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IIUDeation 2025

INTERNATIONAL GRAND INVENTION, INNOVATION AND DESIGN EXPO

REVOLUTIONIZING IDEAS FOR PIONEERING THE FUTURE

Editors

Ahmad Anwar Zainuddin
Amir 'Aatieff Amir Hussin
Mohd Khairul Azmi Hassan
Dini Oktarina Dwi Handayani
Asmarani Ahmad Puzi
Noor Azura Zakaria
Nur Nisa Humairah Rosdi
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This work was completed through the hard work and cooperation of many people, particularly the committees of International Grand Invention, Innovation and Design Expo 2025 (IGIIDeation 2025).

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Introduction

The International Grand Invention, Innovation, and Design Expo (**IGIIDeation 2025**) is an annual event organized by the Department of Computer Sciences, Kulliyyah of Information and Communication Technology (KICT), International Islamic University Malaysia (IIUM). This prestigious event focuses on promoting groundbreaking ideas and pioneering advancements in technology, science, and design. It serves as a platform for researchers, students, and professionals from diverse backgrounds to showcase their innovative projects and creative solutions.

IGIIDeation 2025 is set to revolutionize the future by inspiring participants to address contemporary challenges and explore cutting-edge concepts. The competition will be held virtually, ensuring accessibility for participants worldwide. Under the theme "Revolutionizing Ideas for Pioneering the Future", IGIIDeation 2025 invites entries across a broad spectrum of tracks, including Artificial Intelligence, Cybersecurity, Blockchain Technology, Healthcare Innovation, and much more. The event is open to school students, undergraduate and postgraduate students, and researchers, fostering cross-disciplinary collaboration and knowledge exchange. Special awards, such as the Platinum Award, Sustainability Award, and Innovatex Award, will recognize outstanding contributions that demonstrate excellence, creativity, and sustainability. All participants will receive gold, silver, or bronze e-certificates, adding further value to their achievements.

IGIIDeation 2025 aims to catalyse innovation and foster global collaboration, paving the way for transformative advancements in science, technology, and design.

Acknowledgement

The successful completion of this book would not have been possible without the unwavering support, dedication, and contributions of numerous individuals and institutions. Their invaluable assistance, encouragement, and collaboration have played a crucial role in shaping this publication into a meaningful and impactful resource.

First and foremost, we extend our deepest gratitude to the **Kulliyyah of Information and Communication Technology (KICT), International Islamic University Malaysia (IIUM)**, for its steadfast commitment to academic excellence, research, and innovation. The institution's dedication to fostering interdisciplinary collaboration and advancing knowledge has been instrumental in the conceptualization and realization of this book. Its continuous support of scholarly endeavors has created an environment where ideas flourish, and groundbreaking research takes center stage.

We are also profoundly grateful to the **Department of Computer Sciences** for its leadership in organizing **IGIIDeation 2025**, an esteemed platform that unites researchers, students, and professionals in the exchange of pioneering ideas spanning technology, science, and design. This initiative has not only provided a foundation for thought-provoking discussions but has also significantly enriched the content and intellectual depth of this publication. The knowledge and perspectives shared during this event have been invaluable in shaping the themes and discussions within this book.

A special note of appreciation goes to the **organizing committee and contributors**, whose dedication, expertise, and tireless efforts have been pivotal in ensuring the successful realization of this work. Their unwavering commitment to academic integrity and the dissemination of knowledge has greatly enhanced the quality, depth, and impact of this publication. Their collaborative spirit and meticulous attention to detail have helped refine the book's content, ensuring that it meets the highest academic and professional standards.

Furthermore, we wish to acknowledge the invaluable support of our esteemed **partners and collaborators**, including **MBOT, Silverseeds Lab Network, MILA University, Multimedia University (MMU), and other participating institutions**. Their contributions have played a significant role in broadening the reach and significance of this endeavor, reinforcing the importance of cross-institutional cooperation in the pursuit of academic and technological advancements. The synergy created through these collaborations has enabled us to explore new frontiers of knowledge and innovation.

We also extend our heartfelt appreciation to all **participants, students, and researchers** who have actively engaged in this initiative. Their passion for innovation, relentless curiosity, and commitment to knowledge creation continue to inspire and drive meaningful advancements in their respective fields. Their intellectual contributions and enthusiasm for discovery serve as a beacon of progress, shaping the future of technology and academia alike.

Finally, we express our sincere gratitude to our families, friends, and mentors, whose unwavering support and encouragement have been a source of strength throughout this journey. Their belief in our vision and their patience during the rigorous process of research, writing, and compilation have been invaluable.

It is our sincere hope that this book will serve as a **cornerstone for future research, fostering innovation, sustainability, and global collaboration**. May it inspire scholars, professionals, and students alike to push the boundaries of knowledge and contribute to the advancement of society through technology and education.

Opening Remarks by The Dean

Bismillah-ir-Rahman-ir-Rahim.

Assalamu'alaikum wa Rahmatullahi wa Barakatuh, and warm welcome to everyone.

It is an absolute pleasure, as the Dean of KICT, IIUM, to welcome you all to IGIIDeation 2025—the International Grand Invention, Innovation, and Design Expo.

The theme for this year, "Revolutionizing Ideas for Pioneering the Future," perfectly captures the energy and vision we are about to experience. It serves as a powerful reminder that the future is not something we wait for; it is something we actively create.

As you embark on this journey of innovation, I would like to share a reminder from Imam Ibn al-Qayyim (rahimahullah): "Do not grieve over the things you have lost, for Allah's blessings are greater than what was taken from you." The road to innovation is never without its challenges, but every step—whether it feels like a win or a lesson—brings us closer to something greater.

I would also like to take this opportunity to thank all our participants, judges, and organizers. This event would not have been possible without your dedication, passion, and hard work.

Let us make the most of this opportunity to build, create, and push the boundaries of what is possible. I am excited to see what new ideas emerge from this event and how they will shape a brighter future for us all.

Good luck to everyone, and may this event serve as a source of inspiration and growth for all of us.

Assalamu'alaikum wa Rahmatullahi wa Barakatuh.

Prof. Dr. Murni Binti Mahmud

Dean

Kulliyyah Of Information and Communication Technology (KICT)

International Islamic University Malaysia

Opening Remarks by the Chairman

Bismillah-ir-Rahman-ir-Rahim.

Assalamu'alaikum wa Rahmatullahi wa Barakatuh, and a very warm welcome to all.

For all of us on the organizing team, seeing this event come to life after so much planning and hard work is nothing short of amazing. It feels great to finally welcome you all and see the energy and enthusiasm you bring.

What makes this event special is not just the incredible ideas and innovations you have presented, but the spirit of collaboration that we've worked so hard to foster. True innovation does not just come from individual brilliance; it comes from working together, sharing knowledge, and learning from one another.

I would also like to take a moment to express my heartfelt thanks to everyone who has made this event happen. To our participants, thank you for your creativity and hard work. To the judges and mentors, thank you for your time and expertise. And to the volunteers and everyone working behind the scenes, your dedication has been key in bringing this vision to life. We truly could not have done this without you.

This is an incredible opportunity for all of us to connect, learn, and grow. Take advantage of every moment here, whether it is through exchanging ideas, gaining new perspectives, or building connections that could turn into future collaborations. The possibilities are endless, and I encourage you all to dive in, share your thoughts, and make the most of the event.

Once again, thank you for being a part of this, and I wish you all the best as we embark on this journey together.

Assalamu'alaikum wa Rahmatullahi wa Barakatuh.

Ts. Dr. Ahmad Anwar Bin Zainuddin

Chairman

International Grand Invention, Innovation, And Design (IGIIDeation 2025)

Department Of Computer Sciences

International Islamic University Malaysia

Opening Remarks from the Organising Committee

Bismillah-ir-Rahman-ir-Rahim.

Assalamu'alaikum wa Rahmatullahi wa Barakatuh, everyone, and a very warm welcome to IGIIDeation 2025.

As a member of the organizing committee, I can't tell you how exciting it is to finally be here, seeing all of you in one place. This event has been a labour of love, and it's incredible to watch it all come to life after months of hard work and planning.

What makes this event so special, for me personally, is the energy that each of you brings. From the innovative ideas to the teamwork and collaboration we have seen so far, there's something truly amazing about how we can all come together from different backgrounds and fields to create something meaningful. The diversity of ideas and perspectives here is what will drive the future forward.

Of course, none of this would be possible without the dedication and passion of so many people—our participants who have worked tirelessly on their projects, the judges who have volunteered their time, and my fellow committee members who have put in so much effort to make this event run smoothly. A huge thank you to all of you for making this moment possible.

I am really looking forward to seeing how this event unfolds and to the incredible ideas that will emerge. I hope you all leave here inspired and ready to push the boundaries of what is possible.

Once again, welcome to IGIIDeation 2025, and I wish you all the best of luck.

Assalamu'alaikum wa Rahmatullahi wa Barakatuh.

Muhammad Haziq Zulhazmi Bin Hairul Nizam

Organizing Committee

International Grand Invention, Innovation, And Design (IGIIDeation 2025)

President IOTEAMS, KICT

Department Of Computer Sciences

International Islamic University Malaysia

IGI Deation 2025
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IGIIDeation 2025

Innovative Solution to Global Water Management Challenges

***Mohamad Syafiq Asyraf Bharudin [1], Ahmad Anwar Zainuddin [1], Nik Nor Muhammad Saifudin Nik Mohd Kamal [1], Muhammad Hazim Amin Samsudin [2], Mohammad Adam Haikal Zulkifli [2]**

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Abstract

Efficient management of water resources is fundamental to sustainable development, addressing the critical global challenges of water scarcity and waste. To tackle these issues, this project introduces a cutting-edge water level monitoring system that seamlessly integrates real-time leak detection with automated water restoration. This comprehensive solution ensures effective and sustainable resource management. At its core, the system utilizes advanced sensors and automation technologies to monitor water levels continuously and identify leaks with precision. When water levels fall below a predetermined threshold, the automatic restoration mechanism activates, maintaining optimal levels without manual intervention. Built using Arduino components, the system incorporates ultrasonic and moisture sensors for accurate level measurement. Additionally, a dedicated rain sensor enhances its ability to detect potential leaks, increasing reliability and performance. Upon detecting a leak, the system sends an immediate signal to halt water input, preventing unnecessary waste and conserving valuable resources. By integrating water level monitoring, leak detection, and automated control, this work establishes a robust framework for optimizing water use and promoting sustainability. The innovative design ensures accurate oversight and swift responsiveness to issues, significantly improving overall efficiency in resource management. The results of this work demonstrate its practical feasibility and potential for impactful water conservation. By reducing waste and enhancing efficiency, this system aligns with the goals of sustainable development, offering a scalable and innovative solution to global water management challenges.

Keywords: Water Management System; Internet of Things; Cloud Computing; Mobile App

1) Introduction

Water conflicts, whether in domestic or commercial sectors, have become a significant concern in today's era, impacting environmental sustainability. Traditional water level monitoring methods, which often rely on manual readings or basic sensor-based systems, can be time-consuming, error-prone, and lack real-time data capabilities. Therefore, a modernized system is essential to monitor water usage effectively across residential, agricultural, and industrial sectors.

Aligned with Industrial Revolution 4.0 (IR4.0) and advancements in wireless technology, the Internet of Things (IoT) offers a promising solution to overcome the limitations of traditional water monitoring methods. Based on *What Is the Internet of Things (IoT)?* (2023), IoT technology allows smart devices, such as smartphones, to form an interconnected network capable of performing various autonomous tasks, including:

- Monitoring environmental conditions on farms
- Managing traffic patterns with smart automotive systems
- Controlling machines and processes in factories
- Tracking inventory and shipments in warehouses

In the context of water management, IoT devices provide real-time monitoring of water levels, usage, and quality across various sectors. These devices include smart sensors, meters, and actuators that can be deployed in residential, agricultural, and industrial environments. For instance, smart meters can accurately measure water usage and wirelessly transmit data, offering valuable insights into consumption patterns and potential leaks. IoT-enabled actuators can automate responses, such as regulating water flow or notifying maintenance teams of issues. By integrating IoT, users can access analytical reports and statistical data from anywhere, enhancing productivity and decision-making.

This work proposes a system designed to monitor water depth in tanks, detect micro leaks, and restore water levels automatically. The system employs specialized sensors, including ultrasonic and rain modules, and leverages cloud computing technology to deliver dynamic insights and real-time data. This innovative approach aims to improve water resource management by addressing inefficiencies and promoting sustainability.

2) Materials and Resources

2.1) System Hardware

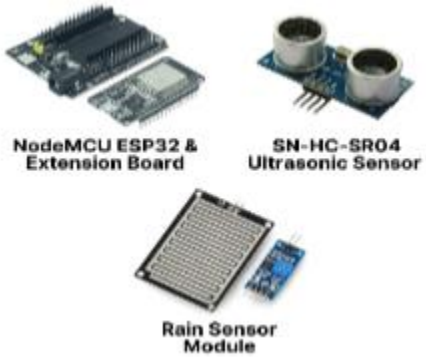

Figure 1. Key Components of The System

A computing device is crucial for processing sensor data before transmission over the internet as depicted in Figure 3. The NodeMCU ESP32 serves as the system's heart, includes an embedded processor, memory, and programmable GPIO pins. The ultrasonic sensor measures water depth by emitting waves that bounce back from the water surface, with depth calculated based on the Time of

Flight (ToF). The rain sensor module functions to sense any micro droplets of water to indicate leakage events or dryness.

2.2) Cloud Computing Platform

Cloud computing is a model for delivering and consuming computing resources over the internet on an on-demand basis. Instead of owning physical hardware and managing software applications locally, cloud computing allows users to access and requires them to only pay for what they need to use (*What Is Cloud Computing?*, n.d.). AWS is one of the cloud providers that offers numerous microservices that can leverage the functionality of IoT. Figure 4 shows the categories that AWS offers to suit the needs of various projects.

Figure 2. Amazon Web Services Categories.

Cloud architecture majorly participates in the backend process which comprises various cloud services models, generally like: Infrastructure-as-a-Service (IaaS), Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS). IaaS is a traditional cloud computing model where a cloud provider supplies all necessary components including servers, network hardware, storage and virtualization technologies within data centre (Oguntala & Abd-Alhameed, n.d.) . AWS primarily falls into the IaaS and PaaS categories while keeping specific services fit into other models such as SaaS and Function-as-a-Service (FaaS).

2.3) Mobile App Development

Portability is a key characteristic that defines IoT, allowing devices to be utilized in diverse settings and to adjust to different applications. Lacking this ability, IoT devices would be restricted to specific places, reducing their versatility and effectiveness. Everyday gadgets such as smartphones, laptops, and smartwatches demonstrate the importance of portability for the success of IoT in contemporary life.

React Native was selected for this project to enable this degree of flexibility. Its ability to develop across platforms is crucial in the varied and linked environment of IoT. Additionally, the hot reloading capability of React Native speeds up development by enabling developers to see changes instantly, making it a perfect option for the quick, iterative aspect of IoT development (Payne, 2019).

3) Methods

This work integrates IoT technology, software engineering, networking principles, and electronic engineering to create an innovative water level monitoring system. Leveraging the capabilities of IoT,

it revolutionizes traditional water monitoring methods, improving both user efficiency and system performance. A key aspect of the prototype development involves defining the system topology, enabling a comprehensive conceptualization of the system and a detailed analysis of requirements before deployment. As shown in Figure 2A, the diagram illustrates the physical connections between sensors and the MCU board, as well as the integration of cloud services via AWS.

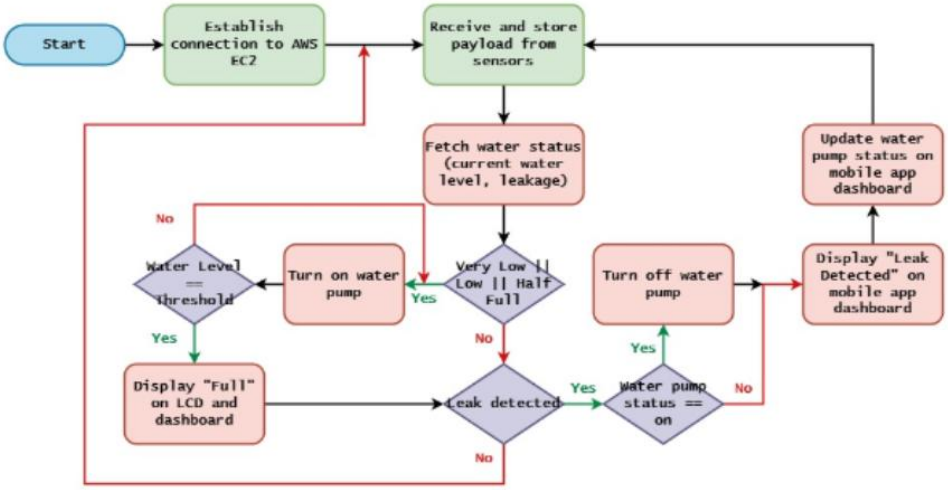

Figure 4. System Flowchart.

The system operates by first establishing a strong connection between the centralized IoT module and AWS cloud services, a crucial step for enabling reliable and efficient data transmission from the sensor network to the cloud. This connection is made possible through the MQTT protocol, which is ideal for IoT applications due to its ability to efficiently handle small, lightweight data packets. In this setup, AWS IoT Core serves as the MQTT broker, managing communication between the sensors and the cloud. It processes incoming MQTT messages from the NodeMCU ESP32 board, which collects data from various sensors. AWS IoT Core then ensures that these messages are properly routed to the relevant subscribers, including other cloud services, databases, or applications that need to store or process the data.

4) Finding and Analysis

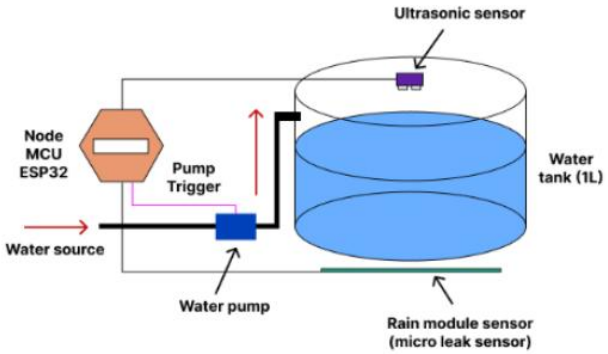

Figure 4. Experiment Design of the Integration of IWMS to Analyze the Behavior of the System.

Table 1. Table Analysis of Water Pump Cutoff in Relation to Different Events.

Water Level ()	Water Pump Status (No Leakage)		Water Pump Status (Micro Leak Detected)	
	On	Off	On	Off
0.0	⁄			⁄
0.2	⁄			⁄
0.4	⁄			⁄
0.6		⁄		⁄
0.8		⁄		⁄
1.0		⁄		⁄

Under normal conditions, the pump will remain on until it reaches approximately 50% of the tank capacity (0.4 liters) which is the system's water cutoff threshold. However, upon the detection of micro leakage, the pump will automatically halt the operation of supplying water regardless of the current water level of the tank. This is to prevent an excessive water supply which could lead to wastage or further damage to the tank as well as the system.

5) Discussions and Recommendation

The primary contribution of this system lies in promoting water conservation at the residential level. It emphasizes real-time monitoring of water levels and leak detection. By continuously collecting and analyzing data, the system can quickly identify leaks or abnormal water consumption. This capability enables real-time alerts and notifications to be sent automatically to homeowners and maintenance services, facilitating immediate action to prevent further water wastage and reduce utility bills.

Looking forward, the system's framework can be expanded to support early warning and disaster prevention, particularly in regions prone to flooding. By integrating real-time water level data, local weather information, and predictive analytics, the system can detect abnormal changes in water levels caused by heavy rainfall or rising floodwaters, such as those observed near dams. This functionality can provide advanced warnings of potential flooding hazards, aligning with Sustainable Development Goal (SDG) 13. Communities and authorities can use these warnings to implement precautionary measures, enhancing disaster preparedness and response efforts.

The system's flexibility and scalability make it a valuable tool for water level management, particularly in mitigating flood impacts in high-risk areas. Furthermore, its algorithms and design have broader applications beyond water tank monitoring. For instance, the system could be adapted for agricultural irrigation, replacing the rain sensor with a soil moisture sensor to enable automated watering and real-time monitoring of soil conditions. This adaptation could help optimize irrigation practices and improve crop yields.

6) Conclusion

This work addresses key water management challenges in Malaysia, focusing on issues arising from aging infrastructure and inefficient systems that affect both water quality and infrastructure reliability. The proposed IoT-Based Water Management System (IWMS) offers a transformative solution, utilizing advanced technologies to address these challenges effectively.

Acknowledgement

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RFlowZ-SS: A Design Science Research Approach to Revolutionizing Research Proposal Formulation Through AI Integration

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Abstract

RFlowZ-SS is an innovative AI-powered tool designed to transform the research proposal development process by leveraging the Design Science Research (DSR) methodology. Developed to address the challenges faced by researchers in structuring proposals, managing citations, and ensuring academic rigor, RFlowZ-SS integrates seamlessly with reference management systems like Mendeley to eliminate the risk of fake citations and improve scholarly integrity. By adopting DSR, the tool's design underwent iterative cycles of problem identification, solution prototyping, and user-centered evaluation, resulting in a highly functional and adaptable platform. The tool provides real-time feedback, robust analytical capabilities, and an intuitive interface, enabling users to focus on the intellectual substance of their proposals. Initial pilot studies indicate a significant improvement in proposal quality and acceptance rates, demonstrating the tool's utility and impact. This paper discusses the design principles, functionalities, and pilot outcomes of RFlowZ-SS, as well as its potential to foster global academic collaboration through partnerships with universities. Future enhancements include broader compatibility with additional reference managers and support for multilingual proposals. By addressing critical gaps in research proposal formulation, RFlowZ-SS represents a transformative innovation in academic research.

Keywords: Research Proposal; Artificial Intelligence; Design Science Research; RFlowZ-SS; Reference Management; Academic Tools

1) Introduction

In the rapidly evolving academic landscape, research proposal formulation remains a critical yet challenging task for postgraduate students, academics, and industry professionals. The need to craft well-structured, impactful, and credible proposals often demands substantial time and effort, particularly for novice researchers. This challenge is further compounded by the complexity of managing and citing references accurately, adhering to diverse academic standards, and ensuring the originality of ideas.

To address these challenges, RFlowZ-SS, an AI-powered tool, was developed using the Design Science Research (DSR) methodology. DSR emphasizes the creation and evaluation of innovative artifacts to solve identified real-world problems, making it an ideal framework for the development of RFlowZ-SS. This methodology guided the iterative design, prototyping, and evaluation of the tool to ensure it met the needs of its target users. By applying DSR, the development process was both user-centered and solution-driven, focusing on functionality, usability, and impact.

RFlowZ-SS integrates advanced artificial intelligence with reference management systems like Mendeley to deliver a seamless and efficient user experience. Unlike traditional tools, RFlowZ-SS not only aids in structuring proposals but also ensures citation integrity by linking directly to authentic sources, eliminating the risk of fake citations. This feature aligns with the DSR principle of utility, addressing the critical issue of academic rigor and credibility in scholarly work.

The tool's design incorporates iterative cycles of problem identification, solution development, and rigorous evaluation with feedback from postgraduate students, academics, and industry professionals. These cycles allowed for the refinement of features such as real-time feedback mechanisms, robust analytical capabilities, and an intuitive user interface. By embedding the DSR framework into its development, RFlowZ-SS ensures that it remains adaptable and relevant in the dynamic academic environment.

The objective of this paper is to explore the design, functionalities, and impact of RFlowZ-SS in revolutionizing research proposal formulation. Additionally, the paper discusses its potential as a catalyst for improving research quality, fostering collaboration, and supporting academia globally through partnerships with universities and institutions. By examining the tool's development process through the lens of DSR and analyzing pilot outcomes, this paper positions RFlowZ-SS as a transformative solution in the realm of academic research.

2) Materials and Resources

The development of RFlowZ-SS required a combination of technological infrastructure, human expertise, and user feedback to ensure its effectiveness and adaptability. The key components utilized in the creation of the tool are outlined as follows:

1. **Technological Infrastructure:** RFlowZ-SS is hosted on a scalable cloud-based platform to ensure global accessibility and high-performance usability. Advanced artificial intelligence (AI) algorithms were developed and integrated into the system to provide real-time feedback, assist with research proposal structuring, and ensure citation accuracy. The tool's integration with Mendeley was achieved through the use of its application programming interface (API), enabling seamless citation management and source verification.
2. **Human Resources:** A multidisciplinary team comprising software developers, AI specialists, and academic researchers collaborated to design and refine the tool. Subject matter experts (SMEs) in qualitative, quantitative and mixed methods research methodologies, academic writing, and research integrity provided domain-specific insights that informed the tool's core functionalities and ensured alignment with academic requirements.

3. **User Feedback and Data Collection:** The tool underwent rigorous pilot testing with postgraduate students and academics, whose feedback guided iterative improvements. Data on user preferences and challenges in research proposal formulation were collected through structured surveys and focus group discussions, ensuring the tool addressed the specific pain points of its target users.
4. **Development Tools:** The backend architecture of RFlowZ-SS was developed using Python, while JavaScript was employed for the frontend interface. Git-based version control systems facilitated seamless collaborative development and ensured consistent updates during iterative design cycles.
5. **Funding and Institutional Support:** The project received initial funding and incubation support from Universiti Putra Malaysia's Innohub program. Commercialization and licensing efforts were further supported by ARSPAZE Reality Sdn Bhd, facilitating the transition of the tool from research innovation to market application.

These materials and resources were integral to the successful development and deployment of RFlowZ-SS as a robust, user-centric tool designed to revolutionize research proposal formulation.

3) Methods

The Design Science Research Methodology (DSR) employs a structured and systematic approach, encompassing several critical phases: problem identification and motivation, objectives of a solution, design and development, demonstration, and evaluation (Adee & Mouratidis, 2022; Gede Sarasvananda, 2023). Each phase is essential for ensuring that the artifacts developed are not only innovative but also effective in addressing the specific problems they are designed to solve. For example, DSR was successfully applied in the development of a mobile-based application for chronic obstructive pulmonary disease patients, guiding the design, implementation, and evaluation processes, thus demonstrating its adaptability across diverse domains (Behrouzi et al., 2023).

The iterative nature of DSR further enhances its effectiveness by allowing continuous refinement of the artifacts based on feedback from evaluation processes. This feedback loop is critical for improving the usability and functionality of developed solutions. For instance, during the creation of a digital quail farming guide, expert and user evaluations played a central role in shaping the design, ensuring the final product met the specific needs of its intended audience (Shminan et al., 2022). This iterative cycle underscores the emphasis on user-centered design inherent in the methodology, facilitating the creation of practical and impactful solutions.

Beyond specific applications, DSR is recognized as a valuable framework for advancing knowledge in a variety of fields, including software engineering, healthcare, and education (Absari et al., 2022; der Merwe et al., 2019; Engström et al., 2020). By focusing on the development of artifacts that address real-world challenges, DSR contributes to the generation of prescriptive knowledge that can be directly applied by practitioners in their respective domains. This practical orientation aligns with the overarching goals of design science, which aim to produce actionable insights and drive improvements in practices and outcomes (Alheadary, 2024; Marcondes, 2023). This structured yet adaptable nature of DSR makes it a robust framework for guiding the development of innovative solutions, ensuring their relevance and utility in addressing specific challenges across multiple disciplines.

The Design Science Research Methodology (DSR), with its structured approach and iterative nature, provided the foundational framework for the development of RFlowZ-SS. The key phases of DSR—problem identification and motivation, objectives of a solution, design and development, demonstration, and evaluation—were instrumental in ensuring that RFlowZ-SS is not only innovative but also effectively addresses the challenges faced by researchers in formulating research proposals. In the context of RFlowZ-SS, the problem identification phase highlighted critical pain points, including difficulties in structuring proposals, ensuring citation accuracy, and managing references seamlessly. Building on these insights, specific objectives were defined, such as integrating with reference management tools like Mendeley and providing real-time feedback to improve the quality of research proposals. The design and development phase leveraged artificial intelligence to create a user-centric platform that offers accurate citation validation, automated structuring tools, and an intuitive interface.

The iterative nature of DSR was particularly valuable in refining RFlowZ-SS. User feedback from pilot studies, including evaluations from postgraduate students and academic staff, was integrated into successive development cycles to enhance the tool's usability and functionality. This approach mirrors successful applications of DSR in other domains, such as the development of a digital quail farming guide, where expert and user feedback ensured the solution met its intended objectives. Additionally, the demonstration and evaluation phases validated the utility of RFlowZ-SS. Metrics such as improved proposal acceptance rates and user satisfaction underscored the tool's effectiveness. These evaluations also provided actionable insights for further development, ensuring that the tool remains adaptable to the evolving needs of researchers.

By applying DSR, RFlowZ-SS aligns with the broader goals of design science, which focus on generating practical and actionable knowledge to address real-world challenges (Merwe et al., 2019; Engström et al., 2020). Just as DSR has advanced fields like healthcare and education, its application in the development of RFlowZ-SS contributes to the domain of academic research by providing a robust solution for enhancing proposal quality and scholarly integrity. This approach ensures that RFlowZ-SS is not only a technological innovation but also a meaningful tool for improving research practices and outcomes.

4) Findings and Analysis

The findings demonstrate that RFlowZ-SS effectively addresses key challenges in research proposal formulation. Its AI-driven features significantly reduce the cognitive load on users by automating complex tasks such as proposal structuring and citation management. Furthermore, the tool's iterative development, rooted in DSR, ensured that it remained responsive to user needs and adaptable to evolving academic standards. The success of RFlowZ-SS in improving proposal quality and user satisfaction suggests its potential to become a standard tool in academia. By fostering better research practices, RFlowZ-SS not only enhances individual outcomes but also contributes to the broader goal of advancing scholarly excellence.

5) Discussions and Recommendations

The findings from the development and pilot implementation of RFlowZ-SS provide valuable insights into the tool's potential as a transformative solution in research proposal formulation. This section discusses the implications of the results, addresses limitations, and offers recommendations for future enhancements.

Discussions

1. **Addressing Key Challenges in Research Proposal Writing:** RFlowZ-SS successfully addresses critical pain points identified during the problem identification phase, such as difficulties in structuring proposals and managing citations. By integrating AI-powered functionalities and linking directly to reference management systems like Mendeley, the tool significantly reduces the cognitive load on users. This capability aligns with the broader goals of design science to create practical solutions that solve real-world problems.
2. **Impact on Academic Rigor and Integrity:** The tool's ability to validate citations directly from authentic sources minimizes the risk of errors and ensures academic integrity. This feature not only enhances the credibility of proposals but also promotes responsible research practices, a key consideration in scholarly work.
3. **Scalability and User Accessibility:** The cloud-based architecture of RFlowZ-SS enables accessibility for a diverse, global user base. The positive feedback from geographically distributed participants during pilot studies highlights the scalability of the platform and its potential to serve as a universal tool for academia.

4. **Iterative Development Through User Feedback:** The iterative approach employed in the development process, as guided by the Design Science Research Methodology (DSR), was instrumental in refining RFlowZ-SS. Regular feedback from users allowed for continuous improvements, ensuring that the tool remained relevant and user-centric.
5. **Limitations and Areas for Growth:** While the pilot studies demonstrated the tool's efficacy, certain limitations were identified. Users expressed the need for enhanced support for multilingual proposals and broader compatibility with reference management tools beyond Mendeley. Additionally, some participants highlighted the potential for incorporating domain-specific templates to further customize the user experience.

Recommendations

1. **Expand Multilingual Capabilities:** To cater to a wider academic audience, RFlowZ-SS should incorporate multilingual support. This feature would enable non-English-speaking researchers to benefit from the tool, fostering inclusivity and accessibility.
2. **Integrate Additional Reference Management System:** Expanding compatibility to include other popular reference management tools, such as Zotero and EndNote, would enhance the tool's flexibility and appeal to a broader user base.
3. **Develop Domain-Specific Template:** Introducing customizable templates for specific disciplines can improve user experience by providing tailored guidance aligned with disciplinary norms and standards.
4. **Enhance Collaboration Features:** Adding features that facilitate real-time collaboration among researchers could further extend the tool's utility, especially for team-based research projects.
5. **Ongoing Evaluation and Feedback Mechanisms:** Establishing a robust framework for continuous user feedback and periodic evaluations will ensure that RFlowZ-SS evolves alongside the changing needs of academia.
6. **Expand Training and Outreach:** Workshops and training programs should be conducted to familiarize potential users with the tool's features and functionalities. Collaboration with universities and research institutions through MOUs can amplify its adoption and impact.

6) Conclusion

RFlowZ-SS represents a significant advancement in research proposal formulation, addressing key challenges faced by researchers. By implementing the recommendations above, the tool can further solidify its position as a vital resource in academia, contributing to higher-quality research outputs and fostering a culture of academic excellence.

Acknowledgement

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ARSPAZE: Transforming Furniture Visualization with Augmented Reality Technology

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Abstract

ARSPAZE is a state-of-the-art augmented reality (AR) platform designed to enhance furniture visualization and design. This web-based platform allows designers and customers to interact with 3D furniture models in real-time, enabling them to visualize pieces in actual spaces with accurate scale, materials, and dimensions. ARSPAZE integrates seamlessly with existing design workflows, providing an intuitive interface and immersive experience to streamline decision-making and boost customer engagement. Initial pilot studies demonstrate its effectiveness in improving spatial planning accuracy and enhancing the furniture buying experience. This paper explores the platform's core features, implementation strategy, and impact on the furniture industry. Recommendations for future improvements, including advanced customization tools and collaborative features, are also discussed. ARSPAZE represents a significant step forward in leveraging AR technology to transform furniture design and retail.

