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IoT based Crowd Monitoring System

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Abstract. There will be unexpected crowds in certain places, such as shopping malls, gaming venues, or other spots with seasonal traffic. We observe that many people arrive quickly without warning, which makes it difficult to manage resources, creates imbalances because of crowding, and manages parking and traffic, among other issues. IR sensors are the greatest option for counting people because they are affordable and simplify and improve the system. Controlling the entry and exit gates with servo motors is all that is required to keep an eye on the throng. The system also includes a buzzer-based exit gate control method for schools and other locations that require exit gate control. With advance knowledge about the crowd in a given region, the system keeps an eye on and manages the crowd, providing necessary individuals with information or a warning. In addition to controlling and monitoring the crowd without allowing for human interaction, the system also uses a bell to ensure that people leave the designated area. The system can be expanded to meet needs like managing student arrivals and departures from schools, keeping crowds within a set number of people in busy situations, parking lots, etc.

1 Introduction

In today's fast-paced world, monitoring and managing crowd density is becoming the major concern. To ensure public safety and efficient usage of resources requires different crowd-managing techniques. One of the solutions to avoid overcrowding is a crowd monitoring system that is integrated with the cloud. Crowded environments like shopping malls, transportation hubs, and public spaces have more chance to get into accidents, stampedes, and inefficient use of space. India is one of the most populated countries in the world, which needs more crowd monitoring techniques. The country is rich in large religious, political, and cultural gatherings. These places have witnessed several deadly stampedes. The motivation behind the project mainly focuses on the stampede cases noted every year that are increasing. According to the National Crime Records Bureau (NCRB), nearly 3,935 stampede cases were recorded between 1996 and 2022, resulting in urgency for the need for better crowd monitoring systems. Most of these incidents are concentrated around religious festivals where massive, uncontrolled crowds are present, which leads to insufficient infrastructure and even deadly outcomes.

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If we consider existing works that have been done to solve this issue, they are single-shot detectors with MobileNet and centroid tracking algorithms. It has higher accuracy in controlled environments by assigning IDs to detect people based on their bounding box centroids. This performance will decrease as the crowd increases and with shadow interference. These types of solutions heavily rely on pre-trained datasets and stable lighting conditions. This disadvantage can reduce the reliability of the system. [1]. Techniques like monitoring the crowd with the help of face detections and NCC tracking also have a good rate of accuracy. These systems are effective in face-based counting. What if the faces are turned or covered from the camera? Here the real-time tracking of a person will be disturbed and result in inaccurate results. [2]. Wireless sensing approaches are going to detect movement behind walls. Such a Wi-Fi-based system requires continuous power and maintenance. It has good scalability and accuracy in large spaces. It also has a chance of miscounting static or slow-moving persons. The system is sensitive to environmental factors such as furniture and interferences. [3].

The proposed system integrates with IoT components such as IR sensors, NodeMCU, servo motors, etc. to provide cost-effective and real-time people counting. Unlike camera-based models and face detection systems, the system focuses on human detection with IR sensors and on remote and real-time monitoring with cloud and LCD displays. Overcrowding can be avoided with a buzzer, which helps in alerting the authorities. These systems are more suitable for small to medium public spaces. The system has advantages like low cost, good reliability, and scalability.

2 Literature Survey

Identifying research gaps is essential for effective problem solving. The gaps that caused in monitoring the public areas can be identified in different existing works that have been done in the past. The public monitoring can be carried out in various ways across different domains, including human detection and camera-based detection. Everyone has their own limitations and advantages. This crowd monitoring is created by combining all the data. One of the approaches to public monitoring is the image-based technique. In such techniques, density maps are generated with the help of semantic segmentation models. These systems have advantages like noise-free, accurate, and effective people estimation but cannot control the rush without human interaction. To address this, our project uses servo motors to lock the entry and exit gates, also integrating with cloud IoT for remote control [4].

