AUTONOMOUS ROBOT FOR INDOOR FIRE SUPPRESSION

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Abstract: *This paper presents an innovative autonomous solution for indoor fire suppression that integrates advanced sensing, real-time monitoring, and robust control systems to enhance fire safety. The system features multi-zone flame sensors that continuously scan the environment and provide directional input to an ESP32-based controller. Upon fire detection, the robot autonomously navigates toward the hazard using a predefined path-following algorithm controlled by DC motors and an L298N motor driver. Once at the fire source, a servo-controlled water pump is activated to suppress the flames effectively. The inclusion of an ESP32-CAM module enables live video streaming for remote supervision, while a GSM module dispatches immediate SMS alerts to ensure rapid response. By seamlessly combining autonomous navigation, wireless communication, and targeted fire extinguishing capabilities, this research demonstrates a scalable and cost-effective approach to modernizing indoor firefighting methods, significantly reducing response times and mitigating potential fire hazards.*

Keywords*: Autonomous Fire Suppression, Indoor Fire Safety, Autonomous Robotics, Real-Time Monitoring, Flame Detection, ESP32, Wireless Communication, GSM Alerts, Embedded Systems, ESP32-CAM*

I.INTRODUCTION

Autonomous fire suppression is no longer a futuristic concept—it's rapidly transforming the way we approach indoor safety. Envision a system that combines cutting-edge sensor technology, intelligent robotics, and real-time communication to create a vigilant guardian against fire hazards. The autonomous fire suppression robot may look like a conventional mobile robot at first glance, but once activated, it springs into action with precision and efficiency. Equipped with multiple flame sensors, the robot constantly monitors its surroundings and swiftly detects any sign of fire. Upon detection, an ESP32-based control unit processes the data and navigates the robot toward the hazard using an optimized path-following algorithm, while a servo-controlled water pump is activated to extinguish the flames immediately.

The robot doesn't stop there—it also features an ESP32-CAM module that streams live video, enabling remote supervision and enhancing situational awareness. Additionally, a GSM module sends instant SMS alerts to designated emergency contacts, ensuring that help is always on standby. This integrated approach not only minimizes the risks to human firefighters but also enhances the overall safety of indoor environments such as smart buildings, warehouses, and industrial facilities.

Section 2 details the system design and component integration, while Section 3 explains the step-by-step working of the fire suppression process. Section 4 provides a comprehensive overview of the functional aspects of the robot, and Section 5 discusses potential challenges and future improvements in this evolving technology.

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II.FUNCTIONAL OVERVIEW

On startup, after power is supplied to the autonomous fire suppression robot, the ESP32 microcontroller initializes and performs a self-diagnostic on all connected components. The system begins by calibrating its multi-zone flame sensors to ensure they accurately detect the presence and direction of any fire. Simultaneously, the ESP32 sets up communication links with the ESP32-CAM for live video streaming and with the GSM module for sending immediate SMS alerts. The RF receiver is also configured to allow manual override if needed.

Once fully operational, the robot continuously monitors its surroundings with its flame sensors. When a fire is detected, the system processes sensor data to determine its exact location—whether it is to the left, center, or right. The ESP32 then activates its autonomous navigation algorithm, directing the L298N motor driver to control the DC motors and steer the robot toward the fire. As the robot approaches the hazard, a servo-controlled water pump is activated to accurately target and suppress the flames. Throughout this process, the ESP32-CAM streams live video to a remote monitoring station, while the GSM module dispatches real-time alerts to emergency contacts.

The system is designed with safety and energy efficiency in mind. It incorporates protocols to power down non-essential functions when no fire is detected, ensuring resource conservation. Additionally, a manual override via RF communication allows users to intervene and control the robot in complex situations. This comprehensive integration of sensor data, autonomous navigation, and real-time communication provides a robust, scalable solution for indoor fire suppression in environments such as smart buildings, warehouses, and industrial facilities.

