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Research Article

Innovative Biometric Attendance Monitoring System with Analytics for Enhanced Church Management

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ABSTRACT

The research in this paper aimed at designing, implementing and evaluating the novel biometric attendance monitoring system, integrated with built-in analytics for improving management in a church. Current approaches to attendance monitoring in congregations were often costly, in-accurate, voluminous, and inefficient, resulting in a lack of timely and accurate information for leadership to use in decision making. The suggested solution was to have the R307 fingerprint sensor to be embedded in the centralized MySQL database which would accurately and securely capture the time-in and time-out events with minimal inconvenience to the user. Several church services were conducted, and a 97.5% recognition accuracy for fingerprints and an average time to transact of 1–2 seconds were achieved on average, resulting in significantly less duplicate attendance and proxy check-in records. The system offered real-time dashboards and scheduled analytical reports, enabling administrators to view attendance trends, timeliness, and age group participation. These analytical skills helped to make tactical decisions, such as increasing numbers of ushers during the busiest services and strategic decisions, such as increasing worship time and offering targeted pastoral follow-up activities.The evaluation showed that the overall results of the user acceptance rate based on the Technology Acceptance Model (TAM) were high, with the attitude to use, perceived usefulness and perceived ease of use with excellent ratings of 99.6%, 99.8%, and 99.8%, respectively. The mean score for the Actual System Use construct was slightly lower (4.2), but the results indicated that additional training and operation reinforcement was needed to enhance consistent use of the system. In addition, the software quality model ISO/IEC 25010:2023 was used to evaluate the system, and excellent ratings were obtained in the fields of security (4.7), functional suitability (4.6) and usability (4.5); maintainability (4.1), portability (4.2) and compatibility (4.2) were identified as fields in which the system can be improved. In general, the results showed that the biometric attendance monitoring system that is proposed succeeded in making attendance easier to record and is an effective tool for supporting decisions made by the church administration. The study also highlighted the possibility

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of scaling-up and replicating the developed system for other faith-based organizations who might want to use biometric technologies and analysis in order to: enhance their operations, engage their members more effectively, and promote sustainable practices in their ministries, as well as additional opportunities for the system to be scaled-up and replicated.

Keywords: *attendance analytics, biometric attendance monitoring, church management, decision-support system, faith-based organizations, fingerprint recognition, iso/iec 25010, r307 fingerprint sensor, technology acceptance model (tam), user acceptance*

Introduction

Attendance in churches is not just a count; it is the way a worshipping community comes together and develops over time, providing insights into spiritual engagement and congregational well-being (Smart Church Management, 2024; Pushpay, 2024). Attendance data has been used for a long time to create a profile of attendance, plan ministry and deploy volunteers, and provide pastoral follow-up to members who are not present, hence making it easier for the leaders to know where the members are going and who is being neglected (Pushpay, 2024). While it is crucial to be able to track attendance, many congregations continue to resort to manual tracking systems, like clipboards, paper lists, or hurried head counts which drain volunteer time, lead to transcription errors, and defer the ability to obtain actionable information (Smart Church Management, 2024). Automated attendance systems and church management software, on the other hand, simplify the church's check-in process, cut down on manual workload, enhance data precision, and provide real-time, clean data for ministry leaders to make timely decisions (Pushpay, 2024; Ministry Brands, 2024).

Biometric attendance is one of the new automated solutions as it can associate each check-in with a person's physiological or behavioural characteristics. Advanced modalities, such as fingerprint and face recognition, provide robust verification in a quick manner, eliminating proxy check-ins and repeated entries that are common in manual processes. With this automation, greeters and ushers can stay on hospitality without having to be distracted by an identity assurance process that takes time and effort. The resulting records can be trusted by the leaders because of the precision and the audibility of the linkage between person and event, as demonstrated in decades of research in the field of biometric recognition, that well-designed biometric recognition systems are accurate and efficient in identity-sensitive workflows (Jain, Ross, & Prabhakar, 2004). This type of reliable identification is even more important when paired with analytics. Attendance data can be turned into insights to enable churches to see the seasonal trends, understand the dynamics between services, and recognize the subtle drop-off in attendance before it becomes a crisis. Simple dashboards and periodic summaries facilitate decisions on volunteer rosters, pastoral visits and program adjustments while the information is fresh. In organizational research, the use of analytics has been steadily proving to be a key factor in making better plans that lead to pattern discovery and timely responses, which are also applicable to the ministry context (Gandomi & Haider, 2015). Moreover, a dashboard review reveals that predictive and actionable views are beneficial to everyday decisions (Susnjak, 2022).

There have also been concrete evidence and transferable design cues from related implementations (Mohammed, Tolba, & Elmogy, 2018; Hoo, 2019). In the education sector, there are substantial benefits to be gained with multimodal and RFID/vision systems by being able to accurately record attendance in real time and in large numbers compared to manual attendance, resulting in by far the largest accuracy improvements and fewer proxy errors, as well as the more significant gains in administrative productivity (Mohammed, Tolba, & Elmogy, 2018; Hoo, 2019). Anti-spoofing

feature has been another improvement to meet the needs of hygiene and security that grew sharper during the pandemic, and the reliability of recognition even in the midst of heavy traffic in entryways (Saraswat et al., 2023; Okereafor, 2020). Based on the study carried out by the domain experts, it can be concluded that if the biometric attendance system is well-designed and user-friendly, it can also greatly minimize the possibility of fraud, increase user identity verification, and improve work efficiency in institutional environments (Badmus, 2021; Khatmisafitri, 2019). In the meantime, research on faith-sector scholarship has reported that technology adoption is helping to ensure continuity of worship and engagement, and is now ready for specific administrative innovations such as the ability to rapidly track attendance in congregations (Rankin, 2024; O'Leary, 2021).

