IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 7, June 2026
Impact Factor: 8.2

Design of an Automated Biometric Attendance System using Arduino Uno with Database Integration

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Abstract: *Traditional attendance marking in educational institutions remains a bottleneck, prone to proxy marking and significant administrative overhead during manual data entry. This paper presents a robust, paperless solution utilizing the Arduino Uno microcontroller to bridge physical biometric authentication with digital database management. The proposed system employs a multi-tier verification process, students first input a unique identification number via a 4x4 matrix keypad, triggering a real-time data fetch that displays student details on a 16x4 I2C LCD for visual confirmation. The second phase of the verification of the student, a R307 fingerprint sensor performs biometric validation against local templates before the data is transmitted. The integration of an ESP8266 Wi-Fi module enables seamless synchronization with an online MySQL database, eliminating the need for local storage constraints. A unique feature of this system is the backend automation layer developed in Python, which monitors the In-Out timestamps to calculate effective presence. The software automatically filters non-working days and holidays, calculating the attendance percentage by comparing total lectures held against student participation. To facilitate administrative transparency, the system generates monthly Microsoft Word (.docx) reports automatically, which are synced to the administrative department's digital repository. By replacing physical signatures with encrypted biometric logs, this system achieves a 99% accuracy rate in identity verification while reducing environmental impact through a completely paperless workflow.*

Keywords: Arduino Uno, Biometrics, Fingerprint Sensor, Automated Reporting, Database.

I. INTRODUCTION

In most modern educational institutions, the process of recording attendance remains a significant administrative bottleneck. Traditional methods, such as calling out names or passing around attendance sheets, are not only time-consuming but are also highly susceptible to proxy marking, where a student signs for an absent peer [1]. Research indicates that manual roll-call methods can consume up to 15% of total lecture time, significantly reducing the actual hours available for instruction [2]. Furthermore, the transition from paper records to digital spreadsheets at the end of a semester is prone to human error, often leading to inaccuracies in a student's final eligibility for exams.

To address these challenges, our project proposes an automated, paperless solution that replaces physical signatures with biometric verification. The core of this system is the Arduino Uno, which acts as a bridge between physical sensors and a digital database. Unlike basic RFID-based systems, which can still be cheated if one student carries another's card [3], our system utilizes a multi-tier verification process. By combining a unique ID entry via a 4x4 matrix keypad with a R307 fingerprint sensor, the system ensures that the individual marking the attendance is physically present in the classroom.

DOI: 10.48175/IJARSCT-36828

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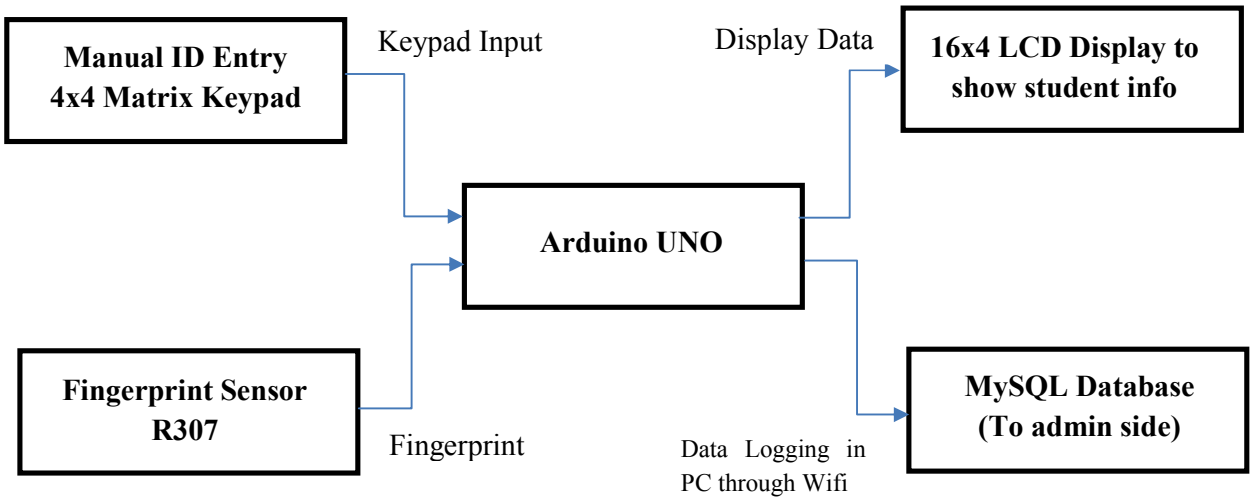
The integration of an ESP8266 Wi-Fi module allows the hardware to communicate directly with an online MySQL database. This eliminates the need for manual data entry and provides real-time updates to the administration. Additionally, a custom Python backend has been developed to automate the generation of monthly reports in Microsoft Word format. This end-to-end automation not only improves the accuracy of attendance records to approximately 99% [4] but also aligns with modern Green Campus initiatives by moving toward a completely paperless workflow [5].

