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FIRE ALERT SURVEILLANCE ROBOT: REAL-TIME FLAME DETECTION AND RESPONSE

Engineering

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ABSTRACT

This paper presents the development of a Fire Detection and Surveillance System that integrates flame detection and automated fire suppression within a mobile surveillance robot. The system utilizes an IR-based flame sensor for accurate flame detection, an ESP32 microcontroller for signal processing, and a SIM800C GSM module to provide real-time notifications and control, enabling remote monitoring and response capabilities. The surveillance robot, equipped with a water sprayer, performs automated fire suppression and guides individuals to safety in hazardous environments. Manual control of the robot and live video feed to a central system allow for enhanced situational awareness and informed decision-making during rescue operations. Future enhancements, including AI-driven decision-making, autonomous navigation, and integration with smart building systems, are proposed to further improve fire detection, response time, and operational efficiency. This system aims to advance fire safety by enabling early detection, coordinated response, and minimizing potential loss of life and property in fire-prone environments.

KEYWORDS

Surveillance Robot, Flame Detection, Fire Safety, Autonomous System

INTRODUCTION

Fire detection and suppression using advanced robotic technology plays a crucial role in enhancing indoor safety, providing rapid, efficient responses that minimize the potentially devastating impacts of fires. This work introduces a robotic surveillance system equipped with fire detection sensors, extinguishing mechanisms, cameras, and GPS, offering a proactive and scalable approach to fire management. By enabling early fire detection, these robots facilitate immediate evacuation, reducing risks to human life while preserving property and financial assets. Unlike traditional manual systems that are susceptible to delays and human error, robotic systems autonomously detect fires, alert responders, and initiate suppression, achieving rapid intervention and minimizing fire spread. Additionally, the robot's real-time video streaming and remote operability allow responders to make informed, strategic decisions while avoiding direct exposure to hazardous conditions. With capabilities to navigate complex indoor environments, access hard-to-reach areas, and efficiently deploy suppressant agents, this system represents a significant advancement in fire safety technology, providing an effective solution for early detection, swift suppression, and enhanced situational awareness in fire incidents.

To advance the field of fire detection and response, a literature survey was conducted to review existing methods and their respective contributions, followed by a comparative analysis with the proposed system. In "Spy Robot with Fire Detection and Water Sprinkling System," Kolambe et al. used two Android phones for camera and monitoring functions, with Bluetooth control and a temperature sensor for fire detection. Harinath et al. introduced an Arduino-based robot employing flame sensors and an H-bridge motor driver for extinguishing fires with a water pump. Suresh utilized a CO_2 cartridge for fire suppression and equipped the robot with ultrasonic sensors for distance measurement. Diwanji et al. used multiple flame sensors for direction control and a relay-operated DC pump for targeted water spraying. Kumbhar et al. developed an Arduino-controlled robot using an ESP8266 module, smoke sensors, and a water pump. Teja et al. created an IoT-based system that employs vision technology for long-distance flame detection and automatic reporting via Wi-Fi or GSM. Lastly, Takeuchi et al. developed a residential fire detection system with an infrared camera and Raspberry Pi for flame size assessment and real-time video monitoring. These approaches provide valuable insights for developing a robust, efficient fire detection and suppression system in the proposed work.

Design And Implementation

Residential buildings are equipped with an SMS interface module integrated with a flame sensor to detect potential fire outbreaks. Upon detecting a flame, the system immediately sends a text alert to the nearest fire station. Key features of this system include: continuous, 24-hour flame monitoring for residential areas; the SIM800C GSM module, which promptly sends the building's address in a text message to fire responders; and an integrated buzzer that alerts residents when fire is detected. The robot operator can remotely navigate the robot to the location provided in the alert and monitor its movements via a specific IP address on any web browser. The surveillance robot is equipped with a water pump and nozzle to automatically extinguish the fire. Additionally, real-time monitoring of the robot is enabled through live-streamed footage, allowing operators to track its actions effectively during the intervention.

