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Automatic Fire Fighting Robot

Omkar N P[1], Naveen S S[2] Manjunath Choori[3], Revati S Muttappagol[4], Professor Sudhakar H M[5]
Department of Electronics and Communication Engineering
Alvas Institute of Engineering and Technology, Moodabidri, India
omkarpattar67@gmail.com, naveenspetimath793@gmail.com, manjunathchoori28@gmail.com, revatismuttappagol642003@gmail.com

***Abstract*—Fire incidents are among the most destructive disasters, often resulting in loss of life, property damage, and long-term disability. Industries like nuclear power plants, petroleum refineries, and chemical factories are particularly vulnerable to fire accidents, which can have devastating consequences. These incidents emphasize the urgent need for effective firefighting solutions. This project proposes an innovative approach to fire control through the development of a robotic firefighting vehicle.**

With advancements in robotics, hazardous operations increasingly rely on robots to enhance safety. Fire accidents can sometimes exceed the capacity of firefighters, putting lives at risk. In such scenarios, firefighting robots offer a safer and more efficient alternative.

This project aims to design an autonomous firefighting robot powered by an Arduino microcontroller. Equipped with advanced sensors, the robot will autonomously detect fires within a predefined area and extinguish them. It will feature a water reservoir, pump, and nozzle for effective water spraying. Infrared sensors will enable precise heat detection, ensuring accurate targeting of fire sources.

The Arduino microcontroller will handle mobility, firefighting operations, and sensor data processing. The robot's durable mechanical framework will withstand extreme conditions, prioritizing efficiency, reliability, and energy optimization. Future improvements may include remote monitoring, wireless communication, and enhanced fire detection algorithms.

This robotic solution seeks to minimize human intervention during fire emergencies, enhance safety, and reduce casualties in hazardous environments. By leveraging advanced technology, it represents a significant step forward in disaster management and industrial safety.

***Index Terms*—component, formatting, style, styling, insert**

I. INTRODUCTION

Fire emergencies often result in catastrophic loss of life and property, highlighting the need for advanced safety measures. This project explores an Arduino-based automated firefighting robot designed to autonomously detect and extinguish fires. Combining sensors, motors, and intelligent control, the robot quickly identifies flames and responds efficiently to suppress them.

The robot's core functionality includes autonomous fire detection and water cannon control. Equipped with sensors, it navigates fire-prone areas and targets flames for rapid intervention. It uses an object detection sensor at the front and additional flame-detection sensors at the corners to locate fire sources and approach them effectively.

Structurally, the robot resembles a remote-controlled vehicle with four wheels, a water tank, a nozzle, and three sensors. Such robots are especially critical in hazardous environments where human safety is at risk, such as industries handling dangerous substances. The integration of robotic technologies, including potential applications with drones, is being explored as an effective firefighting method.

The increasing prevalence of fire-related destruction has driven demand for robotic solutions. These systems significantly reduce human intervention, offering safer and more efficient fire control, especially in situations where human entry is unsafe. Designed for both autonomous and remote operation, the robot adapts to various scenarios, enhancing its versatility. [3]

By leveraging robotics, this project represents a major advancement in handling hazardous tasks, minimizing risks to human lives. Firefighting robots are invaluable in rescue operations, as they navigate dangerous environments to safeguard people and property. With intelligent sensors, mobility, and fire suppression capabilities, these robots provide a modern, effective approach to firefighting, particularly in inaccessible or high-risk areas, marking a significant leap in disaster management technology.

II. LITERATURE REVIEW

Autonomous Fire Fighting Robot

Mohammad Mahfujul Islam (2021) presented a design for an autonomous robot capable of extinguishing fires in hazardous environments without human intervention. Utilizing Atmega microcontrollers and ultrasonic sensors, the robot features fire detection through IR sensors and obstacle navigation. Its additional functionalities include live video streaming and remote operation, making it suitable for both industrial and disaster rescue applications.

