Fire Fighting Robot

Abstract

This project presents the design and implementation of an IoT-enabled fire-fighting car system to enhance fire safety and response efficiency. The system combines hardware, IoT technologies and AI-driven decision-making to detect, analyze, and combat fires autonomously [(1)]. Fire incidents pose significant risks to life and property. This system improves firefighting strategies by providing real-time detection, identifying fire sources and causes (such as electrical faults or gas leaks), and executing an efficient response, reducing damage and ensuring safety [(2)]. The fire-fighting car is equipped with advanced sensors to detect temperature, smoke, and gas levels. When a fire is detected, the flame sensor identifies its presence and transmits real-time data to a cloud-based platform. This data is then analyzed by an AI model, which determines the fire's causes such as an electrical fault, gas leak, or combustible material. Based on the AI's classification, a specific code is generated to indicate the appropriate extinguishing method, whether water or CO_2. The Arduino microcontroller processes this information and autonomously directs the robotic unit to navigate toward the fire source and deploy the necessary suppression mechanism. [(3)]. Upon detecting a fire, the flame sensor immediately sends the fire data to the cloud, where it is processed and forwarded to the AI model. The AI analyzes the fire, determines its cause, and generates a unique code corresponding to the most effective extinguishing method. This ensures precise and automated fire suppression, minimizing response time and optimizing fire-fighting efficiency. By integrating IoT, AI, and robotics, the system delivers a smart, data-driven approach to fire control, making it a valuable asset for emergency response teams and industrial safety applications [(4)].

Introduction

One of the most important parameters in fire disaster is life, i.e. lives lost in saving someone else life. It is sometimes impossible for fire-fighters personnel to access the site of a fire because of explosive materials, smoke, and high temperatures. A fast response to detect the fire can avoid many disastrous things. From the given statics (Fig.1), it is observed that fire can take place at domestic as well as at industrial level. A normal spark can generate a massive fire breakout. Not only lives of industrial people but also the lives of domestics people is at risk because of poor fire management system. Fire can take many lives to and can injure many people for their life time. But it can be avoided using proper fire control methods. For such environments, fire-fighting robot is proposed. In today's generation a lot of robots are proposed and designed to remove the human factor from dangerous and deadly work. The use of robots is becoming very common that safely completes the labour intensive or deadly work for human beings. A Fire Extinguishing Robot is based on IOT Technology. In Fire Extinguishing robot, we intend to build a system that could extinguish a small flame by sensing and moving to the location itself. It will automatically detect the fire with the help of flame sensors. Once it detects the fire breakout location, it navigates itself accordingly to reach the fire source and extinguishes the fire by using built-in fire extinguishing system. For fire detection it uses three flame sensors. First one for the left direction, second one for the forward direction and third one for the right direction. Fire extinguishing systems will get activated when fire detection system detects fire. It then reaches the breakout point and the water pump will start ejecting the water when it detects fire. The key features of this system are to provide surveillance of fire so that major fire accidents can be prevented and loss of human lives gets minimized.

