AutoCAD. The area of the image was automatically calculated by drawing the line along the leaf perimeter using POLYLINE tools in the software based on the coordinates at the leaf perimeter principle. The mean leaf area of twenty sampled leaves of oil palm obtained was compared with the results of the Manual Method using grid count and the Calculation Method based on estimates using the formula. The mean value of the Calculation Method was shown with the highest leaf area of 1438.67 cm$^2$, followed by the Manual Method and AutoCAD method with 1153.67 cm$^2$ and 1141.00 cm$^2$, respectively. The three methods had no significant differences, as ANOVA indicated a p-value of 0.253. There was only 1.1 percent difference between the Manual Method and the AutoCAD Method compared to the 24.7 percent difference between the Manual Method and the Calculation Method. The AutoCAD Method was concluded to be more efficient and accurate in determining the leaf area of oil palm.*

**Keywords:** *AutoCAD; leaf area; oil palm*

## INTRODUCTION

In 2022, palm oil was the biggest contributor to the Malaysian gross domestic product (GDP), with a 4.9 percent share of the total 8.9 percent share in the agriculture sector in Malaysia (Statista, 2023). As oil palm makes a significant impact on the Malaysian agriculture sector, it is important to enhance the production of oil palm. Yield production is highly dependent on the growth performance of oil palm.

The leaf area is an important part of the oil palm for identifying growth performance. It is highly correlated with photosynthesis, transpiration, evapotranspiration, and inspecting pests and diseases in that area (Marlon et al., 2011). According to Chaudhary et al. (2012), the measurement of leaf area can be done by destructive and non-destructive methods. The destructive method requires the removal of the leaf from the plant to be measured, while the non-destructive method is a direct measurement without removing the leaf from the mother plant. The traditional methods for leaf area measurement commonly used are the grid count method, hand-planimetry, gravimetric method, dot counting, photoelectric planimetry, air flow, linear measurement of leaves, leaf weighing, detached leaf counting and the rating method (Pandey & Hema, 2011). In the report of Chaudhary et al. (2012), a simple, fast and accurate algorithm for leaf area measurement using image processing was introduced. Two approaches in oil palm can determine leaf area. based on manual or calculated methods (Jonckheere et al., 2004). In the manual or planimetric method, leaf area, the leaf perimeter, can be measured with a planimeter, and its area is computed based on the correlation between individual leaf area and the number of area units covered by that leaf in a horizontal plane. In the calculated method, the leaflet is measured using the length and mid-width and estimated using the formula rla=2n x b where rla stands for mean area per leaf, N is the number of leaflets on one side and b is the length x width (Corley & Breure, 1981).

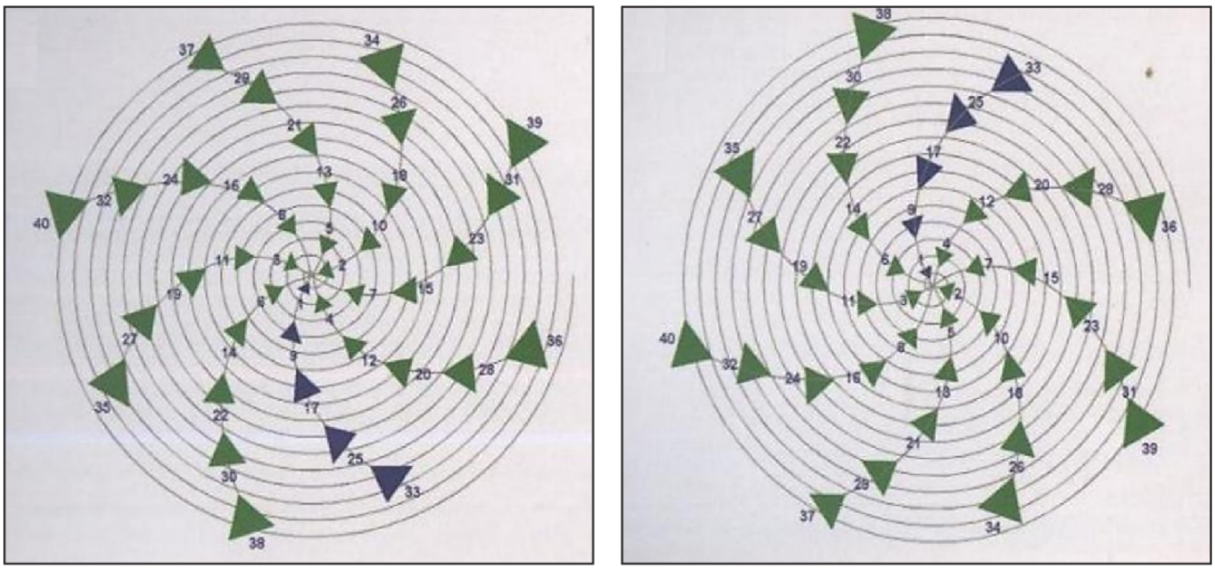
AutoCAD is a commercial software application for 2D and 3D computer aid design (CAD) and drafting, available since 1982 as a desktop application used for engineering and surveying work (Cohn, 2010). With the aid of a digital camera to create an image, the application of AutoCAD was described by Tian et al. (2008) as a rapid and non-destructive method for measuring the leaf area of landscape plants with a needle or small leaf. The limitation was that the same distance of the camera had to be maintained to take the picture so that only one calibration was needed in AutoCAD. The destructive method could resolve it by scanning the leave to capture the image with a scanning printer. This has been done by Rico-Garcia and Hernandez (2009).

This paper describes the methodology used to prepare oil palm leaf for image acquisition, image processing, and leaf area calculation using AutoCAD. Two other methods, the direct manual method using grid count and the indirect method using a calculation based on a formula, were carried out for validation.

## METHODOLOGY

20 leaf samples from Frond 17 from six years' oil palms were taken in the morning due to low-level sunlight exposure to the leaflet of oil palm. Frond 17 was identified as a fully open frond at the terminal shoot as the frond 1 counting downwards where on the left or right of the shoot depending on the left-handed and right-handed harvesting pattern shown in Figure 1.

**Figure 1**
*Graphical Representation of Oil Palm Spiral with Left-Handed Spiral (a) and Right-Handed Spiral (b) (Fairhust, 1998)*



(a) (b)

The Frond 17 was cut at the base and removed from the palm. At the point on the rachis where the flat top changed to an angular shape, approximately two-thirds along the frond from the base was located, and four adjacent leaflets from each side were selected and detached with a sharp knife. The central one-third of each leaflet was then cut and placed in a clean, labelled polythene bag. Twenty samples were used for leaf area determination using three methods, and the analysis of variance (ANOVA) of data was computed using IBM SPSS Statistic 21.

## AutoCAD Method

The actual length of the biggest width of a sampled leaf was measured first to be used for calibration for the reference length in AutoCAD for all sampled leaves. Each sampled leaf was cut into segments and inserted in a transparency file to ensure the leaf would not get twisted or curled. Then, the image of the plant leaf was acquired using a scanner and saved in JPEG format. It is important to ensure that the picture was taken parallel to the surface where the leaf segments were placed to maintain a fixed distance for scale factors to be the same for all images. The scanned image was then uploaded into the AutoCAD software version 2014, as shown in Figure *2*. Figure 3 shows measuring the leaf area of oil palm using the AutoCAD software.

**Figure 2**
*Uploaded Image of the Scanned Oil Palm Leaf Saved in JPEG Format into the AutoCAD Software*

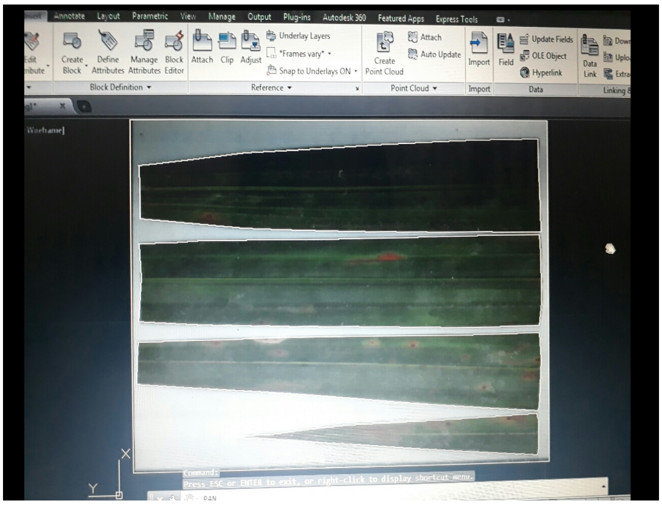
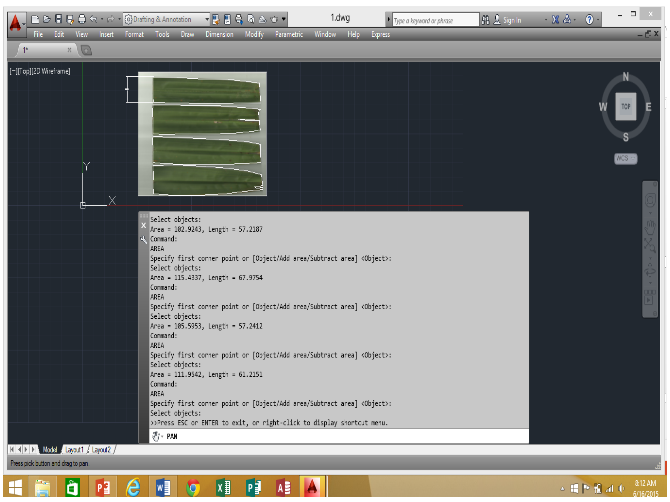



**Figure 3**
*Measuring Leaf Area of the Oil Palm in the AutoCAD Software*




Once the image was in the workspace of the AutoCAD software, sized to its real scale, a continuous line was plotted around the leave using the POLYLINE command to form a closed object. The area of the object would be calculated automatically. The process is described in Table 1.

**Table 1**
*Steps of Measuring Leaf Area Using AutoCAD Version 2014*

| Steps | Description of action | Command | | |
|---|---|---|---|---|
| | | Comm | Start | End |
| 1 | Attaching the image in AutoCAD work | In ordinary way | | |
| 2 | Knowing the dimension before scaling the image | In ordinary way | | |
| 3 | Scaling the image to real scale | Scale | | Enter |
| 4 | Selecting the image to specify scale factor | r | Enter | Enter |
| 5 | Specify the new length of the object based on the actual size of the biggest width of leaf | | | Enter |
| 6 | Ensure the length of leaf is same. | Dist | | Enter |
| 7 | Drawing a close line around the leaves. | Pline | | Enter |
| 8 | Knowing the area of the leaf image by selecting the line of the leaves. | Area | Enter | Double Enter |

The sampled leaf was cut into segments and inserted in a transparency file to ensure the leaf would not get twisted or curled. A photocopied transparency grid of one cm x one cm prepared from graph paper was placed over the leaf. The leaf area was manually determined by counting the grids overlapping the leaf.

### Calculation Method

The length and midpoint of the sampled leaf were measured using a measuring tape. The leaf area was calculated based on equation (1).

$$A = 2n \times b \quad (1)$$

where n was the width of the midpoint of the leaflet on one side and b was the length.

## RESULTS AND DISCUSSIONS

Table 2 shows the mean leaf area obtained from the three methods used for the same twenty sampled leaves. The mean value of the Calculation Method was shown with the highest leaf area of 1438.67 $cm^2$. It was followed by the Manual Method, which recorded the mean leaf area of 1153.67 $cm^2$ while the AutoCAD method obtained 1141.00 $cm^2$.

**Table 2**
*Comparison of Mean Leaf Area ($cm^2$) from AutoCad, Manual and Calculation Methods*

| No | Method | Mean | Standard Deviation |
|---|---|---|---|
| 1 | AutoCAD | 1141.00 | 134.842 |
| 2 | Manual | 1153.67 | 219.246 |
| 3 | Calculation | 1438.67 | 282.797 |
| | Total | 1244.44 | 240.427 |
| | ANOVA @ $\alpha = 0.05$ | | p = .253 |

However, there were no significant differences among the three methods, as ANOVA indicated a p-value of .253. There was only a 1.1 percent difference between the Manual Method and the AutoCAD Method compared to the 24.7 percent difference between Manual Method and the Calculation Method. The standard deviation of the AutoCAD method was shown to be the lowest, while the Calculation Method was the highest. This would be expected as the Calculation Method described by Corley and Breure (1981) was based on estimates and thus indicated that this method would give an overestimated value of mean leaf area. The manual Method was accepted to be accurate but labour-intensive and has since been replaced by indirect methods like the Calculation Methods. Or, most recently, digital methods using imaging analysis.

