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Development of an Autonomous Fire-Fighting robot using Arduino-Based System

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ABSTRACT

As the increase in density of population and industrialization increase, the chances of unpredictable fire incidents have become a critical threat to human safety and Property. Sometimes help arrives too late and this causes many Casualties. With this in mind and to find a better way to extinguish fire. we have created This Fire-Fighting System and this Paper describes the Fire-Fighting Robot using Arduino. The main goal is to detect fire early and respond quickly, especially where there is a risk to human beings. A simple sense-think-act cycle was implemented in this robot. It has three infrared flame sensors oriented in different directions, constantly watching for fire. Rather than just an alarm like common detectors, the robot performs a comparison using the signals from all three sensors to locate the source of the fire. With this information, it decides which direction to go and then heads towards the flame.

An L298N motor driver Controls the Wheels of the Robot and Provides a smooth, Steady motion. When the robot Reaches the fire, a relay switches on a small water pump attached at the back of the Robot. The water nozzle, which is mounted on a servo motor, allows the robot to hit the target with precision at the fire to Extinguish it effectively. In other words, this project integrates mere hardware with intelligent control logic for an efficient system that contributes to minimizing fire hazards and enhances safety, especially in hazardous locations.

Keywords:- Arduino Uno, Flame Sensor, Motor driver, Water Pump, L298N motor driver, Relay module

1. INTRODUCTION

The lab is very fire-hazardous because of the flammable substances, high-voltage equipment, and complicated experiments. According to the National Fire Protection Association, there is an increasing number of fire incidents among laboratorians **[2]**. Traditional fire safety methods, such as manual extinguishers and fixed ventilation systems, fails many times due to hidden or hard-to-reach areas. Rapid flame spread can make manual intervention difficult **[4]**.

The first purpose is to use this robot as an alternative path for reducing risk to fire-fighters life and improving their fire extinguishing abilities. The second goal is to warn that by developing firefighting robots, the time required to place the robot in a high-risk fire zone may be reduced. The final goal is to determine whether the robot is capable of performing its tasks in a hazardous zone with high temperatures **[2] [5].**

Background: Risks to Life and Property

Recent statistical evaluations from 2025 indicate a notable **14.8% surge** in emergency fire calls within the capital during the first four months, signifying a growing strain on urban safety infrastructure. According to Delhi Fire Services (DFS) data accessed by The Hindu, the fire department received 6,626 calls in 2025 against 5,772 in the first four months of 2024. In 2023, the calls stood at 4,904, marking a 17.7% in 2024 and a cumulative 35.1% rise over the three years. However, the number of fatalities in fire incidents has decreased in 2025 **[7].**

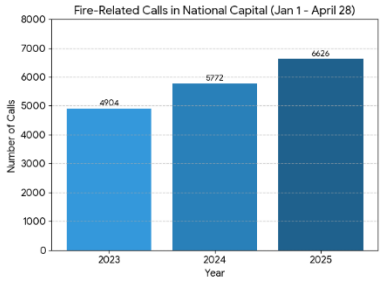

Chart-1: Comparative Analysis of Fire-Related Calls (2023-2025) [7].

Fire is one among the leading global threats to life and property. This is because a fire originating in either a residential setting or an industrial setting may lead to a disaster in a matter of minutes.

Problem Case

Manual fire-fighting in high-hazard zones like fuel stores, chemical plants is extremely dangerous. While advance firefighting systems exist but they are often too costly for small schools, laboratories, and warehouses. There is a critical need for a simple, low-cost, and autonomous system that acts as a first responder.

2. LITERATURE SURVEY

The development of autonomous fire-fighting systems has various technological approaches, ranging from high-end vision systems to network-dependent Iot frameworks. This section evaluates existing methodologies and justifies the sensor-driven approach used in this research.

Technological Comparisons

The project is based on multiple sensor arrays rather than complex Vision-Based Systems. While vision-based systems can improve the accuracy. While vision-based system can improve the accuracy of flame detection through image processing, they significantly increase the overall cost and computational complexity of the robot. Likewise, most contemporary systems incorporate IoT-based monitoring systems, which can be updated remotely using a smartphone. In contrast, IoT-based systems may not be reliable, such as in emergency systems, since they work by depending on Wi-Fi/network connections. If network fails, the robot cannot make decisions independently. In simple words, a sensor-only robot is low-cost and easily maintainable, ensuring it can operate independently by sensing the light emitted directly by flames without requiring an external network.

Navigation and Search Patterns

Most research indicates that while GPS is highly useful for outdoor navigation, it is ineffective for indoor environments because walls and ceiling block the satellite signals. For an indoor for fire-fighting robot using multiple sensors is a much more efficient and reliable method for simple navigation.

3. SYSTEM REQUIREMENTS

The technical specifications of the fire-fighting robot consist of basic hardware components like the Arduino Uno board, three-sensor flame sensor module, and L298N motor drive module for navigation and fire suppression capabilities of the robot. The fire-fighting robot's software solution is implemented using the Arduino Integrated Development Environment and Embedded C++ programming language.

