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Development of a Fingerprint-Based Attendance Monitoring System

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***Abstract:** This paper presents the design and execution process of a fingerprint-based attendance system at Bells University of Technology for Electrical/Electronics Engineering Department, to enhance the accuracy and efficiency of student attendance monitoring. Traditional methods often suffer from errors, are tedious, and capable of being manipulated. The developed system employs fingerprint (biometric) technology, offering a secure, dependable, and tamper-proof solution to these issues. By capturing and verifying students' fingerprints, the system makes sure that only the appropriate individual marks the attendance, effectively eliminating problems like impersonation. The system consists of two modes namely: register and record modes respectively. Firstly, fingerprint data was extracted and stored in a database. For attendance taking, after a user's fingerprint is placed on the device, checks for similarity is done in connection with the database and the user is marked as present if a match is found. Thereafter, the information is uploaded. With the proposed system, the time taken per student to mark attendance was 6.16 seconds while for the manual method, it was 22.25 seconds per person. The fingerprint-based system streamlines attendance management by automating the recording process, thus saving time for both students and lecturers. It enhances data accuracy by removing the potential for human error and provides a reliable method for maintaining and retrieving attendance records. Additionally, the system offers improved data security, as biometric data is less likely to be compromised compared to the manual method.*

***Keywords:** Fingerprint-based, Biometric, Attendance Monitoring, Manual Method, Database*

1. INTRODUCTION

The need to precisely track people's presence in a place at any given time for future reference led to the development of this system. Attendance is the acknowledgment of people who show up in a particular place at a specified time for a planned event. Effective attendance record management is essential for student evaluation. Educational institutions highly prioritize class attendance, and students who fails to meet the required attendance threshold are often barred from taking examinations. Conventional attendance procedures are laborious for both students and instructors and are subject to human error. Other defects include but not limited to loss of past records, impersonation, loss of time and inaccuracy [1-5]. Thus, this calls for the implementation of an attendance tracking system that is more effective, dependable, and impenetrable. Modern technology offers advanced solutions, and biometric systems particularly fingerprint-based attendance systems, have emerged as an effective solution. Fingerprint systems provide a unique and secure way to verify an individual's identity based on the distinctive patterns of the person's fingerprint. Unlike ID (identity) cards or passwords, fingerprints are inherently linked to the individual and cannot be easily lost, stolen, or duplicated [6-7].

Executing an attendance system that is fingerprint-based addresses several key issues associated with traditional methods. Firstly, it eliminates the risk of impersonation or buddy punching, where one person signs in for another. Because each person's fingerprints are distinct, the system makes sure that only the real person may record their attendance. Thus, enhances the accuracy and reliability of attendance records [4]. Secondly, the system reduces the time required for attendance marking. In large classes or gatherings, manual roll calls can consume a significant amount of time, decreasing productivity and wasting valuable instructional time. With a fingerprint-based system, students can quickly scan their fingerprints, and their attendance are recorded instantly. This streamlined process allows for more efficient use of time and resources [1], [5]. Additionally, the system provides a dependable method for maintaining and retrieving attendance records. Traditional paper-based records are susceptible to loss, damage, and tampering. Digital records stored in the cloud offer a more secure and easily accessible alternative. Administrators can quickly generate reports, analyze attendance patterns, and identify students with attendance issues. This data-driven approach facilitates better decision-making and timely interventions to address attendance-related problems [3], [8].

The fingerprint-based attendance system includes several key processes to ensure the accuracy and security of the records. The primary processes are the registration and the authentication process. For the former, individuals provide their fingerprints to the system. This step involves capturing an image of the fingerprints using a fingerprint scanner. The system then extracts unique features from the captured fingerprints to create a digital representation of the fingerprint patterns. These unique features are stored in the cloud and used as reference points for future comparisons. This process ensures that each individual's fingerprint data is accurately recorded and securely stored, forming the basis for subsequent attendance tracking [4], [7]. While for the later process; when individuals want to record their attendance, they place their finger on a fingerprint scanner. The scanner captures the current fingerprint image and sends it to the system for comparison with the stored fingerprint data in the cloud. Advanced algorithms are usually employed to match the captured fingerprint with the stored data. If a match is found, the individual is authenticated, and their attendance is recorded. This process is quick and efficient, ensuring that attendance is marked accurately and securely [2], [5], [9].