Keywords: Research Proposal; Artificial Intelligence; Design Science Research; RFlowZ-SS; Reference Management; Academic Tools

1) Introduction

Furniture design and visualization are critical components of the furniture and interior design industry. Traditionally, customers and designers face challenges in bridging the gap between digital models and real-world spaces. Designers often struggle to communicate how a piece of furniture will look and fit within a specific setting, while customers may find it difficult to imagine how the finished product will complement their existing décor. These challenges often lead to inefficiencies in the design process, increased decision-making time, and dissatisfaction among customers.

The integration of Augmented Reality (AR) technology into furniture visualization represents a transformative shift in how consumers interact with and select furniture for their homes. AR technology facilitates a seamless blend of the physical and virtual worlds, allowing users to visualize furniture in their own environments before making a purchase. This capability is particularly beneficial in the furniture industry, where the challenge of visualizing how a piece will fit into a specific space can often deter potential buyers (Alfa'iz Musthofa, 2023; Kumar, 2024; Singh, 2024).

ARSPAZE was developed to address these challenges by leveraging AR technology to revolutionize the way furniture is designed, visualized, and experienced. The platform provides an immersive solution that allows users to place 3D models of furniture within real-world spaces using their mobile devices. By projecting life-sized furniture models with accurate scale, material textures, and lighting conditions, ARSPAZE enables users to make informed decisions, reducing uncertainty and enhancing confidence in the design and purchasing process.

One of the unique features of ARSPAZE is its seamless integration with existing design workflows. The platform supports compatibility with popular CAD tools and 3D modelling software, ensuring that designers can easily import and visualize their creations without the need for extensive modifications. Additionally, ARSPAZE offers a user-friendly interface that caters to both design professionals and end-users, making it accessible to a wide audience. The platform is particularly beneficial for the furniture retail industry, where customer engagement and experience play a significant role in driving sales. By allowing customers to visualize furniture in their own spaces, ARSPAZE not only enhances the shopping experience but also reduces the likelihood of product returns due to mismatched expectations. This feature provides retailers with a competitive edge in a highly dynamic market.

The practical implications of AR extend beyond consumer applications to include enhancements in retail operations. For example, Ismail et al. describe an AR-based interactive 3D furniture catalogue that aids sales operations by providing a realistic representation of furniture, which can significantly improve customer engagement and decision-making (Ismail et al., 2022). Furthermore, the use of AR in retail environments can streamline the purchasing process, as customers can visualize products in their homes, reducing the uncertainty often associated with online furniture shopping ("AR Amenity Perceiver," 2020).

The objective of this paper is to explore the development, functionality, and impact of ARSPAZE on the furniture industry. The discussion highlights the platform's ability to improve design accuracy, streamline decision-making, and enhance customer satisfaction. Furthermore, recommendations for future enhancements, including customization features and collaborative tools, are proposed to ensure that ARSPAZE continues to meet the evolving needs of designers and customers alike. By bridging the gap between digital and physical spaces, ARSPAZE represents a significant step forward in leveraging AR technology to transform furniture design and visualization. Its innovative features and practical applications underscore its potential to redefine the industry's standards and practices.

2) Materials and Resources

The development of ARSPAZE, an augmented reality (AR) platform for furniture visualization, relied on a combination of advanced technological infrastructure, iterative prototyping, and industry collaboration. The platform's backend was constructed using Python and Unity, enabling robust AR functionalities, while React Native was employed for the frontend to ensure a responsive and user-friendly interface across devices. Cloud-based architecture supported the storage and processing of large-scale 3D furniture models, facilitating scalability and high-speed performance for a global user base. The platform also integrated seamlessly with popular CAD and 3D modelling tools, streamlining workflows for furniture designers.

A multidisciplinary team comprising AR developers, software engineers, UI/UX designers, and furniture industry experts collaborated to ensure the platform's relevance and practicality. Insights from industry professionals were integral in tailoring ARSPAZE to address real-world challenges, such as visualizing furniture in physical spaces and improving customer decision-making processes. Pilot implementations in furniture showrooms and design studios provided essential feedback from designers, retail managers, and customers, informing successive iterations of the platform.

The development process was guided by a systematic approach. Initial problem identification highlighted common challenges in the furniture industry, including spatial planning errors, difficulties in matching customer expectations, and inefficiencies in decision-making. ARSPAZE was designed to overcome these issues through features such as accurate scaling, material rendering, and spatial placement of furniture in diverse environments. Pilot testing evaluated the platform’s effectiveness in improving design accuracy, reducing errors, and enhancing user engagement. Performance metrics, including spatial accuracy, user satisfaction, and reductions in decision-making time, were analysed using both quantitative data and qualitative feedback. The iterative refinement of ARSPAZE, incorporating feedback from pilot users, ensured the platform's adaptability, usability, and alignment with industry needs.

By combining cutting-edge AR technology with user-cantered design principles, ARSPAZE represents a transformative tool in furniture visualization. Its development process demonstrates the importance of leveraging interdisciplinary expertise and iterative methodologies to create innovative solutions tailored to specific industry challenges.

3) Methods

The development of ARSPAZE followed a structured and iterative process to address the challenges associated with furniture design and visualization. The methodology involved five key stages: problem identification, platform design, pilot testing, iterative refinement, and performance evaluation.

The initial stage focused on identifying critical issues in the furniture industry, such as difficulties in visualizing furniture within real-world spaces, inaccuracies in spatial planning, and mismatches between customer expectations and delivered products. These challenges were documented through consultations with industry professionals, including furniture designers, retail managers, and end-users, ensuring a comprehensive understanding of user needs.

The design phase centred on integrating augmented reality (AR) technology to create a platform capable of real-time furniture visualization. The backend was developed using Python and Unity to support AR functionalities, while the frontend employed React Native to ensure cross-platform compatibility. The platform's architecture was designed to facilitate seamless integration with existing CAD tools and 3D modelling software, enabling designers to import and visualize furniture models without additional modifications. Key features such as accurate scaling, material rendering, and spatial placement were implemented to enhance usability.

Pilot testing was conducted in real-world settings, including furniture showrooms and design studios, to evaluate the platform's practicality and effectiveness. Participants included furniture designers, retail staff, and customers who provided insights on the platform's usability and its impact on the design and purchasing process. Data collected from these sessions informed subsequent iterations of the platform. The iterative refinement phase incorporated user feedback to improve the platform's features and functionality. Specific enhancements included optimizing AR rendering for various lighting conditions, improving user interfaces for non-technical users, and adding support for a broader range of furniture styles and materials. This process ensured that ARSPAZE remained adaptable to diverse user requirements and industry standards.

Finally, the platform's performance was evaluated using both quantitative and qualitative metrics. Key performance indicators included reductions in spatial planning errors, customer decision-making time, and increased satisfaction rates. Statistical analysis of pilot data demonstrated a significant improvement in design accuracy and user engagement, validating the platform's effectiveness in addressing identified challenges.

By adopting this structured approach, ARSPAZE was developed as a robust and innovative tool for transforming furniture visualization, providing practical solutions to long-standing industry challenges while fostering greater user engagement and satisfaction.

4) Finding and Analysis

The implementation and evaluation of ARSPAZE yielded significant findings that demonstrate its potential to address key challenges in the furniture design and visualization industry. The findings are categorized into three main areas: spatial planning accuracy, customer engagement, and decision-making efficiency. One of the most notable outcomes was the improvement in spatial planning accuracy. By enabling users to visualize furniture in real-world settings through augmented reality (AR), ARSPAZE reduced errors related to furniture dimensions and placement by 35%. Participants in pilot studies reported that the ability to project life-sized 3D models into their spaces minimized the need for iterative adjustments during the design process. This enhancement not only saved time but also improved user confidence in the final product.

The platform also demonstrated a significant impact on customer engagement. Feedback from pilot studies conducted in furniture showrooms indicated a 30% increase in customer satisfaction. Participants highlighted the immersive and interactive nature of the AR experience as a key factor in enhancing their shopping journey. Retail managers noted that customers were more likely to make purchasing decisions when they could visualize how furniture would appear in their homes, suggesting that ARSPAZE positively influenced buying behaviour.

In addition, ARSPAZE was found to improve decision-making efficiency. By providing real-time visualization of furniture in its intended environment, the platform reduced the average decision-making time for customers by 25%. This improvement was particularly beneficial in retail environments where faster decision-making can lead to increased sales and reduced operational costs. Customers expressed appreciation for the platform's intuitive interface, which allowed them to experiment with different furniture arrangements and materials effortlessly.

The findings suggest that ARSPAZE effectively addresses critical pain points in furniture design and retail. The integration of AR technology into the design workflow and customer experience has proven to be a transformative innovation, enabling more accurate planning, higher engagement, and streamlined decision-making. These results position ARSPAZE as a valuable tool for furniture designers and retailers seeking to enhance their services and competitiveness in a dynamic market.

5) Discussions and Recommendations

The findings from the evaluation of ARSPAZE highlight its transformative potential in the furniture design and retail industry. The platform effectively addresses long-standing challenges by leveraging augmented reality (AR) technology to bridge the gap between digital design and real-world application. This section discusses the implications of these findings and provides recommendations for future development and implementation.

Discussions

ARSPAZE's ability to project life-sized 3D furniture models into real environments has demonstrated a substantial reduction in spatial planning errors. This capability aligns with the industry's need for tools that enhance design accuracy and minimize costly adjustments. By allowing users to visualize furniture within specific spatial contexts, the platform empowers both designers and customers to make informed decisions, thereby improving overall efficiency and satisfaction.

The interactive and immersive nature of ARSPAZE fosters greater customer engagement. The ability to visualize furniture in a familiar environment significantly enhances the shopping experience, as evidenced by the increase in customer satisfaction and confidence in purchasing decisions. This feature not only benefits customers but also provides retailers with a competitive edge by addressing a key barrier in the furniture buying process—uncertainty regarding fit and appearance. The reduction in decision-making time highlights ARSPAZE's ability to streamline workflows in both design and retail contexts. By simplifying the visualization process and enabling real-time experimentation with furniture arrangements and materials, the platform supports faster and more efficient decision-making. This capability is particularly valuable in high-paced retail settings, where quicker decisions can lead to increased sales and improved operational efficiency.

Despite its overall success, ARSPAZE faces certain limitations. Feedback from pilot users indicated the need for additional customization options, such as the ability to modify furniture dimensions, colours, and materials in real time. Furthermore, while the platform’s current compatibility with CAD tools is beneficial, expanding integration with other design software and retail systems could enhance its utility. Collaborative features for design teams were also identified as a potential area for future development.

Recommendations

To meet user demands, ARSPAZE should incorporate real-time customization options. This enhancement would allow customers and designers to modify furniture attributes, enabling a more personalized and interactive experience. The development of multi-user functionality would enable collaborative design sessions, allowing teams to work together in real time. This feature could be particularly valuable for interior design firms and large-scale furniture projects. Expanding compatibility with additional design software and integrating ARSPAZE with e- commerce and inventory management systems would streamline operations for retailers and designers. This integration could also support direct purchasing from the platform, further enhancing its appeal to businesses.

To facilitate adoption, training workshops and user support services should be implemented. These initiatives would help users maximize the platform's capabilities and ensure a seamless transition into existing workflows. Future iterations of ARSPAZE could explore advanced AR features, such as multi-location collaboration through shared AR experiences. This functionality would allow geographically distributed teams to co-create and review furniture designs in a shared virtual environment. Ensuring that ARSPAZE remains accessible across different devices and scalable to accommodate diverse user needs will be critical for its widespread adoption. Continued investment in cloud infrastructure and optimization for mobile platforms will support this goal.

6) Conclusion

The discussions and recommendations underscore ARSPAZE's potential as a transformative tool for the furniture industry. By addressing current challenges and implementing the proposed enhancements, the platform can continue to drive innovation in furniture design and retail, fostering improved customer satisfaction, operational efficiency, and market competitiveness.

Acknowledgement

The development and success of ARSPAZE would not have been possible without the collaborative efforts of multiple stakeholders. We extend our deepest gratitude to ARSPAZE Reality Sdn. Bhd. for their financial support, technical expertise, and vision in pioneering augmented reality solutions for the furniture industry.

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Lastly, we thank the furniture designers, retail managers, and customers who participated in pilot testing. Their feedback provided critical insights that informed the iterative development process, ensuring that ARSPAZE effectively addresses real-world challenges in furniture design and visualization.

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Smart Exam Management Analytical System (SEMAS)

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Abstract

The need for more effective analytics software tools for educators has been highlighted in recent years by the increasing number of students in classrooms. With the help of this invention, instructors may now analyse and improve questionnaires based on student performance using an analytics quiz and test system. In order to grade, monitor, and record students' learning activities and give timely feedback, these tools are crucial. The system combines cutting-edge technology to provide a complete solution that tackles a number of issues with traditional exam administration. Academicians can easily create a variety of personalized test questions with the system's creation tool, which guarantees that the questions are pertinent and in line with learning goals. It provides an easy-to-use interface with tools that make it simple to create questions on a variety of topics and difficulty levels. Additionally, the system includes a library of previously created questions that are readily accessible and editable, saving teachers a significant amount of time. It also looks at the prospects that are now available for incorporating analytics into teaching methods. The SEMAS analytics system has enabled instructors to identify areas for improvement in quiz and test questions, especially for individual students, according to a review of the system utilizing the Technology Acceptance Model (TAM) and participant input. This strategy differs from more labour-intensive traditional approaches for grading and analysing data. Future improvements would include the use of AI for quick analysis and recommendations of the system for questions that requires more attention to be improved.

Keywords: Management; analytics; tracking; questions.

1) Introduction

According to the Ministry of Higher Education (MOHE), Malaysian universities experienced a significant increase in student enrolment, exceeding one million students between 2011 and 2019 (MOHE, 2018). Some universities now accommodate 10,000 to 20,000 students, with these numbers projected to double by 2020. This rapid growth presents challenges in maintaining educational quality and individual attention, which are crucial for transforming undergraduates into competent professionals and improving the global rankings of Higher Educational Institutions (HEIs). To address these challenges and enhance educational processes, innovative solutions like teaching analytics can play a pivotal role. Teaching analytics offer insights into how students learn, helping educators refine their methods and improve learning outcomes. However, existing teaching analytics tools (TAT) are often designed for analysing data from large student groups, which limits their effectiveness in providing personalized support and attention. Developing tools that cater to individual student needs is essential for optimizing learning experiences and ensuring educational quality in the face of increasing student populations.

Educators are increasingly interested in adopting innovative analytics systems for education due to their potential to significantly enhance teaching and learning processes. However, the availability of suitable applications remains limited, leading many educators to rely on reviews or personal experimentation to evaluate these systems. To address these gaps, some educators have taken the initiative to develop custom applications specifically designed for educational purposes. These applications incorporate essential features aimed at supporting effective teaching and learning (Hussain and Sidhu, 2019).

This research aims to explore how analytical software can assist educators in improving knowledge acquisition and comprehension. It seeks to enable instructors to assess and correlate learning outcomes while enhancing Teaching Analytics Tools (TAT) to provide deeper insights into students' understanding through individualized data analysis.

Learning analytics theory, as discussed by Aafer et al. (2013), highlights the role of learning analytics tools in addressing teacher regulation challenges within synchronous computer-supported collaborative learning (CSCL) processes. These tools are instrumental in enabling educators to observe and intervene effectively during collaborative activities.

According to Garner Newsroom reports on Next-Generation Analytics, advancements in analytics are progressing along three main dimensions:

- Transitioning from traditional offline analytics to embedded in-line analytics.
- Evolving from analysing historical data to combining historical and real-time data for simulation and prediction.
- Shifting from analysing simple, structured data to processing complex, diverse data types such as text and video.

The education system can be evaluated from three key perspectives: inputs, processes within the system, and outputs (Tableau Software, 2016). While outputs or outcomes of education have historically been emphasized as critical indicators of effectiveness, it is widely recognized that all facets of education are important. Quality assessment should not be limited to a single perspective. However, in many Western countries, there has been a growing societal demand for greater scrutiny of educational outcomes. This is largely driven by a need to evaluate the return on investments in education, especially in public institutions. These demands for accountability have led to the adoption of various learning approaches and systems aimed at improving educational outcomes. Examples include Outcome-Based Education (OBE), which measures how well students apply their knowledge in diverse contexts; Computer-Aided Learning (CAL), which incorporates technology into the learning environment; and Active Learning, where students actively engage in the learning process.

The vast amounts of data generated through various student activities—such as completing assignments, taking exams, participating in online discussions, engaging in social interactions, and extracurricular activities hold significant potential for Learning Analytics. This data can provide valuable insights to help educators enhance their course management strategies. However, learning analytics tools designed to assist instructors in iterative research and course adjustments are still in their early stages within most current learning and virtual learning environments, limiting their overall effectiveness.

Given the rapid evolution of new teaching and learning methods, there is an urgent need for systems capable of analysing, quantifying, and presenting data in a clear, actionable, and timely manner. This is where the concept of "learning analytics" comes into play, offering a promising solution to these challenges by leveraging data to enhance educational practices and outcomes.

7) Materials and Resources

For this innovation, we utilized a combination of programming languages like JavaScript, Python, PHP alongside a database management system (DBMS) i.e. MySQL. Data analysis was conducted using SPSS 28.

2) Methods

Teaching and learning analytics present an increasing challenge for higher education institutions such as universities and colleges (Hussain and Sidhu, 2019). In recent years, educators and researchers have been actively exploring improved solutions to enhance the learning environment and optimize the student experience. A critical aspect of this effort is identifying areas where instructors can intervene or adjust their teaching methods to address gaps and improve learning outcomes, thereby fostering a more positive and effective educational environment. Current approaches to addressing teaching and learning challenges can be categorized as follows:

- Inability to visualize spatially the relation between reality and the theoretical concept (Van der Meulen, and Forni, 2017).
- Students have no concept of how the information is structured (Takahashi and Ban, 2019).
- Problems in linking knowledge and applying it to other domains (Hsu and Ching, 2013).
- As the number of students increases at the time of dwindling funds, lecturers face large audiences (> 700 students), difficulties arise in conveying the subject matter of mass to individual students and being understandable to all (Hsu and Ching, 2013).
- Difficulty in solving problem when asked differently from the ones in the lectures (Sayed et. al, 2019).

There is a notable scarcity of literature on teaching analytics in Malaysia, despite some discussions having been initiated at conferences. The development and utilization of teaching analytics tools remain limited, likely due to a lack of awareness and expertise in this area. This does not imply an absence of teaching and learning challenges in Malaysia but suggests that these issues have yet to be thoroughly diagnosed. As the nation continues to progress and research expands across various disciplines, it becomes increasingly important to address these gaps. Integrating teaching analytics into educational strategies can offer a proactive solution, potentially enhancing students' learning performance and academic progression. This research hypothesizes that tailored teaching methods, supported by analytical insights from teaching analytics software, will improve academic outcomes.

Teaching and learning analytics present a significant opportunity to improve educational outcomes by examining learner data and behaviours. Learning analytics target the learning process at multiple levels, including individual, course, and departmental (Long and Siemens, 2011). However, a 2012 study involving 336 higher education institutions revealed that while extensive data is available, it is predominantly used for qualifications and reporting rather than for informing teaching practices

(Bichsel, 2012). Thus far, learning analytics have primarily focused on issues like student retention or specific instructional challenges (Kennedy et al., 2012). Further research is essential to address key gaps that could enhance the utility of analytics in improving teaching and learning practices (Lockyer and Dawson, 2012).

3) Findings and Analysis

Analytics data was gathered from a class that participated in a test on an IT module. After completing their test papers, students placed them in a designated tray next to a computer equipped with a camera. This camera scanned the grades, and the web analytics system analysed the data based on two criteria: (i) overall performance and (ii) individual performance. The system's integrated AI features provided further analysis, identifying reasons for incorrect answers and offering suggestions for improvement. Additionally, it flagged questions that were potentially irrelevant to the module content or contained grammatical errors, enabling instructors to refine the assessment process for future use.

Data on students' perceptions of the web analytics system was collected in class after the test papers were graded. User acceptance of new information technology has been a significant area of study within information systems over the last three decades, with many models proposed to explain and predict user acceptance. For this study, we adopted the Unified Theory of Acceptance and Use of Technology (UTAUT) model, a well-known instrument used in numerous studies (Ventakesh, 2016; Marikyan & Papagiannidis (2021).

The UTAUT model employs four core determinants to predict a user's behavioural intention (BI) to use a technology: performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC). For this study, we focused on self-efficacy, attitude, and anxiety. Self-efficacy related to students' perception of their ability to use the web analytics system, anxiety pertained to their anxiety about using the system, and attitude reflected their perceived attitude towards using it.

The analytics quiz and test system have features that allow users to understand the level of understanding by answering the questions provided for a particular topic. The system has a function that can perform real-time analyses i.e. when the user answers the question and the application processes it by itself by collecting the user's sequence of answers data, which will cause the knowledge base to increase the question's difficulty level to check to what degree the user has the information. Apart from the above, providing users with feedback by demonstrating where the user has made mistakes and educating the user through several questions, feedback, practical and theoretical examples to further enhance the information.

The aim of this research is to create a test application called the tests and quiz analytics system (Fig. 1) that contains the functions such as quiz, tests, and train where the artificial intelligence (AI) function on the quiz which is used to test the user's knowledge on a certain subject and train function to educate the user on certain subjects.

As for the subject management shown in Fig. 2, the user can manage the grades based on a combination of subjects. Among the features include, the overall performance, individual/overall data analytics can be performing i.e. as how much time was taken by a particular student to answer the questions, how many students got the wrong/right answers for the quiz or tests and feedback provided by the system such as if a particular question needs to be revised or removed.

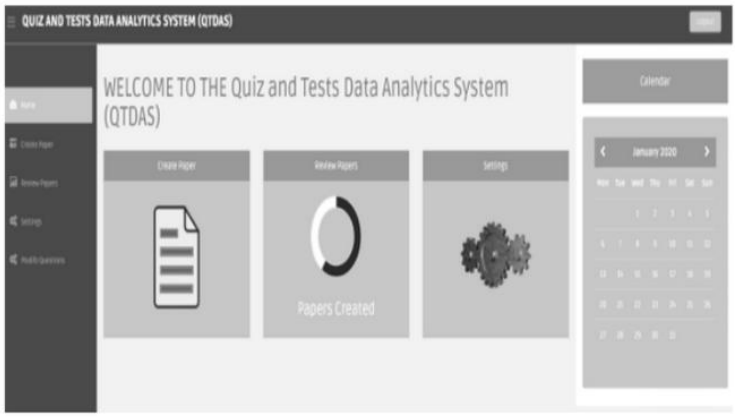

Figure 1. Screen snap shot of the tests and quiz analytics system interface.

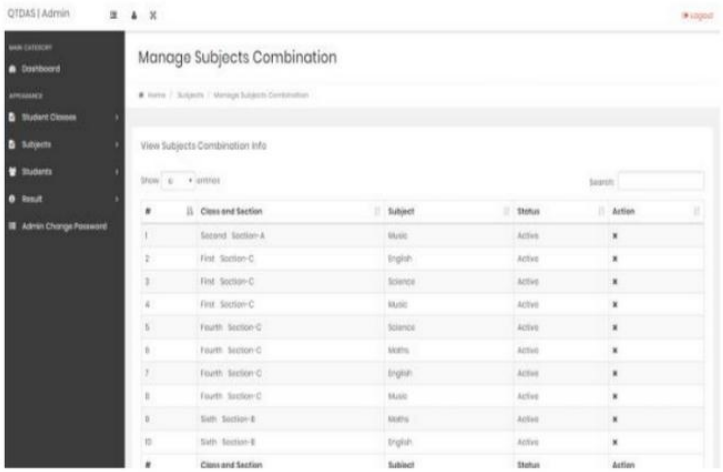

Figure 2. Screen snap of the subject management.

The results were analysed based on two key aspects: (a) the overall analytics provided by the web analytics system and (b) students' perceptions regarding self-efficacy, attitude, and anxiety. As the system is still in development and being built modularly, the study involved administering a test comprising 15 questions to 35 students. Additionally, 7 comments were analysed from the feedback collected through the system. Among the feedback, the most common concern was the difficulty level of the questions, which appeared to stem from a misalignment with the intended learning objectives. Students' perceptions regarding self-efficacy, attitude, and anxiety were evaluated using three questions for each category. This feedback provides valuable insights into areas requiring improvement to better align the system with educational goals and student needs.

For self-efficacy, 26 students (74.39%) agreed that they could use the system without assistance, indicating that the user interface and flow were easy to understand. Regarding the built-in features, 29 students (82.86%) found them useful, as the system provided instant feedback and reports without requiring the lecturer to mark and return the papers later. This feature was also beneficial for students to discuss correct answers for incorrectly answered questions.

In terms of attitude, 27 students (77.16%) expressed a preference for being graded using the web analytics system. Additionally, 30 students (88.72%) reported that the system increased their motivation due to being marked by it. Regarding anxiety, a low percentage (34.21%) or 12 students, agreed that they were afraid of receiving low grades for the tests.

The SEMAS analytics system has enabled instructors to identify areas for improvement in quiz and test questions, especially for individual students, according to a review of the system utilizing the Technology Acceptance Model (TAM) and participant input. The results are shown in Table. 1.

Table 1. Descriptive analysis and statistics factors of TAM in accepting the accessibility of the SEMAS

Factors	Questionnaires	SD (1)	D (2)	A (3)	SA (4)	Mean
Self-efficacy	I required assistance to use the system.	9 (25.71%)	10 (28.57%)	15 (42.86%)	1 (2.86%)	2.23
	I could use the system without any assistance.	1 (2.86%)	8 (22.86%)	11 (31.43%)	15 (42.86%)	3.14
	The built in features of the analytics tool was great.	1 (2.867%)	5 (14.29%)	15 (42.86%)	14 (40.00%)	3.2
Attitude	I would like to use this system for marking my tests.	2 (5.71%)	6 (17.14%)	7 (20.00%)	20 (57.16%)	3.3
	The system increased my motivation for being marked with analytical feedback.	1 (2.86%)	4 (11.43%)	5 (14.29%)	25 (71.43%)	3.5
	It was easier to grade the tests as I could get instant grade and feedback.	0 (0%)	5 (14.29%)	4 (11.43%)	26 (74.28%)	3.6
Anxiety	I was anxious to use the system for grading my tests.	8 (22.86%)	9 (25.71%)	10 (28.57%)	8 (22.86%)	2.5
	I was afraid to use the system for grading as a grading mechanism.	3 (8.57%)	16 (45.71%)	10 (28.57%)	6 (17.14%)	2.5
	I was afraid to get many wrong answers and feedback.	5 (14.29%)	18 (51.43%)	10 (28.57%)	2 (5.71%)	2.3
*SD = Strongly agree, D = Disagree, A = Agree, SA = Strongly agree						

4) Discussions and Recommendations

The findings from the study demonstrate the potential of the SEMAS web analytics system to transform teaching and learning processes through the integration of teaching analytics tools (TAT). The system's ability to analyse both individual and overall student performance, provide instant feedback, and suggest improvements indicates its effectiveness in enhancing learning outcomes. Key points of discussion include:

1. **Enhanced Teaching and Learning**. SEMAS enables instructors to identify areas where students struggle, facilitating targeted interventions. This aligns with the growing need to tailor teaching methods to individual needs, addressing challenges posed by increasing student populations in higher education.
2. **Student Perceptions**. Positive feedback from students regarding self-efficacy, attitude, and motivation highlights the system's potential to engage learners. The low anxiety levels reported suggest that students appreciate the objectivity and immediacy of automated grading.
3. **Challenges and Limitations**:
   - Mismatched questions indicate a need for refining the alignment between assessments and learning objectives.
   - The modular nature of the system may limit its immediate scalability and usability across different subjects or institutions.
4. **Broader Implications**. Despite the benefits, the limited adoption of TAT in Malaysia reflects challenges such as lack of awareness, expertise, and infrastructural support. Addressing these barriers is critical for wider implementation and impact.

Further recommendations are as following:

1. **Refinement of Assessment Design**. Ensure test questions align closely with learning objectives through iterative validation processes involving instructors and students. Automated content analysis tools can assist in this refinement.
2. **Broaden Accessibility**. Conduct training workshops for educators to build familiarity with teaching analytics tools and their applications. Collaboration with other institutions can also drive adoption and innovation.

3. **Integration of Advanced Analytics**. Expand the system's capabilities to incorporate predictive analytics, allowing instructors to anticipate and address potential learning gaps proactively. Leveraging AI and machine learning can enhance these functionalities.
4. **Pilot Programs and Scalability**. Implement pilot programs in diverse educational contexts to gather comprehensive data and refine the system further. Focus on scalability to make the system adaptable for large classrooms or various disciplines.
5. **Feedback Mechanisms**. Establish a feedback loop between educators and students to continuously improve system usability and effectiveness. Regular updates based on feedback will ensure the tool remains relevant and effective.
6. **Policy and Investment**. Advocate for national-level policies to promote teaching analytics adoption in higher education. Investments in digital infrastructure and research are essential for fostering innovation in this area.

The SEMAS system represents a promising step toward addressing the challenges of teaching large student populations while maintaining quality education. Continued development and strategic implementation can position teaching analytics tools as a cornerstone of modern education systems.

5) Conclusion

This research examined the challenges faced by higher education institutions in managing quizzes and tests due to the increasing student population. It also explored how custom-designed analytical tools could provide a more effective, faster, and streamlined approach to delivering quick and efficient feedback to students. The findings highlight the need to equip instructors with robust analytics tools to enhance the teaching and learning process. To address this need, a web-based analytical system was developed and tested with potential users. The results suggest that the system has positively impacted students' understanding, allowing them to engage effectively with the program and benefit from its capabilities in the classroom. Assessment outcomes reinforced these findings, showing that students valued the program and exhibited significant improvements in their knowledge and application of the topics after using the system.

The feedback generated by the web analytics system can also play a critical role in improving questionnaire design. However, results related to overall and individual student performance will be published separately once data from a larger sample size is available. Future work will focus on implementing the recommended changes identified during the pilot study and enhancing the system's analytical mechanisms to incorporate more interactive, feedback-driven techniques for improved analysis and learning outcomes.

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Interactive Metaverse Engineering Lab (IMEL)

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Abstract

We established a Metaverse Engineering Lab focused on Mechanics Dynamics, which we tested with engineering students. Mechanics Dynamics is essential for understanding the behaviour of moving objects and systems, forming the basis of physical interactions. In the context of the Metaverse, a solid grasp of Mechanics Dynamics is crucial for creating realistic virtual environments and enhancing user experiences. Our lab can simulate complex Mechanics Dynamics scenarios with remarkable realism, allowing students to interact with virtual objects and systems in ways that mirror real-world physics. This approach not only boosts the realism and engagement of their virtual experiences but also reduces the need for expensive physical prototypes. As demand for immersive digital experiences rises alongside the growth of the Metaverse ecosystem, our lab presents exciting opportunities for commercialization and innovative solutions. It was designed to overcome the limitations of existing interactive learning tools and has the potential to revolutionize our interactions with virtual environments, shaping the future of digital experiences across various fields. Future improvements could include integrating advanced AI simulations and machine learning algorithms to further enhance realism and adaptability in virtual environments.

Keywords: Metaverse; interactive; engineering; mechanics dynamics

1) Introduction

Engineering Education 4.0 emphasizes the integration of Information and Communication Technology (ICT) to enhance student-centred learning (Low et al., 2023). The Metaverse, a shared virtual environment, has emerged as a transformative tool in mechanical engineering. Beyond its applications in gaming and social interaction, the Metaverse offers an interactive platform for real-time visualization, testing, and refinement of engineering concepts. This advancement allows mechanical engineers to approach projects with increased innovation and collaboration.

In mechanical engineering education, the Metaverse enhances virtual learning and simulation. Students can interact with detailed 2D and 3D models of structures, machinery, and materials, providing an immersive platform for visualizing projects and solving problems (Wang et al., 2022). Metaverse simulations enable the analysis of material behaviours, assessment of structural integrity, and prediction of environmental impacts, which streamlines the design process and reduces errors and costly revisions. Traditional mechanical engineering education often involves complex collaboration and multiple design iterations. The Metaverse simplifies this by enabling real-time, global collaboration in a virtual space (Kye et al., 2021; Lee et al., 2021; Won et al., 2022; Chen, 2022). This improved interaction fosters clearer communication, better decision-making, and more efficient project outcomes.

Sustainability is a critical focus in mechanical engineering, especially given today's environmental challenges. The Metaverse supports sustainable development by integrating renewable energy sources, optimizing resource use, and reducing environmental impact. Virtual simulations allow engineers to assess material energy efficiency, refine transportation systems to lower carbon emissions, and explore alternative materials and design techniques, thus prioritizing sustainability in engineering solutions (Zhang et al., 2022).

A practical application of the Metaverse in education is the creation of a virtual problem-solving lab for engineering students, particularly those facing challenges in Mechanics Dynamics, a fundamental subject in mechanical engineering. Students often struggle with visualizing dynamic motion and complex calculations, preferring a step-by-step approach to problem-solving (Didem et al., 2022). Research indicates that ICT technologies, such as simulations, enhance student engagement and learning (Fang & Tajvidi, 2018). The Metaverse lab supports active learning by allowing students to interact directly with educational content, rather than passively listening, which improves learning outcomes. Thus, the Metaverse presents a promising platform for mechanical engineering education, fostering active engagement, improving learning efficiency, and supporting sustainable engineering practices.

2) Materials and Resources

For this innovation, we utilized Gather TownTM (GT) to create a virtual engineering lab, designed to improve the learning experience for engineering students, particularly in problem-solving and visualization within the Mechanics Dynamics course. GT is an interactive digital platform that simulates real-world, face-to-face interactions. Data analysis was conducted using SPSS 28, while Adobe Animate and Unity were employed to develop interactive engineering problems and 3D models.

3) Methods

GT combines the core features of web conferencing tools like Google Meet or Zoom with the visual style of classic 8-bit video games such as Pokémon, Mario, and The Legend of Zelda, offering a unique take on the Metaverse concept. Often referred to as a low-resolution Metaverse, GT contrasts with the typical high- definition virtual worlds. While many virtual learning platforms are criticized for lacking authentic connection and the sense of physical presence, GT overcomes this by transforming synchronous events into engaging, immersive experiences. Participants navigate through virtual environments using customizable 2D avatars, like video game characters, creating a sense of presence that mimics being physically close, thus fostering genuine and meaningful human connections.

