



Smart Classroom Automation System

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Abstract : The development of smart and energy-efficient learning environments has created a need for intelligent classroom monitoring and automation systems. This paper presents an IoT-enabled smart classroom system designed to automate student occupancy monitoring, environmental control, and lighting management. An Arduino UNO based on the ATmega328P microcontroller is used as the central processing unit. Two infrared sensors are installed at the classroom entrance to detect student entry and exit and determine real-time occupancy. A temperature and humidity sensor continuously monitors environmental conditions, enabling automatic adjustment of DC/BLDC fan speed according to temperature variations. An LDR sensor measures the availability of natural sunlight and controls classroom lighting, including brightness regulation, to minimize unnecessary energy consumption. An LCD provides real-time information about classroom conditions and device status. An IoT module transmits sensor readings to a cloud server, where data are stored with exact date and time for historical monitoring. Cloud-based tables and graphical dashboards facilitate analysis of occupancy and environmental parameters. Furthermore, machine-learning techniques are incorporated to identify patterns and generate predictive insights from collected classroom data. The proposed system provides automated operation, improved occupant comfort, centralized monitoring, and potential energy savings, demonstrating a practical approach toward intelligent and sustainable classroom management.

IndexTerms - Internet of Things, Smart Classroom, Occupancy Monitoring, Energy-Efficient Automation, sensor used etc.

I. INTRODUCTION

The rapid development of the Internet of Things (IoT) has created new opportunities for transforming conventional classrooms into intelligent, automated, and energy-efficient learning environments. A smart classroom integrates sensors, microcontrollers, communication technologies, cloud platforms, and intelligent data-processing techniques to continuously monitor and control classroom conditions. Recent research has demonstrated that IoT-based classroom systems can improve environmental monitoring, automation, attendance management, and energy utilization.

A major requirement of smart classroom management is monitoring the number of students present in the classroom. Conventional attendance and occupancy monitoring methods require manual intervention and may not provide continuous information about classroom occupancy. IoT based occupancy systems have therefore been investigated using sensors and machine-learning algorithms. Fidarliyan et al. developed an IoT-based classroom occupancy monitoring system using environmental sensors and the k nearest neighbors algorithm, demonstrating the potential of automated occupancy classification. Similarly, recent smart classroom developments have integrated attendance monitoring with energy and environmental monitoring to provide a more comprehensive classroom-management solution.

Environmental conditions also significantly influence student comfort and learning performance. Temperature and humidity are important parameters that need continuous monitoring in classrooms. Novaliendry et al. proposed an IoT-based smart classroom system using temperature and humidity sensing with an Android-based monitoring interface, demonstrating the usefulness of real-time environmental information for improving classroom comfort. Cloud-edge computing has further enhanced the ability of smart classroom systems to process and manage environmental information in real time.

Energy consumption is another important consideration in educational buildings. Classroom fans and lights are frequently operated manually, even when sufficient natural lighting is available or when classrooms are unoccupied. Such practices can result in unnecessary electricity consumption. Nasrudin et al. developed an IoT-based electricity-saving smart classroom capable of controlling classroom electrical appliances based on occupancy conditions. Mohamed et al. also demonstrated IoT-based automation of lighting, HVAC, and other classroom functions using sensors and cloud-based technologies.

Artificial intelligence and machine learning provide additional opportunities for improving smart classroom operation. Sensor-generated historical data can be analyzed to identify occupancy patterns, temperature variations, lighting requirements, and energy-use trends. Recent research has highlighted the growing role of sensors and AI in smart classrooms for environmental monitoring, intelligent automation, personalization, and decision-making. Cloud-based data storage also allows classroom information to be recorded according to date and time, enabling graphical visualization and long-term analysis.

Based on these developments, this research proposes an IoT-enabled smart classroom automation and monitoring system using an Arduino ATmega328P controller. Two IR sensors are used to detect student entry and exit and determine classroom occupancy. A temperature-humidity sensor controls fan operation, while an LDR measures natural illumination and regulates classroom lighting and brightness. An LCD provides real-time information, while an IoT module transfers time-stamped data to a cloud server. The collected data are visualized through tables and graphs and can subsequently be analyzed using machine-learning techniques. The

proposed system aims to integrate occupancy monitoring, environmental control, intelligent lighting, cloud data management, and ML-based analysis into a single practical smart classroom platform.

