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ESP32-CAM Controlled Fire Detection and Suppression Robot

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Abstract:

This system is to analyze, Fire accidents can cause serious damage to life and property, especially in hazardous or hard-to-reach environments. To reduce human risk and improve firefighting efficiency, a Fire Fighting Robot with ESP32 Camera is designed and implemented. The proposed system uses an Arduino Nano as the main controller and an ESP32-CAM module to provide live video streaming to the user through a web page. This enables the user to monitor the surroundings and control the robot remotely using a mobile phone or web browser. The robot operates in two modes: manual mode and automatic mode, which can be selected through the web interface. In manual mode, the user controls the robot's movement along with water motor and head light while observing the live video stream. Autonomous mode: The robot is equipped with four flame sensors to detect fire. When the fire is detected, the robot moves towards the fire source and activates a DC water pump through a relay to spray water and extinguish the fire. The movement of the robot is controlled using DC motors driven by an L298 motor driver, and a servo motor is used to adjust the direction of the water pump. A buzzer provides an alert indication when fire is detected. This project demonstrates an effective and low-cost solution for remote fire detection and firefighting using robotics and wireless monitoring technology. It can be useful in industrial areas, warehouses, and locations where human access is dangerous during fire emergencies.

Keywords — Arduino Nano, Rechargeable Battery, Four Fire Sensors, ESP32CAM, DC motors with L293d, Relay, Servo motor, Water motor, Buzzer.

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1. INTRODUCTION

Fire accidents in industries, homes, and public places can cause serious damage to property and loss of human life. Early detection and quick response are very important to control fire hazards. In recent years, robotic technology has been widely used in hazardous environments where human involvement is risky. A fire-fighting robot is an automated system designed to detect fire and extinguish it without direct human intervention.

The proposed system uses flame sensors to detect the presence of fire and a water pump to extinguish the flames. The robot can be operated in manual mode and automatic mode through a web interface. In manual mode, the user controls the movement of the robot and operates the water pump while watching the live video stream. In automatic mode, the robot detects fire using multiple flame sensors and automatically moves toward the fire source.

The movement of the robot is achieved using DC motors controlled by the L298 Motor Driver, which allows proper direction and speed control. A servo motor adjusts the direction of the water pump, while a buzzer provides an alert when fire is detected. This system helps in reducing human risk and improves fire safety by providing a quick and efficient response to fire accidents.

2. METHODOLOGY

The methodology of the proposed fire fighting robot involves a systematic approach that includes system design, hardware integration, software development, and performance evaluation. Initially, the system architecture is designed by identifying the required components such as Arduino NANO, ESP32-CAM, flame sensors, motor driver (L298), DC motors, relay module, water pump, servo motor, buzzer, and a rechargeable battery. The system is divided into three main sections: input, processing, and output.

In the hardware implementation phase, all components are interconnected properly. The flame sensors are connected to the Arduino NANO to detect fire. The motor driver is interfaced with Arduino to control the movement of DC motors, enabling forward, backward, left, and right motion of the robot. The relay module is connected to control the water pump, which is used for extinguishing fire. A servo motor is used to adjust the direction of the water spray, and a buzzer is included to provide an alert when fire is detected. The ESP32-CAM module is connected separately to enable wireless communication and live video streaming.

In the software development phase, Arduino is programmed using embedded C to read sensor inputs and control the actuators accordingly. The ESP32-CAM is programmed to act as a web server, providing live video streaming and hosting a web interface. The web interface includes control buttons for robot movement and options to select manual or automatic modes.

The working of the system is based on two modes. In manual mode, the user monitors the live video and controls the robot remotely using a web browser. In automatic mode, the flame sensors continuously monitor the surroundings. When fire is detected, the Arduino processes the signal and automatically directs the robot towards the fire source. Once the robot reaches the fire, the relay is activated, turning ON the water pump to spray water. The servo motor ensures accurate targeting of the fire, while the buzzer provides an alert indication.

The results show that the proposed system provides faster response, better accuracy, and improved safety, making it suitable for real-time fire detection and firefighting applications.