IoT-Based Fire Fighting Robot

Megha Kanwar and Agilandeeswari L. (2018) developed an IoT-enabled firefighting robot designed for real-time monitoring and remote operation. The robot integrates CO2 sensors for fire-type classification, allowing for optimal selection of extinguishing agents such as water or CO2. Control and monitoring are facilitated via MQTT dashboards, with features for communicating with individuals in affected zones.

Automatic Fire Fighting Robot Using Arduino

Basavaraj K. Hosamani et al. (2024) proposed an Arduino-controlled robot emphasizing accessibility and cost-efficiency. This robot employs flame sensors for fire detection and uses a water pump for extinguishing. It features a straightforward

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design with autonomous navigation capabilities, making it ideal for both industrial settings and educational purposes.

Integrated Semi-Autonomous Fire Fighting Robot

Saravanan P. (2015) introduced a semi-autonomous firefighting robot incorporating an Atmega2560 microcontroller. The system includes ultrasonic and IR sensors for navigation, LDR and temperature sensors for fire detection, and a water pump for extinguishing. Remote operation is supported through GUI-based controls, making the design versatile for extreme environments.

Intelligent Fire Extinguishing System

Poonam Sonsale et al. (2014) developed an intelligent fire extinguishing system employing multiple sensors such as smoke, temperature, and fire sensors. The system integrates a sprinkler-based extinguishing mechanism, capable of detecting and addressing fires in localized areas with precision and efficiency.

III. Objectives

The primary objective of this project is to design and develop an autonomous firefighting robot capable of detecting and extinguishing fires without human intervention. This robot aims to address the significant risks posed by fires, especially in environments where human entry is dangerous or delayed. The key objectives are:

1) **Fire Detection and Localization:** The robot will be equipped with a flame sensor and ultrasonic sensor to detect the presence of fire and estimate the distance to the fire's source. This enables the robot to accurately navigate towards the fire-prone area.
2) **Autonomous Navigation:** The robot will be capable of navigating autonomously through a predefined environment, avoiding obstacles, and reaching the fire location. This reduces the need for manual intervention and ensures faster response time in emergency situations.
3) **Fire Suppression System:** Upon detecting fire, the robot will activate its fire extinguisher, controlled through a wireless communication system. The extinguisher will suppress the fire, minimizing potential damage and loss of life.
4) **Wireless Communication Control:** The system will be controlled remotely via wireless communication, allowing for manual operation if necessary, especially in complex or high-risk scenarios. This feature ensures flexibility and the ability to adapt to different fire emergency situations.
5) **Minimizing Human Risk:** By automating fire detection and suppression, the robot aims to reduce the risk to human firefighters and emergency responders, especially in hazardous or hard-to-reach areas, such as industrial sites or residential buildings with limited access.
6) **Enhancing Fire Safety and Prevention:** The proposed robot model will contribute to improving fire safety measures in vulnerable regions, such as developing countries with insufficient fire suppression infrastructure. It will provide a reliable, fast-response solution that can be deployed in fire emergencies to reduce damage and loss of life.
7) **Cost-effective and Scalable Solution:** The system aims to offer a low-cost yet scalable solution for firefighting, making it accessible to both small-scale and large-scale fire emergencies, offering a significant improvement over traditional firefighting techniques.

The proposed firefighting robot will serve as a valuable tool in mitigating the dangers posed by fires, particularly in areas where human intervention is not immediately possible, and will contribute significantly to the safety and well-being of communities and industries.

IV. Proposed System Architecture

The Fire Fighter Robot is a comprehensive system that integrates multiple components working together to autonomously detect and extinguish fires. The architecture is designed to provide seamless communication between the sensors, controllers, and actuators, ensuring rapid response in fire emergencies. Below are the key components and their respective functionalities:

- **Flame Sensors (x3):** The robot is equipped with three flame sensors, strategically positioned to detect fire from different angles. These sensors continuously monitor the environment and send input signals to the Arduino when they detect a fire. By detecting the heat signature and intensity of flames, these sensors enable the robot to accurately locate fire outbreaks and take appropriate action for fire suppression. The sensors also allow the robot to avoid false positives, ensuring that it only responds to genuine fire hazards.
- **Arduino UNO (Main Controller):** The Arduino UNO acts as the brain of the firefighting robot. It processes the input data from the flame sensors and uses this information to control the movement of the robot and activate the fire suppression system. The Arduino controls the motor functions, the direction of the water spray, and triggers the water pump. It also communicates with other components, ensuring that the system operates efficiently and autonomously. Through programming, it can adjust the robot's behavior based on real-time data received from the sensors.
- **BO Motors with Wheels (x4):** To provide the necessary mobility for the robot, four BO motors are used, each connected to a wheel. These motors allow the robot to move forward, backward, turn, and navigate through obstacles. The wheels are designed to offer stability and maneuverability, allowing the robot to navigate complex environments, such as homes, buildings, or industrial sites. The motors are controlled via the L298 motor driver, ensuring smooth movement across different terrains.
- **L298 Motor Driver:** The L298 motor driver is responsible for controlling the BO motors, providing the appropriate voltage and current for precise movement. The driver acts as an intermediary between the Arduino

and the motors, allowing the robot to change directions, speed, and perform other movements. It also enables the robot to rotate in place, which is critical for fine-tuning the robot's position during fire suppression activities.

- **Mini Servo Motor:** The mini servo motor is an essential component for controlling the water spray direction. It adjusts the angle of the water nozzle, enabling precise targeting of the fire. The servo allows the robot to focus the water stream at the exact location of the flames, maximizing the effectiveness of fire suppression. This motor plays a critical role in ensuring that the robot can extinguish fire from different directions and in various environmental conditions.
- **Water Pump:** The water pump is responsible for drawing water from the onboard tank and expelling it through the nozzle to put out the flames. The pump is activated by the Arduino once the robot reaches the fire location. The water flow rate is controlled to optimize fire suppression without wasting resources. The pump ensures a continuous supply of water to the nozzle during firefighting operations.
- **TIP-122 Transistor Circuit:** The TIP-122 transistor circuit drives the water pump system. This circuit provides the necessary current to the pump, allowing it to operate efficiently under varying conditions. By using a transistor, the water pump can be controlled without overloading the system, ensuring reliable performance over time. The TIP-122 transistor serves as a switch, enabling the Arduino to turn the pump on and off based on the real-time requirements of the fire suppression process.

V. PROPOSED SYSTEM WORKFLOW

1) **Fire Detection:** The flame sensors constantly monitor the environment for the presence of fire. When one of the sensors detects flames, it sends a signal to the Arduino, which processes the information.
2) **Navigation:** Once a fire is detected, the robot activates the motors, allowing it to move towards the fire. The robot uses its sensors to navigate around obstacles and head directly to the fire location.
3) **Fire Suppression:** Upon reaching the fire, the Arduino triggers the water pump to start, while the mini servo motor adjusts the water spray direction to target the fire precisely. The water pump expels water from the tank, effectively extinguishing the flames.
4) **Autonomous Operation:** The entire process is autonomous, with minimal human intervention. The robot continuously monitors the fire situation and adapts its actions accordingly. It moves towards detected flames, suppresses them, and returns to standby mode once the fire is put out.

VI. COMPONENTS DESCRIPTION

A. Flame Sensors

Flame sensors communicate with the Arduino by detecting the infrared light that fire emits. These sensors, which are positioned strategically throughout the robot, enable precise fire detection and direction estimation. This guarantees that the robot can recognize and react to fire dangers in an efficient manner.

B. Arduino UNO

The Arduino UNO functions as the main processing unit, taking in data from flame sensors and managing the water pump, servos, and motors. It is a strong option for this application due to its broad compatibility and simplicity of programming.

C. BO Motors with Wheels

Four BO motors provide the necessary locomotion for the robot. Their compact size and efficiency make them ideal for smooth navigation across various surfaces. The L298 Motor Driver ensures precise control over the motors for accurate movement.