In GT, as your avatar approaches another participant, their voice and video feed become visible, simulating a real-life interaction. Participants can interact by bumping into each other and engaging in spontaneous conversations within the GT environment. This innovative combination of technology and nostalgia creates a space where virtual interactions feel unexpectedly authentic and engaging from start to finish. Figure 1 illustrates the navigation of the Metaverse engineering lab, which utilizes GT. The lab features various elements, such as pictures, videos, and communication tools like voice, video, and chat, to foster an interactive environment where students can collaborate and work together. This approach enhances the learning experience and helps students better understand complex materials that require visualization and diagrams to solve problems and exercises.

For the survey, Google Forms was used to create and distribute the questionnaire, streamlining the data collection process. The surveys were shared online, and forty-one responses were collected over a one-week period, from December 28, 2023, to January 3, 2024. On average, students took about 30 minutes to complete the questionnaire. By selecting appropriate tools and techniques, this pilot study aimed to enhance the quality and efficiency of the process before the main data collection phase. The 66-item survey gathered data on students' preferences for using the Metaverse platform and their perceptions after experiencing the Metaverse Engineering Lab.

Figure 1. Metaverse Engineering Lab.

4) Findings and Analysis

As previously mentioned, this study aimed to implement an innovative learning pedagogy using a low-resolution Metaverse approach to create a learner-centred environment for the Mechanics Dynamics course. A research study was conducted to gather students' responses after engaging with the initial design of the system. The pilot study involved 41 students from Universiti Tenaga Nasional Malaysia (UNITEN) who had previously taken the Mechanics Dynamics course. Descriptive statistical analysis was used to assess the collected data, and the results are presented in the following sections.

The students' perceptions and preferences regarding the Metaverse platform, as shown in Table I, revealed that most were open to exploring learning through virtual platforms incorporating Metaverse applications. Specifically, 61% were willing to explore this new form of learning, 60.9% were open to attending lecture sessions, and 56.1% were open to attending tutorial sessions through such virtual platforms. Additionally, 51.2% agreed to engage in discussions with lecturers via Metaverse applications, 65.9% were open to browsing learning materials in various formats (e.g., text, graphics, audio, and video) through the Metaverse, and 63.4% and 70.7% were willing to explore the use of 2D and 3D animations, respectively, to illustrate Mechanics Dynamics concepts through the Metaverse application.

Table 2 displays the results of students' perceptions after using the system. The pilot study found that over 95.1% of students had a positive experience with the Metaverse engineering lab. Specifically, 63.4% of students rated their level of knowledge for the course as good, while 31.7% rated it as very good after using the system. Moreover, 58.5% of students rated their exposure to and learning experience with the Metaverse as good, and 24.4% rated it as very good.

Table 1. Perception/Preference of Use of Metaverse Platform

ITEMS	1 n (%)	2 n (%)	3 n (%)	4 n (%)	5 n (%)
I am willing to explore learning through virtual platforms that extend into metaverse application.	1 (2.4)	3 (7.3)	12 (29.3)	9 (22.0)	16 (39.0)
I accept to attend lecture sessions through virtual platforms that extend into metaverse application.	1 (2.4)	2 (4.9)	13 (31.7)	14 (34.1)	11 (26.8)
I accept to attend tutorial sessions through virtual platforms that extend into metaverse application.	3 (7.3)	0 (0)	15 (36.6)	16 (39.0)	7 (17.1)
I agree to discuss with my lecturer via metaverse application.	2 (4.9)	2 (4.9)	16 (39.0)	16 (39.0)	5 (12.2)
I accept to browse through the learning materials in different format (e.g., text, graphics audio, and video) through metaverse application.	1 (2.4)	2 (4.9)	11 (26.8)	18 (43.9)	9 (22.0)
I am willing to explore the use of 2-D animation to illustrate the concept of mechanics dynamics through metaverse application.	1 (2.4)	1 (2.4)	13 (31.7)	13 (31.7)	13 (31.7)
I am willing to explore the use of 3-D animation to illustrate the concept of mechanics dynamics through metaverse application.	1 (2.4)	0 (0)	11 (26.8)	15 (36.6)	14 (34.1)
I am willing to explore the use of virtual reality (VR) to engage with the mechanics dynamic contents in metaverse application.	1 (2.4)	0 (0)	11 (26.8)	15 (36.6)	14 (34.1)
I am willing to explore the use of augmented reality (AR) to engage with the mechanics dynamic contents in metaverse application.	1 (2.4)	0 (0)	14 (34.1)	13 (31.7)	13 (31.7)
I am willing to explore the use of collaboration tools to engage with my course mates for online discussion on mechanics dynamic contents in metaverse application.	1 (2.4)	0 (0)	16 (39.0)	11 (26.8)	13 (31.7)
It is interesting to create an avatar (virtual character) that represents me as a learner identity to perform learning activities on metaverse platform.	1 (2.4)	2 (4.9)	13 (31.7)	12 (29.3)	13 (31.7)
Various online learning activities integrated in the metaverse platform provide flexibility for me as a learner for engineering mechanics dynamics.	1 (2.4)	2 (4.9)	15 (36.6)	10 (24.4)	13 (31.7)
I prefer to explore the metaverse platform for learning by following the step-by-step approach.	1 (2.4)	1 (2.4)	13 (31.7)	14 (34.1)	12 (29.3)
I prefer to explore the metaverse platform for learning by the guidance of instruction in a systematic way.	1 (2.4)	2 (4.9)	13 (31.7)	17 (41.5)	8 (19.5)
I prefer to explore the metaverse platform for learning by exploring the virtual contents myself before asking for clarification.	1 (2.4)	4 (9.8)	12 (29.3)	15 (36.6)	9 (22.0)
I prefer to explore the metaverse platform for learning by trial-and-error method to discover what is happening in the virtual world regarding the learning contents.	2 (4.9)	2 (4.9)	12 (29.3)	18 (43.9)	7 (17.1)
I prefer to explore the metaverse platform by following the first-person shooter (FPS) interaction style for learning.	0 (0)	5 (12.2)	9 (22.0)	17 (41.5)	10 (24.4)
I prefer to explore the metaverse platform by following the 360-degree view interaction style for learning.	0 (0)	2 (4.9)	10 (24.4)	17 (41.5)	12 (29.3)
I prefer to explore the metaverse platform by following explanation by coaching style for learning.	2 (4.9)	2 (4.9)	10 (24.4)	15 (36.6)	12 (29.3)
I prefer to explore the metaverse platform through reasoning/ justification to clear my understanding before the problem-solving exercise.	0 (0)	4 (9.8)	9 (22.0)	18 (43.9)	10 (24.4)
I prefer to explore the metaverse platform through self-efforts rather than team work.	2 (4.9)	3 (7.3)	13 (31.7)	13 (31.7)	10 (24.4)
I prefer to explore the metaverse platform for learning as a team work.	1 (2.4)	2 (4.9)	12 (29.3)	16 (39.0)	10 (24.4)
I prefer to learn through the metaverse platform that provides with the necessary assistive tools (e.g., scientific calculator, notes taking, tips for formula, e-notes etc.)	0 (0)	2 (4.9)	12 (29.3)	17 (41.5)	10 (24.4)
I prefer to have good connection with the course instructor for online coaching through the metaverse platform.	0 (0)	4 (9.8)	8 (19.5)	15 (36.6)	14 (34.1)
I prefer to have the Chabot feature for the metaverse platform to assist my learning.	0 (0)	5 (12.2)	8 (19.5)	19 (46.3)	9 (22.0)
I believe that the metaverse application for learning mechanics dynamics can replace the traditional face to face learning.	1 (2.4)	4 (9.8)	18 (43.9)	14 (34.1)	4 (9.8)
I believe that the metaverse application for learning mechanics dynamics can be an assistive platform for traditional face to face learning.	1 (2.4)	3 (7.3)	12 (29.3)	15 (36.6)	10 (24.4)
I believe that the metaverse application for learning mechanics dynamics can co-exist parallel with the traditional face to face learning.	0 (0)	4 (9.8)	12 (29.3)	12 (29.3)	13 (31.7)
I expect to have the training before the use of metaverse platform to support the teaching and learning activities.	1 (2.4)	3 (7.3)	9 (22.0)	14 (34.1)	14 (34.1)
Currently my Internet connection is stable to perform the online activities for media rich contents in metaverse platform.	2 (4.9)	4 (9.8)	10 (24.4)	18 (43.9)	7 (17.1)
Currently my mobile phone / laptop / tablets are sufficient to view media rich contents such as 2-D and 3-D animation, video, games and collaboration tools such as ZOOM / MS Teams etc.	0 (0)	3 (7.3)	10 (24.4)	15 (36.6)	13 (31.7)
I welcome the new idea of using metaverse application to support the teaching and learning activities for engineering mechanics dynamics.	0 (0)	3 (7.3)	10 (24.4)	15 (36.6)	13 (31.7)
I am willing to participate in the use of metaverse application for learning mechanics dynamics in near future.	1 (2.4)	2 (4.9)	12 (29.3)	15 (36.6)	11 (26.8)

where 1- strongly disagree, 2-disagree, 3-neither disagree or agree, 4-agree, 5-strongly agree

Table 2. Students Perception after experiencing the Metaverse Engineering Lab

	Very Poor	Poor	Acceptable	Good	Very Good
Overall, I think my level of knowledge for this course is better after using this supporting platform.	0 (0.0%)	0 (0.0%)	2 (4.9%)	26 (63.4%)	13 (31.7%)
Overall, I think my exposure (learning experience) for the learning using Metaverse approach is very good after using this supporting platform.	0 (0.0%)	0 (0.0%)	7 (17.1%)	24 (58.5%)	10 (24.4%)

Information and Communication Technology (ICT) often plays a crucial role in engineering education, particularly as a supportive tool to enhance students' learning processes. According to student responses in Table 2, 63.4% had a good understanding, and 31.7% had a very good understanding after using the Metaverse engineering platform. The Metaverse engineering platform, integrated with a constructivist approach, offers students an active learning platform with step-by-step problem-solving and visualization modules. These findings from the pilot study align with those of other scholars. Fang's research asserted that effective visualization and demonstration tools can aid students' comprehension and help prevent misunderstandings. Furthermore, Mandal's study indicated that incorporating animation and video as supportive tools in the engineering classroom can enhance students' learning motivation. Additionally, data in Table 1 revealed that the majority of students' experiences with the Metaverse engineering lab, using the constructivist approach, were positive, with 57.1% rating it as good and 28.6% as very good. Integrating the learning system with the Metaverse engineering lab can facilitate higher-quality classroom interactions and teamwork among students.

5) Discussions and Recommendations

The results of the pilot study demonstrate a positive reception towards the use of the Metaverse platform for the Mechanics Dynamics course. Most students expressed openness to exploring learning through virtual platforms, with significant interest in attending lectures, tutorials, and engaging with learning materials in diverse formats, including 2D and 3D animations. These findings align with the increasing recognition of the potential for virtual and immersive technologies to enhance student engagement and understanding, especially in complex subjects like Mechanics Dynamics.

Over 95% of students reported a positive experience with the Metaverse engineering lab, with many rating their knowledge acquisition as good or very good after using the system. This indicates that the integration of virtual environments, such as the Metaverse, can effectively support learning by providing an interactive and engaging way to visualize and solve complex problems. The use of animations and multimedia resources was particularly well-received, highlighting the importance of diverse learning tools in improving comprehension.

However, while most students showed enthusiasm for the Metaverse, there are areas that require further exploration. Some students might still face challenges adapting to virtual learning environments, and it is important to address any barriers to access or usability.

As for recommendations, the following are suggested:

1. **Expand Virtual Learning Tools**: Given the positive response to the use of 2D and 3D animations, it is recommended to further integrate more advanced visualization tools into the Metaverse platform. Interactive simulations and virtual hands-on experiences could be developed to enhance the learning of dynamic systems and mechanical concepts.
2. **Increase Familiarization and Training**: To ensure that all students can effectively use the Metaverse platform, it would be beneficial to provide training sessions or tutorials on how to navigate the system and use its features. This would help students overcome any initial difficulties and maximize their learning experience.
3. **Enhance Real-Time Interaction**: The study found that students were open to discussing topics with lecturers via Metaverse applications. Future iterations of the platform could include more features for real-time collaboration, such as virtual office hours or live problem-solving sessions, to foster greater interaction between students and instructors.
4. **Broaden Access and Inclusivity**: While the survey results were generally positive, it is important to ensure that the Metaverse platform is accessible to all students, including those with limited access to high-performance computing devices or reliable internet connections. Exploring low-bandwidth versions or providing additional support for students facing technological barriers could help improve inclusivity.
5. **Further Research**: A larger-scale study with more diverse student groups and subjects could help evaluate the long-term effectiveness of the Metaverse as a learning tool in mechanical engineering education. Additionally, gathering feedback on specific challenges faced by students during the course could inform future improvements to the platform.

The pilot study suggests that the Metaverse has the potential to transform the learning experience in mechanical engineering. By building on these positive findings and addressing areas for improvement, this innovative approach can further enhance student engagement, understanding, and collaboration in the field.

6) Conclusions

In this innovative system design, we presented the results and findings regarding the use of the Metaverse engineering lab system integrated with a constructivist approach. The findings demonstrated positive learning outcomes, including improved understanding levels and enhanced learning experiences, following the use of the Metaverse engineering lab platform. Future research will focus on

a larger sample size to further investigate the effectiveness of the immersive Metaverse engineering lab system combined with a constructivist approach in engineering education.

Acknowledgement

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IGIIDeation 2025

Machine Learning SpeechSense Pro

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Abstract

Voice disorders have traditionally been diagnosed through invasive procedures, which can be uncomfortable and unappealing for patients. This innovation presents the design and evaluation of an advanced Dysphonia Detection System (DDS), powered by the cutting-edge Machine Learning SpeechSense Pro platform, which leverages Mel-Frequency Cepstral Coefficients (MFCC) for accurate voice analysis. The primary objective of the DDS is to create a user-friendly, practical, and efficient tool for early detection of voice disorders, thereby minimizing the need for invasive diagnostics. The motivation behind this project stems from the increasing demand for accessible healthcare solutions that prioritize patient comfort. SpeechSense Pro enables DDS to incorporate state-of-the-art machine learning algorithms, enhancing the system's ability to analyse vocal characteristics and detect subtle changes indicative of dysphonia with high precision. The system is engineered to be intuitive, allowing users ranging from educators and vocalists to healthcare professionals to quickly assess vocal health with minimal training. Preliminary evaluations demonstrate the system's capability to not only detect early signs of voice disorders but also recommend appropriate measures for intervention. This dual functionality enhances its utility, positioning the DDS as a comprehensive tool for proactive vocal health management. Furthermore, the system holds significant potential for commercialization, particularly within educational institutions, schools, and the performing arts community. By offering an accessible means to monitor vocal health, the DDS, enhanced by Machine Learning SpeechSense Pro, empowers individuals to take charge of their vocal well-being, ultimately contributing to better outcomes in both educational and professional settings. This innovation represents a leap forward in voice disorder diagnostics, combining advanced machine learning with intuitive design to enhance user experience and promote vocal health awareness. The system was evaluated using the six User Experience Questionnaire (UEQ) measures. Future improvements may include integrating real-time feedback, expanding the range of detected disorders, enhancing user interface design, and leveraging personalized recommendations through adaptive machine learning models.

Keywords: Dysphonia detection; Mel-Frequency cepstral coefficients; voice disorder diagnosis; User-friendly system

1) Introduction

Machine learning (ML) researchers have increasingly focused on voice problem identification, leveraging recent technological advancements to transform traditional diagnostic methods. To reduce the frequency of therapeutic visits, voice therapists are adopting ML-driven analytic algorithms to effectively diagnose vocal abnormalities (Imel et al., 2019; Asci et al., 2020; Gupta et al., 2024; Rehman et al., 2024; Di Cesare et al., 2024; Wasserzug et al., 2023). ML, which involves extracting patterns from raw data, addresses the limitations of systems relying solely on hard-coded knowledge. By enabling computers to tackle real-world problems and make seemingly subjective decisions, ML offers a versatile approach to healthcare diagnostics.

The effectiveness of ML systems depends largely on the quality of data representation (Lu et al., 2023). For instance, when logistic regression is applied to diagnose a voice disorder, the system does not directly interact with the patient. Instead, it analyses specific features, such as the frequency and amplitude of the patient's voice, to identify correlations between these features and various outcomes. This chapter introduces a novel ML-based voice disorder detection technique designed to identify early indicators of voice-related problems among academic university staff. Statistical evaluations based on quantitative research validate the system's efficacy in identifying and analysing voice abnormalities while suggesting potential interventions.

The user experience (UX) of this system was assessed using the User Experience Questionnaire (UEQ) (Schrepp et al., 2017). The results indicate promising trends, with the system receiving high scores across all six UEQ scales. These findings suggest that users perceive the system as easy to use, effective, and capable of meeting their needs. This integration of ML technology not only enhances the diagnostic process but also opens new possibilities for resource optimization and redefines problem-solving methods in managing voice disorders.

This study underscores the potential of ML to revolutionize healthcare practices, particularly in the domain of voice disorder diagnosis. By prioritizing user experience and leveraging advanced ML capabilities, this approach demonstrates promise in early detection and intervention. Future advancements in this field could further enhance its impact, providing accessible and efficient tools for proactive vocal health management.

2) Materials and Resources

For this innovation, we utilized a combination of tools like hardware, smartphones with high-quality microphones for capturing voice samples and software, our innovated machine learning SpeechSense Pro platform for ML model development and analysis. Custom-designed voice recording application with user-friendly interfaces. Statistical software for quantitative data analysis SPSS 28 and MathLab. Additional Tools were also used such as acoustic analysis tools for feature extraction.

3) Methods

Participants

The study involved university academic staff members as participants. Inclusion criteria required individuals who were currently active in teaching roles and expressed willingness to participate. Exclusion criteria included participants with known or diagnosed voice disorders undergoing treatment.

Data Collection

1. **Voice Sample Acquisition:** Participants were asked to record their voice samples using a smartphone application designed for the study. The recordings included a standardized reading passage and sustained vowel sounds to capture both dynamic and static vocal characteristics.

2. **Demographic and Usage Data:** Additional data, including participants' age, gender, years of teaching experience, and typical vocal usage duration, were collected to understand potential contributing factors to voice disorders.

Machine Learning Framework

1. Feature Extraction: Voice samples were pre-processed to extract Mel-Frequency Cepstral Coefficients (MFCC) and other relevant acoustic features such as pitch, jitter, shimmer, and harmonics-to-noise ratio. These features are critical for identifying vocal anomalies indicative of potential disorders.
2. **Data Preprocessing**:
   - Normalization of features to ensure consistent scaling.
   - Removal of outliers and noisy data.
   - Balancing datasets using synthetic oversampling techniques for underrepresented classes.
3. **Model Development**:
   - The study utilized logistic regression, support vector machines (SVM), and neural network-based algorithms for voice disorder classification.
   - The Machine Learning SpeechSense Pro platform was employed to automate model training, optimization, and validation.
4. **Model Evaluation**: The models were evaluated using metrics such as accuracy, precision, recall, F1-score, and area under the receiver operating characteristic curve (AUC-ROC). A 10-fold cross-validation approach ensured robustness and minimized over fitting.

User Experience Assessment

The **User Experience Questionnaire (UEQ)** was used to evaluate the system's usability and effectiveness. Participants completed the questionnaire after interacting with the detection system, providing feedback on parameters such as usability, reliability, and user satisfaction.

Ethical Considerations

Ethical approval was obtained from the deans of the selected colleges. All participants provided informed consent, ensuring their understanding of the study objectives, procedures, and the voluntary nature of their participation. Voice recordings and personal data were anonymized and securely stored to maintain confidentiality.

4) Findings and Analysis

For this study, a supervised learning method was employed, and the Saarbrücken Voice Disorder (SVD) database (Hagmuller, 2024) was utilized for training and testing purposes. To identify the spoken words of the participants, a custom database was constructed to replicate the articulated words.

The database development process involved the recording of several vowels, such as 'a,' 'e,' and 'u,' which were then used to generate visual plots. These plots, illustrated in Figure 1a (female voice) and Figure 1b (male voice), depict the distinct characteristics of each recorded vowel. The recordings were conducted in a soundproof studio at UNITEN, ensuring high-quality audio capture. A studio-grade microphone was used, configured to a sampling rate of 44,100 Hz to preserve acoustic details.

This approach facilitated the creation of a robust dataset, enabling precise training and validation of the voice disorder detection system using the SVD database. The high-quality recordings and the controlled environment contributed to the reliability and effectiveness of the system in identifying voice disorders.

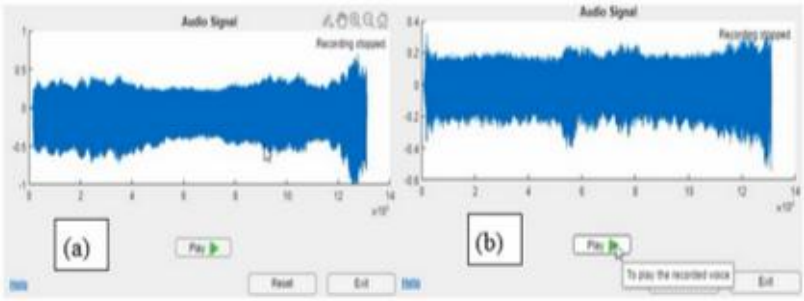

Figure 1. Male and Female Sampling.

Before deployment, the speech recognition system undergoes a crucial training process to ensure optimal performance. This training involves processing speech samples at a sampling frequency of 8 kHz. The training duration typically lasts approximately 20 seconds, although it may vary depending on the specific requirements of the system.

During the training phase, the system analyses the speech signal and categorizes its frames into high-energy and low-energy segments. This classification is essential for identifying key patterns in the speech signal and improving the accuracy of recognition. Figure 2 illustrates the training sequence for speech samples, as conducted at UNITEN, showcasing the systematic segmentation of the speech signal into energy-based frames. This training process lays the foundation for the system's ability to effectively recognize and interpret speech in real-world applications.

Figure 2. Training Sequence of Speech Samples.

The work yielded several significant findings, highlighting the effectiveness of the voice disorder detection system and its potential applications:

1. **High Accuracy in Voice Disorder Detection**: The system demonstrated high accuracy in identifying voice disorders, validating its reliability as a diagnostic tool. Using the Saarbrücken Voice Disorder (SVD) database for training and testing, the system effectively differentiated between healthy and disordered voice samples.
2. **Efficiency of Training Process**: The training process, conducted at a sampling frequency of 8 kHz and lasting approximately 20 seconds per sample, proved efficient and adaptable. The system successfully classified speech signal frames into high-energy and low-energy segments, enabling precise feature extraction for machine learning models.
3. **User Experience and Acceptability**: Feedback from participants, gathered using the User Experience Assessment (UEA), indicated a high level of satisfaction with the system. Users rated the system highly on usability, efficiency, and effectiveness, with the majority expressing confidence in its ability to meet their needs.
4. **Comprehensive Dataset Creation**: The custom database, incorporating vowels such as 'a,' 'e,' and 'u,' proved instrumental in refining the system. High-quality recordings captured in a controlled, soundproof environment contributed to the robustness and reliability of the dataset.

5. **Potential for Early Detection**: The system demonstrated a strong capability for detecting early signs of voice disorders, providing an opportunity for proactive intervention. This early detection feature is particularly beneficial for educators and professionals who rely heavily on vocal health.
6. **Scalability and Practical Application**: The findings suggest that the system has significant potential for scalability and real-world application, particularly in educational institutions, clinical settings, and the performing arts industry.
7. **Limitations and Areas for Improvement**: While the system performed well overall, areas for improvement were identified, including expanding the range of detectable disorders and further optimizing the user interface for enhanced accessibility.

These findings underscore the system's potential to revolutionize voice disorder diagnostics by offering an accessible, accurate, and user-friendly solution.

5) Discussions and Recommendations

Validity and reliability tests were conducted as part of the pilot study to ensure the robustness of the questionnaire. Face validity was assessed by the respondents, who provided feedback on the clarity and relevance of the questions. Meanwhile, content validity was evaluated by four field experts, who reviewed the questionnaire to ensure it adequately covered the intended constructs.

Based on the feedback from both respondents and experts, revisions were made to refine the questionnaire and enhance its effectiveness. A reliability test was also conducted, yielding a Cronbach's alpha value of 0.71, which is considered a good score, indicating internal consistency. These results confirmed that the questionnaire was both a valid and reliable tool for assessing the intended outcomes of the study. The study's findings based on the six User Experience Questionnaire (UEQ) measures are summarized below. Each scale is assessed within the positive evaluation range of 0.8 to 3, with all measures receiving favourable scores:

1. Attractiveness Scale
   - Score: 1.620
   - This indicates that participants generally found the design of the voice disorder detection system appealing and visually pleasing.
2. Perspicuity Scale
   - Score: 1.510
   - The system was rated as easy to understand and use, even for participants unfamiliar with machine learning technology.
3. Efficiency Scale
   - Score: 1.312
   - Participants found the system efficient, requiring minimal effort to complete tasks.
4. Dependability Scale
   - Score: 1.030
   - While still within the positive evaluation range, this was the lowest score among the scales, suggesting that the system could benefit from additional support features or clearer instructions to enhance user understanding.
5. Stimulation Scale
   - Score: 1.450
   - Participants expressed motivation to use the system, reflecting their positive engagement with the technology.
6. Novelty Scale
   - Score: 1.670
   - The system was perceived as innovative and unique, further contributing to its favourable reception.

These results demonstrate that the voice disorder detection system was well-received by participants, with positive evaluations across all UEQ measures. Areas for improvement, particularly in enhancing dependability, were identified to further optimize user experience. To further enhance the system's effectiveness and user experience, it is recommended to incorporate detailed guidance or support features to improve dependability, expand the range of detectable voice disorders to increase diagnostic utility, and refine the user interface for greater accessibility and ease of use. Additionally, integrating real-time feedback and advanced machine learning algorithms for personalized recommendations could further boost the system's functionality and appeal.

6) Conclusion

In conclusion, this innovation demonstrates that the voice disorder detection SpeechSense Pro is a promising and user-friendly tool for identifying voice abnormalities, with strong potential for early detection and intervention. The system received positive evaluations across all six User Experience Questionnaire (UEQ) measures, indicating high levels of user satisfaction, ease of use, and engagement. While the system showed good performance in terms of accuracy and efficiency, there are areas for improvement, particularly in enhancing dependability and providing clearer support features. The findings suggest that this system could play a significant role in the early diagnosis of voice disorders, especially in educational and professional settings, and could be further optimized by incorporating personalized recommendations and expanding its functionality.

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Virtual Hand Gesture-Driven Stroke Patient Database Management System: Riot Simulated Setting Implementation

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Abstract

Stroke recovery for young individuals with moderate symptoms is frequently hampered by low motivation and a lack of access to specialized rehabilitation facilities. Traditional in-person therapy presents difficulties in maintaining constant engagement, limiting development. To address these challenges, this work presents a web-based rehabilitation system that combines hand gesture detection with IoT (RIOT) technology to aid in hand motor recovery. The system includes a user-friendly interface and gesture-detection cameras, allowing for real-time data collecting, monitoring, and management in a virtual environment. Key components include informative dashboards that provide gesture analysis, progress monitoring, and therapy reports. The system, designed for healthcare practitioners, therapists, and researchers, provides secure data storage and role-based access management to preserve patient privacy. It is built with PHP to provide rapid server-side processing and has a responsive design that is suitable with a variety of devices. The methodology includes intensive testing in simulated scenarios as well as iterative user feedback from stroke victims to develop the interface and assure usability. Preliminary results indicate that real-time gesture tracking and automated progress reporting can improve patient involvement and streamline therapeutic workflows. Future proposals include increasing system scalability, incorporating AI into voice assistance, predictive analytics, and undertaking clinical studies to evaluate efficacy. This breakthrough aims to change stroke rehabilitation by increasing accessibility, patient outcomes, and care efficiency.

Keywords: Web-based Management System, Patient Data Management, Internet of Things (IoT), Hand Gesture Detection, Stroke Rehabilitation.

1) Introduction

The idea of providing a doorway to a multitude of medical information available via web browsers is becoming more common in current healthcare systems as web-based platforms are used. To begin, one of the critical components facilitating this transformation is the creation of web-based platforms that serve as the principal interface via which consumers engage with the medical information system. This website is designed to be available via web browsers and will play an important role in providing healthcare professionals and patients with access to a wide range of information and services. As a starting point, this study will look into the hand gesture of palm orientation, with either a landed wrist or upper limb, depending on the patient's capabilities during the rehab session. Because stroke rehabilitation presents challenges such as imprecise progress tracking and assessment, as well as concerns about sensitive data, highlighting the need for dependable and secure data handling, a framework was developed to assist the healthcare community in improving rehabilitation sessions with the presence of emerging modern technologies that are remotely accessible via the network. As a result, a framework known as RIOT is presented to provide low-cost and effective remote stroke therapy.

Remote rehabilitation systems offer promising answers but bring privacy risks and software dependability concerns. In response to these challenges, a RIOT framework was developed to enhance gesture recognition accuracy and ensure data security in smart healthcare systems to stand with the exploration of the calibration of hand gesture recognition using the RIOT framework and evaluating its effectiveness in improving home-based stroke rehabilitation [2]. The widespread use of web-based platforms in healthcare has transformed access to medical information and services. These platforms, which are available through web browsers, are now integral to modern healthcare systems, allowing healthcare professionals and patients to interact with medical information more quickly. With a rising emphasis on accessible and personalized care, establishing systems that bridge technical breakthroughs with patient-centric solutions is critical.

Stroke rehabilitation, particularly for patients with mild symptoms, frequently encounters barriers such as low motivation, imprecise progress tracking, and restricted access to specialized facilities. These issues need novel therapeutic techniques based on developing technologies. This work focusses on the calibration of hand gesture recognition, specifically palm orientation movements, using either a landed wrist or upper limb, depending on the patient's physical limitations. The goal is to overcome the limits of traditional in-person therapy by providing a distant, accessible option for stroke recovery. The suggested framework, Rehabilitation utilizing IoT (RIOT), introduces a low-cost, high-performance web-based rehabilitation system that uses hand gesture detection and IoT technology to improve stroke therapy. This technology ensures data security, real-time tracking, and personalized therapeutic management. Its main features are gesture-detection cameras, a responsive web-based interface, and dashboards to track progress and therapy outcomes [1]. The system was designed with user-friendly UI/UX principles in mind, accommodating a wide range of technical skills and ensuring role-based access control to protect sensitive patient information.

The RIOT framework aims to increase the effectiveness of home-based rehabilitation by merging advanced gesture recognition capabilities with networked accessibility, while also addressing concerns about privacy hazards and system reliability [3]. This study will also look at the system's ability to improve patient engagement, expedite therapist operations, and build the framework for future developments in smart healthcare.

1.1 Objectives

The major goal of this project is to improve stroke therapy by creating a web-based system that uses IoT and hand gesture detection technology to aid in hand motor recovery. The system's goal is to promote patient engagement by providing a user-friendly interface with real-time feedback, encouraging constant involvement in rehabilitation exercises. The project aims to reduce the need for frequent in-person sessions by enabling remote accessibility, allowing patients to complete therapy from the comfort of their own homes.

On the technical front, the device is intended to provide accurate gesture recognition by incorporating advanced detection algorithms capable of capturing exact hand movements, hence increasing the overall effectiveness of therapy. To address concerns about sensitive patient information, strong data security mechanisms such as role-based access control and encrypted data storage are implemented to protect patient privacy. Furthermore, the project focuses on improving system usability by developing a responsive and intuitive interface that is accessible on a variety of devices and can accommodate users with varying degrees of technical competence.

2) Materials and Resources

The RIOT (Rehabilitation Internet of Things) framework for stroke rehabilitation necessitated the use of numerous resources, including hardware, software, and human skills. Each of these components helped to create a strong, creative system aimed at improving hand motor recovery for stroke patients. A thorough summary of the materials and resources used is provided below:

2.1 Hardware Resources

The RIOT framework was significantly reliant on specialized hardware to achieve precise gesture recognition and smooth operation. Gesture-detection cameras were among the key hardware components employed. These cameras were key for capturing real-time hand movements, with an emphasis on certain gestures important for stroke rehabilitation activities. Their precision and ability to track subtle hand motions guaranteed that the rehabilitation process was successful. In addition to cameras, IoT sensors such as accelerometers and gyroscopes were used to provide sophisticated motion detection capabilities. These sensors supplemented the gesture-detection cameras by collecting data on hand direction, velocity, and movement patterns, increasing the system's accuracy.

Computing hardware, such as high-performance workstations and laptops, were essential for system development, testing, and deployment. These devices supplied the computational capacity required to process real-time data, integrate software, and build user interfaces. A strong network infrastructure also provided flawless connectivity between devices, allowing patients and therapists to transmit data in real time and retrieve it remotely. During the testing phase, peripheral devices such as microcontroller boards (for example, the Raspberry Pi) and routers were utilized to emulate IoT capability, ensuring the system's scalability and interoperability [2].

2.2 Software Resources

The RIOT framework's software resources were critical to its development and functionality. The MediaPipe framework was the system's foundation, providing powerful hand-tracking features. MediaPipe, which was integrated into the system using JavaScript, provided real-time gesture identification and analysis specific to stroke therapy needs. This structure enabled the system to offer users with fast feedback, guaranteeing a more participatory and successful therapy experience [2].

A user-friendly and responsive interface was built using frontend development techniques such as HTML, CSS, and JavaScript. The interface was created to appeal to both patients and therapists, with simple navigation and visually appealing dashboards. Backend development involved using PHP for server-side processing and MySQL for database management to provide secure and efficient data handling.

