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Automatic People Counting Machine

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ABSTRACT:
This project presents an Automatic people counting machine integrated with Light Control using RFID technology and the ESP32 microcontroller. Designed for educational institutions and workplaces, the system automates the process of recording people counting by uniquely identifying individuals via RFID tags. When a tag is scanned, the ESP32 processes the data, records the people counting with a timestamp, and updates a cloud-based database for real-time monitoring. In addition, the system incorporates an intelligent light control mechanism: classroom lights are activated when occupancy is detected and automatically turned off when the room is empty, thereby promoting energy efficiency.Leveraging robust IoT protocols and cloud computing, This dual-functionality approach not only minimizes manual errors and eliminates paperwork but also reduces administrative workload and supports sustainable energy practices. The solution is highly scalable, allowing for seamless expansion across multiple rooms or institutions without significant infrastructure changes.Furthermore, the project exemplifies how the integration of hardware components—such as RFID readers, sensors, and microcontrollers—with modern cloud technologies can create smart, automated environments.

Keywords: Automatic people counting machine , RFID technology, ESP32 microcontroller, automated people counting , light control, real-time monitoring, cloud computing, energy efficiency, remote accessibility, scalability

I. INTRODUCTION

In today's fast-paced educational and corporate environments, managing people counting efficiently is essential to ensure operational productivity and effective resource allocation. Traditional people counting methods—such as manual roll calls and paper-based registers—are not only time-consuming but also prone to errors and inconsistencies. The rapid evolution of IoT (Internet of Things) and automated systems presents a transformative opportunity to streamline these conventional processes.The integration of RFID (Radio Frequency Identification) technology with microcontroller platforms like the ESP32 has paved the way for developing sophisticated, automated Automatic people counting machine s. In this project, each student or employee is assigned a unique RFID tag. When an individual enters the classroom or workplace, the RFID reader detects the tag and the ESP32 processes the data, recording the people counting along with an accurate timestamp. This automated approach eliminates manual intervention and significantly reduces the likelihood of errors in people counting tracking.Beyond people counting management, this project also addresses the issue of energy inefficiency in facilities. Often, lights remain on in unoccupied spaces, leading to unnecessary energy consumption. By integrating an intelligent light control mechanism, the system not only registers people counting but also manages classroom or office lighting based on occupancy. When the space is detected as occupied through RFID scans, the lights are activated; conversely, when no presence is detected, the system automatically turns the lights off, thereby promoting energy conservation.The choice of the ESP32 microcontroller is strategic, given its built-in Wi-Fi and Bluetooth capabilities, which facilitate seamless communication with cloud platforms and other IoT devices. This connectivity enables real-time monitoring of people counting data and remote access for administrators, ensuring that the system is both scalable and versatile enough to be implemented across multiple classrooms or workplaces.[1]Overall, the primary objective of this project is to develop a cost-effective, scalable IoT-based solution that not only automates the people counting recording process but also optimizes energy usage through smart light control. By merging RFID technology with the robust capabilities of the ESP32, this system exemplifies how modern hardware and cloud integration can work together to enhance administrative efficiency and contribute to sustainable resource management.

I. Literature Survey

1. IoT in Education and Resource Management

The application of IoT in educational settings represents a significant paradigm shift. IoT enables seamless connectivity between various devices, leading to improved administrative processes and resource management. Researchers such as Khan et al. (2016) have demonstrated that IoT-enabled systems facilitate smart classroom environments by interconnecting devices (e.g., lights, projectors, and Automatic people counting machine s) for centralized monitoring and control. Furthermore, Raza et al. (2017) highlighted that real-time data acquisition via IoT significantly reduces manual intervention and enhances the accuracy of routine tasks like people counting tracking.

2. RFID Technology in Automatic people counting machine s

RFID technology has emerged as a reliable method for automating people counting management. By leveraging electromagnetic fields, RFID systems allow for rapid, contactless identification of individuals. Gupta et al. (2015) and Liu et al. (2017) have shown that RFID-based Automatic people counting machine s can effectively eliminate errors inherent in manual roll calls while offering scalability for larger institutions. The uniqueness of RFID tags ensures that each student or employee can be individually identified and recorded, thereby streamlining the people counting process.