In crowd and object monitoring, computer vision techniques such as YOLO algorithms are used to detect and classify the pedestrians and vehicles. This approach needs constant monitoring. As this method uses large datasets, it can be used in complex urban environments. The crowd monitoring device uses a sensor-based IoT approach using a cloud platform, which is a lightweight, energy-efficient, and low-cost system. [5]. Methods like face detection are done with colour-based skin detection and facial feature analysis. This system heavily depends on optimal lighting, visibility, and camera position. The proposed system is unaffected by any lighting conditions or visual obstructions. This ensures the reliability of the system [6]. A prevalent method for indoor people counting employs PIR sensor arrays, which are combined with machine learning algorithms. As it involves complex hardware configuration, the crowd monitoring system using cloud IoT is a simplified and cost-effective system using a single NodeMCU. Public monitoring can be achieved without any complex algorithms and large datasets [7].

People counting can be captured with disjoint cameras, where overlapping of field views can be avoided. Overlapping is avoided by tracking objects that disappear from one camera and reappear in another within a short time. This site analyses the data about the appearance and disappearance of humans within a span of time. The challenges faced in such ways are person re-identification and more power consumption, which can produce inaccurate results. The proposed system does not rely on visual data; rather, it depends on entry and exit gate detection and monitoring with gates [8, 9]. A contemporary solution for human detection is captured with deep learning techniques such as YOLO. In an overhead view, the system can capture and monitor the crowd with models. It can produce high accuracy and true positive rates and low false rates but demands high-resolution cameras and GPU-based processing [10].

RFID infrastructure is one where spatial and waveform characteristics are used to estimate the number of persons passing a predefined path. This approach avoids the need for tagging each person and offers a passive counting mechanism. It has an experimental validation that it can handle continuous movement up to 75 individuals. Such a system depends on RFID readers and required environmental conditions to ensure signal consistency [11]. By utilizing Raspberry Pi and camera module estimation, the occupancy level can be determined. This system highlights the use of snapshots locally and only uploads aggregate crowd data. The proposed system does not rely on any image capture, which requires continuous monitoring and human presence. The system is integrated with the cloud; it can be used for remotely accessing [12].

The strategy that integrates IoT with smart surveillance systems uses ultrasonic sensors, facial recognition, and remote camera access to detect unauthorized intrusions. This system can also detect the human presence but for a different approach. The technology used has greater accuracy. The system captures the person completely, but for crowd monitoring, it does not need much deeper, like face detection. This mechanism can also be turned into monitoring the crowd but needs to be challenged with power usage and re-identification [13]. Dirichlet Process Mixture Models are the ones that estimate the crowd size by clustering detection outputs based on spatial, colour, and temporal features. It can handle an unknown number of people in a video frame and estimate the total crowd. This focus on image processing and modeling. The proposed system is simplified with fewer components like microcontrollers and gates.

3 Proposed System

The entry and exit counts are essential to manage the crowd in the area. First step in monitoring the crowd is to know the number of people present in that area. The projects need an IR sensor to detect human presence. The infrared sensors operate by emitting light at varying intensities whenever a person crosses. The infrared system consists of a transmitter and a receiver that detect individuals, and the gathered data will be sent to the NodeMCU. If the emitted beams confirm the presence of a human, the servo motor gate will be opened. The project utilizes a 90-degree phase shift. Once a person passes through the gate, the servo motor rotates in the anticlockwise direction with the same phase shift to ensure the opened gate closes once the person has exited. The NodeMCU serves as the microcontroller, which is a board based on ESP8266, and the Wi-Fi module is employed in this project to receive data from the infrared sensor. The code is insisted with increment or decrement the person count as person enter or leave the area, respectively.

The overall crowd count in the area is calculated by taking the difference between the number of people entered the area and the number of people exited the area. The headcount will be displayed on two output devices: 6X12 LCD display and the Arduino IoT Cloud dashboard. The purpose of using a dashboard is to allow individuals to check crowd levels at their intended location, regardless of where they are. The buzzer ensures that it activates whenever someone exits the area, and it will sound when the crowd limit is exceeded.

