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THE DESIGN AND DEVELOPMENT OF FIRE FIGHTER ROBOT

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ABSTRACT :
Fire is a major threat to our lives and properties. This work offers a fire-fighting robot meant for quick fire detection, suppression, and control. Minimizing false alarms, the robot combines three flame sensors to offer a detection angle of 40° to 120° for dependable identification of fire from many directions. A 500ml fire extinguisher fitted with a servo-controlled nozzle in the suppression system allows for exact flame targeting. Although efficient in controlled tests, the extinguisher's small size emphasizes the need for improvement in bigger fire situations. The robot provides both manual and automatic control options. It scans and puts out fires in autonomous mode without human involvement. Though its small range limits efficacy in bigger settings, Bluetooth helps to enable manual control. Equipped with four 30 RPM metal gear motors and 100mm rubber wheels, the robot ensures stable mobility across various surfaces, effectively supporting its 7 kg weight. A 12V 7Ah battery with a power distributor PCB efficiently powers the system, ensuring stable performance during extended operations. While the robot successfully meets its objectives, improvements in obstacle avoidance algorithms and enhanced fire suppression capacity are recommended for improved performance in complex and larger environments. This project demonstrates a promising solution for early-stage fire suppression with the potential for further advancements.
Keywords: Fire-fighting robot, flame detection, fire suppression, autonomous control, manual control, metal gear motors, power distribution, obstacle avoidance, fire safety.

INTRODUCTION:

Between 2010 and 2014, India saw over 1.2 lakh fatalities due to fire-related incidents. That's a staggering number. It could have been reduced with better safety measures in place[7]. When left unattended, even for brief periods of time, open stove flames can cause mishaps. 60 to 70 firefighters lose their lives while on duty each year, which is a very high number. [11].
Even though they are useful, traditional fire detection systems may have issues with accessibility, coverage, and response time, especially in complex indoor environments.[2]. Firefighting is one of the most hazardous jobs out there.[9] Robots that use artificial intelligence to control fires, provide real-time practice, and put out fires with little exposure to firefighters are used in firefighting.[10]. Robots can detect and locate fires before they become major hazards. But even the best flame sensors have their limitations. They can only detect fires within a certain range, and their accuracy isn't always perfect. That means the distance at which a robot can deliver water is limited to about 50 to 60 cm. And challenging terrain can really put a robot's performance to the test. That is why this prototype is best suited for residential environments [8]. Experiments show that the robot can successfully put out

Class A fires in 15 seconds and detect fires within 2 meters with 95 percent accuracy.[1]. Three components make up the development of a robot: programming, electronics, and hardware. The robot is driven by four DC motors and is guided by a castor wheel. [6]. An Arduino Uno development board controls this firefighting robot. Additionally, it has a fire-flame sensor to detect fires.[3]. The Arduino IDE programming language was utilized to ascertain the robot's movement based on the input from the sensors. uses a pump to move water from the main water tank to the water nozzle and a water tank to put out the fire. Because it uses more current than the controller can supply, this pump is required for the driver circuit.[5].

METHODOLOGY :

Phase Of Fire Detection:

The initialization phase of fire detection: All connected components are initialized by the Arduino when the system is turned on. The servo motor is oriented to face forward, the motor driver is set up for movement control, and the infrared sensors are configured to monitor flame signals.

Fire Detection Phase*:* The three infrared sensors are used by the robot to continuously scan its environment. In order to detect fire in various directions, each infrared sensor is positioned strategically. The front sensor (attached to A1) detects fire directly in front of the robot, the left sensor (attached to A2) detects fire on the left side, and the right sensor (attached to A0) detects fire on the right side. The Arduino receives a signal from any sensor that detects a flame. The system then determines the fire's location based on the activated sensor.

Navigation Phase: If there is fire in front of it, It moves forward; if it detects fire on its left side, it turns left; if there is fire on the right side, it turns right. Arduino controls the L298N motor driver to run the specific motors to cause the movement. The robot can change the PWM signal through the ENA and ENB pins, making it easier for it to control its speed for accurate moves.

Fire Extinguishing Phase: Secondly, as soon as the robot gets aligned to the source of fire, the servo motor rotates to block the path of the water nozzle in the way of aim. The Arduino subsequently triggers the relay that operates the water pump, which begins spraying water onto the fire. The DC fan is also turned on to blow air when overheating to prevent the Arduino board from overheating.

System Reset and Standby Phase: When the fire is extinguished, the robot resets its position, turns off the motor, and prepares itself for further detection. The system repeatedly scans the surroundings in search of more fires. The robot can now detect, navigate to, and extinguish the fire while making it all more reliable and safer with the algorithmic way.