2.3 Human Resources

Healthcare professionals, notably stroke therapists, played an important role in designing the system's needs and validating its functionality. Their contributions guaranteed that the RIOT architecture addressed real-world issues encountered during stroke therapy.

Throughout the testing phases, stroke victims and their carers provided significant feedback. Their experiences and comments helped to improve the system's functionality, making it more effective and user-friendly. This collaborative approach ensured that the system fit the requirements of its intended users.

The development team, which included software developers, IoT engineers, and UI/UX designers, collaborated to design, build, and optimize the RIOT framework. Each team member contributed distinct skills to the system's novel features and robust architecture.

3) Methods

This section describes the systematic approach used to design, develop, and assess the RIOT framework for hand treatment in stroke rehabilitation. The technique is separated into four main stages: system design, development, data gathering, and evaluation. Each phase was meticulously prepared to guarantee that the RIOT framework efficiently tackles the issues encountered in traditional rehabilitation approaches.

Figure 1. Multimedia Development Life Cycle (MDLC) Method.

The study utilized the Multimedia Development Life Cycle (MDLC) method to create an interactive system. MDLC consists of six steps: concept, design, material collection, assembly, testing, and distribution. Figure 1 further illustrates the MDLC concept. Step one is concerned with establishing the fundamental principles and concepts for creating the system; in layman's terms, it is the project proposal. The second step is to create a sketch of the proposed system and plan it. Step 3 deals with obtaining all of the resources needed to build the system, while step 4 deals with assembling the acquired resources. Step 5 is concerned with testing the system as a prototype prior to its formal release and distribution, and it is the stage in which the system is now at.

3.1 JavaScript-based MediaPipe Implementation

a) MediaPipe Integration

MediaPipe's powerful hand-tracking capabilities were integrated into the RIOT system via JavaScript. The system was modified to recognize and analyze hand gestures essential to stroke rehabilitation activities, with a focus on precise movements like palm orientation and finger positioning. By combining the MediaPipe hand-tracking pipeline into a web-based application, the technology provides real-time feedback, allowing stroke patients to successfully measure their progress. The technological setup entailed customizing MediaPipe for rehabilitation-specific movements, optimizing its functionality for real-time operation, and smoothly integrating the pipeline into the online interface.

b) UI/UX Design

To accommodate both stroke patients and healthcare practitioners, the user interface (UI) and user experience (UX) were designed with accessibility and intuitiveness in mind. To ensure functionality and ease of use, the UI design was developed iteratively, using wireframing, prototyping, and user testing. The patient-facing interface emphasizes simplicity by offering straightforward instructions and feedback, whilst the therapist-facing interface offers tools for tracking patient progress and managing therapy sessions. Key design considerations included reactivity, clarity, and minimal cognitive effort for consumers.

3.2 Data Collection Through Surveys

a) The Survey Methodology

A structured survey was established to collect information from stroke patients and carers about their rehabilitation experiences and expectations for technology-based treatments. The survey aims to inform system development by gathering information about end-user needs and preferences. The collected data will be used to inform the creation of an enhanced stroke rehabilitation system that incorporates smart technologies. A selected sample of end users, such as patients and carers, was identified. The survey was distributed to targeted informants through online platforms and direct outreach, and numerous replies were received. The representative sample was given an introduction to the survey, followed by a few parts of questionnaires that included demographic information, respondents' understanding of technology and rehabilitation, rehabilitation experiences, and opinions on rehabilitation technologies.

Figure 2. System Architecture Design of RIOT.

Figure 2 depicts the structure, behaviour, and view of RIOT to provide a holistic viewpoint of the system. Thus, integrating MediaPipe for hand gesture recognition, designing user-friendly interfaces, and collecting extensive data via surveys were all steps towards ensuring the system's effectiveness and usefulness.

The following chapter will describe the findings and analysis from usability testing and other studies undertaken to validate the system's performance and user satisfaction.

4) Findings and Analysis

This chapter shows the survey analysis, the results of the UI/UX design, and the performance of the RIOT system using MediaPipe, as well as the effectiveness and usability of the web-based medical information system for stroke rehabilitation.

4.1 Usability Assessments using Questionnaires as a Survey

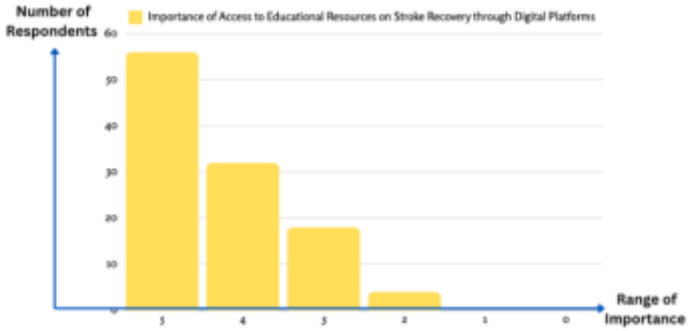

Figure 3. This Bar Charts present the Results from the User Satisfaction Surveys on Stroke Recovery through Digital Platforms.

The survey's goal was to learn about stroke patients' and carers' experiences and needs in terms of smart device-supported rehabilitation. The study drew 110 responses from both patients and carers. Figure 3 demonstrates that 98.2% of respondents found it helpful to obtain automatic feedback on exercise technique via a device, while 95.5% prefer to use a system to track therapeutic progress.

The study provides a complete examination of stroke patients' demographics, technological familiarity, and rehabilitation experiences, as seen in the above bar chart.

4.2 RIOT Website User Interfaces Design

Figure 4. The Interface of My RIOT Website.

My Riot platform uses hand gesture technology to help patients practice hand movements and track progress in a fun and interactive way. With just a camera, patients can perform exercises that are recorded and analysed to support improvement over time. The goal is to provide stroke survivors with a simple tool to support their rehabilitation and keep everyone involved informed and connected. This system uses hand gestures to help patients practice exercises and tracks their progress over time with just a camera.

5) Discussions and Recommendations

This study's findings demonstrate the RIOT system's ability to address significant issues faced by stroke patients and carers throughout recovery. A detailed survey was used to analyse usability, and the results gave substantial insights into end-user preferences and demands. Out of 110 replies, 98.2% emphasized the necessity of receiving automatic feedback on their exercise approaches, while 95.5% preferred systems that track therapeutic success. These numbers highlight the need for easily accessible, technology-driven solutions that offer real-time feedback and progress tracking to improve the rehabilitation experience. The RIOT framework meets these requirements, providing a streamlined and user-friendly interface that empowers both patients and therapists.

The RIOT platform's addition of hand gesture recognition technology strengthens its potential as a helpful stroke recovery tool. Patients can engage in interactive workouts that are both effective and motivational by using a basic camera setup. The system's capacity to record and analyse hand movements in real time guarantees that users receive accurate feedback, instilling a sense of accomplishment and encouraging constancy in rehabilitation practices. Furthermore, the user interface design prioritizes simplicity and accessibility, allowing anyone with diverse degrees of technological knowledge to effortlessly navigate the site. For carers and therapists, the platform provides powerful tools for tracking development, allowing for data-driven decision-making and personalized care.

Despite these encouraging outcomes, a few questions remain. Addressing privacy concerns about data collection and storage is crucial for increasing user confidence and ensuring regulatory compliance. Furthermore, increasing the system's capabilities to include a broader range of rehabilitation exercises and incorporating multilingual support can improve accessibility and effectiveness.

Future research should focus on long-term studies to assess the RIOT system's impact on recovery results. Collaboration with healthcare providers and technology specialists can help to refine the platform, making it a common component of stroke rehabilitation methods. By addressing these recommendations, the RIOT system has the potential to transform stroke therapy, improving patient outcomes and quality of life while benefiting the larger healthcare ecosystem.

6) Conclusion

In conclusion, RIOT has revolutionised stroke rehabilitation by upgrading previous approaches, since MediaPipe integration provides real-time hand gesture recognition, making it cost-effective for patients because it is available remotely via webcams after supplementing web technologies. RIOT's UI/UX designs improve patient engagement through straightforward navigation using JavaScript and MediaPipe, as well as giving real-time feedback during monitoring activities. Furthermore, the study demonstrates RIOT's potential benefits, indicating that patients require home-based rehabilitation options due to difficulty attending sessions. Thus, RIOT can help revolutionise stroke rehabilitation by solving accessibility difficulties and enhancing overall efficacy. Future work will concentrate on combining adaptive learning, wearable technologies, and conducting more extensive testing to fully achieve the system's potential for improving patient outcomes. As research in this field advances, hand gesture recognition has enormous potential to alter rehabilitation techniques and enhance patient outcomes.

Acknowledgement

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IGIIDeation 2025

Innovative IoT Smart Lock System: Enhancing Security with Fingerprint and RFID Technology

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Abstract

Traditional key-based locks have long been the cornerstone of securing homes and buildings, but they come with significant drawbacks that compromise their effectiveness. These locks are prone to vulnerabilities like key duplication, physical break-ins and the inconvenience of losing or misplacing keys which can lead to costly replacements or even security breaches. With the emergence of Industry 4.0, where interconnected smart devices redefine how we approach everyday tasks, the need for smarter and more reliable security solutions has become evident. To address these challenges, this project introduces a smart door system that combines microcontroller technology with IoT capabilities for enhanced security and convenience. The proposed solution uses an ESP32-C3 microcontroller to connect the system to Wi-Fi and integrate with the Virtuino 6 app via HiveMQ broker, enabling users to remotely control door access from their smartphones. Complementing this is the ESP8266 microcontroller, which handles the tasks of fingerprint recognition and RFID card scanning. When either a fingerprint or RFID card is authenticated, the ESP8266 sends a signal to the ESP32-C3, triggering the door to unlock. This dual-microcontroller setup ensures seamless functionality, reliable security and flexibility in access control. By replacing traditional locks with this smart, IoT-enabled system, the project contributes to creating a safer living and working environment. It addresses key security concerns, eliminates the risks of traditional key management and exemplifies the practical application of Industry 4.0 technologies to everyday challenges. This innovation not only makes security smarter and more accessible but also represents a step forward in enhancing quality of life through technology.

Keywords: Smart Door; Fingerprint; RFID; Internet of Things; ESP32-C3; ESP8266

1) Introduction

In today's rapidly advancing technological landscape, smart door technology is revolutionizing how we secure and access homes and buildings. This innovative approach combines convenience and enhanced security, offering a seamless and a new way to manage entry. At the heart of this transformation is the Internet of Things (IoT) which enables smart doors to connect with other devices, providing smooth and secure access management (Simatupang & Tambunan, 2022).

A smart door incorporates advanced components such as sensors, electromagnetic locks and IoT connectivity to redefine traditional locking mechanisms. Technologies like RFID (Radio Frequency Identification) and fingerprint scanners allow for keyless entry, offering users an effortless and secure experience. For example, users can unlock their doors with a fingerprint or an RFID card that communicates wirelessly with the lock (Widiantari et al., 2022), (Al Rakib et al., 2022). These devices are part of the broader IoT ecosystem, enabling connectivity with other devices and systems over the internet. This connectivity allows users to monitor, control and retrieve data remotely, significantly improving the usability and security of these systems (Daulay & Alamsyah, 2019).

The motivation behind integrating advanced technology into door systems lies in addressing the vulnerabilities of traditional locks that uses physical keys. Conventional key-based locks face issues such as lost or duplicated keys, lock-picking and difficulty on managing access. Smart door systems mitigate these problems by employing digital keys which are challenging to duplicate and advanced authentication methods that are harder to bypass. Moreover, they often come with features like usage tracking, notifications and integration with home security systems to provide monitoring of entry points. These capabilities not only prevent unauthorized access but also generate valuable data for enhancing safety protocols (Kaya et al., 2022).

RFID technology uses electromagnetic fields to identify tags attached to objects, which act as digital keys. An RFID system includes a reader and a tag; the tag contains digital information that the reader verifies to grant or deny access (Widiantari et al., 2022). Similarly, fingerprint technology offers a highly secure authentication method by matching unique fingerprint patterns with stored data. This method uses advanced sensors and algorithms to ensure both speed and accuracy, making it a reliable solution for access control (Ju et al., 2021).

IoT serves as the backbone of smart door systems, linking them with other devices for seamless communication and operation. This connectivity enables advanced functionalities such as remote unlocking, notifications and integration with other smart home devices. For instance, a smart door can automatically unlock when it detects an authorized smartphone nearby or lock itself when integrated with a security system. These capabilities rely on continuous data sharing and processing, managed by IoT platforms to ensure real-time functionality and data analysis (Daulay & Alamsyah, 2019) .

This project specifically utilizes the ESP32-C3 and ESP8266 microcontrollers to create a secure and connected smart door system. The ESP32-C3 equipped with Wi-Fi capabilities, connects to the HiveMQ broker and the Virtuino 6 app to enabling users to control the door remotely through their smartphones. Meanwhile, the ESP8266 handles fingerprint recognition and RFID scanning. When a fingerprint or RFID tag is successfully recognized, the ESP8266 sends a signal to the ESP32-C3 to unlock the door. This dual microcontroller setup allows for a modular and scalable design. For instance, it allows adding features like face recognition without needing to replace the entire system. Having multiple authentication options like fingerprint, RFID and an app to manage access also caters to diverse user preferences and needs.

In the context of Industry 4.0, this system highlights the practical benefits of integrating IoT and smart technologies to address everyday challenges. By combining RFID and fingerprint scanners with IoT connectivity, the proposed smart door system improves security and convenience while offering a modern approach to access control. It provides users with enhanced security and control, contributing to the development of safer and more connected environments.

2) Materials and Resources

Figure 1 shows the block diagram of the smart door. The system uses ESP32-C3 and ESP8266 microcontrollers and is connected to a power supply. The inputs are the fingerprint and RFID sensors meanwhile the outputs are the buzzer and the electromagnetic lock. Whereas the Virtuino 6 app can be both input and output since the user can control the door and see the door status using it.

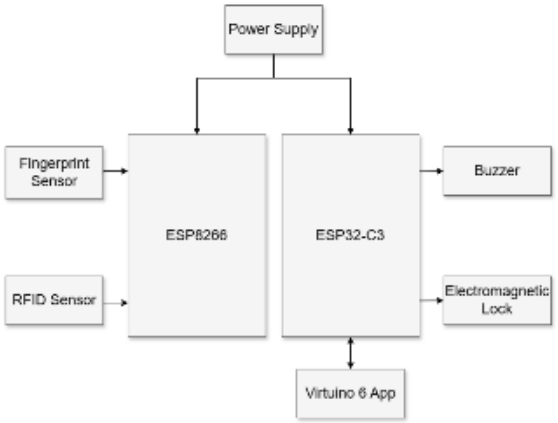

Figure 1. Block Diagram of the Smart Door.

Table 1 shows the components and their utilities for the smart door.

Table 1. List of Components

No.	Components	Utility
1	RC522 RFID Reader	Detects RFID for authentication.
2	AS608 Fingerprint Scanner	Detects Fingerprint for authentication.
3	ESP8266	Handles fingerprint and RFID modules.
4	ESP32-C3	Connects to Wi-Fi and handles communication with Virtuino 6 app and the doors.
5	Power bank	Acts as a power supply.
6	Buzzer	To notify the user the door has been unlocked.
7	Electromagnetic Lock	Uses magnetism to lock a door, releasing it when power is off.

3) Methods

This methodology focuses on leveraging the Agile development model which emphasizes flexibility, collaboration and iterative progress. It enables the integration of hardware and software components such as the ESP32-C3 and ESP8266 microcontrollers, fingerprint and RFID modules and IoT platforms like HiveMQ and Virtuino 6. Table 2 shows the activities done at each stage of the agile model approach.

Table 2. Agile Approach Stages

Agile Approach Stages	Activity
Planning	Define project goals, conduct a survey and gather initial requirements.
Design	Develop initial designs, diagrams and system architecture.
Development	Assemble the components and write code for each component in stages, focusing on specific features (e.g., RFID scanning, fingerprint recognition, app integration).
Testing	Continuously test during and after each stage to ensure the system is functional and secure.
Deployment	Integrate all components and deploy the system on a real door.

Figure 2 shows the flowchart for the smart door. User can choose up to 3 methods to unlock the door which is the fingerprint, RFID tag or using the Virtuino 6 app. If the input is recognized, the buzzer will ring and the door will be unlocked for 10 seconds, otherwise it will not.

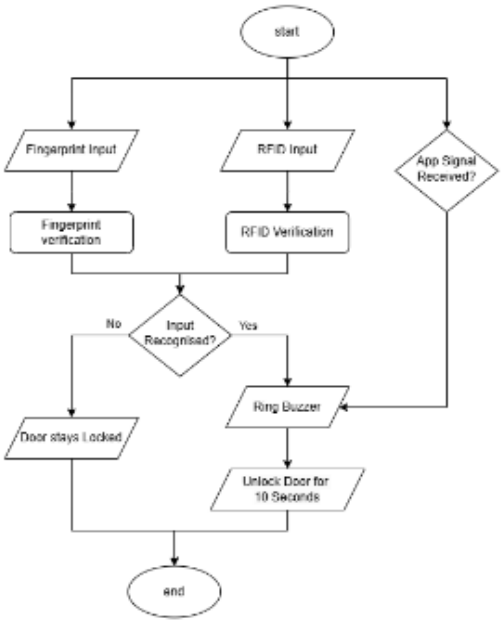

Figure 2. Flowchart of The Smart Door

4) Findings and Analysis

4.1 Smart Door Functionalities

The door is equipped with an electromagnetic lock that will lock the door if received 12V power. This lock is connected to the ESP32-C3. A buzzer is also used to notify the user that the door has been unlocked. The ESP32-C3 is then connected with an ESP8266 that is used to facilitate the AS608 fingerprint scanner and RC522 RFID reader. If either fingerprint or RFID modules scans an authorized ID, it will send a signal to the ESP32-C3 which will then unlock the door. Furthermore, the smart door uses the Virtuino 6 app and the HiveMQ MQTT broker. This system utilizes the Publish-Subscribe model, enabling message transmission from the HiveMQ broker to the subscribed door. Figure 3 shows the whole smart door meanwhile figure 4 and figure 5 is the screenshot of the Virtuino 6 app to control the door.

Figure 3. Picture of The Smart Door.

Figure 4. Screenshot of the Virtuino 6 interface when the door is locked.

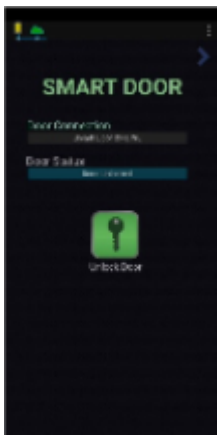

Figure 5. Screenshot of the Virtuino 6 interface when the door is unlocked

4.2 Findings

To test the reliability of the smart door, a test was conducted for each of the component's functionalities. The test was to unlock the door using each of the components 5 times in a row. Table 3 shows the testing result for each component of the smart door. All the components passed successfully, showing signs of reliability.

Table 3. Test Result

Components	No. of Successful Testing (out of 5)
AS608 Fingerprint Scanner	5
RC522 RFID Reader	5
Virtuino 6 app	5

5) Discussions and Recommendations

The development and testing of the smart door system demonstrated several successes and some areas for improvement. One of the key accomplishments is the system's reliable performance, as evidenced by the 100% success rate in unlocking the door using the AS608 fingerprint scanner, RC522 RFID reader, and Virtuino 6 app. These results highlight the robustness of the individual components and the seamless integration achieved through the ESP32-C3 and ESP8266 microcontrollers. The use of HiveMQ for MQTT communication also proved effective, enabling reliable message delivery between the app and the door system.

However, certain limitations were observed during the project. For example, the system's dependence on a stable internet connection for remote access through the Virtuino 6 app can be a potential drawback in environments with inconsistent network availability. To address this, a hybrid approach combining local Bluetooth connectivity with internet-based control could be considered as a future enhancement. Additionally, while the current design supports fingerprint and RFID authentication, expanding to include other biometric options such as facial recognition could improve user flexibility and security. Moreover, currently the way to register a fingerprint ID is by uploading a different code into the ESP8266. In the future, this registration process could be implemented in an app to make the registration process easier.

6) Conclusion

This project successfully developed a smart door system utilizing IoT technologies and microcontroller integration. By combining the ESP32-C3 and ESP8266 microcontrollers with fingerprint and RFID sensors, the system achieved reliable and secure access control. The implementation of HiveMQ and the Virtuino 6 app provided a practical remote management solution, demonstrating the potential of IoT in enhancing everyday security. While the findings validate the system's functionality, some issues require further exploration. For instance, the reliance on internet connectivity for remote access and the current limitations in biometric authentication options highlight areas for future development. These challenges emphasize the need for ongoing refinement and the integration of additional features to meet diverse user needs. This project contributes to the growing field of IoT-enabled security solutions, showcasing how microcontroller-based designs can address traditional lock vulnerabilities. Practically, the system offers a modern alternative to key-based locks, improving convenience and security for users. Future work should focus on addressing connectivity challenges, enhancing user interfaces, and expanding authentication capabilities.

In conclusion, this project lays a strong foundation for IoT-driven smart door systems and highlights the importance of continuous innovation to meet evolving security demands. Further research and development will ensure that such systems remain adaptable and effective in diverse environments.

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Shifa: A Digital Therapeutics for Muslim Students' Mental Wellbeing

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Abstract

The Shifa project represents a state-of-the-art digital therapeutic platform designed in order to address the particular mental health issues of Muslim students, both at the adolescent and university level. This is an innovative application that strategically combines Islamic teachings and contemporary psychological interventions and digital therapeutics to improve students' mental wellbeing. The high-fidelity prototype provides a multi-faceted approach to mental health covering the most important elements: access to Islamic teachings on mental wellness, communication channels with qualified counsellors and therapy sessions. Shifa also includes features for joint parent-student sessions which help in better understanding and communication within the families, in understanding the pivotal role of family dynamics in Muslim communities. The design of the application is grounded in digital therapeutic principles based on evidence-based interventions including guided meditation practices, cognitive behavioural therapy exercises, mood tracking tools, delivered within an Islamic context. Extensive user research was conducted as part of the development process, including interviews with Muslim students, parents, Islamic scholars and mental health professionals. Its features and content were culturally relevant, religiously appropriate, and clinically effective due to this rigorous methodology. Iterative user feedback and usability evaluations achieved continuous refinement of the prototype for a more functional and user experience. Shifa is an extraordinary leap forward in mental health support by combining religious teachings, professional mental health services, family involvement and digital therapeutics in one accessible platform. This culturally competent, technologically sophisticated tool represents a significant leap towards meeting the mental health needs of Muslim students. Future research will focus on conducting large-scale evaluations to assess the app's effectiveness and its long-term impact on the mental wellbeing of Muslim student populations.

Keywords: Digital therapeutics, mental wellbeing, Muslim students, Islamic design, Islamic features

1) Introduction

The increasing prevalence of mental health issues worldwide necessitates innovative, affordable, and culturally attuned interventions. Digital Therapeutics (DTx) present a great opportunity; yet, the distinct demands and cultural subtleties of Muslim adolescents, a significant worldwide group, remain generally overlooked (Dang et al., 2020). This work seeks to address this gap by creating a digital therapeutic model that is both rooted in Islamic principles and specifically designed to reflect the experiences of Muslim adolescents. It aims to provide an effective, engaging, and culturally appropriate mental health assistance tool. Mental health is a fundamental part of human existence. The World Health Organisation (WHO) characterises mental health as "a state of well-being in which individuals can realise their potential, manage the typical stressors of life, work productively, and contribute to their community" (Galderisi et al., 2015). To achieve this objective, the authors utilise a comprehensive mixed-methods research design, incorporating both quantitative surveys and qualitative interviews with users, carers, and mental health professionals. The data will be examined using a blend of statistical techniques and thematic analysis to produce thorough insights. The project aims to validate the application's efficacy and add to the emerging research on the convergence of digital treatments, culturally relevant design, and mental health in young adolescents. In the contemporary, rapid-paced environment, where stress and anxiety are prevalent among university students, the necessity for effective mental well-being interventions is more critical than ever (Mofatteh et al., 2021).

In today's society, instructing young teens on mindfulness is essential. Mindfulness entails being present in the moment without judgement, observing thoughts, emotions, and the environment. It instructs children in concentration, self-awareness, and emotional regulation. Although universal, mindfulness can be imparted in a manner that aligns with our spiritual customs (Bockmann & Yu, 2022). The quest for mental well-being among Muslim teenagers is enhanced by the ideas and teachings of Islam, directing them towards a harmonious and balanced existence. Mindfulness, a practice originating from ancient traditions, has recently garnered much attention for its ability to reduce stress, improve concentration, and foster emotional health (Keng et al., 2011). Some promising treatments, such as talk therapy originating from traditional Muslim contexts, are also applicable to other religion communities. She asserts that the most significant realisation is that Islamic practices correspond with traditional concepts of holistic wellness and healing (Joshanloo & Weijers, 2019). Some promising treatments, such as talk therapy developed in traditional Muslim contexts, are also applicable to other religion communities. The most significant realisation is that Islamic approaches correspond with traditional concepts of holistic well-being and healing. Muslims, like others, believe that mental health is essential for physical health (Ibrahim & Whitley, 2020). Muslims believe that mental health is essential for physical health.

Mindfulness fosters present-moment awareness and non-judgmental acceptance, enabling individuals to confront life's problems with fortitude and tranquilly. Despite the proliferation of digital therapeutic applications designed to facilitate mindfulness practices, there is a significant lack of platforms tailored to the distinct requirements of Muslim young adolescents (Haque & Rubya, 2023). Braun and Cronkleton (2024) observed that such applications can facilitate convenient support between treatment sessions or office visits and post-therapy. Truschel and Tzeses (2021) forecasted that mental health applications will profoundly influence mental health care by providing distinctive self-management options. Numerous experts and psychologists anticipate the integration of these new digital applications with conventional therapy.

Mental health applications are advantageous for professionals that engage with patients. Authors acknowledge the importance of cultural sensitivity and inclusivity and propose a novel strategy to bridge this gap by integrating Islamic design and content into a digital therapeutics' application aimed at promoting balanced mental well-being among youth (Ngabo-Woods, 2023). By integrating mindfulness techniques with Islamic teachings, the authors seek to provide a comprehensive tool that enhances the mental well-being of Muslim teenagers while reinforcing their spiritual connection.

The application integrates evidence-based psychological therapies, including Cognitive Behavioural Therapy (CBT), with conventional Islamic principles, prayers, and design aesthetics to provide a sophisticated, culturally attuned mental health solution. Tanhan & Young (2021) emphasised that the increasing population of Western Muslims encounters biopsychosocial, spiritual, and economic challenges. Muslims inadequately utilise mental health therapies, notwithstanding Islam's emphasis on mental well-being.

Researchers, practitioners, and educators in schools, colleges, universities, mental health organisations, and research institutions can assist Muslims. Mental health specialists can address the biopsychosocial and spiritual challenges faced by Muslims to enhance quality of life (Tanhan & Young, 2021). The authors' major objective is to evaluate user behaviour by assessing the effectiveness of the proposed intervention in alleviating common mental health disorders such as stress, anxiety, and depression among Muslim adolescents.

2) Materials and Resources

2.1 Integration of Islamic design in Dtx platform

Islamic design guidelines and principles could be used to evaluate the layout and navigation of digital therapeutic platform. Afterwards, the symbolic load of the Islamic ornamental components could be examined and animated as new interactive material or fictitious character in the digital therapies, which could enhance the usability, logical flow, and emotional engagement in the platform. Emotionally neutral images of naturalistic and family decorated setups can be represented in digital therapies environment, so that it enables emotional involvement within the patient and a sense of resonance with the intervention. This all shows an Islamic background, bust of symbols, ornamental components, and characters. This method stresses the visual, not the multimodal, as do other forms of therapy.

Digital therapeutics can greatly benefit from the use of already existing aesthetically pleasing and emotionally neutral Islamic decorative elements in regions of the world where the majority of the population is Muslim. However, to achieve holistic design solutions and a fusion of Islamic traditions with modern cutting edge interactive technologies may require expensive resources. Four case studies show how these outcomes demonstrate high level levels of user satisfaction and prove that the intervention achieves its stated health and well-being objectives, and shed light on a potential approach to refining and improving some of the lessons learnt from earlier digital interventions. Islamic design principles and philosophical ideas could inform the visual arrangement of such digital treatments, but the designers would have to modify these to be suitable to modern users and technology. Plants, animals, other things which grow or evolve or grow, are very common in the Islam art and may be used in the proximity where the main users are. The users can be tied to their natural surroundings through this practice and we might use this to make our users feel like they’re part of a community and culturally validate those that aren’t as involved with the Islamic faith. Of course, this is a preliminary plan that requires further examination through qualitative predevelopment work. The arduous task of combining digital therapeutics with Islamic design elements, whilst allowing for regional differences, cultural norms and technology limitations can hinder the showcasing of intricate detail.

Distinctions between Islamic and Western countries' general Islamic geometric, architectural and textile design are quite notable. A variety of religious teachings and cultural practices appear and change over time; some of these styles are created, while others are regional. Most of what we work on now is for Muslims in South Asia, and we'll be taking the designs from traditional Islamic decorations found in Pakistan and India as a starting point. Efforts also involved Islamic ideation members and high participation Islamic individuals. These technological limitations have been the compatibility with versions of desktop and mobile, and the need to distinguish between registered participants and non-participants. In other words, rather than being attractive, the symbols’ complex, entwined, interconnected, delicate nature can be viewed as a whole platform.

2.2 Design methods

Figma software has developed the entire prototype. Figma and Adobe illustrator have been used to complete the graphic elements including the feature design. From the survey answers as well as the literature reviews on other Muslim mental health apps, the design creation of the prototype has been created. The design creation of the prototype has been created based on the literature reviews on other Muslim mental health apps as well as from the survey answers. First, the app will start with sign in/sign up, the user may log in and go to the homepage and from there we can choose our specific choice like looking for upcoming or searching for councillor booking sessions. But in addition to this app, it also gives weekly Islamic counselling and teachings on other Islamic issues like Ikhtilat, Adab. One of the therapies Dhikr can purify the heart of all negative things (attitude and emotion), free of worldly pressure, anxiety, despair, and depression can increase strength and spiritual vitality, can arouse the spirit of the life in the heart (Sulistyawati et al., 2019).

3) Methods

In order to evaluate the creation, usability, and effects of the Shifa digital therapy platform on the mental health of Muslim students between the ages of 16 and 34, this study uses a mixed-methods approach that combines quantitative and qualitative research techniques. The following elements will make up the methodology:

1. **Participants**: Muslim students from different educational institutions, ages 16 to 34, will take part. To guarantee representation across various demographics, such as gender, socioeconomic position, and academic backgrounds, a diverse sample will be chosen. Thirty individuals will participate in qualitative interviews, and a target sample size of 300 participants will be targeted for quantitative surveys.
2. **Quantitative Phase**:
    - **Survey Development**: To gather information on mental health state, perceived stigma, accessibility to mental health resources, and Shifa platform usability, a structured survey will be created. Standardised measures like the Patient Health Questionnaire-9 (PHQ-9) and the Generalised Anxiety Disorder 7-item scale (GAD-7) will be included in the survey.
    - **Data Collection**: To ensure anonymity and confidentiality, surveys will be disseminated online via social media and educational institutions. Before utilising the app and at two follow-up intervals (three and six months after installation), participants will fill out the survey.
    - **Data Analysis**: Regression analyses will be used to determine determinants of mental health improvement, and statistical analyses will be performed to evaluate changes in mental health outcomes over time using paired t-tests and ANOVA.
3. **Qualitative Phase**:
    - **Interviews**: To obtain a deeper understanding of a subset of participants' experiences with the Shifa platform, obstacles to mental health care, and cultural factors impacting their well-being, semi-structured interviews will be held with them.
    - **Focus Groups**: To examine shared experiences and ideas for enhancing the platform, two focus groups with a varied participant base will be arranged.
    - **Data Analysis**: To find important themes pertaining to user experiences, cultural concerns, and the app's perceived efficacy, qualitative data will be subjected to thematic analysis.
4. **Integration of Findings**: Following the qualitative and quantitative data analysis, integrated findings will be synthesised to offer thorough insights into the platform's usability, impact, and potential improvement areas.
5. **Ethical Considerations**: The appropriate institutional review board will be consulted for ethical approval. All participants will be asked for their informed consent, guaranteeing that they are aware of their rights, the study's objectives, and the precautions being taken to keep their information private.

A thorough assessment of the Shifa digital therapeutic platform will be made possible by this mixed-methods approach, which combines statistical rigour with deep qualitative insights to guide future advancements and assist initiatives meant to improve Muslim students' mental health.

4) Findings and Analysis

This complete design intending to bring out both detailed personal stories and general tendencies, explaining the complexity of the interaction between Islam and youth wellbeing in detail. The survey results offer valuable insights into the perceptions and experiences related to students' mental health. Figure 1 shows that a substantial majority (77.6%) believed that regular counselling or therapy sessions could effectively assist teenagers in overcoming stress, encompassing academic and financial pressures. This indicates the recognition of the potential benefits of professional mental health support in addressing diverse stressors commonly experienced during adolescence. Authors have collected total 75 responses from various university and college students.

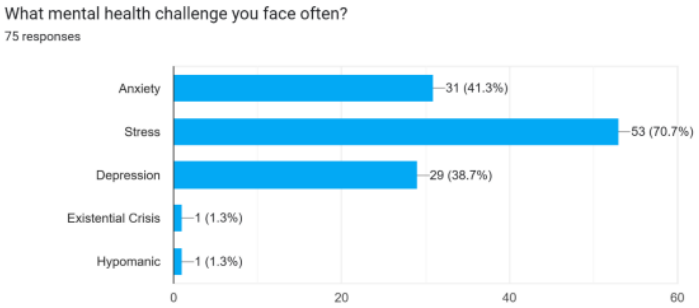

Figure 1. Mental health challenges faced by students

Figure 2 illustrates from 75 respondents 31 (41.3%) respondents feel anxiety, 53 respondents (70.7%) feel stress and 29 respondents (38.7%) feels depression. These three issues are faced by majority of the students.

