APTISI Transactions on Technopreneurship (ATT)
Vol. 6, No. 3, November 2024, pp. 608−622
E-ISSN: 2656-8888 | P-ISSN: 2655-8807, DOI:10.34306

Smart Attendance in Classroom (CObot): IoT and Facial Recognition for Educational and Entrepreneurial Impact

Ahmad Anwar Zainuddin[1*], Rizal Mohd Nor[2], Dini Handayani[3], Mohd. Izzuddin Mohd. Tamrin[4], Krishnan Subramaniam[5], Siti Fairuz Nurr Sadikan[6]
[1, 2, 3]Department of Computer Science, International Islamic University Malaysia, Malaysia
[4]Department of Information System, International Islamic University Malaysia, Malaysia
[5]Faculty of Mechanical Engineering, Mila University, Malaysia
[6]Department of Agricultural and Biological Engineering Technology, Universiti Teknologi MARA, Malaysia
[1]anwarzain@iium.edu.my, [2]rizalmohdnor@iium.edu.my, [3]dinihandayani@iium.edu.my, [4]izzuddin@iium.edu.my, [5]krishnan.subramaniam@mila.edu.my, [6]fairuznurr@uitm.edu.my
***Corresponding Author**

Article Info

Article history:

Submission September 04, 2024
Revised October 29, 2024
Accepted December 06, 2024
Published December 11, 2024

Keywords:

Smart Attendance System
Facial Recognition
ESP32-S3
Raspberry Pi 5
Internet of Things

ABSTRACT

Current attendance methods, though simple, are prone to manipulation and can be time consuming for both educators and students. For instance, manual systems and QR code based methods allow students to register attendance on behalf of others due to the lack of unique identification. While calling names individually improves security, it disrupts the learning process by consuming significant time. **This study addresses** these issues by developing an autonomous robot, CObot, equipped with a facial recognition system powered by a Raspberry Pi microcontroller. CObot navigates classrooms autonomously, avoiding obstacles, and efficiently records attendance without requiring movement from students or educators. The use of facial recognition ensures that only registered individuals can mark attendance, creating a secure and tamper-proof system. Additionally, the integration of Internet of Things (IoT) technology enables real-time data transfer to Google Sheets, simplifying record-keeping and reducing educators administrative workload. A 3D-printed, customizable car structure enhances the robot design, while the Raspberry Pi 5 was selected over alternatives like the ESP32-S3 for its superior processing power and faster data transfer speeds, ensuring smoother operations. In testing with **60 participants**, the Raspberry Pi 5 demonstrated a 99% accuracy rate in facial recognition, outperforming the ESP32-S3 90% accuracy. By saving time, improving security, and reducing manual effort, CObot enhances the classroom environment, benefiting both students and educators. While the improvement in attendance systems may appear incremental, CObot represents a meaningful step toward fostering a more efficient and effective learning environment.

This is an open access article under the CC BY 4.0 license.

DOI: https://doi.org/10.34306/att.v6i3.497
This is an open-access article under the CC-BY license (https://creativecommons.org/licenses/by/4.0/)
©Authors retain all copyrights

1. INTRODUCTION

Traditional attendance systems in classrooms have, for decades, relied on manual methods such as roll calls, sign-in sheets, or physical registers maintained by instructors. While these approaches are straightforward

and widely used, they come with a host of challenges that undermine their efficiency and reliability. Roll calls consume precious teaching time, often leading to disruptions in the flow of lectures. Sign-in sheets, on the other hand, are not only cumbersome to manage but also prone to issues like illegible handwriting, misplaced records, and the risk of proxy attendance. Such methods are inherently time-intensive and vulnerable to human error, making them less effective in ensuring accurate attendance tracking. Moreover, the manual nature of these systems creates opportunities for manipulation and fraudulent practices, such as students signing in on behalf of absent peers.

Imagine, however, a classroom environment where attendance is tracked effortlessly and in real-time, without requiring any manual intervention from either students or instructors. Picture a system that liberates valuable teaching hours, eliminates the hassle of verifying attendance records, and eradicates the possibility of fraudulent attendance practices. This vision of a seamless and efficient attendance management system is no longer a distant dream but a tangible reality, as evidenced by advancements in smart technologies and their applications in educational settings [1–9].

In this context, our research introduces an innovative and groundbreaking solution a state-of-the-art autonomous system named CObot. This system is designed to revolutionize the way attendance is managed in educational environments. CObot represents a paradigm shift in classroom management by integrating cutting-edge technologies, including 3D printing for its structural design, the Internet of Things (IoT) for real-time data communication, and the advanced computational capabilities of Raspberry Pi 5 for facial recognition and data processing. Unlike traditional attendance methods that interrupt the learning process with manual roll calls or semi-automated systems that require direct interaction such as scanning QR codes, tapping RFID cards, or using smartphone applications CObot operates independently and autonomously, ensuring a seamless experience for both educators and students [10–14].

Even modern digital systems are not without their flaws. Errors in QR code scanning, manipulation of RFID cards, or technical glitches in smartphone-based systems often compromise their reliability. Additionally, these methods are still susceptible to fraudulent practices, such as students exchanging QR codes or RFID cards. CObot addresses these shortcomings by offering a fully autonomous functionality that eliminates such risks entirely. It provides a secure, efficient, and tamper-proof solution to attendance tracking, redefining what is possible in the realm of educational technology.

CObot addresses **research gaps** identified in previous studies. By eliminating manual intervention entirely, it removes risks associated with proxy attendance and user errors, issues commonly reported in systems such as QR-based or RFID-based methods. Its integration of advanced facial recognition algorithms, combined with autonomous navigation capabilities, overcomes the environmental limitations of earlier biometric systems. Furthermore, the IoT-enabled real-time data synchronization ensures that attendance records are tamper-proof and instantly accessible, addressing reliability concerns highlighted in prior research [7, 8].

CObot aligns with **Sustainable Development Goal 4** (Quality Education) by automating attendance tracking, reducing administrative tasks, and enabling educators to focus more on teaching. This ensures accurate attendance monitoring, promoting consistent student participation and better learning outcomes. It also supports **Sustainable Development Goal 9** (Industry, Innovation, and Infrastructure) by utilizing advanced IoT solutions and autonomous technology to modernize educational systems. With facial recognition and cloud-based synchronization, CObot demonstrates how innovation can enhance infrastructure and drive progress in education [15]. By addressing these goals, CObot enhances education quality while showcasing the transformative role of technology in shaping modern learning environments. Through its contributions to both SDG 4 and SDG 9, CObot represents a forward-thinking solution that not only enhances the quality of education but also underscores the importance of innovation in shaping the future of learning environments.

This paper is organized as follows: Section 1. introduces the concept and objectives of implementing a smart attendance system, highlighting the need for innovation in this domain. Section 2. reviews the existing literature on smart attendance technologies and autonomous vehicle development, providing a foundation for understanding the significance of this research. Section 3. details the methodology employed in designing and developing CObot, offering insights into the technical and design processes. Section 4. presents the results and analysis, showcasing the system performance and advantages over traditional methods. Section 4.4. discusses the broader implications of the findings, emphasizing the transformative potential of CObot in educational and other contexts. Finally, Section 6. concludes the paper by summarizing the key contributions of this research and outlining potential directions for future work.

