

Development of a Smart Classroom Monitoring Mobile Robot

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Abstract:

In the modern era, monitoring and engaging the students in the classroom is a tedious process for the teacher among their other academic activities. In our paper we have attempted to create a system to monitor as well as manage classrooms whenever teachers are absent through the creation of an affordable automated Smart Classroom Monitoring Mobile Robot. Developed around ESP32 the Smart Classroom Monitoring Mobile Robot utilises time-based teacher confirmations, IR sensors to follow a predefined path, ultrasonic sensor to avoid collisions, RFID module for teacher identity check, Real-Time Clock (RTC) module to follow schedule of classes and DFPlayer Mini MP3 for playing pre-recorded motivational audio stories to engross the students in constructive academic activities. The robot not only self-navigates within the classroom at time of teacher's absence but also sends an automatic alert on the principal's / administrator's mobiles through Blynk IoT platform. The entire system is simple to use, user-friendly and affordable. This paper explains the system architecture, methodologies, utilised hardware components and their specifications, software modules developed and outcome of the Smart Classroom Robot for effective educational monitoring.

Keywords—Smart classroom, mobile robot, ESP32, teacher absence detection, IoT, Blynk, RFID, classroom monitoring, student engagement

I.INTRODUCTION

Education quality is further eroded if learning time is lost through avoidable absenteeism by teachers. While an occasional day's absence may be unavoidable for "sick" teachers, such absence is a regular, accepted phenomenon in most educational institutions. The usual consequences are that students are left with nothing to do (and consequently become unruly), or worse, they simply

don't come to school. This is unsustainable for the academic success and discipline of any educational institution.

Typical workflows for handling absent teachers involve staff manually monitoring a page or students' agents/ADMs informing the school about absent teachers. This reactive approach is error prone and slow to respond. Schools require a more automated, proactive workflow that detects teacher

absence and escalates automatically to minimize disruption

This project aims to design a Smart Classroom Monitoring Mobile Robot. The robot will work on auto-mode according to the class timings. It will keep checking from the robot's side whether the teacher has marked his presence at the beginning of the class or not. If the teacher has not marked his presence within a set time period and students are detected in the class then it will assume that teacher is absent for that class. The robot will then enter the class, play some motivational songs and make the students engaged in some productive work. Administrator/principal will also be informed instantly via Blynk mobile application.

Our system is made using simple, affordable electronic parts and free software tools, which makes it easy to use and suitable for schools of any size. This way, it's practical and can be used by many educational institutions.

II.LITERATURE REVIEW

To identify what gaps in research the present project would fill, research was reviewed on smart classrooms, autonomous robots, and classroom management technology.

Paudel P., Kim S., Park S., and Choi K.-H. (2020) In a proposal of a context-aware IoT and deep learning smart classroom system to reduce energy consumption from the classroom's electrical loads by using sensors and automation technologies that can intelligently monitor classroom activities the researchers concluded that with IoT and deep learning technology significant reductions in unnecessary energy consumption can occur in educational institutions.

F.B.J., R.R., S.M., and G.M.N.R. (2020) An IoT-based national integrated smart classroom system was developed for the purpose of creating a sustainable campus using cloud technology to facilitate the centralised monitoring and automation of classroom resources. The authors concluded that cloud-based integration of the classroom system

expands the automation capabilities, maximisation of resource use and sustainability of the campus through classroom systems.

Rajesh, Sreekanksha, Miralee, Govind, and Deepak (2022) that details the development of a "smart classroom" robot created using digital control, RFID, and environmental sensors to provide classroom automation including attendance, lighting, fans, and sanitization [9:4,5]. Their study found that their classroom automation system was cost-effective and easy-to-use for both teachers and students in a classroom environment.

Zhao M., Zhao G., and Qu M. (2022) that describes the implementation of an attendance management system that combines RFID with facial recognition for automated attendance tracking in the classroom environment. The researchers concluded that the combination of IoT technologies with facial recognition for class attendance management will increase accuracy of attendance records and reduce the manual errors associated with this type of tracking

“A Survey on an IoT Based Automated Classroom Appliances Controlling System” (2022) in which they surveyed many different types of IoT based automated classroom appliance control technologies for controlling classroom energy usage and improving operational convenience within the classroom. They found that automation in the classroom is critical for improving both the classroom's footprint on the environment and the ease this technology can provide to teachers and students

Espressif Systems (2023) The accompanying Technical Reference Manual for the ESP32 explains how the device works including its design architecture, communication methods, uses for GPIO pins, and its wireless capabilities as well. The report confirmed that the ESP32 is an excellent platform and very economical for both Internet of Things projects and embedded applications.

