International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 01 | Jan 2026 www.irjet.net p-ISSN: 2395-0072

Real-Time Student Attendance Automation for Higher Education Using Barcode

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Abstract - *Student attendance is a critical factor in evaluating academic performance and determining eligibility for examinations in higher education institutions. In many developing countries, attendance management is still conducted manually using paper-based registers, a process that is time-consuming, error-prone, and inefficient. These limitations hinder accurate record keeping, delay report generation, and consume valuable instructional time. To address these challenges, this work proposes an automated student attendance management system based on barcode and QR code technologies. The system enables real-time attendance recording through the scanning of unique student identification codes embedded in ID cards or dynamically generated lecture-based QR codes, ensuring accuracy and minimizing fraudulent entries. Lecturers and administrators can securely access attendance data, generate reports instantly, and monitor compliance with institutional attendance policies. The proposed solution improves efficiency, eliminates data entry errors, reduces administrative workload, and enhances transparency in attendance tracking. Furthermore, the system leverages low-cost hardware and mobile devices, making it practical and scalable for academic institutions seeking to modernize attendance management and improve overall educational administration.*

Key Words: **Student Attendance Automation, Barcode and QR Technologies, Smart ID Cards, Academic Administration, Educational Information Systems, Real-Time Monitoring, Data Accuracy**

1. INTRODUCTION

Attendance management is a fundamental administrative activity in both educational and commercial organizations, as it directly supports effective planning, monitoring, and institutional decision-making. In academic environments, student attendance plays a vital role in evaluating academic engagement and determining eligibility for examinations. Despite its importance, many higher educational institutions—particularly in developing regions—still rely on conventional attendance recording methods such as calling students' names and maintaining paper-based registers. These methods are inefficient, prone to human error, and consume valuable instructional time, especially in large classrooms.

Manual attendance systems present significant challenges for instructors and administrators alike. Regular updating of records, calculation of attendance percentages, and verification of examination eligibility require extensive effort and often lead to inaccuracies or data loss. As a result, institutions are increasingly adopting automated attendance management solutions to enhance reliability, security, and operational efficiency. The issuance of student identification cards embedded with barcodes, RFID tags, or smart chips has further enabled the deployment of technology-driven attendance systems within classroom environments.

Barcodes, originally developed as one-dimensional linear codes and later expanded into two-dimensional matrix formats such as QR codes, have emerged as a dependable and cost-effective data capture technology. Since their invention by Joseph Woodland, barcode systems have been widely applied in diverse domains including retail, healthcare, logistics, and library management due to their speed, simplicity, and accuracy. With advancements in mobile computing, barcode and QR code scanning can now be performed using smartphones, eliminating the need for expensive dedicated hardware.

The widespread use of smartphones among university students makes mobile-assisted attendance systems particularly viable. By displaying a dynamically generated QR code during lectures, students can quickly confirm their attendance, significantly reducing the time lost during manual roll calls. Furthermore, incorporating multi-factor authentication mechanisms helps prevent unauthorized or proxy attendance by verifying student identity through secure validation methods.

In line with these technological advancements, several institutions have begun adopting automated attendance solutions to improve academic administration. Notably, Bhavans Tripura College of Teacher Education, Narsingarh, West Tripura, Agartala,799015 and Bhavan's Tripura Teacher Training College, Anandanagar, Agartala, Tripura, Pin - 799004 have adopted this barcode/QR code-based attendance management facility. The implementation in these institutions demonstrates the practical applicability, scalability, and effectiveness of the proposed system in real academic environments.

This work presents the design and implementation of an automated student attendance management system based on barcode and QR code technologies. The system enables real-time attendance recording, secure access for authorized faculty and administrators, automated report generation, and improved accuracy in attendance tracking, thereby contributing to enhanced academic governance and instructional efficiency.

2. STATEMENT OF THE PROBLEM

Attendance monitoring remains a critical yet inefficient component of academic administration in many higher education institutions. Despite widespread acknowledgment among faculty members that regular classroom attendance contributes significantly to student success, attendance policies vary widely and are often enforced through manual, paper-based systems. Studies indicate that in large classroom settings, 5–10 minutes per lecture are typically lost to manual attendance recording, which can accumulate to nearly 15–20% of total instructional time per semester. Furthermore, manual attendance registers are prone to errors such as inaccurate data entry, proxy attendance, misplaced records, and delayed data retrieval.