2. LITERATURE REVIEW

Research on facial recognition systems continues to evolve for various applications, such as attendance tracking, security, and autonomous vehicle control. Relevant literature highlights different research designs, tools used, achieved results, and limitations faced in each study.

Table 1. Extracting Information from the Literature Review

Ref	Research Design	Equipment	Important Findings	Limitations of Study	Research Gap
[16]	The system uses facial recognition to track attendance by capturing, comparing, and updating student records online.	Embedded devices, camera, cloud server, and pre-trained algorithm achieve 89% accuracy with 82ms recognition speed per face.	The facial recognition system for automated attendance in classrooms achieves an accuracy of 89%. The recognition speed is 82ms per face.	The study does not include environmental factors such as lighting conditions and angles of view that might affect the reliability of the data.	The study evaluates facial recognition for attendance but doesn't address challenges in integrating with IoT for real-time data or scalability in large classrooms.
[17]	This variable assesses students perception of the face recognition system effectiveness in replacing traditional attendance methods.	Camera, OpenCV library	A comparative analysis of different facial recognition methods, each verifying faces using a pre-uploaded picture.	Some camera models might perform well in powerful environments but struggle in resource-constrained environments.	The study does not examine how environmental conditions, such as poor lighting or face obstructions (e.g., masks or spectacles), affect recognition accuracy.
[18]	It discusses using deep learning techniques like LBPH algorithm and Haar Cascade classifier to analyze and verify the identity.	Raspberry Pi, Webcam, OpenCV library	It compares attendance methods and finds facial recognition most effective, using a Raspberry Pi to capture and compare facial images with a database.	The document mentions that the system did not train on a large amount of data and had a lower accuracy rate for classifying faces.	The system does not consider integrating advanced facial recognition algorithms with edge computing devices for improved real-time processing.
[19]	Building a prototype autonomous vehicle system using Raspberry Pi and computer vision algorithms.	Raspberry Pi, Camera module, OpenCV library, Excel sheet	The system uses Raspberry Pi and computer vision to improve car safety.	Sensor accuracy and reliability affect autonomous vehicle performance.	The study emphasizes autonomous vehicles but neglects attendance tracking, creating a gap in understanding cost, accuracy, and usability in education.

The Table 1 below summarizes key findings from the related literature, including research design, equipment used, main findings, study limitations, and identified research gaps. This analysis aims to identify opportunities for further development in integrating facial recognition technology with smart and IoT-based systems.

3. METHODOLOGY

The controller plays an important role in this work. It is comparable to the function of the brain for humans. Therefore, the selection of the controller can be crucial for the work so that CObot can operate at its best level. In this case, ESP32-S3 and Raspberry Pi 5 are initially chosen to be the best fits in this work. These two controllers both have different hardware specifications, and the direct comparison can be seen the topologies depicted in Figure 1 and Figure 2.

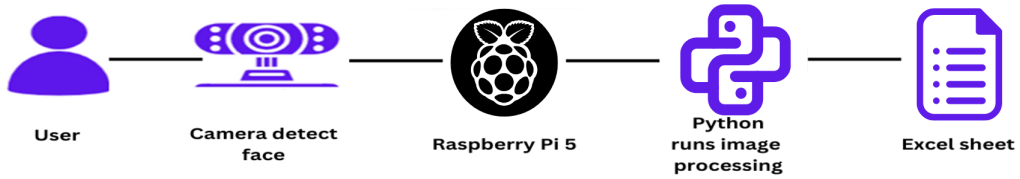


Figure 1. Topology of CObot when using Raspberry Pi

Figure 1 presents the topology of the CObot system, showcasing its configuration when utilizing the Raspberry Pi microcontroller as its core processing unit. This topology diagram provides a detailed overview of the interconnected components that enable CObot to function autonomously and effectively. The Raspberry Pi serves as the central hub, orchestrating various subsystems, including the facial recognition module, motor control unit, IoT connectivity, and obstacle detection sensors.

The facial recognition module, powered by the Raspberry Pi robust processing capabilities, captures high-resolution images through an integrated camera. These images are processed in real-time using advanced algorithms to identify individuals accurately [20]. Once the identity is confirmed, the IoT system immediately transmits the attendance data to a cloud-based Google Sheet for secure storage and accessibility.

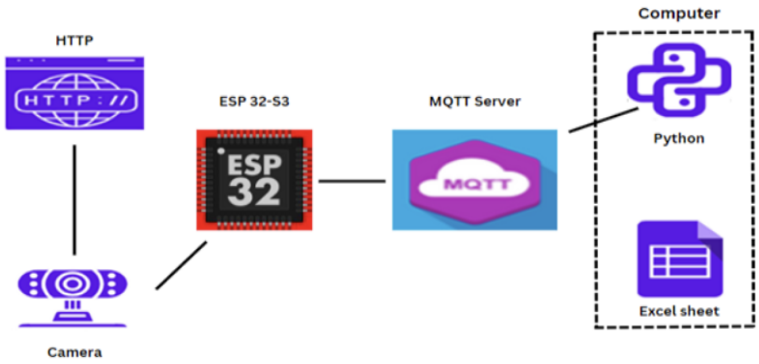


Figure 2. Topology of CObot when using ESP32-S3

Figure 2 illustrates the topology of the CObot system when utilizing the ESP32-S3 microcontroller as its primary processing unit. This topology highlights the interconnections between the various components that enable CObot to function effectively, with the ESP32-S3 serving as the central controller for managing its operations. While the ESP32-S3 is known for its efficient processing and wireless communication capabilities, its implementation in CObot introduces certain trade-offs compared to the Raspberry Pi-based system.

The facial recognition module, integrated with the ESP32-S3, processes image data captured by a connected camera. Although the ESP32-S3 provides sufficient computational power for facial recognition tasks, its performance is slightly constrained compared to the Raspberry Pi, which impacts the speed and accuracy of image processing. Nevertheless, the system is capable of identifying individuals and recording their attendance with a reasonable degree of accuracy. The captured attendance data is then transmitted via Wi-Fi to cloud-based storage platforms, such as Google Sheets, using the ESP32-S3 robust IoT connectivity features. This ensures that attendance records remain accessible and securely stored.

Explaining research chronological, including research design, research procedure (in the form of algorithms, Pseudocode or other), how to test and data acquisition. The description of the course of research should

be supported references, so the explanation can be accepted scientifically. Tables and Figures are presented center, as shown below and cited in the manuscript.

