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Fire Fighting Robot

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ABSTRACT:

Fire incident is a an such a disaster which can cause great trouble to the nature not only Human Beings bus animal and ecosystem everybody it covers all so in order to prevent this disaster we require reliable and efficient method In this recent era technology have reached to an great extent due several factors like artificial intelligence and many more but somewhere implementation of these field is not seen much some fields out of which we can say firefighting field so that is the reason to developing firefighting robot using Arduino which is comparatively cheaper as well as less difficult then. Other controllers so that by using this technology we can prevent the incidents of fire in small industries as well as we can use it for domestic purpose also

Keywords—Firefighting robot; Artificial Intelligence, Arduino,

1. Introduction:

Fire hazards pose a significant risk to life and property, necessitating the development of advanced fire detection and suppression systems. Traditional fire- fighting methods often rely on human intervention, which can be slow and dangerous in critical situations. To address these challenges, automation in fire response has gained increasing attention. This research focuses on the development of an Arduino-based fire-fighting robot capable of detecting and extinguishing fires autonomously. By integrating fire sensors, navigation systems, and an extinguishing mechanism, the robot enhances fire safety measures with greater efficiency and reliability.

The fire-fighting robot is designed to operate in real-time, continuously scanning its surroundings for potential fire outbreaks. Upon detecting a fire, the robot navigates towards the source and activates its onboard extinguishing system to suppress the flames. The use of Arduino technology allows for precise control and coordination of various components, making the system both cost-effective and adaptable. This research aims to contribute to the advancement of intelligent fire mitigation technologies, offering a promising solution for reducing fire-related risks in residential, industrial, and commercial environments.

In addition to its core fire detection and suppression capabilities, the robot is equipped with a GSM module to enhance emergency communication. When a fire is detected, the GSM module sends an alert message to pre-configured phone numbers, such as those of building authorities or emergency responders. This feature ensures that even if the fire cannot be controlled immediately, timely notifications can facilitate quick human intervention, preventing further damage. By integrating fire-fighting automation with real-time communication, the system provides a more comprehensive approach to fire safety and emergency response

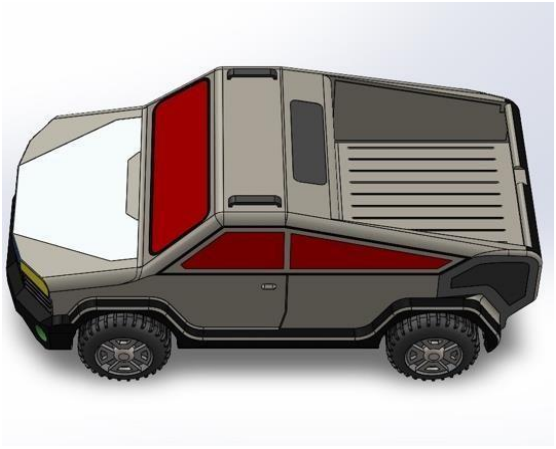

Figure 1.1 Schematic of Fire Fighting Robot

1.1. Define User based problem

Firefighting is a highly dangerous profession, often exposing firefighters to life-threatening situations such as intense heat, toxic smoke, and structural collapses. In many cases, firefighters must enter hazardous environments to extinguish fires, putting their lives at significant risk. Traditional firefighting methods rely heavily on human intervention, which increases the chances of injury or fatality. To address this issue, there is a need for a technology-driven solution that minimizes human involvement in high-risk fire scenarios. Our Arduino-based fire-fighting robot is designed to tackle this problem by detecting and extinguishing fires autonomously, reducing the need for direct human exposure to danger. By integrating smart sensors and automated response mechanisms, this project aims to enhance firefighter safety and improve fire suppression efficiency.

1.2. Problem Definition

Firefighting remains one of the most hazardous professions, often requiring responders to enter life-threatening environments where extreme heat, toxic fumes, and collapsing structures put their safety at risk. Despite advancements in protective gear and firefighting techniques, human intervention remains a critical yet dangerous necessity. Our objective is to minimize this risk by developing an intelligent, Arduino-based fire-fighting robot capable of autonomously detecting and extinguishing fires. By integrating smart sensors, automated navigation, and an efficient extinguishing system, this solution reduces direct human exposure to danger while enhancing the speed and precision of fire suppression. This research leverages technology to create a scalable, cost-effective, and life-saving alternative to traditional firefighting methods, ensuring a safer and more efficient response to fire emergencies.