3. ESP32 Microcontroller in IoT Applications

The ESP32 microcontroller is a key enabler in IoT applications due to its integrated Wi-Fi and Bluetooth capabilities, low power consumption, and cost-effectiveness. Studies by Lai et al. (2019) and Ravi et al. (2020) have underscored the microcontroller's versatility in handling multiple sensors and peripherals, which is essential for complex IoT projects. Moreover, Patel et al. (2021) demonstrated the successful integration of the ESP32 in smart Automatic people counting machine s that incorporate cloud connectivity, ensuring that data can be remotely accessed and managed in real time.

4. Light Control in Smart Classrooms

In addition to people counting management, efficient energy use is a critical focus in modern educational environments. Traditional lighting systems often lead to energy wastage when classrooms are unoccupied. Research by Mishra et al. (2020) and Sivaraman et al. (2018) has emphasized the benefits of IoT-enabled light control systems. These systems dynamically adjust lighting based on occupancy, thereby reducing unnecessary power consumption. Integrating RFID data to control lighting not only enhances user comfort but also promotes sustainable energy practices.

5. Cloud Integration and Data Management

The shift towards cloud-based solutions has revolutionized data management, enabling real-time access and analytics. Liu et al. (2016) demonstrated that cloud integration in IoT systems facilitates the storage, retrieval, and analysis of people counting records, allowing administrators to monitor trends and generate reports remotely. Cloud platforms such as Firebase, ThingSpeak, or AWS IoT provide the necessary infrastructure to support scalable and secure data management, making them ideal for integration with IoT-based people counting and light control systems.

II. METHODOLOGY

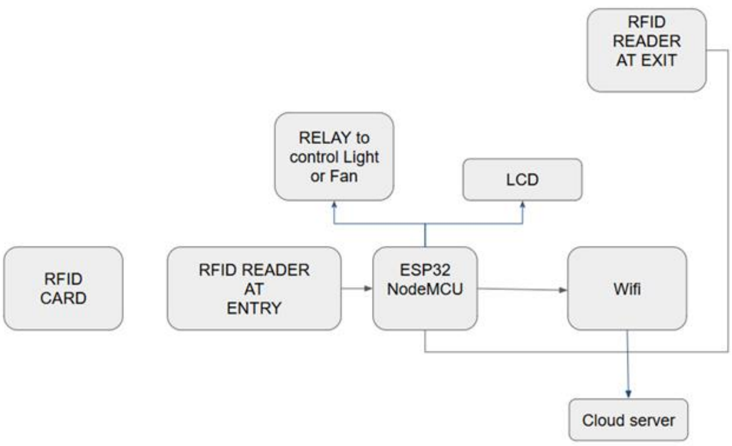

Fig 1:-flow chart

The methodology for developing the Automatic people counting machine with RFID and Light Control using an ESP32 microcontroller involves a structured sequence of hardware and software integrations, guided by a focus on reliability, scalability, and real-time data management. First, the hardware design is conceptualized by identifying the key components essential for the system's functionality: an RFID reader placed at the entry point of the classroom or office, an additional RFID reader at the exit (optional but useful for more precise occupancy tracking), an ESP32 (or NodeMCU) microcontroller, a relay module to control the lights or fans, an LCD display for immediate status feedback, and a Wi-Fi connection for communication with the cloud server. In this setup, each user (student or employee) is issued an RFID card embedded with a unique identifier. Upon arrival, the individual presents the card to the RFID reader stationed at the entry point. The RFID reader then extracts the user's unique ID, relaying this data to the ESP32 microcontroller via the Serial Peripheral Interface (SPI) or another supported communication protocol. Once the ESP32 receives the user ID, it performs an internal check against a pre-registered database stored either locally on the microcontroller's flash memory or on a remote server. If the ID is valid, the microcontroller records the people counting event, marking the user as present and storing the timestamp associated with the entry. Simultaneously, the system increments the occupancy count, indicating that one more individual is inside the room. In scenarios where a second RFID reader is placed at the exit, the same validation and logging mechanism is applied in reverse; that is, when an individual scans their card at the exit reader, the system logs their departure time and decrements the occupancy count accordingly.