Niveditha S., Anushree N.D., ChaithraShree A.V., Likhitha M.C., and Yogitha R. (2023) Created a smart classroom monitoring system which utilized machine learning as well as the Internet of Things for

automating light/fan control through LDR sensors, temperature sensors, and detection of human presence in the room by using an array of different types of sensing devices. The findings of this study indicated that implementation of this intelligent monitoring will improve the comfort level of students in the classroom; as well as provide additional energy savings through more efficient use of lighting and HVAC systems.

Huang K., Liu R., Cheng Y., Hui M., and Xu X. (2023) The authors created an IoT based smart classroom environmental monitoring system to enable real time monitoring of classroom conditions including temperature and humidity. The study concluded that the use of this system would provide reliable environmental monitoring; creating better management of classrooms and therefore increasing management efficiency for teachers.

In an article titled "IoT Based Smart Energy Management in Classroom" (IOT), the author presented a smart energy management system that uses camera-based occupancy detection to manage energy usage for classroom appliances depending on student presence and seating arrangements. The study concluded that using occupancy-based energy control would decrease wasting energy.

The author of the Wang H. (Wang), also used a teaching quality monitoring system based on the use of 6G IoT wireless technology combined with data mining in order to monitor real time classroom performance. The Wang study concluded that the use of IoT-based monitoring leads to improved evaluation of the quality of teaching and the management of education.

Budiman A., Fabian, Yaputera R.A., Achmad S., and Kurniawan A., (Budiman) conducted a systematic literature review to study the available literature on the use of facial recognition to verify student attendance in the classroom. In this review, the performance of two methods used for taking attendance in the classroom setting, LBP and CNN, were compared. The finding shows that facial recognition is an effective method of automating the process of managing attendance.

Ranjana Thakuria, Prajwal K., Sindhu H., Soumya A. Bavagi. 2024 and created smart classroom management software to improve the educational experience by better student engagement, participation and support that arise from the creation of new technology. Results of their study showed that smart classroom management software enhances learning outcomes and classroom performance.

M. Yaganoglu et al. (2024) developed an “internet of things” (IoT)-enabled smart classroom to monitor and automate classrooms. The study found that using IoT technologies in automation, monitoring, and overall operational effectiveness will be improved.

The Arduino Foundation (2024) documentation contains in-depth information on embedded programming methods and hardware interfaces for the Arduino IDE platform. With the help of this documentation the authors show that the Arduino IDE platform is an appropriate solution for novice and experienced developers working on IoT and robotics projects

Lampropoulos G. et al. (2024) Intelligent tutoring systems, robotics, and IoT convergence for smart education. The paper discussed a number of research articles related to automation of learning spaces and applications of artificial intelligence in learning. It was concluded that in the future robotics and Internet of things would have a great impact on smart education systems.

Research conducted by “Automation of IoT-Based Classrooms: Control of Light & Fan Using an ESP32” that was published in 2024 proposed an ESP32 based automated classroom system utilizing various types of sensors as a method for Intelligent Control of Fans, Lights, and Modes In A Classroom. The conclusion of this research determined that utilizing an ESP32 based automated system in classrooms can increase both the energy efficiency of the classroom and provide more control over the environment.

In 2024, Nidhya R., Pabi D.J.A., DivyaSree U., Abhishek B., Harika A., & Alim S.A. examined the use of Facial Recognition Technology to manage classrooms and monitor attendance/security. The

conclusion reached was that, when used for automation and to monitor students/Attendance/Facts/Activities of Classrooms, Facial Recognition Technology greatly improves the accuracy of both Automation as well as Classroom Monitoring.

Sudeheesana and Priyanka (2025) using a robotic based system combined with cloud technology to facilitate automated attendance management in classrooms. The outcome of their study indicated that robotic attendance systems can reduce the workload of teachers while increasing transparency within the system of attendance.

Nafiz Ahmed Chisty (2026) suggested a modern IoT-based smart classroom solution which incorporated security and automation technologies. This study mainly concentrated on designing a solution for the limited resource environment. Chisty concluded that the integration of IoT technology increased classroom security and automation efficiency.

Solangkili K., Hari Prasath, Arshavarthan G., Balaji T., and Vignesh S. (2026) Proposed a classroom surveillance system with automated attendance mechanism based on Edge AI and IoT. The system was based on KNN face recognition, RFID authentication, and unattended classroom alerts. According to the researchers, Edge AI and IoT can improve classroom surveillance along with attendance recording.

From our review of the literature, it is evident that existing smart classroom solutions mainly enable attendance tracking and student monitoring; there continues to be a dearth of research on those that are specifically geared towards detecting teacher absenteeism and providing automatic corrective actions in terms of increasing engagement levels for students and notifying the legitimate authority. The Smart Classroom Monitoring Robot fills in that void.