D. Water Pump System

The water pump, powered by a 5-9V power source, draws water from a tank to extinguish fires. The TIP-122 transistor circuit efficiently manages the power supply to the pump, enabling controlled activation during firefighting operations.

E. Servo Motor

The water pump's nozzle is precisely adjusted by a tiny servo motor to target the flames. This guarantees efficient suppression and the best possible use of water

VII. METHODOLOGY

The methodology for designing and implementing the Autonomous & Wireless Fire-Fighter Robot is structured into two primary operational modes: Autonomous Mode and Remote Control Mode. The system relies on the integration of multiple sensors, controllers, and actuators to detect and extinguish fires autonomously while providing the option for human control when necessary.

In Autonomous Mode, the robot operates entirely without human input, executing fire detection and suppression tasks automatically. The system begins with the initialization of its sensors and actuators, ensuring that all components are ready for operation.

1) Initial Setup and Calibration: When the robot is powered on, the two servo motors attached to the fire and obstacle detection sensors reset their position to face the front of the robot. This ensures the sensors are aligned and ready to detect objects and fire in the surrounding environment.

2) Fire Detection and Localization: The robot employs an Infrared (IR) sensor to detect the presence of fire. The IR sensor is a passive infrared sensor capable of detecting infrared radiation emitted by flames within the wavelength range of 760 nm to 1100 nm. The sensor continuously monitors the environment, and when it detects the infrared radiation from a fire, it sends a signal to the Arduino microcontroller.

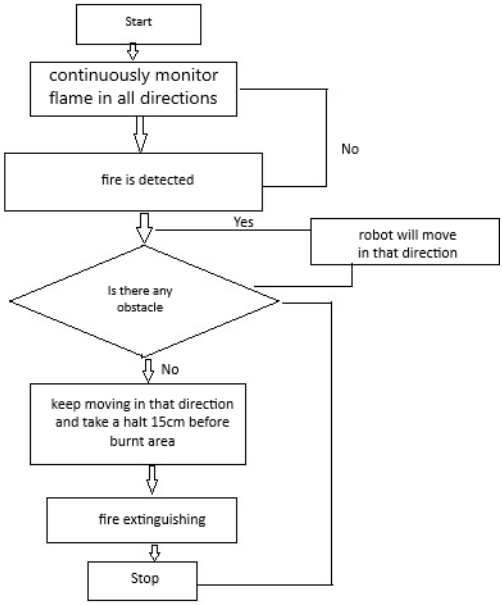

Fig. 1. Flow chart

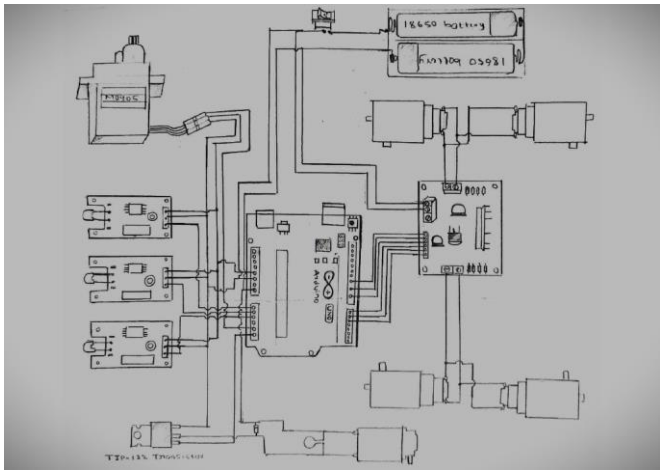

Fig. 2. Circuit diagram

3) Movement Towards Fire: Once the fire is detected, the robot uses its motorized wheels to move towards the fire source. The robot approaches the fire while avoiding obstacles, using ultrasonic sensors to monitor its surroundings. If the path is clear, the robot continues moving forward. If an obstacle is detected, the robot adjusts its direction to avoid collisions. [1]

4) Fire Suppression: Upon reaching the fire, the robot activates its water pump and solenoid valve. The water pump sprays water on the fire, while the solenoid valve dispenses CO2 gas to help extinguish the flames. The robot ensures that it maintains a safe distance from the fire during this process.

