

Efficient Emergency Exit System Leveraging Real-Time Image Processing and IoT

Indira Devaki Vutukuru¹, Kranthi Madala², Lakshmi Swetha Sri Kalepalli³, Anupama Anumolu⁴,
Anantha Sriram Donepudi⁵ and Dr. Swathi Nadipineni⁶

^{1, 3-5}Department of EIE, VR Siddhartha Engineering College, Vijayawada, India

Email: indiradevakivutukuru@gmail.com, kalepallswetha@gmail.com, anumoluanupama10@gmail.com,
ananthasriramdonepudi@gmail.com

^{2, 6}Asst. Professor, Department of EIE VR Siddhartha Engineering College, Vijayawada, India
Email: kranthimadala16@gmail.com, swathinadipineni@vrsiddhartha.ac.in

Abstract—In emergencies like fires, gas leaks, and earthquakes, swift and safe evacuation is critical to protecting occupants in buildings. This paper introduces a "Smart Emergency Exit System Using Image Processing" to ensure swift and safe evacuation during emergencies. The system integrates YOLOv5-based image processing, Arduino controllers, and IR sensors to monitor the environment, detect dangers, and guide occupants. It provides warnings via buzzers and directs crowds toward less congested exits using light signals and audio cues. By dynamically adjusting evacuation routes in real-time, the system minimizes evacuation time, reduces risks of overcrowding, and enhances safety in large buildings and public spaces.

Index Terms— Emergency, Infrared sensor , evacuation, Arduino microcontroller, Image processing, YOLOv5.

I. INTRODUCTION

In high-risk emergencies, such as fires, gas leaks, and earthquakes, the ability to evacuate buildings swiftly and safely is paramount. However, numerous incidents have shown that conventional evacuation systems are often inadequate, leading to severe consequences. For instance, in recent years, India has experienced multiple tragic events where insufficient emergency planning and overcrowded exits resulted in significant casualties. One prominent example is the 2019 fire in Surat, where over 20 students lost their lives in a coaching center due to blocked or insufficient exits and delayed response times by rescuers [1]. Similarly, a fire at a COVID-19 hospital in Ahmedabad in 2020 underscored the need for reliable evacuation routes and systems, as blocked exits and overcrowding impeded patient rescue efforts, resulting in multiple fatalities [2].

These incidents highlight the urgent need for enhanced evacuation systems that can dynamically adapt to emergency situations, providing safe and efficient escape routes based on real-time conditions. Conventional systems, often limited by static exit signage and non-adaptive routes, fail to address challenges like overcrowded exits, obstructed paths, and delayed response times in high-density buildings. To overcome these limitations, this paper proposes a "Smart Emergency Exit system by image processing" Arduino-based IR sensors, and IoT integration to provide real-time evacuation guidance and monitoring. By continuously identifying occupant locations and dynamically adapting evacuation routes, this system aims to reduce evacuation time, alleviate congestion at exits, and improve safety outcomes in large buildings and public areas.

II. LITERATURE SURVEY

To support the development of the "Smart Emergency Exit system by image processing" system, a comprehensive review of existing literature was conducted, focusing on the integration of IoT, wireless communication, and adaptive tracking technologies in emergency evacuation systems.

In recent years, various research efforts have been made to enhance emergency evacuation systems using tracking, IoT, and real-time monitoring technologies.

J. Lee and K. Choi [3] examined the use of IoT- enabled evacuation systems in high-density buildings, demonstrating that IoT sensors can improve safety by providing real-time updates on occupant locations and dynamic exit routes during fire incidents.

Similarly, **S. Kumar and A. Singh** [4] explored the integration of Wi-Fi-based tracking in evacuation systems, showing that Wi-Fi modules can effectively locate occupants and provide personalized exit guidance, reducing congestion at key exits.

This is further supported by **M. Rao et al.** [5], who demonstrated that using wireless communication for evacuation in multi-floor buildings significantly improved escape times by dynamically adapting routes to avoid congested or inaccessible exits.

In another study, **T. Tanaka and S. Nakamura**

[6] developed a system that uses Arduino-based sensors, including passive infrared (PIR) sensors, to detect movement and flame presence, which helped responders pinpoint high-risk areas and locate trapped individuals. Their results showed that Arduino-based systems are feasible for large- scale buildings due to their low cost and adaptability.