3.1. Printing Development

In the development process, each plan is considered thoroughly, including the assembly of the robot car. The body is designed using Fusion 360, a robust CAD (Computer-Aided Design) software, known for its user-friendly interface and powerful modeling capabilities. Fusion 360 was chosen for this project because it offers advanced features like parametric modeling, which ensures precise dimensions and allows for easy design modifications. Additionally, its integration with 3D printing workflows simplifies the export process for slicing and printing. The final design, which is both functional and efficient, is shown in Figure 3 below. The figure clearly shows that there are three main structures, each depicted in Figure 3 (a), 3(b), and 3(c). These structures have unique functions: (a) acts as a camera holder, (b) stores the Raspberry Pi 5 and the power supply, and (c) serves as the base structure for the robot car.

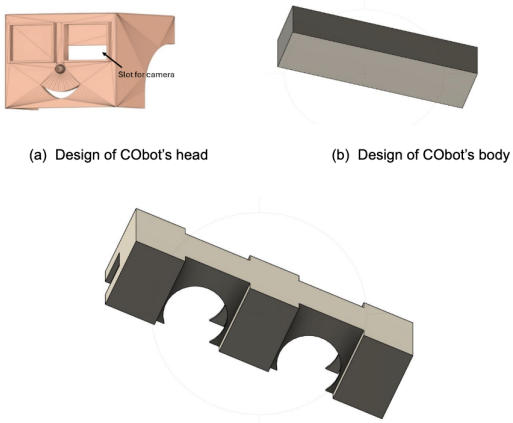


Figure 3. Design of CObot structure

The methodology uses 3D printing for its cost-effectiveness, flexibility in design, and ability to produce prototypes quickly. This allowed for iterative testing and modifications to optimize CObot structure without significant delays or costs. However, one obvious limitation of 3D printing is the size constraint, as the printer bed cannot accommodate large designs in a single print. To address this, the car structure was divided into three modular parts, which were later assembled seamlessly to ensure robustness and functionality

3.2. Block and Schematic Diagram

The design depicted in Figure 4 and Figure 5 is optimized to ensure efficient integration and communication between the hardware components of autonomous car for CObot. Figure 4 showcases the block diagram with a modular approach, where each components is interconnected through a central controller. This modularity facilitates scalability and simplifies troubleshooting. Similarly, the schematic diagram in Figure 5 highlights the physical connectivity and logical flow between the components, ensuring seamless data transmission.

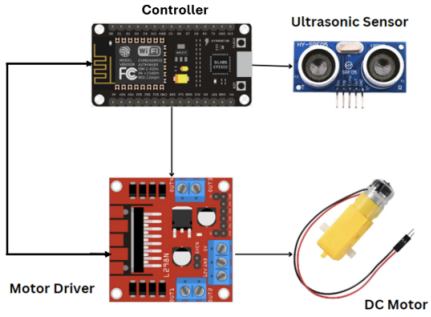


Figure 4. Topology of CObot when using Raspberry Pi

The central placement of the Raspberry Pi 5 allows for low-latency communication with the camera and motors, crucial for real-time operations like facial recognition and obstacle avoidance. This design aligns with best practices in autonomous system architecture, where centralization reduces delays and ensures synchronized control across multiple subsystems. Figure 5 illustrates the schematic diagram of the autonomous car (CObot), detailing the intricate interconnections and relationships among its key components. This diagram provides a comprehensive view of the hardware architecture, showcasing how the various modules work together to enable the autonomous navigation and attendance tracking functionalities of CObot.

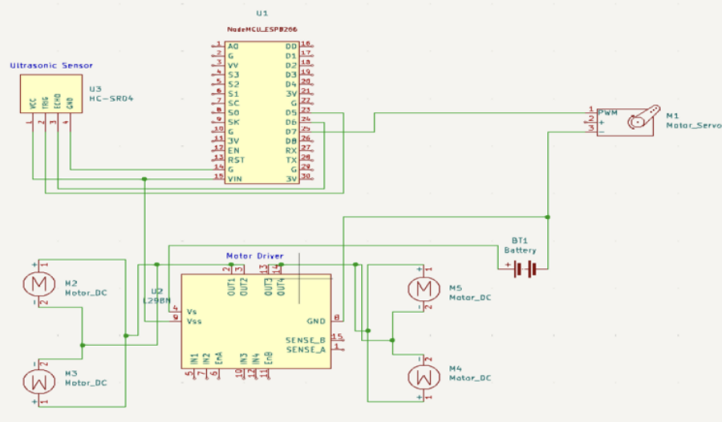


Figure 5. Autonomous car schematic diagram

Furthermore, studies have shown that modular and centralized designs enhance system performance and simplify future upgrades, as highlighted by Nguyen in their exploration of IoT-based systems [16].

3.3. Controller Performance Comparison

As mentioned earlier, the controller is the most crucial component in CObot. Both the Raspberry Pi 5 and ESP32-S3 utilize different architectures to operate CObot, resulting in significant differences in output. While the ESP32-S3 is designed for low-power applications, its limited processing power and memory make it less suited for complex tasks like real-time facial recognition. In contrast, the Raspberry Pi 5, with its quad-core processor and 8 GB RAM, offers superior computational capabilities, enabling faster and more accurate image processing [17, 18, 21]. A detailed comparison of the performance metrics of both controllers is provided in the results section.

4. RESULT AND DISCUSSION

4.1. Comparison of ESP32-S3 and Raspberry Pi 5 in Image Processing

Table 2 illustrates the Raspberry Pi 5 significantly outperforms the ESP32-S3 in terms of processing speed for facial recognition. For instance, processing 60 images takes approximately 73 minutes longer on the ESP32-S3. This substantial difference highlights the Raspberry Pi 5 superior processing power for the autonomous attendance system. A performance test between both controllers is conducted, and 60 participants joined the trial. In the trial, the ESP32-S3 achieves around 90% accuracy rate whereas Raspberry Pi 5 managed to get a 99% accuracy rate. Consequently, Raspberry Pi 5 is faster but also more accurate and secure in image processing for facial recognition.

Table 2. Running times for ESP32-S3 and Raspberry Pi 5 under different subject loads.

Number of Subject Load	ESP32-S3 Running Time (Minutes)	Raspberry Pi 5 Running Time (Minutes)
30	0:45.81	0:4.14
40	0:54.60	0:5.31
50	1:13.27	0:7.04
60	1:20.33	0:7.34

Figure 6 and Figure 7 demonstrate the successful implementation of the facial recognition system, where the identities of various individuals are accurately captured and verified using both the Raspberry Pi 5

and ESP32-S3 microcontrollers. In these figures, the system showcases its ability to identify individuals by capturing their facial images, processing the data, and matching it against a pre-registered database. Once the identification is confirmed, the system displays the corresponding name of the individual on a screen or LED matrix positioned in front of them. This immediate visual feedback allows both the identified individual and nearby observers to quickly verify the system accuracy. By doing so, the system not only ensures correct attendance tracking but also facilitates real-time interaction, creating a more dynamic and engaging classroom environment.

