PYROPATROL – AUTONOMOUS FIRE DETECTING AND EXTINGUISHING ROBOT

A MINI PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certified that this project report **“PYROPATROL : AUTOMATION FIRE DETECTION AND EXTINGUISHING ROBOT”** is the Bonafide work of **“PARAMESH KUMAR S (730421104052), PURUSOTHAMAN R (730421104058), THARUN M (730421104086)”** who carried out the project work under my supervision. Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

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ABSTRACT

PyroPatrol is an innovative autonomous system engineered to detect, locate, and extinguish indoor fires with minimal human intervention. Its primary functionalities include fire detection, obstacle avoidance, navigation, and precise deployment of fire-suppressing agents. By integrating advanced sensors and motor control mechanisms, PyroPatrol operates in real-time, efficiently processing data to make rapid decisions in dynamic environments.

PyroPatrol emerges as a pioneering solution for indoor fire suppression, driven by its autonomous capabilities. Focused on enhancing fire safety, PyroPatrol offers invaluable advantages in scenarios where human intervention is limited or hazardous. By deploying water or foam strategically, PyroPatrol effectively mitigates fire risks while minimizing collateral damage. This abstract encapsulates PyroPatrol's core mission and highlights its transformative impact on modern fire safety practices.

Key components of PyroPatrol include motor systems for movement, sensors for fire detection and environment monitoring, and sophisticated algorithms for decision-making and control. The system's robust design ensures reliable performance in diverse indoor settings, from residential homes to industrial facilities.

The development of PyroPatrol represents a significant milestone in modern fire safety technologies, offering promising prospects for safeguarding indoor environments against fire hazards. As an autonomous solution, PyroPatrol has the potential to revolutionize firefighting practices, reducing reliance on human intervention and enhancing overall safety standards.

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LIST OF ABBREVIATIONS

ABBREVIATION	FULL FORM OF ABBREVIATION
AMRs	Autonomous Mobile Robots
MAV	Micro-scale Unmanned Aerial Vehicle
MBZIRC	Mohamed Bin Zayed International Robotics Challenge
UAS	Unmanned Aerial System
IR	Infrared
TEB	Timed Elastic Band
ORCA	Optimal Reciprocal Collision Avoidance
TEB-CA	Timed Elastic Band-Collision Avoidance

CHAPTER 1

INTRODUCTION

In the realm of fire safety, the ability to swiftly and effectively respond to indoor fires is paramount. Traditional firefighting methods, while effective, often require significant human intervention and may pose risks in certain environments. The PyroPatrol project emerges as a pioneering solution to address these challenges by harnessing the power of autonomy and precision engineering.

PyroPatrol represents a groundbreaking advancement in indoor fire suppression technologies, aiming to autonomously detect, locate, and extinguish fires while minimizing human intervention. By integrating state-of-the-art sensors, motor control systems, and intelligent algorithms, PyroPatrol offers a proactive approach to fire safety, capable of navigating complex environments and swiftly deploying fire-suppressing agents.

This Project delves into the conceptualization, design, development, and implementation of PyroPatrol, highlighting its key components, functionalities, and performance metrics. Through a comprehensive analysis, we aim to elucidate the significance of PyroPatrol in modern fire safety practices and its potential impact on safeguarding indoor environments against fire risks.

By exploring the technical intricacies, challenges, and innovations associated with PyroPatrol, this report seeks to provide a thorough understanding of its capabilities and implications for the field of fire safety. Furthermore, it aims to shed light on the broader implications of autonomous firefighting technologies in enhancing safety standards and reducing reliance on human intervention in critical scenarios.

As we embark on this journey to explore the evolution of PyroPatrol and its implications for fire safety, we invite readers to delve into the depths of this transformative project and envision a future where autonomous systems play a pivotal role in safeguarding lives and property from the ravages of fire.

CHAPTER 2

LITERATURE REVIEW

2.1 COMPUTER VISION AND SMOKE SENSOR BASED FIRE DETECTION SYSTEM

AUTHOR: NAHID CHOWDHURY, et.al.,

PUBLISHER: IEEE Xplore

YEAR OF PUBLICATION: 2019

Unwanted fire causes many disasters. Thus, fire detection has been an important phenomenon to save human life. In this paper, we proposed a hybrid model that incorporates computer vision and smoke sensor-based fire detection into a single system to devise a more accurate and smart fire detection system. Our vision-based fire detection model utilizes color and motion attributes of fire combustion. Rule-based color segmentation is performed for classifying fire color regions and a modified image difference technique is used for detecting the motion of fire regions in consecutive frames. The proposed dynamic threshold technique is used for mitigating the false positive rate of the vision-based model. After performing a vision-based analysis, the proposed algorithm uses the MQ-2 smoke sensor to detect environment smoke and gas caused by fire combustion. Our implemented system raises a fire alarm in the form of remote notification after analyzing vision and smoke sensor-based model data. Real life experimental data shows that our system can detect fire with 86.67% of accuracy. In addition, the proposed system can be incorporated in existing surveillance systems at an adequately low extra expense.[1]

METHODOLOGY:

Development of a hybrid model incorporating computer vision and smoke sensor-based fire detection. The system uses color and motion attributes, rule-based color segmentation, modified image difference technique, dynamic thresholding, and an MQ-2 smoke sensor to detect fires and raise alarms.

ADVANTAGE:

- Enhanced accuracy (86.67%) in fire detection.
- Reduction in false positives.
- Improved reliability of the fire detection system.
- Robustness in detecting fire incidents.
- Minimization of erroneous alarms.

DISADVANTAGE:

- Complexity in integrating vision-based analysis with sensor data.
- Requirement for precise calibration.
- Maintenance needs for optimal performance.
- Potential challenges in synchronization between vision and sensor inputs.
- Dependency on accurate calibration for reliable operation.