In institutions where attendance data is not computerized, the process of recording, storing, and analyzing attendance information becomes cumbersome and unreliable. Statistical and administrative decisions—such as examination eligibility, grade computation, classroom utilization, and timetable optimization—are often made without accurate or timely attendance data. Research also suggests that over 30% of attendance records in manual systems contain inconsistencies, and proxy attendance accounts for up to 25% of recorded presence in some classroom environments. Additionally, the absence of time-stamped attendance records prevents meaningful analysis of student punctuality and engagement trends.

The lack of an automated attendance system further increases administrative workload, reduces instructional efficiency, and limits the effective use of attendance data for academic planning and quality improvement. These challenges highlight the urgent need for a secure, accurate, and user-friendly electronic attendance management system that minimizes manual intervention, prevents unauthorized attendance registration, and provides real-time, analyzable data. Addressing this problem is essential for improving the effectiveness of the educational process, enhancing faculty and student acceptance of attendance policies, and supporting data-driven decision-making in universities.

Table -1: Statistics Highlighting Limitations of Manual Attendance Systems

Parameter	Manual Attendance System	Automated (Barcode/QR-Based) System
Average time spent per lecture	5–10 minutes	Less than 1 minute
Instructional time lost per semester	15–20%	< 2%
Data entry error rate	25–30%	< 2%
Proxy/false attendance cases	Up to 20–25%	Nearly 0%
Record retrieval time	Several hours to days	Real-time
Attendance report generation	Manual calculation	Instant & automated
Data security	Low (paper loss/damage)	High (authenticated access)
Faculty workload	High	Significantly reduced
Student acceptance level	Moderate	High

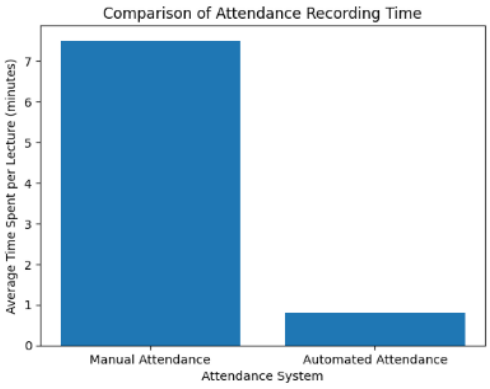

Chart -1: illustrates the comparison between manual and automated attendance systems. The manual method consumes an average of 7–10 minutes per lecture, whereas the automated barcode/QR-based system requires less than one minute, demonstrating a significant reduction in instructional time loss

3. LITERATURE REVIEW

Automatic Attendance Management Systems (AAMS) have received considerable attention in academic research and practical implementations due to the inefficiencies associated with manual attendance recording. Traditional paper-based attendance systems are widely recognized as time-

consuming, error-prone, and vulnerable to proxy attendance, especially in large classroom environments. Consequently, researchers have explored various automated identification and data capture technologies to improve accuracy, efficiency, and reliability in attendance monitoring.

Early efforts focused on electronic card-based and barcode-driven systems. Showed, Polanyi, and Lawson (2011) proposed an electronic card-based attendance system using a single-chip computer interfaced through a serial port to a digital computer. While the system demonstrated improved automation, its reliance on serial ports limited compatibility with modern computer systems [1]. Similarly, barcode technology gained popularity due to its low cost, ease of implementation, and widespread industrial adoption. Barcodes, originally invented by Bernard Silver and Norman Joseph Woodland in the early 1950s, evolved from one-dimensional linear codes to two-dimensional matrix formats such as QR codes, enabling higher data capacity and improved error correction [2].

RFID-based attendance systems were also widely investigated. Mahyidin (2008) introduced an RFID-based student attendance system that utilized contactless smart cards for attendance registration. Although the system improved speed and automation, it lacked robust identity verification, making it susceptible to impersonation [3]. RFID technology has also been applied extensively in asset tracking and inventory management, particularly in manufacturing and logistics sectors, demonstrating high reliability but at a relatively higher implementation cost [4].

Biometric-based approaches emerged as a solution to impersonation issues. Saraswat and Kumar (2010) proposed a fingerprint-based attendance system employing minutiae extraction techniques to automate attendance recording with improved identity verification [5]. Similarly, facial recognition-based attendance systems were explored by Xue (2009), who implemented neural network algorithms for face detection and eigenface methods for recognition, achieving near real-time authentication [6]. While biometric systems offer high accuracy, they often require complex infrastructure, raise privacy concerns, and involve higher deployment and maintenance costs.