Following the initial RFID scanning phase, the ESP32 transmits the people counting data to the designated cloud platform through Wi-Fi, ensuring that the information is accessible in real time. This step typically leverages HTTP, MQTT, or WebSocket protocols to push the data to a server such as Google Firebase, Amazon Web Services (AWS), or a custom server. Once the data reaches the cloud, it is processed and stored in a secure database. Administrators or instructors can then access this data remotely via a web dashboard or mobile application, thereby eliminating the need for manual people counting sheets and significantly reducing administrative overhead. Additionally, if the design includes an LCD display connected to the ESP32, the microcontroller can provide immediate feedback to the user by displaying messages such as " people counting Marked" or "Unknown Card" in cases where the RFID tag is not recognized. This immediate feedback mechanism not only improves user experience but also helps in quickly diagnosing any issues with the RFID scanning process.

On the software side, the methodology begins with configuring the ESP32's development environment, typically through the Arduino IDE or the ESP-IDF (Espressif IoT Development Framework). Libraries for RFID (e.g., MFRC522 or similar) are integrated to enable smooth communication with the RFID reader, while Wi-Fi libraries (like WiFi.h in Arduino or the native Wi-Fi stack in ESP-IDF) handle internet connectivity. The developer then sets up routines to read and parse the RFID tag data, to validate the incoming user ID against a locally stored or remotely fetched list of valid IDs, and to invoke the correct functions for data logging. Additionally, the relay pin is defined in the code, and logic is introduced to activate or deactivate the relay based on occupancy status. A timer-based or interrupt-based approach is often used to update the occupancy count and send data to the cloud server at regular intervals. For cloud connectivity, the methodology involves creating or subscribing to a web API, database, or IoT platform. Data is formatted in JSON or another standard data exchange format and sent to the server using HTTP POST or MQTT publish messages. Once stored in the cloud, the data can be visualized using dashboards or front-end applications. Security considerations, such as using HTTPS or MQTT over TLS, are crucial to protect sensitive user information and prevent unauthorized data manipulation. In parallel, the LCD display is managed through either I2C or SPI protocols, allowing the system to present concise messages regarding the user's people counting status or system alerts. Lastly, thorough testing is conducted to ensure robust operation. This includes verifying that RFID cards are consistently recognized, the occupancy count reflects the actual number of individuals in the room, and the lights or fans behave correctly under various scenarios .

Sr. No.	Component Name	Specification
1	ESP32	CAM
2	RFID Reader	MFRC522
3	RFID Tags	MIFARE Classic 1K
4	Relay Module	Operating Voltage: 5V
5	LCD	16x2
6	Wi-Fi Router	2.4 GHz

7	Power Supply	5V DC
8	Cloud Platform	HTTP, MQTT,

Table No. 1 Components and specification

In this project, all data related to people counting and classroom occupancy is centralized and visualized through ThingSpeak, a cloud-based IoT analytics platform. The integration process begins at the hardware level, where the ESP32 microcontroller serves as the central hub connecting the RFID reader, relay module, and any optional sensors (such as a PIR motion sensor). When a student or employee presents an RFID tag to the reader, the ESP32 captures the unique identifier, processes it, and verifies whether it matches a valid entry. If valid, the system updates local variables—such as the occupancy count—and triggers the necessary action, such as switching lights ON through the relay if the room was previously empty.

To transfer data to ThingSpeak, the ESP32 uses its built-in Wi-Fi to connect to a local access point (e.g., a campus router or mobile hotspot). Once online, the microcontroller sends an HTTP or MQTT request containing key data fields (such as user ID, timestamp, and current occupancy status) to a designated ThingSpeak channel. Each channel on ThingSpeak can hold multiple fields, enabling you to log various parameters in real time. For instance, Field 1 might store the RFID user ID, Field 2 could record the timestamp, and Field 3 might keep track of the current occupancy count. By updating these fields after every RFID scan, ThingSpeak provides a live feed of people counting data and room usage.