Implementing a fingerprint-based attendance system for the Department of Electrical and Electronics Engineering, Bells University of Technology Ota will address the shortcomings of the current manual system utilized. The new system will provide a more accurate, efficient, and secure method of recording attendance, thereby improving the overall management and reliability of attendance records. This solution will enhance the operational efficiency of the Department and contribute to a more accurate assessment of student engagement and academic performance. By addressing the current limitations and leveraging biometric technology, this study seeks to establish an efficient attendance tracking system that will significantly aid in the administrative and academic operations of the Department. In the succeeding part of this study, review of related works will be discussed in section two while in sections three and four, the materials and methods and results and discussion of the study will be presented. Lastly, the conclusion of the study will be given in section five.

2. SURVEY OF RELATED STUDIES

Olasupo et al [6], modelled and deployed a biometric attendance management system for students. It was however not web application based. While the system executed by Justina [10] was EduTAMS authentication based, and provided an automatic time, secured, robust and attendance management system for students. Large scale deployment and utilization of the said system is expensive on the other hand. For the system proposed by Shoewu & Idowu [3], theirs did away with the necessity of staff to maintain records. Using biometric technology, Mohamed & Raghu [5] automated the attendance process of an academic institution. A hand-held device was utilized for attendance marking without the need of a tutor. The effectiveness of the system implemented by Li et al, Saraswat & Kumar, Lebi & Sogbodjor, Akinduyite et al [11-14] may be compromised by poor-quality fingerprints or sensor issues while students with injuries/scars on their finger could not be accommodated by Onyishi & Igbinoba [7] system. Lasisi et al [15] created a biometric cloud-based solution for teachers in a developing nation. The developed system is solely reliant on consistent internet connectivity for cloud operations and same is applicable to the system presented by Monish & Harekal [16]. A fingerprint reconstruction technique was used by Josphineleela & Ramakrishnan [17] for modelling an attendance system. However, the reconstructed fingerprints posed security risks, as type-II and type-I attacks could be launched against the system. Optimal performance of Guebla et al, Krishnamurthi et al, Ihama & Aziegbemhin [18-20] proposed systems is dependent on the fingerprint recognition framework. Furthermore, Mittal et al [21] executed a fingerprint system for managing classroom attendance and access. Using a fingerprinting instrument, the access control segment for person-specific door access was shown. Ohanu et al [22] implemented an attendance system based on radio frequency identification and detection (RFID) technology. A wireless smart card and RFID reader was utilized in the system in order to ensure prompt attendance taking. It is noteworthy that the performance of RFID technologies can be influenced by electromagnetic noise, liquids and metal surfaces. Meanwhile Jain et al [23] implemented system was IoT (internet of things) based. Finger print sensors were utilized in their system, and these are sensitive. Making it less flexible in identifying people with cuts or wound as well as dirt on their fingerprint. In the system developed by Rahman et al [24], parents or guardians can monitor their ward's attendance to class and in so doing, help to facilitate their continuous attendance to classes. This was achieved through the incorporation of GSM (global system for mobile) module that has the capability to send text messages to the parents or guardian of a student. However, the effectiveness in ensuring students attendance to classes can be marred if the wards' parents phone numbers are breached by their wards or contracted third parties. In Feng et al [25] system, SM (Samsung mobile)-2B series autonomous pressure-sensitive fingerprint recognition module was utilized in conjunction with other components in the attendance monitoring management system they developed. The drawback of their system is that the student check-in interface is in Chinese language. On the other hand, Dharmale et al [26] executed a biometric monitoring system utilizing Raspberry Pi but its limited memory and processing power as well as its dependence on SD (secure digital) cards for storage are some of its drawbacks.

