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Fire-Fighting Robot Using Arduino

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ABSTRACT:

In environments where fire outbreaks pose significant risks, quick action can make the difference between safety and catastrophe. This paper presents the development of a compact, affordable, and efficient fire-fighting robot that operates in both autonomous and manual modes. The robot utilizes IR sensors to detect flames and is equipped with a servo-controlled water nozzle for targeted suppression. A mobile application connected via Bluetooth enables remote user control. Designed with accessibility and safety in mind, the robot proves useful in households, schools, labs, and small warehouses for mitigating small fires before they escalate.

KEYWORDS:

Fire detection, robotics, IR sensor, ESP32-CAM, Arduino, Bluetooth control, servo motor, water pump, embedded system.

1. Introduction:

Fire incidents pose serious threats due to their unpredictable nature and rapid spread. Conventional firefighting approaches often depend on human involvement, which can lead to delays and endanger lives. With the advancement of robotics and automation, it is now possible to create systems that respond to fires more efficiently and with reduced risk. This paper presents a dual-mode fire-fighting robot capable of operating both autonomously and under user control. In autonomous mode, it detects fire using infrared (IR) sensors and responds by directing a water jet toward the source. In manual mode, users can control the robot remotely via a Bluetooth-enabled smartphone application. Additionally, a live video feed is provided through the integration of an ESP32-CAM module, allowing users to monitor the robot's surroundings in real time through the app, enhancing situational awareness and control.

2. System Design:

2.1 Hardware Overview:

- Microcontroller: Arduino Uno R3
- Flame Sensors: Infrared (IR) flame detectors
- Vision Module: ESp-32 CAM
- Actuation: Water pump with a servo-mounted nozzle
- Mobility: DC motors controlled by L298N motor driver
- Connectivity: HC-05 Bluetooth module
- Power Supply: 12V Lithium-ion battery

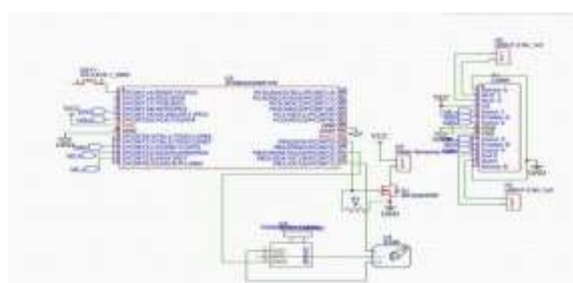

Figure 1: Circuit Diagram

2.2 Functionality:

The fire-fighting robot operates in two modes: autonomous and manual. In autonomous mode, it uses IR sensors to monitor its surroundings for signs of fire. When a flame is detected, the robot halts, and the microcontroller activates a servo motor to aim the nozzle. A water pump is then triggered to spray water at the flame until the fire is no longer detected or a preset time elapses. This mode enables fast, hands-free fire response in hazardous or unmanned areas.

In manual mode, the robot is controlled via a Bluetooth-connected mobile app. Users can drive the robot in all directions and manually activate the water pump. This is especially helpful when environmental conditions interfere with autonomous detection. The system also allows switching between modes, offering flexibility in varied scenarios. Together, these features make the robot well-suited for navigating indoor spaces and responding quickly to small fires.

Additionally, the robot is equipped with an ESP32-CAM module that enables real-time video streaming over Bluetooth application. This allows users to visually monitor the robot's environment remotely through a mobile device or computer. The live video feed enhances situational awareness, especially in low-visibility areas, and assists users in manually targeting flames or navigating the robot during manual operation. The camera operates independently of the Arduino, adding an extra layer of safety and control during both autonomous and manual firefighting tasks.

3. Methodology:

3.1 Autonomous Mode:

The robot operates independently in this mode. It continuously scans its environment using IR sensors. When a flame is detected, the robot stops and directs the water nozzle at the flame, activating the pump until the flame is extinguished or the cycle ends.

3.2 Manual Control via Mobile App:

Users can control the robot through a custom Android application connected via Bluetooth. The app allows movement in all directions and manual activation of the water pump. This feature provides greater flexibility and control in environments that require human judgment.