On the ThingSpeak dashboard, administrators can visualize the data in real time using built-in charts, gauges, or custom widgets. They can also configure alerts or webhooks to be sent when specific conditions are met—such as when the occupancy count exceeds a threshold or when a particular RFID tag is scanned. This allows for automated notifications to be sent via email or SMS, improving the system's responsiveness and overall management efficiency.From a security perspective, API keys provided by ThingSpeak ensure that only authorized devices can write to or read from a given channel. The ESP32 firmware includes the channel's Write API Key, preventing unauthorized parties from injecting spurious data. If needed, HTTPS communication can be employed for an additional layer of data encryption during transit.Overall, this integration with ThingSpeak offers a streamlined and robust mechanism for capturing, storing, and visualizing people counting and occupancy data. By consolidating all relevant information on a single cloud platform, administrators benefit from real-time insights and automated record-keeping, while also leveraging ThingSpeak's built-in analytics to enhance decision-making and resource optimization.

IMPLEMENTATION

The implementation of the Automatic people counting machine with RFID and Light Control using an ESP32 and ThingSpeak involves a series of coordinated steps encompassing hardware assembly, firmware development, and cloud integration. First, the hardware layout is designed to accommodate the key components: the ESP32 development board, the RFID reader, a relay module for light control, and any optional sensors

On the software side, the Arduino IDE or ESP-IDF is used to program the ESP32. Necessary libraries—such as the MFRC522 library for RFID communication and the WiFi library for network connectivity—are installed. The code is structured to perform three main tasks: (1) read RFID tags and validate them against a local or remote database of authorized IDs, (2) determine and maintain a count of current occupants, and (3) transmit people counting and occupancy data to ThingSpeak at predefined intervals or upon specific events (like a new RFID scan). In practice, each RFID scan triggers a function that captures the user ID, logs a timestamp, increments or decrements an occupancy counter (if an exit reader is also used), and publishes this information to the designated ThingSpeak channel using an HTTP POST or MQTT request.

The software development for the Automatic people counting machine using RFID, ESP32, and ThingSpeak plays a crucial role in enabling smooth operation, communication, and automation of people counting management with integrated light control. The software is designed and implemented using the Arduino IDE, which provides a flexible and user-friendly platform for programming the ESP32 NodeMCU board.

The first step in the software development process is setting up the Arduino IDE and configuring it to program the ESP32. This involves installing the ESP32 board manager via the additional board URL and including essential libraries such as MFRC522 library for RFID communication, WiFi library for network setup, and HTTPClient or ThingSpeak library for data transmission to the cloud.

Data Transfer to the Cloud

In the proposed RFID-based Automatic people counting machine , data transfer to the cloud plays a crucial role in ensuring real-time monitoring, storage, and analysis of people counting records. The entire process of transferring data to the cloud is efficiently managed using the ThingSpeak IoT platform, which provides a robust and user-friendly environment for storing and visualizing data. The ESP32 NodeMCU microcontroller, equipped with built-in Wi-Fi, acts as the central controller responsible for reading data from RFID tags and sending it directly to the cloud. Once a user scans an RFID card at the entry or exit point, the system captures the unique identification number (UID) associated with the card. This UID, acting as a unique identifier for each user, is read by the RFID module and transmitted to the ESP32 board for further processing. The ESP32 board establishes a secure connection to the local Wi-Fi network using predefined SSID and password credentials, ensuring seamless internet access for cloud communication. After establishing a stable connection, the ESP32 prepares an HTTP GET request that includes the RFID card data and the unique API key generated from the ThingSpeak channel. The API key acts as an authentication token, allowing only authorized devices to send data to the cloud server.The RFID card data, along with relevant timestamps and status (such as entry or exit), is encapsulated within the HTTP request and sent to ThingSpeak. Once the ThingSpeak server receives this data, it stores the information in designated fields within the user's channel and updates it in real time. ThingSpeak also offers live visualization tools such as graphs and charts, allowing administrators to view people counting logs as soon as the RFID is scanned. This feature is particularly useful for real-time people counting monitoring and historical analysis of data, making it easier to maintain accurate and accessible records. Additionally, ThingSpeak automatically timestamps each data entry, creating a detailed log of each instance when an RFID tag is scanned. Through this cloud storage mechanism, users can easily retrieve, analyze, and generate reports on people counting data without manually handling records.