AutoCAD would be the method to provide the most accurate leaf area as the method had the ability to trace the tooth area and other related features at the perimeter of the leaf. The findings of Hong and Jufen (2003) showed there were close relationships between the CAD image processing method and the other traditional methods like the grid-counting method, leaf-copy and weighing method and instrumental scanning method. Similarly, in the report of Tian et al. (2008), AutoCAD provided a non-destructive method for measuring the leaf area of leaf captured by a digital camera. In comparing the results with traditional methods that included the grid method, paper-cut method and instrumental scanning method, the value measured was significantly correlated with those measured by the traditional methods and thus concluded that the AutoCAD method was suitable for measuring the leaf area of plants with needle leaf or small leaf. However, for big leaves like oil palm, it was necessary to employ a destructive method, thus allowing the capturing of the image by using a scanner, which overcame the limitation of digital camera image whereby there had to be a constant picture of the camera to the intended measured leaf sample and ruler as an indicator for actual scale. The method described, therefore, was found to be more efficient and accurate.

## CONCLUSION

Leaf area measurement is important for ensuring the productivity of oil palm yield it describes a fundamental property of the oil palm canopy related to the growth and metabolism of plants, as well as the accumulation of dry matter and yield. The traditional Calculation Method was an overestimated value. The Manual Method using grid lines overlapping the leaf was assumed to be an accurate value. However, it was tedious and time-consuming. It was also based on some estimates of grid count at the irregular leaf edge. Therefore, it can be concluded that the AutoCAD method provided a reliable method, and the process was very efficient, accurate and user-friendly in estimated leaf area.

## ACKNOWLEDGEMENT

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# A Short Course on IoT

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**ABSTRACT**

*We present a short course on the Internet of Things designed to give a first understanding of the main issues in developing IoT solutions. The course is organised into four main sessions of 3 hours each. The first session introduces the main IoT concepts. It focuses on the relationship of IoT with Big Data and the constraints introduced by the limited availability of resources on IoT devices. The second session is focused on hands-on. To simplify the experiments, we exploit a convenient online simulator and Arduino IDE, focusing on the maker approach, namely in doing the right thing with minimal consideration in terms of efficiency. The third session focuses on the engineering approach where efficiency is crucial and introduces a more advanced developing tool based on FreeRTOS, a Real-Time Operating System for embedded devices. The last session introduces IoT-LAB, an infrastructure for multiple node experiments. The last section of the paper discusses the lessons learned in the first edition of the course and introduces possible future work. All the material for the course is available at "A Short Course on IoT" (n.d.).*

**Keywords:** *Course plan; Education targets; Maker approach; Experimentation infrastructure; IoT deployment*

## INTRODUCTION

This paper presents a short course on the Internet of Things designed to give a first understanding of the main issues in developing IoT solutions. The course is organised into four main sessions of 3 hours each.

The first session provides (see section 2) an introduction to the Internet of Things. In particular, we investigate the connection between the IoT and Big Data. In our vision, IoT is the fuel of Big Data, allowing us to quantitatively measure phenomena that, up to yesterday, we were only able to guess. Thanks to such measures, we can build models to understand the observed phenomena better and predict future behaviours. This way, we build actionable intelligence that allows us to act in the environment consciously. However, it is crucial to understand that IoT means a network of resource-constrained devices: if computational power, memory, energy, bandwidth, and costs are not constrained, it is likely the Internet, not the Internet of Things. Such constraints need the introduction of concepts such as edge-computing and duty cycles.

We believe experimenting is the most efficient way to learn this subject. Consequently, the course encourages attendants to put their hands on it. No background is needed, even if basic electronics and computer science knowledge might help. The second session (see section 3) is designed to start experimenting with real devices. The main goal is to allow students to integrate sensors suitable for monitoring. In this session, we pursue the Maker approach; namely, we focus on effectiveness, i.e., doing the right things, without considering efficiency. The hands-on start on the very nice and practical simulator WOKWI ("Wokwi - Online Arduino and ESP32 Simulator," n.d.). It leverages the Arduino Programming language, allowing us to experiment with several hardware platforms and integrate various sensors and actuators in the simplest but realistic way. Indeed, after some simulations, students can upload their projects into real devices. In our case, we used the well-known ESP32 platform. We exploited the ESP32- DevKit, which provides WiFI and BLE connectivity. During the course, we stress that even if such technologies are not well suited for the IoT, they represent a very practical means of experimenting with the IoT. Furthermore, Heltec provides an ESP32 device supporting LORA ("ESP32 Series — esp32 latest documentation," n.d.).

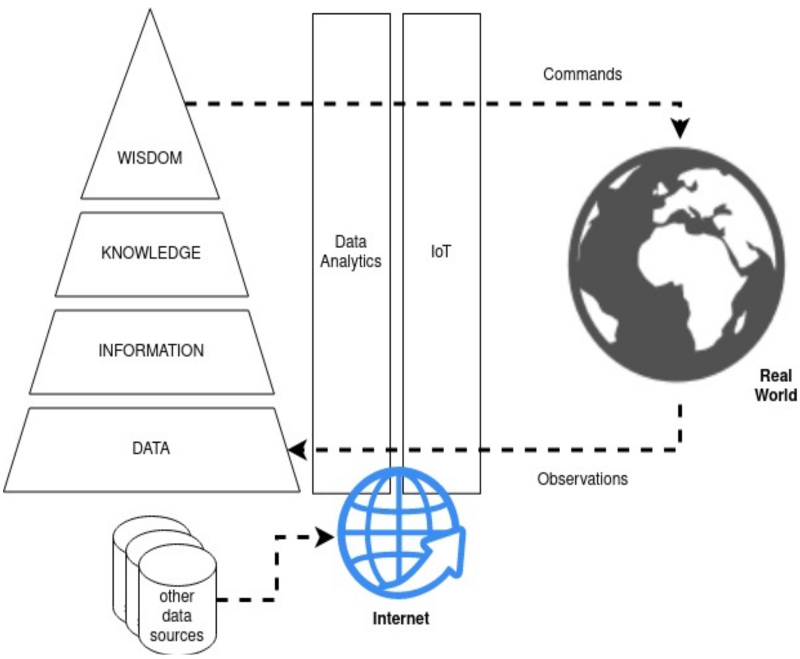
Once students have familiarised themselves with simple projects, it is time to clarify that the Maker approach is insufficient. Session 3 (see section 4) is designed to introduce the Engineering approach focused on efficiency, namely doing things right. The main concept here is that we need metrics to measure how much our solution satisfies the user requirements. An interactive approach that, step after step, converges toward a satisfactory solution is encouraged. Only clear metrics allow us to measure to what extent we indeed converge. Furthermore, while the Arduino programming language is a very nice introduction, we discuss the need for a more sophisticated RTOS supporting multitasking, Real-Time Applications and Real-Time Scheduling. To this purpose, in this section, students experiment with FreeRTOS ("FreeRTOS," n.d.) running on ESP32.

Finally, session 4 (see section 5) is designed to scale up the solutions developed in the previous sessions in a testbed supporting many nodes. We introduce the IoT-LAB ("FIT IoT-LAB.," n.d.), a large-scale infrastructure suitable for testing small wireless sensor devices and heterogeneous communicating objects. Furthermore, IoT-LAB allows us to measure the use of resources on the nodes conveniently so that students can easily understand the impact of simple duty-cycle approaches.

All the material for the course is available at "A Short Course on IoT" (n.d.). The course design leverages the experience of teaching IoT in the MSC in Computer Engineering at Sapienza University of Rome (Chatzigiannakis, n.d.).

The paper concludes with section 6, in which we discuss the lessons learned during the first edition of the course and introduce possible future work.

**Figure 1**
*The IoT allows us to observe real-world phenomena at an unprecedented level of granularity and to consciously act in the environment in view of informed decisions obtained by analysing the collected data.*



## INTRODUCTION TO THE INTERNET OF THINGS

The course is designed to be an introduction to the IoT. Most people relegate IoT to a convenient way to implement remote control by mobile phones. This is a nice feature of the IoT, but we believe IoT should be placed in a wider perspective. Lord Kelvin, the father of the first and second laws of thermodynamics, said: “When you can measure what you are speaking about and express it in numbers, you know something about it”. The IoT is indeed a tool to measure phenomena at an unprecedented granularity level observed only qualitatively before the advent of such technology. In other words, the IoT fuels Big Data Analytics (Malek et. al., 2017). This is summarised in Figure 1. The IoT is made of resource-constrained devices connected to the Internet. Internet connectivity guarantees that IoT devices can be anywhere and interrogated at any time. The ubiquitous presence of IoT devices allows us to collect data on many phenomena at an unprecedented level of granularity. Such data, possibly enriched by other data available on the Internet, are distilled into actionable intelligence, thanks to data analytic tools such as Machine Learning. The actionable intelligence operates in the environment, commanding the actuators of the IoT devices. New monitoring data confirm the effectiveness of such actions in an iterative process trying to converge to optimal solutions. The main goal of the first session is to illustrate this vision. However, students must understand that the IoT is a network of resource-constrained devices. Nowadays, students deal with relatively powerful computers that provide GHz clocks, GB of RAM, Mbps connectivity, and high-capacity batteries that can be recharged daily. In contrast, a typical IoT device can have a MHz clock, hundreds of KB of RAM, a few Kbps of connectivity (e.g. LORA), and a battery with limited capacity that cannot be recharged easily. Moreover, the goal of ubiquitous deployments requires cost-effective devices that limit the quality of hardware components.

These constraints impose a careful design of the IoT solutions (Pereira et. al., 2020) and the employment of energy-aware approaches (e.g. duty-cycle) as well as delegating the computation to more powerful devices on edge, when possible, just to mention two possible approaches. Furthermore, to support access to low-level functionalities, IoT coding is mostly done in C or C++ languages, and in some cases, students need some time to familiarise themselves with such languages. Designing a reliable IoT solution requires moving from the maker approach, mostly focused on effectiveness, to an engineering approach where efficiency is a key design ingredient.

At the end of this session, as an exercise, students are encouraged to explore IoT projects presented on well-known platforms (e.g. Hacker Noon), identifying possible issues regarding the inefficient use of the resources.

### First Experiences with Real Hardware: The Maker Approach

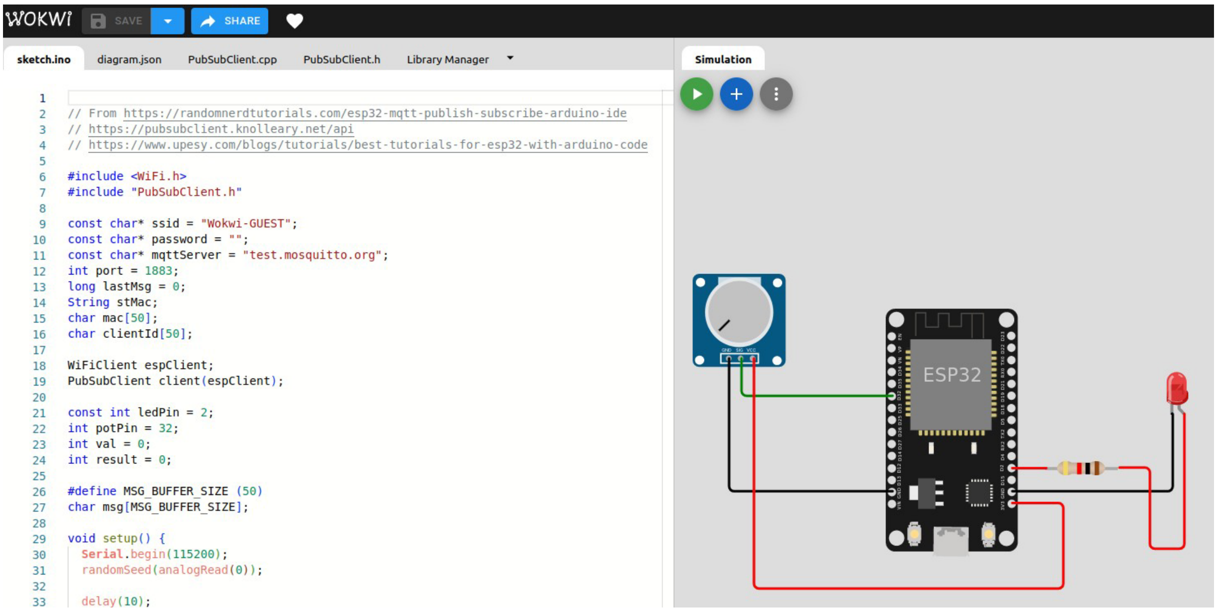
The main goal of this session is to put hands on. We believe this allows students to understand better the concepts discussed so far and have fun carrying out practical activities. Initially, we pursue the maker approach; namely, we focus on doing the right thing with minor concerns in terms of efficiency. To simplify this activity, we initially focus on WOKWI (“Wokwi - Online Arduino and ESP32 Simulator,” n.d.), an online tool capable of realistically simulating many popular boards, parts and sensors. In particular, we simulate an ESP32 programmed in the Arduino Programming language (see Figure 2) performing the following four main activities that will be replicated in the other sessions:

a) The simplest actuator, namely a led.
b) The simplest digital sensor is a button.
c) An analogue sensor, namely a potentiometer, is connected to the ADC.
d) A simple example is the SR04 Ultrasonic Sensor.
e) MQTT connectivity.