The project has three IR sensors for spotting fire or heat. These sensors link to the Arduino's analog pins: the first to A0, the second to A1, and the third to A2. They keep an eye out for flames and send info to the Arduino. An L298N motor driver module handles the robot's movement. It connects to the Arduino like this: ENA to pin 10, IN1 to pin 9, IN2 to pin 8, IN3 to pin 7, IN4 to pin 6, and ENB to pin 5. The module runs on 12V and controls two DC motors, helping the robot move. A servo motor helps with exact steering to aim the water nozzle at the fire. Its signal wire goes to pin A4, while its power hooks up to 5V and GND. To put out fires, the robot uses a water pump motor. A transistor controls this motor, with its signal wire going to pin A5, power coming from a 12V supply, and ground connected as needed. To keep the Arduino board from getting too hot, a DC fan is integrated into the system. A distribution box and terminal box control this fan. A 12V supply powers it. For device safety during extra-current flows, a 10-ampere fuse connects to the system. A regulated 5V supply provides power to the Arduino, sensors, and low-voltage parts. Motors and other systems run on a 12V power source. The circuit has switches and directions to allow manual control. This system combines sensors, motors, and output devices to create a responsive fire-fighting robot. It detects fire through IR sensors, guides movement with motor drivers, and puts out flames using a servo-controlled nozzle and water

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pump. The design ensures effective and automated fire suppression. A DC fan helps with heat control. The block diagram of proposed topology is shown on Figure. 1

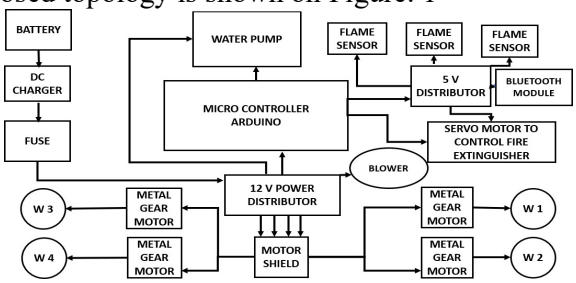

Fig. 1. Block Diagram of Fire Fighter Robot

FUNCTIONAL DESIGN OF THE FIRE FIGHTING ROBOT:

Initialization and Setup:

The process starts by setting up serial communication, PWM signals, and pin configurations. This setup allows the Arduino system to control motors, sensors, and actuators. After setup, the robot moves its servos to calibrate its position. Then, it sets the motor speed to make sure the robot moves at the right pace.

Sensor Readings and Command Control

The robot reads the IR sensor values, which play a key role in spotting fire and obstacles. Then, it looks for any Bluetooth commands coming in, which lets someone control it by hand if needed.

Movement Control:

Based on the instructions it gets or what's going on around it, the robot chooses to go Forward, Backward, or Turn I/R (left or right). When the robot backs up, it shows the current IR sensor values to help find and fix any issues.

Fire Detection Logic:

The system looks at the IR sensor values: If 252 S1 701, the robot moves Back Right. If 252 S2 801, the robot goes forward. If 252 S3 701, the robot moves Back Left. If it doesn't spot any fire, the system turns off the pump and stops.

Pump Control and Fire Extinguishing:

The system checks each sensor's readings to spot fires: When S1 drops below 250, it turns on the pump between 90 and 140 to put out the fire. If S2 goes over 350, it also starts the pump. The same goes for S3 - if it's above 350, the pump kicks in

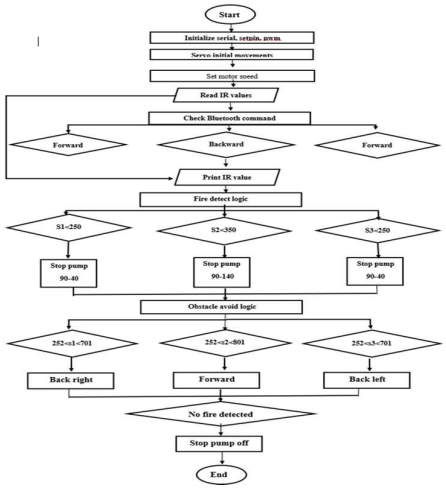

Figure. 2. Data Flow Chart

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Obstacle Avoidance:
The system checks each sensor's readings to spot fires: When S1 drops below 250, it turns on the pump between 90 and 140 to put out the fire. If S2 goes over 350, it also starts the pump. The same goes for S3 - if it's above 350, the pump kicks in.

No fire detected:
If no fire is detected or the fire is successfully extinguished, the system ends the operation with the pump turned off.

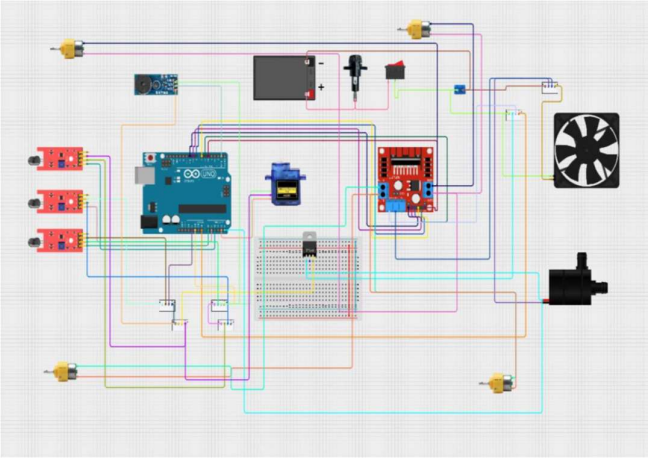

Figure.3. Circuit Diagram of Fire-Fighting Robot

RESULTS AND DISCUSSION :
The Figure. 3 shows the circuit of fire-fighting robot. This robot met the specific goals set for it: for fire detection, suppression, and control. The fire detection system used three flame sensors to give a detection angle of 40° to 120° and was able to detect flames from various sides to improve reliability and minimize false detections along with accurate identification of fire when used in controlled tests. The system efficiently could detect fires under different inclination and distances. The suppression system was designed with a 500ml fire extinguisher mounted on a servo-controlled nozzle enabling targeting precision on the flame. The small volume of the extinguisher limits effectiveness in larger fire incidents; while effective laser extinguishes small fires, enhancement in this area is definitely required for future efforts. The control system of the robot operates efficiently in automatic or manual mode.