2.2 VOICE OPERATED INTELLIGENT FIRE EXTINGUISHING VEHICLE

AUTHOR: R.KARTHIK, et.al.,

PUBLISHER: IEEE Xplore

YEAR OF PUBLICATION: 2021

At present all the works of human beings are replaced by the robots. Generally robotics are classified into service robotics and industrial robotics. Nowadays all fields are occupied by robotics including, hospitals, agriculture, defense, hazardous environment and office. The Robots are used where ever human does not do their work efficiently and safely such as handling poisonous and explosive products in industries. The direction of the robotic vehicle and the spraying of water in the fire is controlled by the voice command. The communication between the vehicle and humans are established through the NODE MCU and ARDUINO. The vehicle consists of three major components such as the NODE MCU, ARDUINO, and water level indicator (on vehicle). This Robotic vehicle is involved to rescue the human beings and extinguishing the fire where fire fighters are not able to enter into the fire accidental area.[2]

METHODOLOGY:

Development of a robotic vehicle controlled by voice commands using NODE MCU and ARDUINO. The vehicle includes a water level indicator and can be directed to extinguish fires in areas inaccessible to human firefighters.

ADVANTAGE:

- Enhanced user accessibility.
- Intuitive control interface.
- Reduced need for technical expertise.
- Improved operator experience.
- Facilitation of rapid deployment in emergency situations.

DISADVANTAGE:

- Reliability concerns in noisy environments.

- Potential issues with speech recognition accuracy.
- Decreased responsiveness during emergencies.
- Limitations in adverse conditions.
- Risk of misinterpretation of commands.

2.3 A LIGHT- AND HEAT-SEEKING VINE-INSPIRED ROBOT WITH MATERIAL-LEVEL RESPONSIVENESS

AUTHOR: Shivani Deglurkar, et.al.,

PUBLISHER: IEEE Xplore

YEAR OF PUBLICATION: 2021

The fields of soft and bio-inspired robotics promise to imbue synthetic systems with capabilities found in the natural world. However, many of these biological capabilities are yet to be realized. For example, vines in nature direct growth via localized responses embedded in the cells of the vine body, allowing an organ- ism without a central brain to successfully search for resources (e.g., light). Yet to date, vine-inspired robots have yet to show such lo- calized embedded responsiveness. Here we present a vine-inspired robotic device with material-level responses embedded in its skin and capable of "growing" and steering toward either a light or heat stimulus. We present basic modeling of the concept, design details, and experimental results showing its behavior in response to infrared (IR) and visible light. Our simple design concept advances the capabilities of bio-inspired robots and lays the foundation for future "growing" robots that are capable of seeking light or heat, yet are extremely simple and low-cost. Potential applications include solar tracking, and in the future, fighting smoldering fires. We envi- sion using similar robots to find hot spots in hard-to-access environments, allowing us to put out potentially long-burning fires faster.[3]

METHODOLOGY:

Development of a vine-inspired robotic device with material-level responses embedded in its skin, capable of growing and steering toward light or heat stimuli. The design includes basic modeling, design details, and experimental evaluation of its responsiveness to IR and visible light.

ADVANTAGE:

- Simple design.
- Material-level responsiveness.
- Cost-effective production.
- Easy to produce.

- Advances capabilities of bio-inspired robots.

DISADVANTAGE:

- Lack of precise control.
- Limited applicability in complex environments.
- Potential for unpredictable movement.
- Challenges in navigating obstacles.
- Restrictions in adapting to changing conditions.

2.4 ROBOTNEST: TOWARD A VIABLE TESTBED FOR IOT-ENABLED ENVIRONMENTS AND CONNECTED AND AUTONOMOUS ROBOTS.

AUTHOR: Shunsuke Aoki ,et.al.,

PUBLISHER: IEEE Xplore

YEAR OF PUBLICATION: 2021

Autonomous mobile robots (AMRs), including delivery robots, security robots, and automated wheelchairs, are very promising for improving the quality of life, safety, mobility, and productivity. To deploy such sensor-rich AMRs in real-world society, we have to resolve not only technical challenges but also ethical and societal issues. In addition, since multiple companies are developing different types of AMRs individually, we have to design and develop practical platform to enable safe cooperation and collaboration before using them in the society. Hence, in this letter, we present a viable Nagoya Experimental Site and Testbed named RobotNEST developed at Nagoya City, Japan, where we leverage vehicular communications and edge/cloud computing technologies to develop cooperative mobile robots. RobotNEST provides real-world AMRs, experimental fields, learning kits, and infrastructural sensors and communications, including 5G private networks. We also introduce multiple developed applications at RobotNEST that enable safe cooperation for autonomous robots. Finally, we discuss the scalability and limitations of the testbed and conclude with future research directions.[4]

METHODOLOGY:

Creation of the Nagoya Experimental Site and Testbed (RobotNEST) in Nagoya City, Japan, leveraging vehicular communications and edge/cloud computing technologies. The testbed integrates real-world Autonomous Mobile Robots (AMRs), experimental fields, learning kits, infrastructural sensors, and 5G private networks.

ADVANTAGE:

- RobotNEST offers a complete environment for testing and developing mobile robots.
- It enables testing in conditions that closely mimic real-life scenarios.
- Focuses on the development and testing of robots that can work together.
- Ensures that different types of autonomous mobile robots (AMRs) can safely interact and cooperate.
- Facilitates collaboration among various AMRs, developed by multiple companies.

DISADVANTAGE:

- Integrating various technologies, such as vehicular communications, edge/cloud computing, and 5G networks, can be technically complex and resource-intensive.