III. WORKING METHODOLOGY

Several issues with regard to classroom monitoring inspired the design of the Smart Classroom Monitoring Mobile Robot. For instance, most schools have no automated process for confirming if

the teacher has attended the scheduled classes. This makes it easy for students to lose instructional hours because of the absence of the teacher. The administration also remains unaware of the situation. The few systems that exist to monitor the situation rely on human monitoring and 3D imaging technology and are therefore prone to delayed action or inconsistency. There is a need for an affordable and scalable solution that requires minimal changes to existing structures. For these reasons, the project will seek to develop a robot that can monitor classroom activities, detect absences of teachers, entertain students while the teacher is away, and report to the administrator via the Internet of Things (IoT) technology.

The Smart Classroom Monitoring Mobile Robot design is a mobile robot built based on a four-wheel drive system placed inside or nearby the classroom. The primary purpose of the mobile robot is monitoring classroom activity based on the preset class schedule. The mobile robot uses low-cost and readily available parts, making its implementation practical in classrooms of institutions such as schools and colleges. The mobile robot is primarily intended for detecting the attendance of teachers based on RFID and RTC module sensors, delivering motivational sound sessions to students while the teacher is away, and sending notifications to the administration via Blynk IoT platform.

The whole process runs by adopting the architecture of the three layers, namely, the sensing layer, processing layer, and action layer. In the sensing layer, different kinds of sensors work together in order to gather information that is needed for the robot's operation. DS3231 Real-Time Clock (RTC) is employed to monitor the present date and time and then compare them with the timetable of the classroom classes. RC522 RFID reader helps to identify the teacher via scanning the RFID card or keychain. There are two TCRT5000 infrared sensors fixed beneath the robot which help to follow the black line laid on the ground in the shape of a track for the robot.

The processing stage is handled by the ESP32 microcontroller that serves as the central processing unit for the whole system. All inputs coming into the

microcontroller come through the ESP32, which analyzes the data received and makes appropriate logical decisions according to predetermined conditions. In addition, ESP32 manages the rotation of the motors, works together with the DFPlayer Mini MP3 module, and can communicate with the cloud server via Wi-Fi for the purpose of notifications. Since ESP32 has capabilities of operating both via Wi-Fi and Bluetooth and has plenty of GPIOs, this microcontroller is perfect for use in this robot.

The action layer of the robot performs all physical motor operations. The L298N motor controller will control both speed AND direction of each DC geared motor (using pulse width modulation [PWM]) produced by the ESP32 micro-controller so that the robot can move forward, move backward, and turn via an established classroom path. The robot also plays pre-recorded motivational or educational audio messages when the teacher is absent using the DFPlayer Mini MP3 module and speaker system. Notifications are sent to the administrator by way of a Blynk mobile application in order for them to quickly alert their school staff (administrative) systems regarding necessary classroom needs.

The robot's operational timeline consists of individual classes, which are time- based, step- by-step processes. The RTC module will send timing information at the start of each class, and at the scheduled time, the robot will start looking for the presence of a teacher. The teacher must be confirmed present by tapping an RFID card on the RC522 RFID reader within the allotted time frame. When the RFID card is read; the ESP32 will check the card and the ESP32 will record the teacher's attendance. Once the teacher has been validated as having been attended, the robot will remain in standby mode for that class until the next regularly scheduled teacher session start time occurs.

The RFID card cannot be scanned by a teacher within that timeframe; therefore, the system will use its Hybrid Decision Method (HDM) to determine if the teacher is absent. The HDM combines two methods of confirming or denying the teacher's attendance, which include time and logic from sensors. The ESP32 starts the countdown clock for

the teacher's attendance as soon as the class starts, and if this time period elapses without a valid commitment from RFID, and there are students seen to be in the classroom, the teacher will be declared absent. The combination of methods is effective; it is simple, dependable, and inexpensive because it does not rely on complex artificial intelligence or image processing technology and the absence identification process does not require internet access as all of the decisions regarding absences will be identified locally with the ESP32 controller.

After confirming an absence, the robot will start to respond automatically. The robot will use a TCRT5000 infrared sensor to detect a black line on the floor and will move towards a classroom autonomously. The robot will also use an HC-SR04 ultrasonic sensor to measure how far away the robot is to any object as it moves through the classroom. If any objects such as chairs or furniture are detected by the robot, an ESP32 will command a L298N motor driver to adjust the motor drive for avoiding collisions, and therefore continue navigating around the classroom safely without colliding into anything.

