Implementation of cloud-based biometric attendance system for educators in a developing country

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Abstract. The rising demand for data and its machine-aided dynamics calls for more deliberate effort on standardized collection, especially in formats suitable for identifying relationships between its features. This paper reports the implementation of cloud-based biometric attendance system to address the limitations associated with the traditional attendance system, which is still predominantly in use across institutions in developing countries. The cloud-based attendance uses a fingerprint recognition system for authenticating attendance, displays user identity via Organic Light Emitting Diode (OLED) display and uploads the processed attendance data into cloud with the aid of the ESP32 microcontroller and its development board. At the point of taking the attendance, the system exclusively authenticates and processes the attendance of the pre-registered candidates whose fingerprints matches those pre-stored and uploads the result into the cloud for access by the administrator remotely. The system is simple and modular with an impressive performance, recording authentication and loading to cloud at an average of 2-5 seconds per candidate. With this system in place, it would be easier to get the required data to enforce the eligibility criteria for assessment and this invariably would also encourage punctuality and students’ participation in classroom activities.

Keywords: Cloud-based, Attendance Monitoring System, Fingerprint, Education, ESP32

1. Introduction
Class attendance remains a vital component for assessing students’ participation in the learning process. Apart from the perceived significance on the performance of students, a regular attendance fosters a smooth teacher-student relationship, thus allowing the teacher to better know each student, identify their strengths and weaknesses, as well as understand and manage their diversities. Similarly, in work related environments, absenteeism is also not usually condoned and as this also has several negative effects on the business or the organization.
Attendance systems may be used in monitoring employees within their working hours in establishments, students’ punctuality for lecture, people participation in an event, and so on. Attendance management is an essential record-keeping activity in any organization. Despite the numerous punitive measures put in place to discourage absenteeism, the traditional method of recording attendance is still prominent in developing countries and it has not proven to be effective for tracking and monitoring punctuality in schools and at various workplaces over the years. For this method, attendance register is usually populated by individual students or employee, while in certain instances, a designated personnel or teacher would call the names of the students or employee to mark them present or otherwise.

The major drawback of the manual traditional method includes the usual time wastage, susceptibility to human error, ease of misplacement or theft, impersonation, and its openness to other several forms of abuses. All these and other associated limitations can be eliminated with the use of biometric-based attendance systems as replacement for the paper-based traditional method, particularly if automated. Several biometric features have been explored in recent past and were also deployed on an automated platform. Some of designs were implemented and have equally been widely documented in literature, mostly covering the use of the various biometric based authentications. According to [1], biometric based authentications are classified as physiological (facial recognition, fingerprint, and iris), behavioural (signatures, handwriting analysis, keystroke detection, voice pattern recognition) and chemical (body odour and thermographs). For instance, face recognition has been widely deployed for attendance system authentication as documented in [2–6]. Similarly, the use of fingerprints is also prominent as reported in the works of [7–11]. In the same vein, a number of practical designs have been documented on the use of voice as a behavioural biometric authentication for attendance systems and this is detailed in the works of [12]-[15]. The use of iris as the biometric feature for logging attendance was explored in [16–18], and several other contributions [19,20] have also been documented on the use of the radio frequency identification (RFID) for attendance system designs.

Most of the previous designs are not commercially available, and those available are rather too expensive for deployment in developing countries that are mostly characterized with epileptic power supply and dearth of robust internet broadband connection for optimal use schools or workplace settings. This paper is therefore aimed at domesticating a modular automated attendance management system with design implemented using fingerprint for recognition and the cloud for direct storage and retrieval by educators in developing countries.

2. Related works

The concern on the impact of absenteeism on the performance of students has fueled several investigations as documented over the years. In [21], the relationship between student’s attendance in class and their corresponding academic performance was examined at the University of Technology, Jamaica. This study employed the use of secondary data consisting of attendance and result records of students enrolled in an introduction to psychology course. A similar investigation was conducted at an International Branch Campus of a British university and documented in [22]. Results from data collated for over 900 students was statistically analyzed and indicates that there is a strong correlation between student’s participation in classroom activities and their respective performances. [23] also evaluated the performance of certain groups of 3rd year MBBS students based on their respective attendance percentages in the classroom. Although their findings support existing evidence from literature, that there is a significant positive correlation between class attendance and academic performance, they however posited that attendance is not the only factor responsible for outstanding academic performance.