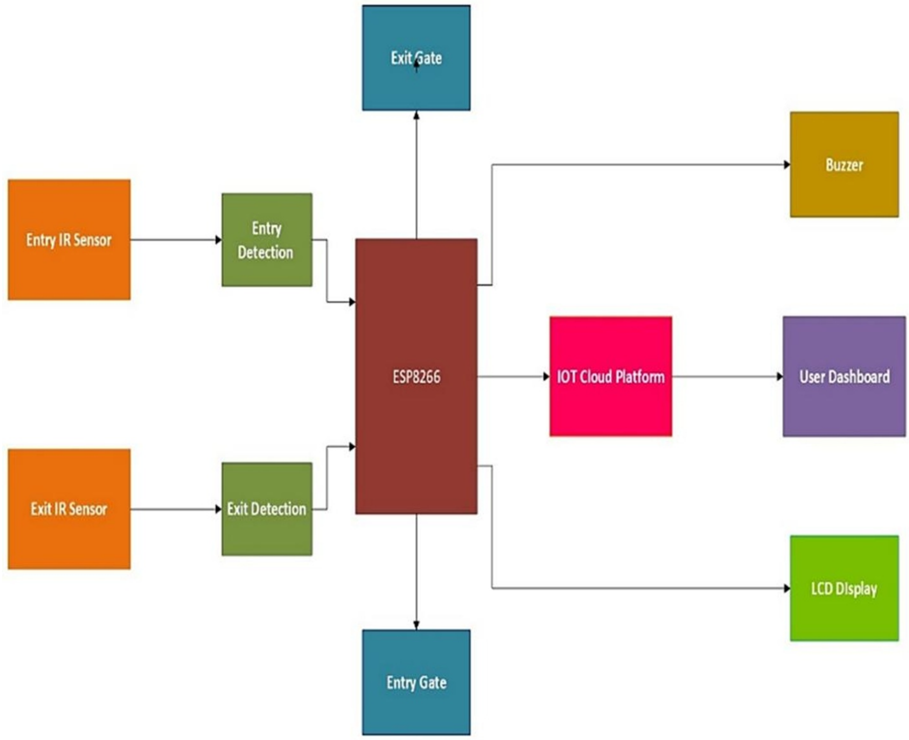

Fig. 1. Block diagram of crowd monitoring system

The above block diagram represents the working flow of the system using IR sensors, the ESP8266 microcontroller, and the Arduino Cloud IoT platform. The first phase involves detecting the presence of humans; IR sensors are positioned at a location's entrance and departure. It recognizes when a person is coming in and going out. The entry and exit detection are responsible for ensuring an object passes through the entry gate and exit gate. Based on the sensor sequence, they are going to identify the direction of movement. The ESP8266 receives data from the two infrared sensors to increase or decrease the number of people. As per the data received from the input, the controller is going to update the value of the total count, control the entry and exit gates, and send data to the IoT cloud platform.

The user is going to access the information through the dashboard of Arduino IOT Remote. It displays the live data of crowd level. For instance, for the display of the crowd, the 6X12 LCD display is going to show the current number of people inside the area. The buzzer, which is directly connected to the ESP8266, serves as a warning system when the number of individuals in an area exceeds the limit as well as whenever someone leaves. The system provides real-time updates of people in an area from both locally and remotely.

The NodeMCU system's logical operation is depicted in the flowchart as shown in Figure 1. Since every other device is connected to the microcontroller, the system begins when the microcontroller is turned on. The IR sensor's activation is continuously monitored by the system. The entry sensor looks for a location's maximum limit when it is turned on. The entry gate will open, increasing the number of people and updating the LCD display and Arduino Cloud dashboard's values if the upper limit is not exceeded. If the limit is exceeded, the entry gate will be closed, and the buzzer will be activated. When the exit sensor is activated, the gate at the exit will open and decrement the person count. The total number of people inside a particular area will be displayed for every entry increment and exit decrement. As the system wants to address the problems in school areas, whenever the exit gate is opened, the buzzer will turn on. The process keeps looping as long as the system is active to ensure real-time crowd monitoring.