For convenience, these activities rely on WiFi connectivity. Still, from the beginning, it is very important to stress that this is a convenient option inappropriate in many IoT deployments, mostly due to its high energy requirements.

**Figure 2**

*A relatively complex simulation where the data acquired by the ADC connected to the variable resistor is delivered to a back-end via MQTT. Similarly, commands can be delivered to the code to switch the LED on/off.*




Once students are familiar with the above simulations, they are ready to experiment with real hardware. In particular, we exploit the ESP32-DevKit ("ESP32-DevKitC V4 Getting Started Guide," n.d.), a very flexible ESP32 platform which provides WiFi and BLE connectivity. Heltec ("ESP32 Series — esp32 latest documentation," n.d.) provides similar hardware supporting LORA connectivity.

Running the experiments on real hardware (see figure 3) is straightforward since WOKWI allow us to download the Arduino code corresponding to the simulations that can be conveniently uploaded to the ESP32 using the Arduino IDE ("Download and install Arduino IDE," n.d.).

A simple backend relying on Thingsboard (ThingsBoard, 2017) allows us to collect the data by MQTT visualise them in a nice dashboard and send MQTT commands to the ESP32 via a nice interface.

## The Engineering Approach: Measure Performance and Exploit an RTOS

This session is focused on two main goals: a) use metrics to measure to what extent your solution satisfies the user requirements, and b) introduce a real-time operating system (RTOS) more suitable for reliable IoT deployments.

For the sake of simplicity, we focus on a simple project based on "Accident study findings" (2016), a paper presenting the results of the accident study findings on household uses of gas. We quickly analysed the document in the class to identify a set of minimal requirements to detect fires in the proximity of gas cabinets and to inform the emergency centre promptly. Here, we focus on a single requirement to clarify the purpose of this activity, namely the need to detect a fire at 5 meters from the cabinet with an accuracy of at least 75% in at most 1 minute. We first analyse different sensors to detect fires. Then, we designed an experiment in which sensors were placed at different distances from the fire source to measure their ability to detect the episode reliably. Students experience concepts such as accuracy, false positives and negatives, and dependence on measures from relevant factors such as distance, the presence of the sun, etc. An iterative process to improve the original solution is encouraged, as well as the design of experiments to quantify the quality of the solutions in view of the user requirements.

**Figure 3**

*An ESP32 is connected to a breadboard with a lead and a button. The USB cable provides power and debug functionalities through the serial terminal.*

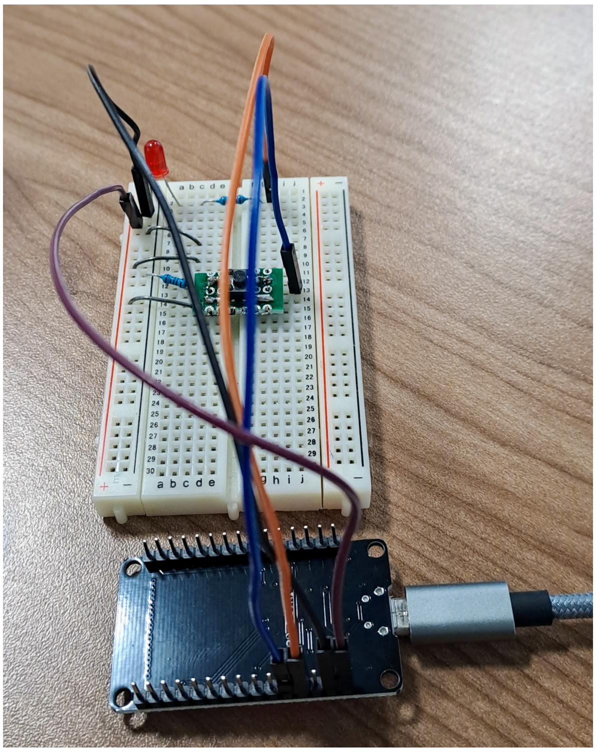


**Figure 4**

*A simple example is to blink two LEDs. On the left, the Arduino code is based on a single loop. On the right is the FreeRTOS code with multiple tasks.*

```
//Arduino code

void setup() {
// initialize digital pin
// LED_GREEN and LED_RED
// as an output.
}

void loop() { digitalWrite(LED_GREEN,
HIGH); digitalWrite(LED_RED HIGH);
delay(1000); digitalWrite(LED_GREEN, LOW);
digitalWrite(LED_RED, LOW); delay(1000);
}
}
```

```
//FreeRTOS code

led_red_blink(void *pvParams) {
gpio_pad_select_gpio(LED_RED); gpio_set_direction (LED_RED,
GPIO_MODE_OUTPUT);
while (1) {
gpio_set_level(LED_RED,0); vTaskDelay(1000/portTICK_RATE_MS);
gpio_set_level(LED_RED,1); vTaskDelay(1000/portTICK_RATE_MS);
}
}
// same structure for function led_green_blink
app_main() { xTaskCreate(&led_red_blink,"LED_BLINK",
512,NULL,5,NULL);
ate(&led_green_blink,"LED_BLINK", 512,NULL,5,NULL);
```

In the second part of the session, we introduce the need for Real-Time Operating Systems (RTOSs). Real-time requirements usually characterise IoT. Namely, IoT devices have to respond to a certain event within a strictly defined deadline. In the above example, we must detect the 1 minute. This requires a deterministic behaviour of the scheduler. In this session, we introduce FreeRTOS ("FreeRTOS," n.d.), a state-of-the-art RTOS that supports the ESP32. In FreeRTOS, the scheduler exploits the user's defined priorities to know which thread of execution to run next. The ability to split a program into tasks with different priorities implies a dramatically different approach to coding compared to the single loop of Arduino coding (see Figure 4).

Students analyse how to split the program into different independent tasks that can be coordinated when needed by mechanisms exploiting suitable OS functionalities. This activity is concluded by porting the activities encoded in session 2 (see section 3) in Arduino into FreeRTOS. A rich set of examples is available at https://github.com/espressif/esp-idf.

### Leverage Existing IoT Infrastructures

Up to this section, students have experimented with a single device with different tools at different levels of complexity. They proved to be able to integrate simple sensors and actuators on real hardware, communicate acquired data to a back-end, and get commands from it. However, real IoT deployments are usually made of multiple devices. To explore scalability issues, we leverage IoT-LAB ("FIT IoT-LAB.," n.d.). It is a large-scale infrastructure for testing small wireless sensor devices and heterogeneous communicating objects. IoT-LAB supports FreeRTOS code https://iot-lab.github.io/docs/os/freertos/, even if the ESP32 is not currently among the supported hardware. This proves to students the capability of FreeRTOS to run on heterogeneous hardware platforms with the same code. IoT-LAB allows us to experiment with ad-hoc networking and LORA, a communication technology more suitable for the IoT, interacting with The Thing Network, a global collaborative Internet of Things ecosystem that creates networks, devices and solutions using LoRaWAN. Finally, it also allows us to collect fine-grained data on the use of resources such as "Consumption monitoring" (n.d.), bandwidth, power consumption, etc., thus supporting the engineering approach introduced in the previous session.

## DISCUSSION AND FUTURE WORK

The first edition of the course was given in August 2003 at the University of Stellenbosch, Sudafrica, during an Erasmus+ teaching mobility exchange. Forty students among more than a hundred candidates have been selected to participate. Students provided positive feedback on the course and appreciated the hands-on (see the post on Linkedin https://acesse.one/bAvKP). Sessions 1,2 and 3 have been successfully delivered, while session 4 has been only introduced. In other words, 12 hours to deliver all the sessions is overoptimistic; realistically, all the sessions can be delivered in at least 16 hours.

All the material is publicly available on github ("A Short Course on IoT," n.d.). The choice of providing a VirtualBox appliance with the development environment and all the necessary toolboxes already deployed and configured has paid off. Likely, the most time-consuming activity in view of the heterogeneous OSs used by students (mostly Windows and MacOS in different flavours), has been setting up the SSH connection with the appliance and the interoperability with a local IDE (e.g. vscode). To simplify this issue further, the current version of the virtual appliance provides micro, a convenient text editor that can run on an SSH terminal.

This course is our attempt to summarise a minimal set of topics to introduce students to the IoT in view of the gained in teaching IoT in the MSC in Computer Engineering at Sapienza University of Rome (Chatzigiannakis, n.d.) . Several relevant topics, such as security, have not been considered with the goal of designing a simple and practical course to be delivered in a relatively short time. However, supplementary material on interesting issues, such as Kalman filters and machine learning on embedded devices, is already available. Depending on the course's length and the student's background, many extensions can be considered. However, we consider a deep understanding of the concepts introduced in sessions 1, 2 and 3 crucial to dealing with IoT beyond the maker approach.

The course material is always a work in progress, and we hope to improve it in view of the feedback provided by attendees, colleagues and experts. Collaborations are very welcome.

## ACKNOWLEDGEMENT

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# Sector Skills Gaps Findings in Industrial Revolution IR4.0

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**ABSTRACT**

*Technical skills that include data and IT are no longer enough for employees to compete in the highly competitive global industry shifting to industrial 4.0. Educational institutions are catching up and adopting the changes, but it is not as quickly as the industries expect. The curriculum has started by adopting the industry requirements from discussion and cooperation with industry to an initial extent. The required skill is still missing in terms of inter-discipline linkage. Not all graduates have the linkage of their major with IoT, IT, and data analysis. These findings are from focus group discussions across partner countries in the ERASMUS+ KA2 Capacity Building in the Field of Higher Education for the Project Master's in Science in Industrial 4.0. In addition, soft skills deficits exist in two areas: social competence skills and personal skills. They are paramount in the workforce at every level, needing agility, self-initiated learning skills, critical thinking, complex problem solving, creativity and innovation, and communication skills. The resistance to the changes in the work process is also encountered.*

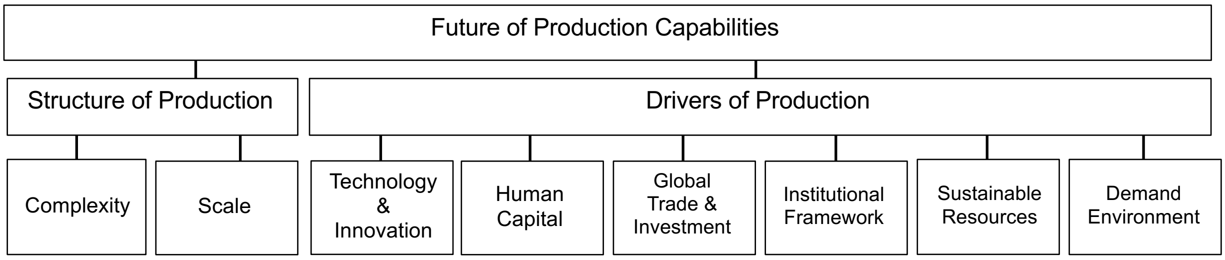
Keywords: *Industrial 4.0; Data and IT Skill; interdisciplinary linkage; Competence Skill; Personal Skill*

## INTRODUCTION

In 2022, the world's population reach 7.9 billion, with 29 billion connected devices predicted to interact with each other, of which around 18 billion will be related to the Internet of Things (IoT). The industry sector is increasingly becoming more interconnected, digital and flexible. The Fourth Industrial Revolution (IR4.0) has brought significant social and economic opportunities and challenges, requiring governments to respond appropriately (Manda & Dhaou, 2019). Cheong and Le (2022) chronologised that the Industrial Revolution began with the invention of steam-powered engines and hydraulic power for the mechanisation of manufacturing in the late 18th century. The arrival of electric power led to the second Industrial Revolution, said to occur in the early 20th century, becoming the driver of both mass production in industry and at home. The third Industrial Revolution was associated with the emergence of ICT for automation in industry, programmable logic controllers (PLCs) and the development of personal computers that began in the 1970s. The beginning of the 4th Industrial Revolution (IR4.0) in 2016 combined human and technological capabilities in industry, including cloud computing, beginning with the most technologically advanced countries. The many innovations such as artificial intelligence, big data analytics, simulation, systems integration, robotics, cloud systems, IoT, and augmented reality are also referred to IR4.0 as the "digital revolution."