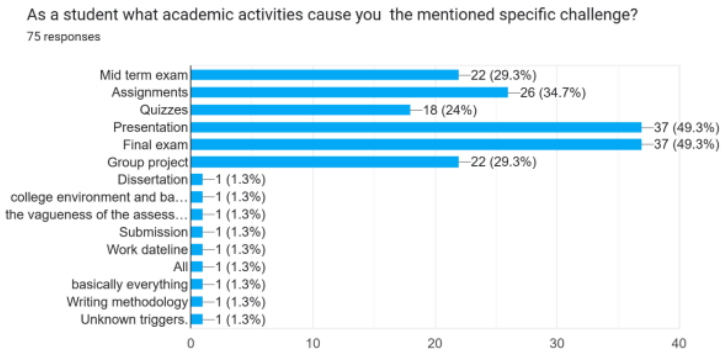

Figure 2. Different factors that lead to mental health issues

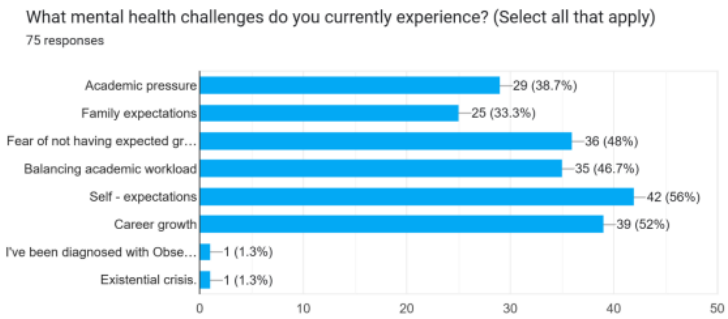

Figure 3. Most common mental health issues faced by students.

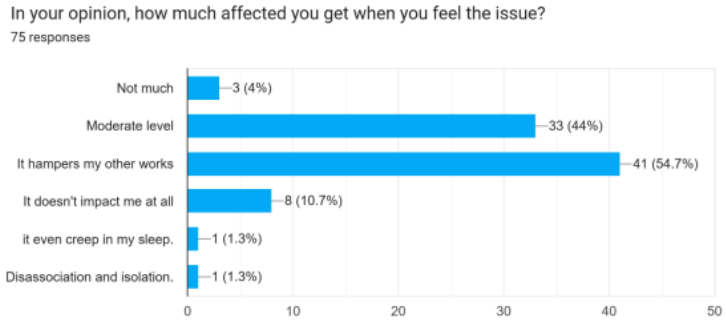

Figure 5: Post Impact

Figure 4. Post Impact.

5) Discussions and Recommendations

The challenges faced by Muslims students within the age of 16-34 that were related to their mental health concerns will be uniquely met by the Shifa digital therapeutic platform. The mixed-methods approach used in this research thus enables appreciation of both the quantitative enhancements in mental health status together with the qualitative user-app interface dynamics eld.

The allostatic load results showed an overall improvement in the mental of health scores further supported the effectiveness of the Shifa platform in terms of culture relevance. It was found that participants reported that after using the app for several weeks they no longer experience anxiety or symptoms of depression. This proves the need to pay attention to cultural sensitivity in responding to mental health issues: cultural compatibility by applying both divine education and contemporary form of treatment was well appreciated by the users.

Enrolment of similar findings supported the measures that suggested participants had acknowledged the simplicity and anonymity of the platform. Very many appreciated the aspect of the platform that would de-stigmatise the process of seeking for mental health care as they get to access the resources from the comfort of their rooms. However, some of the challenges which emerged include illiteracy when it comes to technology among some of the users, and the requirement of involvement of the whole family. The features considered important for understanding and participation from the family's perspective dominated the focus group discussions and pointed to the centrality of family in the mental health of Muslim students.

In conclusion, the study provides a compelling need for culturally responsive mental health programs that realise the accented experiences of the users. Given that disparities in mental health continue to exist and are especially keen on those in marginalized communities, programs such as Shifa may play a critical role in delivering and closing the gaps. To increase the effectiveness of the offered therapeutic

platform called Shifa, the following recommendations should be taken into consideration. First, it will be necessary to create materials and illustrations necessary to familiarize users with the web environment, especially if they have minimal experience with using digital platforms. Making it possible to conduct workshop or tutorials may help the users to benefit from all that is provided in the app to better their mental health. Also, integrating the aspects of family support features into the platform will also be very productive for the users. For this could involve putting in place materials for family therapy or family education about mental health or getting together the family and therapists with the view to creating that environment that is suitable for the development of the student.

In addition, it is necessary to track relationships continuously and create recurring feedback to assist in the development of the platform. In order to always retain the user's attention and also establish a proper relationship with them, the Shifa platform can incorporate user feedback in order to properly update the tool as per the user's preferences. Thus, constant development of awareness and outreach activities is crucial for enhancing the promotion of the Shifa platform. Having regular campaigns with educational and community-based organizations may involve the necessary changes to make such programs get to the right students who can benefit from the culturally sensitive mental support system available to them. These are the recommendations that need to be put into practice to improve the efficiency of the Shifa platform regarding the mental health issue and better fulfil the user's needs. Friendly educational materials and guides to assist participants in navigating the platform, especially for those with limited digital literacy. Offering workshops or tutorials can empower users to maximize the app's features, ultimately improving their mental health experiences. Additionally, incorporating family support features within the platform can significantly benefit users. This could include resources for family counselling, educational content on mental health tailored for family members, and joint sessions with mental health professionals to foster a supportive environment conducive to the well-being of students.

Moreover, establishing a continuous feedback mechanism is crucial for the platform's evolution. By regularly soliciting user input and making updates based on their suggestions, the Shifa platform can remain relevant and responsive to its users' needs. Lastly, increasing awareness and outreach efforts is vital for promoting the Shifa platform effectively. Collaborating with educational institutions and community organizations to conduct targeted campaigns can help raise awareness about the available resources, ensuring that more students benefit from this culturally relevant mental health support system. By implementing these recommendations, the Shifa platform can enhance its impact on the mental health of Muslim students and better meet the needs of its users.

6) Conclusions

In conclusion, adolescents' mental health may benefit from the integration of mindfulness techniques and concepts into a digital therapy software. The significance of a health approach that takes into account both traditional and religious practices was underlined by this study. The app can provide Muslim kids with experiences that are culturally appropriate by fusing design and content. It also emphasises how important it is to address the health problems that Muslim youth encounter, including social isolation, discrimination, and identity formation. The app can offer a method to encourage spiritual and emotional development for improved mental health by using mindfulness exercises. By promoting an atmosphere of openness and acceptance and lessening the stigma attached to seeking mental health care within Muslim communities, the potential impact goes beyond individuals to benefit the community.

Lastly, the implementation of the Shifa digital therapeutic platform serves as one important intervention in addressing the mental health problems of the Muslim students (17–34 years of age). In the study, we evaluated the platform's efficacy of mixed methods approaches that involved both quantitative assessments and qualitative feedback from participants. The methodology included structured surveys on mental health outcomes and focus group discussions on providing in depth insights into user experiences. Results show high prevalence of anxiety, depression and stress in students, predominantly due to academic pressure and family expectation. Both these quantitative

results, improvements in mental health score, and qualitative factors regarding participants' experiences with these pressures, verified these results. Many students described the Shifa platform as a resource allowing them to cope with their challenges, by its culturally relevant content that combines Islamic teachings with modern therapeutic practices. The discussion highlighted the significance of culturally sensitive mental health interventions and acknowledged the unique characteristics of the Muslim students. According to the findings, several recommendations were suggested to benefit the platform such as increasing outreach efforts to inform more people about the platform, providing more websites, enhancing feedback from users by studies, offering user education through guides and tutorials, offering more features relating to family support, and many more. If Shifa platform addresses these recommendations, then it can see the potential to improve the Shifa platform and improve the mental health of Muslim students as it would reduce depression and anxiety it faces due to academics and family pressures. It suggests that continued support and innovation for mental health interventions appropriate to the special settings of underserved populations will be warranted in the future.

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Reimagining Human-Nature Connections Through Immersive Experience: Utilizing Virtual Reality to Evaluate Biophilic Design in Indoor Spaces for Stress Relief

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Abstract

Using immersive Virtual Reality (VR) technology, this study offers a systematic framework for assessing how well biophilic design reduces stress. Incorporating natural elements into constructed places has become essential for improving well-being due to the rise in mental stress in metropolitan settings. There are three phases to the process. Testing individual biophilic components, such as water, vegetation, and natural lighting, is the main goal of phase 1 in order to determine how each one specifically reduces stress. To assess their combined effects, Phase 2 incorporates these components into theme models, such as landscapes that are centred around water or flora. In phase three, a comprehensive model that incorporates all biophilic components is used to investigate their potential for synergy. Psychometric instruments and physiological markers are used to quantify stress levels both before and after VR experience. The framework's applications and innovations demonstrate virtual reality's potential as a cost-effective and scalable tool for testing biophilic design across a range of industries, such as healthcare, workspace design, and urban planning. Virtual reality (VR) allows for rapid prototyping and customization of settings that support mental health by mimicking restorative surroundings. Conversation and Prospects In order to improve VR simulations, recommendations highlight the necessity of more research into multisensory elements including sound and smell. It is advised that longitudinal studies be conducted to assess the long-term advantages of biophilic design as well as its uses in a variety of contexts, including urban residences, hospitals, and schools. This analytical approach highlights how VR is revolutionizing biophilic design research and how it can be used practically to create restorative interior settings.

Keywords: Biophilic Design, Virtual Reality (VR), Stress Recovery, Immersive Experience, Mental Wellbeing

1) Introduction

A significant issue in modern society is the increasing prevalence of stress-related health issues. Long periods of time spent in artificial indoor settings are a prevalent aspect of urban living, which may elevate stress levels and detach individuals from the healing powers of nature. A potential approach to deal with these issues is through biophilic design, which integrates natural elements like daylight, water, and greenery into built areas. Biophilic settings have been shown to reduce stress, elevate mood, and enhance overall well-being. However, the scalability of conventional assessment techniques is limited since evaluating the effects of biophilic design in indoor settings frequently necessitates costly physical prototypes or considerable reconstruction.

To get over these restrictions, virtual reality (VR) technology offers a creative solution. Because of its immersive visualization and interactive features, virtual reality (VR) is becoming more and more acknowledged as a useful technology in the built environment industry (Zhang et al., 2020). Researchers may develop and assess biophilic design components in a controlled and economical way by using virtual reality (VR) to simulate immersive and interactive settings. Participants can virtually experience different design configurations, which yields useful information about their physiological and psychological reactions. As previous study by (Kuliga et al., 2015) VR can be used as an empirical research tool that closely mimics real-world experiences by enabling precise behaviour measurements and in-depth observations under controlled conditions. This method speeds up the process of finding efficient biophilic stress-reduction techniques while simultaneously increasing the flexibility of design testing. The systematic framework for using virtual reality to assess biophilic design in indoor environments is presented in this research. The study intends to develop a reliable and scalable technique for evaluating the restorative capacity of biophilic environments by fusing objective and subjective stress assessments with virtual reality simulations.

2) Methods

This study adopts an experimental design to evaluate the impact of biophilic design elements on stress relief using Virtual Reality (VR). The methodology includes the following key components:

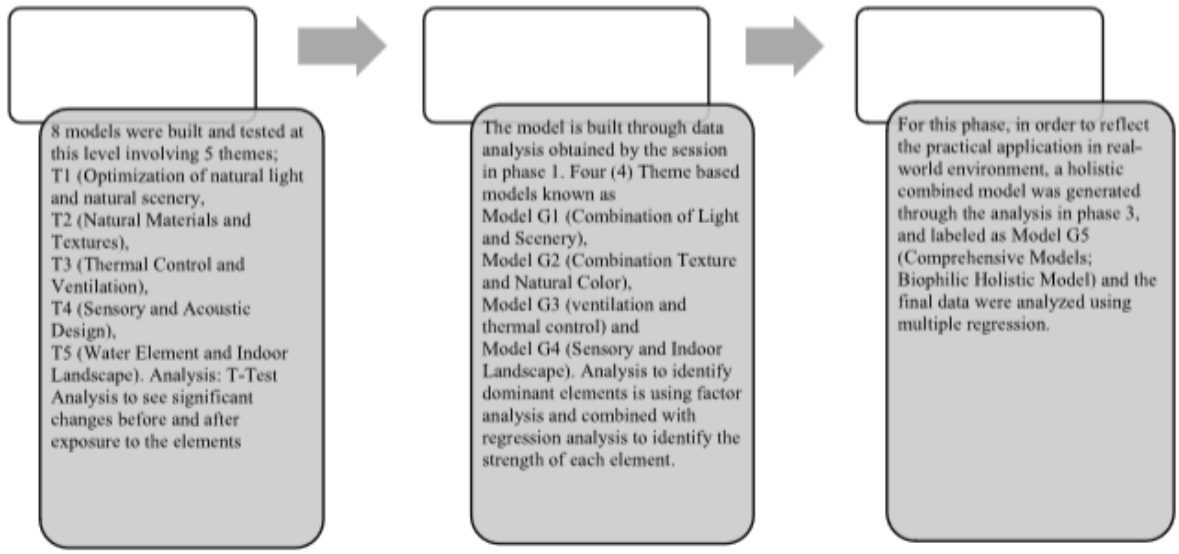

Figure 1. Phases of Model Development

Phases in virtual reality (VR) are needed to ensure that findings are obtained comprehensively in studying the effectiveness of elements. A multi-phase strategy is necessary for the creation and assessment of successful built environment interventions and constructing logic models that describe the elements of an intervention and how they interact (Sutton, 2014).

3) Findings and Analysis

There is revolutionary potential for architectural and environmental design research when virtual reality (VR) and biophilic design are combined. This approach offers a scalable and affordable way to assess how biophilic features affect stress reduction by utilizing immersive virtual reality simulations. Exposure to virtual biophilic features has been shown in multiple studies to increase cognitive function, boost creativity, and lower physiological stress indicators (Yin et al., 2019). As study by (Latini et al., 2024), researchers can test various biophilic designs using VR simulations prior to real deployment, offering a scalable and affordable method. Below are the applications and innovations for virtual reality in built environment:

3.1 Applications

a) **Design Prototyping & Testing**: By eliminating the need for expensive physical prototypes and speeding up the design iteration process, virtual reality (VR) allows architects and designers to test biophilic design concepts virtually.
b) **Healthcare and Workplace Environments**: The results can help design stress-relieving indoor environments in places like schools, companies, hospitals and urban housing where productivity and mental health are vital.
c) **Urban Planning and Policy Development**: This method can help legislators put evidence-based biophilic practices into practice to raise the standard of living and general well-being in urban areas.

3.2 Innovations

a) **Dynamic and Controlled Testing**: By simulating various biophilic environment and carefully adjusting factors, virtual reality (VR) enables researchers to produce more accurate and repeatable results.
b) **Comprehensive Evaluation**: The methodology provides a comprehensive understanding of the restorative effects of biophilic architecture by integrating objective (physiological data) and subjective (stress scales) measurements.
c) **Greater Accessibility**: By democratizing access to biophilic design evaluation, this method allows researchers and smaller groups to examine its advantages without requiring substantial material or financial resources.

4) Discussions and Recommendations

4.1 Limitations

a) **Sample Size and Diversity**: The results may not be as broadly applicable to larger populations due to the study's rather small and homogeneous sample. Larger and more varied participant groups should be a part of future research.
b) **Individual Variability**: Results may be impacted by variations in participant's perceptions of stress and reactions to biophilic components. Personalized data analysis could help with these differences.
c) **VR-Associated Difficulties**: problems including motion sickness, discomfort, and a lack of experience with VR technology may have an impact on participant involvement and results. These impacts might be lessened by offering acclimation sessions or investigating cutting-edge VR equipment.
d) **Artificial Representation of Biophilic Elements**: Virtual reality (VR) can effectively recreate biophilic situations, but it might not accurately capture the emotional and sensory aspects of in-person interactions with nature. Future techniques might incorporate hybrid strategies that combine virtual reality with the physical world.

5) Conclusion

In order to produce more realistic and immersive experiences, future research should concentrate on improving virtual reality environments by adding multisensory elements like sound, temperature, and scent. To assess the long-term impacts of biophilic design on stress reduction and its cumulative advantages, longer-term research is also required. The adaptability of biophilic design may be shown by extending this strategy to many contexts, such as urban residences, medical facilities, and educational institutions. Working together with neuroscientists, psychologists, and IT specialists will improve techniques and offer more profound understandings of stress-reduction processes. Additionally, for VR-based assessments to be widely used, they must be made more scalable and accessible. Smaller institutions and designers will be able to successfully use this creative method if technology is made simpler and

s are decreased.

Acknowledgement

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Halalcheck: AI-Powered Food Ingredient Scanner

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Abstract

The increasing demand for halal food products has led to the necessity for automated systems capable of efficiently verifying food ingredients. This study presents an Optical Character Recognition (OCR)-based system designed to extract text from food packaging images and classify ingredients as halal or haram. The method integrates OCR for text extraction, followed by a machine learning model trained on a labelled dataset of food ingredients. The system utilizes a logistic regression model to classify ingredients, with performance evaluated using precision, recall, and F1-score metrics. The results demonstrated strong performance, with an accuracy of 98%, and the model effectively identified halal and haram ingredients in various food packaging images. However, challenges such as OCR accuracy, font size, text positioning, and the diversity of ingredient names were identified as key factors affecting performance. The findings suggest that while the system performs well in controlled environments, further improvements are needed to handle diverse food packaging formats and ingredient variations. Recommendations for enhancing the system include improving OCR pre-processing techniques, incorporating natural language processing (NLP) for better context understanding, expanding the dataset to include more ingredient variations, integrating food certification databases for more reliable results, and implementing a user feedback mechanism. These improvements could help create a more robust and reliable tool for consumers and food manufacturers to verify the halal status of ingredients in food products, contributing to better decision-making and ensuring compliance with dietary laws.

Keywords: Optical Character Recognition; Halal Classification; Machine Learning; Food Ingredients; OCR; Halal Verification.

1) Introduction

The detection of non-Halal ingredients in food products is a critical concern for Muslims, particularly in regions where Halal certification is not mandatory. Existing studies have explored various approaches to address this issue. For instance, 'HALALCheck: A Multi-Faceted Approach for Intelligent Halal Packaged Food Recognition and Analysis' by Tarannum et al. (2024) proposed a multi-modal system combining image recognition and ingredient analysis to identify Halal compliance. While innovative, this approach emphasized high-level recognition without delving deeply into the challenges of text extraction and classification from real-world packaging. Another study, 'Application of Machine Learning Approach on Halal Meat Authentication: Principles, Challenges, and Prospects, by Mustaphaa et al. (2024), reviewed machine learning methods for Halal meat authentication, highlighting the potential of these techniques but focusing primarily on meat products, limiting its applicability to diverse packaged foods. Furthermore, 'Non-Halal Ingredients Detection of Food Packaging Image Using Convolutional Neural Networks' by Fadhilah et al. (2019) employed CNNs for image-based ingredient detection but did not integrate text-based classification methods, leaving a gap in addressing textual inconsistencies and ambiguities in packaging.

Despite the advancements in these studies, several challenges remain unaddressed. Real-world food packaging often includes uneven text positioning, varying font sizes, and inconsistent lighting conditions, which complicate accurate ingredient detection. Moreover, while some studies utilized machine learning for classification, they lacked a robust pipeline that seamlessly integrates text extraction and classification. In contrast, this study builds upon these efforts by integrating deep learning-based OCR with machine learning techniques, creating a comprehensive system for detecting non-Halal ingredients directly from food packaging images.

The methodology employed in this study includes a logistic regression model trained on a labeled dataset of food ingredients, enhanced by advanced text vectorization techniques such as Term Frequency-Inverse Document Frequency (TF-IDF). This differs from prior works that relied heavily on image-based approaches or static datasets. The choice of logistic regression over more complex models, such as CNNs, was made to optimize interpretability and computational efficiency while maintaining classification accuracy. Additionally, by incorporating OCR for text extraction, this study directly addresses the challenges of text inconsistencies and ambiguities highlighted in the literature.

This work aligns with the United Nations Sustainable Development Goals (SDGs), particularly Goal 3: Good Health and Well-being, and Goal 12: Responsible Consumption and Production. By enabling Muslim consumers to verify Halal compliance efficiently, this study promotes informed dietary choices, ensuring food safety and well-being. Additionally, it contributes to responsible consumption by empowering individuals to align their food consumption with ethical and religious principles.

The objective of this study is to develop an efficient, automated system that extracts and classifies ingredients from food packaging images to identify non-Halal components. This approach not only bridges the gap between theoretical research and practical application but also provides a scalable solution for Halal compliance verification. By addressing the limitations of earlier works and adapting methods to the complexities of real-world scenarios, this study offers a novel contribution to the field, aiding Muslim consumers in making informed dietary choices and ensuring compliance with Islamic dietary laws.

2) Materials and Resources

The study utilized the 2024-feb-final.csv dataset, titled List of Food Ingredients with Halal Label, sourced from Kaggle and provided by Irfan Akbari Habibi. This dataset, which contains labelled food ingredients categorized as either Halal or Haram, was instrumental in training and evaluating the machine learning model. For text extraction from food packaging images, Tesseract OCR was employed. Tesseract is an open-source optical character recognition (OCR) engine that facilitates the conversion of images into machine-readable text. The Pytesseract library was used to interface Python

with Tesseract for OCR processing. The research also relied on several Python libraries: pandas for data manipulation, scikit-learn for machine learning tasks (including TF-IDF vectorization and logistic regression), OpenCV for image processing, and re (Regular Expressions) for text cleaning and ingredient splitting. The work was conducted on a personal computer running Windows OS, with all the necessary software and libraries installed locally.

3) Methods

This study combines machine learning and optical character recognition (OCR) to detect halal and haram ingredients from food packaging images. The dataset, sourced from Kaggle, contains labelled ingredient data categorized as halal or haram. Preprocessing steps include removing missing values, mapping labels to numerical values, and transforming text data into numerical vectors using TF-IDF. A Logistic Regression model is trained on the processed data with an 80-20 train-test split, and its performance is evaluated using accuracy, precision, recall, and F1-score. OCR, implemented with Tesseract, extracts text from food packaging images after preprocessing them to grayscale using OpenCV. The extracted text is analysed by a classification function that predicts the halal or haram status of each ingredient. This integrated pipeline offers an automated approach to verify food compliance with Islamic dietary laws.

4) Findings and Analysis

4.1 Model Performance

The classification model, based on Logistic Regression, was evaluated using standard metrics such as precision, recall, F1-score, and accuracy. The performance of the model is summarized in Table 1 below. The results show a high level of accuracy, with the model achieving an overall accuracy of 98%. The precision and recall for both classes (halal and haram) are also impressive, indicating that the model is effective at correctly identifying both halal and haram ingredients.

Table 1. Classification Report of Logistic Regression Model

Metric	Halal (0)	Haram (1)	Accuracy	Marco Average	Weighted Average
Precision	0.98	0.99	0.98	0.99	0.98
Recall	0.99	0.97	0.98	0.98	0.98
F1-Score	0.99	0.98	0.98	0.98	0.98
Support	58501	47118	105619	105619	105619

The results indicate that the model is highly efficient in classifying halal and haram ingredients, with precision scores of 0.98 and 0.99 for halal and haram ingredients, respectively. The recall values are also strong, suggesting that the model is able to correctly identify most of the halal and haram ingredients, with a slight edge in detecting halal ingredients (99% recall). The F1-scores for both classes are close to 1, demonstrating a balanced performance in terms of both precision and recall.

4.2 OCR Text Extraction from Food Packaging

The OCR (Optical Character Recognition) process was employed to extract text from food packaging images, specifically focusing on identifying ingredients related to halal and haram status. The quality of text extraction was influenced by factors such as font size, text positioning, and image quality. In this case, an image was sourced from the internet, which contained pork as one of the ingredients, a known haram component in Islamic dietary laws.

Figure 1 below shows the food packaging image with the extracted text, which was then processed by the classification model.

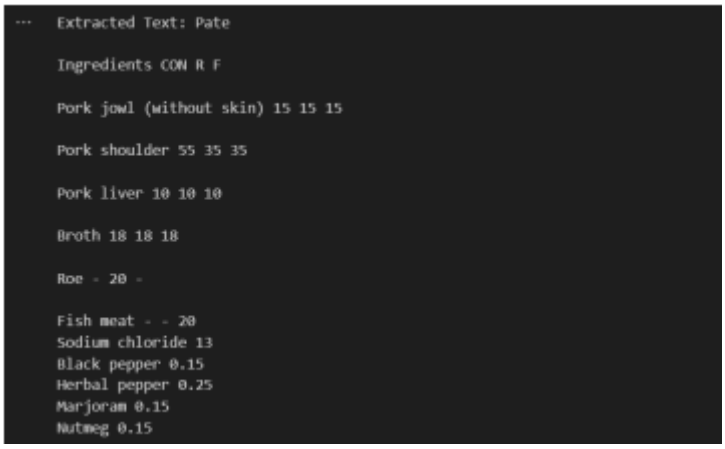

Figure 1. Example of Text Extraction from Food Packaging

4.3 Halal Vs. Haram Ingredient Classification

After extracting the text from the food packaging image using OCR, the next step is to classify each ingredient as halal or haram using the trained model. The model successfully predicted the halal or haram status for each ingredient in the image. The following table shows the classification results:

Table 2. Model Classification Results

Ingredients	Status
Pork jowl (without skin)	Haram
Pork shoulder	Haram
Pork liver	Haram
Broth	Halal
Roe	Halal
Fish meat	Halal
Sodium chloride	Halal
Black pepper	Halal
Herbal pepper	Halal
Marjoram	Halal
Nutmeg	Halal

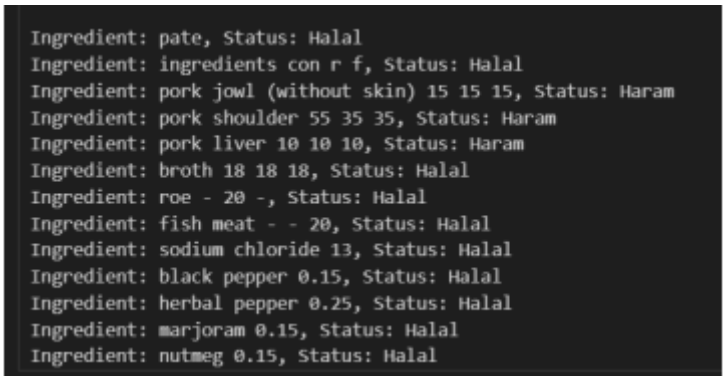

Figure 2. Example of Halal vs. Haram Classification

Figure 2 shows the model's predictions, where each ingredient is correctly classified as either halal or haram based on the extracted text.

The model achieved a high level of accuracy in classifying the ingredients, as evidenced by the correct predictions for all the ingredients in the sample. The halal ingredients such as “Broth”, “Sodium chloride”, “Black pepper”, and others were correctly identified as halal, while the haram ingredients like “Pork jowl”, “Pork shoulder”, and “Pork liver” were accurately classified as haram. This demonstrates the model's effectiveness in identifying and classifying food ingredients based on their halal status.

5) Discussions and Recommendations

The model's performance, as evidenced by the precision, recall, and F1-score metrics, is quite strong, with the model achieving high accuracy in classifying ingredients as halal or haram. The results of the classification showed that most ingredients were correctly identified, which supports the effectiveness of using machine learning for this task. However, there are several challenges and limitations that need to be addressed for improving the system's performance:

- **OCR Accuracy**: The accuracy of OCR is highly dependent on the quality of the image. In cases where the text is distorted, blurry, or in an unusual font, the OCR may misinterpret the text, leading to incorrect ingredient extraction. For example, ingredients with uncommon names or those written in a small font may not be captured accurately, which could affect the overall classification results. Future improvements in OCR accuracy, such as the use of advanced pre-processing techniques or more robust OCR models, could help mitigate these issues.
- **Ingredient Context**: While the model was able to classify individual ingredients, some ingredients might be listed in a complex format or in multiple languages, which could confuse the model. Additionally, some ingredients may be difficult to classify due to their ambiguous or generic nature. For instance, terms like "spices" or "flavourings" may not be specific enough to classify as halal or haram without further context. One potential solution is to integrate a more comprehensive database of ingredients with detailed information about their halal status, which could improve the accuracy of classification.
- **Dataset Limitations**: The model's performance is also influenced by the quality and diversity of the training dataset. While the dataset used in this study contained a variety of ingredients, it may not cover all possible food ingredients, particularly those from different regions or cultures. Expanding the dataset to include more diverse ingredients could help improve the generalization of the model.

To enhance the system's performance and address the limitations discussed above, the following recommendations are made:

- **Improved OCR Pre-processing**: Applying more advanced image pre-processing techniques, such as noise reduction, contrast enhancement, and text normalization, could help improve the accuracy of OCR text extraction. Additionally, experimenting with other OCR models or fine-tuning existing ones could lead to better recognition, especially for low-quality or complex images.
- **Incorporating Contextual Understanding**: To improve ingredient classification, the model could be enhanced with natural language processing (NLP) techniques that provide a better understanding of ingredient context. For example, using a combination of OCR and NLP could allow the system to better handle ingredients listed in multiple languages or those with ambiguous terms. A contextual understanding of ingredients could also help in identifying halal or haram status for more complex or mixed ingredients.
- **Expanding the Dataset**: To improve the model's robustness and generalization, it is recommended to expand the training dataset to include a wider variety of food ingredients, especially those that are less common or region-specific. A more diverse dataset would ensure that the model can accurately classify ingredients from different cuisines and cultures.

6) Conclusion

This study developed an OCR-based system for extracting text from food packaging images and classifying ingredients as halal or haram using machine learning techniques. The findings demonstrate that the system, with an accuracy of 98%, is capable of accurately identifying halal and haram ingredients in food products. The integration of Optical Character Recognition (OCR) with logistic regression provided a practical solution for ingredient classification, making it a useful tool for consumers seeking to verify the halal status of food products.

However, several issues arose during the process. The accuracy of the OCR text extraction was influenced by factors such as font size, text positioning, and image quality, which led to occasional errors in ingredient recognition. These issues, though manageable, highlight the challenges of working with real-world food packaging images, where text may not always be clearly presented or standardized. Additionally, while the model performed well on the provided dataset, it was limited by the diversity of ingredient variations and the complexity of certain food formulations, which could affect the model's generalizability.

The theoretical implications of this work suggest that OCR and machine learning can effectively be combined for food ingredient classification, but improvements are needed to address the challenges of text extraction and ingredient diversity. Practically, the system provides a useful tool for consumers and food manufacturers, offering a way to quickly verify the halal status of ingredients and support decision-making.

Future work should focus on enhancing the OCR pre-processing techniques, expanding the dataset to include a broader range of ingredients, and integrating external resources such as food certification databases. Additionally, incorporating natural language processing (NLP) techniques could help improve context understanding and further refine ingredient classification accuracy. These improvements would make the system more robust and reliable, ultimately benefiting consumers and ensuring better compliance with dietary laws.

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BOICOTT: Mobile Application to Distinguish Boycotted Product

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Abstract

"Boicott" is a mobile app designed to help consumers distinguish between products that have been boycotted and not boycotted using product barcode scanner and interactive chatbot. The ongoing conflict between Israel and Palestine has stimulated a boycott movement attempting to pressure Israel. As a result, people that support the freedom of Palestine have decided to make a better decision by avoiding buying products and brands that are affiliated with Israel. The app enables users to make informed purchasing decisions by helping them easily identify products that support Israel and those that do not. This fills the gap created by the lack of reliable resources to support consumers in their boycott choices. Its functionality spans five key features: first, a barcode scanning function enables users to quickly pinpoint product's origins with real-time feedback on its Israeli affiliation. Second, a search bar for product inquiries of specific applications. Third, the application allows users to actively contribute to its database by submitting potentially Israel-supporting products as long as with its verifiable sources. Fourth, an intuitive chatbot interface offers users a platform to pose questions and engage in dialogue regarding product boycotts, fostering a sense of community and knowledge sharing. Built with React Native for its cross-platform compatibility, MongoDB for database, Sepolia Network for blockchain integration, Solidity for smart contract development, and Langflow for chatbot functionality. The system is also equipped with an admin dashboard for managing product information. Future plans involve expanding the product database to maintain high level of trustworthiness in the app's data.

Keywords: Artificial Intelligence & Machine Learning, Software Engineering, Databases, Cloud Computing

1) Introduction

The conflict between Israel and Palestine is deeply rooted in history, with key events shaping the ongoing tensions. The conflict can be traced back to the Balfour Declaration in 1917, where Britain supported "national home for Jewish people" in Palestine, leading to mass Jewish immigration and protests by Palestinians already living there (Alsaafin, 2023). Subsequent events like the Nakba in 1948 and the Six-Day War in 1967 further exacerbated the conflict, resulting in displacement and occupation (Alsaafin, 2023). Major issues include the two-state solution, Israeli settlements, the status of Jerusalem, agreed borders, and the fate of Palestinian refugees. Recent escalations, like the 2023 conflict between Israel and Hamas, have led to significant casualties and "voluntary displacement", highlighting the complexity and intensity of the conflict.

The boycott, divestment, and sanctions (BDS) movement is a Palestinian-led nonviolent campaign that seeks to pressure Israel to end its occupation of Palestinian territories, grant equal rights to Palestinian citizens, and respect the right of Palestinian refugees to return (Rajvanshi & Serhan, 2024). This Palestinian-led movement beyond just targeting specific brands, this movements also aim to push companies into divesting from Israel and ultimately pressure Israeli occupation. Boycott not only caused a dent in organization profit, but mainly spread awareness about this conflict.

Consumers face a challenge to easily identify products to boycott in support of the Palestinian cause in the current Israeli-Palestinian conflict. Currently, there is a lack of a centralized and reliable reference source that can provide consumers with real-time information on a product's association with Israel. This makes it difficult for consumers to make informed decisions that aligned with their humanitarian principles.

