SDM COLLEGE OF ENGINEERING AND TECHNOLOGY, Dharwad-580002

An autonomous Institution affiliated to

Visvesvaraya Technological University, Belgaum – 590018

Department of Electronics and Communication Engineering

A Report on Minor Project-1 [22UECL505]

"Automatic Fire Extinguisher Robot"

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CERTIFICATE

It is hereby certified that the team consisting of

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has satisfactorily completed the **Minor Project - 1 [22UECL505]** entitled

"Automatic Fire Extinguisher Robot"

for the partial fulfillment of the requirements for the completion of **5th semester** of Bachelor of Engineering in Electronics and Communication during academic year 2024-25.

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ABSTRACT

A fire incident is a disaster that can potentially cause the loss of life, property damage and permanent disability to the affected victim.

Fire accidents pose a significant threat to human lives, property, and the environment. The need for a reliable and efficient method to detect and extinguish fires has led to the development of the Automatic Fire Fighting Robot, a cutting-edge solution designed to enhance safety and mitigate risks. This autonomous robot is equipped with advanced sensors for fire detection, a mobility system for navigating, and a water extinguishing mechanism.

The robot employs technologies such as flame sensors, infrared and thermal imaging, and gas detection to identify fires accurately. A microcontroller processes sensor data, enabling the robot to make real-time decisions about locating the fire and deploying its extinguishing system. The robot's mobility system, powered by motorized wheels or tracks, allows it to traverse obstacles and reach fire-prone or hazardous areas inaccessible to humans.

Key features of the robot include autonomous navigation, obstacle avoidance using ultrasonic or LiDAR sensors, and remote monitoring capabilities for human operators via wireless communication. These features make it suitable for applications in industries, warehouses, residential buildings, and other fire-sensitive environments.

By minimizing human intervention, the Automatic Fire Fighting Robot reduces the risk to firefighters, increases response efficiency, and enhances the overall safety of fire management systems. This project represents a significant step forward in the integration of robotics and automation for emergency services

Table of contents

Chapter Number	Title	Page Number
1.	Conception of Project	
	1.1 Introduction	1
	1.2 Literature Survey	2
	1.3 Problem Statement	2
	1.4 Classes of fires	3
	1.5 Types of fire extinguishers	4
	1.6 Objectives	5
	1.7 Working	6
	1.8 Applications	7
	1.9 Benefits	8
2.	Design of Project	
	2.1 Design outline of automatic fire fighting extinguisher robot	9
	2.2 Methodology	
	2.3 Block diagram	9
	2.4 Circuit Diagram	10
		10
3.	Implementation of Project	
	3.1 Components and technologies	11
	3.1.1 Flame sensor	12
	3.1.2 DC motor with Wheel	12
	3.1.3 Arduino mega	13
	3.1.4 Motor driver	13
	3.1.5 DC water pump	14
	3.1.6 Relay module	14
	3.1.7 Servo motor	15
	3.2 Hardware/Software tools	16
	3.3 Stages of implementation	17
4.	Results of the Project	
	4.1 Sets of inputs	18
	4.2 Observation	18
	4.3 Limitations of our prototype and scope for future works	19
	References	20

CHAPTER 1 -- CONCEPTION OF PROJECT

1.1 Introduction:

Evolution of Fire Safety

The evolution of fire safety reflects humanity's growing awareness and technological advancements to prevent, detect, and combat fires. This journey spans from rudimentary methods to sophisticated modern systems:

- **Fire Prevention**: Primitive fire safety practices involved simple measures such as creating firebreaks and clearing vegetation. Early civilizations recognized the importance of keeping fire under control.
- **Manual Tools**: Tools like buckets, wet cloths, and rudimentary water sprayers were used to extinguish fires. By the Middle Ages, hand-operated pumps were developed to deliver water more effectively to fire sources.
- **Fire Suppression Systems**: The 19th century saw the invention of devices like the sprinkler system (patented in 1872), which could automatically douse fires.
- **Firefighting Equipment**: Improvements in hoses, ladders, and protective gear enhanced firefighters' efficiency and safety.
- **Fire Detection Technologies**: Smoke detectors, heat detectors, and flame sensors became widely adopted, enabling early warning systems.
- **Chemical Fire Suppressants**: The development of chemical extinguishers like CO_2 and Halon significantly improved firefighting capabilities.
- **Building Codes and Standards**: Governments introduced stringent fire safety regulations, including fire-resistant materials and mandatory fire exits.
- **Fire Trucks**: The mechanization of fire brigades included motorized fire engines and high-capacity pumps.