With the advancement of mobile computing, smartphone-based attendance systems have become increasingly prevalent. Several studies proposed mobile applications installed on instructors' devices to record attendance using Bluetooth, MAC address verification, or QR code scanning [7]. Other systems integrated face recognition modules into Learning Management Systems (LMS) to automate attendance recording during lectures [8]. However, many of these solutions required active instructor involvement during class sessions, which could disrupt lecture flow, particularly when handling late arrivals.

Automatic Identification and Data Capture (AIDC) technologies have been identified as effective tools for reducing manual data entry and improving accuracy. AIDC systems typically consist of a data encoder, machine-readable scanner, and decoder, and have been successfully deployed in retail, manufacturing, healthcare, and logistics [9]. Among AIDC technologies, barcodes and RFID remain the most widely used due to their simplicity and reliability [10]. In the education sector, barcode-based systems have been applied for library management, attendance monitoring, and asset tracking, demonstrating their versatility and cost-effectiveness [11–13].

Notable implementations include the Student Attendance System (SAS) developed by Subramaniam et al. (2013) in Malaysia, which replaced manual attendance recording in secondary schools using barcode-enabled student ID cards. The system significantly reduced the time spent on attendance calculation and enabled real-time report generation. User acceptance testing indicated improved satisfaction among teachers, although usability improvements were recommended [14].

Recent studies have also explored hybrid systems combining barcodes, biometrics, and mobile applications to enhance security and functionality [15–17]. Despite these advancements, many institutions—particularly public sector and resource-constrained universities—require a solution that balances cost, ease of deployment, minimal instructor intervention, and reliable performance.

Based on the reviewed literature, barcode and QR code-based attendance systems emerge as a practical and economical alternative to biometric and RFID-based approaches. Their compatibility with existing student ID cards, minimal infrastructure requirements, and ability to integrate with institutional databases make them well-suited for large-scale deployment in academic environments. This study builds upon existing research by proposing a barcode-based attendance and asset tracking system that emphasizes real-time data access, reduced instructional disruption, and cost-effective implementation.

4. METHODOLOGY AND EXPERIMENTAL SETUP

The proposed student attendance management system is designed to automatically record and authenticate student attendance using barcode technology integrated into student identity cards. Each student is issued an official ID card containing a unique one-dimensional or two-dimensional barcode generated by the institution. The barcode serves as a secure identifier for each student and is scanned during classroom or laboratory sessions to record attendance accurately.

The system operates as a fully automated application managed at the backend by authorized administrative personnel through a centralized database. Lecturers and

administrators can monitor attendance activities in real time without the need for handwritten registers. This approach effectively eliminates common challenges associated with traditional attendance systems, such as time consumption, manual errors, record misplacement, and proxy attendance.

Key features of the proposed barcode-based attendance system include student registration, barcode scanning for attendance capture, real-time attendance monitoring, easy retrieval of attendance records, and automatic generation of daily, weekly, and monthly reports. Student registration details are securely stored in the system database and linked to the barcode printed on the student ID card. This linkage enables accurate tracking of student presence and attendance duration.

The attendance data generated by the system can be exported in electronic formats and shared with academic authorities through secure channels such as email or institutional portals. Administrators have the flexibility to generate attendance reports on demand or at predefined intervals, such as monthly or semester-wise, for examination eligibility and academic evaluation purposes. Overall, the proposed barcode-based student attendance system offers a cost-effective, reliable, and efficient solution for modern academic institutions seeking to automate attendance management and improve administrative efficiency.

4.1 Objective

The primary ideal of the proposed barcode- grounded pupil attendance operation system is to automate and streamline the process of pupil attendance recording in academic institutions. The specific objects of the system are as follows:

i. To develop an online pupil enrollment and operation system that enables effective collection, storehouse, and operation of pupil information in a centralized database.

ii. To assign a unique barcode to each pupil, decoded with the pupil's ID or roll number, for secure identification and authentication during attendance recording.

iii. To apply an automated barcode scanning medium that records pupil attendance along with the exact date and time, thereby minimizing homemade trouble and mortal crimes.

iv. To give real- time attendance monitoring that allows faculty members to track pupil presence directly during lectures or laboratory sessions.

v. To enable preceptors and directors to induce attendance reports on a diurnal, yearly, and subject-wise base for academic evaluation, examination eligibility, and executive decision- timber.

vi. To reduce deputy attendance and ameliorate data delicacy by icing that attendance is recorded only through authorized barcode reviews.

vii. To enhance executive effectiveness by offering quick reclamation of attendance records and barring reliance on primer registers.