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Components Required:

- ESP32 Microcontroller – Acts as the central processing unit for data handling and control.
- Multi-Zone Flame Sensors – Detect fire presence and provide directional information.
- ESP32-CAM Module – Streams live video for remote monitoring.
- GSM Module – Sends immediate SMS alerts with fire detection and location details.
- RF Receiver – Allows for manual override and remote control of the robot.
- L298N Motor Driver – Controls the DC motors for autonomous navigation.
- DC Motors – Provide mobility to navigate towards the fire.
- Servo Motor – Adjusts the water pump nozzle for precise targeting.
- Water Pump – Dispenses water or fire retardant to extinguish fires.
- Relay Module – Acts as an electrical switch to control the water pump.
- Battery Pack/Power Supply – Provides continuous power for all components.
- Supporting Hardware – Includes wiring, connectors, and additional components necessary for system integration

III.BLOCK DIAGRM OF PROJECT.

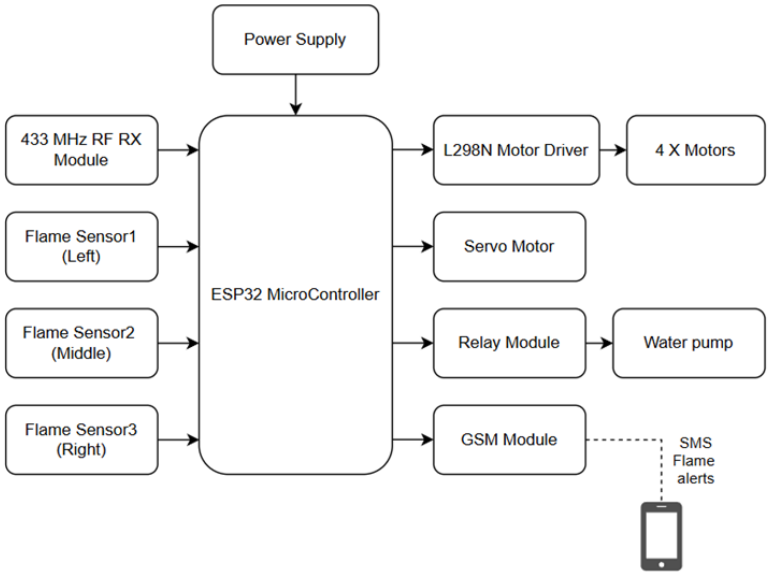

Fig 1:Block diagram Of Project

- This block diagram represents an autonomous fire suppression system designed for rapid detection and response using advanced sensing and communication technologies. Let's break down each component and its role:
- **Core Processing Unit:**
- **ESP32 Microcontroller:** Serves as the brain of the system, processing inputs from various sensors, executing the navigation algorithm, and controlling all actuators. It also manages communications with remote monitoring modules.
- **Power Supply:**
- Battery Pack/Power Supply: Provides the essential power needed for uninterrupted operation of the entire system.
- Voltage Regulators: Ensure stable power levels for sensitive components like the ESP32, sensors, and communication modules.
- **Sensors:**
- Multi-Zone Flame Sensors: Detect the presence and direction of fire by measuring infrared radiation, providing critical data for fire localization.
- Additional Environmental Sensors (if applicable): May support future upgrades for enhanced monitoring.
- **Actuators:**
- L298N Motor Driver: Controls the DC motors to maneuver the robot towards the fire.
- DC Motors: Enable the robot's autonomous movement across various terrains.
- Servo Motor: Adjusts the water pump nozzle for precise targeting of the fire.
- Relay Module: Functions as an electrical switch to control the activation of the water pump.