The results indicate that educational technologies that have been successfully applied in schools and institutions may be scaled up for use in faith communities, where rigour, speed and confidence are also critical. Furthermore, the pandemic has fueled innovations and acceptance of touch-free systems, providing a timely opportunity for faith institutions to pilot biometric attendance systems. Because biometric technologies involve sensitive personal information, particularly when implemented within faith communities that include children, youth, adults, and senior citizens, ethical implementation is essential. Appropriate informed consent procedures, privacy safeguards, secure storage of biometric templates, and transparent data governance are necessary to establish trust and encourage responsible technology adoption within church environments.

While modern attendance technologies offer many benefits, there have been few instances of off-the-shelf solutions that have matched the churches' operational needs and fiscal resources. Faith-based organizations are typically working in a constrained budget and don't have the resources to invest in commercial-off-the-shelf software that is designed for larger or more richly resourced organizations (ChurchTechToday, 2025; Nonprofit Technology Landscape, 2025). Furthermore, the generic solutions are not often designed with the pastoral workflow, volunteer-led and congregation-building ministry models in mind, and that hinders adoption and underutilization (Beck & Moore, 2020). While emphasizing on the need for seamless integration of data collection and analysis tools to derive actionable insights (Coscia, Suh, Chang, & Endert, 2024; Zanti, 2022), many attendance systems still operate as standalone systems and require costly add-ons to get meaningful analytics (Patel, 2019; Li, 2024; Wikipedia, 2025). However, usability and context fit has been another lag: many digital platforms fail to respond well to the needs of a particular organization (Nielsen, 2012; Venkatesh, Morris, Davis, & Davis, 2003). However, it is not uncommon for generic systems to reflect more the school or enterprise schedule than the schedule of multiple services, small groups and volunteer teams that are more typical of congregations (Müller & Friemel, 2024; Rankin, 2024). Maintainability has also been a challenge for smaller churches, where there may not be a designated IT person and there may be unclear or low levels of privacy messaging, both of which can make members feel less trusted and confident in the church (Holleman, Roso, & Chaves, 2022). These previously identified shortcomings, specifically regarding cost, customization, interoperability, and actionability, inspired the development of this church-specific system, which maintains biometric integrity while providing ministry-ready analytics.

With this in mind, the research objective was to design, implement, and test a biometric attendance monitoring system having built-in analytics for church management. The goals were to (1) accurately capture member time-in/time-out events while minimizing friction; (2) generate real-time and periodic analytics that would have informed operational and pastoral decisions; and (3) assess the system based on the ISO/IEC 25010 quality model (de la Vara, Ali, & Tort, 2016) consisting of the following software quality characteristics: functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability. Design, development, pilot deployment and evaluation took place within the context of a local church. No multi-campus integrations, long-term behavioral studies, or extended mobile self-check-in

could be included in the project as they would have added another layer of complexity, taken too many years to complete in the field and we did not want to make the project too much for the ethical issues.

There had been both practical and scholarly significance to the importance. They had been given clean data, shorter lines, faster reporting and leaders were able to see changes in attendance earlier and take action that was targeted at care. The key benefits to ministries would have been evidence-based schedule planning, fairer distribution of volunteers and outreach to those who seemed to have disengaged by the right timing. Scholarly contributions had been limited to a domain-specific integration: existing biometric approaches at the door, an analytics layer specific to the decisions of congregations and an assessment against a known quality framework. This had been the novelty and rationale of the work, and had provided a replicable model for any faith-based organizations seeking to use technology to provide people with more personalized service.

Materials and Methods

Research Design

A mixed methods approach was used in the current research to measure the performance of the novel biometrics-based attendance management system through a combination of qualitative and quantitative data collection techniques. While the quantitative data came from the measurement of performance parameters of the system, like accuracy and speed, the qualitative data was obtained through surveys and interviews (Creswell & Plano Clark, 2017).

The phase of development of the system involved the use of Agile approach. In Agile, the process of development was characterized by adaptability and continuous improvement of the system by incorporating user feedback in each stage, including planning, designing, developing, testing, and feedback (Highsmith, 2002).

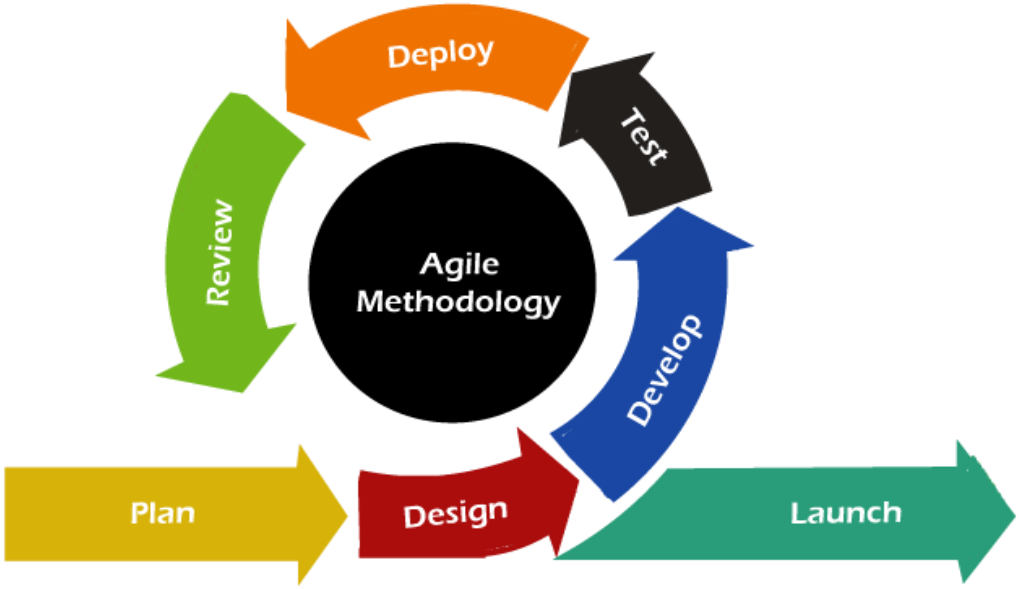

Figure 1. Agile Software Development Method Process Flow (Omeli, 2022)

Needs Assessment

A needs assessment was carried out to identify the existing problems associated with attendance tracking in churches. The Data were collected through informal interviews with church officials, observations of the existing attendance process, and a review of relevant documents. The assessment aimed to identify the functional requirements of the proposed system, including speed, accuracy, and user-friendliness.