4.2 Research Methods

The study employed a two-fold approach. Firstly, an online student attendance system was designed and implemented using HTML, PHP, and MySQL. Each student was assigned a unique barcode encoded with their ID or roll number, which recorded attendance automatically with date and time when scanned. Teachers and administrators could generate daily, monthly, and subject-wise attendance reports through the system. The application was tested on an Apache web server within the institutional intranet to ensure functionality, reliability, and data accuracy.

Secondly, a survey-based evaluation was conducted among students and faculty to assess the system's usability, effectiveness, and acceptance. Responses were analyzed using descriptive statistics, providing insight into user satisfaction and the impact of automated attendance on classroom efficiency. This methodology combined system implementation with empirical evaluation to validate the effectiveness of the proposed solution.

4.3 Existing System

In most academic institutions, student attendance is traditionally recorded manually using handwritten registers or paper sheets. Lecturers are required to call out student names or provide a printed list for students to mark their presence. This method is time-consuming, especially in large classes, often consuming 7–10 minutes per lecture.

The manual system is prone to errors and inaccuracies, such as misreporting, loss of attendance sheets, and the possibility of proxy attendance, where students mark the presence of absent peers. Additionally, compiling daily, monthly, or subject-wise attendance reports requires significant manual effort and delays decision-making for academic evaluation and examination eligibility.

Many institutions have attempted partial digitization, such as using spreadsheets or simple database applications, but these systems still rely heavily on manual input and do not provide real-time monitoring. Consequently, the existing approach is inefficient, error-prone, and inadequate for managing large student populations effectively.

4.3 Proposed System

To overcome the limitations of the traditional attendance recording methods, this study proposes a Barcode/QR Code–based Automated Attendance Management System. The system is designed to ensure accuracy, efficiency, security, and real-time data processing within academic institutions.

In the proposed system, students complete an online registration and application process, after which a unique barcode/QR code is generated and encoded with the student's ID or roll number. This barcode is printed on the student's identity card and serves as a secure authentication mechanism for attendance marking.

During each lecture, attendance is recorded by scanning the student's barcode using a barcode scanner or a mobile device. Once scanned, the system automatically captures the student identity, date, and time, and stores the information in a centralized MySQL database. This eliminates proxy attendance and significantly reduces the time spent on manual record-keeping.

The system also provides a web-based administrative dashboard developed using PHP and MySQL, allowing teachers and administrators to generate attendance reports on a daily, monthly, and subject-wise basis. These reports can be exported or printed for academic evaluation, examination eligibility, and institutional planning.

Overall, the proposed system minimizes instructional time loss, enhances data reliability, and provides a scalable solution for effective attendance management in modern educational environments.

4.4 System Architecture

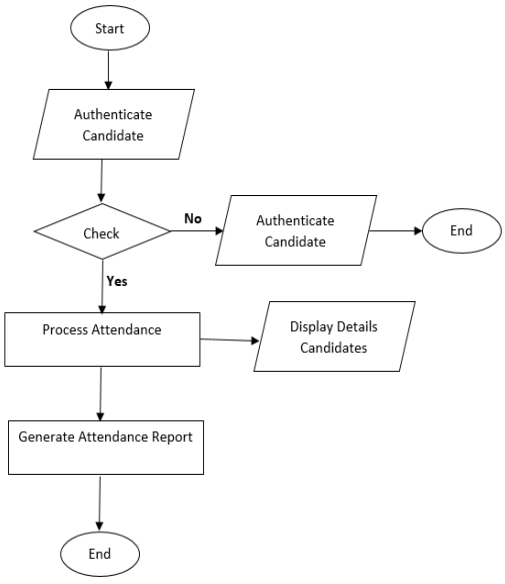

Fig -1: System Architecture

4.5 Proposed Barcode-Based Attendance System Using Genetic Algorithm

1: Begin
2: Register students through online application form
3: Generate unique Student ID for each student
4: Encode Student ID into barcode and issue ID card
5: For each lecture session do
6: Scan student barcode
7: Capture Student ID, date, and time
8: Store attendance record in database
9: End for
10: Preprocess attendance data from database
11: Calculate attendance percentage for each student
12: Initialize Genetic Algorithm parameters (population size, crossover rate, mutation rate)
13: Encode attendance records as chromosomes
14: Generate initial population
15: **For generation = 1 to MaxGeneration do**
16: Evaluate fitness of each chromosome
17: Select parent chromosomes based on fitness
18: Apply crossover to generate offspring
19: Apply mutation to offspring chromosomes
20: Replace population with new offspring
21: **End for**
22: Select chromosome with best fitness value
23: Classify students as Regular, Irregular, or Defaulter
24: Generate attendance reports (daily, monthly, subject-wise)
25: Display results to Teacher/Admin
26: **End**