3. MATERIALS AND METHODS

3.1 System Components Description

A combination of both hard and software components was utilized in achieving the objective of this study. The objective here been to develop an integrated solution that combines these elements in a way that results in an effective biometric attendance construct. The key components utilized are:

i. AS608 optical fingerprint sensor module: this interfaces readily with microcontrollers, such as Arduino, to provide fingerprint scanning and identification functions. Simple connections are made possible by the pinout, which contains the following: V+ (power supply), RX (serial receiver), GND (ground) and TX (serial transmitter). It was utilized for fingerprints capture and storage, and for cross-referencing users fingerprints against the ones already stored. V+ pin supplies the AS608 module's operating voltage (3.3V). GND pin is plugged to the microcontroller ground. The AS608 uses TX to exchange data with the microcontroller. This pin is attached to the RX pin (this is further linked to TX) of the microcontroller.

ii. Esp8266 nodeMCU: the Espressif Node Microcontroller unit is an open-source development platform which integrates a processor and Wi-Fi into a single microcontroller board. It provides 16 General Purpose Input/Output (GPIO) pins (GPIO1 to GPIO16) for digital control, analog pin A0 for reading analog voltage levels, and dedicated SPI (SD0, CMD, CLK, SD1) and UART (RXD0, TXD0, TXD1, RXD2) interfaces for specific communication protocols in order to interface with external devices.

iii. Ds1302 module: real-time clock (RTC) modules like the DS1302 are frequently utilized in electronic applications that need to have timekeeping capabilities. The DS1302 chip, which powers the DS1302 module, has 31 bytes of non-volatile RAM that can be used to store date and time information. The module utilizes a straightforward three-wire interface consisting of a data line, a clock line, and a control line to communicate with external microcontrollers or other devices.

iv. 1602 monochrome LCD: the 1602 monochrome LCD (Liquid Crystal Display) is a display module. It was employed in this build to display a variety of prompts.

v. Push buttons: it comprises of two pins internally connected together when clicked and disconnects when depressed. It is utilized in this build to aid users navigate through the system's software in order to provide control to them.

vi. BMS (Battery Management System) module: monitoring the voltage levels of each battery cell in the pack to guarantee even charging and discharging is one of the main responsibilities of the BMS module. The main function of the BMS module in this build is to charge the batteries efficiently and supply steady power to the entire circuit.

vii. 3.7V lithium-ion batteries: in order to make the system concise, 3.7V rechargeable Li-ion batteries was used.

viii. Arduino IDE: it serves the major role of compiling the supplied code into binary file which is further loaded into the microcontroller connected to a specified port. It supports code upload to not just Arduino boards but also boards like Esp8266, PLCs. The IDE was used in this case to write and compile the code applied to run the entire hardware of this build.

ix. Visual studio code: referred also as VS code and is a text editor designed for code writing in various languages. To develop the web application, react JavaScript framework was used.

3.2 Methodology

3.2.1 System block diagram

The proposed system block diagram is depicted in Figure 1 and it is an overview of the various elements that makes up the overall system.