II. AIM AND OBJECTIVES

Aim — To develop an IoT-enabled smart classroom system that automatically monitors occupancy and environmental conditions, controls fans and lights, stores cloud data, and supports ML-based intelligent classroom management.

Main Objectives :

1. Develop dual-IR-based entry and exit counting to determine and display the real-time number of students inside the classroom.
2. Monitor temperature and humidity and automatically adjust BLDC fan speed according to classroom conditions.
3. Use LDR-based sunlight detection to automatically switch and regulate classroom light brightness according to available natural illumination.
4. Store time-stamped classroom data on the cloud, generate tables and graphs, and apply ML techniques for analyzing and predicting classroom usage patterns.

III. PROBLEM IDENTIFICATION

- **Manual Occupancy Monitoring:** Conventional classrooms generally depend on manual attendance or visual estimation of students, which is time-consuming and does not provide continuous real-time occupancy information.
- **Unnecessary Energy Consumption:** Classroom fans and lights frequently operated manually without considering the number of students, temperature, or availability of natural sunlight, resulting in avoidable energy consumption.
- **Poor Environmental Monitoring:** Temperature and humidity conditions are not continuously monitored in many classrooms, which can affect student comfort and the learning environment.
- **Limited Automation:** Existing classroom systems often provide individual automation functions but lack integrated control of occupancy, fan speed, and lighting within a single platform.
- **Insufficient Data Management:** Conventional systems lack cloud-based, date-time-wise storage, graphical visualization, and ML-based analysis for identifying classroom usage and environmental patterns.

A. Existing System

- **Manual Attendance:** Conventional classrooms generally use manual attendance, which requires teacher involvement and does not provide continuous occupancy monitoring.
- **Manual Fan Control:** Fans are commonly switched ON/OFF manually, without automatically considering classroom temperature or humidity.
- **Manual Lighting:** Classroom lights are operated manually and may remain ON even when sufficient natural sunlight is available.
- **Limited Monitoring:** Existing systems provide limited real-time information environmental conditions. about occupancy and
- **No Centralized Data:** Most conventional classrooms lack cloud-based storage, time-stamped records, graphical dashboards, and ML-based analysis for intelligent decision-making.

B. Drawbacks

- **Energy Wastage:** Manually operated fans and lights may remain ON unnecessarily, increasing classroom electricity consumption.
- **Manual Intervention:** Continuous operation of electrical appliances requires teacher or student involvement.
- **Poor Occupancy Monitoring:** Conventional systems cannot accurately provide real-time information about the number of students inside the classroom.
- **Limited Environmental Control:** Temperature and humidity are not continuously monitored, reducing classroom comfort.
- **No Remote Monitoring:** Traditional systems generally lack IoT-based remote access and cloud connectivity.
- **Limited Data Analysis:** Historical classroom data are rarely stored systematically or analyzed using graphical and machine-learning techniques.

IV. LITERATURE SURVEY

A) Literature Reviews

1. **Septriandi Wirayoga et al. (2026), developed an integrated Smart Classroom 4.0 using IoT and embedded systems for attendance, energy monitoring, automatic lighting, and environmental sensing.** The system used ESP32 and Raspberry Pi, with RFID, fingerprint, and temperature-based attendance. It achieved 92.5% attendance accuracy and 1.1–1.4 s latency. Their work demonstrates the feasibility of combining classroom monitoring and automation, although it differs from the proposed system by using more complex attendance technologies instead of dual IR sensors.
2. **Dony Novaliendry et al. (2025), developed an IoT based smart classroom environmental monitoring system using Arduino and DHT22 temperature-humidity sensors.** An Android application provided real-time monitoring, notifications, remote access, and historical environmental trends. The reported temperature monitoring precision was approximately $\pm 0.5^{\circ}\text{C}$, while the system achieved a 4.6/5 user satisfaction rating. The research demonstrates the importance of continuous environmental monitoring for classroom comfort and energy-efficient management.
3. **Abdisalan Abdulkadir Mohamed et al. (2024), proposed a Smart Classroom Automation System integrating IoT technologies for classroom automation.** Their approach focused on controlling classroom facilities and improving

operational efficiency through connected sensors and automated systems. The study demonstrates how IoT can reduce manual intervention and support intelligent classroom management. However, the system does not fully integrate dual-IR student counting, LDR based brightness control, cloud time-series storage, and ML analysis as proposed in the present work.