Y. Zhao and L. Li [7] proposed a machine learning-enhanced evacuation model that uses sensor data to predict and adjust evacuation paths, allowing the system to make quick decisions that mitigate overcrowding. By focusing on real-time adaptability.

A. Gupta and R. Mehta [8] discussed the benefits of using integrated IoT and wireless communication technologies, finding that these systems reduced overall evacuation times by over 30% in simulation-based scenarios.

Furthermore, **M. Singh et al.** [9] evaluated the impact of audio and visual cues in emergency evacuations, finding that light signals combined with audio instructions significantly increased occupants' response speeds, especially in low- visibility conditions caused by smoke.

P. Bhattacharya and D. Roy [10] emphasized the need for multi-modal guidance systems to enhance situational awareness during evacuations, highlighting that combined use of light signals, audio alerts, and display screens helps reduce confusion among occupants and supports quicker decision-making. In sum, recent literature underscores the potential of IoT, wireless communication, and sensor-based technologies to address challenges in emergency evacuation by providing real-time, adaptive guidance tailored to building-specific conditions.

III. PROPOSED SYSTEM

The incorporation of all components onto an Arduino Uno Board not only ensures cost- effectiveness but also facilitates seamless interaction. The Arduino IDE is utilized for programming the Arduino Board. The Block diagram of proposed model as shown in Fig.1.

A. Methodology

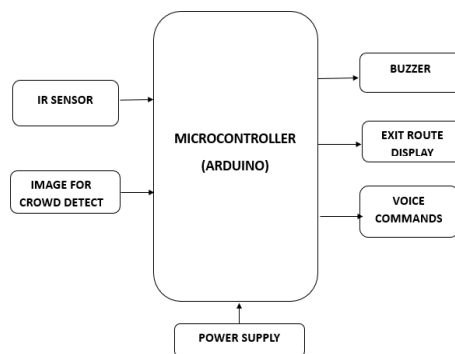


Fig .1. Block Diagram of Proposed model

B. Hardware and software

Various types of sensors and indicators were connected to Arduino Uno board. Arduino board acts as heart of the project and makes it less complex. The Arduino Uno is as depicted in Fig.2. is based on the ATmega328P microcontroller, which is an 8-bit AVR microcontroller with 32KB of flash memory for storing program. It operates at a clock speed of 16MHZ. The board has 14 digital input/output pins. Among these, 6 can be used as PWM (Pulse Width Modulation) outputs. There are 6 analog input pins on the Arduino Uno, labeled A0 through A5. The Arduino Uno has a UART for serial communication interfaces. Arduino Integrated Development Environment (IDE), which simplifies the process of writing, compiling, and uploading code to the board.



Fig.2. Arduino UNO Board

IR Sensor

In our Smart Emergency Exit System by image processing, infrared (IR) sensors are essential for detecting emergencies by identifying the presence and movement of people. IR sensors work by emitting infrared radiation, invisible to the human eye, which is then picked up by the sensor's receiver. The sensor typically consists of two main components: an IR LED, which serves as the emitter, and a photodiode, which acts as the receiver. The IR LED sends out infrared light, and when this light encounters an object, it reflects back to the photodiode. By measuring the amount of reflected light, the sensor can detect the presence and distance of objects, allowing it to sense movement and identify obstructions.

IR sensors can play an integral role in emergency detection for your system. By detecting people, IR sensors make it possible to monitor the presence of individuals, which helps to manage and guide evacuation routes more efficiently. In addition, active IR sensors can detect obstacles that might obstruct exits, allowing the system to adjust and update escape routes dynamically. By strategically placing IR sensors at hallways, doorways, and critical points along evacuation paths, our system can track the flow of people towards exits, thus enabling a smooth and organized evacuation process. The IR sensor which we used in our prototype is shown in Fig.3.