Modern Innovations

- **Digital Fire Detection Systems**: Smart alarms integrated with IoT technologies allow remote monitoring and instant alerts.
- **Automatic Fire Suppression**: Advanced systems like water mist, foam suppression, and gas-based systems are now commonplace.
- **Firefighting Robots**: Autonomous robots equipped with fire detection and suppression capabilities reduce human risk in hazardous areas.

This project involves creating a robot that autonomously detects and extinguishes fires in enclosed or open environments. The robot is designed to enhance fire safety, especially in areas that are challenging or dangerous for human access. Equipped with fire sensors, a movement system, and an extinguisher mechanism, the robot acts as a first responder to prevent fire escalation.

1.2 Literature Survey:

As per the National Crime Records Bureau, about over 60 people die every day in India due to fire.
Every year, about 25,000 persons die due to fires and related causes, in India.[1]
Women account for about 66% of those killed in fire accidents.
Fire accounts for about 6% of the total deaths reported due to natural and unnatural causes.
Bulk of the cases reported every year are under the other causes category. Between 2001 and 2014, a total of 3.16 lakh fire accident cases were reported in the country.
More than 20000 cases were reported in 12 of the 14 years.
The highest number of cases were reported in 2011 (26343).
The number of cases reported witnessed a mixed trend in the last 14 years.
The number of cases saw a decline from 2001 to 2004 only to increase continuously from 2004.
This increasing trend continued till 2011 only to be followed by a decreasing trend till 2014.

1.3 Problem Statement:

Fire accidents pose a significant risk to lives, property, and the environment, requiring rapid and efficient detection and suppression systems. Traditional firefighting methods often rely on manual intervention, which can be delayed, leading to greater damage. To address this challenge, there is a need for an intelligent robotic solution capable of detecting and extinguishing fires autonomously, ensuring safety and minimizing harm.

We propose the development of a fire-fighting robot equipped with the following features:

1. **Fire Detection**: Advanced sensors, such as IR flame sensors, for real-time identification of fires.
2. **Fire Extinguishing Mechanism**: A mounted extinguisher system designed for Class A fire types, featuring adjustable water spray nozzles for precise suppression.
3. **Control Modes**: Autonomous operation, enabling fully automated fire detection and extinguishing without human intervention.
4. **Power Supply**: A reliable power system powered by rechargeable batteries, offering continuous charging options for uninterrupted operation.

1.4 Classes of fires :

Fires are classified by the type of fuel they use or what caused them. Here are the five main classes of fire:

Class A: Fires caused by combustible solids like paper, wood, fabric, and some plastics

Class B: Fires caused by flammable liquids like paint, turpentine, gasoline, alcohol, ether, oil, and grease

Class C: Fires caused by flammable gases like methane, butane, or hydrogen

Class D: Fires caused by combustible metals like potassium, magnesium, sodium, titanium, or zirconium

Class K: Fires caused by burning grease or oil from cooking

Using the wrong type of fire extinguisher can cause injury, damage property, or spread the fire. For example, using a pressurized water extinguisher on a Class B or C fire can cause the fire to spread or an electrical shock.

Here are some tips for using fire extinguishers:

If you need to travel through doorways, reduce the maximum travel distances.

Label extinguishers properly if you have different types for different risk types.

Fit extinguishers with suitable nozzles or hoses to suit the risk.

Portable extinguishers are good for small fires, but not for large, spreading fires. In those cases, close the doors to contain the fire.

Class of fires	Materials
A	Solid (paper, wood, plastic)
B	Liquids (paraffin, petrol, oil)
C	Gases (propane, butane, methane)
D	Metals (sodium, lithium, maganese, aluminium, magnesium, titanium in the form of swarf)
E	Electrical apparatus

Table 1.1[3]

1.5 Type of fire extinguisher explanation

There are many types of fire extinguishers, each designed to put out different types of fires:

Water:

The most common type for Class A fires, which involve ordinary combustibles like wood, cloth, paper, and many plastics. Water cools the fuel, causing it to burn more slowly.