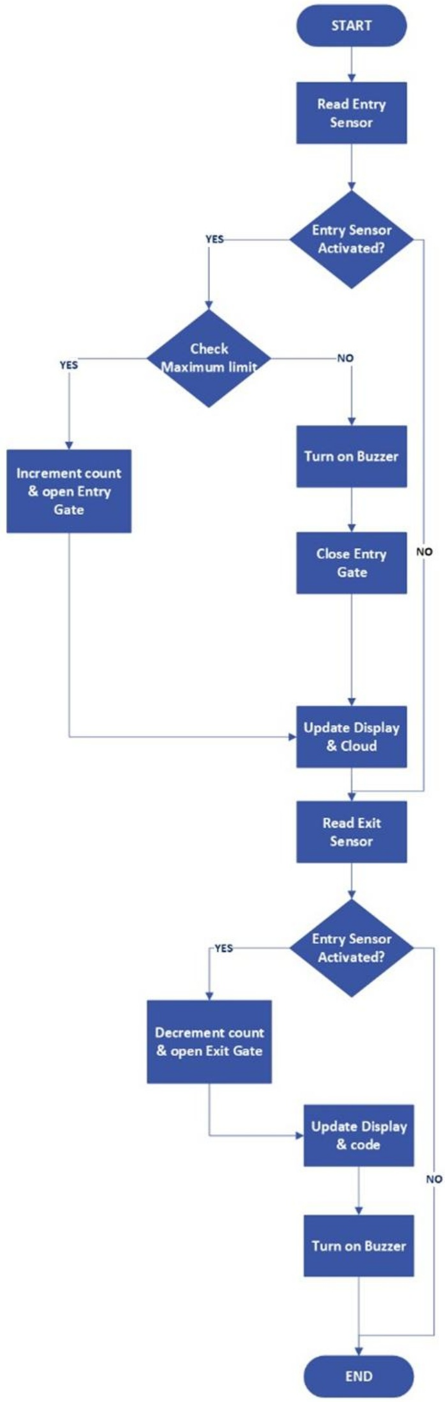

Fig. 2. Flow chart of operation

Parameters are the ones that define the performance and functionality in a real-world environment. The above tables show the parameters used in this project. In order to customize the system as per the area crowd count, a threshold value is defined for a specific area to overcome overcrowding. For developing the prototype, the low range IR sensor is used. However, the range of detection can be increased up to 4m by using Time-of-flight (TOF) sensors (VL53L1X). By increasing the range, we can rectify the error due to miscount near doorway. It is suitable for detecting human movement when placed properly near doorways. Wi-Fi connectivity is necessary for remote control of the crowd at a required area. As Arduino IoT Cloud needs Wi-Fi connectivity for real-time data transfer. The system requires less power, which makes the system ideal for continuous operation.

Table 1. System Parameters.

Parameters	Range
Maximum count	Customizable
Sensor range (for prototype)	2-5 cm
TOF Sensor	Up to 4 m
Wi-Fi connectivity	yes
Power consumption	low

4 Results

The system is kept under conditions to evaluate the functionality and the reliability. The IR sensors are detecting humans accurately. It consistently updated the count in real time, and the delay time is comfortable. Whenever the system is placed in an environment that should be capable of handling different test cases that may happen during the execution. Considering different inputs that the microcontroller gets during the execution is framed in the following table. The table also shows how the system is trained for different test cases.

Table 2. IR Sensor-Based People Counting and Buzzer Activation Logic Table.

Entry IR sensor	Exit IR sensor	Action	People count	Buzzer
1	0	Person entered	+1	OFF
1	1	Person exited	0	ON
1	1	Invalid	No change	OFF
0	0	No movement	No change	OFF
10	1	Count>limit	No change	ON

In the Table 2, ‘1’ represents a true statement and ‘0’ represents a false condition. The first case is about a person entering the area. At that time the entry IR sensor and entry servo motor are operating with the help of NodeMCU. LCD display showing the person count as 1. During this, the buzzer will be turned off because the buzzer is not linked with entry sensors. The second case is the person exits from the area. During this phase, the exit IR sensor and servo motor are operating. The people count is 0 because the person entered and exited. During this exit phase, the buzzer is turned on as an alert mechanism. In the third case, both the entry and exit counts are 1, which simultaneously do not appear. In this time, the system does not open gates for entry and exit. When no human enters or exits from the area, then there is no movement; the person count remains the same as previously. Currently the limit set for the area is 10. When the entry is more than 10, the entry gate is closed and the buzzer turned on. Figure 3 shows the count of the people who entered the area.