2. Literature survey:

The development of autonomous fire-fighting robots has garnered significant attention in recent years due to the growing need for more effective, safer, and efficient fire suppression systems. The rise of robotics in various sectors has prompted researchers to explore how these machines can be integrated into fire safety protocols. Various studies have focused on the design and deployment of robotic systems that utilize advanced sensors for detecting flames and heat sources, alongside automated response mechanisms. In particular, fire sensor modules have proven to be valuable for identifying the presence of flames, with many systems triggering an automated extinguishing action once fire is detected. These developments have emphasized the importance of accurate fire detection and quick response times in mitigating fire hazards. Furthermore, the inclusion of GSM (Global System for Mobile Communications) modules in fire detection systems has allowed for real-time alerts and notifications, which enable remote monitoring and quick emergency responses even in hazardous situations.

In addition to sensor integration, relay modules have been widely explored in studies focusing on fire-fighting robots. Relay modules are instrumental in activating pumps for water or chemical suppression, ensuring a swift and targeted response to the fire. The ability to control extinguishing agents remotely offers a substantial advantage in reducing response time and preventing further damage or injury. Furthermore, advancements in motor driver ICs, such as the L293D, have been pivotal in enhancing the mobility of these robotic systems. These motor driver ICs are crucial for controlling the movement of fire- fighting robots, allowing them to navigate through challenging environments autonomously. Such technological advancements provide fire-fighting robots with the ability to maneuver towards fire sources with precision, providing a much-needed advantage in emergency situations.

Building upon these previous advancements, our proposed model seeks to integrate the most effective components from past research while introducing a more robust and reliable system. By combining the GSM module for sending fire alerts, the fire sensor module for accurate flame detection, and the relay module for activating the water pump, we aim to create a fire-fighting robot with enhanced efficiency. Additionally, the L293D motor driver IC will enable controlled robotic movement, ensuring the robot can navigate complex environments to locate and suppress fires autonomously. This system will be powered by Arduino-based automation, known for its versatility and ease of integration, which will provide a solid foundation for further enhancing the robot's fire- fighting capabilities. Through the integration of these components, we aim to increase the reliability of fire-fighting robots, reducing human exposure to dangerous environments while improving the overall effectiveness of emergency response systems.

3. Block Diagram :

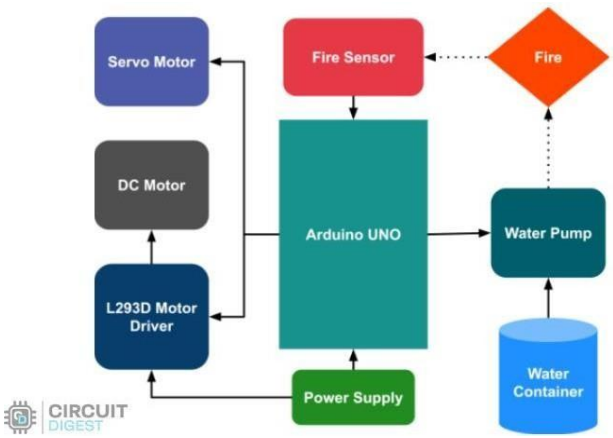

Figure 3.1: Block Diagram [5]

The flame sensor identifies the presence of fire and transmits signals to the Arduino, which processes the input and initiates appropriate actions. Upon detecting a fire, the Arduino activates the water pump, which draws water from a reservoir and disperses it over the flames for extinguishment.

At the same time, the robot advances toward the fire using DC motors regulated by the L293D motor driver. A servo motor adjusts the nozzle position to ensure precise water spraying. The system is powered by a dedicated power source, guaranteeing continuous and reliable operation.