Foam:

Most common for Class B fires, which involve flammable liquids like gasoline, grease, solvents, and alcohols. Foam extinguishers create a barrier between the flame and the fuel.

Dry powder:

Also known as "ABC" extinguishers, these are used for Class A, B, and C fires. They discharge a fine powder that breaks the chemical reaction and creates a barrier between the fuel and oxygen.

Carbon dioxide (CO_2):

Used for Class B and C fires, as well as electrical fires. CO_2 extinguishers suffocate fires by displacing the oxygen they need to burn.

Wet chemical:

Used for Class K fires, which involve cooking oils and fats. The agent forms a foam blanket to prevent reignition.

Specialist dry powder:

Used for flammable metals.

Extinguishers should be properly labeled and fitted with nozzles or hoses that suit the risk involved.

Types of Fires Extinguishers Table:

Types	Characteristics
Water	-Cheapest and commonly used to put off Class A fire. -Not suitable for Class B fire.
Foam	-Slightly expensive than water type. -Used to put off Class A and B fires. -Not suitable for fire involves electricity.
Dry powder	-Multipurpose Extinguisher. -Used for Class A, B, and C fires. -Best for running liquid fires (Class B). -Effectively extinguishes Class C Gas fire.
Carbon dioxide	-Ideal for fires involves electrical apparatus. -Disadvantages: Fire might re-ignite for Class B liquid fire.
Wet chemical	-Used to put off Class F fire.
Metal	-Used to put off Class D fire.

Table 1.2

1.6 Objectives:

- **Fire Detection**:

Design and implement a reliable system to detect fires using flame sensors, infrared sensors, or smoke detectors.

- **Autonomous Navigation**:

Develop a mobility system that allows the robot to navigate autonomously, avoid obstacles, and reach the fire source efficiently.

- **Fire Extinguishing**:

Equip the robot with an extinguishing mechanism (e.g., water sprayer) to suppress fires effectively and safely.

- **Risk Reduction**:

Minimize human exposure to hazardous environments by enabling the robot to operate in high-risk areas.

- **Energy Efficiency**:

Optimize the robot's power consumption to ensure prolonged operation in emergency scenarios.

- **Compact and Cost-Effective Design**:

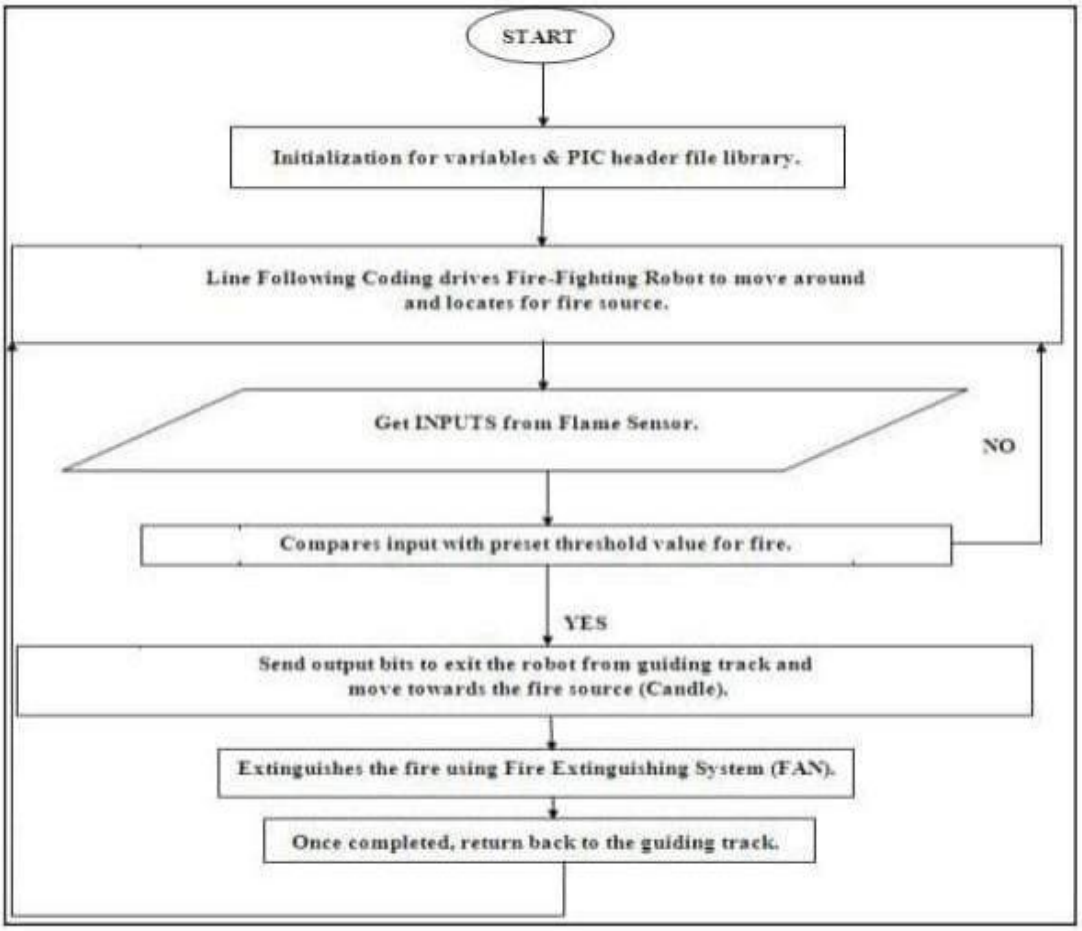
Create a lightweight, portable, and affordable system that can be widely deployed.