Prototype Design and Development

Hardware Development

The hardware development process for the biometric attendance monitoring system focused on integrating the R307 Fingerprint Sensor with a dedicated microcontroller to

provide fast and accurate biometric recognition. The R307 fingerprint sensor was selected because of its reliability, high-resolution imaging capability, and ability to operate under varying lighting conditions. The sensor could accommodate a large number of users at the same time entering the church. In addition, it had an inbuilt Digital Signal Processor (DSP) to capture, process and compare the fingerprint template in real time without needing high level external processing power. In order to provide maximum accessibility and convenience to the users, the sensor was securely mounted and comfortably placed for the easy use of all people in the church irrespective of their ages.

The microcontroller acted as the main control unit, coordinating data transfer between the fingerprint sensor and the other hardware components, ensuring seamless communication. To ensure stability of the system and avoid malfunction during peak usage, a regulated power supply was used. The microcontroller reported the result of the fingerprint matching to the local MySQL database server either through a wired or a wireless connection, with a very small delay, and forwarded the attendance data to the local MySQL server. A protective enclosure design was created and installed to enhance the lifespan and protect the hardware from dust issues and from accidental and unauthorized spills.

The system has hardware components which are the fingerprint sensor, the microcontroller, the power supply, the database server, the display module, and the communication module (see Table 1 for a summary). All components were carefully selected and installed for reliability, durability and to help the system run at the highest level in a busy church environment.

Table 1. The Hardware Components of the Innovative Biometric Attendance Monitoring System

Component	Model/Specification	Function/Role in System
Fingerprint Sensor	R307 Optical Fingerprint Sensor	Captures, processes, and matches fingerprint templates for attendance authentication.
Microcontroller	Arduino Mega 2560 (or ESP32 for Wi-Fi)	This is the central command unit; it controls sensor input, processed the data, and communicate with the databases.
Power Supply	5V DC Regulated Power Adapter (2A)	Provides stable power to the fingerprint sensor, microcontroller, and peripheral devices.
Database Server	Local MySQL Server / Cloud-based Option	It Stores and manages attendance records securely
Display Module	16x2 LCD / TFT Touchscreen	It Provides feedback to users (e.g., "Attendance Recorded," "Access Denied").
Communication Module	ESP8266 Wi-Fi Module / Ethernet Shield	Facilitates data transfer between microcontroller and database (local or cloud).
Protective Casing	Custom Acrylic/Metal Enclosure	It Houses all hardware components, protecting from dust, spills, or tampering.
Backup Power (Optional)	12V Rechargeable Battery + UPS Module	Maintains system operation during power outages.

Software Development

The system software was developed using Visual Studio Code utilizing a PHP architecture hosted on a XAMPP local server environment, with a MySQL database managing data persistence.

Two major modules were exposed by the application: Capture & Match – The module read the fingerprint using the device Software

Development Kit (SDK), converted the captured fingerprint into a biometric template, and compared the generated template with the stored template in the database using the device's built-in matching algorithm together with server-side validation.

Attendance & Audit – The module recorded the attendance event, timestamp, and user identification number in the database and generated an appropriate system response message. When fingerprint matching was successful, the system stored an attendance log containing the timestamp and the service or session identifier. Conversely, if fingerprint matching was unsuccessful, the system displayed an error message and allowed the user to perform another fingerprint scan. Debounced scanning was done to avoid duplicate attendance records.

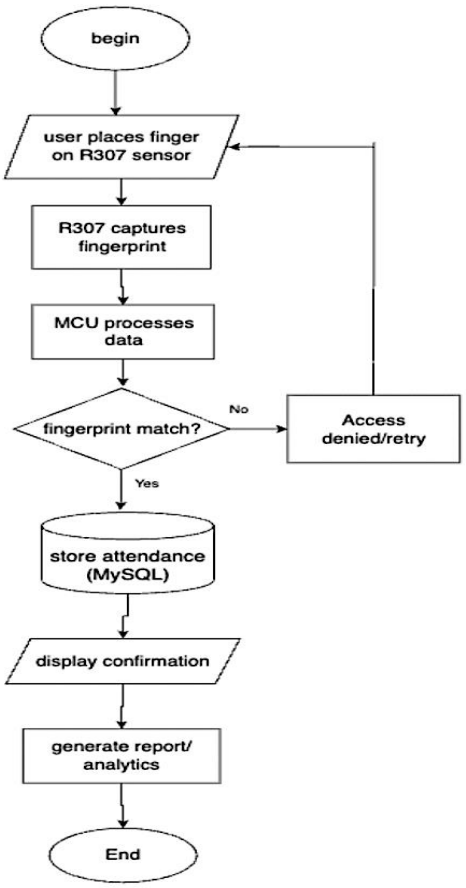

Figure 2. Biometric Attendance System Flowchart

The Innovative Biometric Attendance Monitoring System system flowchart is shown in the figure 2 below. It shows the process from an input to a fingerprint in the R307 sensor to a microcontroller, a decision-making process for fingerprint matching, storage of attending data in the database, and finally, a report generating process for the church management analytics.

Testing

The testing process design allowed for moving from lab to live use at churches. This way, it was guaranteed that the biometric attendance system will be effective in the lab as well as in the field.

