METHODS

Automation attendance systems approaches: a practical review

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Accounting for people is the first step for every manpower-based organization in today's world. Hence, it takes a significant amount of energy and value in the form of money from respective organizations for both implementing a suitable system for manpower management as well as maintaining that same system. Although this amount of expenditure for big organizations is near to nothing and rather just a formality, it does not hold as much truth for small organizations, such as schools, colleges, and even universities, to a certain degree. This is the first point. The second point for discussion is that much work has been done to solve this issue. Various technologies, like biometrics, RFID, Bluetooth, GPS, and QR Code, have been used to tackle the issues of attendance collection. This study paves the path for researchers by reviewing practical methods and technologies used for existing attendance systems.

Keywords: biometric, attendance systems, QR code, RFID, face recognition, software system

Introduction

Student collection and management is one of the most time-consuming tasks in any school, university, and education system. In fact, gathering attendance is a time-consuming job that takes lecture time and the teacher's energy. But if the teacher does not do so, the school and family will not know if the students are pursuing the light of education. This issue has been tried to be solved using various approaches and technologies currently available. The previous record on the research paper and product shows the biometrics, including palm, iris, facial recognition, RFID, NFC, Bluetooth, barcode, and QR, which are more demanding to make the system as automated as possible. In the next section, various types of these technologies are described. This paper divides them into five subsections—biometric attendance system, facial recognition-based attendance system, RFID-based attendance system, QR code-based attendance system, and finally embedded system-based attendance system. Following this review of existing attendance systems, the paper concludes with a summary of the types and a short excerpt about the importance of attendance management systems and integrating existing technologies to solve modern problems.

Attendance systems variety

Biometric attendance system

The word biometric comes from the word "biometry," which means the process by which a person's unique biological

or physical traits are accounted for identification. The most common biometrics used today are palmprint, fingerprint, face, and iris. The biometric attendance system uses one or more of these traits in conjunction to confirm the identity of the personnel attending lectures. A few existing research works are reviewed to highlight existing work in the sector. In their review paper, Tsai-Cheng Li et al. (1) studied biometrics technology applied in the attendance management system. Their aim was based on some pertinent literature reviews, through which they concluded that attendance management is an important measure and means for discipline as it dictates the productivity of an organization and its sustainability. Biometric data is a measurable biological trait that is unique to every person on the planet and can be automatically verified to confirm a person's identity. Most of the studies have shown that either hand geometry or fingerprint recognition is a very suitable method for the attendance management system. Even on the topic of improving efficiency and service quality, most of the respondents gave a reply of "agree" or "no comment". According to the paper, the biometric recognition system has the least controversies as it is exceedingly difficult to crack, and employees and respondents feel safe and fair that it should be used to manage public attendance. In their paper, O. Shoewu et al. (2) talked about developing a biometric-based attendance management system and compared it with a traditional manual attendance system (**Figure 1**).

According to **Figure 1**, their system uses two steps to both enroll and authenticate the users. First, all biometric data is scanned securely through biometric devices; then, their software executes a program for feature extraction from the scanned data and stores it with the biometric owner ID. Although the authentication only performs the same steps once, it matches the data stored in the SQL database. The system also produces an attendance summary report and flags mismatch attempts. The researchers concluded that the system was particularly useful because of its short implementation time and high success rate. On the contrary, one of the most secure forms of biometric recognition is iris recognition. In fact, it is more secure than traditional fingerprint recognition or palm recognition. In their paper, Seifedine Kadry et al. (3) described a wireless attendance management system based on this very technology (**Figure 2**).

Figure 2A shows the iris scan procedure of the system. **Figure 2B** shows how the iris recognition module connects to the workstation and completes the system. The system follows three basic modules: image acquisition and pre-processing texture extraction and signature encoding, and iris signature matching for authentication. The researchers devised a less expensive method of accomplishing the task by incorporating offline iris recognition and connecting it to a management computer *via* a PTR2000 + wireless communication module (4–12). Their test resulted in a 98.3% success rate. Hence, they concluded that implementing such

a technique with iris recognition can ease access to the attendance management systems.