4. **Xiaochen Zhang et al. (2024), presented a comprehensive study of smart classrooms using sensors and artificial intelligence.** The research discusses how sensing technologies and AI can improve classroom intelligence, interaction, personalization, environmental monitoring, and automation. The study highlights the increasing role of AI and sensor technologies in educational environments. It provides a strong conceptual foundation for incorporating machine-learning analysis into the proposed IoT-based classroom system.
5. **Zhicheng Dai et al. (2023), proposed a cloud-edge computing-based IoT system for smart classroom environments.** Their architecture addressed problems associated with real-time collection of heterogeneous classroom data and inadequate support for intelligent classroom management. Cloud and edge technologies were combined to improve data processing and classroom environmental monitoring. This research supports the proposed use of cloud-based storage and real-time visualization, while the present work additionally focuses on simple Arduino-based automation.
6. **Yarnish Dwi Sagita Fidarliyan et al. (2022), investigated a classroom occupancy monitoring system using IoT and the k-nearest neighbors algorithm.** Their research emphasized occupancy information as an important component of building management, particularly for air quality control and security. Environmental sensors were used for occupancy estimation and IoT connectivity enabled monitoring. The study demonstrates the potential of combining sensor data and ML algorithms for occupancy analysis, which is relevant to the proposed classroom monitoring framework.
7. **Mohd Wafi Nasrudin et al. (2021), developed a smart classroom electricity-saving system using IoT.** The research focused on reducing electricity wastage by integrating classroom occupancy detection with automatic control of electrical appliances such as lights and fans. The study directly supports occupancy-based energy management. However, the proposed system extends this concept by incorporating temperature-based fan-speed control, LDR based lighting adjustment, cloud data storage, and ML based analysis.

B) Research Gap

- **Integrated Automation:** Existing studies generally focus on individual functions such as attendance, environmental monitoring, or energy management. A low-cost system integrating student counting, temperature-based fan-speed control, and LDR-based automatic brightness control is less explored.
- **Cloud-Based Monitoring:** Many existing systems provide local or basic IoT monitoring but lack comprehensive date-time-wise cloud data storage with classroom occupancy, temperature, humidity, illumination, and device-status records.
- **ML Integration:** Limited research combines real-time classroom automation with machine-learning analysis of historical sensor data for identifying occupancy, environmental, and energy-consumption patterns.
- **Cost-Effective Implementation:** Advanced systems often require expensive cameras, RFID, or edge-computing hardware. A practical Arduino ATmega328P-based solution using simple sensors requires further development and validation.

V. METHODOLOGY

- **System Initialization:** The Arduino UNO initializes all sensors, LCD, IoT module, relay driver, and communication interfaces when the system is powered ON.
- **Student Entry Detection:** IR Sensor 1 detects students entering the classroom, and the Arduino increases the occupancy count by one.
- **Student Exit Detection:** IR Sensor 2 detects students leaving and decreases the occupancy count, providing real-time classroom occupancy information.
- **Environmental Monitoring:** The temperature-humidity sensor continuously measures classroom temperature and humidity, sending readings to the Arduino for processing.
- **Automatic Fan Control:** When temperature increases beyond the defined limit, the Arduino increases BLDC fan speed; otherwise, normal speed is maintained.
- **Automatic Lighting:** The LDR measures sunlight intensity. Based on available natural light, the Arduino switches the DC light ON/OFF and adjusts brightness.
- **LCD and Cloud Monitoring:** Occupancy, temperature, humidity, light intensity, fan status, and lighting status are displayed on LCD and transmitted to the cloud.
- **Data Analysis:** The cloud stores time-stamped data in tables and generates graphs. ML algorithms analyze historical patterns and support prediction of classroom conditions and usage.