- Water Pump: Dispenses water or fire retardant to extinguish detected fires effectively.
- **Communication and Connectivity:**
- ESP32-CAM Module: Streams live video to remote monitoring stations, providing real-time visual feedback.
- GSM Module: Sends immediate SMS alerts with fire detection details and location information.
- RF Receiver: Allows for manual override, enabling remote control in case of emergencies.
- **Mobility and Structural Components:**
- Wheels & Chassis: Provide the necessary mobility and stability for the robot, ensuring it can navigate towards the fire safely.
- Supporting Hardware: Includes wiring, connectors, and other mechanical linkages that integrate all system components for seamless operation.
- **Connectivity:**
- IoT Integration: Facilitates remote monitoring, control, and data analysis by connecting the system to cloud services and mobile interfaces.
- This integrated architecture ensures that the system can rapidly detect fires, autonomously navigate towards the hazard, and deploy targeted suppression measures while keeping users informed in real time

Component Category	Component	Description
Core Processing Unit	ESP32 Microcontroller	Processes sensor data, runs navigation algorithms, controls actuators, and manages communication with remote monitoring modules.
Power Supply	Battery Pack/Power Supply	Provides the essential power needed for uninterrupted operation of the system.
	Voltage Regulators	Maintain stable power levels for sensitive components such as the ESP32, sensors, and communication modules.
Sensors	Multi-Zone Flame Sensors	Detect fire presence and provide directional information by measuring infrared radiation.
Actuators	L298N Motor Driver	Controls the DC motors to maneuver the robot toward the detected fire.
	DC Motors	Provide mobility, allowing the robot to navigate across different terrains toward the fire.
	Servo Motor	Adjusts the water pump nozzle for precise targeting during fire suppression.
	Relay Module	Acts as an electrical switch to control the activation of the water pump.
	Water Pump	Dispenses water or fire retardant to effectively extinguish the fire.
Communication & Connectivity	ESP32-CAM Module	Streams live video for remote monitoring, providing real-time visual feedback.
	GSM Module	Sends immediate SMS alerts with fire detection details and location information to designated contacts.
	RF Receiver	Enables manual override and remote control, allowing user intervention in emergency situations.
Mobility & Structural Components	Wheels & Chassis	Provide the necessary mobility and stability for the robot to navigate toward the fire safely.
	Supporting Hardware	Includes wiring, connectors, and mechanical linkages that integrate all system components for seamless operation.
IoT Integration	Cloud Connectivity	Facilitates remote monitoring, data analysis, and control via cloud services and mobile interfaces, ensuring comprehensive system oversight.