Table-1: Software Requirement

Software Tool	Purpose
Arduino IDE	Code development and upload
Embedded C/C++	Microcontroller programming language

Table-2: Hardware Requirements

Component	Quantity
Arduino Uno	1
Flame Sensors	3
L298N Motor Driver	1
DC Motors + Wheels	2–4
Servo Motor	1
Water Pump + Relay	1
Rechargeable Battery	1
Chassis & Mounts	1 set

4. METHODOLOGY

This system focuses on a practical, cost-effective design which is meant to be reliable or which prioritizes reliability in an emergency situation. This robot uses a triple-sensor array of infrared flame sensors to create a 180° detection zone which very cost effective unlike complex system that rely on expensive vision processing. Arduino Uno is the brain of our system. which processes the analog signals in real time to determine the direction of the fire.

A L298N motor driver is used to handle the mechanical movements which allows the robot to move towards the strongest heat signal. Instead of bulky gas cylinder It has a small underwater water pump is connected to a nozzle that is controlled by a servo motor. Which allows the robot to precisely aim and extinguish the fire without having to move the entire body of robot. The entire System is Powered by a Lithium-ion battery pack, which provides power for both logic circuits and the high-draw functional water pump and helps it work simultaneously.

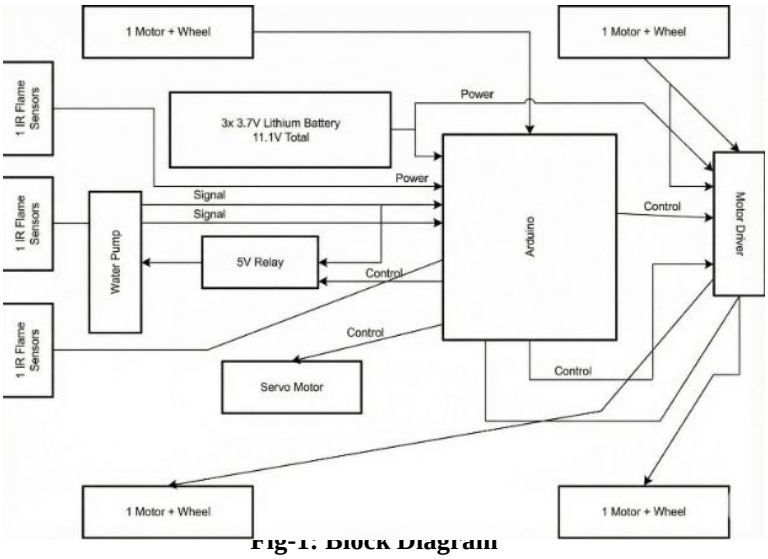

Fig-1: Block Diagram

4.1: Working Mechanism

In the fire-fighting robot, there are three important logic levels of operation, which are Detection, Processing, and Action.

Input Stage (Detection): There are three infrared flame detectors that scan the surroundings for heat sources. These Flame Sensors are said to be the "eyes" of the system and offer a 180° field of vision.

Processing Stage (Decision): In this stage, the Arduino Uno card receives signals from the sensors, which will be processed using a comparison algorithm to pick the sensor with the largest signal and thus determine the direction of fire.

Output Stage (Action): The L298N motor driver then uses the confirmed direction to drive the DC motors to make the robot approach the target. Upon reaching a safe distance, the relay module then turns on the water pump to make the servo motor aim the nozzle to put out the fire.

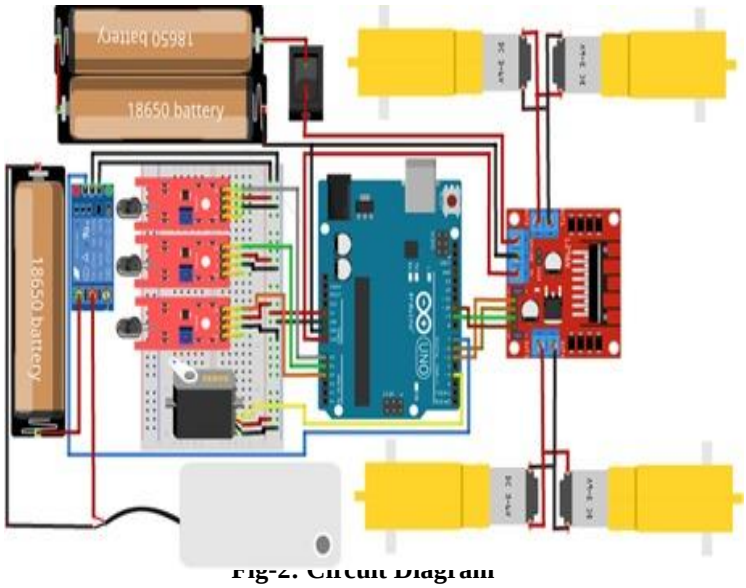

Fig-2: Circuit Diagram

5. CONCLUSIONS

The development and conceptualization of the Fire Fighting Robot using Arduino successfully validate the project's core objectives, culminating in a compact and highly cost-effective autonomous system.
The system demonstrably achieves autonomous flame detection, navigation, and suppression. By leveraging readily available components like the Arduino Uno, IR flame sensors, and, the prototype successfully fulfils the requirement for a low-cost, reproducible safety aid. The foundational success of this project lies in its immediate practical and educational utility.

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