- **Scalability and Upgradability**:

Design the system to allow for future enhancements, such as integrating advanced sensors or AI-based decision-making.

1.7 Working :

A. Detection of Fire:
To begin with, the robot needs to detect a fire, and this is done using sensors:
Flame Sensor: Flame sensors (IR-based) are used to detect the infrared radiation emitted by fire. When the robot detects a flame (i.e., fire), the sensor sends a signal to the Arduino to notify it of the fire's location.



B. Movement and Navigation:
The robot is powered by motors that are controlled by an L298 motor driver. The motors allow the robot to move in forward, backward, left, and right directions.

C. Approaching the Fire:
Once the robot detects a fire (either through the flame sensor or high temperature reading), it moves toward the fire source. The robot can navigate autonomously by following a simple pathfinding algorithm or by following a set of predefined behaviors:

If the fire is detected on the left, the robot will turn left to approach it.
If the fire is detected in front, the robot will continue moving forward.

The robot may also use obstacle avoidance techniques, where if an obstacle is detected in front, it will turn or reverse to find a clear path

D. Extinguishing the Fire:

The robot is equipped with a water pump or fire extinguisher to put out the detected fire.
Water Pump: The water pump is usually a small 12V DC water pump. The Arduino controls the pump using a relay or transistor. When the robot detects fire, the Arduino triggers the relay to turn on the water pump, which sprays water directly on the fire.
Nozzle Control: The robot may also have a nozzle that can aim the water stream, either manually or using a servo motor controlled by the Arduino.

Simple Movement Logic:
The robot can move towards the detected fire using a basic navigation system that directs it to follow the fire's location (based on the sensor data). The robot may have left and right motors, and it can use the ultrasonic sensor to determine when to avoid obstacles by turning or adjusting its path.
Movement Example:
If the flame sensor detects a fire to the left, the robot will turn left.
If the flame is detected in front, it will move forward.
If an obstacle is detected, the robot will either stop, turn, or reverse.
The water pump is activated when the robot detects fire. The pump is controlled via a relay or transistor, which allows the Arduino to turn it on or off. The water pump is usually connected to a nozzle or pipe system that directs water at the fire.

1.8 Applications:

1.Fire safety in warehouses, bookstores and libraries.
2.Residential fire protection systems.
3.Prevention of burning buildings.

There are various other applications but as we have chosen class A type of fire these are the main applications.

Various other applications include:

1.Fire Rescue Operations:
Industrial Facilities: Useful in factories or warehouses where fires may be difficult to reach.
2.Search and Rescue:
Disaster Scenarios: Assists in locating and extinguishing fires in disastrous areas or during building collapses.
3.Automated Safety Systems:
Monitoring and Maintenance: Can be integrated into building safety systems to provide real-time fire monitoring and response.

1.9 Benefits:

1.Enhanced Safety:
Reduces human risk by operating in hazardous environments.