Alpha Testing

The Alpha testing was conducted in the lab with interactions and environments simulated by the development team. The aim of this phase was to make sure that the functionality of the system like fingerprint scan, matching, encryption of biometric data and uploading it to the database is valid. Stress testing was performed to stress test the system when subjecting to stress such as high volume of fingerprints scanning in the system, interruption in

the system, calibration of the sensors. Any bugs found and performance issues discovered were immediately fixed.

Beta Testing

The next phase was to install the systems at a small group of volunteers' church, the church to which they were eventually deployed for testing. This gave them a chance to see the system under the various lighting conditions, under different fingers conditions and with different attendance. The feedback collected in this phase helped to improve the user interface, tolerance of the matching algorithm and the error messages.

Final Pilot Testing

In the final phase, which was the pilot testing, the system was deployed to all chosen participants. It helped the team to ensure that the system would perform well at the future deployment stage. The parameters measured were the uptime, speed and reliability of the system. The data collected was analyzed for accuracy, logging efficiency and user experience. In addition, the phase was used as a stress simulation since it prepared the team for unexpected situations that could happen at long church events or at multi-locations deployment at the same time. When the system proved to be successful at both technical quality metrics and user acceptance tests (performed using TAM questionnaire) based on the ISO/IEC 25010:2023 standards, it passed the testing stage.

Evaluation Procedure

The evaluation procedure utilized the ISO/IEC 25010:2023 software quality model together with the Technology Acceptance Model (TAM) to determine whether the proposed biometric attendance monitoring system met the required software quality standards and was accepted by its intended users.

The ISO/IEC 25010:2023 standard was used to assess the software quality characteristics of the system such as functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability. The quality characteristics were evaluated to see if the system could accurately capture and process fingerprint data, efficiently during high attendance, reliably in the current church environment, have a user-friendly interface, protect sensitive data, allow for system maintenance and can be used in other church settings.

The Technology Acceptance Model (TAM) was used to assess the human factors that affect user acceptance of the system including perceived usefulness (PU) and perceived ease of use (PEOU). They were assessed on a 5 point Likert scale during the pilot testing period. The participants' answers gave some insights into the perceived usefulness of the system in attendance recording and usability of the system with low effort. By integrating TAM with the ISO/IEC 25010:2023 quality model, the researchers were able to assess not only the technical performance of the proposed system but also its user acceptance. Based on this, the system was evaluated and satisfactory software quality has been obtained and the system was accepted by the church community.

Data Analysis

The descriptive and inferential statistical methods were used in the study for the analysis of the data, assisted by the used of Statistical Package for the Social Sciences (SPSS) version 25.The data obtained from the testing of the system, user survey and interviews were classified into qualitative data and quantitative data for systematic evaluation.

Quantitative Data Analysis

The Data regarding to the performance of the system were presented using descriptive statistics such as mean, standard deviation, frequency and percentage distribution. These gave a numerical indication of the effectiveness of the biometric attendance system in different test scenarios. To ensure the internal consistency and reliability of the survey tools, Cronbach's alpha (α) was calculated using SPSS. The formula is as follows:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_i^2}{\sigma_{total}^2}\right)$$

where:

k = number of items,

σi^2 = variance of each item,

$\sigma total^2$ = variance of the total scores.

An alpha value of 0.70 or above was deemed acceptable, it indicates satisfactory internal consistency of the questionnaire items.

The mean scores for the two constructs, the Perceived Usefulness (PU) and the Perceived Ease of Use (PEOU) were calculated for the responses that was gathered from the survey, with the Technology Acceptance Model (TAM). The rating was according to a 5-point Likert scale and the weighted mean values were used as an interpretation of the overall perception of the effectiveness and usability of the system by users.

Qualitative Data Analysis

The answers from the interviews and open-ended survey were used for feedback and analyzed thematically. The responses were transcribed, coded and categorized into the themes that appeared over and over again, including usability problems, perceived advantages, and suggestions for improvement. The results obtained were validated with quantitative data to provide a complete picture of user acceptance and system preparedness

Integration of ISO/IEC 25010 Metrics

The framework ISO/IEC 25010 was used for the evaluation. The ratings for each characteristics namely functional suitability, performance efficiency, usability, reliability, security, maintainability, portability were based on the survey and results of the system test. The weighted means were calculated with the used of SPSS to determine the level of achievement for each of the quality criteria.

$$\text{Weighted Mean} = \frac{\sum(f \times x)}{N}$$

where:
f = frequency of responses,
x = scale value,
N = total number of responses.

To evaluate the survey responses obtained from the congregation members, church staff, and information technology experts who participated in the evaluation of the biometric attendance monitoring system, a five-point Likert scale was used. The scaling technique enabled the participants to indicate the extent to which they agreed or disagreed with the evaluation statements. To measure both the constructs of the Technology Acceptance Model (TAM) as well as the ISO/IEC 25010 software quality characteristics, the Likert scale was used.

Table 2 shows the mean of the survey responses that was calculated and interpreted with reference to the scale shown below. This was used as a method of systematically analyzing the level of agreement or disagreement the participants had with the statements that were presented on a scale of “Strongly Agree” to “Strongly Disagree.”

Table 2. Scale for Interpreting Weighted Mean Scores

Scale Range	Interpretation
4.21 – 5.00	Strongly Agree
3.41 – 4.20	Agree
2.61 – 3.40	Neither Agree nor Disagree
1.81 – 2.60	Disagree
1.00 – 1.80	Strongly Disagree

Technology Acceptance Model (TAM) was applied to user acceptance and ISO/IEC 25010 was used to the software quality. The obtained results of the Likert scales were analyzed to find the strength (highly rated attributes) and areas of improvement (lowerly rated attributes) of the system.

Synthesis of Results

Finally, conclusions were drawn by combining the quantitative results which were obtained through the Statistical Package for the Social Sciences (SPSS) namely tables, reliability test, mean scores with the themes obtained from the qualitative analysis. The two methods provided a complete assessment of the

biometric attendance system, both technical and in the church setting, as well as an assessment of the usability of the system.