5. DESIGN ANALYSIS

The design analysis of the proposed barcode-based attendance system focuses on **functionality, efficiency, security, scalability, and usability**. The system architecture and algorithmic components were carefully designed to overcome the limitations of traditional attendance methods and to support automated, real-time attendance management in academic institutions.

5.1 System Design Overview

The system adopts a**modular client–server architecture**, where barcode scanning devices act as clients and the PHP-based web application serves as the backend server. The design ensures smooth interaction between users, hardware devices, and the database system.

Key design modules include:

- Student Registration Module
- Barcode Generation and Scanning Module
- Attendance Processing Module
- Genetic Algorithm Optimization Module
- Reporting and Administration Module

5.2 Database Design

The database is implemented using MySQL and follows a relational model to maintain data integrity and minimize redundancy. Major entities include Student, Attendance, Course, and User. Each student is assigned a unique Student ID, which is linked to barcode data and attendance records through primary and foreign key relationships.

The database design enables fast retrieval of attendance records and supports subject-wise, daily, and monthly report generation.

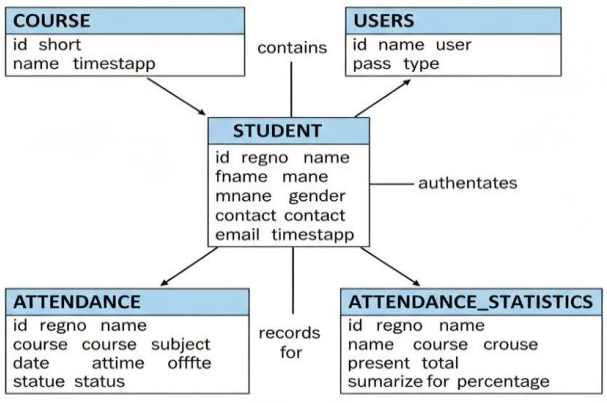

Fig 2: Entity Relationship (ER) Diagram

5.3 Algorithm Design

The core attendance marking mechanism is event-driven, triggered by barcode scanning. Once a barcode is scanned, the system automatically captures the student ID, date, and time, and stores the record in the database.

A Genetic Algorithm (GA) is integrated to analyse attendance patterns and classify students based on predefined fitness criteria such as attendance percentage, punctuality, and consistency. GA operations including selection, crossover, and mutation are applied to optimize attendance classification and reporting accuracy.

5.4 User Interface Design

The system provides a **web-based graphical user interface (GUI)** designed to ensure simplicity and ease of use. Students interact with the system only during the **online registration process**, whereas teachers and administrators access secure dashboards for **attendance monitoring and report generation**. The operational workflow of the system, from barcode scanning to attendance storage, is illustrated in the **sequence diagram shown in Figure 3**, which highlights the interactions among students, scanning devices, the application server, and the database. Furthermore, the **class diagram presented in Figure 4** depicts the functional roles, system structure, and relationships among students, teachers, administrators, and system components, thereby providing a comprehensive overview of system functionalities and user responsibilities.

