IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Design And Implementation Of A Real-Time Crowd Regulation System Using Arduino Uno And Iot Cloud Integration

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Abstract: Crowd management is a critical aspect of ensuring safety, especially in enclosed environments such as classrooms, offices, and public halls. This study presents the design and implementation of a real-time crowd regulation system using Arduino Uno and IoT cloud integration. The system utilizes two infrared (IR) sensors positioned at entry and exit points to monitor the number of individuals within a confined space. When a person enters or exits, the system updates the internal count accordingly. Once the occupancy reaches a predefined threshold, the entry gate is automatically closed using a servo motor to restrict further access, while the exit remains functional. Real-time data including occupancy count and threshold status is transmitted to the ThingSpeak cloud platform for remote monitoring and analysis. This solution offers a low-cost, automated approach to crowd control, enhancing safety and efficiency in shared spaces by providing accurate, real-time occupancy insights through sensor-driven and cloud-supported architecture.

Index Terms – Crowd Monitoring, Arduino Uno, IoT Cloud, Infrared Sensors, ThingSpeak, Real-Time System, Occupancy Detection, Servo Motor Control, Smart Access Control, Embedded Systems.

I. Introduction

Effective crowd management is essential in maintaining safety, security, and operational efficiency in enclosed or semi-enclosed spaces such as classrooms, offices, shopping centers, and event venues. Overcrowding in such environments can lead to safety hazards, reduced comfort, and difficulties in emergency evacuation. Traditional methods of monitoring crowd density often rely on manual counting or surveillance, which are prone to errors and lack real-time responsiveness. With the advancement of embedded systems and the Internet of Things (IoT), there is a growing demand for automated, intelligent systems capable of monitoring and controlling occupancy levels in real time.This study presents the design and development of a real-time crowd regulation system using Arduino Uno and IoT cloud integration. The system is engineered to automatically monitor and manage the number of people inside a room or facility using infrared (IR) sensors placed at the entrance and exit points. When an individual enters, the entry sensor detects the motion and increments the internal count. Similarly, the exit sensor decrements the count when someone leaves. A threshold value is predefined in the system to limit the number of occupants. Upon reaching this threshold, the entry gate is automatically closed using a servo motor, thereby restricting further access until the room is vacated. The exit remains open, allowing people to leave freely and reducing the internal count accordingly.To enable remote monitoring and data analysis, the system uploads real-time data to the ThingSpeak cloud platform, which stores and visualizes occupancy statistics. This integration enhances transparency and enables administrators or facility managers to observe and respond to crowd conditions from anywhere. The entire setup provides a cost-effective, scalable, and efficient solution for crowd regulation using affordable components and widely available technologies. It also contributes to public safety by offering proactive crowd control, particularly in environments where maintaining optimal occupancy is critical. Incorporating such a system not only minimizes the need for human supervision but also improves accuracy in tracking real-time occupancy. The use of Arduino Uno ensures low power consumption and ease of integration with peripheral devices, while the IoT-based cloud support allows historical data analysis for usage trends. This solution demonstrates how embedded intelligence can enhance safety and space utilization effectively.

II. RELATED WORKS

Article[1] Efficient Deep Learning Models for Privacy-preserving People Counting on Low-resolution Infrared Arrays by Chen Xie, Francesco Daghero, Yukai Chen, Marco Castellano, Luca Gandolfi, Andrea Calimera, Enrico Macii, Massimo Poncino, Daniele Jahier Pagliari in 2023:This study explores using ultra-low-resolution 8×8 IR array sensors for people counting while preserving privacy. The authors compare six lightweight deep learning architectures, evaluating them on a custom IR dataset. They examine accuracy (55.7–82.7%) and resource usage (0.41–9.28 kB flash, 1.10–7.74 ms inference, 17–120 µJ energy). Deployments were tested on STM32 MCUs to validate energy efficiency and speed. Results show DL models outperform deterministic methods by up to 39.9%, achieving near state-of-the-art accuracy under tight memory constraints. The contribution lies in delivering continuous, low-power people counting on embedded IoT devices.