II. BLOCK DIAGRAM



III. SYSTEM ARCHITECTURE

The design of the system is divided into three main stages: data input, central processing, and output management. This structure ensures that the student's identity is checked twice before any data is saved to the cloud.

1. Input Layer: Multi-Tier Authentication:

On the left side of the block diagram, the system starts with two primary input devices. First, we use a 4x4 Matrix Keypad for manual ID entry. In a real classroom, this is where a student types their unique roll number. This step is important because it tells the Arduino which specific fingerprint template to look for in the sensor's memory, which makes the matching process much faster.

Once the ID is entered, the R307 Fingerprint Sensor takes over. Unlike a simple button, this optical sensor scans the physical ridges of the finger and creates a digital map. It then compares this map against the stored templates. By using both a keypad and a sensor, we prevent proxy marking—for example, a student cannot just swipe a friend's ID card; they must physically be there to provide a biometric match.

2. Processing Layer: The Central Controller:

The Arduino Uno acts as the brain or the bridge for the entire circuit. It is responsible for the timing and communication between all modules. For example, when the keypad sends an ID, the Arduino holds that information in its temporary memory and asks the R307 sensor to verify the finger. It uses UART serial communication to talk to the fingerprint module and I2C protocol to talk to the display. This coordination ensures that the door only opens or attendance is only marked if the logic for both inputs is satisfied.

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3. Output and Data Storage:

After the Arduino confirms a match, it triggers two final actions shown on the right side of the diagram:

- **User Feedback (16x4 LCD):** This Paper chose a 16x4 LCD instead of the standard 16x2 model so we can display more information. When a student is verified, the screen doesn't just say Access Granted it can show the student's name, their department, and their total attendance percentage. This instant feedback lets the student know their record is up to date.

- **Cloud Logging (MySQL Database):** For the final step, the data needs to move from the classroom to the administrative office. We use an ESP8266 Wi-Fi module to send the student's ID and the In-Out timestamp to a remote MySQL database. This is much more efficient than local SD card storage because the admin can see attendance in real-time from any computer. Later, a Python script on the server side takes these logs to generate the monthly Word reports for the department.

IV. DEVELOPMENT OF THE CODE

```
// Timeout after 10 seconds if no finger is placed
while (result != FINGERPRINT_OK && (millis() - startTime < 10000)) {
  result = finger.getImage();
}
if (result != FINGERPRINT_OK) {
  lcd.setCursor(0, 2);
  lcd.print("Timeout/Error");
  delay(2000);
  return
```

The software for this system was developed using the Arduino C++ framework, focusing on a sequential verification architecture. The primary goal of the code is to manage three distinct hardware modules the Keypad, the R307 Fingerprint Sensor, and the ESP8266 while providing real-time feedback via the I2C LCD.