[(1)] What [(2)] Why [(3)] How [(4)] Result

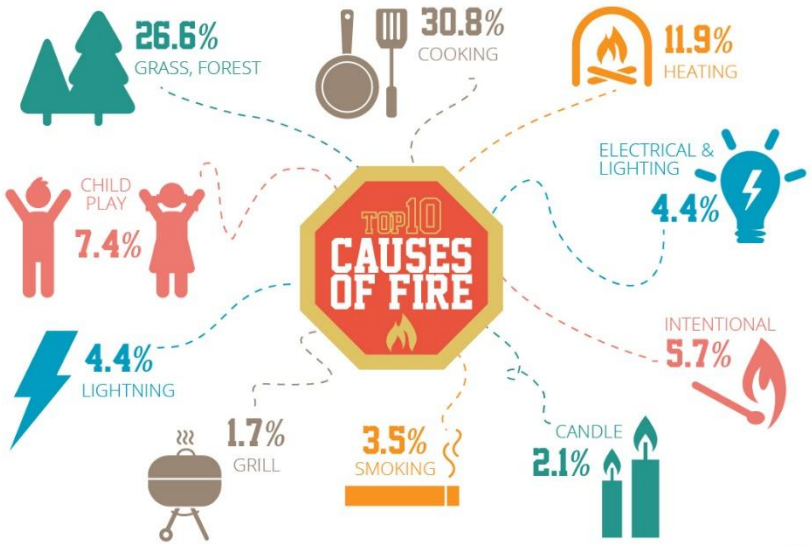


Fig. 1 Fire Causes

The firefighter robot represents a significant advancement in emergency response technology, designed to assist firefighters in hazardous situations. Equipped with sensors and cameras, it can navigate through smoke-filled environments, detect heat sources, and assess the severity of fires without risking human lives. Its robust design enables it to withstand extreme temperatures and operate in challenging conditions. With remote control capabilities, firefighters can maneuver the robot to extinguish fires or locate trapped individuals, enhancing overall efficiency and safety during rescue operations. Additionally, its integration with AI algorithms allows for real-time data analysis, providing critical information to responders for making informed decisions. Overall, the firefighter robot serves as a valuable tool in modern firefighting efforts, augmenting human capabilities and minimizing risks in dangerous environments.

Literature Review

Paper No.	Abstract	Functionality	Advantages	Limitations	Testing & Results
1	IoT-based autonomous robot for indoor fire detection and suppression using ESP32 microcontroller.	Detects fire using flame/smoke sensors, activates water pump, and can be controlled remotely via Blynk app.	Remote control, cost-effective, autonomous operation, IoT integration for real-time monitoring.	Struggles in highly cluttered environments, water pump capacity limits fire suppression.	Tested in controlled environments; effective fire detection, navigation, and suppression.
2	Microcontroller-based system with GSM communication for early fire detection and suppression.	Monitors temperature, smoke, and flame; sends SMS alerts via GSM; activates firefighting pump.	Early fire detection, wireless communication via GSM, visual feedback via LED panel.	Limited by GSM network coverage, it may not work in areas with poor signal.	Tested for sensor accuracy, GSM communication, and pump activation; satisfactory results.

Paper No.	Abstract	Functionality	Advantages	Limitations	Testing & Results
3	Autonomous robot with flame and IR sensors for fire detection and extinguishing.	Detect fire using flame sensors, navigates using IR sensors, and extinguish fire.	Compact design, autonomous fire detection, remote monitoring via camera, lightweight.	Limited range of flame sensors may struggle in large or highly obstructed areas.	Tested for fire detection and extinguishing; successful in small, controlled environments.
4	A firefighting robot designed to detect and extinguish fires autonomously using IoT technology, equipped with sensors, AI, and a water pump.	Detects fire using IR flame sensors, navigates autonomously, and extinguishes fires using a submersible water pump.	Reduces human risk, operates in hazardous environments, real-time fire detection, and autonomous navigation.	Struggles in large or highly obstructed areas, limited water pump capacity, and reliance on battery power.	Successfully tested in controlled environments; effectively detects and extinguishes small fires.
5	A firefighting robot controlled via PC, using Bluetooth for wireless control, with both automated and manual modes.	Detects fire using IR sensing, controlled wirelessly via Bluetooth, and extinguishes fires using a 3-axis fire hose.	High efficiency (95%), operates in both automated and manual modes, reduces human risk in firefighting.	Limited by Bluetooth range, EMI interference from motors, and reliance on operator skill in manual mode.	Automated mode is faster in extinguishing fires, but manual mode is more reliable in complex situations.

Methodology

The theme of this paper is to automatically sense the environmental fire and extinguish it without human intervention. The methodology is divided into three parts. The first part is on the design structure, followed by hardware description and finally on the programming design. All these three parts were assembled together, and experiments were then performed to build a system that can extinguish the fire that was carried out.

System Architecture

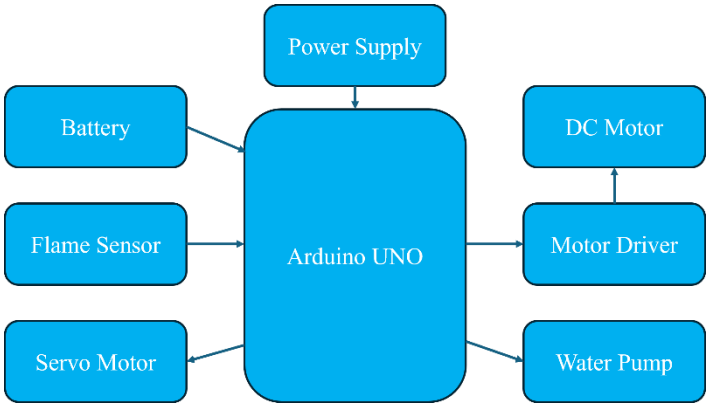


Fig. 2 System Architecture

Design Structure

In this section, the prototype of robotic system is presented, in which it consists of IR flame sensors, servo motors, submersible water pump, motor driver, mini breadboard, BO motors, rubber wheels, processor, and communication module for exchanging data between the fire-fighting robot and Arduino software. Fig. 4.1 shows the basic prototype of our firefighting robot. The robot carries four main functions: First, it initializes itself i.e. its sensors get initialized as the power is supplied. Second, robots sense the surrounding environment (for instance for the level of temperature) and identify the fireplace. Third, the robot sends the navigating information and starts to navigate itself towards the fireplace. Fourth, finally the robot starts to extinguish the fire with the help of servo motors and submersible water pump.