3. WORKING OF PROPOSED SYSTEM

The proposed fire fighting robot with live video surveillance is designed to operate through an integrated combination of sensing, communication, control, and actuation units. The complete system is powered by a rechargeable battery, which supplies regulated power to all modules including the Arduino NANO, ESP32-CAM, motor driver (L298), flame sensors, relay module, servo motor, buzzer, and DC water pump.

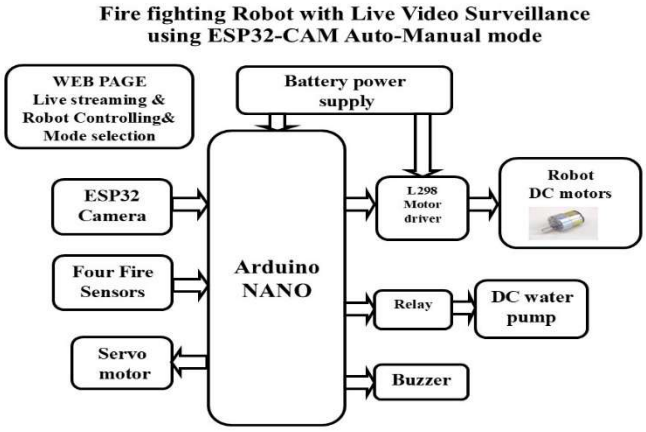

Figure 1: Block diagram of Firefighting Robot

with Live Video Surveillance using ESP32-CAM Auto-Manual mode.

Once the system is powered ON, the ESP32-CAM module initializes and establishes a Wi-Fi connection. It acts as a web server and generates a user interface (web page) that can be accessed through a mobile phone or computer browser. This web page provides three main functionalities: live video streaming, robot movement control, and selection of operating mode (manual or automatic). The live video feed captured by the ESP32-CAM enables real-time monitoring of the robot's surroundings, allowing the user to safely observe the environment from a remote location.

The ESP32-CAM also serves as a communication bridge between the user and the robot. Control commands entered through the web interface are transmitted via Wi-Fi to the ESP32-CAM, which then forwards these commands to the Arduino NANO. The Arduino NANO acts as the central processing unit of the system, responsible for handling both user commands and sensor inputs.

In the input stage, four flame sensors are strategically positioned around the robot to detect fire from different directions. These sensors continuously monitor the environment for infrared radiation emitted by flames. When fire is detected, the corresponding sensor sends a signal to the Arduino NANO. Based on the sensor inputs, the controller determines the presence and direction of the fire source.

For movement control, the Arduino NANO sends appropriate control signals to the L298 motor driver. The motor driver acts as an interface between the low-power controller and high-power DC motors. It drives the motors to move the robot in required directions such as forward, backward, left, and right. This enables the robot to navigate towards the detected fire location either automatically or based on user commands.

Simultaneously, an alert mechanism is implemented using a buzzer. When the fire is detected, the Arduino activates the buzzer to provide an audible warning, indicating the presence of fire. This enhances safety and awareness in the system.

Once the robot reaches close to the fire source, the fire extinguishing process is initiated. The Arduino NANO sends a signal to the relay module, which acts as an electrically operated switch. The relay then activates the DC water pump by providing the necessary power supply. The pump sprays water onto the fire to extinguish it effectively. Additionally, a servo motor is used to control the direction of the water nozzle. The Arduino adjusts the servo angle so that water is accurately directed towards the flame, improving extinguishing efficiency.

The system supports two modes of operation. In manual mode, the user directly controls the movement of the robot and activates the extinguishing process while observing the live video feed. In automatic mode, the robot operates autonomously; the flame sensors detect fire, and the Arduino processes the signals to navigate the robot towards the fire and activate the pump without human intervention.

Finally, the entire system operates in a continuous loop where sensing, processing, and actuation occur simultaneously. The integration of ESP32-CAM for real-time monitoring and Arduino NANO for precise control ensures efficient performance, faster response time, and improved reliability. This coordinated working mechanism makes the proposed system highly effective for real-time fire detection and firefighting applications in hazardous environments.