3.3 Suppression Mechanism:

A water pump, connected to a small tank, supplies water through a nozzle mounted on a servo motor. The servo allows for precise targeting of the flame. This combination enhances the robot's effectiveness in putting out fire from different angles.

3.4 Power Management and Safety Features:

Efficient power management plays a crucial role in ensuring consistent performance and operational safety of the fire-fighting robot. The system is powered by a 12V lithium-ion battery, which supplies energy to all components, including the microcontroller, sensors, motor driver, and pump. Voltage regulators are used to distribute stable and appropriate power levels to each module, preventing potential damage due to overvoltage or power surges.

In addition to power regulation, the robot is equipped with basic safety mechanisms. A manual override function allows users to switch from autonomous to manual mode instantly, providing control in situations where automatic response might be unreliable or unsafe.

3.5 Visual Monitoring via ESP32-CAM:

To enhance situational awareness and enable remote monitoring, the robot integrates an ESP32-CAM module that provides live video transmission over a Wi-Fi connection. This allows users to view the robot's surroundings in real time through a smartphone or computer browser. The camera operates independently of the main control unit and streams continuously, offering valuable visual feedback, especially in areas with poor visibility. This visual feed supports users during manual control and adds an extra safety layer by confirming flame location or navigation paths without physical presence.

4. Construction:

The construction of the fire-fighting robot involves the integration of mechanical movement systems, control electronics, sensors, and fire suppression components, all mounted on a compact mobile platform. The foundation of the robot is a sturdy chassis, typically made of lightweight but durable materials such as acrylic or aluminum. This chassis houses the core hardware, including the microcontroller, power supply, and actuators, while maintaining a balanced weight distribution for smooth movement.

At the heart of the control system is the ATmega328P microcontroller, embedded within the Arduino Uno board. This microcontroller serves as the decision-making unit, interpreting signals from various sensors and issuing commands to actuators like motors and the water pump. The mobility of the robot is facilitated by two or four DC motors, which are connected to an L298N motor driver. This setup enables the robot to move forward, reverse, and turn, depending on the logic defined in the control program. Infrared flame sensors are strategically placed to detect heat signatures and trigger the fire response sequence automatically when a flame is within range.

For extinguishing fires, a small water tank is mounted on the chassis and connected to a mini water pump. Water is dispensed through a nozzle attached to a servo motor, which allows the direction of the spray to be adjusted for accurate targeting. The system is capable of both autonomous operation—where the microcontroller takes full control based on sensor data—and manual operation, where commands are received through an HC-05 Bluetooth module from a smartphone app. This dual-mode functionality ensures adaptability in different fire-prone scenarios.

To provide remote visual access, the robot includes an ESP32-CAM module that streams live video over Wi-Fi. This independent camera system allows users to monitor the robot's surroundings in real time through a web interface, offering additional safety and control, especially when operating manually in low-visibility or hazardous areas. The power to all components is supplied by a 12V lithium-ion battery, with voltage regulators ensuring each module receives stable and appropriate voltage.

Figure 2: Prototype Model of the firefighting robot/testing phase

A detailed overview of each component used in the system is provided below to explain their specific roles and interconnections:

Microcontroller (ATmega328P):
This is the central processing unit of the robot, responsible for interpreting sensor inputs and controlling actuators. It is programmed via Arduino IDE and is compatible with a wide range of modules.

Figure 3: ATmega328P

Motor Driver (L293D):

A dual H-bridge motor driver IC is used to control the movement of the DC motors. It allows bidirectional control and speed variation of both left and right wheels through PWM signals from the microcontroller.

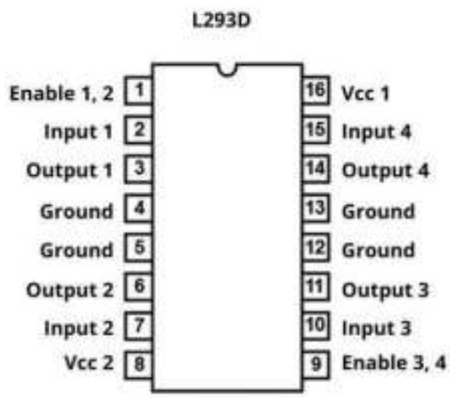

Figure 4: Motor Driver (L293D)

IR Sensor Module:

An IR (Infrared) sensor in a fire-fighting robot detects heat and flames by sensing infrared radiation. When it identifies a significant rise in temperature, it signals the control system to locate and approach the fire. This enables the robot to respond quickly and activate its extinguishing mechanism. IR sensors are ideal for fire detection due to their fast response, low power use, and high sensitivity.