The World Economic Forum (WEF, 2018, p. vii) revealed that as the IR4.0 unfolds, companies are seeking to harness new and emerging technologies to reach higher levels of efficiency of production and consumption, expand into new markets, and compete on new products for a global consumer base composed increasingly of digital natives. As workforce transformation is deemed to accelerate, the question is how ready business leaders across all industries and regions are to meet the challenges of this new era of accelerating change and innovation. In the same report, one of the key findings is the growing instability of skills. The World Economic Forum's Readiness for the Future of Production Report 2018 defines 'readiness' as the ability to capitalise on future production opportunities, mitigate risks and challenges, and be resilient and agile in responding to unknown future shocks. The assessment measures readiness for the future of production across two different components, Structure of Production and Drivers of Production, on a scale of 0 (worst score) to 10 (best score), as shown in Figure 1.

**Figure 1**
*Readiness Diagnostic Model Framework*




*(Source: World Economic Forum's Readiness for the Future of Production Report (2018, p.5)*

Note (Source: World Economic Forum's Readiness for the Future of Production Report (2018, p.6):

A country's Structure of Production depends on several variables, including the strategic decisions a country makes to prioritize sector development across agriculture, mining, industry and services reflecting the complexity and scale of a country's current production base

- Complexity: Assesses the mix and uniqueness of products a country can make as a result of the amount of useful knowledge embedded in the economy and the ways in which this knowledge is combined.
- Scale: Assesses both the total volume of manufacturing output within a country (Manufacturing Value Added) as well as the significance of manufacturing to the economy (Manufacturing Value Added, % of GDP).

Drivers of Production The framework's Drivers of Production are key enablers that position a country to capitalize on emerging technologies and opportunities in the future of production.

The three ASEAN countries, Malaysia, Indonesia and Cambodia benchmarked to the top 5 countries either in the Structure of production or Drivers of production is shown in Table 1. Japan has the highest Structure of Production score, followed by Korea, Germany, Switzerland and China until the 5th ranking. On the other hand, the United States performs the best across all Drivers of Production, followed by the next top five: Singapore, Switzerland, the United Kingdom and the Netherlands. Only Switzerland is within the top 5 in both components. Malaysia, ranking at 20 in the Structure of Production and 22 in Drivers of Production, is thus considered doing very well.

**Table 1**
*Readiness for Future Production for Cambodia, Indonesia and Malaysia*

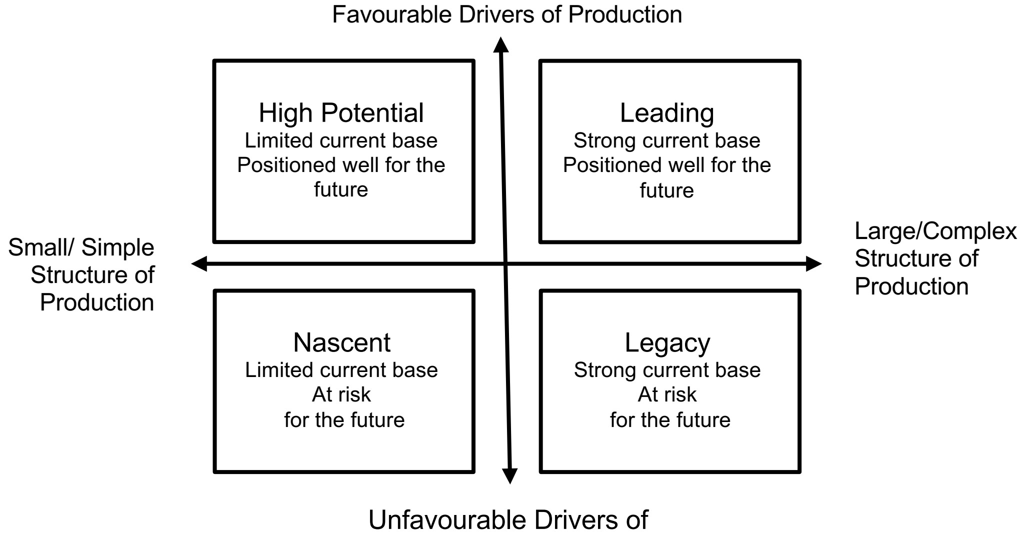
| Country | Archetypes | Structure of Production | | Drivers of Production | |
|---|---|---|---|---|---|
| | | Score | Rank | Score | Rank |
| Japan | Leading | 9.99 | 1 | 6.82 | 16 |
| Korea | Leading | 8.85 | 2 | 6.51 | 21 |
| Germany | Leading | 8.69 | 3 | 7.50 | 6 |
| Switzerland | Leading | 8.39 | 4 | 7.92 | 3 |
| China | Leading | 8.25 | 5 | 6.14 | 25 |
| United States | Leading | 7.78 | 7 | 8.16 | 1 |
| Singapore | Leading | 7.28 | 11 | 7.96 | 2 |
| United Kingdom | Leading | 7.05 | 13 | 7.84 | 4 |
| Netherlands | Leading | 6.32 | 26 | 7.75 | 5 |
| Malaysia | Leading | 6.81 | 20 | 6.51 | 22 |
| Indonesia | Nascent | 5.41 | 38 | 4.89 | 59 |
| Cambodia | Nascent | 3.56 | 81 | 3.63 | 91 |

*Source: World Economic Forum's Readiness for the Future of Production Report (2018, p. 12)*

The 4 Archetypes categories based on weighted Structure of Production and weighted Driver of Production scores from the top 75 countries are derived recognising that each country has its own unique goals and strategy for production and development and does not receive an overall global ranking from the World Economic Forum's Readiness for the Future of Production Report (2018, p.8) as shown in Figure 2. Malaysia is categorised as a leading Archetype country, while Indonesia and Cambodia are categorised as nascent.

**Figure 2**

*The lines dividing the four quadrants were drawn using the average Driver of Production score (5.7) and Structure of Production score (5.7) for the Top 75 countries to create Archetype borders.*




*(Source: World Economic Forum's Readiness for the Future of Production Report (2018, p.9)*

Vora-Sittha and Chinprateep (2020), in exploring the readiness of the ASEAN Community for IR4.0 using SWOT (Dess, 2018) and TOWS analysis (Watkins, 2007), reported that only Singapore is the readiest country to face 4IR. The rest of the ASEAN members, including Malaysia and Indonesia, are moderately prepared for the world 4IR, except Brunei, Cambodia, Laos, and Myanmar. In 2020, analysts predict that in the next 10 years, 3.5 million people will be needed to fill specific manufacturing vacancies with high competencies in emerging technologies such as IoT, digital twins, and smart factories (Hernandez-de-Menendez et al., 2020). According to Hecklau et al. (2016), competencies needed in the IR4.0 era range from managing complex manufacturing systems to having more creativity, strategic thinking, and coordination skills. Deloitte's Global survey (2018) shows that 87% of survey participants in Asia lack confidence in executives' ability to act as stewards of Industry 4.0, with the Asia-Pacific region standing out as the region with the lowest confidence worldwide. Thus, Cheong and Li (2020) questioned what role higher education plays in addressing human and technological capabilities and enabling all stakeholders to be current in IR4.0 knowledge and use. In addition, what type of education is best suited to ensuring proficiency?

It is in this context that the consortium of 16 Partners led by Universiti Teknologi MARA was involved in ERASMUS+ KA2 Capacity Building in The Field of Higher Education – master's degree in Industry 4.0 / Ind4.0 Project with the problem statement that the educational sector of the Asian partners from Malaysia, Indonesia and Cambodia is not yet ready to produce Industry 4.0- ready graduates. Educational programmes in target country institutions need to be reinforced in order to prepare students to cope with the technological diversities of the field and the practical implications of applying these technologies to existing production and business models. An assessment had to be conducted on the gap between Asia businesses' need and capability to adopt Industry 4.0.

Note:

| |
|---|
| The consortium partners:<br>Malaysia: Universiti Teknologi MARA, Universiti Teknologi Malaysia, Universiti Kuala Lumpur<br>Cambodia: University of Heng Samrin Thbongkhmum, National University of Battambang, National Mean Chey University, Ministry of Education and Youth<br>Indonesia: Syiah Kuala University, Universitas Sumatera Utara<br>Italy: Università Degli Studi Guglielmo Marconi, "La Sapienza" University of Rome<br>Greece: Hellenic Open University (Greece), AMC Metropolitan College, Skybridge Partners<br>Germany: BK Consult |

## METHODOLOGY

The two Asian partners, Malaysia and Indonesia, used focus groups from the Manufacturing, Agriculture /Aquaculture and Health sectors. I focus group guidelines on collecting information from the field of IR 4.0, focusing on the training needs of their personnel. This was aimed at them participating in the professional training component of the IR4.0 project that is to be developed at a later project stage. The structure consisted of a series of open-ended questions, the order of which and their exact wording were largely up to the interviewer. The interviewees were motivated to answer in as much detail as possible; aspects that the interviewee raised him/herself were further explored. The data collection took place online by sending a softcopy of the questionnaire to the different participants via email due to the Movement Control Order enforced during the COVID-19 pandemic in 2019. A detailed and in-depth qualitative data analysis was carried out for selected questions relevant to the aim of the need analysis. In Malaysia, 7 respondents were from the agriculture sector, 2 from the manufacturing and 1 from the health sector. In Indonesia, only one respondent came from the manufacturing, automotive and agriculture sectors.

## RESULTS AND DISCUSSION

The responses to the field skills gap exploratory questions by respondents of the four sectors: Manufacturing, Automotive, Agriculture, and Health are as follows:

*Recruitment of skilled employees in the field of Industry 4.0 is an increasing problem. What do you think should be the ideal profile of an employee in the Field?*

Table 2 shows the respondents' ideal profile of an employee. The common element is that employees must have very good problem-solving skills, reflected in the manufacturing, agriculture, and health sectors. The employee should have technical skills and fundamental knowledge with a lifelong learning attitude in the perspective sectors, as mentioned by the manufacturing and agriculture sectors.

**Table 2**
*Ideal Profile of an employee in the manufacturing, automotive, agriculture and health sectors*

| Manufacturing | Automotive | Agriculture | Health |
|---|---|---|---|
| • Good technical skills with basic and specialist knowledge from a person's own speciality or discipline<br>• Good in the management area<br>• Very good problem-solving skills.<br>• Data and IT skills: Control, use, checking of data- | • Willingness to face challenges.<br>• Good business acumen | • Good communication skill<br>• Leadership<br>• Innovative<br>• Fast life-long learning goal<br>• Integrity<br>• Willingness to work in a hi-tech environment with a passion for new emerging technologies.<br>• Graduate technicians should have exposure to field automation or Agriculture 4.0-related | • Very good problem-solving skill |

| | | | |
|---|---|---|---|
| based systems, data analysis, data security/data protection, etc.<br>• Social competence: Interdisciplinary cooperation<br>• Good communication skills<br>• Leadership competence<br>• Good decision-making<br>• Self-initiated learning skills | | study with adequate practical training.<br>• Mandatory fundamental knowledge in Agriculture Science, System Science, Computing and Engineering.<br>• Very good problem-solving skill<br>• Moving forward attitude<br>• Good communication skills<br>• Commitment and discipline | |

*What do you think are the main skills missing from the current employees?*

The key findings of the main skills missing from the current employees showed that the current manufacturing sector employees miss personal skills. In contrast, the automotive and agricultural sectors miss technological skills, as shown in Table 3. In the health sector, the employees do not have business acumen.

**Table 3**

*The main skills missing in an employee are in the manufacturing, automotive, agriculture, and health sectors.*

| Manufacturing | Automotive | Agriculture | Health |
|---|---|---|---|
| • Management skill<br>• Communication skill | • Readiness of the graduates to enter the work force with the needed skillset. | • Ability to handle and master automation technology such as remote sensing-based monitoring techniques.<br>• Attitude with outdated knowledge<br>• The slow learning process to take control of new technology in the field with Agriculture 4.0 application.<br>• Self-driven attitude<br>• Critical thinking<br>• Resistant to the changes of work process<br>• Big data analysis ability in using the knowledge of programming and modelling. | • Business acumen |

*Are you familiar with the term "soft skills"? Can you name some of them?*

The respondents' familiarity with the term "soft skills" was mapped from levels 3 and 4 of the Global Skills Taxonomy to represent skills of interest to organisations across sectors based on the Future of Jobs Report 2023 (World Economic Forum, 2023). Table 4 shows respondents' familiarity with the term 'soft skills' in the manufacturing, automotive, agriculture, and health sectors categorised based on skill taxonomy.

The terms of the respondents were mapped into two components of the Skill Family: Attitudes and Skills, knowledge, and abilities. Under the Attitude category, 3 skills clusters were identified: Ethics, Self-Efficacy and Working with others. Under the Skills, knowledge, and abilities, 2 skills clusters were identified: Cognitive Skills and Management Skills.