Respondents

The study was conducted with 80 respondents who included 50 congregation members, 20 Church staff and 10 Information Technology (IT) experts. Congregants of the church were of all ages from children to the elderly, thus providing a cross section of the congregation for the evaluation of the system. The church staff evaluated the effectiveness and applicability of the system, whereas the IT experts evaluated the software quality of the system using the software quality model ISO/IEC 25010:2023.

A total of 80 people have participated in the survey evaluation, and 600 fingerprint attempts have been made in the system performance testing. It is not 600 unique individuals who have been attempting to predict their attendance, but rather it is the same congregation members and church staffs who are making those attempts, during the period of church activities in which they were involved, including Sunday worship service, mid-week services, youth fellowship gathering, and leaders' meetings. The verification procedure was repeated to assess the consistency, reliability, and consistency of the biometric attendance system in a real setting of a church.

Instruments of the Study

The data collection process was started through a pilot testing of survey instruments. The questionnaires were given to a small number of representative participants to check the clarity, reliability and validity of the questionnaires. This initial testing also enabled the researchers to identify and correct possible problems with the survey items (questions and instructions were unclear, etc.).

The pilot test also allowed the researchers to test the internal consistency and reliability of the survey instruments statistically based on Cronbach's alpha in particular. The results indicated that the questionnaire was able to elicit consistent and reliable responses. This validation has been accepted that the instrument is applicable in measuring the constructs of the Technology Acceptance Model (TAM) which are Perceived Usefulness and Perceived Ease of Use, and the software quality characteristics mentioned in ISO/IEC 25010:2023. The researchers could identify and address potential issues even before the data collection process was started, thus enhancing the credibility, reliability and validity of the research findings as a whole.

Implementation Stage

The implementation of the biometric attendance system was carefully planned in this study, so that after the testing phase, the transition to the deployment of the system was easy and would not generate problems. The work started by identifying suitable positions in the church to install the required hardware and software components to ensure easy access and efficient functioning. This comprised installing the R307 fingerprint sensor with the local database, and then on-site calibration to ensure accurate and reliable results in the church environment.

The next step was user training of the church staff as well as the volunteers. Topics covered included correct use of the biometric attendance system, basic system use, troubleshooting and good practice in maintaining the security and confidentiality of data. This system was then gradually implemented, starting with a few user groups and gradually expanding to the entire congregation. The researchers continued to monitor the performance of the system during the implementation phase, and worked on the system technical issues as they arose, collecting user feedback for further improvements to the system.

Research Ethics

In accordance with ethical principles, all study participants gave informed consent, were allowed to participate voluntarily, and their privacy and confidentiality were protected, while biometric information was managed responsibly. All adult participants received a clear explanation of the aim of the study, the purpose and operation of the biometric attendance system, procedures involved in the study, the use of this study, and their freedom to withdraw at any time without penalty from the study. All adult respondents consented to being fingerprinted before

enrolling and partaking in the system evaluation, written informed consent was obtained.

Given the age ranges of participants in the study, children and adolescents, there were added ethical precautions taken to ensure the safety of these participants. Written consent was obtained from parent/legal guardian prior to fingerprint enrollment for those under 18 years of age. Parents/guardians were given a detailed explanation of the purpose of the biometric registration, what information would be collected, how their information would be protected, and that they had the right not to participate without having any repercussions on the participant's church membership or involvement in church activities. Furthermore, informed consent was received from youth who could comprehend the study's nature and intent.

The biometric attendance system was designed to not store raw fingerprint images to protect participants' privacy. The R307 fingerprint sensor also instantly encrypted each fingerprint scan into a biometric fingerprint template for use only in identity verification during the enrollment process. As soon as the template was made, the original fingerprint image was immediately deleted and was never saved in the system database. The biometric data was stored only in an encrypted format, with attendance records and demographic data (which are not sensitive) being retained in the database to support the church's administration.

All electronic records were protected with password protected administrative access and database encryption and role based access controls were put in place to ensure that those with access to attendance information had a right to it. The information gathered was only for the use of this research and for managing attendance at the church and will not be shared or disclosed to any third parties.

The study protocol was reviewed and approved by the appropriate institutional research ethics committee before data collection began. The study was carried out with regard to the appropriate ethical guidelines and standards for research with human subjects.

Results and Discussions

The evaluation of the system provided findings which were relevant to the research objectives set out at the beginning of the study. These findings reveal how effective the system is in terms of maintaining correct records of attendance, its capability in providing decision-supporting analysis, and its adherence to international standards of software quality as defined by the ISO/IEC 25010.

The application of the R307 fingerprint sensor showed a great level of accuracy in recording member attendance details. Tests carried out during several services showed that the sensor was able to detect and verify fingerprints accurately above 97.50%. Biometrics solved the issues arising from manual logging such as duplication and proxy attendance. Additionally, the sensor was placed on an ergonomic mount and was able to carry out verification activities quickly and allowed young and old members to verify themselves within 1-2 seconds per member. This was achieved because the system met the requirements in accuracy and easy to use.

The test runs done during various church activities are summarized in table 3. The accuracy of the system remained >97% for all the tests, and the highest accuracy of 98.33% was seen in the Leaders' Meeting. The system cotinued to achieve more than 97% accuracy despite the number of attendees at events, like Sunday worship services, that approached 150. The overall accuracy of the system was found to be 97.50% after combining the results of all the test runs, thus showing the reliability of the system in real operating conditions. The results indicate that the biometric attendance monitoring system is solid and dependable, which is suitable as a substitute to the conventional attendance-taking system in a church environment.