Facial recognition-based attendance system

Facial recognition is a part of biometrics but again, not quite so. Because facial recognition can be fooled, whereas biometrics defines uniqueness, identifying traits must be unique. Facial recognition is common in every face because no face is the same in most cases, and it is easy to implement because any camera with appropriate software can do the task. In their research, Naveed Khan Balcoh et al. (13) introduced face detection as an accurate and efficient replacement for the old-school manual attendance system (**Figure 3**). Their system from **Figure 3** used the EigenFace method to verify faces one by one and match them with their face database, then commit the attendance task. Their face database was populated with face data through a series of image processing techniques, including image histogram normalization, noise gratification, skin classification, and finally, face detection by selecting the region of interest.

The same process goes for attendance by face recognition. In their research, Preeti Mahita et al. (14) showed a facial recognition-based attendance management system on the raspberry pi 2 using the included raspberry pi camera (**Figure 4**).

They used the Voila Jones algorithm and a local binary pattern in conjunction to identify the faces of the people in a photo. The faces will be stored in the database again with the personal identification, which will then be used to identify the personnel present. They conclude that their system has a 92% accuracy. This accuracy is unacceptable when it comes to class attendance, as classes are very much vital. Priya Pasurmati et al. (15) showed a much more advanced version of the facial recognition-based attendance management system. Their research uses an open-source facial recognition framework called OpenCV and Python as their main work environment (**Figure 5**).

In **Figure 5**, their system design shows the components used. They used a physical Webcam to accomplish the task. But the paper concludes with no real-world application proof of the system but only the results of an efficient facial recognition system using Python.

RFID/NFC attendance system

RFID is an abbreviation for "radio-frequency identification," which basically means that the communication is done through radio frequencies. In this system, information is digitally stored inside a tag or card, which can be read through radio frequencies. Near-field communication (NFC) is an RFID-based technology that can act as a tag and
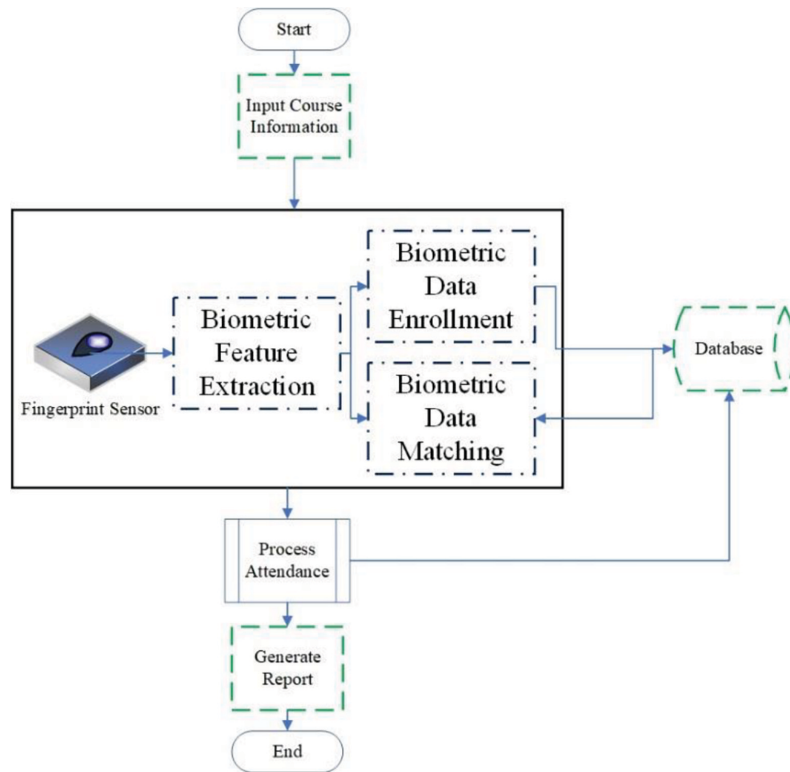
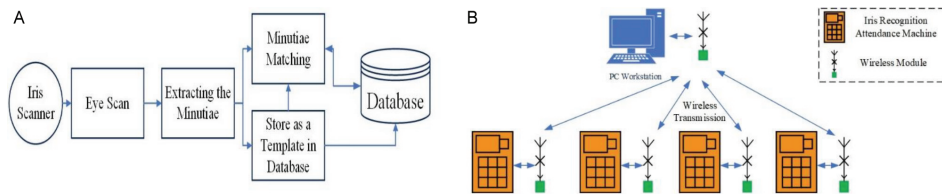**FIGURE 1 |** System Design of O. Shoewu et al. (2).