**Table 4**
*Familiarity with the term 'soft skills' by respondents in the manufacturing, automotive, agriculture and health sectors categorised based on skill taxonomy at Level 1 and Level 2 of the Global Skill Taxonomy*

| Skill family (Level 1) | Skill Cluster (Level 2) | Manufacturing | Automotive | Agriculture | Health |
|---|---|---|---|---|---|
| Attitudes | Ethics | Integrity<br>Work Ethic | - | Responsibility<br>Work Ethic | - |
| | Self-efficacy | Flexibility<br>Interpersonal<br>Positive Attitude<br>Professionalism | Flexibility<br>Interpersonal | Dependability<br>Empathy<br>Flexibility | - |
| | Working with others | Communicating Skill<br>Courtesy<br>Teamwork | Communication skill<br>Leadership<br>Teamwork | Communication skill<br>Adaptability<br>Leadership<br>Teamwork | Communication skill<br>Adaptability |
| Skills, knowledge, and abilities | Cognitive skills | Problem Solving | - | Critical thinking<br>Decision making<br>Problem solving | Problem Solving |
| | Management Skill | Management<br>Time management | - | Organisational<br>Time management | - |

*Are you satisfied with the soft skills and competencies of your employees?*

Table 5 shows the perception of satisfaction with employees' soft skills and competencies. The agriculture sector showed the lowest level of satisfaction, followed by the manufacturing sector, while respondents from both the automotive and health were satisfied.

**Table 5**
*Perception of Satisfaction by the Soft Skills and Competences of Employees*

| Manufacturing | Automotive | Agriculture | Health |
|---|---|---|---|
| Moderately Satisfied | Satisfied | Not satisfied to moderately satisfied | Satisfied |

*If you could summarise in 3 words the profile of a successful employee, what skills would you put first?*

Individual respondents have different opinions, and no trend was based on the Global Skill Taxonomy recognised, as shown in Table 6.

**Table 5**
*Summary of a 3-word profile of a successful employee*

| Manufacturing | Automotive | Agriculture | Health |
|---|---|---|---|
| • Smart, Agile, Collaborative<br>• Smart in technical competency<br>• Skilful, fast, and Flexible | Possess the skill needed, willingness to face challenge, with good business acumen. | • Communication skills, problem-solving, and innovation.<br>• Thinking outside the box<br>• Knowledgeable, ethical, self-motivated.<br>• Dare to try.<br>• Attitude, Soft Skills, Expertise<br>• Hardworking and innovative<br>• Obey your Boss.<br>• Knowledge, commitment, and time management | Innovator, creative, adaptability |

The key findings of focus groups showed that the current health sector employees lack business expertise, which will help them be more efficient, while in the manufacturing sector, more management skills are needed; in the agricultural sector, the current employees lack automation and technology skills. One of the major challenges is the “Old” Employees because they are.

- still in the mind of belief in the old era of technology.
- wants to be in a comfort zone.
- Either they are naive in using the technology or object to use it.

One of the representatives of low development of IR4.0 is the retention of the aged and old generation of employers followed by employees. Therefore, the awareness and actions to reshape new and advanced skills and competency are left behind (Salleh et al., 2022)

## CONCLUSION

The focus group discussion unanimously indicated that existing programmes are not advocating for the Ind4.0. There is a lack of skills and competencies needed in IR4.0. One barrier is the mindset of the aged and old generation of employees and their reluctance to change and adapt.

## ACKNOWLEDGEMENT

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# A Roadmap to Industrial Revolution 4.0: Preparing Students' Sustainable Skills via STEM Education

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**ABSTRACT**

*The Fourth Industrial Revolution (InD4.0) needed a workforce in digital technologies, automation, and data-driven processes. Individuals need sustainable skills to excel in rapidly evolving industries and workplaces to thrive in this era. STEM education is a gateway to acquiring sustainable skills. The skills are closely linked to the 21st-century skills, knowledge, and competencies crucial for individuals to thrive and succeed in the modern world. The Malaysia Education System prepares students to become a competent workforce for InD4.0, guided by the Malaysia Education Blueprint. Malaysia Higher Education also nurtures sustainable skills as a continued effort to reinforce the skills acquired at the school level. This paper outlines the initiatives in STEM education, provides an overview of the current status, and presents plans for STEM education to prepare a skilled workforce for InD4.0 in Malaysia.*

**Keywords:** *Sustainable skills; 21st century skills; STEM education, InD4.0*

# Impact of Embedded-TCP Key Exchange for Fragmented Segments

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**ABSTRACT**

*Many encryption methods are offered in the application layer. Meanwhile, security offered by the transport layer protocol is limited to securing the end-to-end connection, not the transport layer payload. This paper proposes key exchange using the pass protocol (TPP) method embedded in the TCP header. To avoid a compromised key, a new one is periodically sent using the previous TCP window. Certain mechanisms should be applied when the new key is not successfully received so that the content decryption process is not disrupted. Evaluation through multiple link simulation shows the security possibility of the proposed method increases, although some delays are injected.*

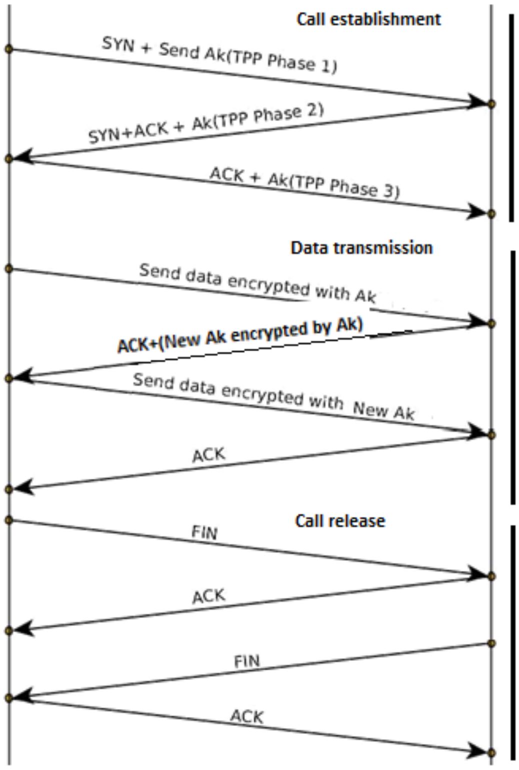
**Keywords:** *Embedded three-pass protocol ; WiMAX; TCP; Secure network*

## INTRODUCTION

Although TCP serves internet packets with a reliable end-to-end connection, the protocol does not guarantee the packet's safety against attack. It relies on the upper layer for packet security. The protocol has had some security issues (Gont & Bellovin, 2012). In 2012 and Gratzer, and in 2016, the QUIC protocol was introduced to enhance transport security, which evolved into HTTP/3 (Radhakrishnan, 2022). Research has found that QUIC performed best with small-capacity web resources (Chatzoglou et. al., 2023). A report also found that the Bleichenbacher attack was able to compromise the key (Christopher et. al., 2014; Oran et. al., 2023).

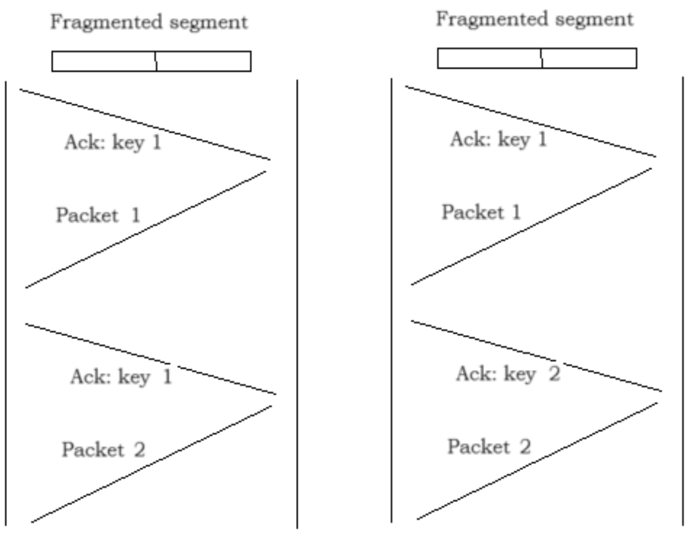
The embedded three-pass protocol (TPP) in the TCP header has been previously proposed (Suherman et. al., 2021; Xiong et. al., 2020). Even though it does not relate to QUIC, which has a different frame arrangement from TCP, the idea is useful as the additional load in the header can contribute to packet security. The three TPP messages inserted in the TCP handshaking process make security a concern at the beginning of the connection. Figure 1 shows how the embedding process occurs. The TCP call establishment inserts the encryption key Ak through the TPP messages. These messages are transported in SYN, SYN-ACK and ACK.

**Figure 1**
*TPP schema in TCP Header*




Once the key has been successfully exchanged, the key can be used for all communication. or only for certain windows. The next key can be piggybacked to the acknowledgement packet. The problem appears when fragmented segments are sent using different packets, experience retransmission, and use different keys. This paper analyses two arrangements for two scenarios. The schemas are similar keys for fragmented segments and keys for different windows, as shown in Figure 2.

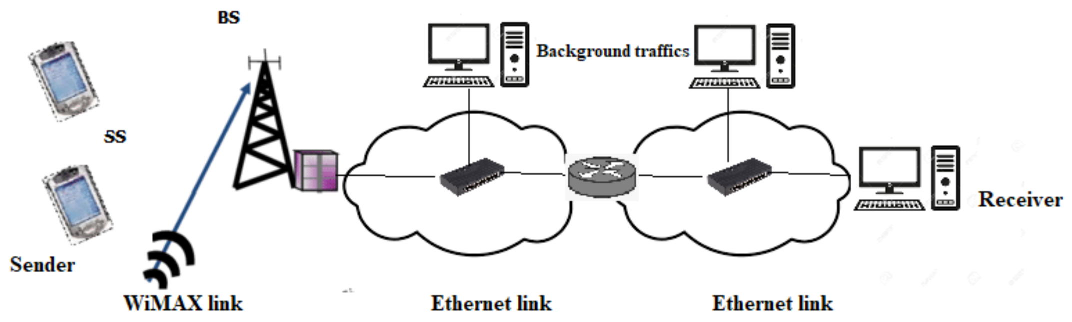
**Figure 2**
*Dynamic keys toward the fragmented segment*



## EVALUATION METHOD

As in Figure 3, a multiple-links simulation was developed using the NS2 simulator. The TCP/full is employed, and a simple one-time-pad encryption was employed to show how the encryption was performed. External traffic background was introduced using unreliable datagram protocol (UDP) streams, but devices are not shown. The application was set for video bit rates, from 275 kbps to 500 kbps.

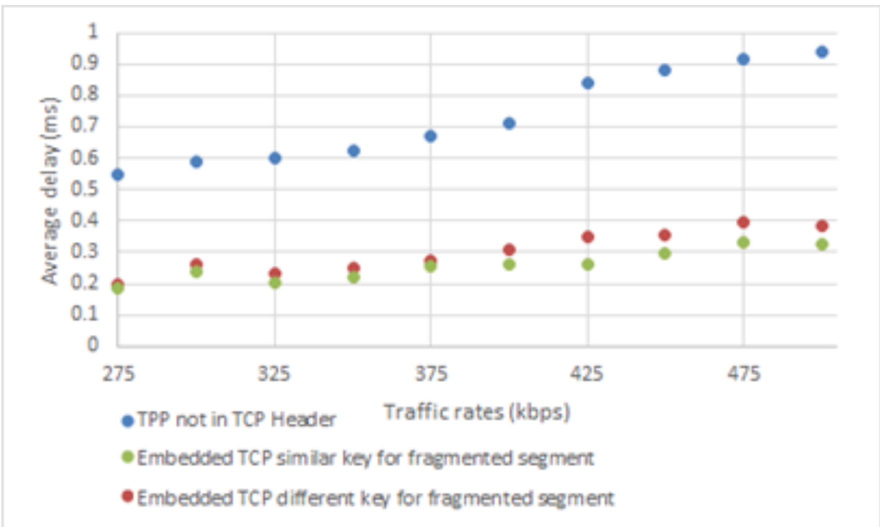
**Figure 3**
*Multiple link simulation*




## SIMULATION RESULTS

Figure 4 shows the average delay for Normal TPP, embedded TPP with different keys for fragmented segments and similar keys for fragmented segments. It is clearly shown that similar keys for fragmented segments yield lower delay. Delay differences are higher when the traffic rate increases. On average, similar keys produce a 16% lower delay than if all packets from the same segment are assigned different keys.

**Figure 4**
*TCP stream performances for Embedded TPP in the MAC layer*




In terms of security, TCP streams for fragmented segments are less protected than the ones using different keys as shown in Table 1.