2.Faster Response:
Quickly detects and suppresses fires, minimizing damage.

3.Increased Efficiency:

Precisely targets the fire and operates continuously without fatigue**.**

4.Cost Savings:

Prevents escalation of fires, reducing property damage and associated costs**.**

5.Innovation Catalyst:
Promotes advancements in robotics, automation, and fire safety solutions.

CHAPTER 2 -- DESIGN OF THE PROJECT

2.1 Design Outline of Automatic Fire Extinguisher Robot:

1.Structural Design

• Base**:** A sturdy chassis with wheels or tracks for stable movement across different surfaces.

• Body Frame**:** Fire-resistant materials to house components like sensors, microcontrollers, and extinguishing mechanisms.

2.Fire Detection Unit

• IR Flame Sensor**:** Detects infrared radiation emitted by flames.

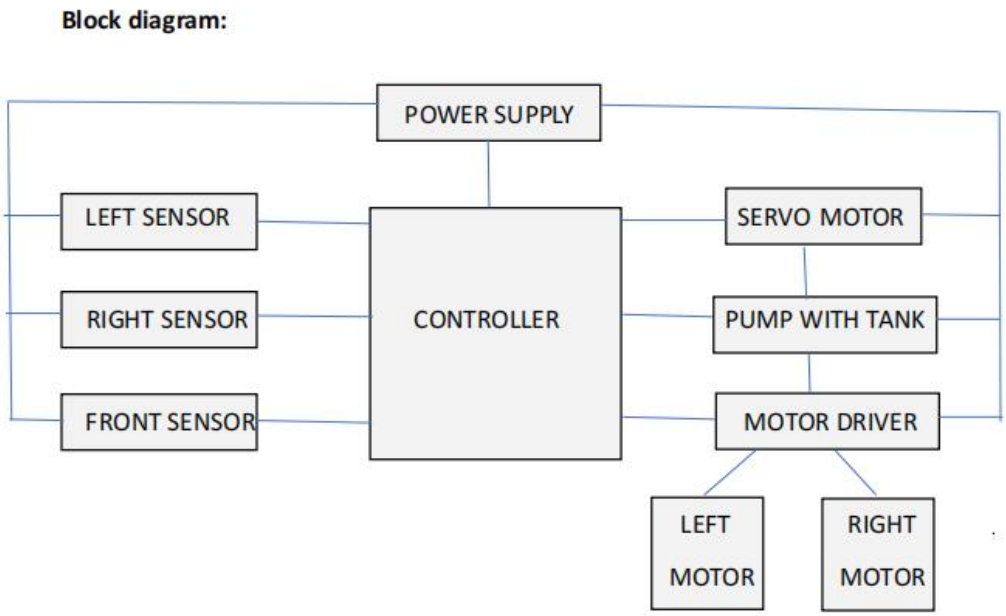
3.Fire Extinguishing Mechanism

• Extinguishing Agent**:** A water spray system for Class A fires.

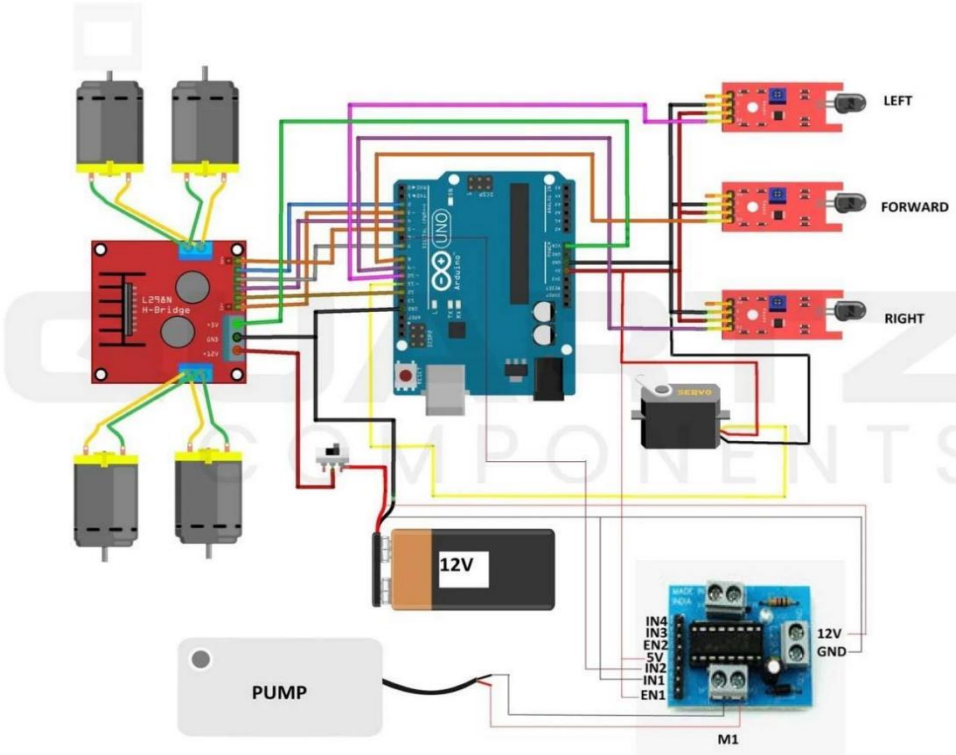
2.2 Methodology:

The implementation of this project involves the construction of the Automatic Fire Fighting Machine/Project (AFFMP), interfacing of hardware such as the motor driver circuitry, Flame Sensors; and the developed algorithm for the ardino to provide artificial intelligence to the Mobile Platform itself. The priority of this project is the fire detection capabilities and its accuracy for flame detection though the developed algorithm, preferably at the minimum level of error as possible.

2.3 Block Diagram:



2.5 Circuit Diagram: [4]



CHAPTER 3 – IMPLEMENTATION OF PROJECT

3.1 Components and Technologies:

1. Fire Detection System:
- Sensors: Utilizes thermal sensors, smoke detectors, or flame sensors to detect the presence of f ire or heat sources.
- Processing Unit: Microcontroller or single-board computer to process sensor data and determine if a fire is detected.

2. Robotic Mobility:
- Chassis: A mobile platform equipped with wheels or tracks for maneuvering through various terrains.
- Actuators: Motors and servos to enable movement and navigation.
- Navigation: Basic algorithms for obstacle avoidance and pathfinding.

3. Fire Suppression System:
- Extinguishing Mechanism: Could include a pressurized water system, foam dispenser, or CO2 emitter.
- Delivery System: A nozzle or tube system to direct the extinguishing agent accurately towards the fire source.

4. Control System:
- Autonomous Operation: Embedded software to handle sensor data, make decisions, and control the movement and extinguishing operations.
- Manual Override: Option for remote control or manual intervention if needed.

3.1.1 FLAME SENSOR:

Early detection: Flame sensors can detect flames early, allowing for a quick response to
minimize damage and loss of life.
Reliability: Flame sensors are robust and can withstand harsh environments.
Accuracy: Flame sensors are designed to be highly sensitive to flame signatures, minimizing
false alarms.
Quick response: Flame sensors can provide a quick response to flame failure(3-5 sec).
Fail safe: Flame rods are essentially "fail safe" and will fail in the event of abnormal situations.
Low cost: Infrared (IR) flame detectors can be low cost and accurate(Rs120).
[3&5]

3.1.2 DC Motor with Wheel:

DC geared motor with rubber wheel are suitable material for this project. This DC motor are suitable to replace 2 WD and 4 WD car chassis. The working voltage for DC motor is around 5V to 10 V DC. While the ratio of the gear is 48:1. Suitable current for this motor is 73.2 mA. DC motor is used to move the robot to the fire. Figure shows the image of the DC motor

3.1.3 ARDUINO MEGA:

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560.
Easy to use.

Open source.
Can be powered by battery or AC adapter.
Can be interfaced with other boards.
Arduino UNO and MEGA are both convenient to use for students and are of low cost and easy to program. Since we already had MEGA we used it.
[4]

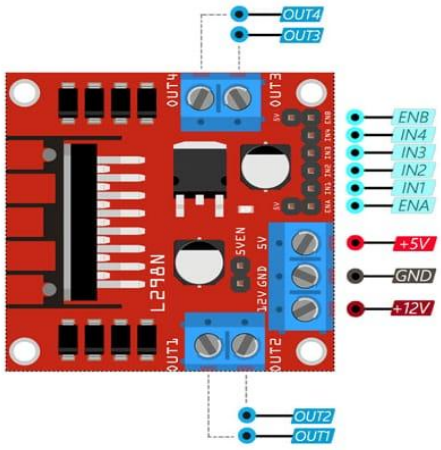
3.1.4 MOTOR DRIVER:

Power Supply **:** Provides the necessary voltage and current to the motor.