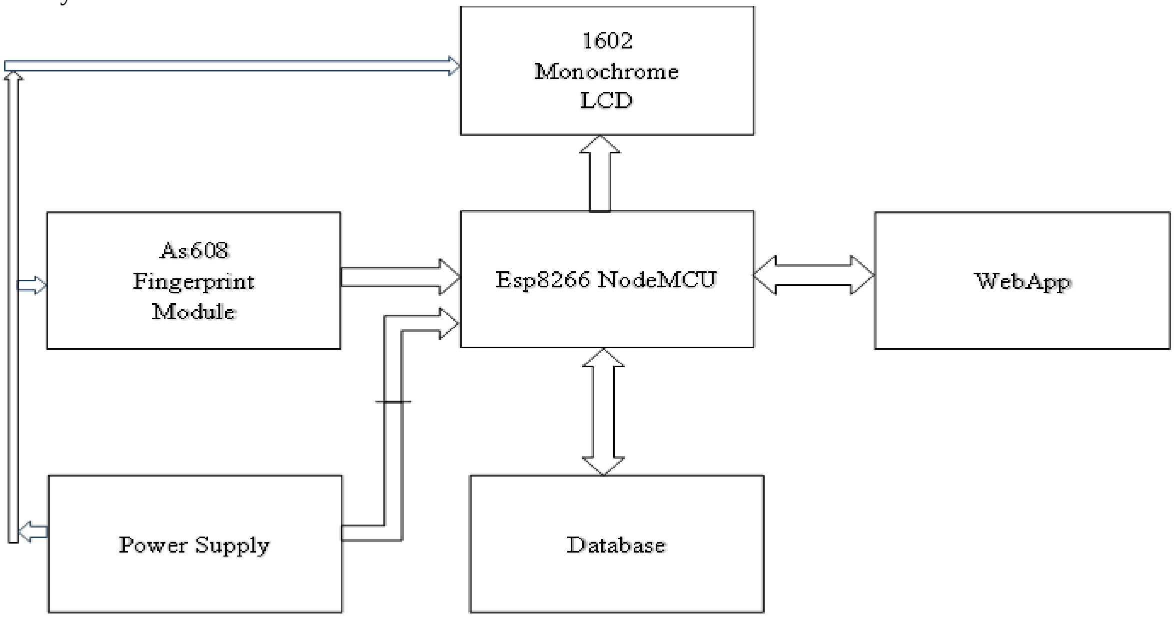

Figure 1: System block diagram

3.2.2 Subunits of the system

i. Esp8266 nodeMCU interfaced with the LCD: The LCD is communicated to by the Esp8266 microcontroller through the I2C (integrated circuit) protocol. Figure 2 shows the circuit connection of the LCD and nodeMCU.
ii. Esp8266 nodeMCU interfaced with AS608 fingerprint module: the AS608 module is so designed to interface with microcontrollers through serial communication. The circuit is depicted in Figure 3.
iii. Push buttons interfaced with Esp8266 nodeMCU: two 1kΩ 1W resistors was connected to the push buttons and they served as pull-up resistors. The output of the push buttons can be connected to pin D4 and D5 of the nodeMCU at will. The connection diagram is shown in Figure 4.

Figures 5 and 6 shows the internal architecture of the proposed system at the development stage.