The fire detection system's SMS Interface Module in Figure 1 utilizes several key components for functionality and communication. The Flame Sensor serves as an input, designed to detect flames and provide feedback on flame intensity to the system. The Arduino Nano operates as the central processing unit, receiving data from the flame sensor, processing it, and managing outputs based on conditions detected. For auditory alerts, the Buzzer is connected to the Arduino Nano, allowing it to generate sound notifications in response to detected events. Additionally, the SIM800C GSM Module facilitates communication by sending SMS alerts through GSM networks, enabling remote notifications and responses to potential fire incidents.

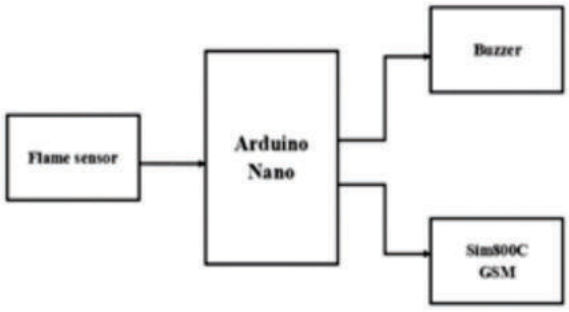

Figure 1: Block diagram of SMS Interface module

The Surveillance Robot block diagram in Figure 2 illustrates the interconnected system enabling automated fire detection and response. It integrates an ESP32 Cam Wi-Fi Module for wireless communication and image/video processing. The ESP32 handles input from the flame sensor and sends control signals to other components. The Relay Module acts as a switch, using the low-power signal from the ESP32 to control high-power circuits, such as activating a pump.

The L298N Motor Driver controls the speed and direction of DC motors. A XL4015 Buck Converter ensures efficient voltage conversion to provide stable power to system components.

The Left Motor and Right Motor are DC motors enabling differential steering for controlled movement. Additionally, the R385 Pump is a compact water pump that manages liquid flow and pressure.

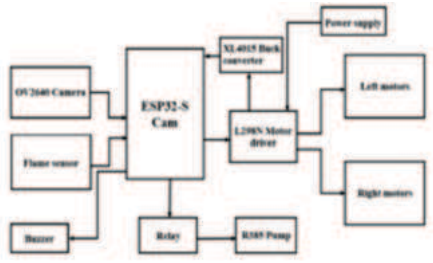

Figure 2: Block diagram of Surveillance Robot

The circuit design of the SMS Interface module aims to create a system that detects flames using the flame sensor, communicates the information via the SIM800C GSM module, and generate an audible alert through the active buzzer and is as given in Figure 3.

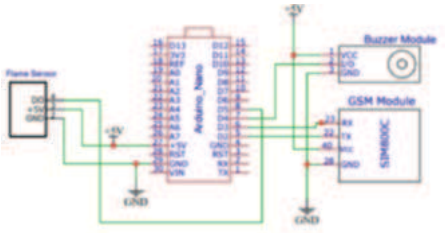

Figure 3: Circuit diagram of SMS Interface module

The Surveillance robot is mainly equipped with a Flame sensor, ESP32 Cam Wi-Fi module, L298H bridge driver, and water pump. The circuit design combines cuttingedge technology to create a robot capable of detecting flames using the flame sensor, transmitting live video feeds through the ESP32 Cam Wi-Fi module, controlling motor movements via the L298H bridge driver, and even deploying a water pump for firefighting applications. Figure 4 shows the circuit diagram of the Surveillance robot. The flowchart of the proposed system is given in Figure 4.

