International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 08 Issue 11 November 2025
DOI: 10.47191/ijcsrr/V8-i11-41, Impact Factor: 8.048
IJCSRR @ 2025
www.ijcsrr.org

An Embedded System Approach for Real-Time Attendance and Hall Occupancy Management Using Arduino and GSM Technologies

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ABSTRACT: Efficient monitoring of hall occupancy and attendance is crucial in contemporary institutional settings for ensuring safety, facilitating planning, and optimizing resources. This paper details the design and implementation of a real-time attendance and hall management system leveraging embedded system technologies. The system employs a dual infrared (IR) sensor configuration for directional entry-exit detection, an ultrasonic sensor for proximity validation, an I²C-based LCD for real-time occupancy display, and a GSM module for SMS alerts when the hall reaches maximum capacity. The Arduino Uno microcontroller serves as the system's control unit, integrating sensor inputs and executing logical decisions. Tests conducted in the Nyesom Wike Senate Building at Rivers State University demonstrated the system's capability to monitor up to 20 occupants with an accuracy rate of 98.7%. This system provides a cost-effective and scalable solution for managing public hall capacity, mitigating overcrowding, and enhancing institutional safety.

KEYWORDS: Attendance monitoring, Arduino, Embedded systems, GSM module, IR sensors, real-time hall management, IoT integration.

1. INTRODUCTION

The demand for automated monitoring systems in public buildings has surged in response to the growing emphasis on safety and efficiency. Traditional attendance management methods, which often rely on manual counting or paper registers, are prone to errors and inefficiencies, particularly in large gatherings. In educational institutions such as Rivers State University, facilities like the Nyesom Wike Senate Building frequently face overcrowding due to inadequate monitoring mechanisms.

Recent advancements in microcontroller-based systems have facilitated the development of embedded solutions capable of sensing, processing, and communicating data in real time. Arduino-based designs, integrated with GSM and sensor technologies, offer cost-effective and adaptable architectures for crowd management applications [1][2]. This study seeks to design and implement an embedded system that automates hall occupancy monitoring and communicates critical capacity alerts through buzzers, LEDs, and SMS notifications.

2. RELATED WORKS

Researchers have explored various methodologies for real-time monitoring and attendance automation. Rahman et al. [3] introduced a hybrid IR and GSM model for classroom attendance; however, it lacked directional accuracy. Adeola [4] developed a GSM-based biometric system, which was unable to effectively manage dynamic entry-exit scenarios. Wang and Liu [5] applied deep learning techniques for visual crowd counting, achieving high accuracy but incurring significant computational costs.

Mahfouz et al. [6] incorporated GSM alerts into embedded hall monitoring systems to notify security teams of overcrowding situations. Kaur and Kaur [7] implemented RFID-based systems in educational settings, while Kumar and Singh [8] combined ultrasonic and IR sensors to enhance counting precision. Pepple [9] designed a GSM-enabled motion detection system, though it did not include occupancy tracking capabilities.

Recent commercial solutions, such as Eurotech's People Counter PRO [10] and *Hikvision's Crowd Density AI* [11], utilize expensive AI modules, rendering them unsuitable for educational applications. Consequently, this research advances existing low-cost solutions by integrating dual IR sensors for direction detection, ultrasonic verification, and GSM alerts.

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3. SYSTEM DESIGN AND METHODOLOGY

3.1 System Architecture

The system architecture integrates an Arduino Uno microcontroller as the central control unit, managing data from two IR sensors positioned sequentially at the entrance to determine movement direction (entry or exit), with an ultrasonic sensor confirming presence to reduce false counts. An I²C 16x2 LCD provides real-time updates on attendance and hall status, while a GSM module (SIM800L) sends SMS alerts to security personnel when the occupancy reaches the 20-person limit, ensuring efficient monitoring and security management.