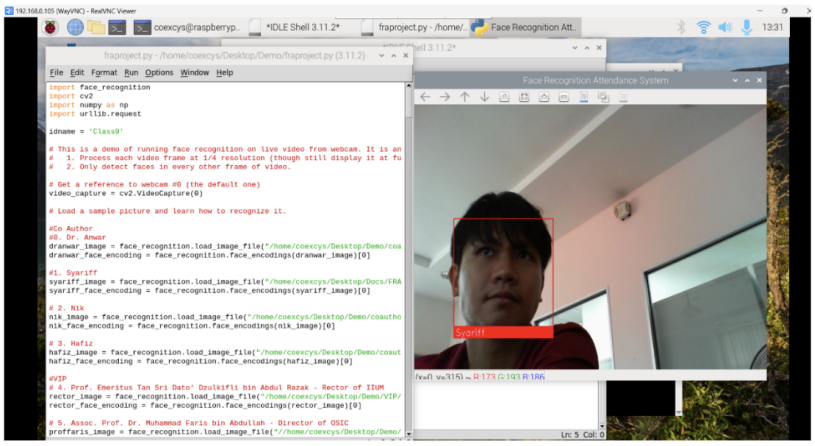


Figure 6. Face identification and the individual name is displayed correctly in front of them using Raspberry Pi 5m

Figure 7 demonstrates the functionality of CObot facial recognition system, where the ESP32-S3 microcontroller accurately identifies individuals and displays their names in front of them. This feature represents a critical aspect of CObot attendance tracking mechanism, showcasing how the system integrates real-time image processing and user-friendly interaction to enhance classroom experiences.

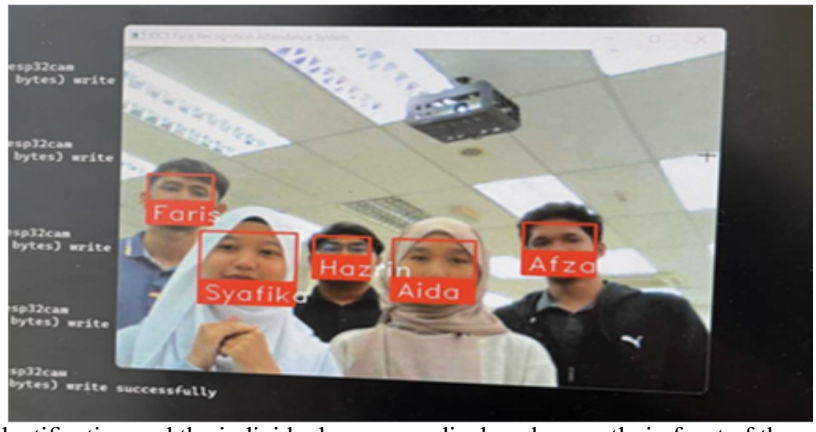
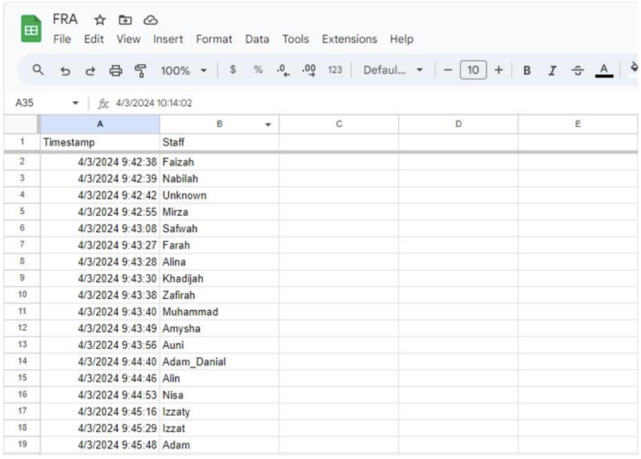


Figure 7. Face identification and the individual name are displayed correctly in front of them using ESP32-S3

After the system successfully identifies a person identity using its advanced facial recognition technology, it leverages an Internet of Things (IoT) system to record the individual details into a cloud-based sheet, such as Google Sheets. This automated data transfer occurs in real time, ensuring that the attendance records are instantly updated and securely stored. These cloud sheets serve as comprehensive attendance logs that educators can access anytime and from any location with an internet connection.

Figure 8 and Figure 9 illustrate the process of data recording in both Google Sheets and Microsoft Excel, respectively. These figures showcase how the attendance data captured by CObot is seamlessly transferred to cloud-based platforms through its IoT integration. In Figure 8, Google Sheets is highlighted as the primary tool for real-time data synchronization, offering a convenient and efficient way for educators to access

attendance records. Google Sheets provides features like automatic updates, version control, and easy sharing, ensuring that attendance information is always accurate and accessible.



FRA

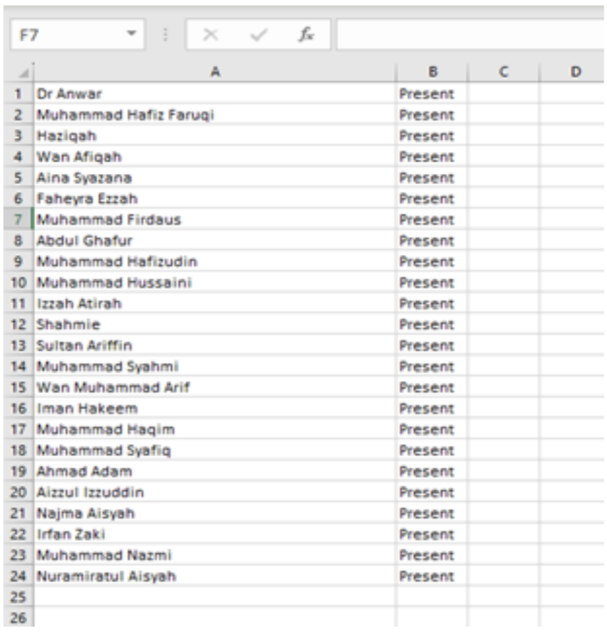
File Edit View Insert Format Data Tools Extensions Help

A35 4/3/2024 10:14:02

	A	B	C	D	E
1	Timestamp	Staff			
2	4/3/2024 9:42:38	Faizah			
3	4/3/2024 9:42:39	Nabilah			
4	4/3/2024 9:42:42	Unknown			
5	4/3/2024 9:42:55	Mirza			
6	4/3/2024 9:43:08	Safwah			
7	4/3/2024 9:43:27	Farah			
8	4/3/2024 9:43:28	Alina			
9	4/3/2024 9:43:30	Khadijah			
10	4/3/2024 9:43:38	Zafirah			
11	4/3/2024 9:43:40	Muhammad			
12	4/3/2024 9:43:49	Amysha			
13	4/3/2024 9:43:56	Auni			
14	4/3/2024 9:44:40	Adam_Danial			
15	4/3/2024 9:44:46	Alin			
16	4/3/2024 9:44:53	Nisa			
17	4/3/2024 9:45:16	Izzaty			
18	4/3/2024 9:45:29	Izzat			
19	4/3/2024 9:45:48	Adam			

Figure 8. Raspberry Pi 5 register in the attendance Google Sheets.

In Figure 9, Microsoft Excel is presented as an alternative platform for storing and reviewing attendance data. While Google Sheets offers cloud-based flexibility, Microsoft Excel is often preferred for its advanced data analysis and reporting capabilities. The system ability to export attendance records to Excel further enhances the usability of the platform, allowing educators to conduct in-depth analysis, generate reports, and integrate the data with other administrative systems.