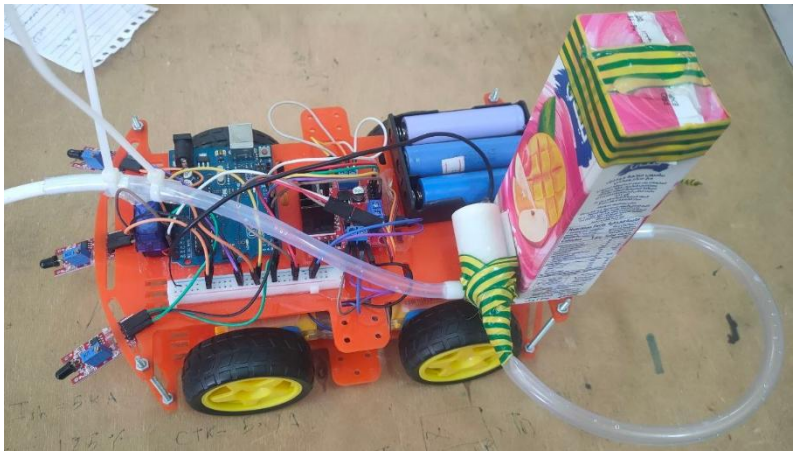


Fig. 2 Fire Fighting Robot

Hardware Implementation

The hardware part is one of the crucial parts in the development of firefighting robots. It includes Arduino UNO, IR flame sensors, servo motors, submersible water pump, motor driver, mini breadboard, BO motors, and rubber wheels. Fig. 4.2 shows the block diagram of firefighting robot which consists of three IR flame sensors as the input of the system. Arduino UNO is used as a micro-controller that connects other components. L293 Motor driver is used to drive motors and can run two DC motors (Left DC motor and Right DC motor) at the same time.

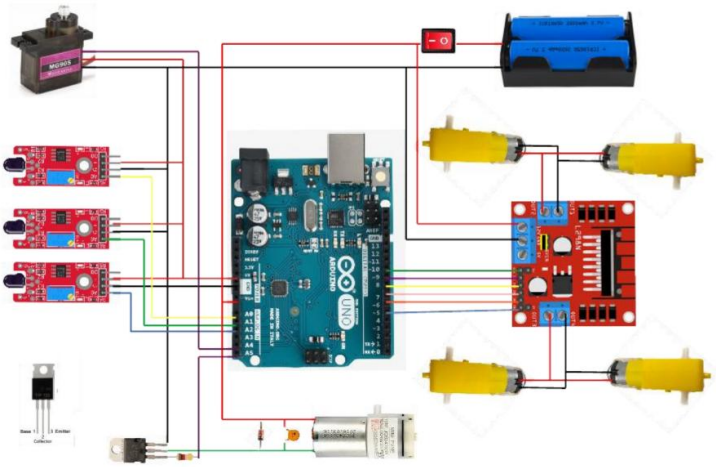
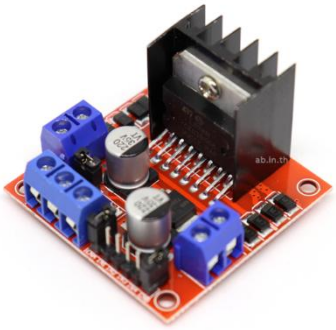
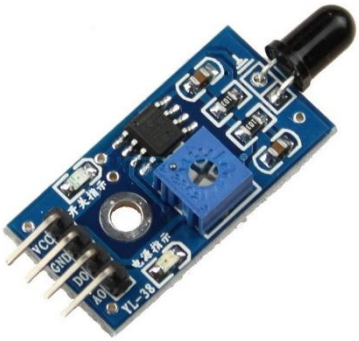