Figure 5: IR Sensor

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ESP32-CAM Module:

ESP32-CAM is added to the front of the robot to provide live video streaming capabilities over Wi-Fi. This helps in remote monitoring during manual operation and adds real-time visual feedback for the user.

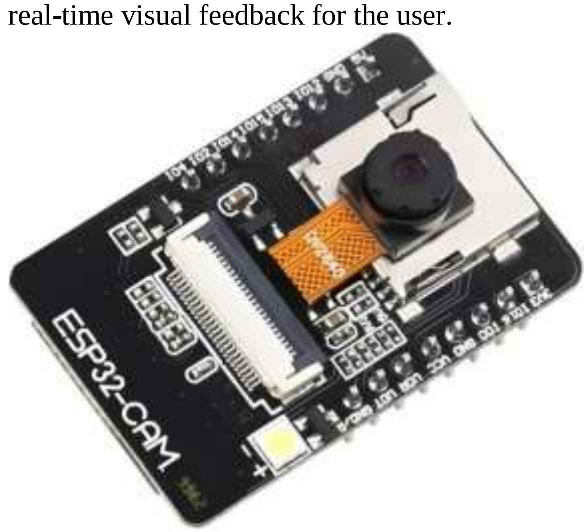

Figure 6: ESP32-Camera

5. Working:

The robot is designed to function in two primary modes: autonomous operation and manual control. In autonomous mode, the onboard IR sensor continuously monitors the robot's forward path for the presence of flame. When a flame is detected, the sensor sends a signal to the ATmega328P microcontroller, which immediately halts the robot's motion. The microcontroller then activates the servo motor to adjust the water nozzle's direction and switches on the water pump to begin extinguishing the fire.

Manual mode allows a user to control the robot remotely using a Bluetooth-connected mobile application. Through the app, the user can maneuver the robot in any direction and manually trigger the water spray when a fire is visually identified. This mode provides flexibility, particularly in complex environments where autonomous sensors might not effectively detect or respond to flames.

To enhance user awareness and control precision during manual operation, an ESP32-CAM module is incorporated into the robot's system. This module streams live video directly from the robot's point of view over a Wi-Fi connection. The video feed can be accessed via a smartphone or browser interface, allowing the user to see the robot's surroundings in real time. Unlike other functional modules, the ESP32-CAM is used solely for video transmission and does not interact directly with the fire detection or suppression logic. Its purpose is to provide the user with visual feedback for more informed decision-making during manual operation. The module is powered through the same battery source, regulated to match its voltage requirements.

Together, these functionalities allow the robot to operate independently in simple fire emergencies while also offering advanced monitoring and user control in more challenging scenarios.

6. Results and Observations:

6.1Functional Testing

The robot was subjected to multiple functional tests to evaluate its performance in detecting and responding to fire within a safe, controlled environment. Simulated fire scenarios using small flames, such as candles, were used during testing.. The ESP32-CAM module was also tested during these trials to assess its ability to stream real-time video over Wi-Fi. The camera consistently delivered clear footage, allowing remote observation of the robot's activity and flame suppression process, which proved especially useful for monitoring in areas with limited visibility. In manual mode, the robot responded smoothly to directional and pump commands via a Bluetooth-connected mobile app, and the servo-mounted nozzle adjusted accurately based on user input. Overall, the tests confirmed the effectiveness of both autonomous and manual modes, enhanced by the added functionality of live video streaming for increased safety and operational awareness.