Moreover, the ThingSpeak platform provides flexibility for extending system functionality, such as integrating with platforms like IFTTT for sending notifications or alerts when unauthorized RFID cards are used. Data stored on ThingSpeak can also be analyzed using built-in MATLAB analytics for deeper insights into people counting patterns, room occupancy trends, or security breaches. The use of the cloud ensures that all people counting records are centralized and accessible remotely, reducing the need for manual entry and preventing data loss. Additionally, since ESP32 communicates directly with the cloud, there is minimal delay between the RFID scan and data logging, enabling instantaneous updates visible on the ThingSpeak dashboard. Security is also ensured, as the API key prevents unauthorized access to the ThingSpeak channel, and Wi-Fi credentials are securely embedded within the ESP32 firmware.

OBJECTIVES

The primary objective of the Automatic people counting machine Using RFID and Cloud Integration is to create an efficient, secure, and automated people counting management system that minimizes human intervention and eliminates traditional manual processes. This system leverages ESP32 NodeMCU, RFID technology, and ThingSpeak cloud to achieve real-time people counting tracking and monitoring. Below are the detailed objectives of the proposed system:

Automate people counting Recording Process:
To design and develop a fully automated system that records people counting using RFID cards, thereby eliminating the need for traditional manual people counting registers or sheets.

Real-Time people counting Monitoring:
To enable real-time capturing and monitoring of people counting data and immediately upload the data to the ThingSpeak cloud platform for remote access and analysis.

Integration with Cloud (ThingSpeak):
To store all people counting records securely on a centralized cloud platform (ThingSpeak), allowing users and administrators to view people counting data anytime and from anywhere using an internet-connected device.

Enhance Security and Accuracy:
To improve the accuracy of people counting records by minimizing the chances of proxy people counting and human error, ensuring that only authorized RFID cards can mark people counting .

Energy Management Integration:
To integrate room automation features by controlling electrical appliances (such as lights and fans) using relays based on room occupancy detected via RFID card scans, thus promoting energy conservation.

User-Friendly Interface and Instant Feedback:
To provide instant visual feedback (such as through an LCD display) upon successful scanning of RFID cards, confirming people counting status to the users.

Entry and Exit Monitoring:
To track both entry and exit timings using RFID readers placed at strategic locations, enabling more detailed data on user movements within a facility.

Minimize Paperwork and Manual Errors:
To reduce the dependence on paper-based Automatic people counting machine s, ensuring eco-friendliness and

reducing administrative overhead related to manual record-keeping.

Facilitate Data Analytics and Reporting:
To enable data analysis and visualization through ThingSpeak's powerful analytical tools, making it easier to generate reports, observe trends, and take informed decisions based on people counting data

IV . Advantages

The Automatic people counting machine using RFID and ThingSpeak Cloud offers numerous advantages that make it a highly efficient and modern solution for people counting management. One of the key benefits of this system is its ability to automate the entire people counting process, eliminating the need for manual record-keeping and reducing human errors. By using RFID cards, users can mark their people counting quickly and securely, ensuring accuracy and preventing proxy people counting . The system's integration with ThingSpeak cloud allows for real-time people counting monitoring, enabling administrators to access and review records remotely from any location. This not only saves time but also enhances transparency and accountability. Furthermore, all people counting data is stored securely on the cloud, offering protection against data loss and allowing easy retrieval of historical records for analysis and reporting purposes. Another significant advantage is the system's ability to control electrical appliances like lights and fans through relays, turning them on or off based on room occupancy, thus promoting energy conservation and reducing wastage. The system also provides instant feedback via an LCD display, confirming successful people counting logging and minimizing confusion among users. Being a paperless and eco-friendly solution, it supports environmental sustainability by eliminating the need for physical registers. Moreover, the use of low-cost components such as the ESP32 NodeMCU and RFID readers makes the system cost-effective and suitable for institutions with limited budgets.