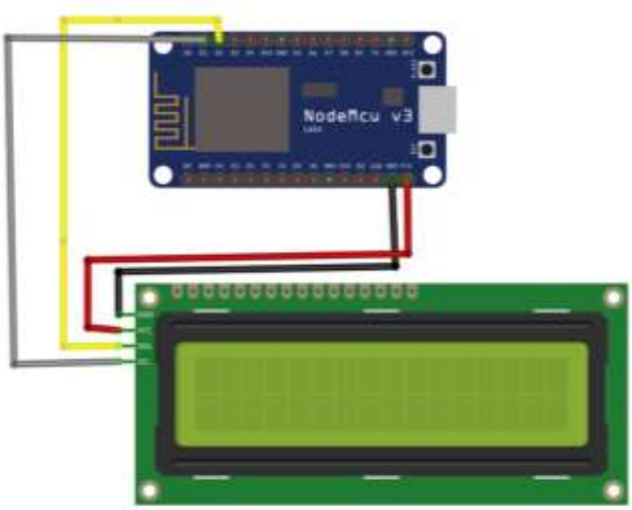

Figure 2: NodeMCU and LCD circuit connection

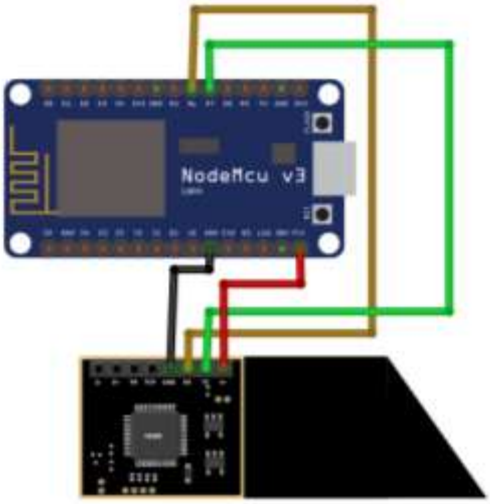

Figure 3: AS608 fingerprint module and nodeMCU circuit connection

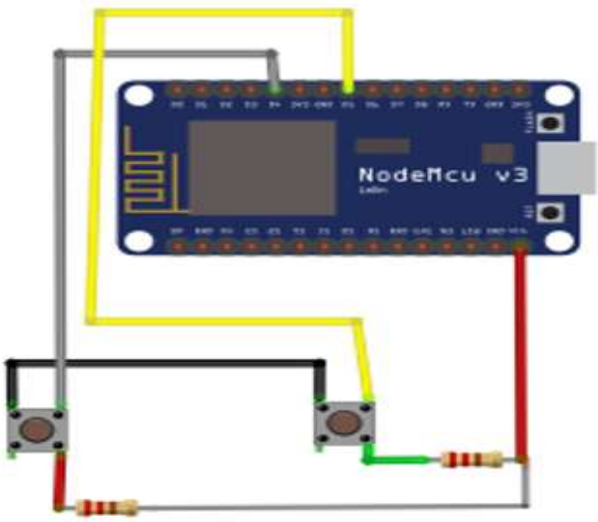

Figure 4: The push buttons and nodeMCU circuit connection

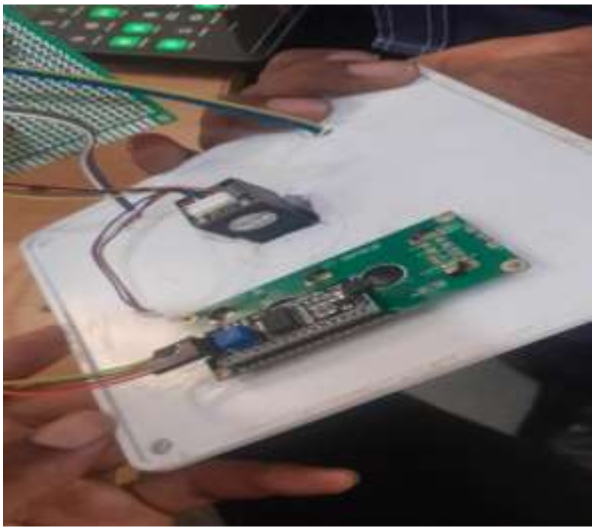

Figure 5: First pictorial view of the system internal setup

3.2.3 System operation

The power supply powers the ESP8266 NodeMCU, LCD and the fingerprint module. A free server (database) was used, and there are two different modes of operation of the system: register mode and record mode. After initialization and establishment of a WiFi connection, the fingerprint module will be activated, and a fingerprint input will be awaited. At this stage still, all client data (lecturer and students' information) will be fetched from the database. After the setup stage, the user can select the preferred operating mode by pressing the push button on the hardware. Now, if a fingerprint is to be registered; the user will first turn on his computer and then go to the web app and wait. Thereafter, on the module code on the hardware device, click on take a fingerprint or register a fingerprint. Once this is done, the ESP8266 NodeMCU communicates with the webApp through the database. And once there's a connection between them, it then informs the user that a fingerprint is ready to be taken. So, a fingerprint is inputted and recorded. Once this is done, the user will be taken to a new page where necessary information of the person will be inputted. Once the person is done and okay clicked, ‘‘it’s been saved’’ will be gotten as feedback. In record mode, the fingerprint input from the administrator (the designated lecturer) will be awaited after ‘‘take attendance’’ prompt on the LCD is selected on the hardware using the push button. When the designated lecturer has inputted his fingerprint, fingerprint inputs of the students will be awaited. When this is done, the attendance (fingerprint IDs of the students) will be uploaded (‘‘lecturer seen uploading data’’ will be displayed in the LCD) to the database under the administrator’s course after the designated lecturer closes the attendance taking by inputting his fingerprint again in the fingerprint sensor on the hardware. The circuit diagram of the developed system is shown in Figure 7 while the front cover pictorial view of the system is depicted in Figures 8 and 9 when at OFF and ON modes respectively.