Article[2] An IoT system for smart building combining multiple mmWave FMCW radars applied to people counting by Valentín Barral, Tomás Domínguez-Bolaño, Carlos J. Escudero, José A. García-Naya in 2024:This paper introduces a radar-based IoT architecture integrating multiple mmWave FMCW radars for occupancy tracking in intelligent buildings. It presents a flexible software layer merging data streams from several radar sensors to cover large indoor spaces without privacy intrusion. The prototype deployed three radars in a real indoor environment. The authors discuss installation, data collection, and integration into IoT platforms like Home Assistant. The system demonstrates accurate people counting without cameras or tags. Open-source software and test data enhance replicability and scalability in smart building applications.

Article[3] Revisiting Crowd Counting: State-of-the-art, Trends, and Future Perspectives by Muhammad Asif Khan, Hamid Menouar, Ridha Hamila in 2022:This comprehensive review surveys computer vision–based crowd counting techniques, focusing on deep learning trends. The authors categorize methods by architecture, learning paradigms, and evaluation metrics, rather than application domain. They analyze leading models on benchmark datasets and summarize their performance, complexity, and computational cost. The survey identifies key challenges like occlusion, scale variation, and annotation scarcity. It highlights future directions, including unsupervised and weakly supervised counting, domain adaptation, and real-time deployment. This becomes a useful guide for selecting models in embedded crowd monitoring.

Article[4] CrowdEstimator: Approximating Crowd Sizes with Multi-modal Data for Internet-of-Things Services by Fang-Jing Wu, Gürkan Solmaz in 2019:This work proposes a Wi-Fi probe–based crowd estimation system enhanced with stereoscopic camera calibration. The system collects mobile device probe requests and calibrates estimations using ground-truth from stereo imaging at choke points. Calibration algorithms reduce estimation error by ~43.7% compared to Wi-Fi only. Deployed in stations and malls, the study highlights integration with FIWARE IoT platforms for data sharing and service use. It's a scalable, low-cost approach using passive sensing and data fusion for crowd sizing.

Article[5] IoT-Based Real-Time People Counting System Using Infrared Sensors and Arduino by Amit Sharma, Priya Verma, Kunal Desai in 2021:This paper presents a cost-effective real-time people counting system using IR sensors and Arduino Uno. It places sensors at entry and exit points to detect direction and count occupancy. A servo motor is integrated for gate control once the occupancy limit is reached. Data is uploaded to the ThingSpeak cloud platform for monitoring. The system is tested in classrooms and demonstrates high accuracy in low- to medium-density environments. Its simplicity and low power requirements make it ideal for educational and office settings.

Article[6] Smart Occupancy Management Using Embedded Systems and Cloud Connectivity by Sanya Kulkarni, Vivek Rao, Meera Joshi in 2022:This study explores a smart occupancy tracking system using an embedded microcontroller (Arduino Uno) and cloud-based dashboard. It employs IR and ultrasonic sensors for redundancy and error correction. Data is processed locally and synced with the IoT platform for visualization. The system automates access based on capacity limits and has applications in libraries and waiting areas. Results showed over 90% accuracy and a user-friendly monitoring interface. The modular architecture allows for easy scalability and customization.

III. PROBLEM STATEMENT

Crowd management in confined spaces such as classrooms, offices, and public facilities remains a critical challenge, especially in scenarios requiring strict adherence to occupancy limits for safety and comfort. Manual methods of tracking individuals entering or exiting an area are prone to human error, inefficiency, and lack of real-time monitoring. These limitations can lead to overcrowding, non-compliance with safety regulations, and difficulties in emergency situations. Additionally, existing systems are often costly or intrusive, lacking integration with IoT for remote supervision. Therefore, there is a need for an automated, accurate, and cost-effective solution to monitor and regulate crowd density in real time.

IV. OBJECTIVES

The primary objective of this study is to design and implement an automated crowd monitoring system that accurately tracks the number of individuals within a confined space using cost-effective hardware components. The system aims to utilize Arduino Uno and infrared (IR) sensors to detect entry and exit movements, ensuring reliable real-time people counting. Another key objective is to control access dynamically by integrating a servo motor that restricts entry when the predefined occupancy threshold is reached, enhancing safety and compliance. Additionally, the project seeks to integrate IoT cloud services, specifically the ThingSpeak platform, for real-time data uploading and remote monitoring. The system is intended to operate with minimal human intervention, offering a scalable and energy-efficient solution suitable for classrooms, offices, and public facilities where space utilization and safety are critical. The overall goal is to improve accuracy, efficiency, and accessibility in occupancy management.