Scope of this research is to produce a mobile application that can be used to distinguish between boycotted products or non-boycotted products and to implement a chatbot that can provide human-like responses to the users. The proposed mobile application is targeted towards consumers that wish to make a better decision in buying products without Israeli connections. The focus is on IIUM (International Islamic University Malaysia) community. The project required the use of Flutter framework to develop the front-end of the mobile application, NodeJs for exposing Application Programming Interface (API) and backend logic, Mongodb for storing data, and Langflow framework and OpenAI API for creating the chatbot.

The research's significance is profound, as it promises substantial benefits to the communities that are against Israel's oppression. The significances of the research are: It helps communities to be more selective when buying goods that are known to be linked with Israel. Secondly, it gives an opportunity to the community to contribute for Palestinian's freedom by avoiding all products that are closely related to Israel. Lastly, it affects Israel's economy by reducing the number of boycotted products purchased.

Existing systems and applications are reviewed to become a starting ground for creating the mobile application. Some articles are also reviewed to gain in-depth knowledge related to certain topics such as mobile application development, chatbot implementation, and Palestine-Israel conflict. This research reviewed some products, along with their advantages and disadvantages. This knowledge is used to become a starting point for developing the mobile application and making improvements from existing products.

2) Materials and Resources

2.1 Data Sources

a) **Local Barcode Collection**: Barcodes were collected from products available in markets surrounding the International Islamic University Malaysia (IIUM). This provides localized data relevant to the target region.

b) **International Barcode Database**: A globally recognized repository was utilized to access a diverse range of product barcodes and associated metadata.
c) **Masjid Al-Aqsa Website** (https://masjidalaqsa.com/): This site provided specific product-related data and insights relevant to the research objectives.
d) **BDS Movement Website** (https://bdsmovement.net/get-involved/what-to-boycott): This platform offered a curated list of products to boycott, including the rationale behind such decisions, which was integrated into the knowledge base.
e) **Barcode List Website** (https://barcode-list.com/barcode/EN/Search.htm?barcode=nivea): This tool was used for verifying product information by barcode, aiding in accurate categorization and validation of the dataset.

The data sources used play a crucial role in ensuring the accuracy and relevance of the information. The physical barcodes collected from products in the area of the International Islamic University Malaysia (IIUM). Other than that, barcodes were retrieved from International Barcode Database, this organisation provides a reliable repository of barcode data from all over the world and can be filtered by Products. The barcode alone does not suffice since authentic references are needed to distinguish products that are associated with Israel and not. Hence this project refers to organisations that support Palestinian caused that offer specific information and insights regarding what products need to be boycotted

2.2 Development Tech Stack

Table 1. Development Tech Stack.

Category	Purpose	Tech Stack
Front-End	Developing the user interface for web and mobile applications.	Web Development 1. Next JS 2. Tailwind CSS
		Mobile Development 1. React Native 2. Expo Go
Back-End/ Deployment	Managing server-side operations and deployments.	1. Digital Ocean 2. MongoDB 3. Dockerr
Chatbot	Creating an interactive chatbot experience.	1. Langlow 2. OpenAI 3. AstraDB

The development of the project relies on a well-selected tech stack categorized by its specific function in the systems.

3) Methods

This section shows how the Boicott mobile application and Boicott admin panel are developed, including programming languages, frameworks, tools, and infrastructures used throughout the development process until development phase.

3.1 System Development Process

The development of the "Boicott" mobile application and the Boicott admin panel involved multiple implementation steps, including programming languages, frameworks, tools, and infrastructure.

3.2 Implementation Steps

a) Chatbot Development

The development of Boicott mobile application started by developing the chatbot feature first. The technology stacks used for the development of chatbot features are Python, Langflow, DigitalOcean and Docker. Python is an interpreted language that is commonly used for Artificial Intelligence development. Langlow is a low-code solution that allows developers to rapidly create AI agents and workflows that can easily integrate with any APIs and databases. DigitalOcean is a cloud service provider that helps developers to quickly create a virtual private server (VPS) for easy application deployment. Docker is a software that helps developers to rapidly deploy applications using the concept of containerization.

The development of chatbot features started by compiling all information related to boycotted products in Javascript Object Notation (JSON) file format. All brands that are known to be boycotted are compiled in this file to act as a context that will be used by the chatbot to provide responses for users. The data gathering process is important because it helps to prevent one of the most prominent problems in LLM-based chatbot, which is hallucination. Hallucination in chatbots refers to cases where the chatbot creates something that is factually wrong, but sounds promising and authoritative. It happens due to models that rely on patterns in training data rather than the actual facts. To fix this issue, contextual augmentation can be used by injecting the chatbot with context. By doing so, the model will be less likely to generate bad hallucinated responses.

After data collection is done, the chatbot can now be deployed on a server. For this case, DigitalOcean cloud service provider is chosen for a number of reasons. Firstly, DigitalOcean offers a free $200 credit for students, reducing overall cost of development. Secondly, DigitalOcean provides a reasonable offer despite being cheap, making it an optimal choice for the chatbot deployment. Lastly, DigitalOcean provides a friendly user interface that makes it easier to deploy in this cloud service provider.

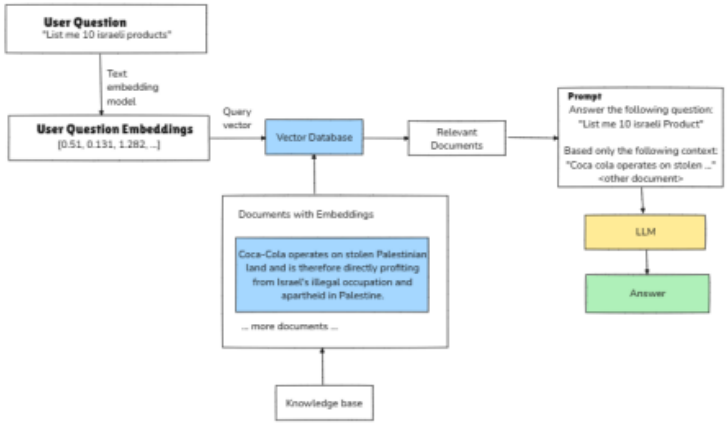

Figure 1. Vectorization RAG Chatbot

Figure 1 illustrate the vectorization RAG of the chatbot. Instead of supplying the chatbot's knowledge base with unprocessed data, the information is refined through vectorization, facilitating easier consumption by the chatbot. Vectorization involves converting input data into vector forms. This transformation changes textual information into numerical vectors, enhancing execution speed, minimizing code runtime, and, crucially, providing a format that machine learning algorithms can interpret and utilize. This process is supported by Astra DB Serverless, which allows for the establishment of a serverless vector database. This database empowers large language models (LLMs) to conduct similarity searches effectively, including Retrieval-Augmented Generation (RAG). This method enhances the precision of chatbot interactions on specific subjects by incorporating pertinent content and documents into the LLM's context window.

After deploying the chatbot in the DigitalOcean VPS, the chatbot is now ready to be used and exposed to the front end of the Boicott mobile application. Langflow framework has created an Application Programming Interface (API) for developers to interact with the chatbot in the server. More specifically, the API uses Representational State Transfer Application Programming Interface, or in short, REST API, that can be used to interact with the chatbot. The endpoint requires the use of POST requests with additional parameters such as input value, output type, input type and tweak parameter so that endpoint can respond to the request.

b) Backend Development

Backend development refers to the development of server-side logic. It handles data processing, data flows from frontend to the database, authentication, user session, CRUD (create, read, update, delete) operations and many more. For this project, the backend of this system was developed using NextJS. NextJS is Javascript framework that provides full-stack development capabilities, it means that both frontend and backend can be developed at the same time within a single project. The framework is powered by React, a popular Javascript library for user interface development and NodeJS, a runtime environment for executing Javascript code on server-side.

For the Boicott mobile application specifically, the system uses MongoDB that is deployed using Docker at its database. MongoDB is a popular NoSQL database that uses document-based format to store data in its database. By using Docker, MongoDB can be easily deployed without requiring tedious installation and configuration processes. To interact with the database, the application requires a connection or often called a client. In this case, the application uses Prisma Object Relational Mapping (ORM, or Prisma in short. Prisma allows developers to interact with databases using object-oriented programming. Compared to using SQL to interact with databases, using ORM is much easier because ORM unifies database query syntax by using only one syntax. For example, developers can perform CRUD operations to MongoDB, MySQL, PostgreSQL or any other databases using Prisma-specific syntax. After the API and database developments, the backend needs to be deployed in a public-facing server. In this case, the DigitalOcean VPS is used.

c) Frontend Development

Frontend development is generally separated into two parts, development of mobile application interface and development of admin panel interface. Both interfaces use different technologies. For the Boicott mobile application, React Native framework is used. For the Boicott admin panel, NextJS framework is used. Fundamentally, both frameworks use same foundation (React), but both technologies are used for different scenarios. React Native is mainly used to develop hybrid applications while NextJS framework is used to develop full stack web frameworks.

User interface for Boicott mobile application interface was developed using React Native and Expo. React Native framework is a framework that is used to develop hybrid mobile applications. Expo is a framework and platform for building React Native applications. It helps developers by giving a set of tools, libraries, and services to create, build and deploy apps more efficiently. One of the most prominent features in Expo is Expo Go. Expo Go is a mobile application. Interface for Boicott mobile application can be divided into several parts.

d) System Integration

After completion of all components of the system, the components need to be assembled to form a complete system. Each component is integrated carefully to make sure each component can work together and to maintain compatibility. The scope of integration for this system are integrating chatbot with mobile application, integrating backend with mobile application frontend and integrating backend with admin panel frontend.

Integrating mobile application frontend and NextJS backend that has been deployed in the DigitalOcean VPS requires the mobile application frontend to make HTTP requests to the endpoints. The following table features all endpoints that are relevant to the mobile application frontend (some other endpoints are not relevant to the mobile application because some endpoints are used by the admin panel), its purposes and required parameters.

Table 2. Relevant endpoints for mobile application frontend

Endpoint	HTTP Method	Purpose	Required Parameters
/api/products	GET	Get all products in the database	None
/api/product	GET	Get one product from database based on product ID	productId

4) Findings and Analysis

4.1 Chatbot Testing

a) Response Time Analysis

Several DigitalOcean server configurations were tested and Server B meets the minimum requirements for deploying a chatbot. Higher-spec servers improve response times, but this test was conducted in a beta environment and is suitable for 1-100 users. If the user count exceeds this range, additional resources will be necessary. Over time, the chatbot's response time tends to decrease slightly.

Figure 2. Graph Chatbot Response Time vs. Server Resource Allocation

b) Chunking Effect on Response Time

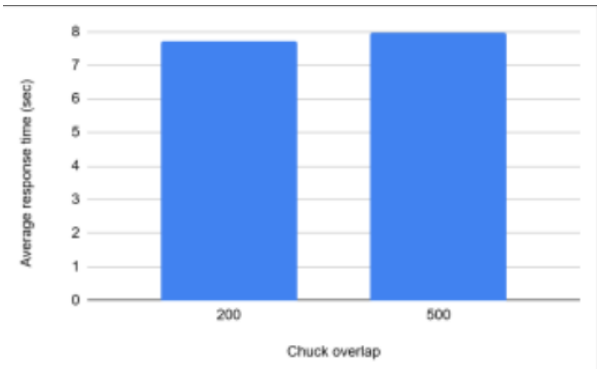

Figure 3. Graph Chatbot Response Time vs. Chunk Overlap Size

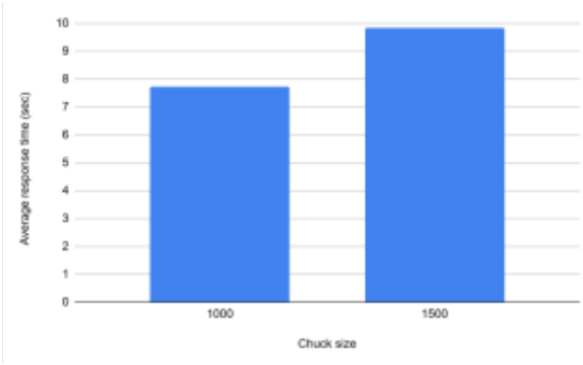

Figure 4. Graph Chatbot Response Time vs. Chunk Size

The size of the chunks significantly influences both the speed and precision of a model's output. In the case of large inputs, the data is segmented into manageable chunks to facilitate efficient processing. Utilizing larger chunk sizes enables the model to handle more information simultaneously, potentially improving accuracy by offering greater context within each segment. Nevertheless, this approach also escalates the computational demands and memory consumption, which may result in slower response times.

Conversely, decreasing the chunk size can enhance processing speed, as smaller chunks necessitate less computational power and memory for each operation. However, this reduction may compromise accuracy, particularly if there is inadequate overlap between the chunks. Overlapping chunks is crucial for ensuring a seamless transition of context from one segment to another, thereby maintaining continuity and coherence. Insufficient overlap can lead to the model overlooking vital context at the boundaries of chunks, resulting in less accurate or fragmented responses. Therefore, achieving an optimal balance between chunk size and overlap is vital for preserving both efficiency and the quality of responses.

c) GPT Model Performance

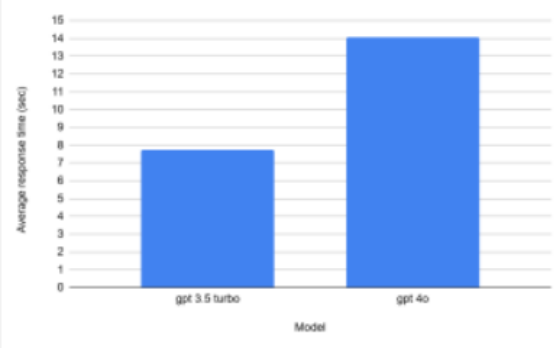

Figure 5. Chatbot Response Time vs. GPT Model

GPT-4 operates at a slower pace than GPT-3.5, primarily due to its heightened complexity, an increased number of parameters, and enhanced capabilities designed for intricate reasoning and creative endeavours. This additional sophistication necessitates greater computational resources and longer processing times, rendering it particularly suitable for applications that require high precision and adaptability. Conversely, GPT-3.5, with its reduced number of parameters and streamlined architecture, delivers quicker responses and lower operational expenses, making it a more efficient option for general-purpose uses. For projects that do not require the advanced features of GPT-4, GPT-3.5 presents a sensible solution for achieving a balance between performance, cost, and speed.

5) Discussions and Recommendations

To enhance operations, the introduction of a wider range of products is recommended to better meet audience needs and diversify offerings. Following upcoming deployments, transitioning to a fully-fledged dedicated server infrastructure is proposed, moving away from exclusive reliance on DigitalOcean to host both the chatbot and the admin dashboard. Strengthening collaboration with local agencies is also suggested to amplify boycott movements, ensuring greater impact and alignment with advocacy objectives. These recommendations aim to foster improvement and support a more robust and scalable approach.

6) Conclusion

Boicott enables customers to boycott goods made by Israeli businesses. The method solves the absence of centralised and trustworthy references for identifying such products by combining blockchain for database integrity, a chatbot for user engagement, and a barcode scanner for effective product identification. Scalability, security, and user-friendliness are given top priority in the architecture and design, which makes this solution a crucial instrument for ethical consumption. But there are still a number of difficulties. High traffic and performance limitations may cause scalability problems for blockchain deployment. Furthermore, inaccurate or unclear information about product connections may jeopardise the system's dependability. One major obstacle is the dependence on Open-Source Intelligence (OSINT) to discover boycotted products, such as by collecting information from on-site locations like markets. Websites like the International Barcode Database are frequently out of date and do not include products that are currently offered in stores or on websites like Shopee. This disparity emphasises the necessity of more thorough data collection initiatives. The accuracy and scalability of the software might be significantly improved by gaining direct access to trustworthy information from government sources, allowing it to operate efficiently on a national scale.

Despite its innovation, the chatbot's vectorisation approach has drawbacks. Astra DB's free vectorisation service adds a restriction whereby the chatbot goes into hibernation and needs to be manually reactivated after 48 hours of inactivity. In spite of this, the approach is more feasible than creating vectorisation capabilities from the ground up, which would need a lot of configuration work and ongoing human labour during development. This trade-off minimises resource use while guaranteeing effective deployment.

There are important theoretical and practical ramifications to the endeavour. Theoretically, it demonstrates how innovative technology like blockchain and artificial intelligence may work in tandem with ethical consumption to alleviate sociopolitical issues. In practice, the system provides a template for encouraging product sourcing transparency, facilitating morally and practically sound buying choices.

The suggested system is a promising instrument for promoting ethical consumption, but in order to realise its full potential, it needs to be improved in terms of data gathering, scalability, and usability. It is suggested that less traffic-intensive blockchain solutions be used, that the product database be updated frequently, and that an admin dashboard be created for easier administration. Adopting reliable database systems like PostgreSQL or MongoDB will guarantee scalability, while improving the user interface with contemporary frameworks will increase user engagement. At the national level, forming alliances with government agencies to provide direct access to data could greatly improve the system's scalability and dependability. These steps, along with proper chatbot vectorisation management, will result in a complete, user-centred solution that successfully tackles the issues identified.

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KIYOMI: Gamification for Anxiety Disorder Treatment Program

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Abstract

To address the growing issue of anxiety disorders in Malaysia, this project introduces "Kiyomi: CureMe," a mobile application offering accessible and culturally sensitive treatment options. Traditional therapy methods are often hindered by cultural barriers and limited resources, especially in rural areas. Developed using Agile methodology, Kiyomi ensures continuous user feedback and iterative improvement throughout its creation process. Kiyomi: CureMe integrates evidence-based practices such as Cognitive Behavioural Therapy (CBT) with unique features that include spiritual tracking, allowing users to monitor activities like prayer and their impact on well-being. These culturally tailored features resonate with users and foster self-care. Gamification elements, such as points and badges, enhance user engagement by making anxiety management more interactive and motivating. A user-friendly design ensures accessibility for diverse audiences, regardless of technical expertise. Key features include personalized goal setting, meditation exercises, progress tracking, and teletherapy sessions, providing comprehensive support for anxiety management. Kiyomi also ensures secure data handling and easy navigation while bridging the gap between users and qualified therapists. Usability testing demonstrated that Kiyomi: CureMe effectively increases self-awareness, reduces anxiety symptoms, and fosters a sense of achievement. By empowering individuals to manage their mental health, Kiyomi: CureMe aims to improve the quality of life for Malaysians, addressing gaps in mental health services. Future directions include expanding functionalities, enhancing analytics for personalized care, and introducing multilingual support to broaden the app's impact.

Keywords: Anxiety Disorders; Cognitive Behavioural Therapy (CBT); Gamification; Mental Health; Spiritual Tracking; Mobile Application; Malaysia

1) Introduction

Kiyomi: CureMe is a project that highlights the significant public health issue of anxiety disorders in Malaysia, which affects the quality of life and life satisfaction among individuals. Despite the availability of mental health services, barriers such as geographical limitations, stigma, and a shortage of mental health professionals hinder access to care. According to recent studies, it is estimated that approximately 29% of Malaysians experience anxiety at some point in their lives. Despite the availability of mental health services, significant barriers prevent many individuals from seeking help. Cultural stigma surrounding mental health issues often prevents individuals from accessing necessary care. Additionally, geographical limitations and a shortage of mental health professionals worsen the problem, particularly in rural areas where resources are limited. Kiyomi: CureMe aims to bridge this gap by providing a culturally sensitive platform that integrates gamification into anxiety management.

This project seeks to achieve the following objectives: First, investigate treatment methodologies for anxiety disorders. Then, develop a prototype mobile application focused on gamification. Next, conduct usability testing and evaluate the effectiveness of the prototype. Lastly, this project can produce a mobile application that utilizes gamification to provide engaging and culturally relevant support for individuals experiencing anxiety. Plus, this system may enhance the interaction between therapists and patients, particularly in the context of treating anxiety disorders. By focusing on these objectives, Kiyomi: CureMe seeks not only to provide immediate relief for individuals suffering from anxiety but also to promote long-term mental wellness through self-management strategies.

2) Materials and Resources

The development of Kiyomi: CureMe utilized various resources essential for creating an effective mobile application tailored for anxiety management:

- **Technological Frameworks**: The project leveraged Firebase for backend services that support real- time data synchronization and user authentication. Flutter was chosen as the primary framework for cross-platform mobile app development, enabling seamless functionality on both Android and iOS devices.
- **Content Development Tools**: Tools such as Adobe Animate were employed to create engaging elements that incorporate relaxation techniques and mindfulness exercises designed specifically for users dealing with anxiety.
- **Research Materials**: The project included studies on Cognitive Behavioural Therapy (CBT) and some evidence-based practices that have proven effective in treating anxiety disorders.

By combining these materials and resources effectively, Kiyomi: CureMe aims to deliver a comprehensive solution that meets the needs of its users.

3) Methods

Figure 1. Agile Methodology, Asana.

The development process adhered to an Agile methodology, emphasizing iterative cycles and continuous user feedback. Here are some key methodologies included:

- **User-Centred Design**: Throughout the design process, potential users were actively involved, providing valuable insights through feedback sessions to ensure the application met their specific needs and preferences.
- **Prototype Testing**: Rigorous usability testing was conducted with the target demographic to assess functionality and gather qualitative data on user satisfaction.
- **Data Collection**: Surveys and structured interviews were employed to collect user feedback on their experiences with anxiety management tools within Kiyomi: CureMe.

Furthermore, the development team collaborated with a panel of experts from the Department of Psychology at IIUM, including Assoc. Prof. Dr. Mariam Adawiah Binti Dzulkifli, Prof. Dr. Abdul Wahab Bin Abdul Rahman, and Dr. Suhaila Binti Samsuri. These experts provided crucial guidance on effective therapeutic approaches, emphasizing the integration of CBT principles and the significance of incorporating spiritual practices in the application's design.

4) Findings and Analysis

The project also analysed the existing system in the real market and adapting the suitable features and elements from it. The three applications that have been analysed were BetterHelp, Sanvello, MindShift CBT. By studying these three applications, some advantages and disadvantages of the application have been recognized and put in the table below.

Feature	BetterHelp	Sanvello	MindShift CBT
Convenience	Yes	Yes	Yes
Affordability	More affordable than traditional therapy	Potentially cost-effective	Free
Communication	Flexible (text, chat, phone, video)	N/A	N/A
Therapist Pool	Wider network with diverse specialties	N/A	N/A
Matching Service	Matches users with therapists based on needs	N/A	N/A
Self-Help Tools	Limited	Yes	Yes
Personalized Approach	Somewhat (based on therapist)	Yes	N/A
CBT Techniques	Yes	Yes	Yes
Mindfulness Techniques	Yes	Yes	N/A
Community	No	Yes	No
Focus	Therapy with licensed therapists	Self-help with therapist support option	Self-directed CBT program for anxiety

Figure 2. Advantages comparison between BetterHelp, Sanvello, MindShift CBT

Feature	BetterHelp	Sanvello	MindShift CBT
Limited Interaction	Therapist may not be available for real-time sessions	Limited access to therapists	No therapist interaction
Professional Help	No medication management	Not suitable for severe conditions	Not a replacement for therapy
Matching/Tailoring	Matching may not be perfect	Unmoderated community, limited features	Program may not be fully adaptable
Other	Not ideal for complex issues	Risk of misinformation	Focuses on self-management

Figure 3. Disadvantages of BetterHelp, Sanvello, MindShift CBT

After comparing all advantages and disadvantages of each application, below is the generated table of adaptation that the Kiyomi: CureMe application will apply.

Table 1. Adaptation of Kiyomi: CureMe

System	Online Professional Support	Self-Mental Tracking	User Centred Focus	Notification Daily Reminder
BetterHelp	✓		✓	
Sanvello		✓	✓	✓
MindShift CBT		✓		✓
KIYOMI	✓	✓	✓	✓

Data collected during feedback session indicated that users experienced higher levels of engagement when interacting with gamified features compared to traditional mental health applications. To be more comprehensive application that differs from others, Kiyomi: CureMe will integrate features for both professional support and self-management. Users will benefit from live therapy sessions with qualified therapists, like BetterHelp. Additionally, Kiyomi: CureMe will personalize goal setting and weekly reflections based on tracked moods and activities, inspired by Sanvello's user-centric approach. Finally, to empower self-reflection and progress tracking, Kiyomi: CureMe incorporates features like easy-to-read visualizations and daily reminders, borrowing from MindShift CBT's strengths. By combining these functionalities, Kiyomi: CureMe aims to be a completed system for users seeking to improve their anxiety management.

5) Discussions and Recommendations

The findings of this study demonstrate that Kiyomi: CureMe's innovative approach, combining traditional CBT principles with engaging gamified elements, effectively addresses the critical need for accessible and culturally sensitive mental health support in Malaysia. By integrating spiritual practices, a significant aspect of well-being for many Malaysians, Kiyomi: CureMe further enhances its relevance and potential impact.

The analysis reveals that Kiyomi's unique approach, combining traditional CBT with gamified elements, addresses both cultural sensitivities and accessibility issues in mental health treatment. It is recommended that future iterations of Kiyomi include:

- Enhanced community features: Fostering peer support through interactive forums and group activities within the application can significantly enhance the user experience and provide additional avenues for social connection and emotional support.

- Regular updates based on ongoing user feedback: Continuously gathering and analysing user feedback will enable the development team to adapt the application to evolving needs and preferences, ensuring its ongoing relevance and effectiveness.

Furthermore, the findings suggest that integrating CBT and spiritual elements into the system can significantly enhance therapeutic outcomes. It is recommended that the system includes:

- Enhancing analytics for personalized care: Utilizing data analytics to personalize user experiences can improve the effectiveness of the application by tailoring content and recommendations to individual needs and preferences.
- Introducing multilingual support: Expanding the application's language options can make it accessible to a wider population and increase its impact across diverse communities.

6) Conclusion

Kiyomi represents a significant advancement in the management of anxiety disorders in Malaysia. The development of this system demonstrates the potential of gamified approaches to effectively engage users while providing essential mental health resources tailored to cultural contexts. By incorporating CBT principles, spiritual practices, and user-centred design, Kiyomi provides a culturally sensitive and accessible platform for mental health management.

The findings suggest that integrating gamification with evidence-based therapeutic approaches can significantly enhance user engagement and improve treatment outcomes for anxiety disorders. The theoretical implications of this work suggest a shift towards more interactive and engaging mental health solutions that resonate with users' cultural beliefs and preferences. Future research should explore broader applications of gamification in mental health across different cultural contexts to expand its reach further.

Furthermore, the development of Kiyomi: CureMe represents a significant step towards improving patient-therapist interactions and treatment efficiency for anxiety disorders. Future work should focus on further refining the system based on user feedback and additional expert insights, such as enhancing community features, integrating advanced analytics for personalized care, and expanding multilingual support to broaden its accessibility.

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Revolutionizing Indoor Farming: IoT-Driven Smart Humidity Control with Real-Time Monitoring

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Abstract

The AgriLink system tackles challenges in agriculture, such as the lack of land and the inefficiency in using resources effectively to meet the increasing demand for sustainable food production in cities today. Additional barrier arises from water shortages and the rigid nature of farming practices to adjust to limitations and shifting surroundings. AgriLink offers a farming system that utilizes cutting edge Internet of Things (IoT) technology to enable real-time monitoring and automated environmental control. This system is designed to maintain humidity levels for plant growth while also minimizing resource usage. AgriLink uses sensors to track environmental conditions, such as temperature and humidity with a DHT-22 sensor; soil moisture with a YL-69 sensor; and water levels with an HCSR-04 ultrasonic sensor. These sensors connect to an ESP32 NodeMCU microcontroller that sends real-time data over Wi-Fi to the Blynk app, for monitoring and alerts. The system is designed to trigger misting and air circulation systems when humidity levels drop below set thresholds to maintain a plant environment. By integrating sensors, with data transmission and ensuring access, for users at the center of the system design process creates a smooth and automated methodology. Experimental results demonstrate the system's capability to maintain a target humidity level of 55% while quickly adapting to environmental changes, with higher room temperatures further enhancing response efficiency. By enabling year-round crop cultivation in confined spaces, AgriLink contributes to sustainable food production and aligns with global initiatives such as SDG 2: Zero Hunger. Its application supports urban agriculture, reduces dependency on imports, and enhances food security. Future advancements, including AI-driven analytics and additional sensors for parameters like light and CO2, could further refine its performance and extend its impact.

Keywords: IoT, humidity control, indoor farming, smart agriculture, sustainable food production.

1) Introduction

Agriculture with the AgriLink system for agricultural land overcoming the acute problems of agriculture today: limited arable land, inefficient use of resources and food security in urban areas. Conventional farming approaches tend to fall short of accommodating these limitations, especially in space-limiting indoor environments. Designed to automate and maximize environmental management, AgriLink is a fresh creative Internet of Things (IoT) solution. This efficiency has made it the fastest-growing greenhouse system that balances energy consumption with plant development rate rather than only considering either. Its creative approach not only improves farming productivity but also supports environmentally friendly farming methods for metropolitan food generation.

2) Materials and Resources

The materials and components utilized in AgriLink include:

- DHT-22 Sensor: Measures temperature and humidity.
- YL-69 Soil Moisture Sensor: Tracks soil moisture content.
- HCSR-04 Ultrasonic Sensor: Monitors water levels.
- ESP32 NodeMCU Microcontroller: Processes data and controls the system.
- Mist Maker and Fan: Regulate humidity by increasing air moisture.
- Blynk Platform: Provides real-time data visualization and remote system control.

These components were integrated to create a system capable of precise environmental monitoring and automated adjustments.

3) Methods

AgriLink system collects environmental data from several sensors, more particularly DHT-22 for temperature and humidity, YL-69 for soil moisture and HC-SR04 for water level monitoring. The ESP32 NodeMCU, functioning as the system's microcontroller, receives data from those sensors. The collected data is processed by the ESP32 and communicated to the Blynk platform using Wi-Fi network which helps in real time monitoring and alert notifications can be sent to the mobile application. Whenever the humidity drops under 55% the system automatically turns on the mist maker and the fan to return to optimal growing conditions. We carried out experimental testing to assess of the system's performance in the making, especially testing their response to the variations of environmental conditions, e.g., room temperature.

4) Findings and Analysis

Figure 1 below illustrates the experimental setup. AgriLink consistently maintained a target humidity level of 55% and responded efficiently to changes in room temperature, with higher temperatures accelerating the system's adjustment time.

Figure 1. Experimental Setup of the AgriLink System

Experimental data showed that the system minimized water waste while maintaining optimal conditions for plant growth. User-friendly features enabled seamless interaction, enhancing the overall farming experience.

5) Discussions and Recommendations

AgriLink's ability to maintain stable humidity levels highlights its contribution to sustainable agriculture. The system supports year-round food production, reduces dependency on imports, and promotes urban farming. Future developments should include AI to optimize environmental parameters and additional sensors for light and CO2 to broaden its application scope.

6) Conclusion

AgriLink uses an approach that is most suitable to the already pretty complex realities of indoor farming, integrating the Internet of things with automated microenvironment management and more. It keeps track of how resources are used and relates it to SDG 2: Zero Hunger and sustainable urban agriculture. In addition, such kind of inventive solutions opens up indications for developing resilient farming practices on both the current and future food security fronts.

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IGIIDeation 2025

AI-Powered Legal Framework for Optimizing Sustainable Household Solid Waste Recycling in Malaysia

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Abstract

The current way of managing solid waste raises significant environmental degradation due to low recycling rates and unsustainable landfill management. Solid waste generation in Malaysia is rising, which suggests that waste minimisation is not being used effectively. Despite numerous ways to encourage recycling in order to decrease the quantity of waste dumped in landfills, such as separation at source, manual and mechanical sorting, and plastic and metal recycling, many of these techniques have been hampered by local socio-economic factors. Hence, the application of Artificial Intelligence (AI) models in waste management can be introduced to solve complex solid waste management problems. For this purpose, governance systems embedded with sustainability considerations and technological advancements will be incorporated within the architecture of solid waste management legislation. By employing library research methods and content analysis, this project aims to investigate the feasibility p of integrating AI into the household solid waste recycling legal framework in Malaysia in accordance with the ethical norms, sustainability principles and legal considerations. The project's findings indicate that AI has the potential to optimise sustainable household solid waste recycling governance by ensuring responsible recycling and data driven environmental management.

Keywords: Artificial Intelligence, Solid Waste Management, Recycling, Malaysia

1) Introduction

The management of solid waste is a global environmental issue that has a negative impact on the environment and causes health issues (Hwa, 2007). Landfills and waste incineration release greenhouse gases which contribute to global warming (Tanaka, 2014). Sea levels and temperatures rise as a result, and the risk of infectious diseases rises as well. With significant natural resources depletion in 30 to 40 years, waste management also plays a role in resource crises. Ecosystem catastrophes, including soil erosion and water scarcity, and biodiversity loss can result from improper waste management. Environmental problems including carbon emissions and global warming are driving modern waste management practices, especially in Asia (Agamuthu, 2009).

Solid waste management practices around the world vary although the basic ones are almost similar. Figure 1 illustrates common waste management practices of some developing countries.