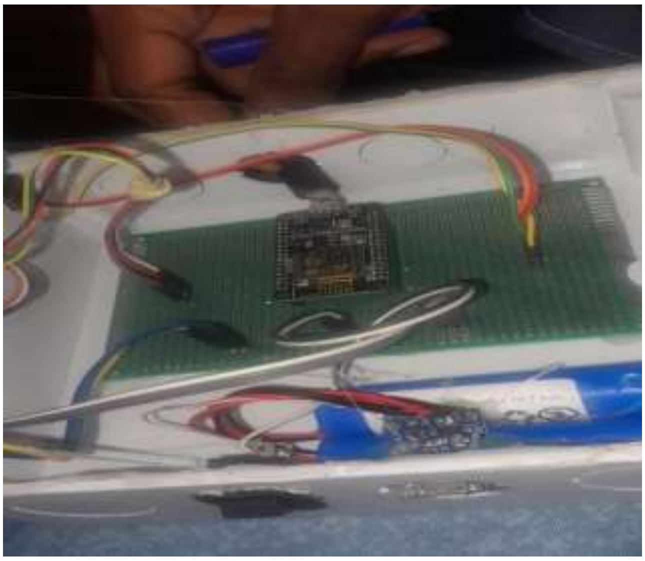

Figure 6: Second pictorial view of the system internal setup

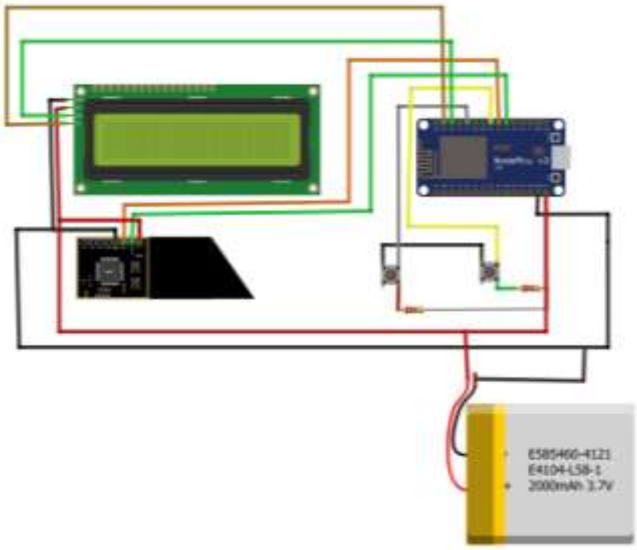

Figure 7: Complete circuit diagram of the implemented system

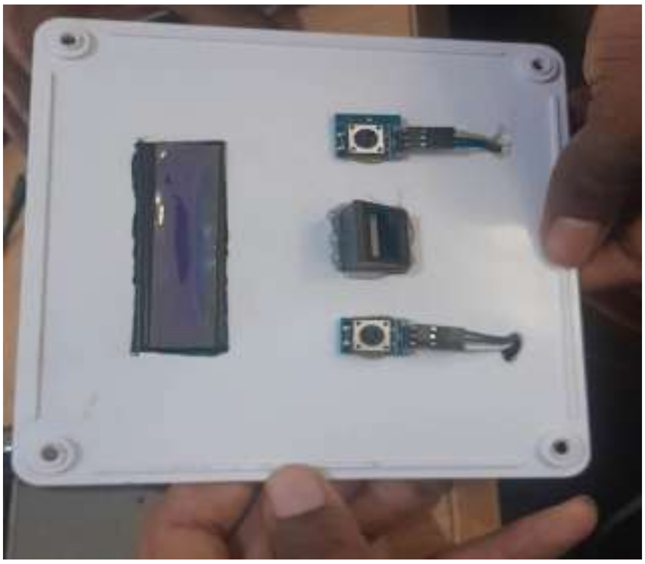

Figure 8: Pictorial view of the developed system at OFF mode

Figure 9: Pictorial view of the of the developed system at ON mode

4. RESULTS AND DISCUSSION

In this section, the different tests executed are presented. Essentially, the system performance was evaluated through the following under listed tests:

i. Boot test: this was done in order to measure how fast the fingerprint module will load and initiate. As seen from Table 1, it takes an average of 10 seconds for the fingerprint module to load and execute its function. It was also executed to determine how fast the fingerprint can connect to the database and read information like that shown in Figure 10, and the strength of the internet at any given point in time influences the outcome.

Table 1: Boot test result

Trial	Time (in seconds)
1st	00:10.20
2nd	00:10.05
3rd	00:10.10
4th	00:09.50
5th	00:10.15

Figure 10: Client data search

ii. Finger sensing test: this test is designed to evaluate the response time of the system's fingerprint sensor, specifically measuring the delay between when a finger is placed on the sensor and when the sensor detects and indicates the user input. The procedure involved repeatedly placing a finger on the fingerprint sensor and recording the time it took for the sensor to sense the user's fingerprint and prompt other processes. Table 2 shows the finger sensing test results for five trials. It thus takes an average time of 1.49 seconds for the system to sense a user's fingerprint.

Table 2: Finger sensing test result

Trial	Time (in seconds)
1st	00:01.20
2nd	00:02.05
3rd	00:01.40
4th	00:01.28
5th	00:01.50

iii. User information fetch test: fetching of user data is largely dependent on internet connection strength. Table 3 shows how quickly the system fetched a user's information under varying network connection strength. It illustrates that response time is affected by various levels of internet latency. Furthermore, Figure 11 depicts the retrieved information of a user.