2.5 AUTONOMOUS FIREFIGHTING INSIDE BUILDINGS BY AN UNMANNED AERIAL VEHICLE

AUTHOR: Vojtech Spurny, et.al.,

PUBLISHER: IEEE Xplore

YEAR OF PUBLICATION: 2021

This paper presents a novel approach to autonomous extinguishing of indoor fires inside a building by a Micro-scale Unmanned Aerial Vehicle (MAV). In particular, controlling and estimating the MAV state, detection of a building entrance, multi-modal MAV localization during the outdoor- indoor transition, interior motion planning and exploration, fire detection and position estimation, and fire extinguishing are discussed. The performance of these elements, as well as of the entire integrated system, are evaluated in simulations and field tests in various demanding real-world conditions. The system presented here is part of a complex multi-MAV solution that won the Mohamed Bin Zayed International Robotics Challenge 2020 (MBZIRC 2020) competition, and is being used as the core of a fire-fighting Unmanned Aerial System (UAS) industrial platform under development.[5]

METHODOLOGY:

Development of a Micro-scale Unmanned Aerial Vehicle (MAV) for autonomous indoor firefighting, focusing on state estimation, entrance detection, multi-modal localization, motion planning, fire detection, and extinguishing. The system is evaluated through simulations and real-world field tests.

ADVANTAGE:

- Accesses and extinguishes fires in indoor environments.
- Operates in challenging or unsafe conditions for human firefighters.
- Enhances safety and effectiveness in fire emergencies.

DISADVANTAGE:

- Limited payload capacity.
- Restricts the amount of firefighting resources carried.
- May limit effectiveness in larger fires.

2.6 CHARACTERISTIC AND FIRE EXPERIMENT OF GASOLINE SPRAYING IN GAS STATION

AUTHOR: Wanning Wang, et.al.,

PUBLISHER: IEEE Xplore

YEAR OF PUBLICATION: 2020

To ensure the safety of autonomous refueling mode is the premise of promoting the construction of self-service gas stations. As an inflammable and explosive hazardous chemical, it is necessary to study the hazards of gasoline in the operation of gas stations. This paper provide a experimental of ground leak, gas diffusion and gasoline-pool-fire burning. The experimental results showed: Heavy gas effect is obvious in the process of volatile diffusion of gasoline. After the spraying amount of 0.5L gasoline was released to the ground, the concentration did not reach the lower explosive limit at the height of 3cm from the surface near the oil surface. while at the spraying amount of 1L and 2L gasoline, the concentration was at the lower explosive limit at the measuring point 3cm from the surface for a long time. In particular, when the spraying amount was 2L, the height measuring point 20cm above the oil surface also briefly reached the lower explosive limit. At the same time, the parameters such as flame height, duration, temperature and radiation intensity of gasoline with different oil quantities were measured.[6] It was found that in the absence of combustibles nearby, there is a risk of fire caused by adjacent non-contact combustibles.

METHODOLOGY:

Conducting experiments on ground leaks, gas diffusion, and gasoline-pool-fire burning to study the hazards of gasoline in gas stations. Measurements include gas concentration, flame height, duration, temperature, and radiation intensity.

ADVANTAGE:

- Detailed insights into gasoline leaks and fires.
- Informed safety measures and protocols.
- Enhanced understanding of associated risks.
- Contribution to improved safety procedures.
- Practical implications for gas station operations.

DISADVANTAGE:

- Controlled experimental environments.
- Potential limitations in replicating real-world conditions.
- Challenges in simulating unpredictable incidents.
- Consideration of variability in actual gas station scenarios.
- Need for additional field studies for comprehensive validation.

2.7 AN ELECTRIC FIRE FLAME DETECTION ALGORITHM BASED ON TEMPORAL CONVOLUTION

AUTHOR: Wei Chao, et.al.,

PUBLISHER: IEEE XPLORE

YEAR OF PUBLICATION: 2020

At present all the works of human beings are replaced by the robots. Generally robotics are classified into service robotics and industrial robotics. Nowadays all fields are occupied by robotics including, hospitals, agriculture, defense, hazardous environment and office. The Robots are used where ever human does not do their work efficiently and safely such as handling poisonous and explosive products in industries. The direction of the robotic vehicle and the spraying of water in the fire is controlled by the voice command. The communication between the vehicle and humans are established through the NODE MCU and ARDUINO. The vehicle consists of three major components such as the NODE MCU, ARDUINO, and water level indicator (on vehicle). This Robotic vehicle is involved to rescue the human beings and extinguishing the fire where fire fighters are not able to enter into the fire accidental area.[7]

METHODOLOGY:

Development of an algorithm using temporal convolution for electric fire flame detection, implemented in a robotic vehicle controlled by NODE MCU and ARDUINO. The vehicle is directed by voice commands for firefighting in hazardous environments.

ADVANTAGE:

- Enhanced accuracy and responsiveness in fire detection.
- Improved detection capabilities with temporal convolution.
- Higher reliability in identifying electric fire flames.
- Increased effectiveness in early fire detection.
- Advancements in real-time fire monitoring and prevention.

DISADVANTAGE:

- Potential reliability issues due to dependency on voice commands.
- Challenges in maintaining accuracy in noisy or chaotic environments.
- Risk of misinterpretation or errors in speech recognition.
- Impact on vehicle responsiveness and effectiveness in emergency situations.
- Need for robust noise cancellation and speech recognition algorithms.