It autonomously scans the area if there is any fire source and turns on the extinguisher without human intervention. Manual control ranges up to a distance where the robot can be operated directly using Bluetooth, although limited range impacts its operation in larger setups. Future improvements may involve far-range communications technologies such as Wi-Fi or LoRa. Mobility and stability are ensured by 4 numbers 30 RPM Metal Gear Motor and 100mm rubber wheels to allow smooth movement on all surfaces. It was seen that the motor configuration selected supported the weight of the robot with 5.6 kg very well and was stable with hardly any vibrations. Distribution of power was via a 12V 7Ah battery and a power distributor PCB, ensuring the even distribution of voltage and stability of operation during the long tests. The L293N motor shield controlled the speed and direction of the motors, allowing smooth acceleration and deceleration, and sharp turns.

The robot did well but had some limitations. Operational distance is reduced against larger environments because of the Bluetooth range, while the configured 500ml extinguisher would be insufficient to put out larger fires. The less-than-efficient performance of the obstacle avoidance system in a cluttered environment warrants further development of path- planning algorithms or the integration of advanced sensors such as ultrasonic or infrared for superior navigation.

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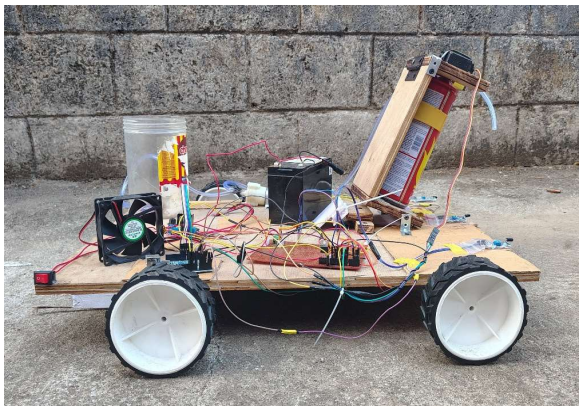

Figure. 4. The Prototype Developed

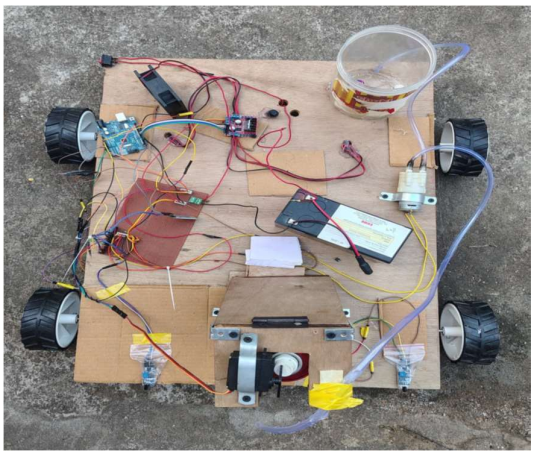

Figure.5. The system model

The implementation of the fire-fighting robot demonstrated several key advantages during testing and analysis. One of the most notable outcomes was its ability to detect and respond to fire hazards promptly, thereby preventing potentially dangerous incidents from escalating. The robot's rapid response helped in minimizing ecological consequences by reducing the spread of fire and limiting the release of harmful emissions into the environment. Additionally, the trials showed that the robot could significantly reduce financial losses by containing fires before they caused extensive damage to property or equipment. A critical benefit observed was the reduction of human exposure to dangerous conditions; the robot effectively operated in high-risk environments without endangering lives. Furthermore, its autonomous nature ensured reliable performance without the need for constant human supervision, making it a practical and efficient solution for fire emergency scenarios. These results affirm the robot’s potential as a dependable and intelligent fire-fighting system.

CONCLUSION :

The project will include an autonomous firefighting robot that will assist firefighters in progressively challenging and hazardous circumstances. The articulated robot navigates by using unique sensors and actuators, detects fire, and ultimately puts it out. The robot’s infrared flame sensors allow it to pinpoint the exact location of a fire. It can traverse uneven terrain thanks to strong motors and incredibly durable wheels, enabling it to reach the scene of the incident promptly. It connects the servo motors and submersible water pumps to squirt water when it detects a fire. People are better equipped to fight fires

as a result of this gradual decrease in risk. [4]. The robot is much more adaptable when a fire extinguisher is included with the water system, especially for various fire classes. To improve its functionality, I can assist in improving the design, control logic, or safety procedures.

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