F7

	A	B	C	D
1	Dr Anwar	Present		
2	Muhammad Hafiz Faruqi	Present		
3	Haziqah	Present		
4	Wan Afiqah	Present		
5	Aina Syazana	Present		
6	Faheyra Ezzah	Present		
7	Muhammad Firdaus	Present		
8	Abdul Ghafur	Present		
9	Muhammad Hafizudin	Present		
10	Muhammad Hussaini	Present		
11	Izzah Atirah	Present		
12	Shahmie	Present		
13	Sultan Ariffin	Present		
14	Muhammad Syahmi	Present		
15	Wan Muhammad Arif	Present		
16	Iman Hakeem	Present		
17	Muhammad Haqim	Present		
18	Muhammad Syafiq	Present		
19	Ahmad Adam	Present		
20	Aizzul Izzuddin	Present		
21	Najma Aisyah	Present		
22	Irfan Zaki	Present		
23	Muhammad Nazmi	Present		
24	Nuramiratul Aisyah	Present		
25				
26				

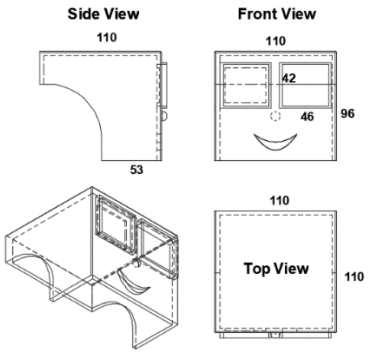
Figure 9. Isometric view and measurement of the car structure .

A performance test between both controllers is conducted, and 60 participants joined the trial. In the trial, the ESP32-S3 achieves around 90% accuracy rate whereas Raspberry Pi 5 managed to get a 99% accuracy rate. Consequently, Raspberry Pi 5 is faster but also more accurate and secure in image processing for facial recognition.

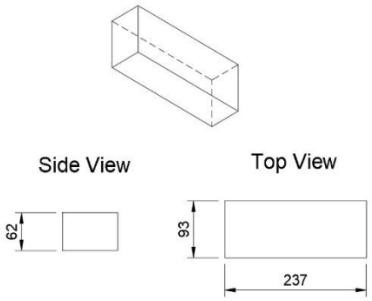
4.2. Result of 3D printed structures

For the first part, the 3D printing technique is used to produce the structure for the autonomous car. As can be seen in the result, the structure is easily customized by creating different colors and shapes as needed

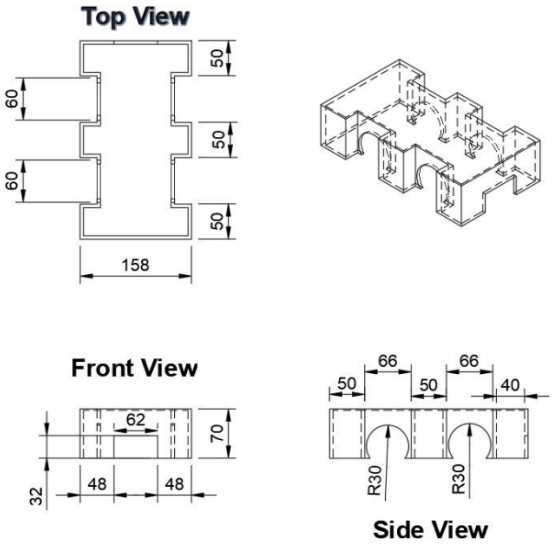
for the research. These advantages are the result of using a 3D printer. The 3D printer which is Bambu Lab P1P comes with remarkable features such as auto bed leveling, slicing features, and filament detection which distinguish this 3D printer from others. As highlighted in Figure 10, those are the measurements and isometric views of the autonomous car structure. The autonomous car structure can be divided into three parts, which are 10(a) – the head, which holds the camera, 10(b) – the body, which stores the controller and power supply and 10(c) – the base, which holds the Cobot and prevent it from falling apart. Therefore these measurements and the isometric view will help in visualizing and understanding each structure for future reference.



a) Measurement of the head in mm



b) Measurement of the body in mm



c) Measurement of the base in mm

Figure 10. Complete structute of Cobot.

From the design that is illustrated, a complete structure of the autonomous car can be printed as can be seen in Figure 11. The figure illustrates the complete structure of CObot, showcasing its modular design divided into three main parts: Part A, Part B, and Part C. This modularity ensures flexibility, structural stability, and ease of assembly.

Part A is the head, this section holds the camera, which is crucial for capturing facial images for recognition. Its elevated position ensures an optimal field of view, enabling accurate image acquisition across different angles in the classroom. Next, part B which is the body. This part houses the controller (Raspberry Pi 5) and the power supply, serving as the central hub for processing and data management. The compact and

enclosed design protects the sensitive components from external damage. Finally, part C is the base. This part acts as the foundation to support the entire CObot structure. It ensures stability and prevents the robot from toppling during navigation. The base also incorporates the motor mechanisms for movement and obstacle avoidance.

Figure 11. Complete structute of Cobot.

The modular nature of the design facilitates maintenance and allows for easy upgrades or replacements of individual parts, contributing to the scalability and versatility of CObot.

4.3. System Performance Analysis

The differences in performance between the ESP32-S3 and the Raspberry Pi 5 are primarily due to their distinct architectural designs, as summarized in the Table 3. The ESP32-S3, as a microcontroller, is optimized for low-power IoT applications, but its dual-core processor and limited memory result in slower processing speeds and lower accuracy for real-time facial recognition. In contrast, the Raspberry Pi 5 functions as a mini-PC with a quad-core processor and 8 GB RAM, enabling it to handle computationally intensive tasks with ease.

Table 3. Comparative Analysis of Raspberry Pi 5 and ESP32-S3 Performance.

Metric	**Raspberry Pi 5**	**ESP32-S3**
Processor	Quad-core 1.8 GHz	Dual-core 240 MHz
RAM	8 GB	512 KB
Accuracy Rate (%)	99	90
Average Processing Time (seconds/image)	0.07	1.33

For instance, the Raspberry Pi 5 achieves a 99% facial recognition accuracy rate with a processing time of 0.07 seconds per image, compared to the ESP32-S3 90% accuracy rate and 1.33 seconds per image. This performance disparity underscores the significance of hardware capabilities in ensuring real-time efficiency and accuracy [19, 22].

Studies by [23] and [17] have similarly highlighted the advantages of using high-performance hardware like Raspberry Pi for computationally intensive tasks, particularly in IoT and facial recognition systems [24]. These studies emphasize that while microcontrollers are cost-effective and energy-efficient, their limitations in processing power make them less suitable for high-speed and high-accuracy applications.