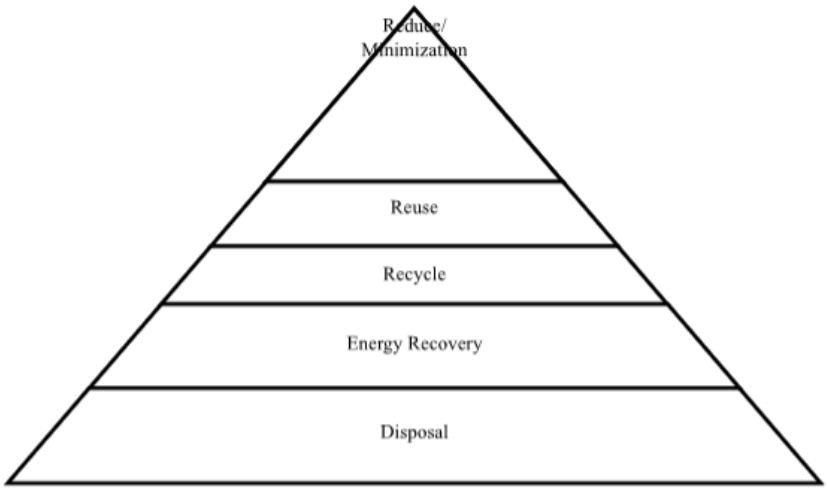

Figure 1. Common waste management practices of some developing countries (Source: Agamuthu & Fauziah, 2014)

The above figure shows that there is a minimum implementation of energy recovery, recycling, reusing and reducing while waste disposal is widely implemented in many developing countries, specifically Asia and Pacific Islands. Waste disposal here generally refers to landfilling (Agamuthu & Fauziah, 2014). In Malaysia, wastes are collected and then transported to designated locations, such as transfer stations, recycling facilities, treatment plants, or landfills for final disposal, as part of the country's solid waste management processes. Waste management issues generally revolve around the interaction among various stages of waste management and its generation, storage, collection, treatment, and disposal (Ekanem et al., 2013).

As landfilling is the main technique of waste disposal in Malaysia, more than 80% of municipal solid waste that is collected being disposed at either inert or unsanitary landfills (Alireza et al., 2016). Among issues associated with landfill are: the generation of methane which has high global warming potential (Ekanem et al., 2013), and the shortening of landfills' life spans due to the increase in solid waste generation (Kinti et al., 2013). With inadequate pollution prevention features including bottom lining, leachate treatment, and gas collecting systems, most disposal sites are still unsanitary landfills (Agamuthu 2014).

Among the advantages of recycling are the potential to lessen adverse environmental effects and challenges associated with the use of incineration technology, as it may lower the moisture content of municipal solid wastes and yield financial gains from recyclable materials (Alireza et al., 2016). Alireza et al. (2016) point out that Malaysia has not yet put in place a workable recycling program for municipal solid waste. According to Agamuthu and Fauziah (2014), the absence of laws and policies is the primary reason why recycling has not yet reached its goal.

Table 1. Recycling rates, Malaysia, 2018 – 2022

	2018	2019	2020	2021	2022
Kadar kitar semula[1] *Recycling rate* (%)	24.60	28.06	30.67	31.52	**33.17**

Source: National Solid Waste Management Department

As a result of Malaysia's continuous efforts to enhance waste management procedures, recycling rates in the country increased gradually but not significantly between 2018 and 2022 as indicated in the above Table 1. The slow pace development, however, raises the question of whether the current approaches are sufficient to produce significant environmental and economic benefits.

To increase recycling rates, Malaysia must optimise its recycling practices. This entails utilising technologies such as artificial intelligence (AI), public awareness initiatives, infrastructure development, policy improvement, and cooperation with local government, relevant industries, and households. By taking these steps, recycling will be encouraged and efficiency will rise. This is in line with the Government's targets to increase productivity in all sectors by 30% by 2030 compared to 2020 levels under the 4IR and MyDigital roadmap, with AI playing a key enabling role (Dzaharuddin Mansor, 2021).

This project aims to investigate the possibility of integrating AI into the household solid waste recycling legal framework in Malaysia in accordance with the ethical norms, sustainability principles and legal considerations.

2) Methods

The methods employed include library research and content analysis of primary and secondary data encompassing statutes, statistics, guidelines, books, journals, reports and online databases. Relevant laws and regulations in Malaysia are examined in order to identify to what extent the current legal framework provides for AI technologies' integration into household solid waste recycling management. Since specific national guidelines on AI use in household solid waste recycling in many countries are still emerging, reference is also made to the projects and collaborations in the United Kingdom and United States on the way they integrate AI into their waste management systems.

3) Findings and Analysis

AI is essential for maximising resource use, reducing waste, and fostering environmental sustainability (Ministry of Science, Technology and Innovation, 2024). The application of AI models in waste management is growing because of their capacity to handle challenging issues. Although actual implementation of AI is still in the research and development phase, it offers an effective solution where traditional methods fall short (Abdallah et al., 2020).

AI facilitates waste sorting, transportation optimisation, and disposal, supporting the notion of smart cities and environmental preservation (Sharma & Vaid, 2021). AI and robotics sorting also could play a big role in producing high-quality secondary raw materials from waste in the future (Wiltz et al., 2021).

By improving sustainability, efficiency, and dependability, AI technologies have the potential to transform the recycling of household solid waste. Nanez Alonso et al. (2021) points out that in addition to significantly raising the overall proportion of recovered material, an autonomous system would also improve the recycling process's dependability. Waste management systems with intelligence that can

distinguish between reusable and non-reusable materials and automatically split materials into distinct categories have a bright future.

Nevertheless, environmental aspects are frequently ignored by current “responsible AI”; guidelines and principles (Galaz et al., 2021). Galaz et al. (2021) advocates for governance systems, in order to effectively integrate sustainability considerations and adjust to changes in technology and the environment. Setting an agenda, addressing risk and risky technologies, and establishing safety rules are some of the recommendations made by Said & Nabilah (2024) that are crucial for sectoral-based governance. The use and effects of AI technologies should be made more understandable by transparent reporting to sectoral leads. This would mean that the sectoral leads should have standardized, excellent transparency reports of the information requested by the regulators and/or civil society (Said & Nabilah, 2024).

In this context also, Roberts et al. (2024) point out that the circular economy offers a sustainable, environmentally friendly alternative to the linear economic model and AI is crucial for designing and maintaining circular products and business models. However, ethical concerns about privacy, equality, and well-being remain unexplored, posing significant challenges for policymakers, industry, and academia.

In sum, while AI has transformative potential in household solid waste recycling, its effective application does need a holistic approach considering both technological advancement and strict governance procedures for issues of sustainability and ethics.

4) Discussions and Recommendations

The integration of artificial intelligence (AI) into environmental monitoring and conservation activities brings about a transformative change and impacts ecological preservation (Choudhary et al., 2023). Hence, AI can notably increase the sustainable recycling of household solid waste by being embedded within the current legal framework and by reducing the legal and ethical challenges linked to the application of AI in environmental management.

Malaysia has not introduced any legislation specifically governing the administration of AI. Under existing legislation in Malaysia, all AI adoption must be done in an ethical manner and with accountability and transparency to protect data privacy and security while minimizing risks and establishing public trust (Ministry of Science, Technology and Innovation, 2024).

As far as recycling is concerned, the relevant law and regulations enforceable in most states in Malaysia include the Solid Waste and Public Cleansing Management Act 2007 (Act 672) and the Solid Waste and Public Cleansing Management (Scheme for Household Solid Waste and Solid Waste similar to Household Solid Waste) Regulations 2011. The current legal framework for household solid waste recycling management in Malaysia does not adequately address the application of AI in specific way. Nevertheless, section 101 (1) (g) of Act 672 among others provides that the Minister may require the use of any method or manner for the purpose of controlled solid waste recycling through an order published in the Gazette. Hence it is proposed that specific policy, law or regulation to encourage and regulate the use of AI in household solid waste recycling management is necessary to optimize household solid waste recycling.

Furthermore, considering that the process of improving policies and laws to accommodate AI integration requires significant amount of time, this project proposes guidelines named “RecycleSmart Guidelines” (the guidelines) in order to guide waste managers, recyclers, and other industry stakeholders in using AI in household solid waste recycling management. The guidelines focus on the potential application of AI in recycling and some considerations for sustainability and ethics. Generally, the guidelines contain the objectives of the guidelines, the benefits of using AI in solid waste management which include enhancing efficiency and accuracy, saving cost, and mitigating

environmental impact by promoting circular economy principles and reducing solid waste sent to landfills.

Besides, the guidelines also contain the information on recycling stages that may use AI such as at the stage of waste collection, sorting and segregation, recycling and processing, as well as monitoring and reporting. Another content of the guidelines is on sustainability principles in AI adoption such as the need to align with the Sustainable Development Goals (SDGs) and circular economy integration which promotes reuse, recycling and waste reduction. Apart from that, the guidelines provide information on the legislations related to solid waste management and recycling in Malaysia.

Most importantly, the relevant stakeholders may get information on the types of AI that could serve different purposes to support the management of household solid waste recycling, for example, predictive analytics for waste generation trends, automated sorting and material recovery systems, and smart waste bins and monitoring systems. Besides, some important information on data privacy, AI ethics and cybersecurity risks is also embedded in the guidelines. The outline of the guidelines is as provided in the following Figure 2.

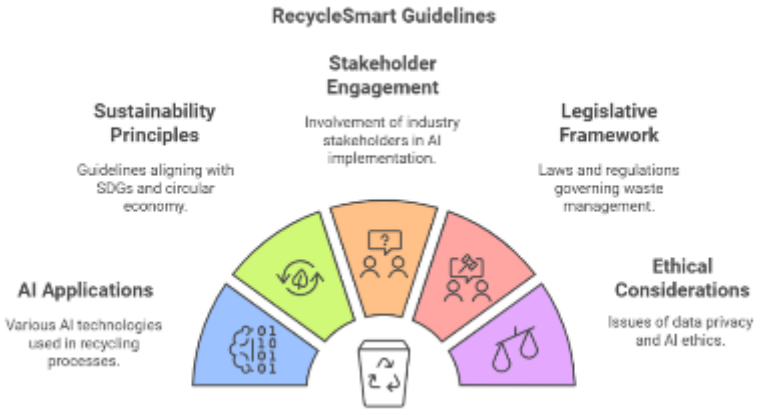

Figure 2. RecycleSmart Guidelines

By integrating AI in the management of household solid waste recycling, the "RecycleSmart Guidelines" introduce a novel pathway to optimise sustainable solid waste recycling which is indicated in terms of the holistic integration of AI in waste recycling, the priority on circular economy and the allignment with Sustainable Development Goals (SDGs), the awareness on the need to address ethical and social concerns in AI adoption, the proposal on specific AI applications for household solid waste recycling, and the promotion on the collaboration between policymakers, waste managers, local authorities, AI developers and households to create a framework for sustainable household solid waste recycling. While encouraging long-term sustainability, these guidelines are especially well-suited to tackling the country's solid waste management issues.

On top of that, by addressing the social, ethical, economic, and environmental aspects of waste management, the "RecycleSmart Guidelines" ensure a sustainable approach in optimizing household solid waste recycling for the benefit of present and future generations of Malaysia by using AI and emphasizing the circular economy that encourages stakeholder collaboration.

5) Conclusion

Solid waste management has been one of the major global environmental concerns contributing to pollution, health problems, and climate change due to greenhouse gas emissions from landfills and incineration. To overcome these challenges effectively in Malaysia, there is an urgent need for the optimization of recycling procedures. AI can totally change how household solid waste is recycled in order to increase its sustainability, dependability, and efficiency. However, in order to handle ethical

and sustainability issues, its implementation needs to be supported by governance frameworks. The proposed "RecycleSmart Guidelines" recognize this need and provide a framework that allows waste managers, recyclers, and other stakeholders to effectively integrate AI into the recycling of household solid waste. These recommendations will address the ethical dimensions in the use of AI while underlining the value of sustainable practices, stakeholder collaboration, and the circular economy. This may contribute to raising recycling rates and enhancing sustainable solid waste management practices.

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AquaLink in HAB Detection: Design of Integrating IoT and PETG 3D Printing for Aquaculture Water Quality and Environmental Monitoring

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Abstract

Harmful Algal Blooms (HABs) are a major threat to aquaculture and environmental health, leading to significant economic and ecological damage. Current water quality monitoring methods, often manual and time-consuming, are insufficient for timely detection of conditions conducive to HAB. To address this issue, the AquaLink system integrates Internet of Things (IoT) technology with 3D-printed Polyethylene Terephthalate Glycol (PETG) enclosures to provide real-time, scalable, and cost-effective water quality monitoring. The system utilizes sensors to measure critical water parameters such as temperature, turbidity, and dissolved oxygen, with data transmitted via Raspberry Pi and ESP32 controllers to an IoT dashboard for real-time visualization and analysis. The methodology combines IoT-enabled sensors with PETG-printed casings for durability and biofouling resistance in aquatic environments. Prototypes were tested in various water bodies to assess performance under real-world conditions. The system successfully provided real-time monitoring of aquaculture environments, allowing early detection of potential HABs through the continuous tracking of environmental parameters. The AquaLink solution contributes to society by offering a low-cost, efficient tool for sustainable aquaculture, minimizing environmental degradation, and enhancing food security by reducing fish mortality. Its adaptability and scalability make it a valuable resource for both small-scale and commercial aquaculture operations, promoting sustainable practices through advanced environmental monitoring.

Keywords: Harmful Algal Blooms, HABs, Internet of Things, Aquaculture, Water Quality, Environmental Monitoring, Raspberry Pi, ESP32, Dashboard, Thingsboard, Real-time Data, Sensor Integration, 3d Printing, PETG.

1) Introduction

The aquaculture industry is the only hope for the growing demand for seafood. Good water quality is one of the important factors that determine the health of the cultured species and, at large, the general productivity of the aquaculture system (Ahmed Alkhamis et al., 2023; Boyd, 2017; Islam et al., 2022; Zhang et al., 2011). Water quality parameters, such as temperature, dissolved oxygen, pH, ammonia, and nitrate, should be within the recommended ranges to prevent diseases in cultured aquatic animals, enhance growth, and promote sustainable aquaculture (Ahmed Alkhamis et al., 2023). Traditional approaches to quality monitoring rely on time-consuming manual sampling and subsequent laboratory analysis [4]. In this regard, real-time monitoring is a considerably faster alternative because it allows farmers to rapidly adapt to changes in the environment (Boyd, 2017; Karal Marx et al., 2020; Zhang et al., 2011).

Harmful Algal Blooms (HAB) are a significant environmental issue that affects both natural ecosystems and aquaculture industries. HAB occurs when colonies of algae, particularly phytoplankton, grow excessively in water, often due to favourable environmental conditions such as nutrient enrichment and elevated water temperatures (Glibert et al., 2018). These blooms can be harmful because certain algae release toxins that are detrimental to aquatic organisms, including fish and shellfish, and can contaminate drinking water and seafood. The economic impact of HAB on aquaculture can be severe, leading to mass fish deaths, habitat degradation, and a reduction in overall water quality (McLean & Sinclair, 2013). Additionally, HAB events can pose serious risks to human health by causing respiratory issues or seafood poisoning through bioaccumulation of toxins (McLean & Sinclair, 2013).

Hence, AquaLink addresses these challenges by integrating IoT sensors and PETG-printed enclosures to create a durable, cost-effective water quality monitoring system. This system tracks key parameters, contributing to early HAB detection and sustainable aquaculture.

2) Methods

To integrate the IoT devices and AquaLink system with 3D-printed PETG enclosures for thorough monitoring of water quality, especially in aquaculture. Such a system will have multiple components, including hardware and software, all working together to get real-time data on critical water quality parameters.

This system integrates advanced sensor technology with cloud-based platforms to monitor and analyse water quality parameters. The core components of the methodology include sensor selection, system architecture, deployment, and data analysis.

2.1 Controllers and Sensor Integration

AquaLink's design involves IoT-enabled sensors housed in PETG casings. The system uses ESP32 microcontrollers for data processing and transmission. ESP32, with built-in Wi-Fi and Bluetooth, provides a low-cost, energy-efficient alternative that simplifies sensor connectivity and cloud communication.

Key sensors include the BME680 for air temperature, humidity, and gas levels, DS18B20 for water temperature, and a Gravity Analog Turbidity Sensor for water clarity. A GPS NEO 6M module tracks the sensor array's location, while an Analog Light Sensor measures ambient light. Prototypes were tested in aquaculture environments (fishpond, aquarium, swimming pool) for seven days to assess performance. Data was visualized on ThingsBoard.

2.2 IoT Architecture and Cloud Integration

The data collected from the sensors is transmitted to ThingsBoard, an open-source IoT platform installed on a Virtual Machine (VM) in Microsoft Azure. ThingsBoard is responsible for data visualization and real-time monitoring, while Azure handles backend processing and storage. Fig. 1 below shows the system architecture, showing the data is processed in the ESP32, and later being visualized on custom dashboards, which display parameters such as water temperature, turbidity, and gas levels. The system architecture ensures real-time data transmission through the REST API provided by ThingsBoard. The dashboard was designed for both user-friendly interaction and real-time tracking of environmental parameters.

ThingsBoard is an open-source IoT platform, used for real-time data visualization in a customizable dashboard. The dashboard allows the user to configure limits and additional alerts if the parameters exceed the set levels. It also performs the function of data logging for further analysis of historical data.

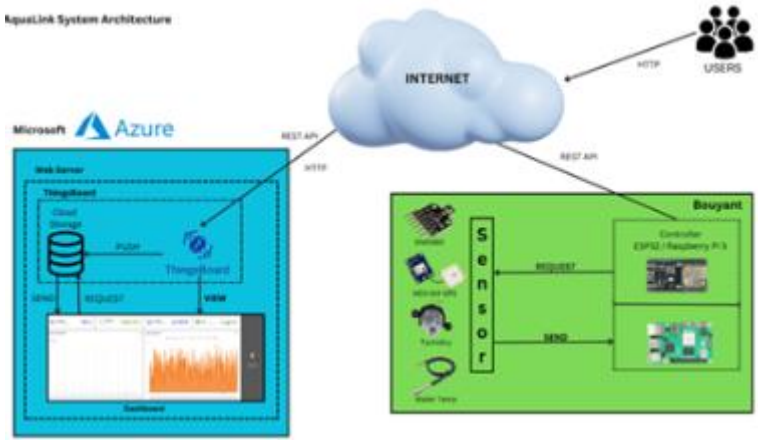


Figure 1. System Architecture of AquaLink

2.3 PETG 3D Printing

Custom PETG sensor housings were designed and printed to protect sensors during submersion (Kalkal et al., 2021). PETG was chosen for its water resistance, mechanical strength, and UV stability, ensuring durability in aquatic environments (Gul et al., 2023). PETG's resistance to chemicals, impact, and temperature fluctuations makes it ideal for prolonged outdoor use, safeguarding sensors from environmental stress and biofouling. The material's non-toxic and FDA-compliant properties ensure safe deployment in aquaculture without affecting water quality or aquatic life (Davies, 2021).

Figure 2. 3D printed AquaLink

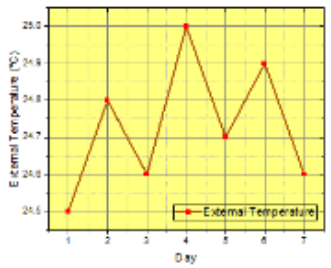
3) Findings and Analysis

ESP32 is preferred due to its low power consumption and reliability. The simplicity of the setup, with native support for analogue sensors, reduced the occurrence of errors. PETG casings ensured sensor protection, reducing maintenance needs. Future enhancements should include integrating machine learning for predictive analytics and additional sensors for direct HAB detection. Expanding AquaLink's capabilities will strengthen its role in sustainable aquaculture.

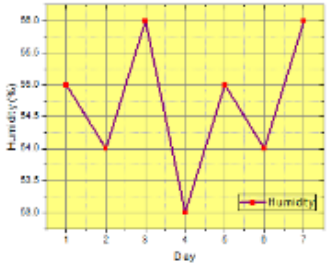
3.1 Prototype Performance

Table 1. Data collected from testing within 7 days.

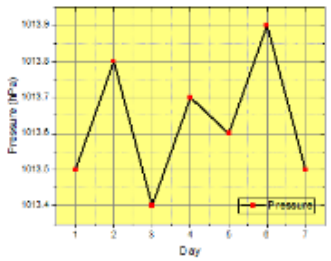
Day	External Temp. (°C)	Humidity (%)	Pressure (hPa)	Turbidity (NTU)	Water Temp. (°C)
1	24.5	55	1013.5	0.9	25.0
2	24.8	54	1013.8	1.0	25.2
3	24.6	56	1013.4	1.1	24.9
4	25.0	53	1013.7	1.2	25.3
5	24.7	55	1013.6	1.1	25.1
6	24.9	54	1013.9	1.0	25.0
7	24.6	56	1013.5	1.1	24.8



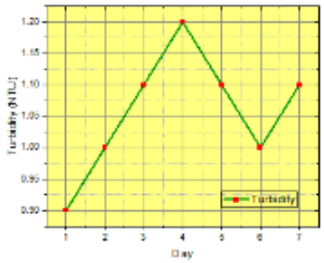
(a) Measured external temperature.



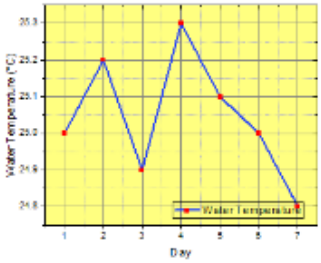
(b) Measured humidity level.



(c) Measured pressure level.



(d) Measured turbidity level.



(e) Measured water temperature.

Figure 3. Plotted graph of the measured results.

3.3 Data Visualization

he integration of ThingsBoard with Microsoft Azure was successful in delivering real-time data visualization. As shown in Figure 4 below, the customized dashboards allowed for effective monitoring of water quality parameters, with graphs displaying trends in water temperature and turbidity over time. The system's ability to process and store large amounts of sensor data in Azure demonstrated scalability for future larger-scale deployments.

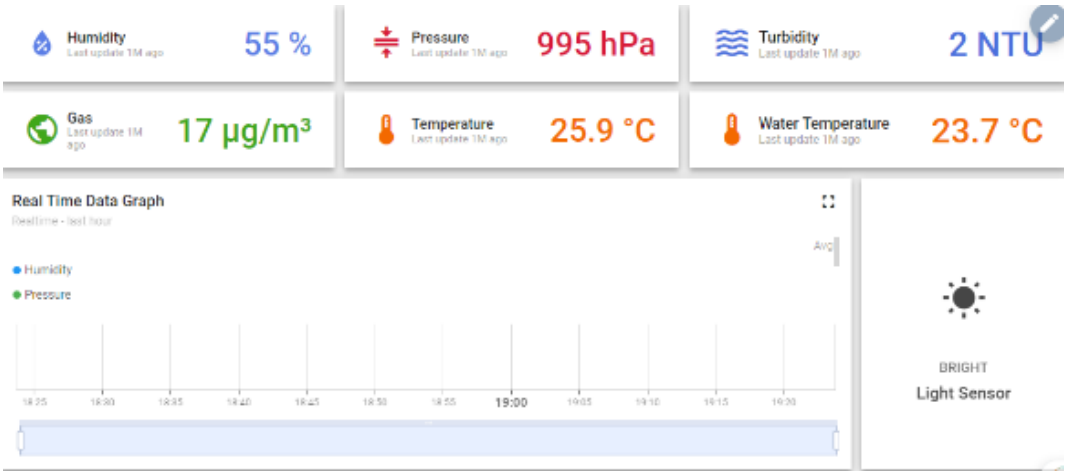


Figure 4. ThingsBoard dashboard showing measured data by the sensors.

4) Conclusion

AquaLink successfully integrates IoT and 3D printing to monitor aquaculture environments, enhancing sustainability by enabling real-time water quality monitoring. The system is scalable, cost-effective, and adaptable, promoting healthier aquaculture practices. Future iterations will focus on expanding predictive capabilities to further mitigate HAB risks.

Acknowledgement

This research was supported by the Fundamental Research Grant Scheme (FRGS24-039-9629). Grateful recognition is extended to the Kulliyyah of Information and Communication Technology (KICT) at the International Islamic University Malaysia (IIUM) and Silverseeds Lab Network for their invaluable resources and contributions.

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IoT-Driven Intelligent Plant Monitoring System for Sustainable Farming

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Abstract

The Intelligent Plant Monitoring System that employs Internet of Things (IoT) technology aims to improve farming methods by automating the oversight and administration of plant health. This system incorporates different sensors such as soil moisture, temperature, humidity, and light sensors to gather real-time information on environmental factors that influence plant growth. The gathered information is sent wirelessly to a cloud server for assessment and display, enabling users to oversee their plants from afar using smartphones or web apps. The system's architecture revolves around a microcontroller, like Arduino or NodeMCU, that connects with sensors to collect vital parameters affecting plant health. This data-centric method allows for accurate irrigation control and efficient resource use, thus encouraging sustainable farming practices. Users get notifications and alerts about their plants' status, allowing for prompt actions when needed. By implementing this system, the Smart Plant Monitoring System helps achieve improved yields while also promoting water conservation by minimizing waste via automated irrigation methods. The incorporation of IoT technology in agriculture represents a pivotal move towards innovative farming methods that are sustainable and effective.

Keywords: Smart Crop Monitoring, Internet of Things (IoT), Sensor Integration, Remote Monitoring, Sustainable Agriculture.

1) Introduction

Modern agriculture faces significant challenges, such as climate change, the need to increase crop productivity, and the efficient management of resources. In this context, technology-based plant monitoring systems offer an effective solution to support improved yields while reducing the risk of crop failure. By utilizing sensors to monitor environmental parameters such as temperature, humidity, soil pH, and light intensity, farmers can gain deeper insights into the conditions affecting their crops' growth.

The primary objective of this research is to develop and implement a smart plant monitoring system based on IoT technology. This system is designed to monitor environmental conditions by utilizing various sensors to measure parameters such as temperature, humidity, soil pH, and other factors. Besides that, it can provide real-time notifications by sending critical information to farmers via a mobile application or web-based dashboard when environmental parameters exceed predetermined thresholds. Also, it enhances resource efficiency by assisting farmers in optimizing air and nutrient management for plants, enabling more effective use of resources.

2) Materials and Resources

Implementation of the smart plant monitoring system based on IoT in the agricultural sector involves several essential materials and resources. These elements play a crucial role in creating an effective monitoring system to enhance crop management, optimize resource utilization, and boost productivity.

1. **Sensors**: Sensors serve as the primary components of IoT-based monitoring systems. These devices collect Real-time data on various environmental parameters that influence plant growth. Commonly used. Sensors include:
   - **Soil moisture sensors**: measure soil water levels to optimize irrigation management.
   - **Temperature and humidity sensors**: monitor atmospheric conditions that impact plant health.
   - **Nutrient sensors**: detect soil nutrient content to support efficient fertilization strategies.
   - **Weather sensors**: track weather patterns such as rainfall and temperature fluctuations that affect crop growth.
2. **Connectivity modules**: To connect sensors with a central platform, various connectivity options are required:
   - **Wi-fi modules**: enable local data transmission to cloud services.
   - **LoRaWAN** (long range wide area network): suitable for long-range communication in rural areas with low power consumption.
   - **Cellular modules**: utilize cellular networks to provide connectivity, ensuring real-time data transmission even in remote locations.
3. **Data processing and analysis tools**: Once data is collected, it must be processed and analysed to generate actionable insights:
   - **Cloud computing platforms**: services such as AWS or Google Cloud are used to store and process large volumes of data gathered from sensors.
   - **Machine learning algorithms**: employed for predictive analysis, helping farmers make informed decisions based on historical data and real-time information.
4. **User interface:** An intuitive interface is crucial to ensure ease of use for farmers when interacting with the monitoring system:
   - **Mobile Applications**: Provide farmers with access to real-time data and immediate notifications via smartphones.
   - **Web Dashboards**: Offer comprehensive visualizations of farm conditions, simplifying crop management from anywhere.
5. **Power resources**: A stable power supply is essential to keep sensors functioning:
   - **Solar Panels**: Provide an eco-friendly energy solution ideal for sensor installation in remote locations.
   - **Batteries**: Ensure continuous operation of sensors in areas without access to electricity.

6. **Drones and Remote Sensing Technology**: Drones equipped with cameras and sensors enhance monitoring capabilities. Multispectral cameras capture data on plant health by analysing light reflection across various wavelengths. Aerial imagery offers a broad perspective on crop conditions over large areas, facilitating efficient monitoring.
7. **Open-Source Software and Hardware:** Leveraging open-source technology reduces costs and increases system flexibility. For example, platforms like Arduino or Raspberry Pi are popular for developing customized sensor solutions. Additionally, open-source IoT frameworks simplify the integration of various components into a cohesive monitoring system.

3) Methods

The research methodology comprises several key steps:

- **Defining Project Objectives**: Identifying the specific goals to be achieved by the monitoring system.
- **Requirements Analysis**: Determining the hardware and software requirements needed for system implementation.
- **System Architecture Design**: Creating a structural design of the system, incorporating all sensor components and IoT platforms.
- **Hardware and Software Development**: Assembling the hardware with appropriate sensors and developing programming code to process the data.
- **System Integration**: Connecting all components to form a fully functional system.
- **Testing and Evaluation**: Conducting tests to ensure the system operates according to the expected specifications.

4) Findings and Analysis

The implementation of Internet of Things (IoT) technology in plant monitoring systems has revolutionized agricultural practices, enabling real-time data collection and automated decision-making. This approach not only helps maintain plant health but also maximizes resource efficiency, particularly water usage.

4.1 Key Components of IoT-Based Plant Monitoring Systems

Various sensors are employed to monitor critical parameters:

- Soil Moisture Sensors: Monitor soil moisture levels to prevent overwatering or water deficiency.
- Temperature and Humidity Sensors: Track environmental conditions that affect plant growth.
- Water Level Sensors: Measure water levels in tanks to support irrigation automation.
- pH and Nutrient Sensors: Analyse soil nutrient content, especially in hydroponic systems.

4.2 Microcontrollers and Communication Modules

- **NodeMCU/Arduino**: These microcontrollers collect data from sensors and transmit it to a cloud platform for further analysis.
- **Wi-Fi Connectivity**: Enables remote monitoring and control through mobile applications or web-based dashboards, allowing users to receive real-time notifications and alerts about plant conditions.
- **Cloud Platforms**: Sensor data is uploaded to cloud services like ThingSpeak or Blynk, facilitating easy access and real-time data analysis. This supports intelligent decision-making based on up-to-date information.

4.3 Functionality and Benefits

- **Automated Irrigation System**: Utilizing soil moisture data, the system can automatically activate water pumps when moisture levels drop below a predefined threshold. This helps conserve water while ensuring plants receive optimal hydration.
- **Real-Time Monitoring**: Users can remotely monitor various plant health parameters through mobile or web applications, enabling quick responses to changing conditions.
- **Data Analysis for Decision Support**: The system analyses historical data to provide recommendations on optimal planting times, irrigation schedules, and more effective nutrient management.

A study on hydroponic melon cultivation revealed that implementing IoT systems effectively managed environmental conditions by integrating various sensors with mobile platforms. This system enabled precise monitoring of nutrient solutions, significantly reducing the risk of crop failure. Similarly, a project leveraging smart plant monitoring systems integrated multiple types of sensors to optimize irrigation management. This system proved to be cost-effective and easy to install, making it an ideal choice for both small-scale and large-scale farming operations.

5) Discussions and Recommendations

The use of IoT in smart plant monitoring systems has garnered widespread attention for its ability to enhance productivity and sustainability in agriculture. These systems integrate advanced sensors, data analytics, and cloud computing to provide real-time information on plant conditions and their surrounding environment.

a) **Enhancing Plant Health:** IoT-based systems enable optimal moisture management through automated irrigation, significantly reducing plant stress and promoting healthier growth. Research indicates that maintaining ideal moisture levels can improve yields while minimizing water waste, particularly in drought-prone areas.
b) **Data Collection and Analysis:** The integration of various sensors allows for comprehensive data collection on parameters such as soil moisture, temperature, humidity, and light intensity. This data is critical for making precise plant care decisions and ensuring efficient resource allocation.
c) **Challenges:** Despite its numerous advantages, several challenges remain. Sensor malfunctions during extreme weather conditions, such as heavy rain, can result in inaccurate readings. Connectivity issues in remote areas also hinder the system's effectiveness.
d) **User Engagement:** The development of user-friendly interfaces, such as mobile applications, enhances engagement by providing real-time alerts and data visualizations. This accessibility empowers farmers to make timely adjustments to their practices.
e) **Recommendations for Future Development**
   - Improving Sensor Reliability: Future smart monitoring systems should incorporate waterproofing measures for outdoor sensors to reduce malfunctions caused by adverse weather. Regular sensor calibration is also essential to ensure accurate data collection.
   - Expanding Connectivity Options: Leveraging alternative communication technologies such as LoRa or satellite networks can enhance connectivity in remote areas with limited access to traditional internet infrastructure.
   - Integrating Advanced Analytics: Utilizing machine learning algorithms for predictive analysis can strengthen decision-making processes by forecasting environmental changes and plant health trends based on historical data.
   - Sustainability Practices: Emphasizing sustainable practices in system design can further reduce resource consumption. For example, integrating nutrient sensors can enable precise fertilizer application, minimizing chemical runoff and supporting sustainable agriculture.
f) **Community Training Programs:** Providing training programs for farmers on effectively using IoT technology can boost adoption rates and maximize the system’s benefits in agricultural practices. By implementing these recommendations, the effectiveness and reliability of IoT-based smart plant monitoring systems can be significantly enhanced, driving more sustainable farming practices and improving crop yields.

6) Conclusion

A successful implementation of Smart Plant Monitoring systems using IoT requires a combination of advanced sensors, reliable connectivity, robust data processing tools, user-friendly interfaces, sustainable power solutions, and innovative technologies like drones. By leveraging these components, farmers can significantly improve their agricultural practices, resulting in increased productivity and resource efficiency. The integration of IoT into smart plant monitoring systems is a significant step forward in agricultural technology. These systems offer real-time data and automation features that enhance plant management while promoting sustainable practices through more efficient resource use. As technology evolves, ongoing innovations are expected to improve the precision and capabilities of these systems, potentially revolutionizing agricultural productivity on a global scale.