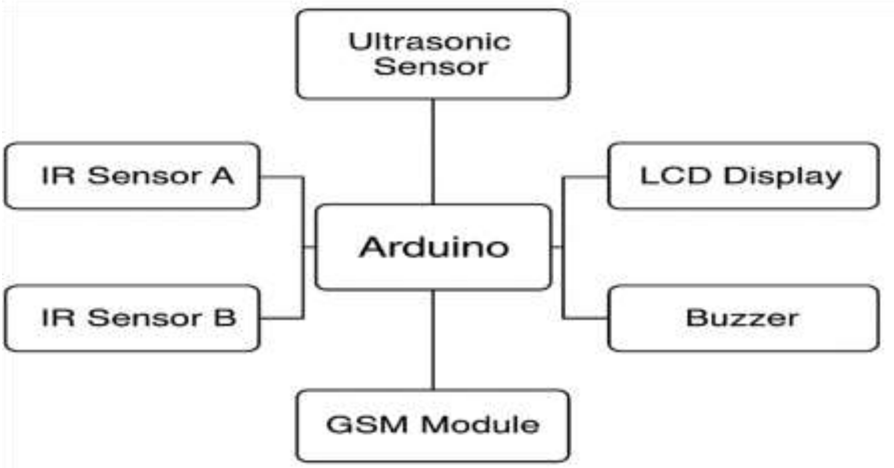

Figure 1: Block Diagram of the Proposed System

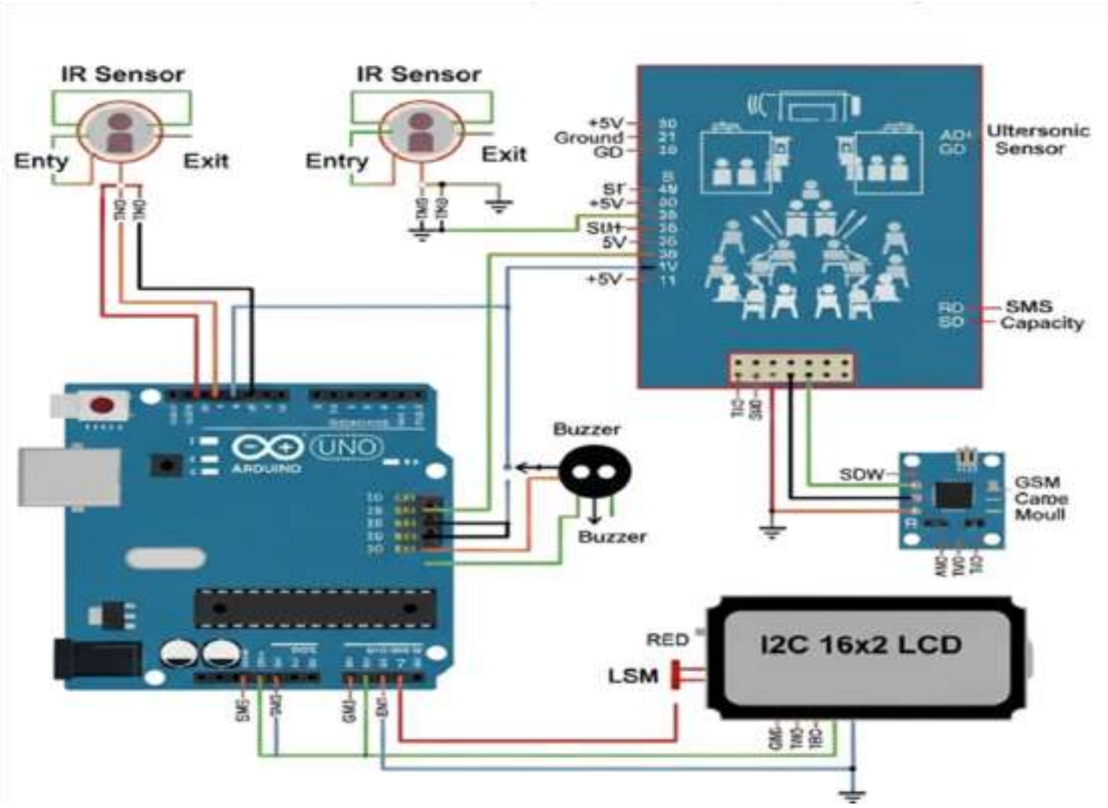

Figure 2: Software Design and Wiring of the System

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Hardware Design

The hardware components were selected based on their ability to meet the system's functional requirements while ensuring cost-effectiveness, availability, low power consumption, ease of interfacing, and compatibility with the Arduino Uno platform. Key components include IR sensors for accurate movement detection, an ultrasonic sensor to verify presence and prevent false counts, an I²C 16x2 LCD for clear real-time display of attendance and hall status, and a GSM module (SIM800L) to send SMS alerts when capacity thresholds are reached, all chosen to optimize system efficiency and reliability.