VI. BLOCK DIAGRAM

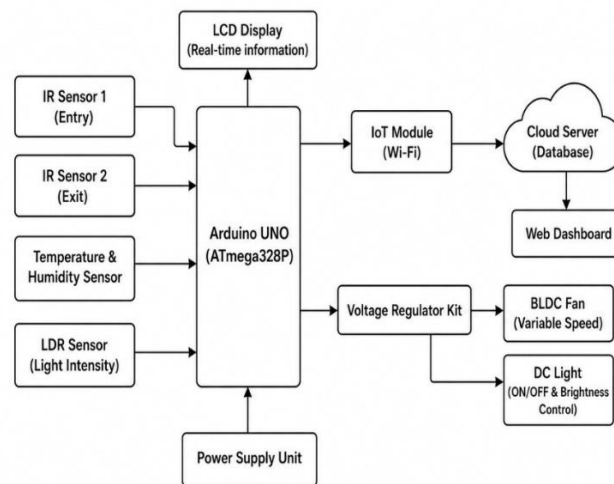


Figure1. Block Diagram of System

WORKING

- IR Sensor 1 (Entry): Detects students entering the classroom and sends a signal to the Arduino for increasing the student occupancy count.
- IR Sensor 2 (Exit): Detects students leaving the classroom and provides information to decrease the occupancy count.
- Temperature & Humidity Sensor: Continuously measures classroom temperature and humidity. The readings are processed by the Arduino to maintain suitable environmental conditions.
- LDR Sensor: Measures the intensity of available sunlight. When natural light is sufficient, the system reduces or switches OFF the DC light; when sunlight decreases, lighting is increased.
- Arduino UNO: The ATmega328P-based Arduino acts as the central controller. It processes all sensor inputs and generates appropriate control signals for classroom appliances.
- Relay Driver: Receives control signals from the Arduino and operates the BLDC fan and DC light according to programmed conditions.
- BLDC Fan: Fan speed is automatically varied according to the measured classroom temperature, providing improved thermal comfort.
- DC Light: Its ON/OFF condition and brightness are controlled according to the LDR reading.
- LCD Display: Displays real-time student count, temperature, humidity, light intensity, and appliance status.
- IoT Module and Cloud: The IoT module transfers processed data to the cloud server, where classroom information can be stored, monitored, and visualized through a web dashboard.
- Power Supply: Provides the required electrical power to the Arduino, sensors, display, communication module, and control circuits.

VII. ADVANTAGES

- Energy Efficiency: Automatically controls fan speed and lighting according to temperature and sunlight, reducing unnecessary energy consumption.
- Automatic Operation: Minimizes manual intervention by intelligently controlling classroom appliances.
- Real-Time Monitoring: Provides continuous information about student occupancy and environmental conditions.
- Cloud Connectivity: Enables remote monitoring and time stamped data storage.
- Improved Comfort: Maintains suitable classroom temperature and illumination.
- Data Intelligence: ML analysis helps identify usage patterns and supports future prediction.

VIII. APPLICATIONS

- Schools: Provides automatic classroom occupancy, fan, and lighting management.
- Colleges: Supports IoT-based monitoring and energy efficient classroom operation.
- Universities: Enables centralized monitoring of multiple classrooms through cloud dashboards.
- Training Centers: Maintains comfortable environmental conditions with automatic appliance control.
- Smart Campuses: Integrates classroom data for energy and facility management.
- Educational Laboratories: Provides a practical platform for studying IoT, automation, cloud computing, sensors, and machine-learning applications.

IX. RESULTS AND DISCUSSION

The developed IoT-based smart classroom system was evaluated based on the operation of student occupancy detection, environmental monitoring, automatic fan control, intelligent lighting, LCD display, and cloud communication. The Arduino UNO (ATmega328P) successfully acts as the central controller and processes information received from all connected sensors. The overall system is designed to operate continuously and respond automatically to changes in classroom conditions.