Control Logic**:** Determines the switching sequence of the driver transistors or MOSFETs based on the input signals.

Driver Transistors/MOSFETs **:**Act as switches to control the flow of current to the motor.

Current Sensing**:** Monitors the current flowing through the motor to prevent overload and overheating.



3.1.5 DC WATER PUMP:

The pump operates by using a DC motor to rotate an impeller or diaphragm, which creates suction and pushes water through the pump.

The motor converts electrical energy into mechanical energy, and the impeller or diaphragm converts that mechanical energy into fluid motion.

Speed of the pump can be adjusted by controlling the voltage supplied to the DC motor, giving fine control over the water flow rate.

Useful for applications requiring precise control of water delivery or circulation.

3.1.6 RELAY MODULE:

A relay works by using an electromagnetic coil to open or close a set of contacts.

When a small control voltage is applied to the coil, it creates a magnetic field that pulls or releases the contacts, allowing current to flow through the high-power circuit.

3.1.7 SERVO MOTORS: [6]

Most of the hobby Servo motors operate from 4.8V to 6.5V.
Most commonly they are operated at +5V.
Almost all hobby servo motors can rotate only from 0° to 180°.
2.5kg/cm torque which comes with the Towerpro SG90 Motor.
This 2.5kg/cm torque means that the motor can pull a weight of 2.5kg when it is suspended at a distance of 1cm.

CHASSIS: The physical frame of the robot that supports and houses all components.

WATER TANK/BOTTLE: Stores the water supply for the pump.

3.7 V BATTERIES (18650):

Powers the Arduino and other electronic components (ensure they are connected in a suitable configuration to achieve the desired voltage and capacity).

JUMPER WIRES: Connects various components to the Arduino and each other.

3.2 Hardware/Software tools:

Arduino Software(IDE):
The Arduino Integrated Development Environment- or Arduino Software(IDE)- contains a text editor for writing law, a communication area, a text press, a toolbar with buttons for common functions and a series of menus.
It connects to the Arduino to upload programs and communicate with them.

3.3 Stages of Implementation:

1. Problem Identification and Requirement Analysis
   - Identify the problem: fire hazards in specific environments.
   - Define requirements: fire detection, extinguishing methods, mobility, and automation.
   - Analyze the environment: indoor, outdoor, industrial, or residential spaces.

2. Conceptual Design
   - Develop a conceptual model of the robot.
   - Determine key components:
     - Sensors (e.g., flame, smoke, temperature, gas).
     - Extinguishing mechanism (e.g., water, foam, gas-based).
     - Mobility system (e.g., wheels, tracks).
     - Microcontroller or microprocessor for automation.

3. Hardware Selection
   - Select appropriate sensors (e.g., IR sensor, MQ2 for gas, DHT11 for temperature).
   - Choose actuators for movement (e.g., DC motors, servo motors).
   - Decide on an extinguishing mechanism (e.g., solenoid valve, pump).
   - Select a microcontroller (e.g., Arduino, Raspberry Pi).

4. Software Development
   - Develop algorithms for:
     - Fire detection and localization.
     - Navigation and obstacle avoidance.
     - Activation of the extinguishing system.
   - Write and test the code for integration with hardware.
   - Use simulation tools for preliminary testing (e.g., Gazebo, Proteus).

5. Assembly and Integration
   - Assemble the robot body with all components.
   - Integrate hardware and software components.
   - Test for communication between sensors, actuators, and controllers.

6. Testing and Calibration
   - Conduct initial tests in controlled environments to validate:
     - Fire detection accuracy.
     - Navigation efficiency.
   - Effectiveness of extinguishing mechanisms.
   - Calibrate sensors and actuators for optimal performance.

7. Prototype Evaluation
   - Evaluate the prototype against design requirements.
   - Identify areas of improvement (e.g., range, speed, extinguishing capacity).

8. Refinement and Optimization
   - Optimize hardware for weight, cost, and durability.
   - Improve software algorithms for faster response time and accuracy.