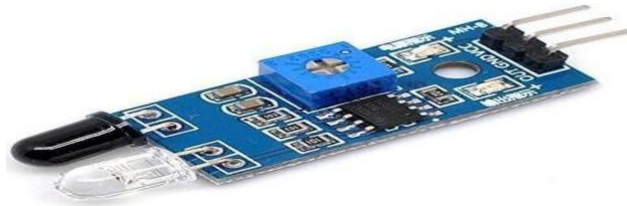


Fig.3. IR Sensor

Software

Image processing technology, integrated with real-time monitoring and IoT, offers a practical approach to assessing crowd density and directing evacuees away from congested areas. The system employs strategically placed cameras near exits to capture live video, which is processed by intelligent detection algorithms to identify individuals and estimate crowd levels in real time.

YOLOv5 (You Only Look Once version 5) is a cutting-edge object detection algorithm renowned for its speed, accuracy, and efficiency. It processes an image using a single convolutional neural network, identifying multiple objects and their locations in real time. With its lightweight architecture, YOLOv5 is computationally efficient, making it ideal for deployment on devices with limited resources. It achieves a balance between precision and speed, enabling effective detection even in complex scenes. Its ability to identify and classify multiple objects simultaneously makes it particularly suitable for dynamic applications like monitoring crowd density and movement in emergency evacuation systems.

At the core of the system, an Arduino microcontroller coordinates inputs and outputs, receiving data from an IR sensor and an image- processing module. The IR sensor detects motion near exits, helping identify areas with high activity, while a camera or image sensor captures real-time visuals of the crowd. This crowd data is processed using image analysis algorithms, allowing the system to estimate the density of people at each exit and identify potential congestion. When an exit becomes overcrowded, the microcontroller activates a series of response mechanisms. An audible buzzer alert is triggered to attract attention, and LED strips light up along alternative routes, guiding evacuees toward less crowded exits. Additionally, a voice command module plays pre-recorded or dynamic messages to reinforce these instructions, directing people to safer exits and reducing confusion. The system operates on a continuous power supply, potentially with battery backup to ensure functionality even in power outages. By providing real-time, multi- sensory guidance, this system helps to streamline evacuation and improve safety, adapting dynamically to the crowd flow at each exit.

IV. RESULT

The prototype of our proposed model is as shown in Fig.4.

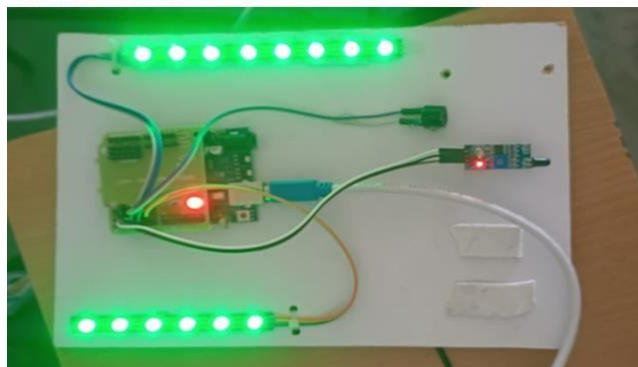


Fig.4.Prototype of our proposed model

When flame is detected by IR Sensor the LED strips blinks lights in the direction of exits as depicted in Fig.5.

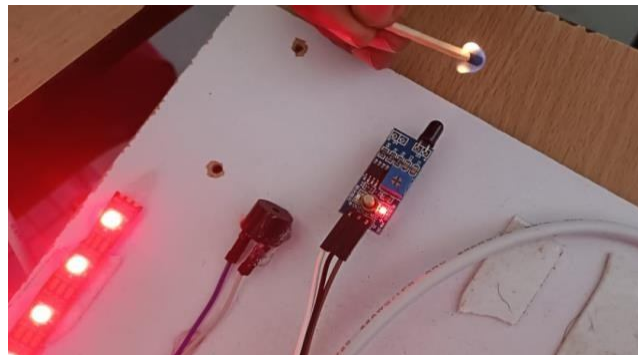


Fig.5.Fire detection by IR sensor

At the beginning the algorithm gives output as welcome through audio cues as shown in Fig.6 when no people were detected.

With the image processing through YOLOv5 algorithm we developed a code with python programming that makes crowd count as shown in Fig.7 and intimates people with voice command “Crowd is more in exit 1 or exit 2,move to other exit”.