FIGURE 2 | (A) Iris Scan Procedure of the System (3). **(B)** System Design of Kadry et al. (3).
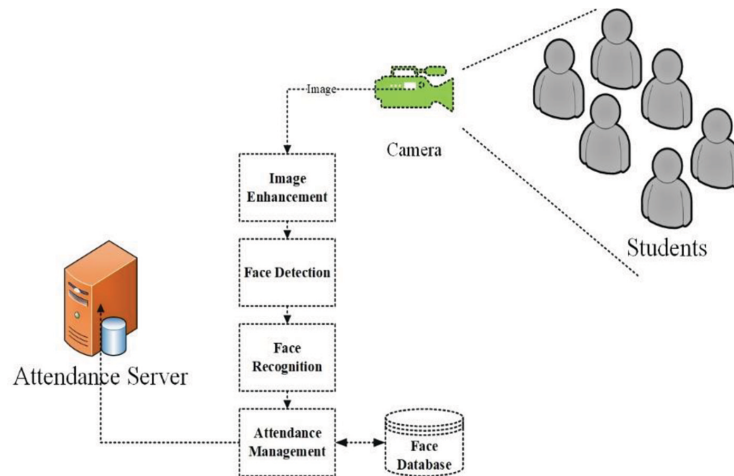

FIGURE 3 | System Design of Balcoh et al. (13).

reader. This technology is cheap to manufacture now and can therefore be readily used in the work sector. Here, a handful of research works on RFID-based attendance systems

have been surveyed, some of which work in conjunction with other technologies like Bluetooth. In their paper, Vishal Bhalla et al. (16) described a system based on
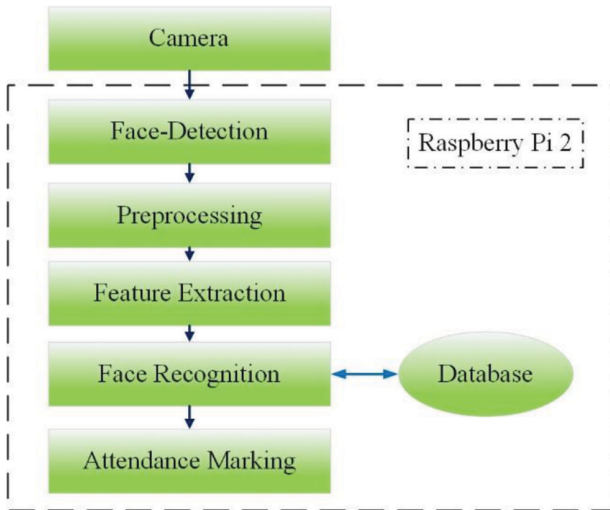
FIGURE 4 | System Design of Mehta et al. (14).

Bluetooth technology and RFID reader application. Their proposed system is very novel because they have used RFID matrix cards to gather students' attendance and then used Bluetooth for the teacher or professor to confirm the attendance before the data gets permanently sent to the main database (**Figure 6**).

As explained in the system design in **Figure 6**, once the data is sent to the central database, it can be edited later, and reports can be generated *via* emails. By adopting this double-layer model, the error rate in their system is extremely low, and almost only human error remains. Their system significantly reduces time consumption in the whole system too. In their paper, the researchers also

mention that this project model can be further secured by introducing a fingerprint when authenticating the use of a terminal. They have used Bluetooth rather than Wi-Fi and other long-range solutions because of its range, power consumption, and ease of availability, as they are using the Bluetooth devices embedded in the cell phones of the teachers taking the attendance, where the teachers will use their very cell phones to confirm the RFID attendances. Arulogun O. T. et al. (17), in their paper, presented an intelligent RFID-based students attendance control and management system. Their simple system is illustrated in **Figure 7**.

In their project, they used passive tags due to the cost and implementation flexibility. Upon bringing those tags close to the designated reader, the reader captures the card's data and sends it to the system, recording the time of arrival and departure. Their software for handling the data is made with Visual C# with Visual Basic GUI incorporated with Microsoft's SQL server to store the data. The researchers conclude that incorporating a facial recognition application would further enhance security.