Fingerprint is indeed a very unique biometric feature, which represents finger skin epidermis, and it is a combination of ridges and valleys [24]. According to [25] “skin epidermis is formed through combination of both hereditary and environmental factors, even identical twins have different fingerprints”. Due to the simplicity, cost effectiveness, ease of use, and non-transferable features of the fingerprint biometric recognition, it has been considered mostly suitable for deployment in developing countries and especially for class attendance. Interestingly, the performance of fingerprint sensors has
attained a reliable level of accuracy with several optimized designs available for integration and use for personal digital devices such as mobile phones and laptops. It also finds wide application for e-banking, airport check-in, access control for automated teller machines (ATM), and for general access control in doors and deposit boxes [26].

Development of a fingerprint biometric attendance system for non-academic staff in tertiary institution was discussed in [7]. The system takes attendance electronically using fingerprint recognition system and saves all the records for subsequent operations. The Staff biometric attendance system employed an automated system to calculate attendance summary of the staff to reduce human errors. In essence, the system curbs lateness, buddy punching and truancy. However, the system is not user friendly as a user interface was not incorporated in the work. Besides, the attendance data of the system is inaccessible remotely.

Another effective system to solve the problem of the traditional manual attendance was proposed in [27]. Here, the system, also employed fingerprint recognition system for attendance authentication and the records are saved in cloud or locally in the device. This staff biometric attendance incorporates a sub-system that calculates attendance of the staff, the monthly attendance summary, and the wages due to the staff based on attendance. This system increased productivity, reduced truancy, and lateness. However, the implementation of the attendance system requires more circuitry; Real Time Clock (RTC) module was used to update the time and date at the point of attendance unlike some cloud-based attendance that uses current time as picked from the internet. Moreover, this system has a limitation of not being portable. An attendance system employing fingerprint identification with website and Graphic User Interface (GUI) was discussed in [8]. The main objective of this approach was to establish a consistent attendance system and hold data in real-time. The system presents online data for parents and other educational uses. With the application, parents can conveniently track how regular or otherwise their children were in attendance during the academic year. Results showed that this program achieved good results in terms of attendance management. However, the system was too expensive as it requires a high cost of website infrastructures and regular maintenance.

Integration of automated fingerprint-based attendance into the university portal system was observed in [9]. The system was designed to provide accurate and efficient attendance management service for staff and students within the existing portal system. The incorporation of a new and reliable identification system into the existing portal offers at least two advantages; accurate and effective evaluation and recording of staff and student’s attendance continuously, enabling the delivery of customized services and improving user experience. However, integration of this system is expensive as it requires large scale deployment and interoperability of multiple devices using existing technology infrastructure. Design and development of a fingerprint-based biometric attendance system where microcontroller controls the entire process, Liquid Crystal Display (LCD) and the various instructions for the process was presented in [10]. Here, index printing was taken as a signature for the system entry. The results showed an improvement in performance over the manual attendance management system. However, the system did not feature a remote data access via cloud or website. Moreover, the used LCD has limited angle view and higher power consumption as compared to some user interface sub-systems.

In this work, a biometric-based attendance system is domesticated using fingerprint with data storage in the cloud. The system can address the limitations of the traditional manual attendance systems. It has not only automated the attendance system, it also a scalable, efficient, low cost, user friendly, fast, and secured system with distinctive features.

3. System design and implementation
The biometric attendance system involves the integration of a FPM10A fingerprint scanner, an Organic Light Emitting Diode (OLED) as the display unit, the ESP32 microcontroller and power supply unit. The architecture of the automated cloud-based fingerprint attendance system is presented in figure 1.
The fingerprint scanner reads and processes the user’s fingerprint to verify and authenticate a candidate’s attendance. Here, FPM10A scanner was employed due to its robust storage capacity. It has a resolution of 50 dots per unit (dpi) with a dimension of 55 mm x 23 mm x 21.5 mm. A 0.96-inch OLED screen of 128 x 64 resolution was integrated as user interface for the system. The ESP32 microcontroller was engaged via its development board to aid the execution of instructions, monitor data communication, establish network connection, and upload attendance data over the cloud. ESP32 is a single 2.4 GHz Wi-Fi and Bluetooth combo chip designed with the Taiwan Semiconductor Manufacturing Company (TSMC) ultra-low-power 40 nm technology [28].
Figure 2 presents the circuit design of the prototype of the attendance system. In the circuit, the microcontroller provides required voltage to other circuitry components via the 3.3 V and GND pins on the board. Data communication between the microcontroller and other components is aided by the communication pins; Tx2, Rx2, D21 and D22. The writing and uploading of the codes were facilitated by the Arduino integrated development environment (IDE) for required specific instructions and functionality of the microcontroller. The top and bottom surfaces of the printed circuit board for the prototype design is presented respectively in figure 3 (a) and (b).