2.8 MOTION PLANNING METHOD FOR CAR-LIKE AUTONOMOUS MOBILE ROBOTS IN DYNAMIC OBSTACLE ENVIRONMENTS

AUTHOR: Zhiwei Wang, et.al.,

PUBLISHER: IEEE Access

YEAR OF PUBLICATION: 2023

Motion planning between dynamic obstacles is an essential capability to achieve real-world navigation. In this study, we investigated the problem of avoiding dynamic obstacles in complex environments for a car-like mobile robot with an incompletely constrained Ackerman front wheel steering. To address the problems of weak dynamic obstacle avoidance and poor path smoothing in motion planning with the traditional Timed Elastic Band (TEB) algorithm, We proposed a hybrid motion planning algorithm (TEB-CA, Timed Elastic Band-Collision Avoidance) that combines an improved traditional TEB algorithm and Optimal Reciprocal Collision Avoidance (ORCA) model to improve the ability of the robot to predict dynamic obstacles in advance and avoid collisions safely. Moreover, We also add new constraints to the traditional TEB algorithm, including: jerk constraints, smoothness constraints, and curvature constraints. The algorithm is implemented in C++ and evaluated experimentally in the Gazebo and Rviz simulation environments of the Robot Operating System (ROS), as well as in actual experimental tests on our car-like autonomous mobile robot ‘‘Little Ant’’ which proves the effectiveness of the method, and that the motion planning scheme is more effective in avoiding dynamic obstacles than the traditional TEB and DWA algorithms.[8]

METHODOLOGY:

Proposal of a hybrid motion planning algorithm combining the Timed Elastic Band (TEB) algorithm with the Optimal Reciprocal Collision Avoidance (ORCA) model. The algorithm includes additional constraints (jerk, smoothness, curvature) and is implemented in C++ for evaluation in Gazebo, Rviz, and real-world tests.

ADVANTAGE:

- Enhanced safety in dynamic environments.
- Improved navigation accuracy.
- Increased obstacle avoidance capabilities.
- Better adaptability to changing surroundings.
- Reduced risk of collisions.

DISADVANTAGE:

- Potential impact on real-time performance.
- Increased computational requirements.
- Dependency on significant processing power.
- Possible constraints on system scalability.
- Need for efficient resource allocation.

2.9 COMPARISON TABLE

REF. NO.	AUTHOR	TITLE	PUBLICATION /YEAR	METHODOLOGY	DEMERITS
[1]	NAHID CHOWDHURY, et.al.,	COMPUTER VISION AND SMOKE SENSOR BASED FIRE DETECTION SYSTEM	IEEE Xplore/ 2022	The proposed system combines computer vision and smoke sensor-based fire detection to create a more accurate and intelligent fire detection system.	The experiments are specific to gasoline and may not be directly applicable to other flammable substances or different environmental conditions
[2]	R.Karthik ,et.al.,	Voice Operated Intelligent Fire Extinguishing Vehicle	IEEE Access / 2023	This study proposes a hybrid motion planning algorithm (TEB-CA) for car-like autonomous mobile robots in dynamic environments	It Is not suitable for accidental environments or noisy environment
[3]	Shivani Deglurkar ,et.al.,	A Light- and Heat-Seeking Vine-Inspired Robot With Material-Level Responsiveness	IEEE Xplore / 2022	This research presents a voice-operated robotic vehicle for fire extinguishing	Voice commands can be unreliable in noisy environments or if there are issues with speech recognition accuracy
[4]	Shunsuke Aoki ,et.al.	RobotNest: Toward A Viable Testbed For IOT-Enabled Environments And Connected And Autonomous Robots	IEEE Xplore / 2021	The RobotNEST project establishes a testbed for IoT-enabled environments and autonomous robots to address technical, ethical, and societal challenges	Despite efforts, scaling such a comprehensive testbed to other locations might be challenging due to infrastructure and resource requirements

[5]	Vojtech Spurny ,et.al.,	Autonomous Firefighting Inside Buildings by an Unmanned Aerial Vehicle	IEEE Xplore / 2021	This study presents a system for autonomous indoor firefighting using a Micro-scale Unmanned Aerial Vehicle (MAV)	It is only work with static Obstacles environment not in dynamic obstacle environment
[6]	Wanning Wang, et.al.,	CHARACTERISTIC AND FIRE EXPERIMENT OF GASOLINE SPRAYING IN GAS STATION	IEEE Xplore/ 2020	The study involves experimental analysis of gasoline spraying in gas stations to understand the hazards associated with gasoline	Voice command control can be unreliable in noisy environments or if the system fails to recognize commands accurately
[7]	WEI CHAO, et.al.,	AN ELECTRIC FIRE FLAME DETECTION ALGORITHM BASED ON TEMPORAL CONVOLUTION	IEEE Xplore/ 2021	The algorithm focuses on using robotics for fire detection and extinguishing, particularly in environments where human intervention is unsafe	Smoke sensors have a limited detection range and might not detect fires in larger or open areas efficiently
[8]	Zhiwei Wang ,et.al.,	Motion Planning Method for Car-Like Autonomous Mobile Robots in Dynamic Obstacle Environments	IEEE Xplore / 2021	This research introduces a vine-inspired robot with material-level responsiveness to light and heat	It is not for any other purposed like assistance or anything else

Table 2.1: Comparison Table

CHAPTER 3
SYSTEM ANALYSIS

3.1 EXISTING SYSTEM

3.1.1 WATER-BASED FIRE EXTINGUISHING SYSTEMS

Fire extinguishing systems play a crucial role in protecting lives and property by suppressing fires effectively and efficiently. Among the most common and effective systems are water-based fire extinguishing systems. These systems use water as the primary extinguishing agent, leveraging its cooling and smothering properties to combat fires. Key types of water-based systems include sprinklers, deluge systems, and water mist systems.

3.1.2 SPRINKLER SYSTEMS

Sprinkler systems are widely used in residential, commercial, and industrial buildings. They operate by releasing water through sprinkler heads that activate individually when the heat from a fire reaches a certain threshold. This targeted approach helps to control or extinguish the fire while minimizing water damage to unaffected areas.

3.1.3 DELUGE SYSTEMS

Deluge systems are designed for high-hazard environments where rapid fire suppression is critical. Unlike sprinklers, deluge systems release water through all nozzles simultaneously when a fire is detected, providing a blanket of water to quickly suppress large fires.