Nikhil P. Shegokar et al. (18), in their study, compared existing technologies in the scope of an automated attendance system based on the raspberry pi and found NFC to be the better path. They compared the various biometric technologies, namely, facial recognition, iris recognition, and NFC. Their paper does not quite show any active system to be implemented, though.
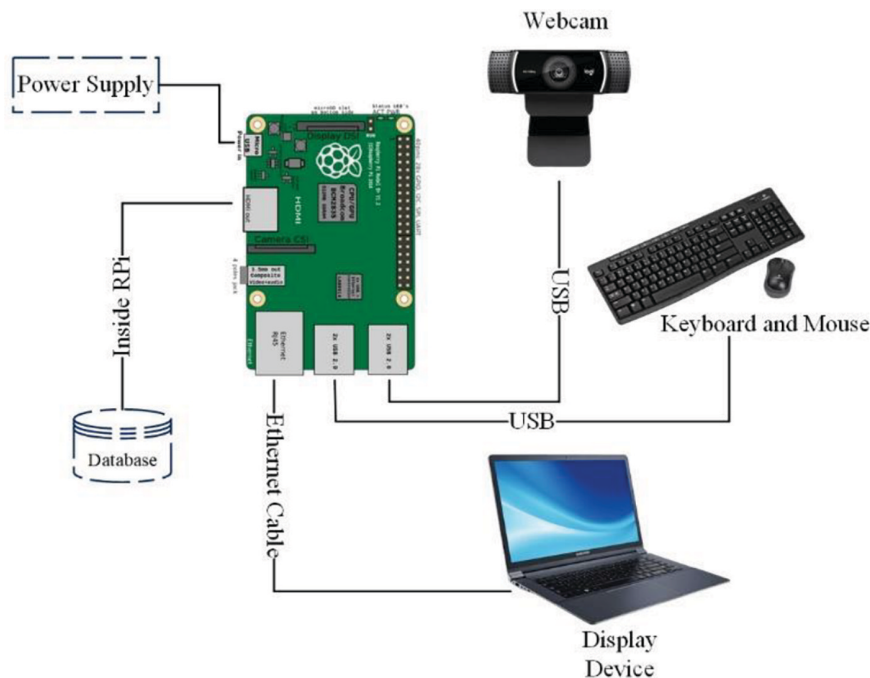

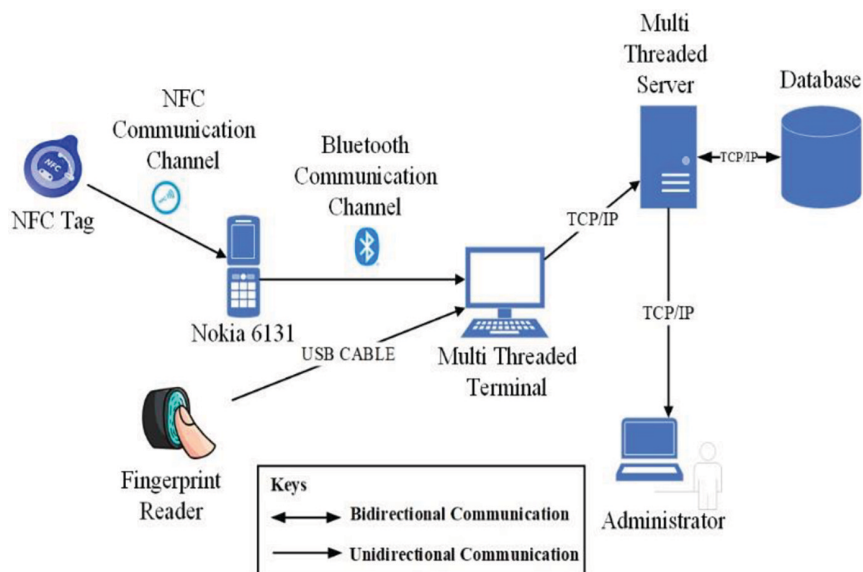**FIGURE 5 |** System Design of Pasurmarti et al. (15).