**Table 1**
*Security Protection*

| Signal | Embedded TPP in TCP Header | |
|---|---|---|
| | **Wireless link** | **Other links** |
| TCP streams unfragmented | Yes/All | Yes/All |
| TCP streams fragmented | Yes/Less | Yes/Less |

## CONCLUSION

This paper examined the impact of embedded TPP into the TCP header on fragmented segments. In terms of delay, keeping the same keys for packets from the same segment reduces the end-to-end connection delay. However, this increases the risk for subsequent packets within the same segment. Some applications may accept separate packets from the TCP process, which makes it suitable for always-change keys. However, another application requires a single segment of packets to be sent at once from the transport layer, which suits similar keys. There may be other security solutions for the later application.

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# Universal Low Power Wireless Sensor Node with Energy Harvesting

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**ABSTRACT**

*Sensor nodes with tethered batteries have the main issue of energy limitation and short lifetime. Laboratory and educational purposes also require the universal sensor node to have more flexibility and capabilities for various IoT applications. This paper uses solar panels to develop a universal wireless sensor node with low-power components and energy harvesting. Gyroscope and solar panel charging were added in the sensor node to track sensor nodes in bad environments and increase the sensor node lifetime. The proposed sensor node worked as expected, and the voltage rate of batteries was reduced by* 0.33 mV/minute *without energy harvesting from solar panels. The sensor node lifetime was estimated at 140 hours or 6 days. However, the sensor node batteries will charge if a solar panel is applied. The voltage of sensor node batteries was gradually increased from 7.76 volts to 8.12 volts, an interval of 300 minutes; therefore, the energy limitation from batteries can be solved.*

**Keywords:** *Sensor node; Gyroscope; Solar panel; Batteries voltage; Lifetime*

## INTRODUCTION

Wireless sensor networks (WSN) and the Internet of Things (IoT) have been popular in every country, including Indonesia. The maker space has recently supported the WSN technology for IoT platforms in Indonesia (Yasirandi et. al., 2020). The Wireless sensor network (WSN) commonly applies to the monitoring system, such as detecting air quality and water and soil pollution (García-Orellana et. al., 2019; Lin et. al., 2017). Wireless sensor networks are widely used in IoT platforms for diverse applications, including manufacturing, process control, smart cities, smart buildings, healthcare, transportation, energy and beyond (Atzori et. al., 2010). The WSN and IoT are comprised of sensor nodes that collect the information by sensor and send the information to another node in a wireless network. Each sensor node includes a radio transceiver, power supply, processing unit, sensors, and power management (García-Orellana et. al., 2019).

Sensor nodes with tethered batteries have the main issue of energy limitation and short lifetime. The energy harvesting technology and routing protocol have been presented to resolve this problem (Tang et. al., 2017; Sittivangkul et. al., 2014; Sravan et. al., 2007; You et. al., 2021; Nguyen et. al., 2014). However, the hardware sensor node also played an important role in developing the low-power sensor node, such as using a low-power regulator, low-power transceiver, and other low-power components for the sensor node (Nguyen et. al., 2014). However, the sensor node is often designed as a semi-permanent prototype using Arduino and other circuits with complicated wiring for laboratory and educational purposes (Munir et. al., 2018; Nasution et. al., 2017; Nasution et. al., 2020). The semi-permanent sensor nodes are easily fragile if applied to WSN and IoT applications. Therefore, the universal sensor node with more flexibility and capabilities was proposed as the solution. The universal wireless sensor node was developed with low-power components and energy harvesting using solar panels. The sensor node was analysed by measuring each component's quiescent current and voltage batteries without and with a charging system.

## THE QUIESCENT CURRENT

The quiescent current test was applied to measure the power usage of each component in the idle sensor node before the sensor node developed. Figure 1 shows the quiescent current test using an oscilloscope for highly accurate current measurement. A load resistor (R) with a resistance of 1Ω was added in a negative line to measure the quiescent current. Therefore, the quiescent current (I) was equal to the oscilloscope's read voltage (V).

The measured quiescent current of each component in the sensor node consists of a regulator, microcontroller, real-time clock, memory card, gyroscope, and GPRS/GSM Module. The microcontroller ATMega328P and real-time clock (RTC) needed a supply voltage of 5 volts, the memory card and gyroscope needed a supply voltage of 3.3 volts, and the GPRS/GSM Module SIM800L needed a supply voltage of 4.1 volts. The low-power regulator MP1584 has been applied in the sensor node to adjust the source voltage from batteries to sensor node components. The quiescent current of regulator MP1584 was measured with a source voltage of 8.4 volts, equal to the maximum voltage of two-cell lithium-ion batteries.

The block diagram of the proposed sensor node can be seen in Figure 2. The GPRS/GSM Module SIM800L, memory card, gyroscope, and RTC were connected to microcontroller ATmega328P, and input power of components has been supplied from two cell lithium batteries through regulator MP1458. The gyroscope and solar panel charging were added to the proposed sensor node to track sensor nodes in bad environments and increase the sensor node lifetime.

**Figure 1**
*Measurement of quiescent current of components*

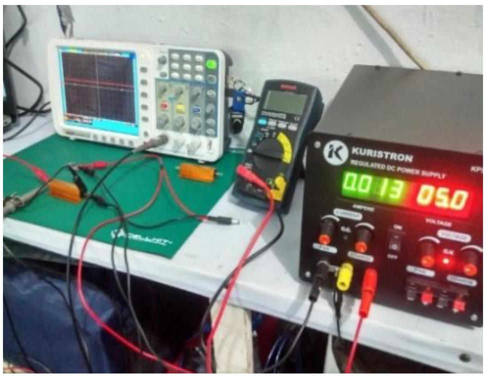
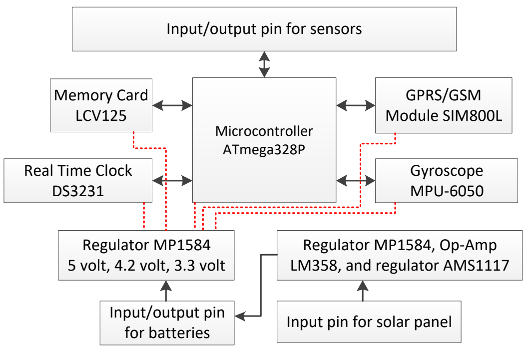


**Figure 2**
*The block diagram of the proposed sensor node*



The proposed sensor node uses the microcontroller ATmega328P; it's most popular in Arduino for sensor node application (Munir et. al., 2018; Nasution et. al., 2017; Nasution et. al., 2020). The ATmega328P has 8 8-bit data buses with a speed of 16 MHz and supports sleep mode for power efficiency (Atmel, 2015). In the proposed sensor node, the ATmega328P was programmed to activate components alternately when processing data and force the components to sleep mode when the components do not process data.

GPRS/GSM Module Sim800L was chip and easy to find in the market; Sim800L works on quad-band (850 MHz, 900 MHz, 1800 MHz and 1900 MHz), supports micro-SIM card, has a smaller socket for additional antenna, and supports sleep mode for power efficiency (SIMCom, 2015). The lower quiescent current of Sim800L was obtained in measurement due to the additional omnidirectional antenna inserted in the test with a good signal.

RTC DS3231 was added in the proposed sensor node to keep accurate track of time. The DS3231 is a serial RTC driven by a temperature-compensated 32 kHz crystal oscillator that provides a stable and accurate reference clock while maintaining an RTC accuracy of ±2 minutes per year from -40°C to +85°C (Maxim, 2015). In the proposed sensor node, the RTC works to wake up the microcontroller ATmega328P when the system is in sleep mode; the wake cycle has been programmed previously by ATmega328P. RTC support an internal battery to backup power if the sensor node is in sleep mode. The regulator HT733 was added to adjust the voltage of backup power from the main batteries to RTC when the sensor node is in sleep mode.

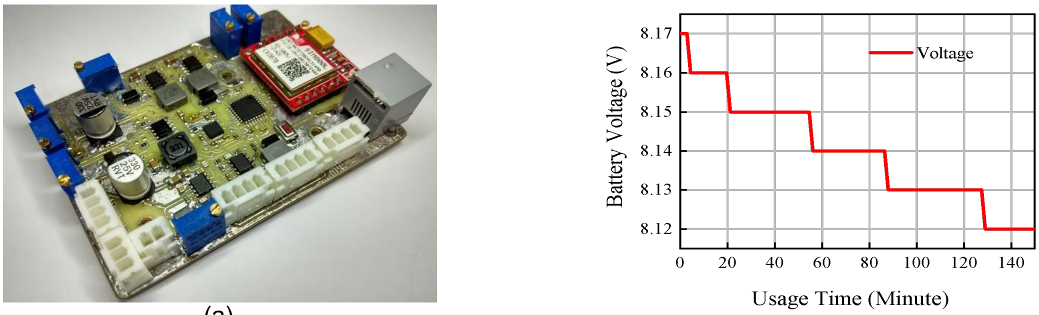
## PROPOSED SENSOR NODE

The circuit layout of the proposed sensor node was designed on a layer-printed circuit board, and via-hole techniques have been applied to connect the two-layer circuit for the fabricated circuit board of the sensor node. Figure 3(a) shows some components assembled on the upper side of the sensor node circuit board, including regulators 5 volt and 3.3-volt, wireless components, gyroscope, and microcontroller. The memory card, RTC, regulators 4.1 volts, and transistors P2222A were assembled on the backside.

The voltage of sensor node batteries was measured without charging from the solar panel, as shown in Figure 3(b). The power source of the sensor node is from two-cell lithium-ion batteries with a voltage of 8.17 volts, and the battery voltage was gradually decreased to 8.12 volts at intervals of 153 minutes**.** Therefore, the voltage rate in the battery sensor node was reduced $\frac{(8.17-8.12)}{153}\ volt/minute$, or equal to $0.33\ mV/minute$. If the minimum voltage in batteries to the sensor node working is 5.4 volts for two-cell batteries, the sensor node lifetime can be estimated to be 140 hours or 6 days.

$$\frac{Max\ voltage - Min\ voltage}{voltage\ rate} = \frac{(8.17 - 5.4)\ v}{(0.33\ \times\ 10^{-3})\ v/min} = 8394\ minute$$

**Figure 3**
*Prototype sensor node (a) final assembly and (b) Measurement of node sensor batteries*




(a) (b)

**Figure 4**
*Proposed sensor node applied with solar panel*

**Figure 5**
*Measurement of node sensor batteries with solar panel*

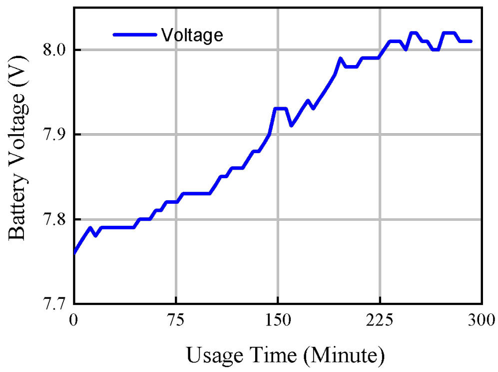



Figure 4 shows the sensor nodes were tested with a solar panel for monitoring and control energy harvesting. Figure 5 shows the voltage changes of the sensor node battery from two-cell lithium-ion batteries with a voltage of 7.76 volts, which gradually increased to 8.12 volts at intervals of 300 minutes. Applying the proposed sensor node with energy harvesting using solar panels effectively solved energy limitations from batteries due to the batteries charging when it has a lower voltage.

## CONCLUSION

The proposed sensor node was worked as expected, and the estimated voltage rate of batteries reduced 0.33 $mV/minute$ and six days estimated lifetime without energy harvesting. Furthermore, periodically activating the sensor node every hour could increase lifetime. The sensor node with energy harvesting using solar panels has more lifetime due to the energy limitation from batteries that have been overcome.

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# Rural Internet Access Distribution Using Regression Model

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**ABSTRACT**

*Internet access has been widely deployed from growing existing PSTN providers and evolving cellular network providers. Internet availability has reached rural areas, enabling connectivity everywhere, every time, and everyone. However, price considerations and speed demands are major reasons for homes, small offices, and rural schools to search for alternative providers. Some small internet providers for those rural demands serve internet connections via digital radio links with limited capacity, but the price and speed are attractive. Providers lease internet connections to a larger company via fibre optics or radio connections in such systems. Subsequently, through a small local area network and PC-based routers, the company distributes internet connections to rural users using low-rate digital radios. All transceivers' antennas are installed in a single antenna tower, forming a local base station. Some techniques are available to be implemented for distributing the bandwidth to users. As the attention is on rural applications, this paper examines the use of regression models from past data for current internet connections.*

**Keywords:** *Rural internet services; Bandwidth scheduling; Statistical model*

## INTRODUCTION

Internet access for rural areas has been in great demand as most activities now partially rely on online activities, including education jobs, as well as the demands of the Industrial Revolution 4.0. In some places, such as in Indonesia, rural areas have been covered by cellular network providers. However, as speed demand increases, a more dedicated network is required. Some smaller internet providers specialise in rural internet services (Svistova et al., 2022). This ubiquitous network access allows access to internet servers through distance digital radio networks to distribute internet access. However, these small companies often face difficulties distributing internet bandwidth for their customer, which is set through their routers or control network. In practical cases, decisions should be taken carefully, as the efficient bandwidth allocations for each customer determine profits. On the other hand, bandwidth allocation should satisfy customer demands, and complaints should be avoided.