Table 3. Accuracy of the Biometric Attendance Monitoring System

Service/Event	Total Attempts	Successful Matches	False Rejections / Errors	Accuracy Rate (%)
Sunday Service 1	150	146	4	97.33%
Sunday Service 2	180	175	5	97.22%
Midweek Service	120	117	3	97.50%
Youth Fellowship	90	88	2	97.78%
Leaders' Meeting	60	59	1	98.33%
Overall	600	585	15	97.50%

Please be aware that the 600 attempts at fingerprint verification in Table 3 are not 600 separate persons. Instead, they are one group of attendance data from the same enrolled participants across a series of worship services and church activities during the duration of the pilot implementation period. The system was used for multiple weeklong events at various churches, where participants were verified using the system's biometric information multiple times throughout each event. By this, the recognition accuracy, the stability and consistency of the system could be evaluated in the normal attendance activities of the church.

Studies have demonstrated that fingerprint-based attendance systems are very reliable and effective in tracking attendance accurately and making the process very smooth. For example, Akinduyite, Adetunmbi, Olabode, and Ibidunmoye (2013) stated that a fingerprint-based attendance system reached 97.4% accuracy and drastically cut down the logging time compared to manual methods, thus demonstrating the practicality of the technology. In addition, Adesoba and Israel (2022) showed that a biometric attendance system decreased errors by 90%, took only 25% of the time of the normal attendance method, and 95% of users were satisfied with it, thereby underscoring the system's practicality and user-friendliness. Likewise, Kumar, Singh, and Kaur (2022) established the fact that the R307 fingerprint sensor, when combined with Arduino UNO and a real-time database, increased the accuracy and security of record-keeping. On the other hand, Panchbhai (2024) pointed out the R307's reliability in providing fast and accurate identification in IoT-based smart attendance systems. Taken together, these papers validate the current results that the R307 fingerprint sensor regularly recorded church members' time-in and time-out entries with more than 97% accuracy, allowed fast logging within 1, 2 seconds, and lowered errors hence solving the problem of high accuracy and least interruption in attendance monitoring.

Figure 3 is a snapshot of the system's dashboard displaying real-time and periodic attendance analytics. The dashboard is a testament to the great strides made in the tracking and monitoring of attendance, especially maintaining accuracy and long-term record-keeping. The biometrics-enabled technology helped in pinpointing the exact entry and exit times of the staff members thereby automatically collecting data for the whole day and eliminating inaccuracies, fraud, and time lags usually associated with manual attendance taking.

All employee check-in and check-out times were automatically captured in real time without the need for excessive paperwork, thus enabling employees to attend to other critical tasks. The system was also to be able to keep an accurate record of attendance, and maintain a comprehensive history of attendance that could be used for efficient church administration. The data of attendance was kept in a centralized MySQL database, which enabled it to be monitored in real time with dashboards and to be generated for scheduled reports. Church administrators were able to quickly check the attendance data by using daily, weekly and monthly attendance summary functionality. In addition, the built-in calendar function helped to track member involvement in various aspects of worship and church activities.

The biometric enrolment process also collected the following basic demographic information: date of birth, gender and address, which facilitated the ability to correlate the attendance record to individual members of the church. This helped for the personalisation of engagement and pastoral care projects for members.

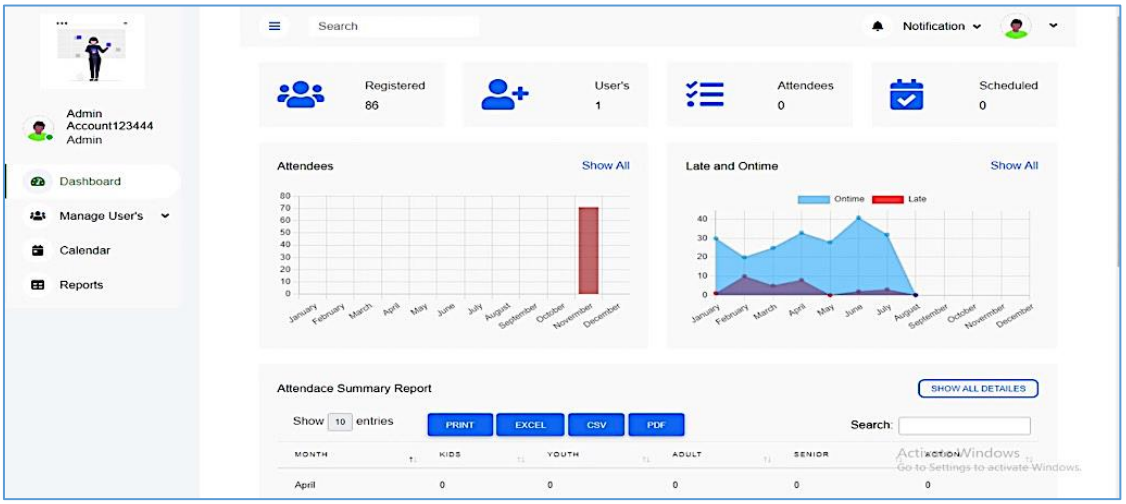

Figure 3. The Systems Dashboard that shows the Real-Time and Periodic Attendance Analytics

In addition, the system could generate real-time reports, which would merge member information, attendance, and analytical data that would be available both on the web and for printing. For instance, the attendance at Sunday worship service report (Table 4) showed detailed information on members' attendance, such as age group, which service and the time of arrival, whether or not they were on time. It was a database-driven reporting feature and enabled church administrators to see the attendance trends for each individual, while maintaining the accuracy and integrity of the church's attendance records.