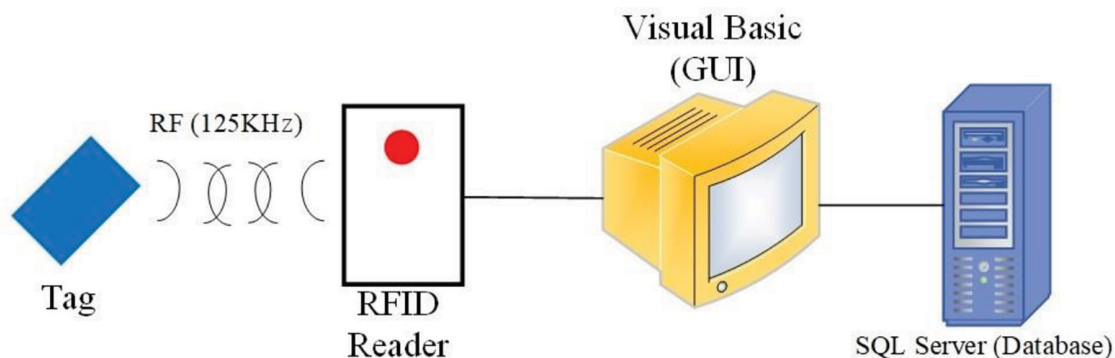**FIGURE 6 |** System Design of Bhallah et al. (16).

FIGURE 7 | System Design of Arulogun et al. (17).

QR code attendance system

The word QR stands for quick response in the term QR code. It belongs to the two-dimensional code family, whose predecessors are actually barcodes. But barcodes have many limitations, hence QR codes have superseded them. One of the main reasons why QR codes are better is that they can store a huge amount of information in any orientation with much more damage tolerance than all other 2D code technology available. At the same time, it is industrially cheap to implement. To make the reasons for why QR code is much more efficient a bit clearer, a small survey on the existing applications of the QR code technology proves useful.

Tin Jin Soon (19) surveyed and explained the fundamentals of QR code in his journal and also showed various widespread implementation of the QR code technology. He reviewed the technologies used in the fields of industry and transport, from the identification of different products to banknotes. Online and local ordering systems, food freshness control systems, bet ticket management systems, patient management systems,
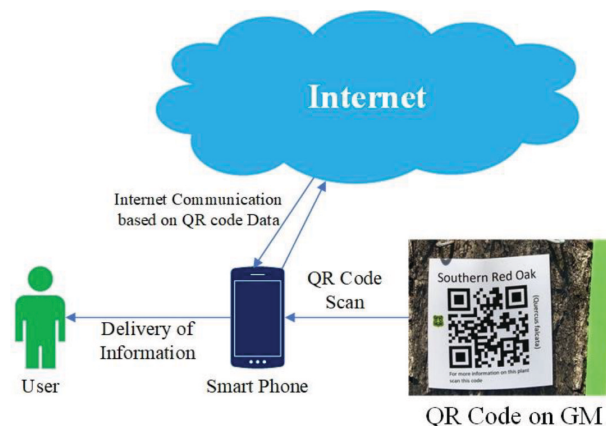

FIGURE 8 | Implementation of QR Codes on GMs (21).

livestock tracking systems, jewelry certification systems, agriculture, telecommunications, payments, and other fields—all use QR codes widely. The merits of using QR codes in all these sectors are the same, i.e., efficiency and profitability. Masahiro Hara (20) showed a similar picture to
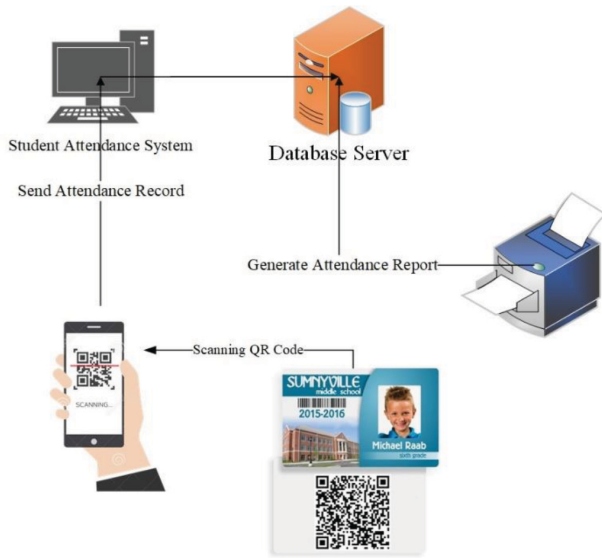
FIGURE 9 | System Design of Hendry et al. (22).