Fig. 3 Block diagram of Fire Fighting Robot

Hardware Utilized in the Project

Components Name	Components	Description
Arduino Microcontroller		The Arduino is an open-source microcontroller board based on the ATmega family, designed for easy hardware and software integration. It features digital and analog I/O pins, supports multiple communication protocols (UART, SPI, I2C), and operates at a clock speed of 16 MHz. The Arduino board is widely used for embedded systems, IoT applications, and robotics due to its ease of programming and vast community support.
DC Motor		Motors are used to move the robot chassis. The movement in robots required to detect and extinguish the flame
L293 Driver Module		The L293 Motor Driver Module is provided with high voltage Dual H-Bridge circuit. Its input of 12V and its output is 5V. Here we used this module to run the motors of robot
Flame Sensor		Flame sensors are used to detect the flame. Here, we used two Flame sensors. Instead, we can use multiple sensors to increase the range and directions. It consists of 4 pins: Vcc, Gnd, digital and analog pin [3]. It has a wavelength of 700nm to 1100nm. It detects the flame at 60 degrees range.

Software Utilized in the Project

- **Arduino-IDE**
  Arduino IDE is the primary development environment used for programming the microcontroller in the fire-fighting car system. It allows writing, compiling, and uploading code to control various hardware components, including sensors, actuators, and communication modules. Its user-friendly interface and extensive library support make it an essential tool for implementing the system's logic and automation.

- **Proteus**
  Proteus is employed for circuit simulation and validation before hardware implementation. It enables testing the interaction between the microcontroller and other electronic components, ensuring the correctness of circuit designs. With its ability to simulate microcontroller behavior, Proteus helps in debugging and refining the system's electrical framework efficiently.

- **TinkerCAD**
  TinkerCAD is used for both circuit design and 3D modeling. It allows for easy visualization and testing of electronic circuits in a virtual environment, helping in the early-stage validation of the fire-fighting car's design. Additionally, it provides a platform for designing and simulating mechanical structures, aiding in the conceptualization of the robotic car's physical framework.

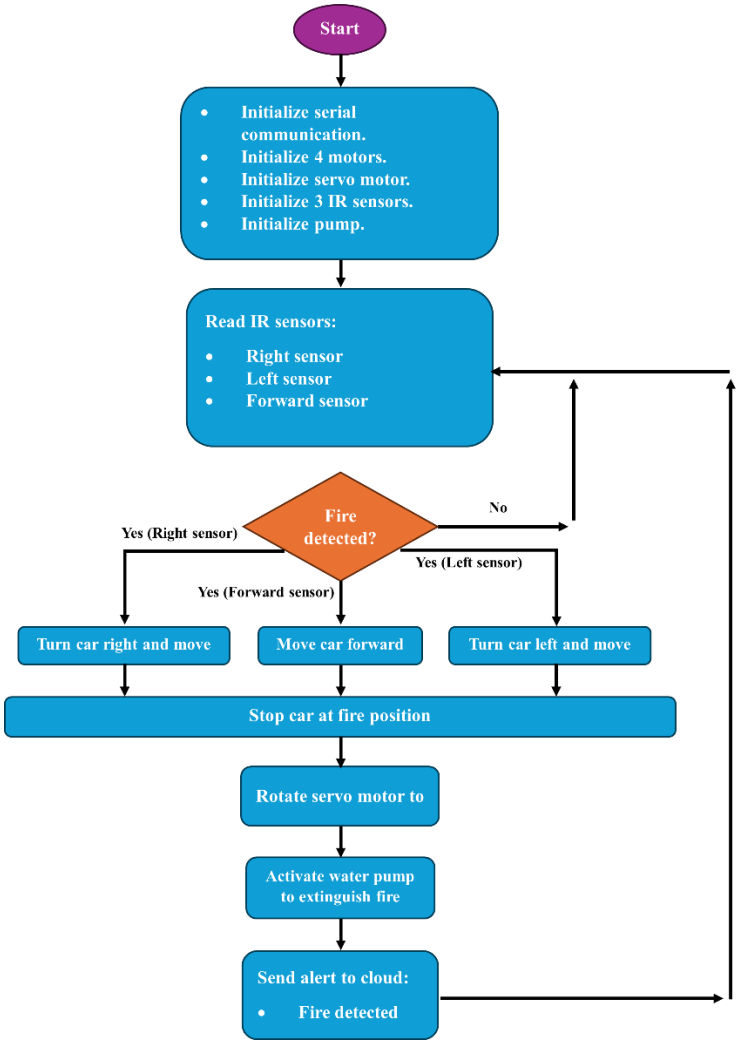


Fig. 4 Flow Chart

Implementation

- **Functional modules of code:**

Motion Control Module

Functions such as forward(), backward(), turnRight(), turnLeft() and stop().

Sensor Reading Module

Values are read using analogRead() and stored in variables.

