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An Autonomous Fire Detection, Navigation and Extinguishing Robot Working in Fire Hazards

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ABSTRACT

Firefighting has long been recognized as a hazardous activity, with many fire-related accidents resulting from human error, delayed response, or inadequate suppression techniques. To mitigate these risks, we propose, an intelligent autonomous robot designed to provide rapid and localized fire suppression in indoor environments. Unlike conventional systems that rely on continuous spraying or simple reactive mechanisms, FireBot integrates Simultaneous Localization and Mapping (SLAM) with a modified pathfinding algorithm to achieve precise navigation and efficient fire targeting. The robot is equipped with a compact water tank and a servo-controlled nozzle, enabling it to deliver focused suppression directly at the fire source. Real-time sensor feedback ensures accurate detection and verifies extinguishing effectiveness, thereby reducing resource wastage and enhancing reliability. FireBot's modular design allows for flexible deployment across diverse settings, including homes, offices, laboratories, and industrial facilities. Its lightweight structure and safety-oriented engineering minimize risks to occupants while ensuring timely intervention. By combining high detection accuracy, adaptive navigation, and reliable extinguishing performance, FireBot demonstrates the potential of robotics and artificial intelligence in advancing fire safety. As an early fire intervention system, it offers a scalable, cost-efficient, and environmentally conscious solution that enhances protection and reduces dependence on human intervention in hazardous scenarios

Keyword: - Firefighting Robot, Simultaneous Localization and Mapping, Fire Suppression, Real-time Sensor, Modular Design for Indoor Safety

1. INTRODUCTION

Fire accidents are among the most devastating hazards faced by modern society, causing significant loss of life, property damage, and environmental destruction. Despite advancements in fire detection and suppression technologies, conventional firefighting methods continue to rely heavily on human intervention. Firefighters are often required to enter hazardous environments where they are exposed to extreme heat, toxic gases, and the risk of structural collapse. These limitations highlight the urgent need for innovative solutions that can reduce human exposure while ensuring rapid and effective fire suppression. Robotics and automation have emerged as promising tools in disaster management, offering the ability to operate in environments that are unsafe for humans. Dhiman et al. [1] demonstrated the use of deep learning and machine vision in firefighting robots, enabling accurate fire detection and suppression in complex environments. This integration of artificial intelligence allows robots to make autonomous decisions, reducing dependence on manual control. Anaka et al. [2] extended this concept by incorporating human detection and audio recognition, thereby enhancing the robot's capability to assist in victim rescue operations alongside fire suppression.

Sensor-based approaches have also been widely explored. Kumar et al. [3] designed an autonomous robot equipped with flame sensors and servo-controlled extinguishing mechanisms, ensuring precise targeting of fire sources. Bharaniet al. [8] developed a prototype capable of detecting heat and smoke, demonstrating the feasibility of autonomous suppression in confined spaces. These studies highlight the importance of sensor fusion in improving detection accuracy and response efficiency. The integration of Internet of Things (IoT) technologies has further expanded the scope of firefighting robots. Kolhe et al. [4] proposed an IoT-enabled firefighting robot that allows real-time monitoring and remote control, making it particularly suitable for hazardous industrial environments such as chemical plants and nuclear facilities. Parshetti et al. [5] provided a comprehensive review of firefighting robots, identifying sensor integration, AI-driven navigation, and suppression systems as critical enablers for practical deployment. Recent works also emphasize autonomy and adaptability. Singh et al. [6] highlighted the importance of designing robots capable of navigating dynamic environments and responding to unpredictable fire scenarios. Gupta et al. [7] proposed next-generation firefighting robots focusing on scalability, efficiency, and improved decision-making, paving the way for systems that can operate collaboratively in large-scale fire incidents. Building upon these advancements, the Fire Bot presented in this research aims to provide a robust, autonomous solution for fire suppression. By integrating flame detection sensors, temperature monitoring, intelligent navigation algorithms, and automated extinguishing mechanisms, Fire Bot is designed to operate in environments unsafe for human firefighters. Its mobility and autonomy make it a valuable tool for minimizing casualties, protecting infrastructure, and enhancing the overall efficiency of firefighting operations. This paper explores the design, functionality, and applications of Fire Bot, emphasizing its role in advancing disaster response robotics. By synthesizing existing research and introducing new design considerations, this work contributes to the growing body of knowledge on autonomous firefighting systems and demonstrates how robotics can revolutionize emergency management.