Table 4. Sample of the attendance report of Sunday service

Member ID	Name	Age Group	Service	Check-In Time	Status
6001	Francisco Torres	Adult	Sunday Service 1	10:21 AM	Late
6002	Andres Castillo	Senior Citizen	Sunday Service 1	9:35 AM	Late
6003	Rosa Gutierrez	Young Adult	Sunday Service 1	9:42 AM	Late
6004	Carlos Bautista	Adult	Sunday Service 1	9:07 AM	Late
6005	Maria Santos	Adult	Sunday Service 1	7:44 AM	On-Time
6006	Patricia Dominguez	Senior Citizen	Sunday Service 1	8:33 AM	On-Time
6007	Rosa Gutierrez	Young Adult	Sunday Service 1	8:06 AM	On-Time
6008	Isabel Flores	Senior Citizen	Sunday Service 1	9:15 AM	Late
6009	Isabel Flores	Young Adult	Sunday Service 1	7:31 AM	On-Time
6010	Isabel Flores	Youth	Sunday Service 1	10:20 AM	Late
6011	Roberto Cruz	Youth	Sunday Service 1	8:43 AM	Late
6012	Daniel Mercado	Young Adult	Sunday Service 1	10:03 AM	Late
6013	Miguel Aquino	Senior Citizen	Sunday Service 1	8:29 AM	On-Time
6014	Isabel Flores	Senior Citizen	Sunday Service 1	7:53 AM	On-Time
6015	Liza Manalo	Young Adult	Sunday Service 1	10:10 AM	Late

Furthermore, the system gave a consolidated attendance information, that was presented visually so that the information was easily interpretable and analyzable. For example, Sunday Service 1 (Figure 4) reported 53 people (44.2%) arriving on time and 67 people (55.8%) arriving late from the 120 people who attended. The following bar graph also showed that Young Adults accounted for the highest number of participants (36), Youth (31) and Adults (29). There was a lower attendance for Senior Citizens (13) and Children (11). These

data visual reports were created by merging the demographic data with the attendance and punctuality data, and they offered valuable information for church administrators to monitor attendance trends, encourage timely attendance and participation, and understand the participation rates of different age groups.

Age Group	Count
Young Adult	36
Youth	31
Adult	29
Senior Citizen	13
Children	11

Metric	Value
Total Attendees	120
On-Time	53
Late	67

Figure 4. Attendance Summary Reports of Sunday Service

Summary findings of the acceptance of the biometric attendance monitoring system using the Technology Acceptance Model (TAM) are tabulated in Table 5. It was observed that users highly acknowledged that the system is not only useful but also very easy to work with, as evidenced by the overall weighted mean of 4.4 (Strongly Agree). Among the different constructs, users showed the highest degree of acceptance through Attitude Toward Using (4.6) and Perceived Usefulness (4.5), which are also the highest weighted means from the data, signaling a strong belief that the system is a performance enhancer and a positive disposition towards the probable adoption of the system. The users' mindset here is very much correlated with Davis' (1989) notion that useful perception is the most significant factor in system acceptance. After all, users tend to adopt those technologies that they deem worthy of their time and tasks.

On a more detailed note, the very positive scores for Perceived Usefulness, Ease of Use (4.4), and Behavioral Intention (4.3) are a reflection of the fact that the system not only functioned well technically but also met user satisfaction, which can be a strong indication of user readiness for long-term adoption. Meanwhile Actual System Use (4.2), is still very positive but it is the lowest number of the lot, which is indicative of a slight discrepancy between users' intentions and their actual usages of the system. A situation-based or a contextual barrier such as equipment being physically present only during services or users still being in a learning phase of the system are some possible reasons for this gap. This gap is also in line with TAM literature where it is recognized that behavioral intention may not completely be reflected in actual system use (Venkatesh & Davis, 2000).

The very low standard deviations for all the constructs (0.52, 0.64) reinforce that the responses are not only scattered but also quite consistent, therefore suggesting acceptance of the system is not confined to a handful of very enthusiastic users (adopters) but is pretty much even across various groups based on

demographics. This goes on to further support the reliability of the results as well as the wide scope for the church to apply the system. Also, if the system is to be adopted at the highest level and user engagement is to be maximized, then the data suggest that ongoing training, further embedding of the system in church workflows, as well as strategies for reinforcement, such as reminders and easy access points, should be implemented.

Table 5. Summary of software acceptance, using the Technology Acceptance Model

Construct	Description	Weighted Mean	Standard Deviation	Verbal Interpretation
Perceived Usefulness	The degree to which the system enhances users' job performance	4.5	0.55	Strongly Agree
Perceived Ease of Use	The degree to which the system is free from effort	4.4	0.60	Strongly Agree
Attitude Toward Using	Users' positive or negative feelings about using the system	4.6	0.52	Strongly Agree
Behavioral Intention to Use	The likelihood that users will use the system	4.3	0.57	Strongly Agree
Actual System Use	The frequency and extent of system usage	4.2	0.64	Agree
Average Weighted Mean		4.4		Strongly Agree

In summary, the analysis shows that the system was greatly appreciated and widely adopted because it was not only useful but also very user-friendly. Nonetheless, the small difference between people's willingness to use it and their actual usage needs to be eliminated as that is what will guarantee that the biometric attendance monitoring system continues to thrive in the long run.

Table 6 shows the results of the software quality assessment of the biometric attendance monitoring system according to ISO 25010 criteria. An overall weighted mean of 4.37 or EXCELLENT with a high performance level in all eight software quality characteristics obtained by the system. In these aspects, the mean score for Security was the highest (4.70), followed by Functional Suitability (4.60) and Usability (4.50) which indicates that the system performed well in those areas.

The results show that the system successfully carries out the desired functions and is user-friendly with the protection of sensitive information. In biometric systems, data security is paramount, and the system's data security efforts against unauthorized access and potential compromise are an important factor in providing users with increased confidence and trust (Yimam & Fernandez, 2016).

The outcome shows that the system has successfully fulfilled the users' expectations, especially in the areas of efficiency, reliability, and data privacy protection. The scores for the two dimensions, Performance Efficiency (4.40) and Reliability (4.30) are high, indicating that the system operates efficiently without significant delays or interruptions, and can be trusted to perform consistently.

The user-friendliness of the system, its robust security measures, and these attributes contribute to building user trust. Therefore, they have a major part to play in the acceptance of the system by the user and in motivating the user to continue using the system.