4. Hardware Description:

4.1. Arduino Uno

The Arduino UNO is the primary microcontroller used in this fire-fighting robot, responsible for processing sensor data and controlling all components. It is based on the ATmega328P microcontroller and operates at 16 MHz. The board features 14 digital I/O pins (6 of which support PWM), 6 analog input pins, and 32 KB of flash memory (with 2 KB used by the bootloader). It runs on a 5V power supply, with an operating voltage range of 7V–12V. The UNO is widely used due to its ease of programming, compatibility with various sensors and modules, and reliable performance in embedded applications.

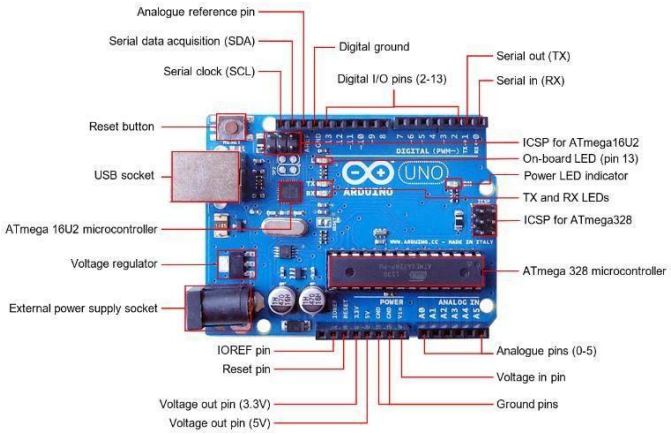

Figure 4.1 Arduino Uno Board

4.2. Flame Sensor Module

The fire sensor module is a crucial component that detects flames and triggers the fire suppression system. It operates by sensing infrared radiation (IR) in the 760 nm–1100 nm range. The module works with an input voltage of 3.3V–5V and has both analog and digital output options for precise fire detection. The sensitivity of the sensor can be adjusted using a built-in potentiometer. This sensor enables real-time fire detection, ensuring the robot responds quickly to fire hazards.

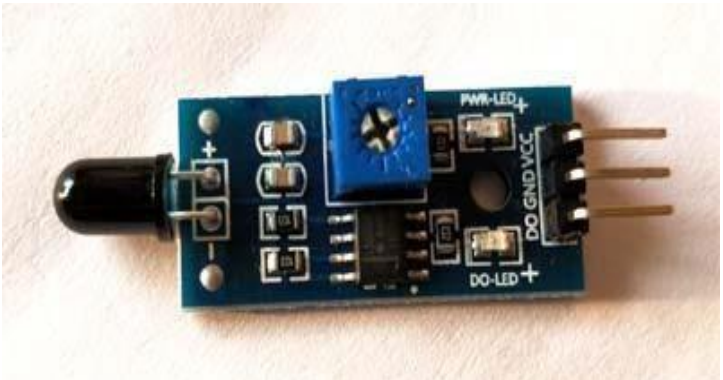

Figure 4.2 Flame Sensor Module

4.3. Servo Motor (SG90)

The SG90 servo motor is used to control the movement of the water-spraying pipe, allowing for precise directional control of the extinguisher. It operates at 4.8V–6V and provides a stall torque of 2.5 kg.cm. The servo has a rotation range of 0°–180° and can be controlled using PWM signals from the Arduino. Its lightweight design and high torque make it ideal for robotic applications that require controlled movement.

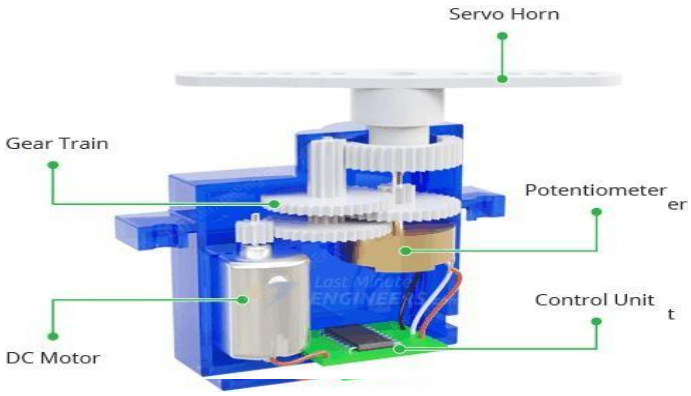

Figure 4.3 Servo Motor(SG90)

4.4. Water Pump

The water pump is responsible for extracting and spraying water onto the fire. It operates at 5V–12V and provides a flow rate of approximately 2–3 L/min, depending on the power input. The pump ensures a steady water supply for fire suppression and is activated by the relay module upon fire detection.