9. Final Deployment
   - Deploy the robot in real-world scenarios.
   - Train personnel to operate and maintain the robot.
   - Monitor performance and collect data for further improvements.

CHAPTER 4 -- RESULTS OF THE PROJECT

4.1 Sets of Inputs:

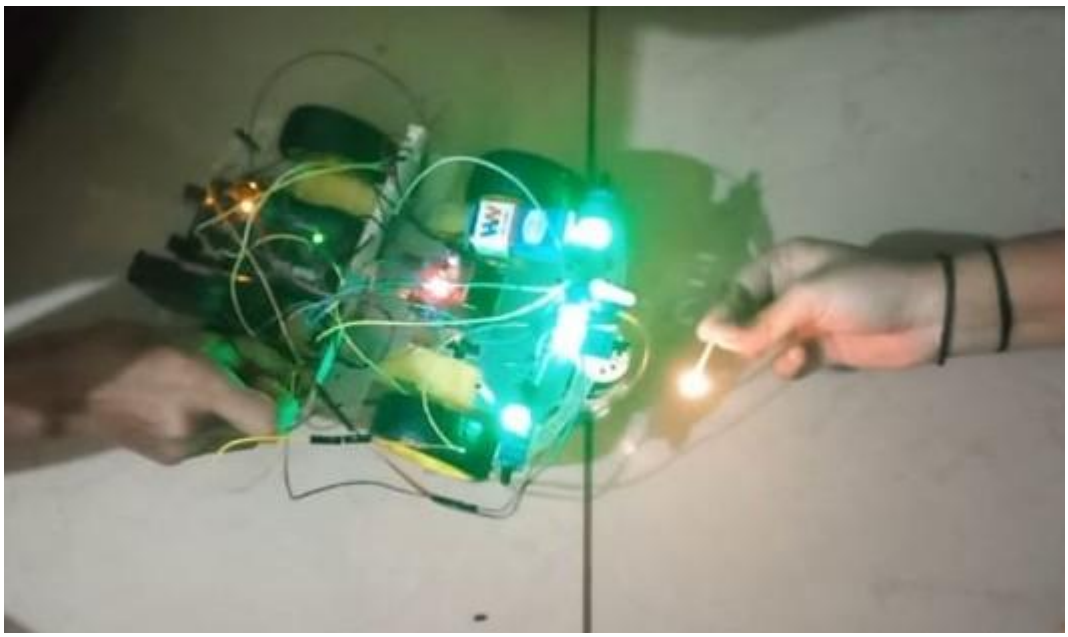
Input 1: Place a piece of burning paper 1 meter away from the robot and observe if it detects the fire.
Input 2: A match stick 1 meter away from robot.

4.2 Observation:

The robot detected the fire successfully at a distance of 1 meters but failed at 3 meters due to sensor limitations.

The flame sensor responded within 2-3 seconds of fire exposure.

The servo motor moved according to the fire detection.



4.3 Limitations of our Prototype and Scope for future works:

1.Sensor Range Limitation

- **Issue**: The sensors used in the prototype had a limited detection range(1 meter).
- **Impact**: This limitation prevents the robot from being effective in larger environments where fires may occur beyond the sensor's maximum range.
- **Possible Improvement**: Use high-range flame sensors or thermal imaging cameras to enhance detection capabilities over greater distances.

2. Weight-Bearing Limitation

- **Issue**: The robot's chassis and motor system were unable to carry the combined weight of all its components, including the water tank, extinguishing system, and electronics. This resulted in reduced mobility and inefficient navigation.
- **Impact**: The robot could tip over or fail to move smoothly with a full water tank. This compromises its ability to perform effectively in real-world fire scenarios.
- **Possible Improvement**: Utilize stronger materials for the chassis, upgrade to high-torque motors, or redesign the robot to better distribute weight.

3. Insufficient Power Supply

- **Issue**: The robot's power supply was inadequate to run all its components simultaneously, such as the motors, sensors, and extinguishing mechanism. This led to interruptions in operation or underperformance of certain systems.
- **Impact**: This could result in the robot stopping unexpectedly or failing to extinguish the fire effectively, which is critical in emergency scenarios.
- **Possible Improvement**: Employ a higher-capacity battery or implement a power management system to prioritize essential functions and ensure consistent operation

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