In this work, it is observed that the Raspberry Pi 5 consistently outperformed the ESP32-S3 in key performance metrics. These metrics included accuracy rates and processing times, as illustrated in Table 3. The Raspberry Pi 5 achieved a 99% accuracy rate in facial recognition and processed images at an average time of 0.07 seconds per image, whereas the ESP32-S3 achieved only a 90% accuracy rate with a processing time of 1.33 seconds per image. These results indicate that the Raspberry Pi 5 is better equipped to handle the complex computations required for real-time facial recognition. Table 3 Comparative Analysis of Raspberry Pi 5 and ESP32-S3 Performance.

In Figure 12, the processing times for performance tests with varying numbers of students are clearly depicted, offering a detailed comparison between the two controllers. As the number of students increases, the processing time for the ESP32-S3 shows a near-linear increase, meaning that the system processing time grows steadily as more individuals are added to the attendance database. This trend reflects the limited processing power of the ESP32-S3, which, although efficient for smaller tasks, faces challenges as the dataset grows in size, requiring more time to handle the increased load.

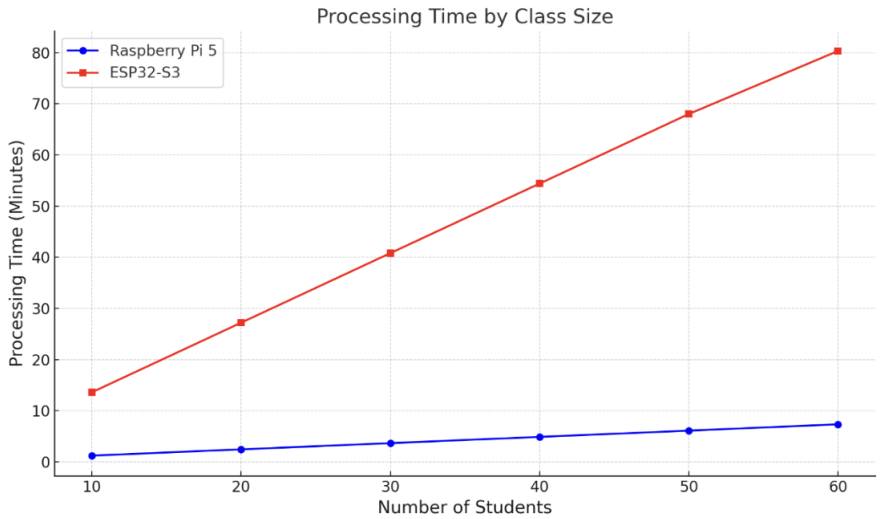


Figure 12. Complete structute of Cobot.

The analysis in this work demonstrated that the Raspberry Pi 5, with its capabilities as a mini-PC, outperformed the ESP32-S3 microcontroller in both accuracy and processing speed. The architectural limitations of the ESP32-S3 contributed to its inability to manage large datasets or execute complex facial recognition tasks efficiently. Furthermore, the Raspberry Pi 5 exhibited resilience under diverse conditions, including variations in lighting and facial occlusions, which are critical factors for real-world deployment.

As for facial recognition, it manages to play its role in capturing student attendance and supplying the information for cloud storage. It captures the facial of the student while matching it with the pre-uploaded picture of the students in the program. Therefore, if the facial matches, the name of the student will be displayed and recorded in the cloud as proof of attendance. This may eliminate elements of manipulation in the attendance sheet as the only way for the attendance to be recorded is by having the camera record individual faces [25–28]. Since it is an operating pre-trained learning machine, it will only compare the facial structure of the individual from its data. Therefore, it can misinterpret the individual who has a similar facial structure.

Choosing the best-fit platform can be tricky because it depends on the system needs. For this work, it requires a direct and powerful processor. The processing speed of the platform does not only focus on uploading data, but it also analyses and makes decisions for the robot system. By conducting the comparison, it does not only prove that Raspberry Pi can upload data better, but it also can help identify the individual face on facial recognition faster than ESP32-S3 [29, 30].

4.4. Discussion

3D printing was chosen as the primary method for producing the autonomous car structure due to its cost-effectiveness and flexibility [31–33]. This technique allows rapid prototyping, enabling the production of test models in a short time while offering the ability to adjust material properties to suit specific design requirements. Flexibility in creation provides more choices when producing the structure. For example, it is easy to produce a prototype for testing in a short period and it is also able to manipulate the material properties which are used. The important factors that lead to these advantages are time efficiency and the customization function of the 3D printer. Flexibility of user experience is where it gives the user the ability to use the printer anytime and anywhere through the printer application. So, it ensures that the user does not need to be there physically and monitor the printer. But there are a few limitations that arise such as the limited size of objects that can be printed. Therefore, if the work dimension exceeds the limit of the printer, an adjustment needs to be made to the structure and extra time needed to complete the whole printing process.

Future research could explore the development of more sophisticated algorithms for facial recognition to improve performance in diverse environments, such as varying lighting conditions or crowded spaces. Additionally, the scalability of CObot design and functionality could be examined to accommodate larger venues or integrate additional features, such as thermal imaging for health monitoring or voice recognition for interactive capabilities. These advancements would further solidify CObot position as a versatile and innovative solution

across various domains.

4.4.1. Scalabilty and Limitation

Scalability has been enhanced by exploring the integration of CObot with Learning Management Systems (LMS), allowing seamless deployment across diverse educational environments, such as larger classrooms, lecture halls, or even multiple institutions. This potential integration extends beyond Google Sheets, enabling compatibility with dedicated attendance tools or synchronization with existing systems. For example, Malaysia School Intelligent Attendance Management System (SIAMS), which employs RFID technology for automated recording and reporting, offers a relevant use case. Similarly, CObot could integrate with the Ministry of Education Student Database application, widely used in schools to manage attendance digitally via facial recognition systems. Beyond classroom attendance, CObot design can be adapted for use in large-scale events, such as conferences or exhibitions, where automated attendance tracking is critical. Additionally, its autonomous navigation and facial recognition capabilities can enhance security features, enabling its use for restricted area access or visitor management in corporate settings

The system performance was rigorously tested under diverse classroom conditions, including varying lighting levels, facial angles, and student positioning. While the Raspberry Pi 5 demonstrated high accuracy (99%), certain limitations were observed. For instance, misidentifications occurred under conditions of facial occlusion, such as when students wore spectacles or face masks. These challenges highlight the need for further enhancements to the facial recognition algorithm and the inclusion of additional sensors to improve reliability. Expanding the training dataset to include diverse scenarios and facial accessories would further increase the robustness of the system.

4.4.2. Broader Impacts and Relevance

compared to the use of similar IoT and facial recognition systems in other industries. For instance, in corporate security, facial recognition technology is extensively utilized for access control, ensuring that only authorized personnel can enter restricted areas. This parallels CObot role in classrooms, where it verifies attendance by identifying registered students, thereby reducing the likelihood of fraudulent entries.

Similarly, in healthcare, IoT-enabled systems streamline patient management by automating check-ins and utilizing facial recognition to identify returning patients. These innovations minimize administrative workloads and enhance operational efficiency. In a comparable manner, CObot automates attendance tracking and integrates data with external systems, presenting itself as a scalable solution to improve workflow efficiency across various sectors.