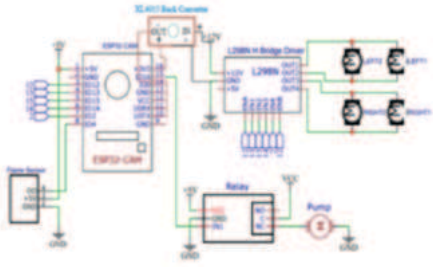

Figure 4: Circuit diagram of the Surveillance robot

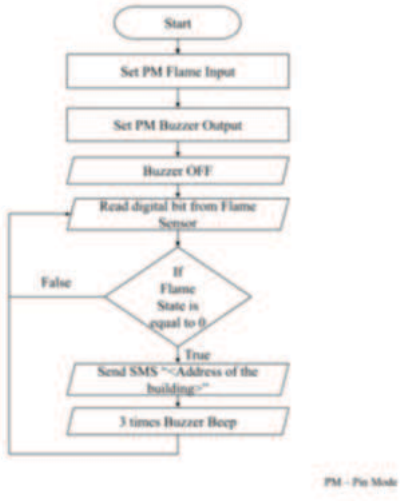

Figure 5: Circuit diagram of SMS Interface module

RESULTS

This work has been developed and executed in multiple phases, each contributing to the overall progress and outcome. The implemented SMS Interface module is shown in Figure 6. When a flame is detected, the SMS Interface Module generates results as shown in Table-1.

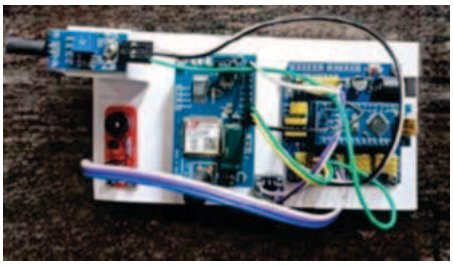

Figure 6: SMS Interface module

Table – 1 Outputs From The Sms Interface Module

Input (Flame Sensor State)	Output (Buzzer)	Output (SMS)
0 (No Flame)	OFF	NA
1 (Flame Detected)	3 times beep	Send SMS

Figure 7: Received message from SMS interface module

The implemented Surveillance Robot is shown in Figure 8. The control mechanisms for the robot are outlined in Table-2

Figure 8: Surveillance Robot - Profile View

Table – 2 Controls Of Robot Module

Input	Left Motor Output	Right Motor Output
Forward button pressed	Move forward	Move forward
Backward button pressed	Move backward	Move backward
Left button pressed	Move forward	Motor OFF
Right button pressed	Motor OFF	Move forward

Table-2 provides a clearer view of how each button press on the joystick control affects the left and right motors of the robot.

Figure 9: Controls of the Surveillance Robot

Table – 3 Results Of Relay Module And Pump

Flame Sensor Digital State	Spray Pump Relay Output
0	OFF
1	ON

Table-3 indicates that the relay will turn the spray pump ON when the flame sensor state is 0, and it will turn OFF when the state is 1.

CONCLUSIONS

The Fire Detection and Surveillance System developed in this project represents an advanced and comprehensive approach to fire safety, integrating multiple technologies to ensure swift detection, response, and mitigation of fire hazards. Equipped with an IR-based flame sensor, ESP32 microcontroller, SIM800C GSM module, and surveillance robot, the system effectively detects flames through infrared sensing and processes this data to activate alarms, alert individuals, and notify a central system in real time. This communication enables rapid deployment of the surveillance robot, which aids in rescue operations and utilizes a water sprayer to suppress fires, creating a safer path for evacuation. Furthermore, the robot's manual control and live video feed enhance situational awareness, allowing operators to make informed decisions during emergencies. Overall, this system combines early detection with responsive action, utilizing innovative technology to protect lives and minimize property damage in hazardous environments.

Future Enhancements

Future advancements in surveillance robots with flame detection will be shaped by technological progress and evolving fire safety needs. Adding sensors like thermal cameras, gas detectors, and air quality sensors can enhance situational awareness during fire incidents. Implementing AI and machine learning can further improve detection accuracy and enable smarter decision-making. Enhanced navigation through autonomous mapping and path-planning algorithms will allow robots to maneuver more effectively in complex environments. Swarm robotics could also be applied, enabling multiple robots to collaborate in fire detection and response. Integrating these robots into smart building systems would allow seamless communication with other fire safety protocols, such as automatic fire suppression, building alarms, and occupant alerts. These future enhancements will boost the effectiveness, reliability, and adaptability of surveillance robots, advancing their role in fire safety and emergency response to better protect lives and reduce fire-related damage.

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