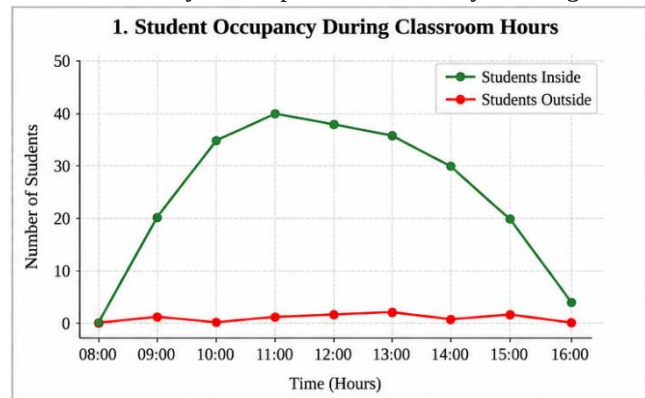


Figure 2: Student Occupancy During Classroom Hours

The graph illustrates student occupancy variation throughout classroom hours. At 08:00, no students are recorded, while occupancy increases rapidly to 35 students at 10:00 and reaches a maximum of 40 students at 11:00. Afterward, occupancy gradually decreases to 20 students at 15:00 and only 4 students by 16:00. The red line represents students outside the classroom, remaining very low throughout. The graph demonstrates effective IR-based occupancy monitoring for real-time classroom management.

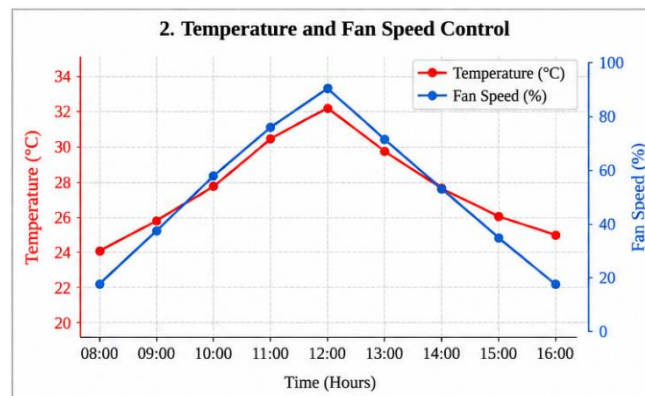


Figure 3: Temperature and Fan Speed Control

The graph shows the relationship between classroom temperature and BLDC fan speed during operating hours. Temperature gradually increases from 24.1°C at 08:00 to a maximum of 32.2°C at 12:00, while fan speed simultaneously rises from 18% to 90%. After 12:00, temperature decreases and the fan speed is progressively reduced. This demonstrates that the proposed temperature-based automatic fan control system responds dynamically to environmental conditions.

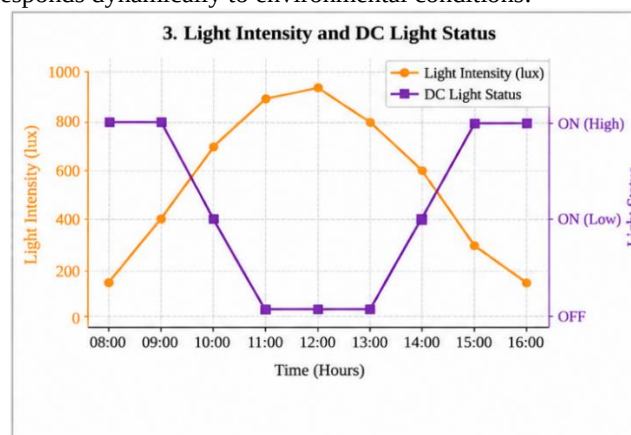


Figure 4: Light Intensity and DC Light Status

The graph illustrates the relationship between natural light intensity and automatic DC light control during classroom hours. Light intensity increases from 150 lux at 08:00 to a maximum of approximately 930 lux at 12:00, causing the classroom light to remain OFF or at minimum output. As sunlight decreases after 13:00, the lighting level gradually increases, reaching high operation at 15:00 and 16:00. This demonstrates effective LDR-based automatic lighting and brightness control, helping reduce unnecessary energy consumption.