Implementation of the attendance system involves the deployment of IFFFT (If This, Then That) application software, which automates the system via a service called webhook, a web call-back service that gets triggered each time the fingerprint sensor senses an enrolled candidate provided the network has been established between the system and the internet. Once triggered, a Hypertext Transfer Protocol (HTTP) request is made from the IFTTT site. The request is a link that contains the unique Event name and webhook key. Using the ‘POST’ command of HTTP request, the attendance data (which includes the name, fingerprint ID, Matriculation number, date, and time of scanning) are sent to Google drive in a Google sheet format. Here, the cloud storage is Google drive, and the attendance data is detailed on a Google sheet file. The system design implementation of the attendance system is as detailed in figure 4.

![Figure 3. The printed circuit board design (a) top surface (b) bottom surface](image)

![Figure 4. System design implementation](image)
4. Results and Discussion

The attendance system boots up with the Adafruit logo and establishes connection between the Wi-Fi router, which is also embedded with the ESP32 development board. Figure 6 shows the typical system operation and response, indicating the system bootup, connection to internet and readiness for fingerprint scanning. Figure 5 (a) shows the start-up display of the system, while figure 5 (b) indicates the available wireless network which has been configured for connection to the device. Figure 5 (c) and (d) indicates connection or otherwise of the biometric attendance system with the internet, while Figure 5 (e) presents the fingerprint start bitmap display, which indicates the readiness of the system to scan fingerprints.

The complete system is shown in figure 6, depicting the typical process for fingerprint scanning. Here the fingerprint scanned is authenticated by comparing with pre-registered fingerprints and a welcome message is displayed on the screen if there is a match, as shown in figure 6 (a), otherwise the screen displays ‘unregistered user’ as shown in figure 6 (b).

A duly verified and authenticated fingerprint initiates the attendance management process of the system. Thus, the unique ID of the authorized candidate is then uploaded into the cloud and the data is stored in Google sheet file format, and consequently a checked fingerprint bitmap image is displayed on the screen as shown in figure 7 (a). This also indicates that the attendance data has been uploaded successfully; otherwise, the screen displays a crossed fingerprint bitmap image as shown in figure 7 (b), indicating a failed upload. The latter may be because of poor network as was experienced during testing. This however stabilized with connection to a more reliable and stable network.

![Figure 5. System fingerprint start bitmap display](image)

![Figure 6. System fingerprint validation display message](image)

![Figure 7. Marked and failed fingerprint bitmap display](image)
The Attendance generated over the cloud is in a form of spreadsheet which contains four columns labelled A, B, C, D and E sequentially. Column A presents the date and time the attendance was taken by a candidate. Column B indicates the event name as ‘Course Code’. Column C shows the first name of the enrolled candidate. Column D represents the candidate’s fingerprint ID number and Column E is for the Matriculation number of the students. This is presented in figure 8, showing the screen shot of the attendance generated over the cloud. The system response is satisfactory, recording an average of 2-5 seconds for initializing, authentication and uploading of the attendance of a particular candidate.

5. Conclusion
A robust, economical, and user-friendly device has been simply designed, implemented, and domesticated for taking attendance of students with a simplified backup and storage to cloud. No form of special skills in multiple programming languages or annual maintenance cost is required for using and maintaining the system. Interestingly, the cloud storage is a free tier plan with a capacity of 15 GB, which is considered sufficient for storage since no video or picture file is involved. The deployment of this system would assist teachers and lecturers to save the time usually expended on the manual traditional attendance and allow for an organized and reliable attendance record, which can be harvested remotely by the teacher at his/her convenience or even by the quality assurance unit of the institution to monitor academic activities across the institution, especially as relating to compliance with the approved timetable and enforcement of the stipulated percentage eligibility requirements for the end of semester examinations.

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