5) Post-Suppression Scanning: After attempting to suppress the fire, the robot scans the surrounding area to check for additional fires or obstacles. It performs a 360-degree scan by turning its sensors at intervals of 90 degrees. If a fire is detected during the scan, the robot halts its current action to address the new threat. Once all fires are extinguished, the robot returns to its original path.

6) Pathfinding and Obstacle Avoidance: The robot uses its ultrasonic sensor to check if the path is blocked. If no obstacles are detected, the robot continues moving forward. If an obstacle is detected, the robot changes direction by rotating 90 degrees and checks if the new path is clear. Once the path is clear, it resumes movement.

7) Locomotion Control: The robot's movement is achieved by controlling the BO motors with the help of an L298 motor driver. The system uses a differential drive method, where the front and rear wheels on opposite sides of the robot turn in opposite directions to achieve turning. The robot can move forward, backward, left, and right as needed. [1]

VIII. Application

The Fire-Fighter Robot is a versatile and highly effective tool for combating fires in challenging and dangerous environ- ments. Its advanced capabilities allow it to be deployed across a wide range of scenarios, providing critical support in various industries and emergency situations.

Firefighting in Inaccessible or Hazardous Locations

The robot is designed to operate in dangerous areas that are difficult or impossible for humans to reach, such as high-rise buildings, remote facilities, or areas with high heat levels. Its ability to detect and extinguish fires autonomously makes it invaluable for ensuring safety in risky environments.

Industrial and Urban Firefighting

This robot is ideal for use in industrial settings and urban areas where rapid fire response is essential. Its mobility and fire suppression systems ensure that it can tackle fires in fac- tories, warehouses, and densely populated areas, minimizing damage and protecting infrastructure.

Nuclear and Combustion Power Plant Applications

When equipped with proper heat and radiation shielding, the robot can be deployed to address fires in hazardous environments, such as nuclear power plants or combustion power stations. Its use can prevent the escalation of accidents and reduce the risk of harm to personnel.

Human Life Protection

By operating in conjunction with human firefighters, the robot can reduce the risk to human lives during fire emergen- cies. It can serve as a first responder to dangerous situations, providing critical fire suppression before human intervention is possible.

Real-Time Monitoring for Informed Decision-Making

The robot's live video transmission capabilities allow remote operators to assess the situation in real-time, making rapid decisions and ensuring that firefighting efforts are targeted and efficient. This capability enhances situational awareness and improves operational response times.

Search and Rescue in Disaster Scenarios

The robot's ability to operate in dangerous environments makes it an invaluable tool for search and rescue operations, particularly after natural disasters such as earthquakes and hurricanes. It can navigate through rubble and debris to locate survivors, providing vital assistance to first responders and aid organizations. [2]

Enhanced Control and Monitoring Capabilities

Unlike traditional Bluetooth-controlled models with limited range, this robot offers superior wireless connectivity, enabling it to be controlled from anywhere in the world. Real-time monitoring and quick command execution enhance its effectiveness in managing fire suppression remotely.

Fire Classification and Tailored Extinguishing Methods

The robot's ability to identify different types of fires allows it to determine the most appropriate method for extinguishment, ensuring that the response is tailored to the specific nature of the fire, whether it's electrical, chemical, or combustible.

Efficiency and Precision in Firefighting

The robot's highly accurate sensors enable precise fire detection and monitoring, allowing for meaningful analysis and more effective firefighting strategies. By reducing the time spent in identifying and responding to fires, it enhances overall efficiency.