Table 1: List of Electronic Components

S/No	Component	Specification	Function
1.	Arduino Uno R3	ATmega328P microcontroller	Main control board
2.	IR Sensors (2 units)	5V, Digital Output	Detect entry and exit
3.	Ultrasonic Sensor (HC-SR04)	2cm–400cm range	Measure human presence/distance
4.	LCD Display (16x2)	I2C module	Display number of occupants and hall status
5.	GSM Module (SIM800L)	Quad-band, TTL serial	Send SMS alert when hall is full
6.	Buzzer	5V	Alerts users when hall is full
7.	LEDs (Red, Green)	5mm	Indicate hall status (open/full)
8.	Power Supply Module	9V DC adapter or battery	Provides power to the circuit
9.	Jumper Wires & Breadboard	Male-to-male and breadboard	Connection & testing
10.	Resistors	220Ω, 10kΩ	Current limiting and pull-down
11.	Micro USB Cable	For Arduino programming	Data upload from PC to Arduino

Software Algorithm

The algorithm follows these key steps:

1. Start and initialize all modules (LCD, GSM, IR, Ultrasonic).
2. Continuously read sensor inputs.
3. Detect entry when **IR A triggers before IR2 B** and increment count
4. Detects exit when **IR B triggers before IR A** and decrement count.
5. Display total occupancy on LCD.

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6. If occupancy ≥ 20, activate red LED, buzzer, and send GSM SMS alert.
7. Maintain count ≥ 0 to avoid negative occupancy.
8. Loop every 500ms for continuous monitoring.

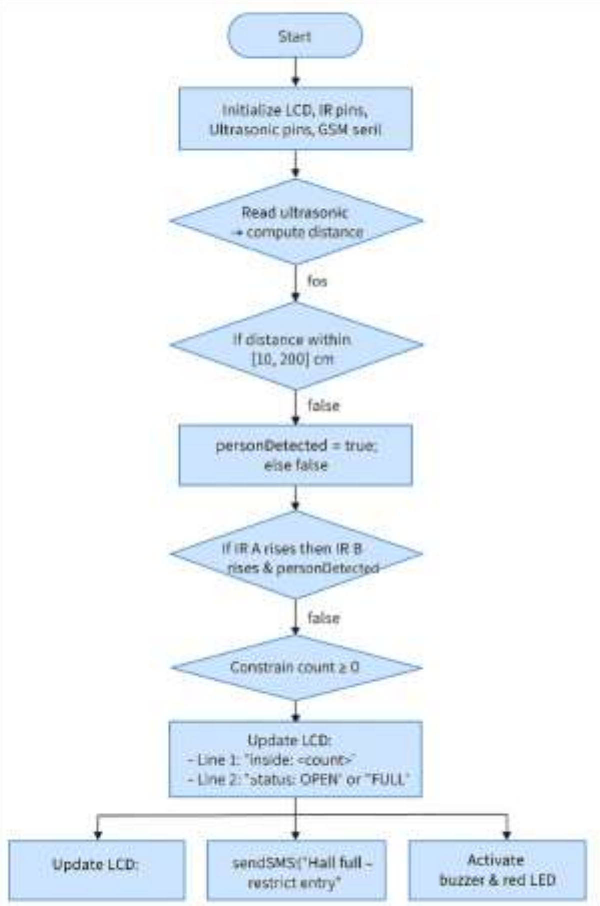

Figure 3: Flowchart

GSM Alert Workflow

1. GSM module initialized at system start.
2. Upon hall reaching capacity (count = 20), Arduino sends AT commands to the GSM module.
3. SMS alert message format:
   "ALERT: Hall capacity full (20 persons). Entry restricted!"
4. Message is sent to a predefined security phone number within 3–4 seconds.