3.1.4 WATER MIST SYSTEMS

Water mist systems utilize fine water droplets to create a mist that cools the fire and displaces oxygen, effectively suppressing the fire with minimal water usage and damage. These systems are particularly beneficial in environments where water conservation and minimal water damage are important.

3.1.5 FOAM-BASED FIRE EXTINGUISHING SYSTEMS

In environments where water may not be suitable, such as those involving electrical equipment or flammable liquids, other fire extinguishing systems are employed. Foam-based systems are particularly effective for flammable liquid fires. These systems use a foam concentrate mixed with water to create a blanket of foam that smothers the fire and prevents re-ignition by creating a barrier between the fuel and the air.

3.1.6 GAS-BASED FIRE EXTINGUISHING SYSTEMS

Gas-based fire extinguishing systems are used in areas where water or foam could cause significant damage, such as data centers, server rooms, and archives. These systems deploy inert gases (such as argon, nitrogen, or carbon dioxide) or chemical agents (such as FM-200 or Novec 1230) to suppress the fire by reducing the oxygen concentration or interrupting the chemical reaction of the fire.

3.2 DISADVANTAGES IN EXISTING SYSTEM

3.2.1 DAMAGE TO PROPERTY:

Many fire extinguishing systems, such as water-based and foam-based systems, can cause significant damage to property and contents. Water from sprinkler systems can lead to extensive water damage, while foam can harm sensitive equipment and surfaces, necessitating costly and time-consuming cleanup and repairs.

3.2.2 SUITABILITY FOR DIFFERENT FIRE TYPES:

Different fire extinguishing systems are often designed for specific types of fires, limiting their overall applicability. Water-based systems are ineffective against fires involving flammable liquids or electrical equipment, while foam systems are primarily suitable for liquid fires but less effective for other types. Gas-based systems work well for electrical and sensitive equipment fires but are unsuitable for open areas.

3.2.3 SAFETY CONCERNS:

The safety of occupants is a critical consideration. Water-based systems can create slippery conditions, posing evacuation risks. Foam can also create slippery surfaces, and gas-based systems can be hazardous to humans if they are not evacuated promptly, as these systems reduce oxygen levels or release chemicals that can be harmful when inhaled.

3.2.4 COST AND MAINTENANCE:

The cost and maintenance of fire extinguishing systems can be significant. While water-based systems have relatively low initial costs, they require a reliable water supply and pressure, and potential water damage can lead to high repair costs. Foam and gas-based systems typically have higher installation and maintenance costs, requiring specialized equipment and regular upkeep to ensure functionality.

3.2.5 OPERATIONAL LIMITATIONS:

Fire extinguishing systems often face operational limitations that can affect their performance in real-world scenarios. Water-based systems rely on individual sprinkler activation, which may be insufficient for large or rapidly spreading fires. Foam systems require precise application, which can be challenging in complex fire situations. Gas-based systems are effective only in airtight environments, limiting their use in areas with high ventilation or open spaces.

3.3. PROBLEM IDENTIFICATION

- Traditional water-based systems can cause significant water damage to property and contents. Foam-based systems can damage sensitive equipment and require extensive cleanup.
- Water-based systems are ineffective against electrical fires and flammable liquids, while foam systems are mainly suited for liquid fires but not for other types. Gas-based systems are not suitable for open or highly ventilated spaces.

- Water-based and foam systems can create slippery surfaces, posing evacuation risks. Gas-based systems can be hazardous to humans if evacuation is not timely, as they can reduce oxygen levels or release harmful chemicals.
- Traditional systems like foam and gas-based systems require specialized equipment and regular maintenance, leading to high costs. Water systems, while cheaper initially, can incur high repair costs due to water damage.
- Water-based systems rely on individual sprinkler activation, which may be insufficient for large or spreading fires. Foam systems need precise application, which can be challenging in complex scenarios. Gas systems are only effective in airtight environments.

3.4. OBJECTIVE

- To Develop advanced fire detection algorithms and sensors for swift identification and location of fires.
- To Implement robust navigation systems for autonomous movement through complex indoor spaces.
- To Design PyroPatrol to deploy fire-suppressing agents precisely at the fire source to minimize collateral damage.
- To Integrate artificial intelligence for real-time decision-making in analysing fire scenarios and adapting actions.
- To Ensure seamless interaction between PyroPatrol and human responders for coordinated firefighting efforts.
- To Engineer PyroPatrol to be versatile and adaptable to various fire types and environmental conditions.
- To Prioritize reliability and robustness for effective operation in challenging fire scenarios.
- To Incorporate safety features into PyroPatrol's design to prioritize the safety of occupants and firefighters.
- To Design PyroPatrol to be cost-effective over its lifecycle, considering initial investment, maintenance, and operational costs.

- To Promote public awareness and acceptance of autonomous fire-fighting technology through stakeholder engagement and demonstration of benefits.

3.5. PROPOSED SYSTEM

3.5.1 ADVANCED FIRE DETECTION:

PyroPatrol utilizes state-of-the-art fire detection algorithms and sensors to swiftly identify and locate fires within indoor spaces.

3.5.2 TARGETED FIRE SUPPRESSION:

PyroPatrol is designed to deploy fire-suppressing agents, such as water, foam, or dry chemicals, precisely at the fire source, minimizing collateral damage while effectively extinguishing the flames.

3.5.3 REAL-TIME DECISION MAKING:

Integrated artificial intelligence enables PyroPatrol to analyze fire scenarios in real-time, make quick and informed decisions, and adapt its actions based on changing environmental conditions.

3.5.4 HUMAN-ROBOT COLLABORATION:

PyroPatrol facilitates seamless interaction between the robot and human responders, allowing for coordinated firefighting efforts and enhancing overall firefighting effectiveness and safety.