FUTURE ENHANCEMENTS

1) **Expansion of Chassis for Increased Capacity**
The robot's chassis can be expanded and fortified to accommodate more water and possibly a CO2 canister. This would enhance its firefighting capabilities by allowing it to handle larger or multiple fires without frequent refills, especially in large industrial complexes or urban areas.
2) **Upgraded Battery Pack for Longer Operating Time**
To extend the robot's operating time, an upgraded, higher-capacity battery pack can be integrated. This improvement would allow the robot to function for longer periods without the need for recharging, especially in critical situations where time is of the essence. [2]
3) **Enhanced Water Pump for Longer Range**
A more powerful water pump would enable the robot to fight fires from a greater distance. This is particularly important when the robot needs to avoid getting too close to the fire, especially in hazardous environments like chemical plants or large industrial fires.
4) **Improved Sensors for Better Detection and Naviga- tion**
By adding more sensitive and advanced sensors, the robot would be capable of detecting fires and sur- vivors from greater distances and through obstacles. This would improve the robot's ability to operate in complex environments such as collapsed buildings or smoky, hazardous areas.
5) **GSM e-SIM Module for Remote Control and Com- munication**
A GSM e-SIM module would allow the robot to commu- nicate over long distances, making it possible to control the robot from anywhere in the world. This would be especially useful for operations in remote locations or disaster areas, where operators may not be physically present.
6) **Multiple GPS Modules for Accurate Positioning** Integrating multiple GPS modules would enable the robot to provide highly accurate positioning data. This would be essential for large-scale operations, allowing the robot to navigate complex environments and improve coordination with other rescue units during search and rescue missions.
7) **Advanced Image Processing and System on Chip (SoC) Integration**
By integrating advanced image processing systems (IPS) and a powerful system on chip (SoC), the robot could make faster decisions based on real-time video feeds and to detect fires and obstacles quickly, increasing overall operational efficiency. [2]
8) **Automated Pump Selection Based on Fire Type**
The robot's pump selection system could be automated based on real-time environmental data, such as building type and fire characteristics. By integrating sensors to monitor factors like CO2 levels, the robot could au- tonomously determine the most effective fire suppression method without requiring manual input.
9) **Electrical Fire Detection and Alternative Suppression Methods**
Introducing specialized sensors to detect electrical fires would help avoid using water, which could cause electric shocks. The robot could use alternative suppression methods, such as CO2 or foam, to safely extinguish electrical fires in areas where water is not a suitable solution.
10) **Drone-Based Firefighting Platform**
Adapting the robot's design for use on a drone could provide faster and more flexible firefighting capabilities. Drones can quickly access hard-to-reach areas like high- rise buildings or forests, making them an ideal platform for rapid fire response in areas where ground-based robots may face limitations.

CONCLUSION

The development of the Autonomous Fire-Fighting Robot presents a remarkable step forward in ensuring the safety and efficiency of firefighting operations. By reducing the need for human intervention in high-risk environments, this robot addresses critical issues such as fire detection, suppression, and search and rescue, while minimizing the dangers faced by fire-fighters. The combination of sensors, motors, and an Arduino-based control system allows the robot to autonomously detect and extinguish fires in real-time, making it a valuable tool in both urban and industrial environments.

One of the key strengths of the robot is its compact and lightweight design, enabling it to access confined spaces that might otherwise be difficult for humans to reach. This feature is particularly beneficial in high-rise buildings, warehouses, or during search and rescue missions following natural disasters, where quick and efficient intervention is crucial. Additionally, the robot's ability to automatically identify fire types and respond with the appropriate suppression method ensures that the risk of exacerbating the fire is minimized.

Through remote control capabilities, the robot can be operated from a safe distance, enhancing the safety of human operators while allowing real-time monitoring of environmental conditions. The system's ability to detect smoke and fire with high accuracy further underscores its potential to support firefighting efforts effectively. As experimental results have demonstrated, the robot performs well in both identifying fire sources and deploying appropriate fire suppression techniques, ensuring the safety of personnel and property.

Looking ahead, the potential for further enhancements, such as integrating advanced sensors, improving battery life, and incorporating more sophisticated communication systems, would undoubtedly increase the robot's versatility and operational range. With these advancements, the autonomous fire-fighting robot could become an integral component of modern firefighting operations, providing more reliable, safer, and cost-effective fire response strategies for both professionals and communities at large.

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