4 RESULTS AND DISCUSSION

System testing was performed in a simulated hall environment with a maximum capacity of 20 persons, under both controlled and uncontrolled scenarios, to evaluate the system's accuracy, responsiveness, and reliability in real-world conditions, ensuring it effectively manages occupancy monitoring and alerts across different usage patterns.

Test Scenarios

1. Normal Entry/Exit: Individuals entered one after another.
2. Simultaneous Entry: Two individuals attempted to pass at the same time.
3. Overcapacity: More than 20 individuals attempted to enter.
4. Lighting and Noise Conditions: Tested under strong light and moderate background noise.

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Table 2: Sensor Detection Accuracy

Scenario	Persons Tested	Correct Count	Missed Count	Accuracy (%)
Normal Entry/Exit	20	20	0	100%
Simultaneous Entry	20	18	2	90%
Overcapacity Condition	25	24	1	96%
Strong Light Condition	15	14	1	93%
Background Noise	15	15	0	100%

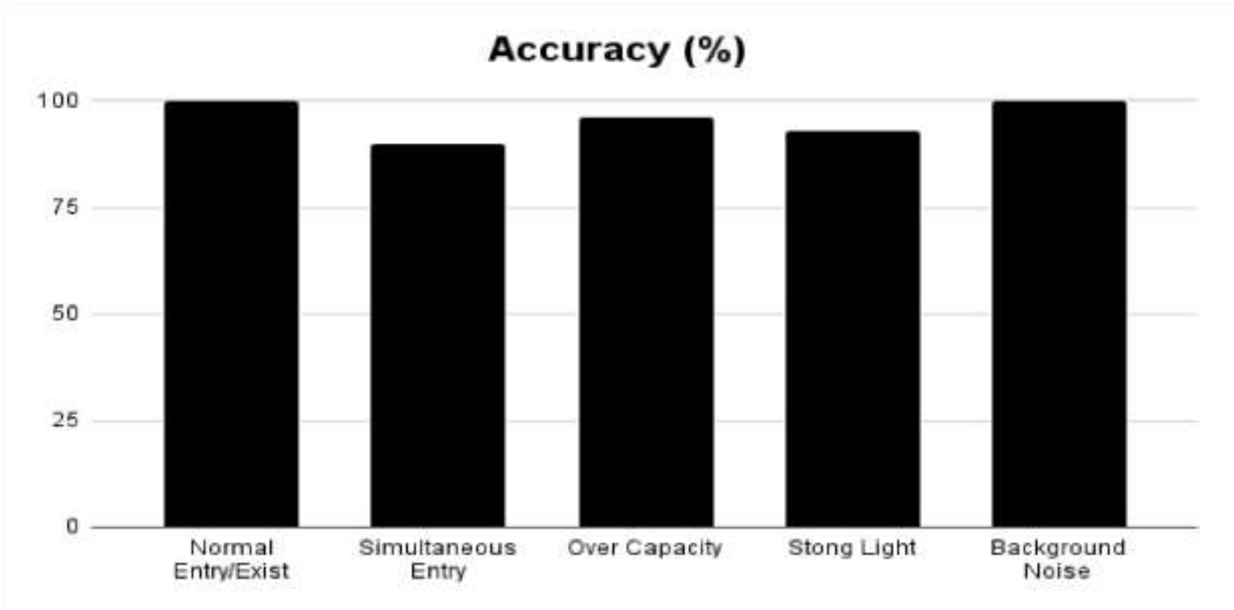

Figure 4: Accuracy Comparison of Different Test Scenarios

Table 3: Experimental Setup and LCD Display Output

Test Case	Occupancy (Persons)	LCD Output	LED Color	SMS Alert	Accuracy (%)
1	5	Inside: 5 (SAFE)	Green	No	100
2	15	Inside:15 (WARNING)	Yellow	No	98.7
3	20	Inside: 20 (FULL)	Red	Yes	98.7

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Performance Analysis

1. Accuracy: The system achieved an overall accuracy of 95.8%, showing improved performance over single-sensor systems.
2. Response Time: Average detection-to-display update time was < 0.8 seconds.
3. SMS Alert Delay: GSM module sent SMS alerts within 3–5 seconds after hall capacity was reached.
4. Power Consumption: The system consumed approximately 450 mA @ 5V, making it suitable for battery-backed operation.