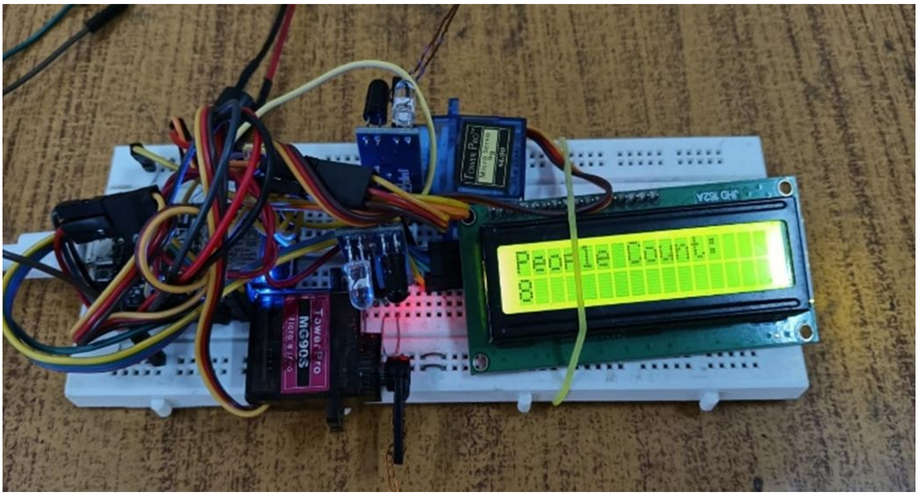

Fig. 3. Test Results

5 Conclusions

The project focus on crowd gatherings in specific locations leads to the resolution of several disasters, such as stampede-related occurrences. Due to urbanization, migration, and city expansion, the population of urban regions has been growing in recent years. Since most workplaces are located in cities, it goes without saying that employees prefer to live close to their places of employment. This is among the factors contributing to the growing population in cities. The population of urban regions is rapidly growing. Public gatherings at places like festivals, religious events, train stations, retail centers, and entertainment venues have increased in parallel with this growth. In these situations, crowd surveillance is crucial. In addition to providing early notifications and preventative measures, the system handles the problem of the population density in a given area. The crowd surveillance system can be accessed remotely by integrating it with cloud IoT. This technology uses infrared sensors to identify and communicate the human count data. Both the LCD display and the IoT dashboard show the processed data. If the limit is exceeded, the buzzer alerts, ends the human interaction moment, and closes the gate. The project's IoT components are appropriate and reasonably priced. The goal of this project is to alert the authorities and manage the crowd and guarantee public safety. The rapid entry and rapid exit can be controlled by using high-speed sensors and edge computing.

This system has the capability of reducing the risk of fatalities during large gatherings. In order to ensure safety, the system provides early alerts. Avoiding close contacts can reduce the spread of the virus. Despite promising outcomes, this system has certain limitations that need to be addressed for even more efficient operation. This system might encounter difficulties in a practical setting. Although the sensors may produce inaccurate results if the individuals are closely placed together, the effects are minimal because this problem can be resolved by narrowing the entry. Since the infrared sensors treat the object and the person as identical, they may yield incorrect findings. When it comes to large objects, that is advantageous.

For cloud updates and real time monitoring needs consistent internet connectivity. These limitations are helpful for future research to integrate the system with advanced sensors and improving accuracy. To enhance the effectiveness of the system, it can be extended by integrating with additional sensors for better detection such as camera-based vision system. Another significant extension could include the development of a SMS alert service for real time notification to alert the authorities for quick action. Addressing the drawbacks of the system in future iteration will be key to making the system more robust and scalable. Such system is essential in future cities for urban management and ensuring safety.

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