3.5.5 VERSATILITY AND ADAPTABILITY:

PyroPatrol is versatile and adaptable to various fire types and environmental conditions, making it suitable for deployment in diverse indoor settings, including commercial buildings, warehouses, and industrial facilities.

3.5.6 RELIABILITY AND ROBUSTNESS:

PyroPatrol is engineered with high reliability and robustness to operate effectively in challenging fire scenarios, ensuring its readiness to respond to emergencies whenever needed.

3.5.7 SAFETY AND RISK MITIGATION:

Safety features are incorporated into PyroPatrol's design to prioritize the safety of both occupants and firefighters, including redundant systems, fail-safe mechanisms, and adherence to safety standards.

3.5.8 COST EFFICIENCY:

PyroPatrol is designed to be cost-effective over its lifecycle, considering factors such as initial investment, maintenance, and operational costs, while delivering superior fire suppression capabilities compared to traditional firefighting methods.

3.5.9 PUBLIC AWARENESS AND ACCEPTANCE:

Efforts are made to promote public awareness and acceptance of autonomous fire-fighting technology through stakeholder engagement and demonstration of the benefits of PyroPatrol in enhancing fire safety measures and reducing human intervention in hazardous scenarios.

3.6. ADVANTAGES OF PROPOSED SYSTEM

3.6.1. DAMAGE TO PROPERTY

PyroPatrol can use targeted fire suppression agents such as dry chemicals, which minimize collateral damage to property and sensitive equipment. This precise application ensures that only the affected area is treated, reducing overall damage.

3.6.2. SUITABILITY

PyroPatrol can be equipped with multiple types of fire suppression agents, allowing it to adapt to various fire scenarios, including electrical fires, flammable liquids, and confined or open spaces. This versatility makes it effective across different fire types.

3.6.3. SAFETY CONCERNS

PyroPatrol operates autonomously, reducing the need for human intervention in hazardous environments. It can be deployed quickly without putting human firefighters at risk, and its use of safe suppression agents ensures that evacuation routes remain safe.

3.6.4. COST AND MAINTENANCE

Although the initial investment in PyroPatrol might be higher, its autonomous operation reduces long-term maintenance costs. The precision and efficiency of its suppression capabilities also minimize damage-related repair costs, offering cost efficiency in the long run.

3.6.5. OPERATIONAL LIMITATIONS

PyroPatrol's mobility and advanced sensors allow it to navigate towards the fire source and apply suppression agents precisely where needed. Its ability to move through complex environments and adapt to changing conditions overcomes the limitations of fixed systems.

the proposed system offers a compelling solution to the challenges of food quality detection and reporting in the food industry. Its accuracy, efficiency, compliance, and consumer-centric approach make it a valuable tool for businesses seeking to uphold the highest standards of quality and safety in their products.

CHAPTER 4
SYSTEM SPECIFICATION

4.1 HARDWARE SPECIFICATION

- **Microcontroller** **: ARDUINO UNO R3**
- **Single Channel Relay**
- **LDR Motor Driver**
- **IR Flame Sensor**
- **5V Water Pump**
- **Nozzle**
- **Jumper Wires**

4.2 SOFTWARE SPECIFICATION

- **Operating system** **: Windows 11**
- **Development Tool** **: Arduino IDE**

4.3 HARDWARE DESCRIPTION

4.3.1 ARDUINO UNO R3 (MICROCONTROLLER)

The Arduino Uno R3 serves as the central processing unit of the system, responsible for coordinating all operations. It receives inputs from sensors, processes data using its onboard microcontroller, and controls output devices accordingly. With its user-friendly interface and robust development environment, the Arduino Uno R3 ensures efficient coordination and execution of tasks, making it a versatile and reliable choice for the system's intelligence.

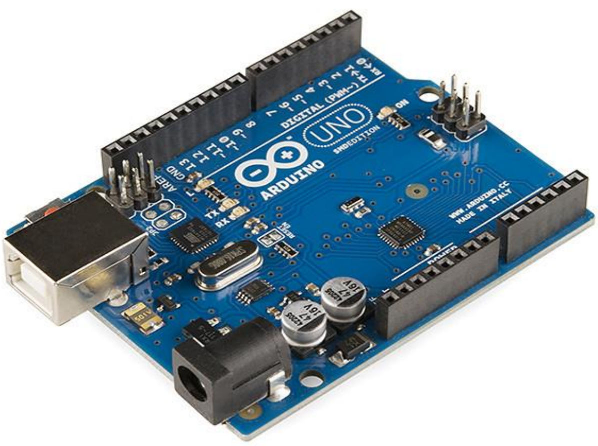

Figure 4.3.1.1: Arduino UNO R3

4.3.2. SINGLE CHANNEL RELAY

The single channel relay, under the control of the Arduino Uno R3, acts as a switch to regulate the power supply to devices like the water pump. This enables precise control over the activation of these devices based on input from sensors or programmed instructions. By allowing the Arduino Uno R3 to manage power distribution effectively, the relay optimizes the system's performance for efficient fire suppression.

Figure 4.3.2.1: Single Channel Relay

4.3.3. L298 MOTOR DRIVER

The LDR motor driver interfaces with the motor responsible for the system's movement, interpreting signals from the Arduino Uno R3 to adjust the motor's speed and direction. This enables precise navigation towards fire sources, facilitated by the Arduino Uno R3's real-time processing capabilities. With the LDR motor driver's assistance, the system can maneuver effectively to reach and suppress fires, minimizing response time and maximizing efficiency.