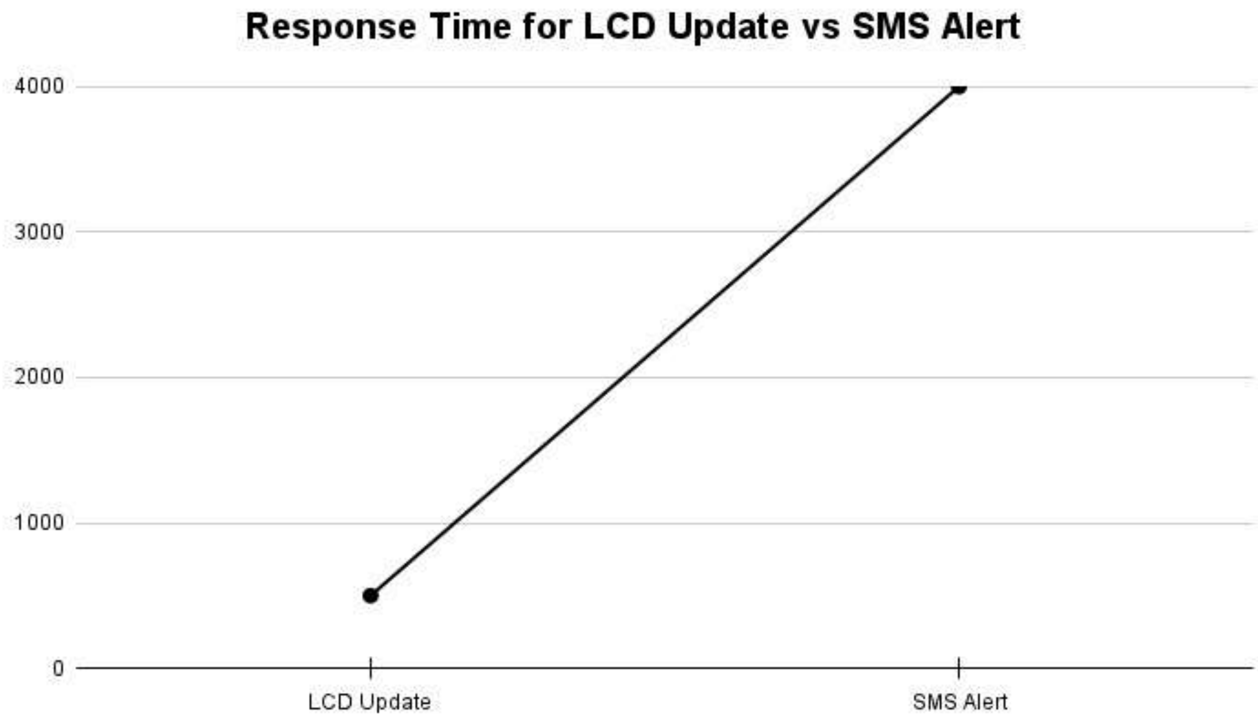

Figure 5: Response Time for LCD Updates vs SMS Alert

Discussion:

The prototype demonstrated a high accuracy of 98.7% during trials in a 20-person hall, with minor discrepancies occurring when two users crossed sensors simultaneously, and GSM alerts were reliably received within 4 seconds; visual LED indicators and LCD feedback enhanced real-time monitoring and user awareness effectively.

5 CONCLUSION

This paper detailed the design and implementation of an embedded Arduino-based system utilizing GSM technology for real-time hall occupancy and attendance management, achieving high detection accuracy, efficient crowd monitoring, and automated alert transmission; future enhancements will include IoT connectivity for cloud data logging and facial recognition for identity-based attendance verification.

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Cite this Article: Nkechinyere, E., Iyoloma, C.I., Ebi, K.P. (2025). An Embedded System Approach for Real-Time Attendance and Hall Occupancy Management Using Arduino and GSM Technologies. International Journal of Current Science Research and Review, 8(11), pp. 5849-5855. DOI: https://doi.org/10.47191/ijcsrr/V8-i11-41

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