Figure 4..4 Pump (5V)

4.5. Relay Module

The relay module is used to switch the water pump on and off based on signals from the Arduino. It operates at 5V and can handle 10A of current at 250V AC or 30V DC. The module provides electrical isolation between the control circuit and high-power devices, ensuring safe operation.

Figure 4.5 Relay Module

4.6. L293D Motor Driver

The L293D motor driver IC controls the movement of the robot's wheels, allowing bidirectional control of the motors. It operates at 4.5V–36V and can deliver 600mA per channel, with a peak output of 1.2A per channel. The IC features built-in diodes for back EMF protection, making it reliable for driving DC motors in robotic applications.

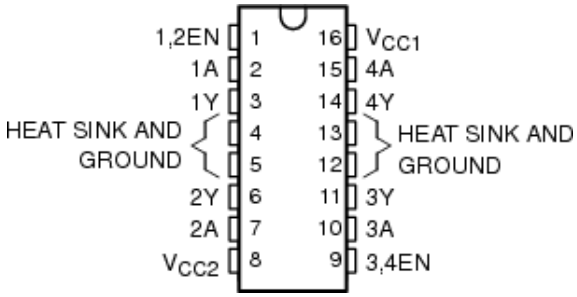

Figure 4.6 L293D Motor Driver

4.7. GSM Module (Sim800l)

The GSM module (SIM800L) enables real-time messaging by sending an alert when fire is detected. It supports quad-band GSM/GPRS (850/900/1800/1900 MHz) and operates at 3.4V–4.4V. The module communicates with the Arduino via serial communication (UART) and requires a SIM card for network connectivity. It ensures that emergency alerts are sent immediately, allowing for quick intervention.

Figure 4.7 GSM Module (Sim800L)

4.8. Robot Chasis &. Wheels

The robot chassis is the base structure that houses all the components and provides stability. The robot is equipped with two wheels, which are driven by DC motors controlled by the L293D motor driver. The chassis is designed for mobility, enabling the robot to navigate towards the fire source efficiently.

This hardware setup ensures that the fire-fighting robot functions effectively by integrating fire detection, autonomous movement, and fire suppression, making it a reliable solution for hazardous environments.

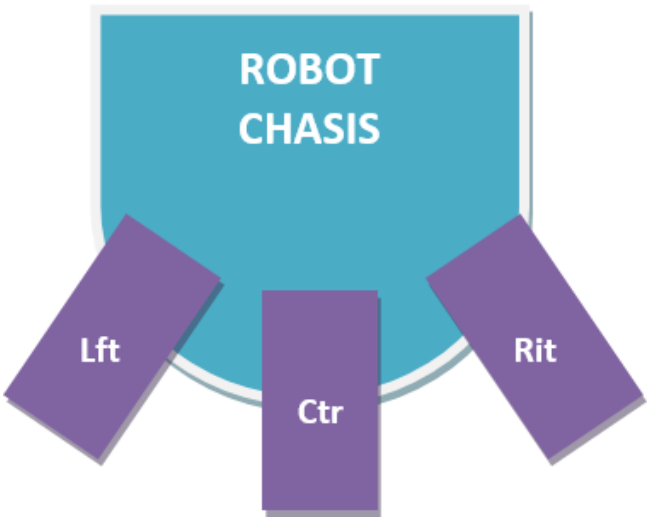

Figure 4.8 Robot Chasis & Wheels [5]

5. Result and Analysis:

a. Fire Extinguishing Time vs. Distance

The time required to extinguish a fire increases with distance between the robot and the fire.

At shorter distances, the robot detects and reaches the fire faster, reducing the suppression time. At longer distances, travel and response time increase, delaying fire extinguishing.

Future improvements can include better path planning and faster response mechanisms to minimize extinguishing time.