Servo Control Module

The servoPulse() function generates PWM signals to control the servo motor.

Pump Control Module

- **Hierarchical Relationship:**

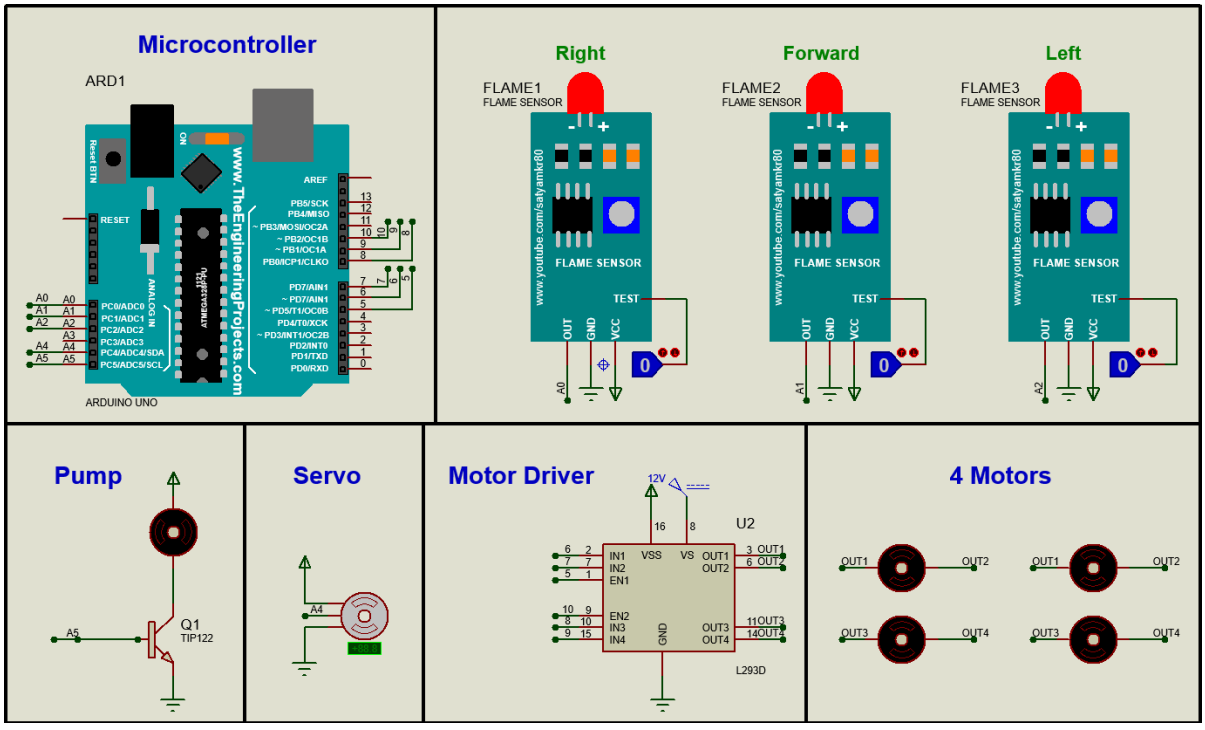
setup() initializes pin modes and performs an initial sweep using the servo.

loop() serves as the central controller, invoking motion or fire handling routines based on sensor data.

Supporting functions (like movement and servo control) are modular and reusable, keeping the code organized and scalable.

Debugging-Test-run

- **GitHub Link:** [Firefighting Robot]



Result Discussion

Fire Fighting Robot has developed to reduce human life loss and to develop such a device that automatically sense fire and extinguishes it without human intervention. In this the fireplace is detected using IR flame sensors and are connected to Arduino UNO, which controls the movement of Motor drive that helps the robot to reach the fireplace and extinguishes it with the pumping mechanisms In the industry if any fire accident occurs, there is a need of person to monitor continuously and rectify it. In this process if any time delay takes place irreparable loss occurs in industry. The firefighting robot continuously monitors the surroundings and helps to extinguish the fire.

Conclusion

This model of Fire Extinguishing Robot aids to share out the burden of fire fighters in firefighting tasks. Our project aims to build a real-time firefighting robot which moves at a constant speed, identify the fire and then extinguish it with the help of a pumping mechanism. The detection and extinguishing were done with the help of basic hardware components attached with the robot. Firstly, IR Flame sensors are used for the detection of fire. Secondly, BO Motors and Rubber wheels are used to navigate the robot to reach the fireplace. Finally, the robot extinguishes the fire with the help of submersible water pumps and servo motors.

References

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