V. CONCLUSION

In conclusion, the Emergency Exit Monitoring System represents a significant advancement in emergency response technology, providing a reliable, IoT-enhanced solution for real-time monitoring, alerting, and evacuation guidance. By integrating essential components such as IR sensors, LED indicators, buzzers,an Arduino microcontroller, the system ensures continuous surveillance of emergency exits and immediate response

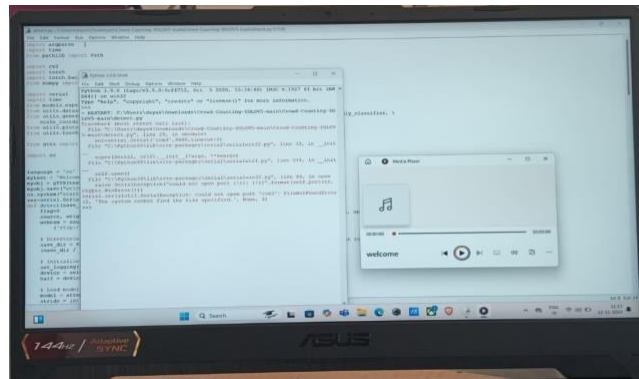


Fig.6. when no people detected

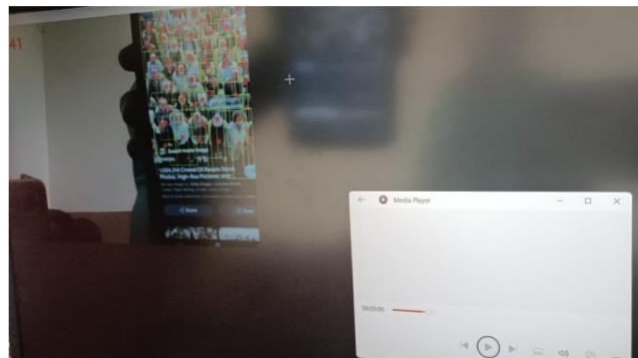


Fig.7.Detection of crowd through image processing

when hazards are detected. The incorporation of wireless tracking offers an added dimension, enabling real-time location updates and assisting rescue teams in efficiently locating occupants. Future enhancements, including advanced sensor integration, machine learning, and scalable modular designs, will further improve the system's capability to address diverse emergency situations while optimizing safety and evacuation efficiency. This project highlights the potential for embedded systems, IoT, and intelligent monitoring to play a critical role in public safety, contributing to the development of smarter, more responsive infrastructures for emergency management. Through its robust design and potential for future growth, the system underscores the importance of technological innovation in safeguarding lives in emergency scenarios.

VI. FUTURE SCOPE

The future scope of the Emergency Exit with Real-Time tracking System envisions numerous advancements to increase its reliability, scalability, and effectiveness in diverse emergency scenarios. While the current system relies primarily on an IR sensor for detecting unauthorized movement or potential fire hazards, future iterations could integrate additional sensor types, such as smoke detectors, temperature sensors, and gas sensors, to enhance its capacity to detect a wider range of emergencies. This multimodal sensing approach would enable a more comprehensive safety solution, ensuring rapid and accurate responses to multiple threat types.

In terms of connectivity, expanding the WiFi- based communication capabilities can facilitate integration with IoT platforms for data collection and real-time analytics. Incorporating cloud-based services would allow the system to perform continuous data logging and predictive analytics, which would support proactive risk management and enable building managers to assess and improve safety protocols based on historical data. Additionally, the incorporation of machine learning algorithms could empower the system to analyze environmental data and anticipate emergencies before they occur. Predictive analysis using real-time sensor data, building layouts, and occupancy patterns could streamline evacuation planning, reducing response times and enhancing occupant safety in emergencies.

For user interaction, the current design primarily employs auditory and visual cues on the serial monitor for notifications and alerts. A future design could integrate a mobile app to provide real-time alerts, interactive guidance, and personalized exit instructions for users, offering tailored guidance that may prove more effective in

emergencies. Furthermore, to accommodate larger and more complex buildings, the system could adopt a modular architecture to support scalability across multiple floors and interconnected spaces. Interoperability with other building management and fire safety systems would ensure that emergency alerts are seamlessly shared across platforms, enabling coordinated responses in extensive facilities.

Monitoring System is poised to evolve into a more robust, intelligent, and adaptive solution, capable of addressing a broader spectrum of emergencies and supporting comprehensive safety management in both public and private infrastructure.

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