that of Tin Jin Soon with a more historic approach. He stated that before QR code was there, barcode was widely used. But it came with some limitations, like reading directions and information capacity. So QR code, or quick response code, was developed, which removed these limitations and even allowed alphanumeric characters in different languages to be encoded and represented through it. Compared to the previous generations of 2D codes like barcodes, QR codes

have error correction capability up to 30%, whereas the other technology has zero. A QR code, which is five times a barcode, can be read in around 30 ms with a bare minimum RISC processor (MIPS: 18) in any orientation. Because of its versatility, high-speed reading, and miniaturization capability, it is widely used in industrial sectors. Two-layered QR codes are used in order to expand security and prevent the copying of confidential QR codes. For the above reasons and the added facility of cheap implementation, QR code technology was chosen for this project.

Here some existing works related to QR code-based attendance system are surveyed below.

Hsin-Chih Lai et al. (21) in their research showed a broad implementation of the QR code technology. They showed the implementation of mobile learning in outdoor education through the implication of QR codes. In their study, they developed an outdoor education information system that combines natural and cultural environment GMs or Green Maps using QR codes. The implementation had QR codes printed on a GM, and then students on site for exploration of the outdoor environment were asked to scan the QR codes to find relevant information from the internet. The idea being that having static QR codes on GMs can easily be scanned by a cell phone to retrieve information about the place and the place's elements. A rough sketch about their implementation of QR codes on Green Maps is shown in **Figure 8**.

MRM Hendry et al. (22) in their paper proposed a smart attendance system by applying QR codes. Their system was
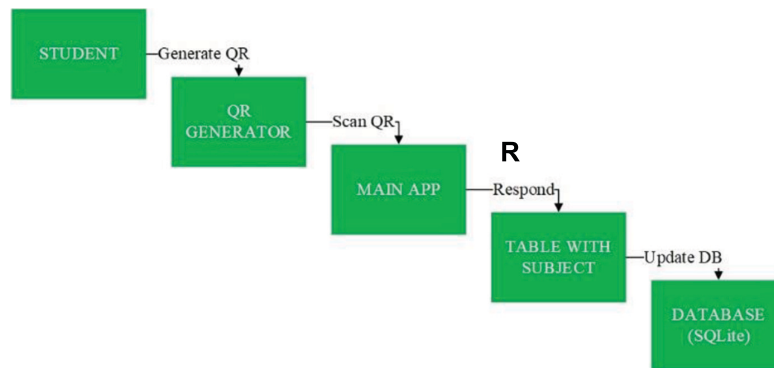

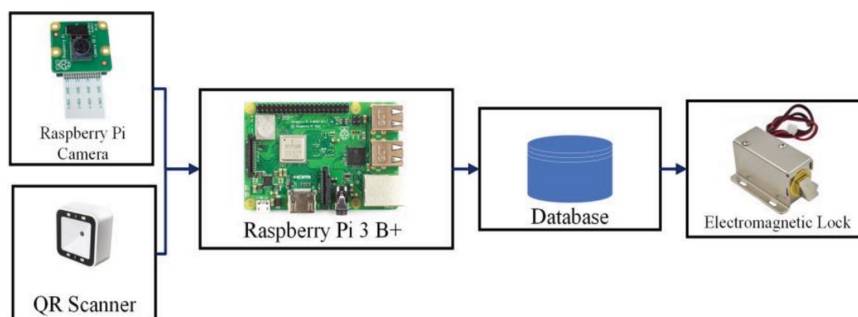**FIGURE 10 |** System Sequence of Wei et al. (23).
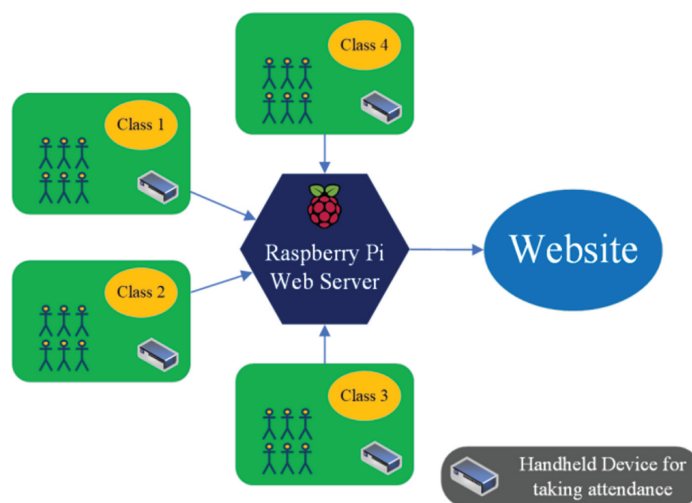