2. MATERIAL AND EXPERIMENTAL PROCEDURE

2.1 Working of the model

The Fire Bot operates as an autonomous robotic system designed to detect, approach, and suppress fire in hazardous environments. Its working is explained through the following subpoints:

• Sensing and Detection -Flame Sensors: Infrared flame sensors are used to detect the presence of fire. These sensors provide real- time input to the microcontroller regarding flame intensity and direction

• Processing and Control -Microcontroller Unit (MCU): The Fire Bot is controlled by a microcontroller (such as Arduino UNO), which processes sensor data and executes decision-making algorithms

• Decision Algorithms: IoT-based modules, as demonstrated by Dhiman et al., can be integrated to classify fire intensity and determine suppression strategies.

• Navigation and Mobility-Locomotion System: The robot uses wheels or caterpillar tracks for mobility, enabling it to traverse uneven terrain and confined spaces.

• Autonomous Path Planning: Algorithms such as AI or Dijkstra can be implemented for efficient navigation in dynamic environments

2. Fire Suppression Mechanism

• Extinguishing Unit: A servo-controlled nozzle connected to a water or foam reservoir is used to suppress fire. The nozzle is directed toward the flame source based on sensor feedback

• IoT Integration: As proposed by Kolhe et al., IoT modules enable remote monitoring and manual override, allowing human operators to intervene when necessary.

3. Communication and Monitoring

• Wireless Communication: IoT-enabled modules transmit real-time data to a control station, allowing operators to monitor fire conditions and robot status

• Victim Assistance: Systems such as human detection and audio recognition can be integrated to identify trapped individuals and provide rescue support.

4. Power Supply

• Battery System: Rechargeable lithium-ion batteries power the sensors, microcontroller, and locomotion system.

Operational Workflow

1. Detection: Sensors continuously monitor the environment for fire.
2. Decision: The microcontroller processes sensor data and determines the presence and location of fire.
3. Navigation: The robot autonomously moves toward the fire source while avoiding obstacles.
4. Suppression: The extinguishing unit activates, spraying water directly at the flame.
5. Communication: IoT modules transmit status updates to the control station for monitoring and possible manual intervention.

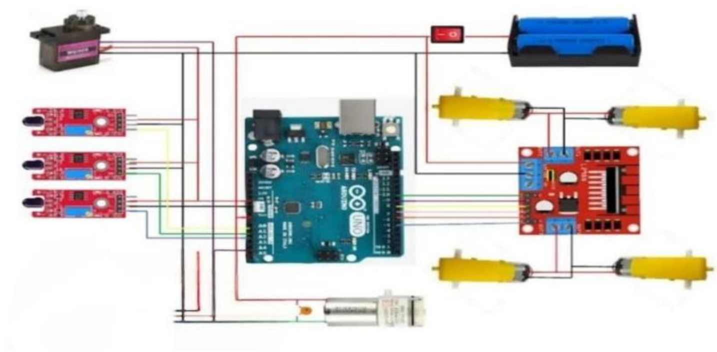

Fig -1: Circuit diagram of the model

2.2 Material and Assembly process

Sr No	Component/Parameter	Specifications	Remarks
1	Chassis Material	PVC sheet	10x6 inch
2	Drive Motors	DC motors connected side by side for clockwise or anticlockwise rotation	4x12V,300rpm
3	Motor Driver	Dual channel motor driver for bidirectional control	L298N
4	Power Source	Rechargeable Li-ion battery with regulated outputs	3.7x4(12 V)
5	Extinguishing Tank	Water reservoir	500ml
6	Pump	5v DC water pump	1.3-1.5L/min
7	Nozzle Actuation	Servo-mounted directional nozzle for targeted spraying	5V servomotor
8	Sensor Suite	IR flame sensor (KY-026)	Set of 5
9	Control Unit	Arduino UNO microcontroller	-
10	Navigation Algorithm	Hybrid SLAM with modified pathfinding for efficient route planning	-
11	Spray Mode	Suppression with effectiveness monitoring	180 Degree control
12	Battery Endurance	Average operational time under mixed load conditions	45–60 minutes