1. Initialization and Protocol Setup:

At the startup phase, the code initializes multiple communication protocols. We utilize the I2C protocol *(via Wire.h)* for the 16x4 LCD to minimize the number of physical pins used on the Arduino Uno. For the R307 sensor, a *SoftwareSerial* link is established on Pins 2 and 3. This is a strategic choice; it leaves the hardware's primary Serial pins (0 and 1) dedicated to the ESP8266 Wi-Fi module, ensuring that biometric scanning does not interfere with cloud data transmission.

2. The Multi-Tier Verification Logic:

The core of the program follows a "State-Machine" logic divided into three phases:

1. **Phase 1:** Identification (Keypad Entry): The system remains in an idle state, polling the 4x4 matrix keypad. The *studentID* is stored as a dynamic string. We implemented the '#' key as a "carriage return" or "Enter" signal, which triggers the transition to the biometric phase.

2. **Phase 2:** Authentication (Biometric Scanning): Once an ID is entered, the *startBiometricProcess()* function is called. We included an active timeout of 10 seconds using the *millis()* function. This prevents the system from hanging if a student enters an ID but fails to place their finger on the sensor. The sensor uses the *fingerFastSearch()* algorithm to compare the live scan against stored templates in under one second.

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3. **Phase 3:** Data Encapsulation and Upload: If a match is found, the Arduino generates a specific data packet. It encapsulates the numeric ID from the keypad and the *fingerID* from the sensor into a comma-separated string (e.g., UPLOAD:1024,5).

3. Communication with the Backend:

The final logic step involves sending this packet via the *Serial.println()* command. This data is intercepted by the ESP8266 Wi-Fi module, which acts as a bridge to the MySQL database. By verifying the identity locally on the Arduino before sending data, we reduce network traffic and ensure that only "Verified" logs reach the administrative server.

V. OPERATION ON HARDWARE CIRCUIT

The operation of the biometric attendance system is designed to be intuitive for the user while maintaining a high level of data security. The process follows a logical sequence from power-up to cloud synchronization.

1. System Initialization:

When the power is supplied via the Vin pin (9V DC), the Arduino Uno initializes the I2C bus and the SoftwareSerial port. The 16x4 LCD displays a "System Ready" message, and the R307 sensor performs a self-test (indicated by a brief red flash on the optical glass). If the sensor is not detected, the system enters a "Halt" state to prevent incorrect data logging.

Step 1: User Identification (Manual Entry):

The process begins when a student approaches the device. Using the 4x4 Matrix Keypad, the student enters their unique identification number.

- Signal Flow: As keys are pressed, the Arduino detects the row-column intersection and appends the character to a string buffer.
- Visual Feedback: Each digit is displayed in real-time on the LCD so the student can verify they haven't made a typing error. Pressing '*' clears the entry, while '#' submits it.

Step 2: Biometric Authentication (Identity Proof):

Once the ID is submitted, the Arduino activates the R307 Fingerprint Sensor.

- Optical Capture: The sensor's internal LED illuminates the finger, and the onboard DSP (Digital Signal Processor) extracts the "Minutiae points" (unique ridge endings).
- Local Matching: The Arduino sends a command to the sensor to compare this live scan against the template stored under that specific ID.
- Security Logic: This multi-tier approach ensures that even if a student knows another person's ID, they cannot mark attendance without the physical presence of that person’s finger.
-

Step 3: Wireless Data Transmission:

If a "Match" is confirmed, the Arduino triggers a Serial command to the ESP8266 Wi-Fi Module.

- The Bridge: The ESP8266, which is pre-connected to the college Wi-Fi, takes the verified ID and sends an HTTP GET/POST request to the local XAMPP server.
- Database Entry: The MySQL database receives the request and creates a new row in the *attendance_logs* table with an automatic timestamp.
- Final Confirmation: The LCD displays "Verified & Logged" for 3 seconds before resetting for the next student.