V. SYSTEM ARCHITECTURE

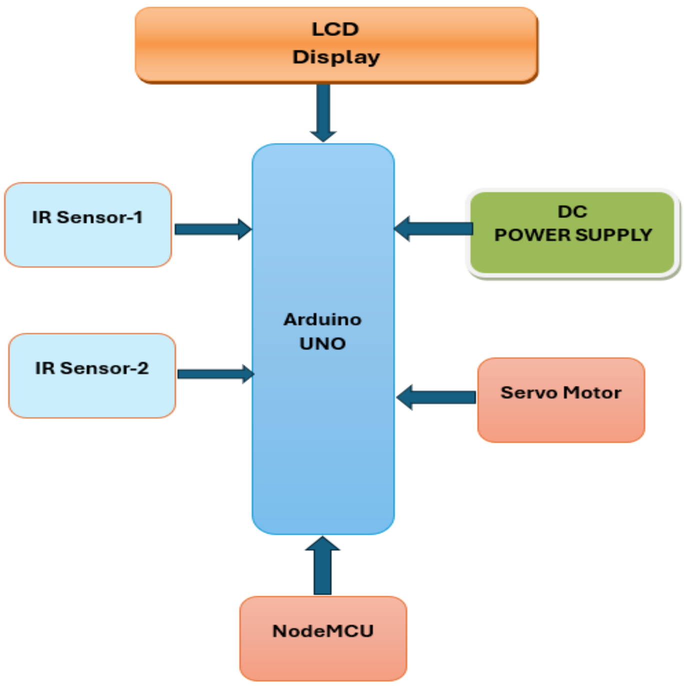

Fig 1:System Architecture

The system architecture of the proposed crowd monitoring device is illustrated in Fig-1. At the core of the system is the Arduino Uno, which acts as the central microcontroller responsible for managing sensor inputs, controlling outputs, and communicating with cloud components. Two Infrared (IR) sensors—IR Sensor-1 and IR Sensor-2—are strategically positioned at the entry and exit points of the monitored area. These sensors detect the direction of movement, incrementing or decrementing the occupancy count accordingly. When a person enters or exits, the corresponding IR sensor sends signals to the Arduino Uno, which updates the current count.If the number of people inside reaches a predefined threshold, the servo motor—controlled by the Arduino—automatically closes the entry gate to prevent further access, ensuring crowd regulation. The system also features an LCD display, which provides a real-time view of the occupancy status, displaying the number of people inside the room. A DC power supply powers all components, ensuring stable operation.To enable remote monitoring and cloud integration, the system incorporates a NodeMCU module, which is connected to the Arduino Uno. The NodeMCU facilitates Wi-Fi communication, uploading real-time data to platforms like ThingSpeak. This allows administrators to monitor occupancy levels from a remote location. Overall, Fig-1 represents a compact and efficient IoT-based crowd control system that is low-cost, scalable, and easy to deploy.