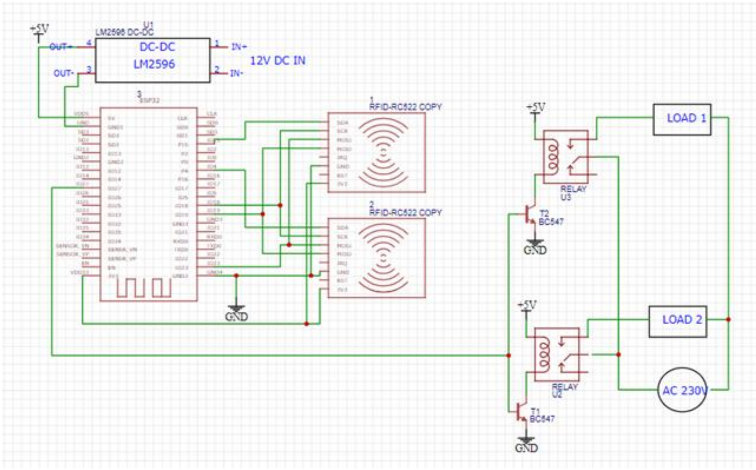

Fig 2: Circuit Diagram of Model

V. Results

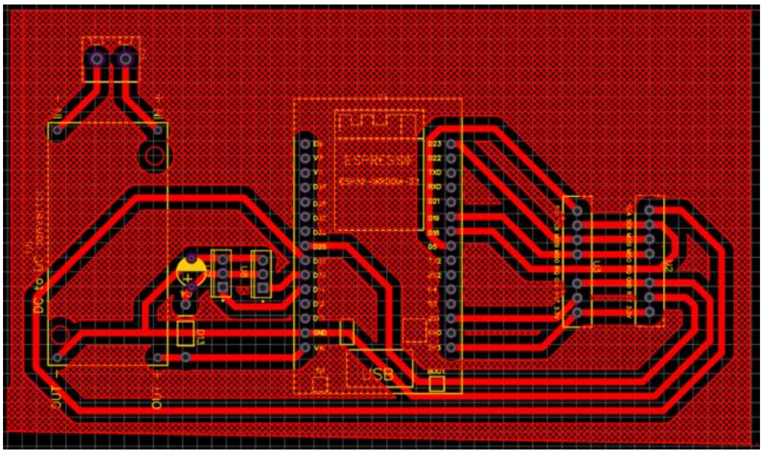

Fig 3: PCB mounting

The Printed Circuit Board (PCB) mounting plays a crucial role in ensuring that all electronic components of the Automatic people counting machine are securely and efficiently integrated into a compact and reliable system. In this project, PCB mounting is used to systematically organize and hold all critical components such as the ESP32 NodeMCU, RFID readers, relay modules, LCD display connectors, and power management units on a single board to maintain connectivity and functionality.
The implementation of the Automatic people counting machine using ESP32 and RFID successfully achieved the goal of automating the people counting process with real-time data monitoring, device control, and remote access to records. The system efficiently captured and recorded people counting when users scanned their RFID cards at

the entry and exit points, with the data being immediately uploaded to the ThingSpeak cloud platform for centralized monitoring. Upon scanning, the system provided instant feedback on the LCD display, showing user-specific messages such as " people counting Marked Successfully" for authorized users and "Unauthorized Access" for unrecognized cards, thereby improving security and ensuring transparency in the people counting process.

Through ThingSpeak, the system was able to visualize data in graphical formats, providing administrators with clear insights into people counting patterns, peak entry/exit times, and individual user records. This real-time visualization made it easier for institutions to monitor and analyze people counting without manual intervention. The system was tested under various scenarios, including simultaneous scanning by multiple users, network disruptions, and power fluctuations, and it continued to deliver stable and reliable performance, indicating its robustness and practical usability.Furthermore, the system eliminated the traditional need for manual people counting sheets and registers, thus reducing paperwork, saving time, and preventing errors associated with manual data entry. Its cloud-based nature allowed administrators to access people counting data remotely from any location, making it especially useful in modern educational institutions and corporate environments where real-time people counting data is essential for decision-making and management. The use of IoT and cloud technologies made the system scalable, meaning more entry/exit points and additional RFID readers could easily be added as required without redesigning the entire system.