4. RESULTS

The developed fire-fighting robot was successfully tested in both manual mode and automatic mode. In manual mode, the robot could be controlled through the web interface to move in different directions while monitoring the surroundings through live video streaming. The user was able to switch ON/OFF the water pump motor and headlight as required.

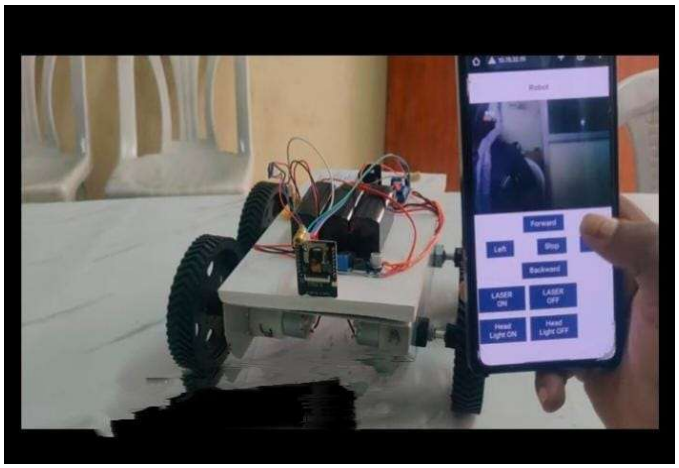

Figure 2: Manual mode of the system

In automatic mode, the flame sensors successfully detected the presence of fire and the robot automatically moved toward the fire source. Once the fire was detected, the DC water pump was activated through the relay and sprayed water to extinguish the flame. The buzzer provided an alert indication during fire detection.

The DC motors controlled by the L298 Motor Driver provided smooth movement of the robot in different directions. The overall system demonstrated reliable fire detection, effective movement control, and successful fire suppression during testing.

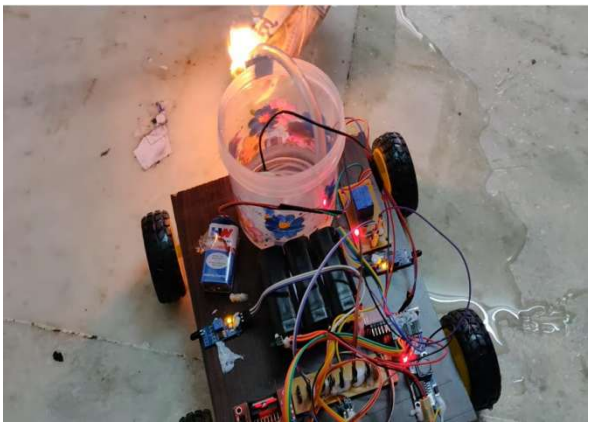

Figure 3: Automatic-Manual mode of the system

5. CONCLUSION

The fire-fighting robot system was successfully designed and implemented to detect and extinguish fire with minimal human intervention. The robot can operate in both manual and automatic modes, providing flexibility for the user. The integration of flame sensors, DC motors, motor driver, water pump, and buzzer helps in efficient fire detection and extinguishing.

The system reduces the risk to human life by allowing remote monitoring and operation in dangerous environments. The robot can be useful in areas where direct human access is difficult or unsafe, making it an effective solution for improving fire safety.

The proposed fire fighting robot with live video surveillance using ESP32-CAM and Arduino NANO provides an efficient and reliable solution for fire detection and extinguishing. The integration of flame sensors enables accurate and timely detection of fire, while the ESP32-CAM ensures real-time monitoring through live video streaming. The use of a web-based interface allows remote control and easy mode selection between manual and automatic operations.

The division of tasks between Arduino NANO and ESP32-CAM improves system performance by reducing processing load and enhancing response time. The motor driver ensures smooth movement of the robot, and the relay-controlled water pump enables effective fire extinguishing. Additionally, the servo motor enhances precision by directing water towards the fire source, and the buzzer provides an alert mechanism for safety.

Overall, the proposed system demonstrates improved efficiency, reliability, and flexibility compared to existing methods. It reduces human risk in hazardous environments and provides a low-cost, scalable solution for real-time firefighting applications. This system can be further enhanced by integrating advanced technologies such as IoT, machine learning, and additional sensors for improved accuracy and automation.

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