Other attributes include rating of Very Good for Maintainability (4.10), Portability (4.20) and Compatibility (4.20) but there are opportunities to improve in these. The relatively high standard deviations for Maintainability (0.74) and Portability (0.68), suggest differences in opinion among the IT experts. Some of the evaluators had indicated that these attributes are good, but some had raised the questions of maintainability, scalability of the system and its ability to be deployed to various environments and platform.

The results indicated that the system is working well under the current conditions, but

there is still potential for improvement to better integrate it with other systems and make it more versatile for future deployment scenarios. As mentioned in ISO/IEC 25010:2023, Software is a product of Quality not only at the moment of its creation, but also over time– maintainability, portability, compatibility and adaptability to technology change and changing organizational requirements are also important software quality attributes. The features are especially vital for church organizations that could wish to distribute the system to various ministry sites or incorporate it with other church administration software. Thus, the next steps in software development should be to implement a modular software design, improve interoperability and optimize maintenance procedures for long-lasting sustainability of the system.

Table 6. Software quality evaluation summary using the ISO 25010 standards

Quality Characteristic	Description	Weighted Mean	Standard Deviation	Verbal Interpretation
Functional Suitability	How well the system provides functions that meet stated needs	4.6	0.52	Excellent
Performance Efficiency	The system's performance relative to the amount of resources used	4.4	0.70	Excellent
Compatibility	The degree to which the system works well with other systems	4.2	0.63	Very Good
Usability	The ease of use and learnability of the system	4.5	0.50	Excellent
Reliability	The ability of the system to operate without failure	4.3	0.65	Excellent
Security	Protection of information and data integrity	4.7	0.48	Excellent
Maintainability	The ease with which the system can be modified or fixed	4.1	0.74	Very Good
Portability	The ease with which the system can be transferred to other environments	4.2	0.68	Very Good
Average Weighted Mean		4.37		Excellent

The results of the biometric attendance monitoring system showed excellent accuracy, response time and low error rates, which are suitable for practical implementation in churches. It demonstrated an overall accuracy of 97.50% with the highest accuracy observed in the leaders' meetings at 98.33%, which is higher than reported in related research, thus showing its reliability in reducing false entries and preventing proxy voting. Furthermore, the R307 fingerprint sensor allowed for quick authentication as each check-in and check-out could be made within about 1-2 seconds for each person. This quick response time meant that a significantly shorter wait for people to arrive at church services, and effectively managed crowds during large services, while providing an easy-to-access system for anyone, regardless of age, including children and old age.

The system achieved a low error rate of 2.5%, with only 15 mismatches out of 600 fingerprint verification attempts.The system had a low error rate of 2.5% with only 15 mismatches out of 600 fingerprints matched. The result shows that the fingerprint sensor has the ability to successfully recognise the authorised fingerprint with a high rate of accuracy. The low number of errors also shows the effectiveness of the design to minimize inaccuracies

during scanning. Furthermore, sensor calibration, the correct positioning of fingers for verification, and regular maintenance of the devices, can increase recognition rate and diminish authentication mistakes.

The high accuracy, fast response rate and low error rate shows the efficiency, ease of use and effectiveness of the system compared to manually taking attendance. These benefits are also indicative of its future scalability, reliability, and sustainability.

In general, the results indicate that the biometric attendance system is appropriate for practical applications and has a very good performance in terms of security, in functional suitability, and usability, which are important elements in ensuring users' trust and acceptance. The results also underscore the need for continuous enhancements in maintainability and portability to ensure enduring sustainability, scalability, and adaptability for the changing requirements of churches and advances in technology.

Conclusion

This was one of the features of the biometric attendance system that was found to be its best, the performance of the R307 fingerprint sensor. The accuracy rate of the system was an average of 97.5% in different church services. This reliable biometric solution proved to be effective in reducing FRE, in blocking the submission of proxy tickets and in allowing rapid check-in, in a time of approximately 1-2 seconds per person. This resulted in reduced waiting, minimal queues and improved crowd control at all such services where there were high numbers of people in attendance.

The system was very useful for decision support because it was able to store attendance data and provide real-time and periodic reports. These all aided the church leaders in making decisions for the operation such as adding additional ushers for high traffic areas and decisions for strategic such as additional services. Data on attendance was also linked to members' age, sex and ethnicity to allow for targeted pastoral care and community engagement.

The findings from the Technology Acceptance Model (TAM) revealed that, Perceived Usefulness, Perceived Ease of Use and Attitude Toward using the technology were the three highest scoring variables and had average scores around 4.6 representing high level of technology acceptance from the users. The average score for Actual System Use (actual usage of the system) was slightly lower at about 4.2, suggesting that there is not a strong consistency between users' attitudes and behavior. The discovery reinforces the need for ongoing training, reminders and system implementation in the normal church life to encourage ongoing use.

The analysis of the system using the ISO/IEC 25010 quality model also showed the strengths of the system, with Security (4.7), Functional Suitability (4.6), and Usability (4.5), respectively, scoring the highest. Whereas these results demonstrate the reliability, security, and suitability of the system for handling sensitive biometric data. However, the relatively low scores for Maintainability (4.1) and Portability (4.2) as well as Compatibility (4.2) suggest there is scope for improvement with regard to adaptability and scalability. Therefore, future development should address the software being modularly structured, be interoperable and easy to maintain this to ensure sustainability and allow it to be deployed to various church branches (and other similar organizations).

The results suggest that the technology can be used to accurately, securely and efficiently tracks members attendance. But there is a need for enhancement in the areas of maintainability, portability and compatibility to enable scalability and implementation of this system in other church branches. In this regard, developers should make the system architecture more modular, which will make maintenance, system updates, and integration with other platforms more convenient. Church leaders, meanwhile, must keep on educating users and promote the habit of using the system, to ensure it becomes part of the church's normal operation. The combination of technical improvements and ongoing user support can help the church realize the full potential of the system, increase the involvement of members and help in pastoral monitoring, and ensure its sustainability in the future.

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