Table 1: basic requirements

IV.FLOW CHART

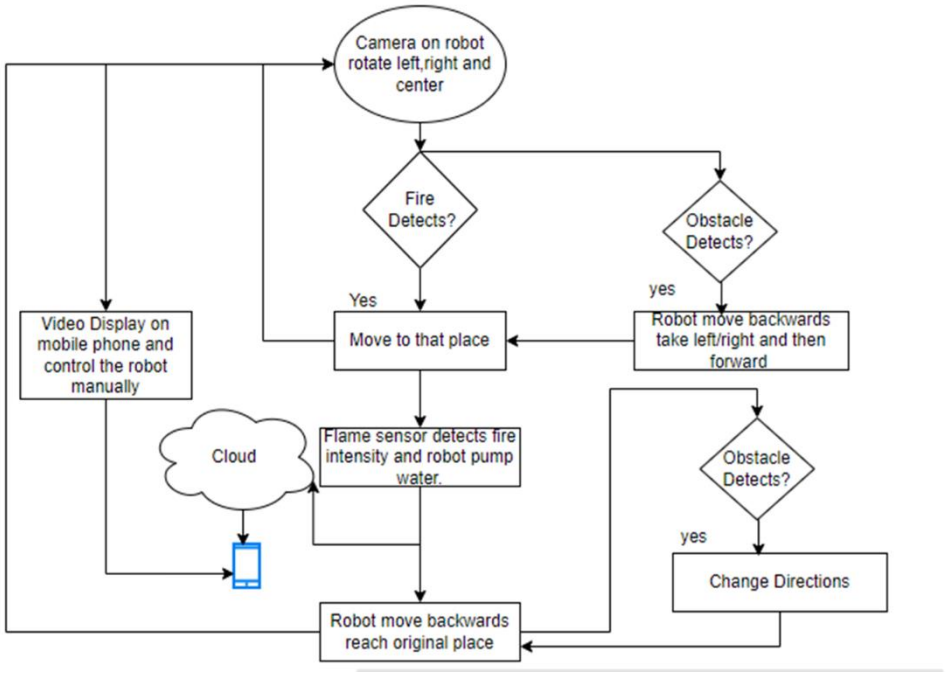

Fig 2 : Flow Chart of Project

- **Start:** The process begins when power is supplied to the system.
- **Initialize System:** The ESP32 microcontroller initializes, performing self-diagnostics and calibrating all connected components.
- **Sensor Calibration:** Multi-zone flame sensors are calibrated to ensure accurate detection of fire and directional input.
- **Continuous Monitoring:** The system continuously scans the environment using the flame sensors for any sign of fire.
- **Fire Detection:**
- **Yes (Fire Detected):**
- The ESP32 processes sensor data to determine the exact location of the fire (left, center, or right).
- The autonomous navigation algorithm is activated to steer the robot toward the fire using DC motors controlled by the L298N motor driver.
- As the robot approaches the fire, a servo motor adjusts the water pump nozzle for precise targeting, and the water pump is activated to extinguish the flames.
- Simultaneously, the ESP32-CAM streams live video for remote monitoring, and the GSM module sends immediate SMS alerts with fire details and location.
- **No (No Fire Detected):**
- The system remains in a power-saving mode, continuously monitoring the environment while keeping non-essential functions on standby.
- **Manual Override:** If necessary, the RF receiver allows users to manually intervene and control the robot.
- **Post-Suppression Check:** Once the fire is suppressed, the sensors verify that no flames remain. The system then deactivates the water pump and returns to an idle monitoring state.
- **End:** The process concludes, and the robot resumes continuous surveillance, ready to respond to any new fire incidents.
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V .WORKING

HARDWARE WORKING

1. ESP32 Controller (Microcontroller)

Acts as the brain of the system.Reads data from sensors and controls motors, pump, and other actuators.Supports Wi-Fi and Bluetooth for remote data monitoring and control.

Fig 3 : ESP32 Controller

2. Multi-Zone Flame Sensors

- Detect fire by measuring infrared radiation in different zones.
- Provide directional information (left, center, right) to guide the robot.
- Data is sent to the ESP32 for rapid fire localization.

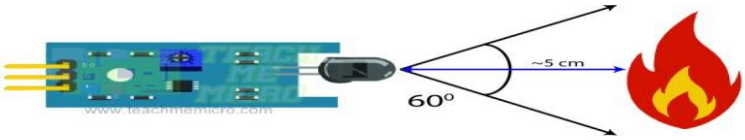

Fig4 : Multi-Zone Flame Sensor

3. Actuators & Mechanisms

a) 5V Water Pump Controlled via a relay module.

Activated based on flame sensor data.Pumps water on fire.

Fig 8 :5V Water Pump

b) Relay Module

Controls high-power devices like the water pump.Acts as an electrical switch based on ESP32 signals.

Fig 9 : Relay Module

c) Stepper Motors

Used for robot movement and precise positioning.Helps navigate the robot across the area.

Fig 10: Stepper Motor

d) Servo Motors

Fig 11: Servo Motor

- Adjusts the water pump nozzle for precise targeting of the fire.
- Ensures accurate dispersion of water or fire retardant.

4. Power & Energy Management

a) Rechargeable Batteries

Powers the ESP32, sensors, and actuators.Ensures long-term autonomous operation.

b) DC-DC Converter Board

Converts battery voltage to required levels (e.g., 12V to 5V for ESP32).Ensures stable power supply to all components.

SOFWARE WORKING

1. Arduino (ESP32/Uno) - Microcontroller

- Developed using the Arduino IDE, which serves as the central development environment for the robot's firmware.
- Implements code to read sensor data from multi-zone flame sensors for accurate fire detection.
- Processes sensor inputs to determine fire direction and triggers appropriate control signals.
- Controls DC motors via the L298N motor driver for autonomous navigation toward the fire.
- Uses a servo motor to adjust the water pump nozzle for precise targeting during fire suppression.
- Activates the water pump through a relay module based on the processed sensor data.
- Supports manual override functionality through the RF receiver, allowing for user intervention.
- Utilizes the Arduino IDE's Serial Monitor for debugging and real-time system status logging.