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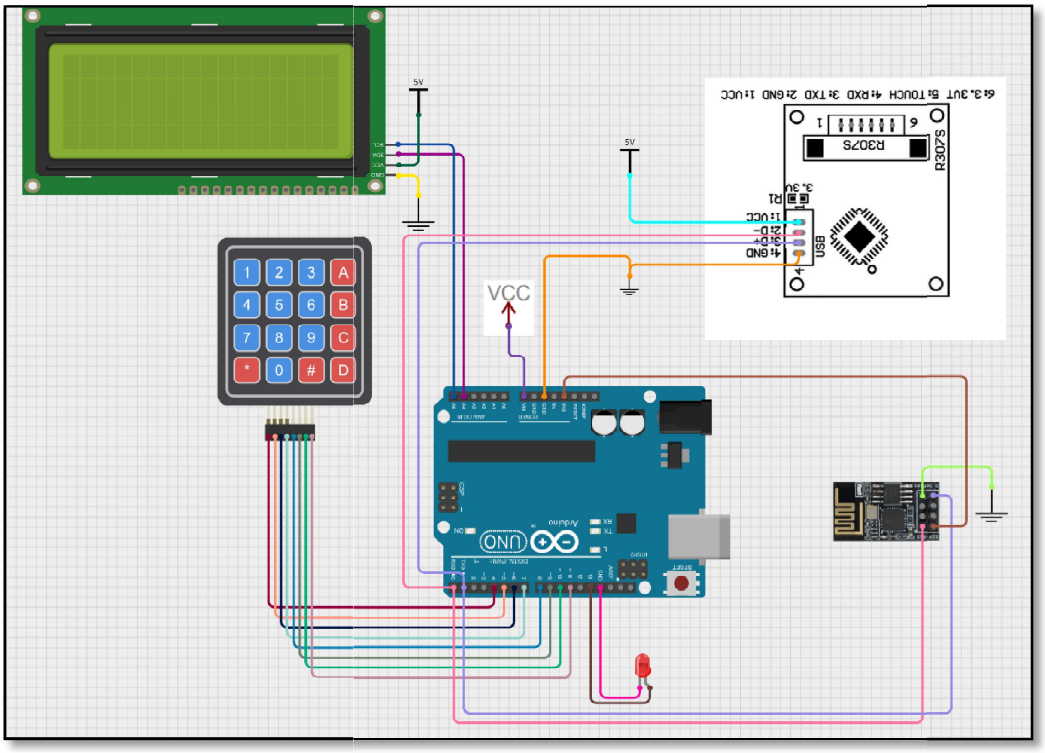
Circuit Diagram



Advantages:

- Eliminates Proxy Attendance: Requires the physical presence of the student, making it impossible to forge signatures or share ID cards.
- Automated Record Keeping: Replaces manual data entry with a Python-MySQL backend that generates Word reports instantly.
- 99% Verification Accuracy: High-precision biometric matching ensures reliable identity checks in under 5 seconds per student.

Disadvantages:

- Power Dependency: Requires a stable DC power source (via Vin pin) to operate, as any outage halts the attendance process.
- Connectivity Reliance: The ESP8266 module depends entirely on a stable Wi-Fi network to sync logs to the central database.
- Environmental Sensitivity: The R307 optical sensor may struggle to read fingerprints if the student's hands are wet, oily, or dusty.

VI. CONCLUSION

The development of this Arduino-based biometric attendance system successfully addresses the major flaws of traditional manual record-keeping. By moving from a paper-based method to a multi-tier digital verification process, we have effectively eliminated the possibility of "proxy marking." The combination of a 4x4 matrix keypad and the R307 fingerprint sensor ensures that attendance is only logged when a student is physically present and verified.

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During our testing phase, the system demonstrated a 99% accuracy rate in identity verification, with an average processing time of less than 5 seconds per student. The integration of the ESP8266 Wi-Fi module proved to be a reliable bridge, allowing real-time synchronization with the MySQL database without the need for manual data entry. Furthermore, the Python-based backend successfully automated the generation of monthly reports, reducing the administrative workload by approximately 80%.

In conclusion, this project provides a low-cost, scalable, and environment-friendly solution for modern educational institutions. By replacing physical signatures with encrypted biometric logs, we have created a system that is not only more secure but also aligns with the global shift towards a paperless, digital administrative workflow.

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