Resource scheduling becomes important when limited resources should be shared among users. The algorithm should determine the task and resource distribution as fast as possible and with as low energy consumption as possible. The scheduling may apply quality of services (QoS) if service differentiation is demanded (Sharma et al., 2023). Scheduling aims to determine which resource and task to execute for a given time slot. The algorithm can be categorised as static and dynamic algorithms (Kumar et al., 2019). The static algorithm requires details on the number of tasks, duration and timing, the available resources, memory, processing power and energy consumption so that the execution setting can be implemented at the front stage. However, the dynamic systems that change in the number of requests, duration, and available resources make this setting unsuitable for most cloud computing scenarios.

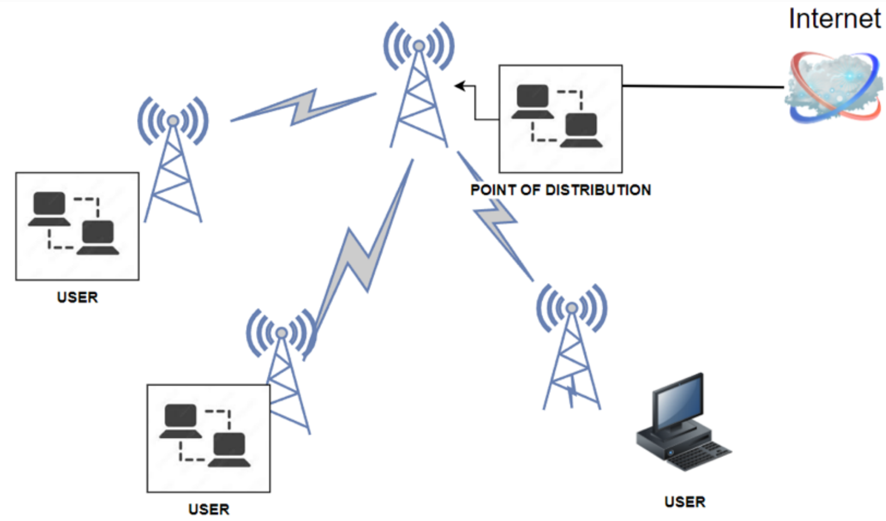
Some static scheduling (Beaumont et al., 2022) includes heuristic round robin (RR), first in, first out (FIFO), and the shortest job first (SJF). Compared to static scheduling, the dynamic algorithm can balance share among nodes. Dynamic scheduling (Wen et al., 2022) mostly outperforms static, for instance, the heterogeneous earliest finish time (HEFT), weighted least connection (WLC) and the clustering-based heterogeneous with duplication (CBHD). This paper examines the dynamic bandwidth allocation by regressing the past bandwidth requirement.

## RESEARCH METHOD

### Network Configuration

To examine the flow of bandwidth distribution among rural internet users from a single base station, the following network configuration is used to fit the rural radio network model, as shown in Figure 1. Each internet user is connected to the server at the distribution point via a radio link. The distribution point connects all networks to the internet. Since there are many ways to implement a point of distribution, one component is assumed to be responsible for bandwidth allocation. In practice, the bandwidth allocation algorithm can be set in the router or a PC dedicated to routing. However, implementing the proposed method to any device may not be relevant as the marketed device allows limited access to its firmware. Simulation is the most appropriate way.

**Figure 1**
*The evaluated network configuration*




### Dataset

The dataset is obtained from Kaggle (www.kaggle.com) with modifications that suit traffic generations from various rural networks. The traffic is classified based on the source of links. One radio link represents one group of users. Therefore, users from the same group represent the traffic source from that group. Table 1 shows the sample representation of the dataset.

**Table 1**
*Sample of the internet traffic*

| No. | Time | Source | Destination | Protocol | Length | Waktu (detik) | Group.1 | SourceNum | ProtNum |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000000e+00 | 103.73.100.205 | 39.62.1.38 | UDP | 1292 | 0.000000e+00 | 10 | 103.0 | 1 |
| 2 | 0.000000e+00 | 103.73.100.205 | 39.62.1.38 | UDP | 1296 | 0.000000e+00 | 10 | 103.0 | 1 |
| 3 | 4.000000e-06 | 103.12.198.146 | 14.2.1.236 | UDP | 1274 | 4.000000e-06 | 10 | 103.0 | 1 |
| 4 | 5.000000e-06 | 103.12.198.146 | 14.2.1.236 | UDP | 1274 | 5.000000e-06 | 10 | 103.0 | 1 |
| 5 | 6.000000e-06 | 103.12.198.146 | 14.2.1.236 | UDP | 1282 | 6.000000e-06 | 10 | 103.0 | 1 |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 406327 | 5.664875e+07 | 103.73.100.140 | 14.2.1.224 | UDP | 1300 | 5.664875e+07 | 10 | 103.0 | 1 |
| 406329 | 5.664890e+07 | 39.62.1.38 | 142.250.181.74 | UDP | 1292 | 5.664890e+07 | 5 | 39.0 | 1 |
| 406331 | 5.664912e+07 | 59.103.93.65 | 14.4.1.237 | TCP | 1466 | 5.664912e+07 | 7 | 59.0 | 2 |
| 406332 | 5.664913e+07 | 59.103.93.65 | 14.4.1.237 | TCP | 1466 | 5.664913e+07 | 7 | 59.0 | 2 |
| 406333 | 5.664913e+07 | 59.103.93.65 | 14.4.1.237 | TCP | 1474 | 5.664913e+07 | 7 | 59.0 | 2 |

This dataset comprises 125,381 internet data that come from 20 links. The data statistic is not in a normal distribution but skewed with the right tail and a bit fat with kurtosis 31.39. The subsequent data has a 0.42 correlation, which means it does not contain many stationary points. These statistical parameters are shown in Figure 2.

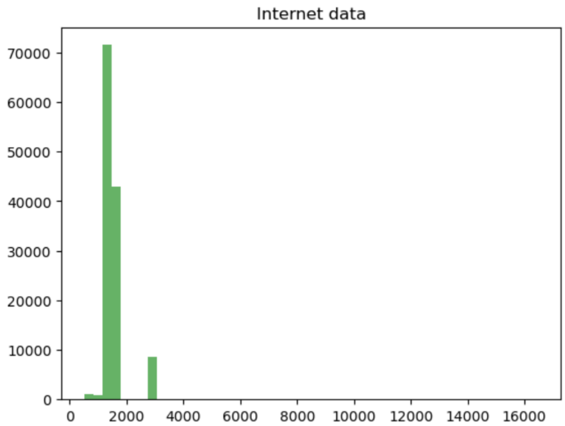
**Figure 2**
*Sample of the internet traffic*

```
count    125381.000000
mean       1470.373119
std         417.436343
min         502.000000
25%        1292.000000
50%        1392.000000
75%        1470.000000
max       16478.000000
Name: Length, dtype: float64

Skewness:  3.7268657088124084
Kurtosis:  31.393624389092103

Autocorrelation:  0.4216861067445908
```

(a)




(b)

## Statistical Analysis

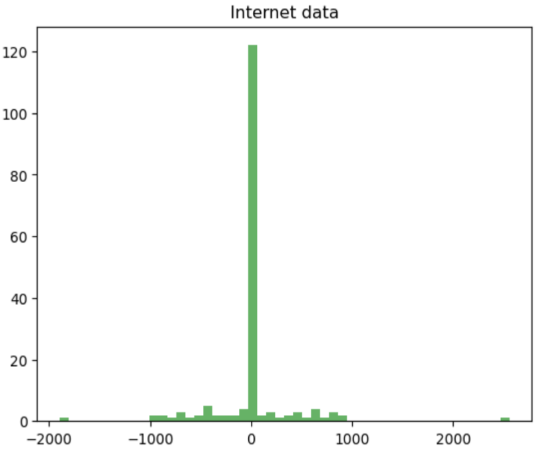
Since data distribution is not balanced, the transformation using the first difference is applied to omit outlier impact. As a result, skewness drops, and even dough kurtosis increases slightly, but the distribution becomes more normal.

**Figure 3**
*Sample of the transformed Internet traffic*

```
Summary Statistics:
count    125380.000000
mean          0.001452
std         448.940351
min      -15012.000000
25%          -4.000000
50%           0.000000
75%           8.000000
max       15012.000000
Name: Length, dtype: float64

Skewness:  0.07612917830049977
Kurtosis:  36.09426904743806
```

(a)




(b)

### Bandwidth Allocation Algorithm

Bandwidth allocation in the router or dedicated PC is performed based on the execution cycle. So, in that execution cycle, the scheduler checks all user requests and stays in the buffer. If the first in, first out (FIFO) algorithm is chosen, then traffic with the lowest time stamp will be the priority, and the latter will be the priority. All queued requests are executed continuously until the transported bytes in that time slot are full. This cycle will be performed repeatedly at all evaluated times. This is a simplification of the queue system within the router. There may be multiple servers. However, this assumption is valid since the outgoing internet connection, as depicted in Figure 1, is only a single channel.

For the proposed algorithm, as mentioned in the first section, the algorithm will continue to observe the recorded data and create a model for future allocation. The model in this paper uses linear regression, autoregression, and ARIMA, where the recorded traffic is split into training and test datasets. The incoming traffic is then predicted using the model. The prediction is then compared to the real data from the data test.

### Performance Parameter Evaluation

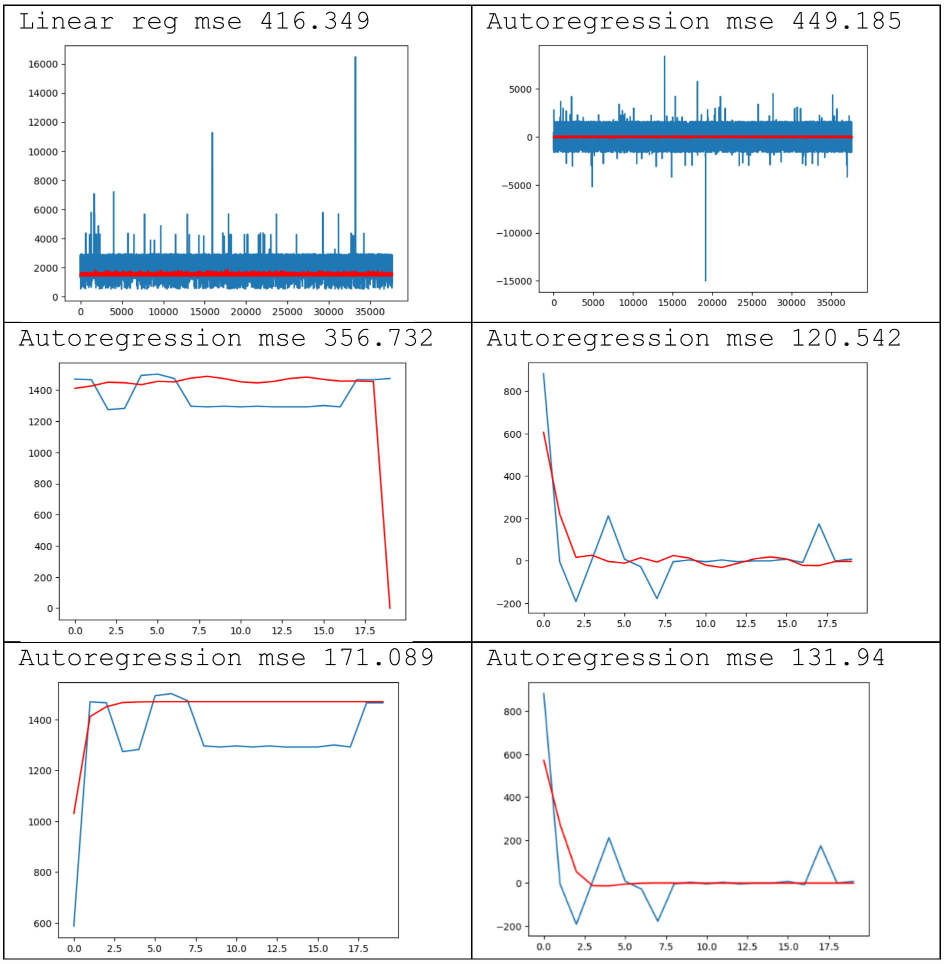
If the requested data exceeds the allocated bandwidth, there will be a delay increment at least twice for that queued data. Otherwise, the delay is assumed to have a 1-unit delay. If this condition occurs subsequently, the probability of dropped packets will increase. The dropping condition should satisfy the following: buffer size is lower than the queued packets. Therefore, delays and dropped packets will be the performance parameters. Bandwidth utility will also be evaluated to measure how efficiently the algorithm uses the available bandwidth.