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Fig 12 : Arduino ide

VI .RESULT

EXPERIMENTAL SETUP

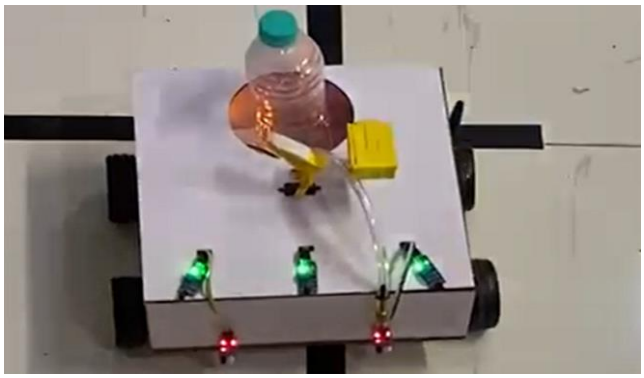

Fig 15 : Top View Of Project

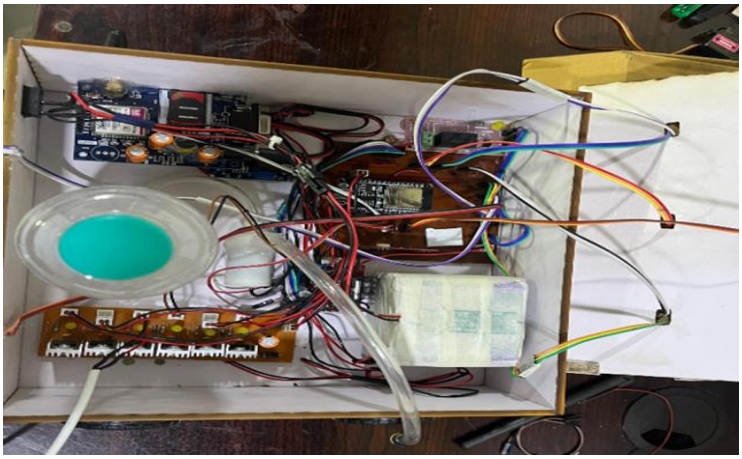

Fig 16 : Internal View Of Project

OUTPUT

Fig 17:Ouput Of Project

OUTPUT PREDICTION INSTRUCTIONS:

Fire Severity Prediction
0: No Fire
1: Minor Fire
2: Moderate Fire
3: Severe Fire

Fire Location Prediction
0: Left Zone
1: Center Zone
2: Right Zone

Suppression Strategy Recommendation
0: Activate Water Pump Only
1: Activate Water Pump & Adjust Nozzle
2: Engage Manual Override
3: Emergency Shutdown Required

VII. CONCLUSION

The Autonomous Fire Suppression system effectively integrates Arduino (ESP32), real-time monitoring, and embedded control software developed in the Arduino IDE to deliver rapid fire detection and targeted suppression. The robotic system continuously gathers data from multi-zone flame sensors, enabling precise localization of fire and guiding the robot's autonomous navigation. By controlling DC motors for movement, a servo motor for accurate water pump nozzle positioning, and a relay module for water pump activation, the system ensures swift and efficient fire extinguishing. Integrated features such as GSM-based SMS alerts and live video streaming via the ESP32-CAM enhance situational awareness and support remote intervention. This approach significantly reduces human risk and property damage while providing a scalable, cost-effective solution for indoor fire safety. Future enhancements could incorporate advanced AI for predictive fire spread analysis, enhanced obstacle avoidance sensors, and improved power management to further optimize performance and sustainability. This project demonstrates a practical and innovative approach to modern fire suppression, promoting safer, more efficient, and proactive fire safety management.

VIII.REFERENCES

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