Table -1: FireBot Components and its specifications

3. CALCULATIONS AND GRAPHS

Sr No.	Distance	Time
1	5	5
2	12	10
3	30	15
4	42	20
5	53	25
6	60	30

Sr No.	Time	Volume
1	3	100
2	5.4	200
3	8	300
4	11	400
5	15	500

Table-2: Readings for Distance and Time

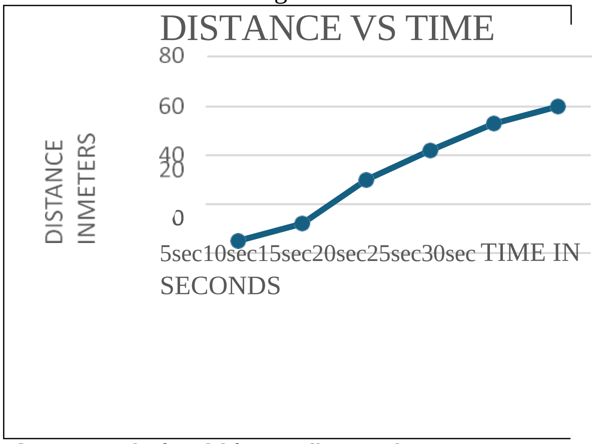

Chart -1: Graph of Model for Travelling speed

Table-3: Readings for Time vs Volume

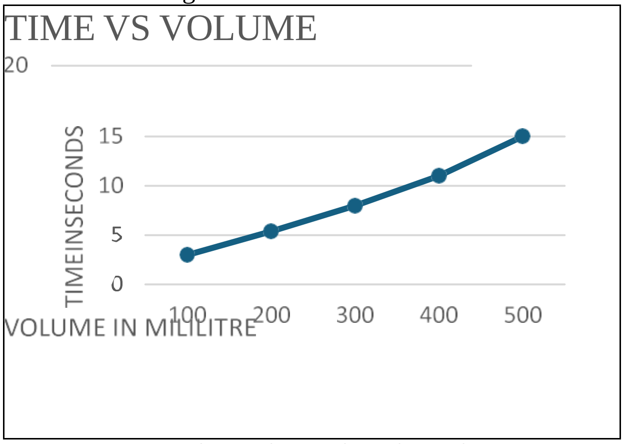

Chart-2: Graph of model for Rate flow of water from

4. RESULT

Fig-2: Side view of model

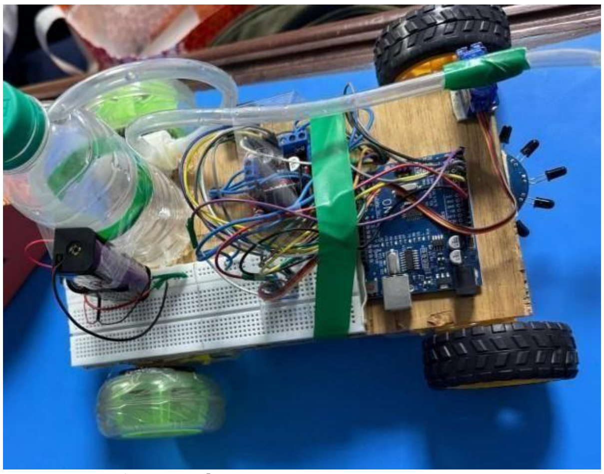

Fig-3: Final connections image

Fig-4: Final image of the model

5. CONCLUSIONS

FireBot demonstrates how intelligent robotics can transform early fire response by moving beyond simple detection to informed, autonomous action. By combining SLAM-based mapping, efficient path planning, and targeted fire suppression, the system shows strong potential as a reliable first responder in indoor environments. Its ability to assess effectiveness and adapt its actions makes it both practical and resource-efficient. Overall, FireBot highlights a meaningful step toward safer spaces, reducing reliance on human intervention while minimizing risk, damage, and response time during critical fire emergencies.

6. REFERENCES

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