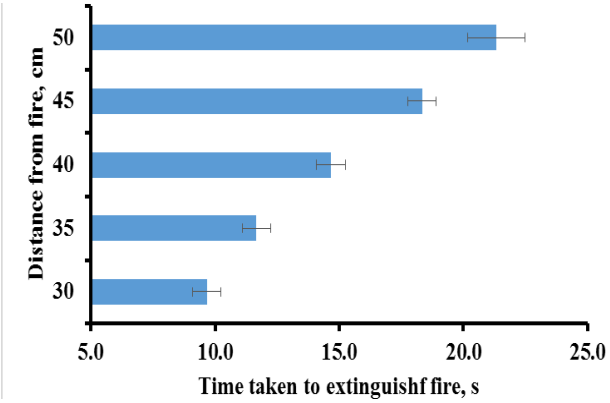

Figure 5.1 Fire Extinguishing Time VS distance [4]

b. Travel Time vs. Distance to Fire Location

The time taken to reach the fire increases as the distance increases.

If obstacles are present, the robot takes a longer, alternative path, increasing travel time.

Experimental data shows that improving sensor accuracy and motor response can help reduce travel time.

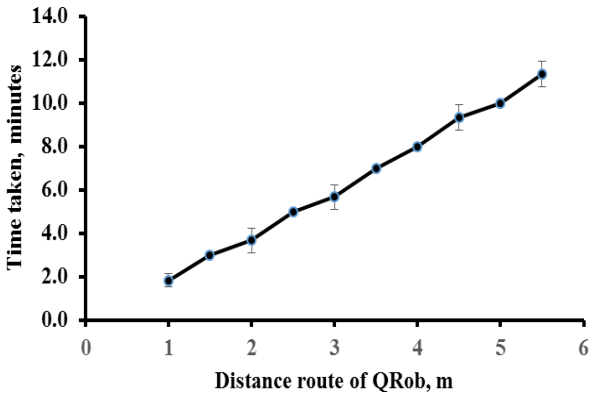

Figure 5.2 Travel Time VS Distance to Fire Location [4]

c. Experimental Fire Extinguishing Process

The robot successfully detected and extinguished the fire.

The flame sensor detected the fire, and the relay module activated the water pump to spray water. The experimental results confirm that the robot can extinguish fire effectively

Figure 5.3 Design of Fire Fighting Robot

6. Future Directions:

- Integration of Multi-Spectral Sensing for Fire Detection: Future work can explore the use of multi-spectral imaging (e.g., infrared, UV, and visible light) to enhance fire detection accuracy and provide real-time data on the fire's intensity, location, and heat distribution. This would help the robot respond more intelligently to different fire types and environmental conditions.
- Edge Computing for Real-Time Decision Making: Implementing edge computing capabilities on the Arduino-based robot could allow for faster, on- site data processing and decision-making. This would reduce reliance on cloud-based processing and enable the robot to react to dynamic changes in the fire environment with minimal latency.
- Self-Charging and Autonomous Maintenance Systems: Incorporating energy-efficient power systems, like solar or wireless charging stations, and self- diagnosing maintenance algorithms could make the robot more autonomous, ensuring it remains operational for extended periods without human intervention during firefighting missions.
- Advanced Heat Transfer and Suppression Techniques: Researching innovative heat transfer mechanisms, such as the use of high-efficiency heat exchangers or cryogenic cooling systems, could significantly improve the robot's ability to suppress fires faster and more effectively, especially in high-temperature environments.
- AI-Based Fire Prediction and Risk Assessment: Implementing machine learning models to predict fire behavior and assess risk levels based on real- time environmental data (wind speed, humidity, temperature) could enable the robot to optimize its firefighting strategies by proactively tackling the most dangerous areas of a fire.

7. Conclusion:

The Arduino-based fire-fighting robot developed in this research provides an efficient and autonomous solution to minimize the risks faced by firefighters. By leveraging technology for fire detection, navigation, and suppression, this system ensures a faster and safer response to fire emergencies. The integration of automation reduces the need for direct human intervention in hazardous environments, enhancing both safety and efficiency. Additionally, the ability to send real-time alerts ensures timely action, further improving emergency response capabilities. This research highlights the potential of robotics in firefighting and sets a foundation for future advancements, such as AI-based decision-making and improved mobility, to make fire suppression even more effective.

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