Upon entering the classroom, the ESP32 utilizes the UART serial port to send instructions to the DFPlayer Mini MP3 module, which will play back audio from Micro SD card and play the MP3 file stored in SD card such as inspirational stories or other educational-related audio through its attached speaker system. This serves to increase student interest, and diminishes student behavioral issues when an instructor is not available to provide classroom instruction. At the same time, the ESP32 makes a Wi-Fi connection to the Blynk cloud platform, and sends an alert notice, via the Blynk mobile app, to notify the principal or other administrator regarding any instructor who has missed classroom instruction. This is a real-time notification system that allows an administrator to make corrective actions in a timely manner any time an instructor fails to report for instruction.

At the conclusion of the class period, the Real Time Clock (RTC) module provides the ESP32 with updated timing data. The robot will then follow a line track on the floor to return to its original standby position. After returning to standby position, the

system will reset itself, prior to being prepared for the next scheduled classroom session. This entire sequence of operations allows for an autonomous robot to function with very little human involvement.

The development of the system was done using the Arduino IDE with an ESP32 board running Embedded C/C++ programming. To communicate with the RTC module, RFID reader, ultrasonic sensor, IR sensors, DFPlayer Mini MP3 module, and Blynk Cloud Platform, various hardware libraries were installed. The software logic consists of time-based scheduling, reading sensor values, controlling motors, communicating via UART, communicating via Wi-Fi, as well as decision-making based on conditional statements needed for the autonomous operation of the robot.

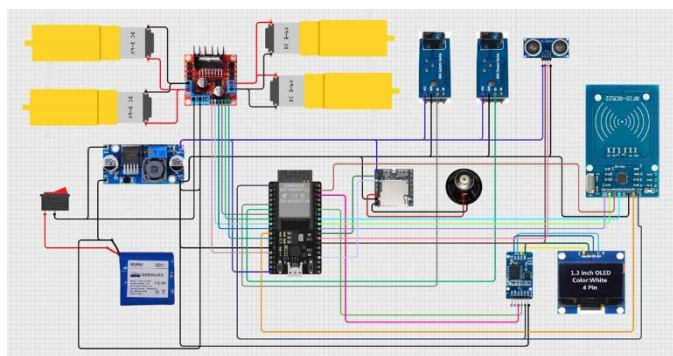


Fig. 1 circuit diagram of Smart Classroom Monitoring Mobile Robot

This system is expected to improve classroom management when teachers miss classes. By utilizing audio playback of motivating and educational materials, students will not be left idle, and the Administrator can be notified immediately if a teacher does not show up for a class. The robot will also help reduce classroom disruption while providing students/faculty with real-world experience in robotics, IoT, and embedded technologies. Therefore, The Smart Classroom Monitoring Mobile Robot can be used in schools/colleges/smart classroom environments and any other educational institution where it is not practical to monitor classrooms with people. Future

smart campus projects that require autonomous classroom monitoring will also benefit from this system.

IV.CONCLUSION

This paper has described the development of an Autonomous Smart Classroom Monitoring Mobile Robot. This autonomous system is an inexpensive way to assist educational facilities by addressing the ongoing global issue of educator absenteeism. It is a hybrid of a mobile robot that follows a path, has time-based educator presence detection, uses RFID for educator presence verification, RTC for scheduling, sends out IoT notifications to staff members if the educator is absent, and gives audio signals to engage students.

The hybrid decision method used for this hybrid system is straightforward and reliable and does not require complicated artificial intelligence algorithms. The system has been built using very inexpensive and readily available hardware; therefore, this system could be implemented easily at both schools and colleges, as well as similar types of educational facilities worldwide.

The anticipated benefits of this system are better student engagement, notification to staff when an educator is absent, and less classroom disruption. Future enhancements for this system may include a camera for visual monitoring, facial recognition for educator identification, and a more elaborate IoT dashboard for academic administrators.

V.FUTURE SCOPE

1. Integration of AI-based face recognition systems can be implemented for automated teacher identification and accurate student attendance tracking.
2. Cloud and IoT technologies can be integrated for real-time classroom monitoring and centralized management accessible to teachers, HODs, and administrators.
3. Live video streaming and CCTV integration can enhance classroom supervision and improve monitoring capabilities.

4. Future versions of the robot can move autonomously without fixed line tracking by using advanced technologies such as SLAM (Simultaneous Localization and Mapping).
5. Voice assistant features can be incorporated to support student interaction and classroom voice announcements.
6. Mobile application support can be developed for remote monitoring of classroom activities and robot status by faculty members and management.
7. RFID and computer vision technologies can be integrated to monitor and analyze student behavior and classroom activities.
8. AI-based obstacle avoidance with multiple sensors can improve robot navigation and provide smoother movement inside classrooms.
9. The robotic system can be expanded for use in libraries, laboratories, examination halls, and other smart campus environments as a multipurpose automation system.
10. Future upgrades may include multilingual audio communication support to improve interaction and engagement with students from different language backgrounds.

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