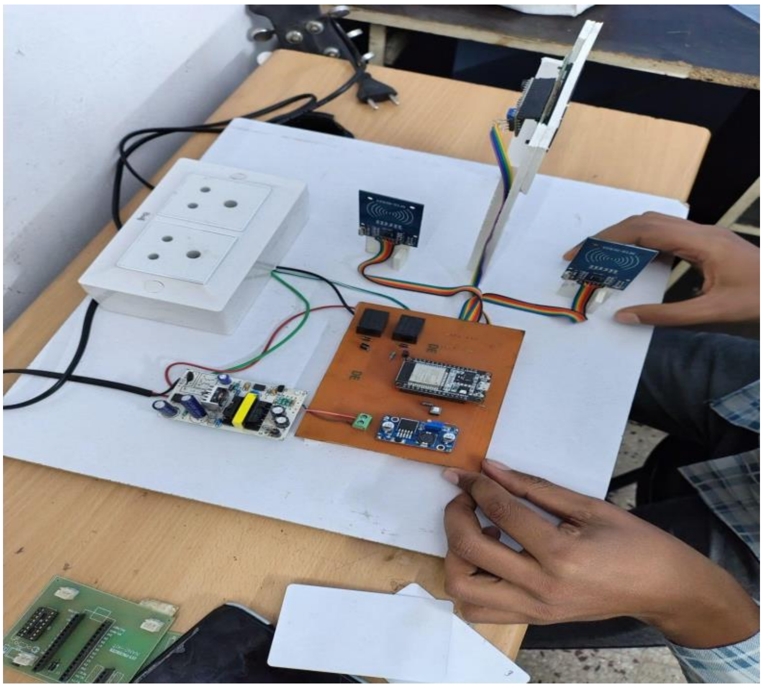

Fig 5 :Overview of model

VI . Challenges and Solutions

During the development of the Automatic people counting machine using ESP32 and RFID, several challenges arose that required innovative solutions to ensure smooth functioning. One of the primary challenges was maintaining stable Wi-Fi connectivity for real-time data transfer to the ThingSpeak cloud platform. Since ESP32 heavily depends on a continuous internet connection, any fluctuation in Wi-Fi signals led to interruptions in data transmission. To address this, auto-reconnection logic was implemented in the code, allowing the ESP32 to automatically reconnect when the connection was lost, thereby ensuring seamless data flow. Another significant challenge was the inaccurate reading of RFID cards, especially when users swiped them too quickly or at an improper angle. To overcome this, debouncing techniques were implemented in the system code, ensuring that only stable and accurate reads were processed. Real-time synchronization of people counting data with ThingSpeak also posed issues due to occasional internet delays and server response time.The system also faced issues with power supply fluctuations, which caused temporary resets or improper functioning of ESP32 and RFID modules. This was resolved by integrating a regulated power supply module and capacitors to stabilize voltage levels, ensuring consistent operation. Data management on ThingSpeak for long-term people counting records was another area of concern, as handling large datasets required organized storage and easy retrieval mechanisms. This was managed by utilizing ThingSpeak's inbuilt visualization tools to create user-friendly dashboards that allowed easy monitoring and analysis of people counting trends.

VII . Conclusion

The Automatic people counting machine using ESP32, RFID, and ThingSpeak successfully demonstrates how modern technology can streamline and enhance people counting management processes. By automating the recording of each user's arrival and departure via RFID tags, the system significantly reduces manual errors, paperwork, and administrative overhead. Real-time data transfer to the ThingSpeak cloud enables immediate visibility of people counting records, facilitating remote monitoring and data-driven decision-making. Additionally, the inclusion of relay-based device control—such as for lights or fans—underscores the system's potential for energy optimization in educational institutions and corporate environments. Throughout development, challenges such as Wi-Fi connectivity issues, RFID detection errors, and power fluctuations were addressed through robust code structures, hardware optimizations, and secure cloud integration. The end result is a cost-effective, scalable, and user-friendly solution that not only saves time and resources but also enhances security and accuracy. This project thus serves as a blueprint for future innovations that integrate IoT, cloud services, and automation to meet the evolving needs of smart institutions and workplaces.

VIII. Future Scope:

The Automatic people counting machine using ESP32, RFID, and ThingSpeak offers a versatile platform that can be expanded and refined in several ways to meet evolving institutional and workplace needs. Future enhancements may include integrating biometric sensors or facial recognition to strengthen security and reduce the possibility of unauthorized RFID card usage. A dedicated mobile application with instant push notifications can further enhance user engagement by providing real-time people counting logs and alerts for administrators and students alike. On the analytics side, machine learning algorithms could predict people counting patterns, identify anomalies, and optimize resource usage such as classroom scheduling or energy consumption. To accommodate larger organizations, the system can be scaled across multiple locations, consolidating all people counting data into a unified dashboard. Additional features like voice announcements, multi-lingual support, and wearable RFID tags can improve accessibility and user convenience.

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