These parallels highlight the potential for CObot to transcend its initial purpose in educational environments, offering transformative impacts in broader operational and technological contexts. Incorporating examples or case studies from these domains strengthens the argument for its significance in engineering and technology, demonstrating how innovations in one field can inspire and inform advancements in others.

4.4.3. Sustainable Development Goals

CObot aligns closely with two key Sustainable Development Goals (SDGs), demonstrating its broader societal and technological impact. Firstly, in relation to SDG 4 (Quality Education), CObot addresses challenges in educational efficiency by automating the attendance process. This innovation minimizes the administrative workload for educators, allowing them to focus more on teaching and improving the overall learning environment. By offering a reliable and accurate attendance solution, particularly for large classrooms or institutions with limited resources, CObot contributes to creating an inclusive and equitable educational system that supports effective learning outcomes.

In terms of SDG 9 (Industry, Innovation, and Infrastructure), CObot ilustrates how cutting-edge technologies like IoT and robotics can drive technological progress. Its scalable and cost-effective design makes it adaptable for various educational contexts, including resource-constrained regions, thus supporting the development of robust and sustainable infrastructure. Furthermore, CObot integration of innovative solutions into classroom management highlights its potential to inspire further advancements in educational technology, fostering a culture of innovation while bridging technological gaps between different regions.

5. MANAGERIAL IMPLICATIONS

The research on CObot, a smart attendance system using IoT and facial recognition technology, offers significant managerial implications for both educational institutions and entrepreneurs. First, CObot enhances

operational efficiency by automating the attendance process, saving valuable time for educators. This time can then be redirected towards teaching and student engagement, improving the overall learning experience. Traditional attendance methods are often time-consuming and prone to manipulation, but CObot ensures a more secure system by utilizing facial recognition, eliminating fraudulent practices like proxy attendance. This feature provides educational managers with a reliable and secure way to track student participation, ensuring the integrity of attendance records.

The study also highlights the scalability of the system, with two microcontrollers ESP32 S3 and Raspberry Pi 5 offering different levels of performance. The ESP32 S3 is suitable for smaller classrooms, while the Raspberry Pi 5 is better suited for larger environments with more data processing needs. This scalability allows managers to choose the appropriate solution based on their institution requirements, ensuring an adaptable and cost effective system. Additionally, the use of 3D printing for customizable car structures and the integration of IoT for cloud-based attendance data management represents an innovative, cost-effective solution for schools and universities. By automating attendance and reducing administrative burdens, educational institutions can save on costs like paper usage and manual record-keeping, while enhancing data security and accessibility.

From a data-driven perspective, CObot provides real-time attendance data that can be accessed and analyzed by educators and administrators. This enables better tracking of student participation and allows managers to identify trends like absenteeism, enabling proactive measures to improve student engagement and retention. The system ability to integrate with cloud platforms like Google Sheets further enhances data accessibility and management, making it easier for educators to keep accurate records. For entrepreneurs in the EdTech sector, CObot presents an opportunity to develop innovative solutions for educational institutions, tapping into the growing demand for more efficient and secure administrative tools. Beyond education, the technology could also be applied to corporate training environments, conferences, or large events, creating new business opportunities.

6. CONCLUSION

This research proposes a new smart attendance system utilizing CObot, a mobile robot built with a 3D-printed car structure. CObot leverages facial recognition technology powered by a Raspberry Pi 5 to automatically analyze student images and record attendance. This innovative system addresses the limitations of traditional attendance methods, such as time consumption, manipulability, and disruption to the learning flow. By automating attendance processes, CObot frees up valuable teaching time for educators and eliminates the need for manual checks and recordkeeping. Furthermore, facial recognition minimizes the possibility of attendance manipulation compared to traditional methods. Overall, this work presents a significant advancement in classroom attendance systems, offering a secure, time-saving, and user-friendly solution for both educators and students.

The evaluation of CObot performance could be expanded to include a more detailed analysis of its system metrics. For instance, exploring the factors behind the Raspberry Pi 5 superior accuracy rates (99%) compared to the ESP32-S3 would offer valuable insights into hardware efficacy and system optimization. Specific comparisons in terms of processing power, algorithm compatibility, and environmental adaptability would further substantiate the discussion on performance.

Additionally, incorporating alternative methods for assessing user satisfaction and ease of use such as user surveys, observational studies, or focus groups would provide a comprehensive understanding of the system impact. These evaluations could explore the usability of the interface, the adaptability of the system to various classroom scenarios, and the overall satisfaction of educators and students with the automated attendance process. By expanding on these aspects, this research would offer a more holistic view of CObot effectiveness and potential scalability, reinforcing its significance as an innovative solution in educational technology.

7. DECLARATIONS

7.1. About Authors

Ahmad Anwar Zainuddin (AA) https://orcid.org/0000-0001-6822-0075

Rizal Mohd Nor (RM) https://orcid.org/0000-0002-8994-2234

Dini Handayani (DH) https://orcid.org/0000-0002-1544-0688
Mohd. Izzuddin Mohd. Tamrin (MI) https://orcid.org/0000-0003-1397-8174
Krishnan Handayani (KS) https://orcid.org/0000-0002-3838-1131
Siti Fairuz Nurr Sadikan (SF) https://orcid.org/0000-0002-8893-0178

7.2. Author Contributions

Conceptualization: AA; Methodology: RM; Software: DH; Validation: MI and KS; Formal Analysis: SF and MI; Investigation: RM; Resources: SF; Data Curation: KS; Writing Original Draft Preparation: RM and DH; Writing Review and Editing: MI and KS; Visualization: SF; All authors, AA, RM, DH, MI, and KS, have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

7.4. Funding

This work is funded by Kulliyyah of Information and Communication Technology (KICT) and conducted in collaboration with the Centre of Excellence for Cyber Security (CoExCyS), the Kulliyyah of Information and Communication Technology, and the Silverseeds Lab Network.

7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

REFERENCES

[1] N. Nordin and N. H. M. Fauzi, "A web-based mobile attendance system with facial recognition feature," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 14, no. 05, p. 193, April 2020.

[2] A. S. Alon, "A yolov3 inference approach for student attendance face recognition system," *International Journal of Emerging Trends in Engineering Research (IJETER)*, vol. 8, no. 2, pp. 384–390, February 2020.

[3] S. C. Hoo and H. Ibrahim, "Biometric-based attendance tracking system for education sectors: A literature survey on hardware requirements," *Journal of Sensors*, vol. 2019, pp. 1–25, September 2019.

[4] A. Puckdeevongs, N. K. Tripathi, A. Witayangkurn, and P. Saengudomlert, "Classroom attendance systems based on bluetooth low energy indoor positioning technology for smart campus," *Information*, vol. 11, no. 6, p. 329, June 2020.

[5] M. Zhao, G. Zhao, and M. Qu, "College smart classroom attendance management system based on internet of things," *Computational Intelligence and Neuroscience*, vol. 2022, pp. 1–9, July 2022.