Table 3: User information fetch test result

Trial	Time (in seconds)
1st	00:08.20
2nd	00:09.05
3rd	00:08.40
4th	00:08.28
5th	00:09.10

Figure 11: Result showing a fetched user's data

iv. Button press test: due to the single-threaded nature of the Esp8266 microcontroller, the program flow was limited to one thread. This meant that certain actions determined the execution of others. This test was carried out to get a perfect delay time to make sure the button press is very responsive. The results obtained is shown in Table 4.

Table 4: Button press test result

Trial	Time (in seconds)
1st	00:00.90
2nd	00:01.01
3rd	00:00.70
4th	00:00.40
5th	00:00.50

In all, with the developed system, a student can mark his attendance within approximately 6.16 seconds. But with the manual method, the time per student was 22.25 seconds. This goes to show that the implemented system is best suited for attendance tracking as it eliminates the time lag associated with the traditional approach (manual method) currently being utilized.

5. CONCLUSION

A prototype fingerprint attendance system for the Department of Electrical/Electronics Engineering, Bells University of Technology Ota, Nigeria was successfully implemented. And the end goal is to enhance student attendance to lectures, forestall attendance taking by proxy and decrease the failure rate in course examinations due to none attendance to classes. The system can also be used as a validation template vis a vis a student poor performance in a course examination as a result of not attending the course lectures. The developed system can further be improved on to accommodate large scale utilization and deployment. A pocket-sized version of the device could not be achieved due to the size of the components utilized. Also, a free server was utilized hence, only a limited number of users can be accommodated in the database and the system cannot function in offline mode. These constraints are thus basis for future research in this area.

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