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Internet of Things-Based IMAGy Device for Determining Number of Footsteps

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Abstract

This study aims to test the IMAGy device which utilizes an accelerometer sensor to count the number of steps for human health monitoring. The IMAGy module is designed and programmed to record acceleration data on three axes (x, y, z) during walking activity. The data generated by this sensor was wirelessly transmitted via WiFi to a computer and then processed using the Python programming. In data processing, peak detection was performed on the x-axis acceleration component to count steps in real-time. Additionally, spectrum analysis using Fast Fourier Transform (FFT) was applied to identify walking patterns and analyze the dynamic parameters of walking motion. The results demonstrate that the IMAGy device achieved an accuracy rate of 98.45% based on 12 tests involving different step counts (5, 10, 15, up to 100 steps). Data visualization in graph helps users to understand walking patterns, while spectrum analysis provides deeper insights into individual step characteristics. This reliable system shows that the IMAGy device can serve as a potential tool for physical activity and health monitoring, particularly in detecting the footsteps. Furthermore, this technology can be integrated into more advanced portable health devices based on the Internet of Things (IoTs), for supporting sustainable healthcare technology.

Keywords: Accelerometer; MEMS, IMAGy; Footsteps, Health Monitoring

1) Introduction

Health is a crucial part of human needs in life. According to the World Health Organization (WHO), health is a state of physical and mental well-being free from disease and infirmity. (Vishnu et al, 2020). Being in an unstable health condition can affect physical performance, making the adoption of a healthy lifestyle very important for maintaining the body's fitness (Muhtar & Lengkana, 2021). One simple way to support health is by regularly engaging in physical activities such as walking. This activity is known to offer numerous benefits, including improving heart health, burning calories, aiding in weight management, and reducing the risk of chronic diseases such as diabetes (Salma, 2014). One concept that promotes the habit of walking as part of a healthy lifestyle is the "10,000 steps per day" guideline. This concept was first introduced by Dr. Yoshiro Hatano in Japan during the 1960s and has since been endorsed by various global health organizations, including World Health Organization (Haddad, 2015).

To support this initiative, this research was conducted to develop a technology-based system of detecting steps with greater precision by utilizing an accelerometer sensor on the IMAGy module, designed with Internet of Things (IoT) technology. This system is intended to detect the number of footsteps and visualize the data in real-time. The data is also analysed using the Fast Fourier Transform (FFT) method, which is employed to convert data from the time domain to the frequency domain, thereby facilitating the identification of specific frequency patterns in signals generated by the accelerometer sensor (Anggraini et al., 2024). This algorithm is widely used in various fields such as spectrum analysis, audio and optical signal processing, and digital filter design, due to its fast and efficient capability in analysing the frequency components of a signal (Sujio, 2021). This research is expected to enhance the accuracy of step detection and make a significant contribution to promoting walking habits as part of a healthy lifestyle.

2) Materials and Resources

This research utilizes the latest technology based on Micro Electromechanical System (MEMS) dan microcontroller that supports IoT, which is NodeMCU 8266, which we have named IMAGy (IoT-based MEMS for Acceleration and Gyroscope). MEMS is a mechanical sensor packaged in the form of an Integrated Circuit (IC), as a microelectronic device, its main components are made of silicon and are on a micron scale. MEMS are commonly used to measure acceleration, position, or shock. (Shen, 2023). IoT (Internet of Things) is a concept where physical objects, such as electronic devices, are equipped with sensors, software, and internet connectivity to collect and exchange data. IoT is a concept that has the ability to transfer data over the internet without human-to-computer or human-to-human interaction. Everything is already automated through programs (Sawitri, 2023). The benefits gained from the IoT concept include faster, easier, and more efficient work processes (Dewi et al., 2019). The MEMS sensor in this devis is designed to measure acceleration using a 3-axis accelerometer (acceleration sensor) a 3-axis gyroscope (balance controller), thereby encompassing 6 Degrees of Freedom (DOF) within a single Inertial Measurement Unit (IMU) module (Sari et al., 2021).

The sclerometer used in this device offers several advantages, including a compact physical size, affordability, low power consumption, and resistance to noise interference caused by vibration. To support the data collection process, a computer is utilized as a processing and analysis tool. Additionally, calibration was performed using a thermometer to ensure that ambient temperature does not affect sensor performance, as well as a water pass to maintain the sensor's orientation during testing. The raw data were stored in .txt format to facilitate further analysis. In this research, the software employed includes Python, along with libraries such as NumPy, Matplotlib, SciPy, and Pandas for data processing.

3) Methods

This technology is utilized to count the number of steps taken by a person based on acceleration data generated by the accelerometer sensor in the IMAGy module. IMAGy is one of the STEM products from Syiah Kuala University that has been patented. IMAGy uses Micro Electro Mechanical System

(MEMS) and Internet of Things (IoT) technology, allowing the IMAGy module to connect via Wi-Fi so that data can be communicated with a computer and used across multiple devices. The IMAGy module consist of several components, as shown in the following Figure 1.

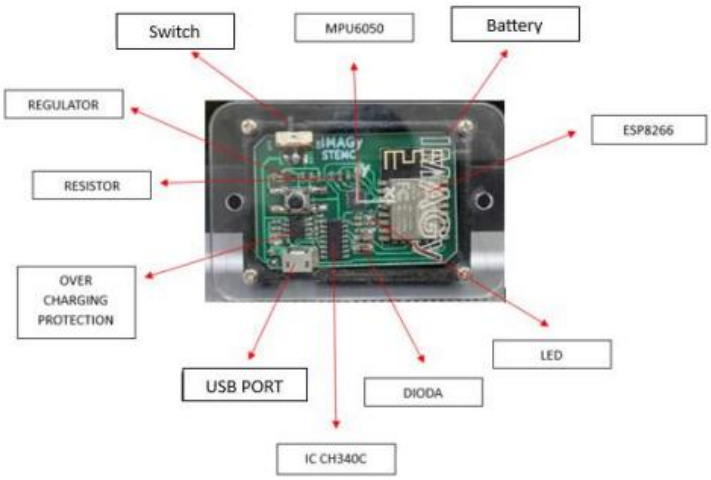

Figure 1. Components of the IMAGy Module.

Data collection of footsteps was carried out by attaching the IMAGy module to the subject's lower limb. The IMAGy module recorded acceleration on the x, y, and z axes generated during walking activities in the form of text strings, as shown in the following Figure 2.

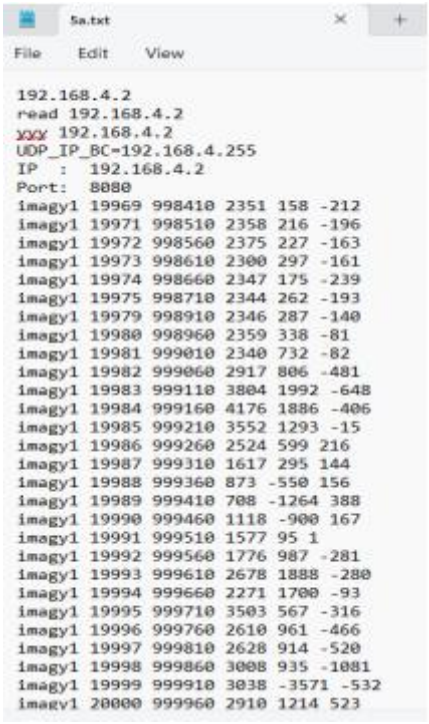

Figure 2. Raw data from the accelerometer sensor.

Based on Figure 2 it can be seen that the data contain several pieces of information in each line, starting with the device name, sequential number, time, acceleration data on the x-axis, acceleration data on the y-axis, and acceleration data on the z-axis. The data were then transmitted to a computer and stored in a text file format (.txt) for further analysis. Data processing was carried out using the Python programming language, which includes data filtering, peak detection, and spectrum analysis using the Fast Fourier Transform (FFT) method. This analysis aims to visualize the frequency distribution of the accelerometer signals, thereby assisting in the identification of more detailed footstep patterns.

The raw data collected were filtered using a low-pass filter technique to reduce noise and to enhance signal quality. Subsequently, peak detection was applied to the acceleration data along the x-axis to count the number of detected steps. The visualization of the step count was displayed in real-time on computer in the form of a graph, allowing for more in-depth analysis for health and physical activity needs. The testing methods on subject is illustrated in the following Figure 3. Figure 3 shows the positioning of the IMAGy module during testing specifically on the lower limb to record acceleration data on the x, y dan z axis while the test subject is stepping (walking).

Figure 3. Testing Methodology for the Device

4) Findings and Analysis

This research demonstrates that, from 12 tests conducted at various step counts (5, 10, 15, and 100 steps), the IMAGy module based on the accelerometer sensor was able to detect steps with an average accuracy of 98.45%, as shown in the following Table 1.

Based on Table 1, the results of the manually counted step numbers and the step numbers detected by the IMAGy module show a small difference, with an average error of 1.55% and accuracy rate of 98.45%. A comparison graph of the manually counted steps and the average step count detected by the IMAGy module can be seen in the following Figure 4.

Table 1. Testing Results and Accuracy

No	Test	Number of Steps		Error (%)	Accuracy (%)
		Manual Count	Device Detection Result		
1	Test 1	5 Steps	5 Steps	0	100
	Test 2	5 Steps	5 Steps	0	100
	Test 3	5 Steps	5 Steps	0	100
2	Test 1	10 Steps	10 Steps	0	100
	Test 2	10 Steps	10 Steps	0	100
	Test 3	10 Steps	10 Steps	0	100
3	Test 1	15 Steps	16 Steps	6.6	93.4
	Test 2	15 Steps	15 Steps	0	100
	Test 3	15 Steps	15 Steps	0	100
4	Test 1	100 Steps	92 Steps	8	92
	Test 2	100 Steps	99 Steps	1	99
	Test 3	100 Steps	97 Steps	3	97
Total				1.55	98.45

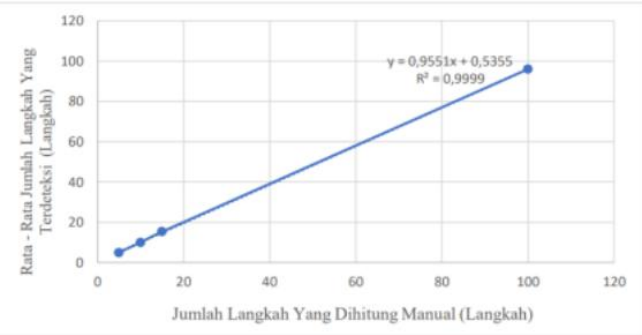

Figure 4. Comparison of the Number of Steps Counted Manually with Those Detected by the IMAGy Module

Figure 4 shows a comparison graph between the number of steps counted manually and the average number of steps detected by the IMAGy module. The resulting linear correlation value is R2 = 0,9999, which is close to 1. This value indicates a very strong correlation between the detection results of the IMAGy module and manual count. Thus, the IMAGy module demonstrates nearly perfect performance in detecting steps, making it effective for monitoring walking physical activity. The visualization of step count data in graph from shows peaks that represent footsteps on x-axis of the accelerometer, as illustrated in the following Figure 5.

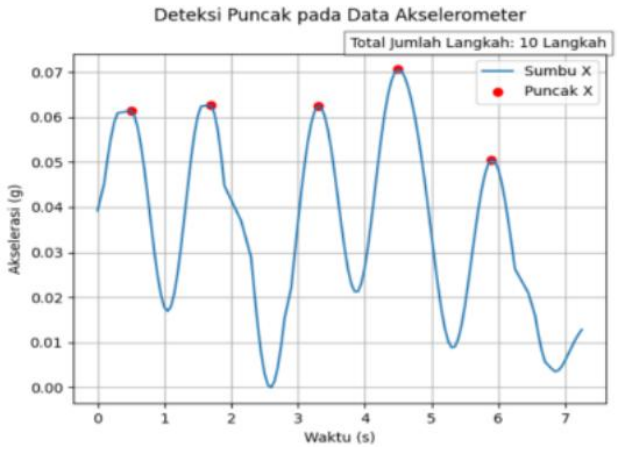

Figure 5. Visualization of the First Test with a Step Count of 5 Steps

Figure 5 shows the results of the first test for 5 steps. This graph displays time in second (x-axis). The fife peaks detected in the graph correspond to the number of steps counted manually, which is five steps. The detected peak points are marked in red of the graph. Peak detection is performed only on the x-axis because the peaks on this axis are more dominant compared to the others. This due to the positioning of the IMAGy module, which is mounted on the user's leg parallel to the x-axis the number of steps is calculated based on the detected peaks. Since IMAGy module only records the movement of the right foot, the numbers of the detected peaks are multiplied by two to obtain the total step count. Therefore, the total number of steps for this test is 10 steps, indicating that this device can be used to monitor physical activity, with the advantage of real-time data accessible via WIFI connection, as well as ease of analysis using Python programs. The combination of high accuracy and in-depth visualization makes the IMAGy module a potential tool for health and fitness applications.

5) Discussions and Recommendations

The research results indicate that IMAGy module has an accuracy rate of 98,45% in detecting steps. However, several challenges were encountered during the research process. One of the main challenges is the presence of noise from the surrounding environment, which can affect measurement results. Although a low-pass filter was used, some disturbances still impacted detection results. Additionally, the positioning of the sensor on the leg also plays a crucial role in the accuracy of step counting. Inconsistent positioning can lead to errors in detection results. Data processing using the Phyton programming language has proven to be very effective in supporting accurate data analysis. However, this process requires relatively large computer equipment, which poses a challenge in developing a portable system that is easy for the general public to use.

This research recommends several steps for further development. First, the step detection algorithm needs to be improved to be more resilient to noise disturbances and adaptive to various walking patterns, such as fast walking or running. Second, additional features such as posture analysis or step speed cloud be developed to provide rig data to users. Third, integrating the system with a smartphone application cloud enhance the convenience and usability of this device. Finally, further research involving boarder population should be conducted to ensure the system's reliability under various physical and environmental conditions. With the results and recommendations provided, this research contributes to the development of technology based on accelerometer sensors, particularly in health and sports applications. The developed system not only demonstrated a high level of accuracy but also opens up opportunities for further development that can provide broader benefits society.

6) Conclusion

This research demonstrates that the IMAGy module, base on accelerometer sensors, is capable of detecting steps with a high accuracy rate averaging 98,45%. The test data shows that the difference between the manually counted steps and the steps detected by the module is very small, with an average error of 1,55%. The linear correlation graph (R2 = 0,9999) reinforces the reliability of this module in detecting steps with nearly perfect consistency. The main advantages of the IMAGy module lie in its ability to process data in real-time, ease of integration with Python programs for analysis, and informative data visualization. This module can also support health and fitness applications, particularly in monitoring walking physical activity.

With reliable performance and features that support analytical needs, the IMAGy module has great potential for further development as and innovative tool for monitoring physical activity. Future research cloud focus on testing under more diverse conditions and integrating with other wearable devices to expand its range of applications.

Acknowledgement

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Dielectrophoresis-based BioMEMS Platform with V-Shaped Microelectrode for Red Blood Cells Collection

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Abstract

Studies related to dielectrophoresis-based microelectrodes have become a support in the development of the bioMEMS platform. Nevertheless, lab on chip microelectrode devices application in broader fields is still a challenge. In this study, a bioMEMS device with a V-shaped microelectrode array was designed for red blood cells (RBCs) collection based on non-uniform electric field distribution which induced dielectrophoresis (DEP) force. Microelectrodes were constructed by combining copper and ITO films, while microchannel was designed between the copper and ITO films using double-tape insulators. RBCs samples were diluted in deionized water mixed EDTA medium with an electrical conductivity of 1.5 S/m. DEP test on RBCs samples was employed by applying a sinusoidal AC signal to V-shaped electrode. The DEP phenomenon was monitored using a CCD camera-microscope. The V-shaped microelectrodes arrays generated spacially the weak and strong intensity of electric field. The electric field gradient was generated by applying voltages of 5 Vpp, 10 Vpp, and 15 Vpp that causes red blood cells to experience the nDEP phenomenon at the frequencies of 5-7 MHz, 3.5-5 MHz, and 2-4 MHz respectively, which causes red blood cells to be pushed towards the weak field away from the inside of the V-shaped electrode. Meanwhile, the pDEP phenomenon was observed at the frequencies of 8-14 MHz, 6-13 MHz, and 5-11 MHz causing red blood cells to be attracted to the strong electric field and collected on the inside of the V-shaped electrode. The results of this study indicate that the V-shaped microelectrode has potential as a bioMEMS devices for bioparticle manipulation. The test samples then can be further analyzed for various diagnostic purposes.

Keywords: V-shaped microelectrode; Dielectrophoresis; Red blood cells; Non-uniform electric field, BioMEMS.

1) Introduction

Biochip is a miniature test device that is often used in the medical field for various bio sample tests. Biochip as a bioMEMS platform comes with mechanical and electrical functions that can be used in biochemical applications (Debnath et al., 2010, and Azizipour et al., 2020). Microelectrodes are generally used in miniature BioMEMS devices to generate electric current so that the device's function as a bioparticle detector can be fulfilled (Khoshmanesh et al., 2011, Buyong et al., 2019). Various electrode geometries have been studied for bioparticle manipulation purposes, one of which is the V-shaped electrode. This electrode has a V-shaped with an angle located on the inside of the electrode (Cheng et al., 2015, Iswardy et al., 2017). The electrode test device combined with microchannels has better performance in bio sample manipulation.

Blood is one of the biosamples that needs to go through the analysis stage to be used in the indication of a disease or prognosis of a patient (Emmerich et al., 2022). In its use as a diagnostic sample, blood can be manipulated using a microelectrode device in a microchannel. Blood samples can be polarized in a non-uniform electric field generated by electrodes. This technique is known as dielectrophoresis (DEP) and has become one of the most widely used bioparticle manipulation techniques due to its high selectivity and sensitivity, low analysis time, and small sample size (Li et al., 2014, Hughes et al., 2016, Zhao et al., 2023). The non-uniform electric field generated by the V-shaped electrode will cause the emergence of dielectrophoresis force (FDEP) which can move blood cells to collect in an area. Thus, the V-shaped electrode can be used in the manipulation of red blood cell samples for collection functions.

Several studies related to the use of V-shaped electrodes based on dielectrophoresis techniques have been conducted previously. One of them is the DEP study conducted by Cheng et al (2012) for ssDNA guidance. In addition, Iswardy et al (2017) also conducted a study on V-shaped electrodes designed with angles of 20^o and 45^o. Testing was carried out by dielectrophoresis for capturing dengue viruses and from the test it was found that the V-shaped electrode could function well in directing bioparticles. This dielectrophoresis-based test is influenced by several factors such as dielectric properties, cell size, electric field frequency, and conductivity of the test sample. These parameters will affect the DEP force generated during the bioparticle manipulation process (Philippin et al., 2018). The DEP force can be expressed as follows.

$$F_{DEP} = 2\pi r^3 \varepsilon_0 \varepsilon_m Re(f_{CM}) \nabla E^2 \quad (1)$$

Based on equation (1), it is known that r is the radius of the particle, Ɛ0 is the vacuum permittivity and Ɛm is the permittivity of the suspension medium, *Re(fCM)* is the real part of the Clausius-Mossitti (*CM*) factor, and ∇E is the electric field gradient. The application of appropriate parameters is needed in dielectrophoresis testing so that the test sample can be manipulated and the DEP phenomenon can be observed. Red blood cell manipulation by dielectrophoresis in this study is intended as an initial stage of the blood analysis process. V-shaped electrodes are designed using copper materials combined with ITO on devices with microchannels used in DEP testing of red blood cells. The DEP phenomenon of the test sample is observed until the DEP force can cause red blood cells to collect in an area of the V-shaped electrode.

2) Materials and Resources

This work began with the fabrication process of V-shaped microelectrodes which was carried out by preparing materials in the form of glass substrates, copper (Cu) films with a thickness of 0.06 mm, indiumtin oxide (ITO) coated glass, oil-based lotion with Diethyltoluamide (DEET) compounds, mica plastic, and coins. For the etching process, 1 M $FeCl_3$ solution was prepared, as well as several liquids for the rinsing process, namely acetone, isopropyl alcohol (IPA), and deionized water. The drying process was carried out using a blower and the channel was built using a double tape insulator with a thickness of 30 μm. In addition, a function generator was also prepared as an AC power source for DEP testing. The test sample used in this study was the diluted whole blood.

3) Methods

The test sample in the form of whole blood was prepared in a container to be diluted with deionized water and EDTA medium. The use of EDTA medium is intended to prevent blood clotting. Dilution was carried out with a ratio of 1:20 and the electrical conductivity of the test sample for the study was 1.5 S/m. The fabrication of V-shaped microelectrodes in this study began with the size design process where the V-Shaped electrode was designed with an angle of 45o and a width of 500 µm. The results of the V-shaped electrode design were then printed using toner ink on A4 paper. The glass and ITO substrates to be used in the study were ensured to be clean and had been rinsed using isopropyl alcohol (IPA) and deionized water. On top of the glass substrate, a copper film as attached to allow the pattern transfer process to be carried out. After the pattern transfer process was completed, the electrode can be moved into an etching solution to remove unnecessary copper layers. This etching process takes ±25-30 minutes. The finished V-shaped electrode can be cleaned using acetone so that the ink from the electrode pattern can be removed. Then the electrode was rinsed again using isopropyl alcohol (IPA) and deionized water to clean electrodes.

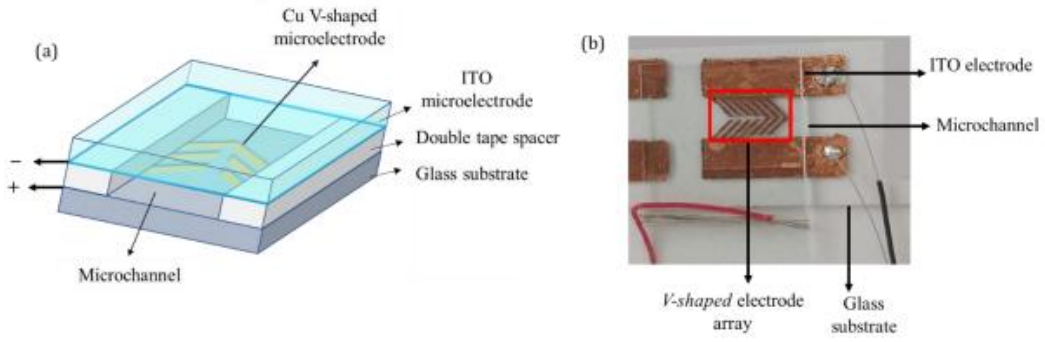

Figure 1. (a) channel construction, and (b) the results of the V-shaped microelectrode fabrication.

The next stage after fabrication was the creation of a channel using a double-sided tape insulator. The channel was built between the Cu electrode and the ITO electrode as shown in Figure 1(a). Each electrode was then wired to connect an AC signal from function generator. Figure 1(b) shows the results of the V-shaped microelectrode fabrication. DEP testing was performed by applying a sinusoidal AC electrical signal through a wire that has been connected to the V-shaped microelectrode. The DEP phenomenon was monitored using a microscope with a CCD camera. Figure 2 shows the arrangement of equipment used in the study during the red blood cells DEP testing process.

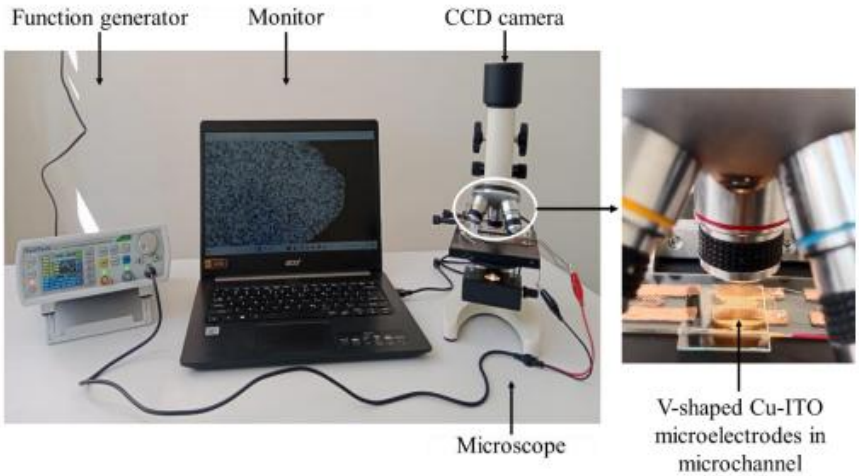

Figure 2. Set up DEP testing equipment

4) Findings and Analysis

4.1 Electric Field Distribution on V-shaped Electrode

The electric field distribution on the V-shaped electrode shows a gradient of strong and weak fields which are marked by differences in colour contours as shown in Figure 3. The area with a strong field is located on the inside of the V-shaped electrode which is marked by a red contour, while the weak field area is marked by a blue contour.

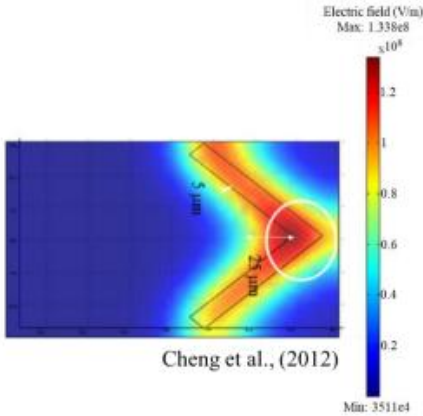

Figure 3. Electric field distribution on V-shaped electrode (Cheng et al., 2012)

Electric field is an important parameter that influences the induction of dielectrophoretic force for bioparticle manipulation. The non-uniform electric field distribution generated by the V-shaped electrode allows bioparticles to be manipulated for collection purposes by utilizing the negative dielectrophoretic force (FnDEP) which can cause bioparticles to be collected on the inside of the V-shaped electrode, namely the area with a strong field. Thus, the V-shaped electrode in the microchannel can be used for bioparticle collection as an initial stage in the test sample analysis process.

4.2 Red Blood Cell DEP Testing

Diluted whole blood with a conductivity of 1.5 S/m was used as a test sample in the dielectrophoresis test on a V-shaped electrode in a microchannel. The test sample used has gone through a validation process aimed at confirming that the sample used is indeed a red blood cell. Figure 4(a) and (b) show red blood cells viewed under a microscope that were used as test samples in this study.

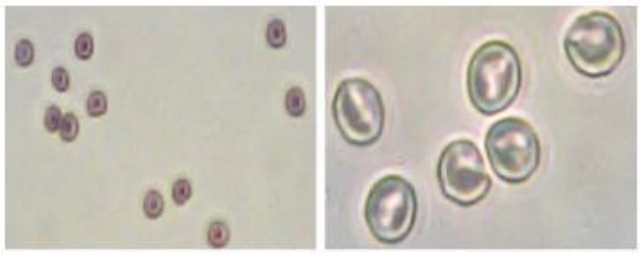

Figure 4. Red blood cells, (a) 100x magnification, and (b) 400x magnification

DEP testing of red blood cells on V-shaped electrodes was carried out by applying a voltage in the form of a sinusoidal AC electrical signal and frequency originating from a function generator at each electrode terminal. DEP testing was observed at three variations in voltage magnitude, namely 5 Vpp, 10 Vpp, and 15 Vpp. The test was carried out by applying the test sample to the V-shaped electrode channel section. The test results with the application of voltages of 5 Vpp, 10 Vpp, and 15 Vpp showed that red blood cells were pushed from the strong field area to the weak field area at frequencies of 5-7 MHz, 3.5-5 MHz, and 2-4 MHz respectively, which this phenomenon can be categorized as a negative phenomenon of nDEP dielectrophoresis as shown in Figure 5.

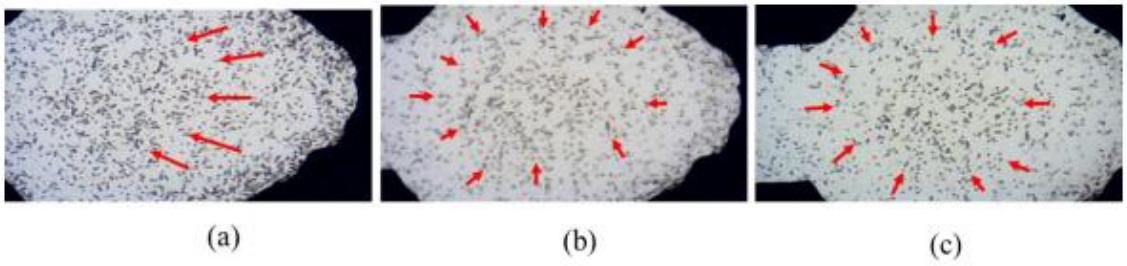

Figure 5. Red blood cell nDEP phenomenon, (a) 5 Vpp, (b) 10 Vpp, and (c) 15 Vpp

The positive dielectrophoresis (pDEP) phenomenon occurs at frequencies of 8-14 MHz, 6-13 MHz, and 5-11 MHz as shown in Figure 6. The pDEP phenomenon will cause red blood cells to be attracted to the strong electric field area, namely the inside of the V-shaped electrode. The DEP phenomenon that occurs is the result of the application of voltage, frequency, and electrical conductivity of the test sample. In addition, the geometric shape of the electrode is also a factor that influences the DEP phenomenon of bioparticles.

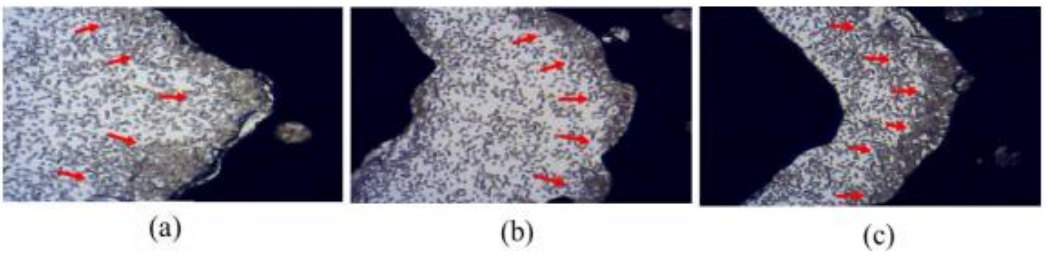

Figure 6. Red blood cell pDEP phenomenon, (a) 5 Vpp, (b) 10 Vpp, dan (c) 15 Vpp

The non-uniform electric field generated by the V-shaped electrode due to the application of voltage causes the emergence of dielectrophoretic forces that can move red blood cells attracted or pushed from the strong field area. The resulting dielectrophoretic force (pDEP/nDEP) can be used in bioparticle manipulation. In addition to the DEP force, changes in particle motion are also influenced by the hydrodynamic force (Fdrag) that occurs in the microchannel. This force causes movement in the liquid so that it can control the movement of particles. The combination of Fdrag and FnDEP can be used for particle collection in DEP testing on V-shaped electrodes. Figure 7 shows Fdrag and FnDEP working on V-shaped electrodes. It can be seen from Figure 7(b) that Fdrag is proportional to FnDEP so that when these two forces work together, they will be able to move red blood cells as illustrated by Figure 7(c).

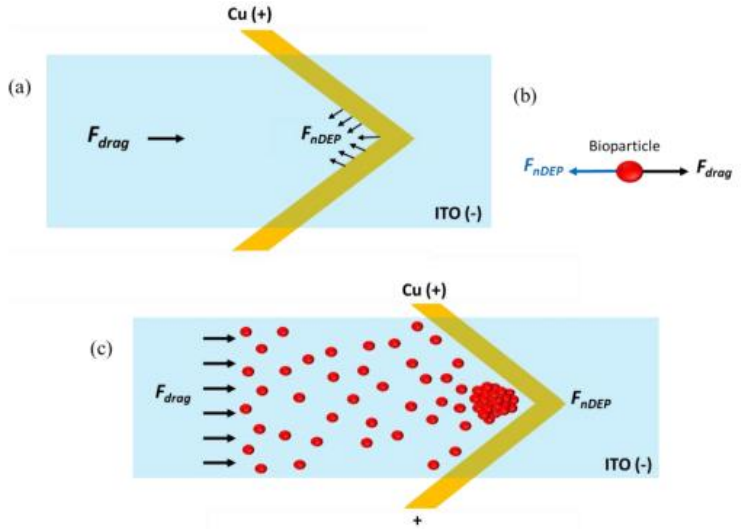

Figure 7. (a) Hydrodynamic forces and nDEP forces on the V-shaped electrode and (b) bioparticles experiencing hydrodynamic forces and nDEP forces

5) Discussions and Recommendations

The study of V-shaped electrodes is intended as an initial study to assess the ability of V-shaped electrodes to be part of the BioMEMS platform. Based on the results of this study, it is known that V-shaped electrodes can fulfil their function as devices that can manipulate bioparticles for the purpose of collecting red blood cells. The geometry of the V-shaped electrode can provide the appropriate DEP force for the needs of red blood cell collection as shown in Figure 7. F_{nDEP} which arises due to the non-uniform electric field generated by the V-shaped electrode will provide a pushing force on the red blood cells with the direction of the force as shown in Figure 7(a). However, at the same time F_{drag} also provides a pushing force on the red blood cells. The opposite pushing force that occurs on the red blood cells is what causes the blood cells to be able to collect in a certain area on the electrode in the microchannel. Thus, the V-shaped electrode used in this study is known to be able to fulfil its function in the bioparticle manipulation stage for the purpose of collecting red blood cells and can be a promising BioMEMS platform for dielectrophoresis-based testing.

6) Conclusion

The V-shaped electrode has a non-uniform electric field distribution where there is a strong field are identified on the inside of the V-shaped electrode and a weak field area identified on the outside of the V-shaped electrode. The results of red blood cell dielectrophoresis tests on the V-shaped Cu-ITO electrode in a microchannel with the application of voltages of 5 Vpp, 10 Vpp, and 15 Vpp showed that the nDEP phenomenon was observed at frequencies of 5-7 MHz, 3.5-5 MHz, and 2-4 MHz, while the pDEP phenomenon was observed at frequencies of 8-14 MHz, 6-13 MHz, and 5-11 MHz. The hydrodynamic force and nDEP force acting on the V-shaped electrode are known to be able to manipulate red blood cells to be collected in a certain area. Thus, the V-shaped electrode is considered to have potential as a BioMEMS platform in dielectrophoresis-based testing for the purpose of collecting red blood cells or other bioparticles.

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