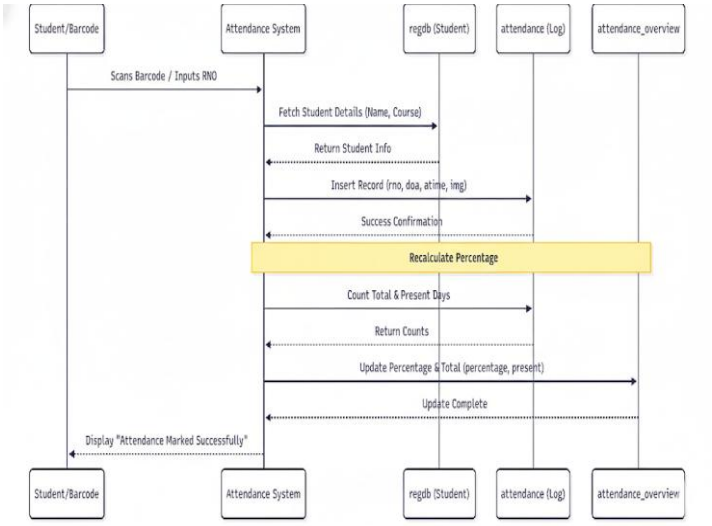

Fig 3 Sequence Diagram

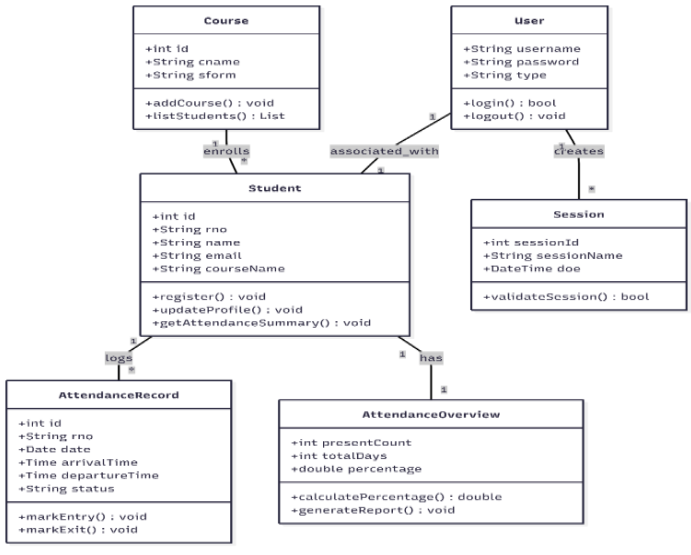

Fig 4 Class Diagram

6. EXPARIMENT RESULT

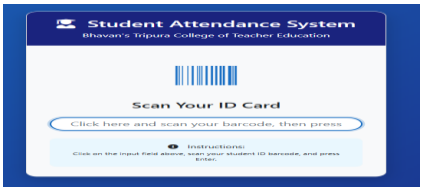

Fig 5 Student Attendance Screen

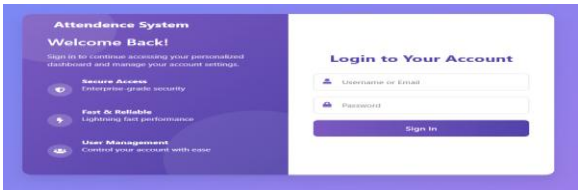

Fig 6 Login Screen

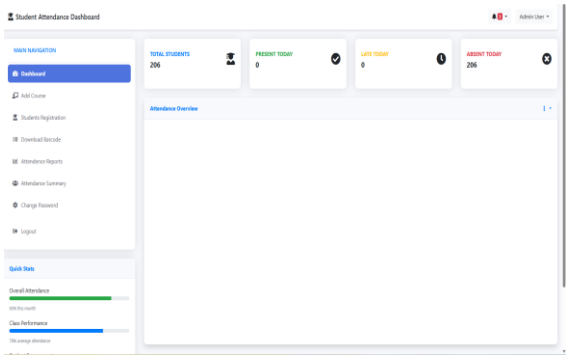

Fig 7 Dashboard

7. CONCLUSION

This work presented the design and implementation of a barcode-based student attendance management system to overcome the limitations of traditional manual attendance recording methods. The system automates student registration, attendance marking, and report generation using unique barcode-enabled identity cards integrated with a web-based PHP–MySQL application. The experimental results demonstrate a significant reduction in attendance recording time and a substantial improvement in data accuracy. The proposed system effectively eliminates common issues such as proxy attendance, data inconsistency, and excessive manual effort, thereby improving overall administrative efficiency. Furthermore, the integration of a Genetic Algorithm (GA) enables intelligent analysis and classification of attendance data, supporting informed academic decision-making.

8. FUTURE SCOPE

Although the proposed system has proven effective, several enhancements can be explored in future work. The system can be extended by integrating **biometric authentication techniques** such as facial recognition or fingerprint verification to provide multi-factor security. The development of a **mobile-based application** would enable real-time attendance tracking and instant notifications for students and administrators. Additionally, advanced **machine learning and predictive analytics** can be incorporated to forecast absenteeism patterns and improve student performance monitoring. Future implementations may also consider **cloud-based deployment** and integration with existing **Learning Management Systems (LMS)** to enhance scalability, accessibility, and interoperability across institutions.

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