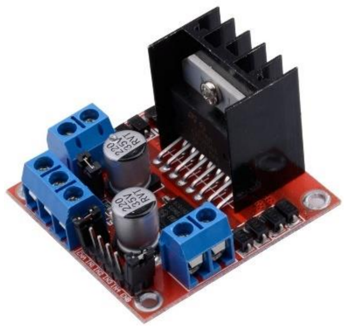

Figure 4.3.3.1: L298 Motor Driver

4.3.4. IR FLAME SENSOR

The IR flame sensor detects the presence of flames by sensing infrared radiation emitted by the fire. It provides crucial input to the Arduino Uno R3, triggering the activation of the water pump and nozzle for fire suppression. This rapid response, facilitated by the Arduino Uno R3's quick data processing capabilities, ensures timely extinguishment of fires, reducing potential damage and risk.

Figure 4.3.4.1: IR Flame Sensor

4.3.5. 5V WATER PUMP

Under the control of the Arduino Uno R3 through the relay, the 5V water pump delivers water from a reservoir to the nozzle for fire suppression. Its efficient operation, managed by the Arduino Uno R3's precise control signals, ensures a steady and reliable water supply. By effectively distributing water to extinguish fires, the pump enhances the system's overall reliability and effectiveness in fire suppression efforts.

Figure 4.3.5.1: 5V Water Motor

4.3.6. NOZZLE

The nozzle plays a critical role in dispersing water in a controlled manner for optimal fire coverage. Guided by the Arduino Uno R3's commands, the nozzle directs water towards the fire source effectively, minimizing water wastage and maximizing extinguishing efficiency. Its design and placement, coordinated with the Arduino Uno R3, ensure thorough coverage of fire-affected areas, facilitating swift and effective suppression of fires.

Figure 4.3.6.1: Nozzle

4.3.7. JUMPER WIRES

Jumper wires serve as essential connections between system components, enabling seamless integration and communication. Facilitated by the Arduino Uno R3's precise control over electrical signals, jumper wires establish reliable pathways for data exchange and power distribution. Their use simplifies system assembly and maintenance, guided by the Arduino Uno R3's user-friendly development environment, enhancing the accessibility and functionality of the overall fire suppression system.

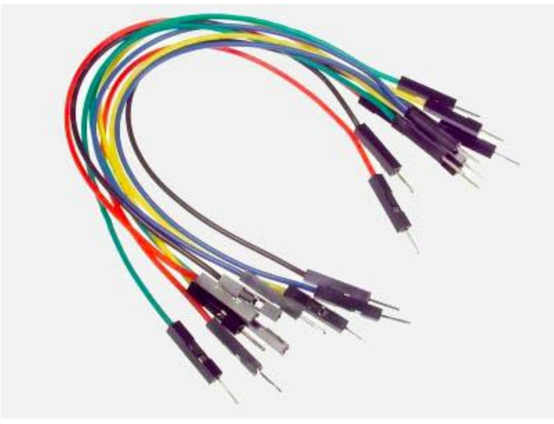

Figure 4.3.7.1: Jumper Wire

4.4. SOFTWARE DISCRIPTION

4.4.1. ARDUINO IDE

The Arduino IDE serves as the primary software platform dedicated to programming Arduino microcontroller boards like the Arduino Uno R3. It provides essential tools and features for crafting, refining, and deploying code for Arduino-based projects. With its user-friendly interface and intuitive layout, the IDE caters to users of all skill levels, enabling them to bring their ideas to life effortlessly. Powered by a robust programming language inspired by C and C++, the IDE offers a rich assortment of built-in functions and libraries for interfacing with hardware components. Crucially, the IDE streamlines the code compilation and uploading process, facilitating rapid deployment of code to Arduino boards. Additionally, it fosters a collaborative community environment, where users can share knowledge, seek assistance, and collaborate on projects. In essence, the Arduino IDE stands as a beacon of innovation, empowering individuals to unleash their creativity and transform ideas into tangible prototypes with ease.

CHAPTER 5

SYSTEM DESIGN AND IMPLEMENTATION

5.1 ARCHITECTURE DIAGRAM

The system architecture for the methodology described is structured into distinct modules, each handling specific tasks within food quality monitoring device. The Data Acquisition Module serves as the backbone for collecting sensor data from various sensors integrated into the food quality detection system, establishing communication, retrieving raw data, and aggregating it into a structured format for processing. Its role includes ensuring data integrity, implementing error-checking mechanisms, and providing timestamping for chronological analysis. The Data Processing Module interprets collected sensor data, employing advanced algorithms to assess food quality parameters, detect anomalies, and extract meaningful insights. Through quality assessment, trend analysis, and anomaly detection, it identifies patterns and abnormalities, communicating analysis results through reports and visualizations. The Alerting and Notification Module acts as the frontline defense mechanism, monitoring processed sensor data for critical events, triggering alerts, and notifying users in real-time via various communication channels, facilitating timely intervention and resolution of issues.

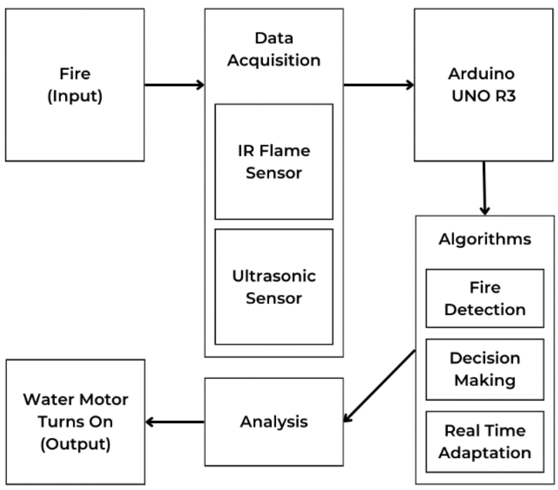

Figure 5.1.1: Flow Diagram

5.2 CIRCUIT DIAGRAM

The circuit diagram illustrates the setup of an autonomous fire-fighting robot, integrating various components to achieve fire detection, navigation, and suppression. At the heart of the system is the Arduino microcontroller, which orchestrates the interactions between sensors, motors, and other peripherals. The Arduino is mounted on a breadboard, simplifying connections and enabling easy modifications during the prototyping phase.