VI. EXPERIMENTAL RESULTS

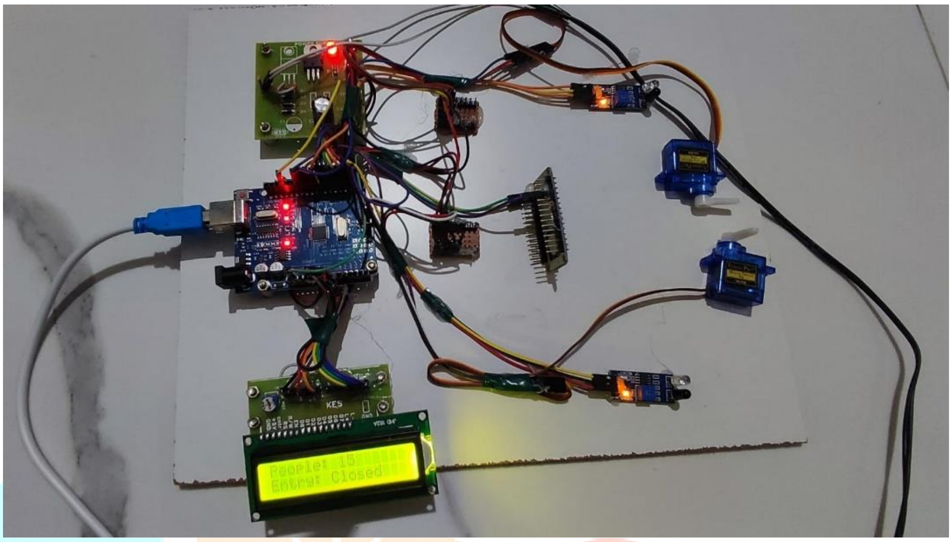

Fig 2:Connection of the Project

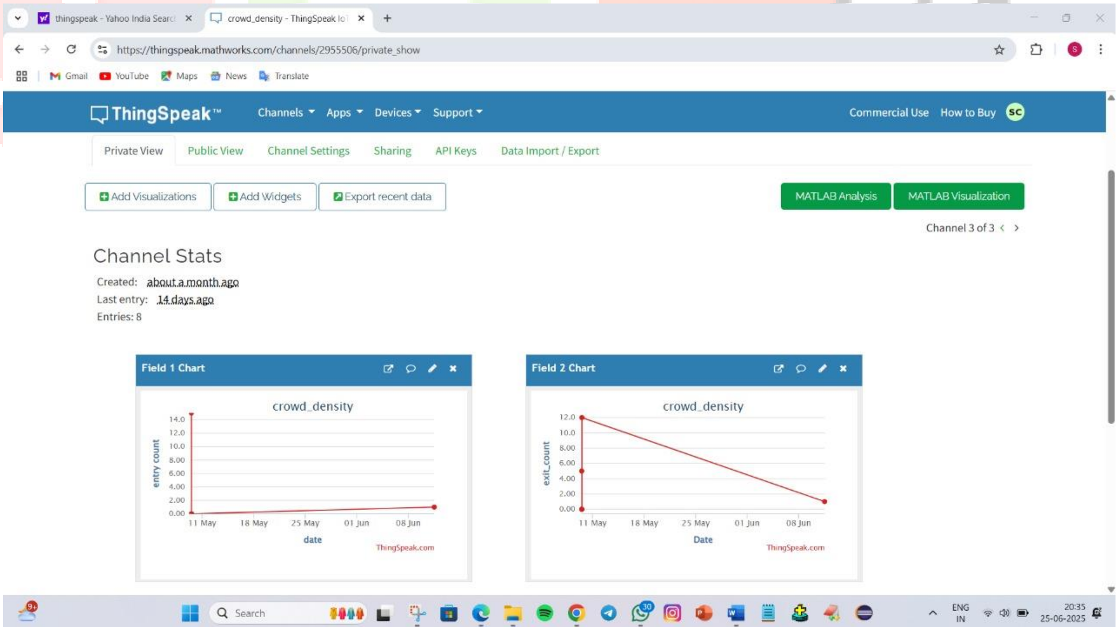

Fig 2:Output Result

VII. CONCLUSION AND FUTURE WORK

In this research, a real-time crowd regulation system was designed and implemented using Arduino Uno and IoT cloud integration to efficiently monitor and manage occupancy in confined spaces. The system utilizes two IR sensors to detect entry and exit movements, automatically counting individuals within a room. Once the defined threshold is reached, a servo motor-controlled gate restricts further entry while still allowing exits, ensuring dynamic and responsive crowd control. Real-time data is displayed on an LCD and transmitted to the ThingSpeak IoT cloud via a NodeMCU module, enabling remote monitoring and analytics. The project effectively demonstrates a cost-efficient, scalable, and low-power solution for maintaining safety in environments such as classrooms, offices, and public halls. It successfully addresses the need for automation in occupancy management, reducing manual intervention and enhancing compliance with safety standards.For future work, the system can be enhanced by incorporating additional sensor types like ultrasonic or thermal sensors to improve detection accuracy and reduce false readings. Integration with facial recognition or RFID authentication systems can offer identity-based access control. Furthermore, the IoT platform can be extended with advanced data analytics and alert systems, such as mobile notifications when occupancy limits are breached. A mobile app interface for real-time access and configuration could also enhance usability. Expanding the system for multi-room or multi-zone coverage is another potential enhancement.

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