FIGURE 11 | System Design of Fauzi et al. (24).

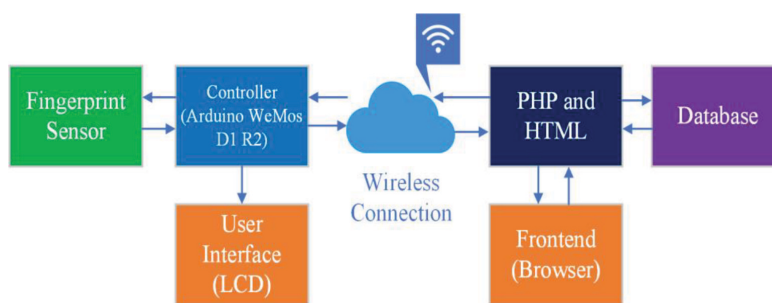**FIGURE 12 |** System Architecture of Shailendra et al. (25).

FIGURE 13 | Overall Design of Asabere et al. (30).

FIGURE 14 | Various Technologies Used for Attendance Management System.

built with PhP, MySQL, and Apache based on WAMP Server. The application would prompt registration for the first time and then be logged in to take attendance by generating

QR codes. The codes can be scanned with a mobile device, and hence attendance can be taken, and then reports are generated *via* checklists and can be printed. Their system provides very minimal functionality yet gives one of the first ideas about implementing QR codes in an attendance management system, which is shown in **Figure 9**.

An enhanced version of MRM Hendry et al.'s (22) research is the research by the next group of researchers. Xiong Wei et al. (23) in their research paper made a system for smart attendance system with QR codes with functionalities such as student details, subject details, and report export as csv. They have used SQLite Database as their primary data storage technology. Their whole system is based on Android applications. Both the teacher and student interact with the system through an app. This system is very suitable for small classrooms but not good for big ones because of this very reason. The researchers conclude that integration with facial recognition would prove the system more secure. Their system's idea of sequence is shown in **Figure 10**.

Ahmad Fahmi Mohd Fauzi et al. (24) showcased a quite different kind of system that functions both as a web-based smart door lock system as well as an attendance management system, although the main focus is on the smart door itself. In fact, their system is one of the few projects out there that uses both a facial recognition system and a QR code system

TABLE 1 | Advantages and Disadvantages of Existing Attendance Management System Technologies.

No.	Method	Hardware	Software	Advantage	Disadvantage
1	Biometric attendance	Fingerprint reader, Retina scan machine	Custom software, Server software, DBMS	Automatic	Cost of machine and maintenance
2	RFID	RFID reader, RFID tags	Custom software, DBMS	Automatic	
4	Facial recognition	Infrared camera, Server	Facial recognition software, Server software, DBMS	Automatic	
4	QR code	Camera, QR or Barcode scanner, Server	DBMS, Server software	Sub- automatic, cheap	
5	Embedded systems	Microcontroller (Arduino/ATMEGA), Single Board Computer (SBC) e.g., Raspberry Pi + Other detection technology	Server software, DBMS	Automatic, easily deployable	Needs expert to operate

in conjunction. Their proposed system has the raspberry pi working with a camera that scans the static QR code on the student's or staff's ID card and matches it with the QR code stored on the database. The researchers conclude that the efficiency of this method needs to be further evaluated in the future as this is a preliminary work. Their research's system design is portrayed in **Figure 11**.

Their proposed system, according to **Figure 11**, has the raspberry pi working with a camera that scans the static QR code on the student's or staff's ID card and matches it with the QR code stored on the database. The researchers conclude that the efficiency of this method needs to be further evaluated in the future as this is a preliminary work.