Test Scenario	Result	Observation
Response Time After Detection	~1.4 seconds	Quick response minimized flame exposure
Servo Nozzle Targeting Accuracy	Alignment deviation < 45°	Consistently targeted flame efficiently
Navigation via Bluetooth	100% successful movement on command	Responsive and stable control
Pump Activation (Manual Mode)	Immediate activation; no delay	Reliable manual suppression control
Live Video Feed (ESP32-CAM)	25–30 FPS, delay ~0.2 seconds	Clear, near real-time video with good frame rate
Camera-Based Nozzle Adjustment	Nozzle adjusted with ~80% accuracy	Video feedback improved manual targeting in low-visibility scenarios
Power Efficiency (Full System)	~23 minutes on 12V Li-ion battery	Battery performance met operational expectations

Figure 7: Functional Testing Results of Fire-Fighting Robot

6.2 Performance Matrix:

In addition to its core functionalities, several performance metrics were tracked to evaluate the robot's operational efficiency. The Bluetooth module demonstrated fast communication, enabling responsive and precise control during manual operation. The integrated ESP32-CAM provided consistent real-time video streaming, offering users clear visual feedback for monitoring the robot's position and flame response, which proved especially useful in manual mode and during navigation in cluttered spaces. The 12V lithium-ion battery supported continuous functioning for approximately 30 to 40 minutes on a full charge, ensuring sufficient runtime for short-duration tasks. A 250 ml onboard water tank allowed for multiple fire suppression actions without needing immediate refilling. While the infrared flame sensors worked reliably under normal indoor lighting, occasional false triggers were observed in environments with intense light reflections. Despite minor limitations, the robot demonstrated solid and repeatable performance in detecting and addressing small-scale fires indoors.

7. Conclusion:

This paper presented a cost-effective fire-fighting robot capable of operating in both autonomous and manual modes. It utilizes infrared sensors for real-time flame detection and a servo-mounted nozzle system for accurate fire suppression. An ESP32-CAM module is incorporated to provide live video streaming, enhancing remote visibility and allowing users to monitor the robot's surroundings during operation. The addition of Bluetooth-based manual control gives users the flexibility to intervene when necessary, especially in complex environments. Future improvements could scale this system for deployment in larger areas or industrial settings, potentially integrating more robust components and advanced navigation systems.

8. References:

[1] S. Kumar, A. Verma, R. Singh, 'Autonomous Fire Fighting Robot Using Flame Sensor,' IJERT, Vol. 9, No. 6, 2020.

[2]A. Sharma, 'Bluetooth Based Mobile Controlled Robot,' IJETT, Vol. 35, 2016.

[3

[3] V. Shah, K. Patel, D. Desai, 'Autonomous Fire Fighting Robot,' IJSER, Vol. 7, No. 4, 2016.

[4]T. Shaikh, P. Walke, 'Design and Development of Fire Fighting Robot,' IJARCCE, Vol. 10, No. 4, 2021. [6]

[5]M. Solanki, P. Patel, H. Thakkar, 'Wireless Fire Fighting Robot,' IJEDR, Vol. 3, No. 2, 2015.

[6]HC-05 Bluetooth Module Datasheet: https://components101.com/bluetooth/hc-05- bluetooth-module

[7]P. Balamurugan, K. Rajendran, 'IoT Based Smart Fire Detection and Alerting System,' IJCA, Vol. 161, No. 11, 2017.

[8] S. A. A. Rizvi, T. Khan, M. A. Khan and S. Islam, "Design and Development of a Fire Fighting Robot," *2019 2nd International Conference on Communication, Computing and Digital Systems (C-CODE)*, Islamabad, Pakistan, 2019, pp. 167-172, doi: 10.1109/C-CODE.2019.8680975.

[9]S. Kulkarni, S. Vora and S. Navghane, "Automatic Fire Fighting Robot," *2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA)*, Pune, India, 2018, pp.

[10]M. S. Islam, T. U. Rahman, M. S. Rahman and M. A. Alim, "Autonomous Fire Extinguishing Robot," *2020 5th International Conference on Electrical Information and Communication Technology (EICT)*, Khulna, Bangladesh, 2020, pp. 1-5, doi: 10.1109/EICT51217.2020.9393230.

[11]R. Pradana, W. Jatmiko and A. Purwarianti, "Mobile Fire Extinguishing Robot Using Visual Detection and Neural Network," *2016 International Conference on Advanced Computer Science and Information Systems (ICACSIS)*, Bali, Indonesia, 2016, pp. 373-378, doi: 10.1109/ICACSIS.2016.7872805.