[6] S. N. Shah and A. Abuzneid, "Iot based smart attendance system (sas) using rfid," in *2019 IEEE Long Island Systems, Applications and Technology Conference (LISAT)*. IEEE, May 2019, pp. 1–6.

[7] H. E. Mrabet and A. A. Moussa, "Iot-school attendance system using rfid technology," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 14, no. 14, p. 95, August 2020.

[8] D. S. Radhakrishnan, "Machine learning biometric system using viola jones algorithm," *International Journal for Research in Applied Science and Engineering Technology (IJRASET)*, vol. 11, no. 5, pp. 5209–5211, May 2023.

[9] K. Sanath, K. Meenakshi, M. Rajan, V. Balamurugan, and M. Harikumar, "Rfid and face recognition based smart attendance system," in *2021 5th International Conference on Computing Methodologies and Communication (ICCMC)*. IEEE, 2021, pp. 492–499.

[10] A. A. Z. et al., "Integration of car rental system with mobile app management and iot for optimised resources and safety in iium," in *THE 1ST INTERNATIONAL CONFERENCE ON ADVANCED COMPUTING, SYSTEMS, AND APPLICATIONS (InCASA) 2023*. AIP Publishing, 2024, p. 030001.

[11] A. A. Zainuddin, R. M. Nor, A. A. A. Hussin, and M. N. M. Sazali, "Mqtt-enabled smart door access system: Design and implementation using nodemcu esp 8266 and hivemq," in *2023 IEEE 9th International Conference on Computing, Engineering and Design (ICCED)*. Kuala Lumpur, Malaysia: IEEE, Nov 2023, pp. 1–6.

[12] A. A. Zainuddin, N. F. Omar, N. N. Zakaria, and N. A. M. Camara, "Privacy-preserving techniques for iot data in 6g networks with blockchain integration: A review," *IJPCC*, vol. 9, no. 2, pp. 80–92, Jul 2023.
[13] A. A. Zainuddin *et al.*, "Recent trends of integration of blockchain technology with the iot by analysing the networking systems: Future research prospects," *JKMP*, vol. 23, no. 1, Dec 2023.
[14] A. A. B. A. Hussin, H. S. B. H. Muzammil, M. A. A. B. Shaharuddin, A. R. B. Ismail, and A. A. B. Zainuddin, "Utilizing different edge detection and preprocessing techniques to improve the accuracy of durian cultivar detection using convolutional neural networks," in *2023 IEEE 9th International Conference on Computing, Engineering and Design (ICCED)*. IEEE, November 2023, pp. 1–6.
[15] Badan Perencanaan Pembangunan Nasional (Bappenas), "Tujuan pembangunan berkelanjutan (sustainable development goals)," 2024, accessed: 2024-11-07. [Online]. Available: https://sdgs.bappenas.go.id/
[16] D. D. Nguyen, X. H. Nguyen, T. T. Than, and M. S. Nguyen, "Automated attendance system in the classroom using artificial intelligence and internet of things technology," in *2021 8th NAFOSTED Conference on Information and Computer Science (NICS)*. IEEE, 2021, pp. 531–536.
[17] P. D. Mishra, "A comparative study of face recognition models for smart attendance," *IJRASET*, vol. 11, no. 5, pp. 6666–6670, May 2023.
[18] A. Kumar, V. Indragandhi, A. Chitra, R. PauL, and S. Banerjee, "Smart attendance management system using raspberry pi and deep learning technique," in *Proceedings of the First International Conference on Combinatorial and Optimization, ICCAP 2021, December 7-8 2021, Chennai, India*, 2021.
[19] U. R. Ughade, S. M. Gikwad, A. N. Yeole, and D. A. O. Mulani, "Automatic attendance system using face recognition," *JIPIRS*, no. 34, pp. 11–18, Jul 2023.
[20] M. H. R. Chakim, S.-C. Chen, C. Nas, R. Supriati, and G. P. Cesna, "Integration of iot and blockchain technologies for enhancing transparency and efficiency in indonesian agriculture," in *2024 3rd International Conference on Creative Communication and Innovative Technology (ICCIT)*. IEEE, 2024, pp. 1–6.
[21] M. M. Sari, S. Pranata, V. D. Sulaiman *et al.*, "Innovative economic development in developing countries through ai and tackling globalization," in *2024 3rd International Conference on Creative Communication and Innovative Technology (ICCIT)*. IEEE, 2024, pp. 1–6.
[22] D. P. Hausherr and D. Berben, "(all-in-one) power supply system for mobile and network-wired raspberry pi-based internet of things applications," *Hardware*, vol. 1, no. 1, pp. 54–69, Dec 2023.
[23] F. Azmi, A. Saleh, and A. Ridwan, "Smart management attendance system with facial recognition using computer vision techniques on the raspberry pi," *IJIRCST*, vol. 11, no. 1, pp. 38–44, Jan 2023.
[24] K. Alhanaee, M. Alhammadi, N. Almenhali, and M. Shatnawi, "Face recognition smart attendance system using deep transfer learning," *Procedia Computer Science*, vol. 192, pp. 4093–4102, 2021.
[25] S. Sawhney, K. Kacker, S. Jain, S. N. Singh, and R. Garg, "Real-time smart attendance system using face recognition techniques," in *2019 9th International Conference on Cloud Computing, Data Science & Engineering (Confluence)*. Noida, India: IEEE, Jan 2019, pp. 522–525.
[26] T.-V. Dang, "Smart attendance system based on improved facial recognition," *Journal of Robotics and Control*, vol. 4, no. 1, pp. 46–53, Feb 2023.
[27] A. Yadav *et al.*, "Smart attendance system using face recognition," *SSRN Journal*, 2024.
[28] N. Rathour *et al.*, "Iomt based facial emotion recognition system using deep convolution neural networks," *Electronics*, vol. 10, no. 11, p. 1289, May 2021.
[29] W. Zhang, H. Liu, X. Zhang, X. Li, G. Zhang, and P. Cao, "3d printed micro-electrochemical energy storage devices: From design to integration," *Adv Funct Materials*, vol. 31, no. 40, p. 2104909, Oct 2021.
[30] Q. Chen, J. Zhao, J. Ren, L. Rong, P. Cao, and R. C. Advincula, "3d printed multifunctional, hyperelastic silicone rubber foam," *Adv Funct Materials*, vol. 29, no. 23, p. 1900469, Jun 2019.
[31] P. M. Cogswell, M. A. Rischall, A. E. Alexander, H. J. Dickens, G. Lanzino, and J. M. Morris, "Intracranial vasculature 3d printing: review of techniques and manufacturing processes to inform clinical practice," *3D Print Med*, vol. 6, no. 1, p. 18, Dec 2020.
[32] M. Tavafoghi *et al.*, "Multimaterial bioprinting and combination of processing techniques towards the fabrication of biomimetic tissues and organs," *Biofabrication*, vol. 13, no. 4, p. 042002, Oct 2021.
[33] C. Li, F. Bu, Q. Wang, and X. Liu, "Recent developments of inkjet-printed flexible energy storage devices," *Adv Materials Inter*, vol. 9, no. 34, p. 2201051, Dec 2022.