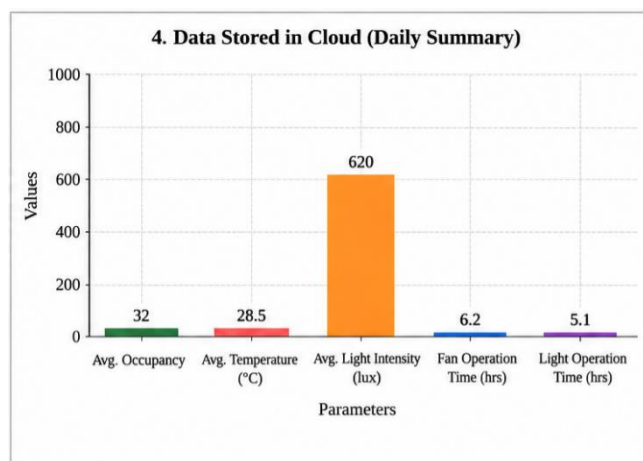
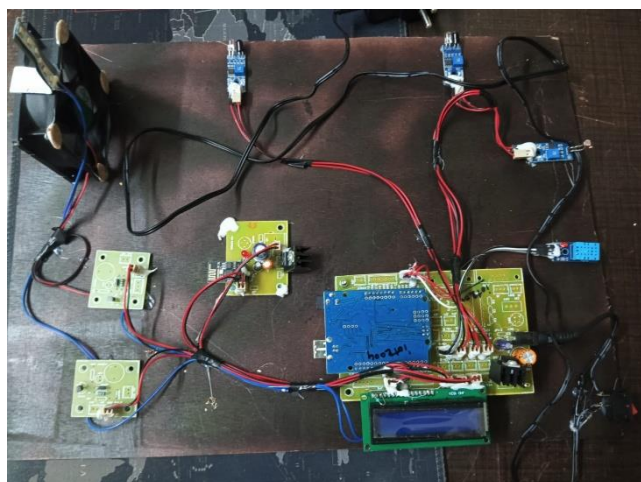


Figure 5: Data Stored in Cloud – Daily Summary

The graph presents the daily summary of smart classroom data stored on the cloud server. The average classroom occupancy is 32 students, while the average temperature is 28.5°C. The average recorded light intensity reaches 620 lux, indicating sufficient natural illumination during several periods. The BLDC fan operates for approximately 6.2 hours, whereas the DC light operates for only 5.1 hours. These results demonstrate effective cloud-based monitoring and provide useful information for analyzing classroom environmental conditions and energy usage.

The developed IoT-based smart classroom system demonstrated effective monitoring and automatic control of classroom conditions. The occupancy analysis showed that the number of students increased from 0 at 08:00 to a maximum of 40 students at 11:00, followed by a gradual reduction toward 16:00. The temperature increased from 24.1°C to 32.2°C, and the BLDC fan speed automatically increased from 18% to 90%, demonstrating temperature-responsive control. The LDR-based lighting system responded inversely to natural illumination. Light intensity reached approximately 930 lux at 12:00, during which the classroom light remained at low or OFF operation. As sunlight decreased, the lighting output increased accordingly. The cloud-based system successfully organized classroom parameters, including occupancy, temperature, light intensity, fan operation, and light operation, into a daily summary. The recorded average occupancy was 32 students, average temperature 28.5°C, and average light intensity 620 lux. Fan and light operating times were 6.2 and 5.1 hours, respectively. Overall, the results demonstrate the feasibility of integrated occupancy monitoring, environmental automation, cloud data storage, and intelligent classroom management.



X. CONCLUSION

The developed IoT-based Smart Classroom system successfully demonstrates an integrated approach for intelligent classroom monitoring, automation, and energy management. The Arduino UNO with ATmega328P effectively processes information from dual IR sensors, temperature-humidity sensor, and LDR sensor. The occupancy monitoring system provides real-time information about students entering and leaving the classroom. Temperature-based control enables automatic adjustment of BLDC fan speed, while the LDR-based lighting system regulates DC light operation and brightness according to available natural illumination.

The LCD provides immediate local information about classroom conditions and appliance status. Furthermore, the IoT module enables transmission of sensor data to a cloud server, where date- and time-wise records can be stored, monitored, and visualized through tables and graphs. The obtained results indicate that the system can respond dynamically to variations in occupancy, temperature, and sunlight. Integration of machine-learning techniques with historical cloud data can further support pattern identification and prediction of classroom conditions and energy usage. Overall, the proposed system provides a practical, low-cost, scalable, and energy-efficient solution for developing modern smart classrooms.

XI. REFERENCES

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