Embedded systems-based attendance systems

A combination of hardware and software designed and deployed for a specific function is called an embed system. Such a system is also able to run inside larger systems. Usually, this system has a finite set of functions. In terms of attendance management systems or attendance methods using technology, embedded systems along with various sensors are used. A design and framework for taking attendance in schools and colleges using the AVR ATMEGA16 of ATMEL, a low-power CMOS 8-bit microcontroller, as the handheld client and the Raspberry Pi as the server were presented by Shailendra et al. (25). The system architecture uses the raspberry pi as the main server, while the ATMEGA-powered handheld device with Xbee is in every class like a zonal model (26) (**Figure 12**).

The system design in **Figure 12** shows an example of a single board computer-based attendance system where the raspberry pi is connected by the ATMEGA-powered handheld device – both are the backbones of the two-part system. In their paper, Swarnendu Ghosh et al. (27) used biometric sensor with Arduino uno. This is an example of technologies being used in conjunction. The Arduino attendance module consisted of the Arduino UNO, fingerprint sensor, Bluetooth sensor, and an LCD was named

the SAS module or Smart Attendance System Module. An Android application was also made and could connect to the module using Bluetooth for management. This kind of combination and application through the connection of an Arduino with an application using Bluetooth or another medium is novel and very practical. Other applications, such as virtual reality and exergames (28), use this kind of communication. Arduino and RFID are also used in combination in many projects such as Arbain et al.'s (29) LAS, which is a web-based laboratory attendance system. They used RFID tags inside ID cards as a medium of attendance for staffs controlled by Arduino, which can connect to the system using a USB connection. Asabere et al. (30) in their paper constructed an attendance system with a fingerprint module and an Arduino Wemos D1 ESP8266 (**Figure 14**).

From their overall system design in **Figure 14**, three technologies, namely, biometric, microcontroller, and Wi-Fi. are used in conjunction. The figure also shows an example of a microcontroller-based attendance system where the Arduino board is the main backbone of the system. **Table 1** compares the different types of attendance systems based on the advantages and disadvantages of the technologies used in them.

According to **Table 1**, biometric attendance, RFID, facial recognition, QR code all require devices and maintenance. All the available technologies require server software and a DBMS as a common requirement to operate. Embedded systems and QR code-based attendance systems are the cheapest and easiest to deploy due to their size. QR code systems are the ones that are sub-automatic as they require clients to scan the QR code themselves.

Conclusion

Finally, based on the survey and discussion above, the attendance management system uses four different techniques, at least one subclass of this technique, such as fingerprint reading under biometrics or NFC under RFID. These are shown in detail in the illustration (22).

As shown in **Figure 14**, attendance management systems can be classified into four basic types based on the technologies used. The first type, biometrics, can be divided into two types: fingerprint and iris. The second type, RFID, can be divided into two types as well: NFC and RFID Tag. The third type, facial recognition, can utilize two methods. They are normal camera, which are used typically to take photos, and the second is IR-based camera. Examples for IR-based cameras are night-vision cameras and CCTV cameras. These are more accurate than normal cameras. The last and final category is QR. Usually QR is application-based. On that basis of methodology, it can be divided into two more categories: Web-based and App-based. Each of these technologies can be used in combination with others to make the system more secure. The last type, embedded systems, can be an example of this statement. The main division of this type is microcontroller-based and single-board computer (SBC)-based. In conclusion, there are different ways a problem can be solved. For attendance management system, the most feasible design seems to be when cloud technologies (31–39) and service robots, deep learning, etc., (40–53) are used in conjunction. Attendance management systems are not just required for schools, colleges, or educational institutions. They are widely used in any place where labor is the main workforce. Software companies, movie studios, and industries require a lot of manpower to function. There may be classified work going on even now. Keeping track of them is vital for the development of the said organization. In this paper, we list the various prominent types of technologies to do exactly that as the world grows and more and more people go toward work better solutions are needed by integrating the most prominent technologies.

Author contributions

AM, LL, AR, and MG: conceptualization. MG and AA: methodology. AM, AR, LL, HL, MG, AA, and SB: investigation. HL, MG, and AA: resources. AM, AR, and HL: writing—original draft preparation. AM, AR, and MG: writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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