## SIMULATION RESULTS

The historical data of internet connections of the evaluated links are analysed using statistical models such as linear regression, autoregression, and ARIMA. As a result, various mean square errors are obtained for original and transformed data, as depicted in Figure 4.

Linear regression with all data is presented but shows under-predicted values for the required allocated bytes. The error values are 416.349 for the original data and 449.185 for the transformed values. Even autoregression and ARIMA yield lower errors, but the predicted allocated bytes are not good enough to achieve the expected performances.

**Figure 4**
*The allocated bytes predictions using linear regression, autoregression and ARIMA*




The predicted bytes are applied to the bandwidth allocation algorithm as in the following snippet:

```
set available_bandwidth
set scheduler_buffer_size
set max_transmission_unit
calculate packet_duration
set packet_number to 0
while scheduler_works
    receive_all_request_to_buffer
    predicted_allocation (receive_request)
    if predicted_allocation == or < scheduler_buffer_size:
        predict_delay
        predict_loss
    else:
        check_transmission_buffer
        predict_delay
        predict_loss
```

As a result, when traffic is lower than the available bandwidth, the regression-based scheduler performed worse than the legacy schedulers, such as first in, first out (FIFO) and round robin (RR), as depicted in Table 2. FIFO performs best as the scheduler necessarily performs no sorting. Statistics mean square errors cause networks to be under or over-utilized unnecessarily. The prediction process also injects additional processing time.

**Table 2**
*Performance when incoming traffic is less than the available bandwidth*

| Performance parameter | FIFO | RR | Statistical prediction |
|---|---|---|---|
| Normalized predicted delay (unit*) | 1.512 | 1.877 | 2.085 |
| Number of loss packets during observations | 25 | 35 | 1025 |

*Unit is measured as one transmission frame length

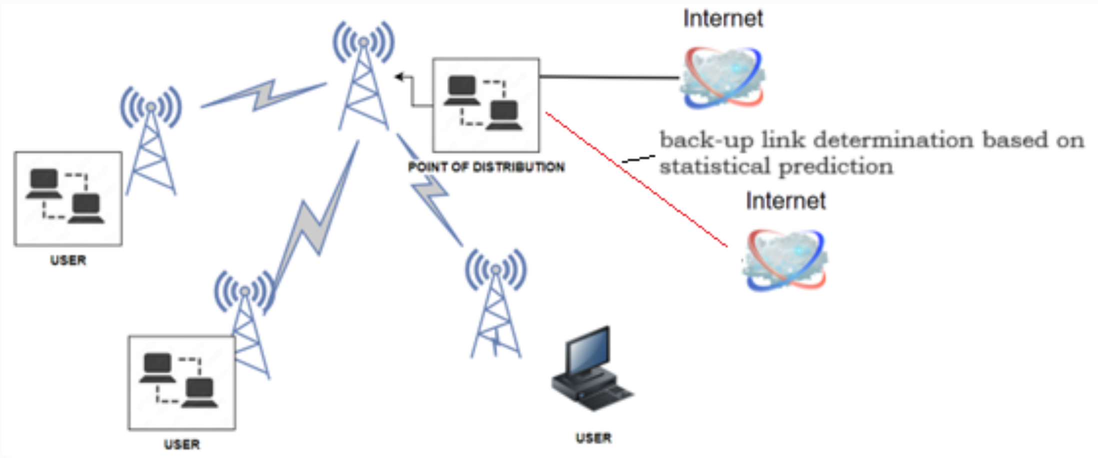
If the bandwidth is less than the incoming traffic, the delay increases significantly, followed by a spike in loss as the buffer is overflowed (Table 3). Again, the regression-based scheduler performed the worst.

**Table 3**
*Performance when incoming traffic is higher than the available bandwidth*

| Performance parameter | FIFO | RR | Statistical prediction |
|---|---|---|---|
| Normalized predicted delay (unit*) | 1.765 | 2.45 | 4.52 |
| Number of loss packets during observations | 214 | 276 | 5665 |

Further modification is then applied; instead of modelling the historical connections, regression is applied to predict the time when incoming traffic is higher than the available bandwidth even though dough statistical processing increases delay and is still not better than FIFO and RR (data is not shown), further applications such as backup link preparation as in Figure 5 may utilise this prediction to enhance network performance.

**Figure 5**
*Further work*




## CONCLUSION

This paper has simulated the rural internet connection bandwidth allocation using regression methods such as linear regression, autoregression and ARIMA on historical data. The predictions did not contribute to performance enhancement. They worsened the performances. However, when predictions were applied to determine when a network jam happens, the performance could improve as overflow traffic larger than the available bandwidth needs solutions. For instance, further work may utilise the prediction results by adding more bandwidth when traffic contention occurs.

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# Empowering Educators: An MSc Curriculum for Industry 4.0

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**ABSTRACT**

*We stand on the brink of the Fourth Industrial Revolution, often termed Industry 4.0; education challenges evolve in tandem with the rapid advancements in technology and industrial practices. Educating for Industry 4.0 is not merely about imparting knowledge on new technologies such as the Internet of Things (IoT), artificial intelligence, or robotics. It fosters a paradigm shift in thinking, nurtures adaptability, and cultivates the skills to integrate and navigate within hyper-connected systems. The transition demands a reimagining of curricula, pedagogical methodologies, and the tools we employ, all while addressing the widening skills gap and preparing learners for an ever-transformative job market. As we plunge deeper into this era, the challenges of equipping individuals with the right skills and mindset for Industry 4.0 become more intricate and imperative (Akdur, 2022). As the landscape of Industry 4.0 broadens, educators and industry professionals alike must recognise that integrating these advanced technologies is not just about equipment or software but about shaping the minds that will drive this revolution forward. Fusing traditional learning with these innovative techniques can lead to a richer, more immersive educational experience, aptly preparing learners for real-world challenges. Further complicating the matter is the ever-evolving nature of Industry 4.0. What is considered avant-garde today may be standard tomorrow, emphasising the importance of continuous learning and adaptability. Educational institutions must foster a culture of lifelong learning, where curricula are not static but dynamically adjust to the pulse of industry innovations. Collaboration between academia and industry becomes pivotal, ensuring the skills taught are relevant and in demand. Moreover, as we progress into this cyber-physical era, ethical considerations take centre stage. The integration of AI into various sectors means decisions once made by humans now have machine influencers. Educators will be responsible for instilling a solid ethical foundation, ensuring that as we leverage these technologies, we focus on the greater good, prioritising humanity, equity, and sustainability (Eriksson et al., 2021). This paper presents insights gained from designing an MSc for Industry 4.0 Erasmus+ Project, a CBHE project that sought to align with the emerging trend of creating a paperless educational ecosystem tailored for Industry 4.0. As the global academic community pivots towards digitising university teaching resources, our initiative takes on a two-fold role: curating and disseminating educational content specific to Industry 4.0. One of the primary challenges encountered is standardising the procedures adopted in designing and developing such specialised content. The Industry 4.0 Master's degree aims to train Theoretical, Natural, Engineering, Computer Science, and Information Technologies graduates to address the new challenges posed by the ever-increasing globalisation in production, manufacturing, and service provision. These challenges are primarily rooted in technological know-how and a high degree of automation using modern production paradigms incorporating individuality, flexibility, and reconfigurability. The growing interconnectedness and rise in cooperation between man and machine change how products are produced and lead to new products and services. These challenges are met by the increasingly complex interconnections between machines, raw workpieces, finished products, transport units, and computers made possible by the Internet of Things, Cyber-physical Systems, Social Networks, Cloud Computing, Big Data Analytics, and Cognitive Computing: a new industrial revolution named Industry 4.0. In this context, the Master's Programme encompasses the different sources of knowledge and experience required by Industry 4.0. It combines the diversity of expertise of leading European Universities. It offers education oriented to a multi-disciplinary understanding through experts from*

*complementary fields in a research-oriented environment with close cooperation with the industry. The program is structured to provide fundamental knowledge of the discipline (core courses) and specialisation (orientation courses) for vertical and horizontal value-creation chains of four key industries: Manufacturing, Agriculture, Aquaculture, and Pervasive Health. These are the main objectives of the program. The program lasts 18 months for full-time and 24 months for part-time students. Courses are arranged as a mix of theory and application in project-led education using a blended mode of delivery (face-to-face and distance learning training). Placements at key industrial players are also offered as an option at the later stages of the program. Students also can perform research by writing a dissertation that will help them further develop the critical skills needed for a career in Industry 4.0. The MSc in Industry 4.0 program trains students to acquire communication skills via project and practical work. Furthermore, the need for research on innovative products and services improves students' entrepreneurship and enterprise skills, and their intellectual property awareness is enhanced. The curriculum and structure educate students on sustainable development, thinking critically and effectively, and being more creative and collaborative, especially in problem-solving. Therefore, the main goal is to prepare the future workforce for all the aspects of the new industrial revolution named Industry 4.0. Given that the project's delivery model is based on virtual tutor presence, the digital educational material is meticulously crafted to incorporate advanced pedagogical and e-learning techniques. This ensures that learners can grasp intricate concepts of Industry 4.0 even in the absence of face-to-face instruction. For a high-stakes domain like Industry 4.0, it is crucial to have educational materials that empower students to meet the pre-defined learning objectives. Beyond process standardisation, evaluating the entire educational journey becomes essential. This involves understanding the tutors' goal-setting mechanisms, the surrounding content design in line with those goals, stakeholders' consumption patterns, and the overall effectiveness of the delivery model. Current methodologies take inspiration from HOU, a pioneering institution in distance learning. As we learned from the project, teaching skills for Industry 4.0 demands a multifaceted approach that imparts technical knowledge and nurtures adaptability, ethics, and a problem-solving mindset. The chosen methodologies must reflect the complexities and possibilities of this transformative era. Given the hybrid nature of Industry 4.0, where physical and digital realms converge, a blended learning approach—mixing traditional face-to-face instruction with online learning—seems fitting. This might involve theory-based classroom sessions integrated with online simulations, enabling students to grasp complex cyber-physical systems. Real-world applications and problem-solving also drive industry 4.0. PBL mirrors this by immersing students in hands-on projects that require solution-oriented thinking. Learners could undertake projects where they design an intelligent factory layout or develop an AI-driven supply chain solution, fostering both teamwork and practical skills. Adaptive Learning: Given the dynamic nature of Industry 4.0, learning must be flexible and tailored to individual needs. Using AI-powered educational platforms, content can be adjusted in real time based on the learner's performance, ensuring they are always engaged and challenged. One aspect to consider when AI and automation play pivotal roles in decision-making is that the ethical foundation becomes paramount. Case-based discussions can be integrated, exploring dilemmas in automation or AI bias, ensuring students can make balanced decisions in real-world scenarios. To understand the intricacies of cyber-physical systems, students can benefit from the immersive experiences of these technologies. VR could transport students inside a digital twin of a factory, while AR might overlay crucial data onto physical processes, providing in-depth insights. Industry 4.0 envisions a world where humans and machines work in tandem. Preparing students for this requires them to collaborate with AI. Assign tasks where AI provides data or suggestions, and students must interpret, validate, or integrate this information into their projects. Industry 4.0 is inherently interdisciplinary, merging fields like engineering, data science, and business. Curricula should be designed to break silos, fostering collaboration between different disciplines to encourage holistic understanding. Industry 4.0 is a gateway to an era dominated by cyber-physical environments in the workplace. This evolution necessitates a transformative pedagogical approach and delivery method shift across all EQF levels. The pronounced need for robust work-based and hands-on learning components within Industry 4.0 curricula bolstered this hypothesis. A central research query arises: How do individuals acquire skills in an ecosystem where humans, machinery, and artificial intelligence intertwine? While foundational hard skills might remain consistent with traditional curricula, integrating artificial intelligence — or the 'machine in the loop' — is poised to take on heightened*

*significance in these cyber-physical contexts. This evolution may spotlight a range of emerging sub-skills, from collaborating within hybrid human-AI teams and refining communication with continually advancing AI to cyber-physical ethics, resource allocation, time management in mixed teams, and risk mitigation. While there is a broad consensus within the academic sphere regarding the core skills essential for Industry 4.0, we advocate for an innovative approach to imparting these competencies. This could encompass novel learning methodologies and cutting-edge mediums for educational delivery, potentially leveraging advancements like augmented reality, virtual reality, academic digital twinning, and beyond (Iniesto et al., 2021).*

**Keywords:** *Industry 4.0; Pedagogical framework; Pedagogical tools; Pedagogical methodologies; Practicum; Employability; Evaluation; Quality assessment*

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