Four DC motors are connected to the motor driver, which is in turn controlled by the Arduino. These motors provide mobility to the robot, allowing it to navigate through the environment. The motor driver ensures that the motors receive the appropriate voltage and current, and it enables control over their speed and direction. The power for the motors is supplied by a 9V battery, ensuring sufficient power for the robot's movement.

Fire detection is handled by a combination of infrared sensors and a flame sensor. The infrared sensors are positioned on multiple sides of the robot to provide comprehensive coverage and obstacle detection, preventing collisions as the robot navigates towards the fire. The flame sensor is focused on detecting the presence of fire, sending signals to the Arduino when a fire is detected. This triggers the fire suppression mechanism.

A relay module, controlled by the Arduino, is used to activate the fire suppression system. The relay switches on a pump or actuator that dispenses the fire-suppressing agent stored in a container mounted on the robot. The dispensing mechanism is designed to target the detected fire accurately, ensuring efficient suppression.

Additionally, the circuit includes a voltage regulator to ensure stable power supply to the sensitive electronic components, such as the sensors and Arduino. This prevents voltage fluctuations from affecting the performance and reliability of the system.

The wiring is meticulously organized to ensure reliable connections and minimize interference. The sensors are connected to the Arduino via digital and analog input pins, while the motor driver and relay are connected via digital output pins. This setup enables the Arduino to process sensor data in real-time, make decisions, and control the motors and suppression mechanism accordingly.

Overall, this circuit configuration showcases a well-integrated system capable of autonomous fire detection, navigation, and suppression. It highlights the effective use of sensors, motor control, and relays to achieve the desired functionality in a compact and efficient design. The modular nature of the setup allows for easy upgrades and enhancements, making it a robust platform for developing advanced fire-fighting robots.

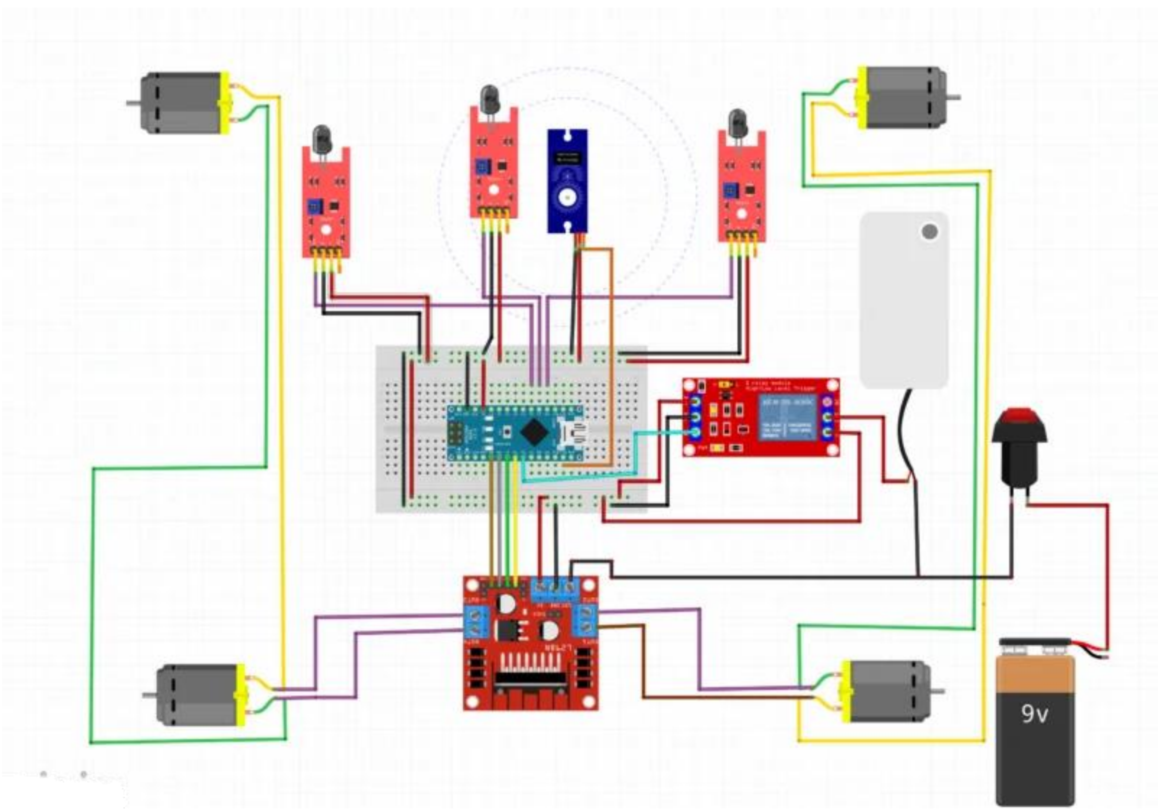

Figure 5.2.1: Circuit Diagram

5.3 MODULES

- Obstacle Avoidance using Ultrasonic Sensor.
- Fire Detection using IR Flame Sensor.
- Water Suppression system using Water Motor.

5.3.1 OBSTACLE AVOIDANCE AND PATH DETECTION USING ULTRASONIC SENSOR

The Ultrasonic Sensor is a critical component for enabling the robot to navigate safely through indoor environments. It operates by emitting high-frequency sound waves, which then bounce off obstacles and return to the sensor. By measuring the time it takes for the sound waves to return, the sensor can calculate the distance to the obstacle. This information is used by the robot to detect and avoid collisions. The continuous scanning of its surroundings allows the robot to create a real-time map of the area, identify clear paths, and dynamically adjust its route to avoid obstacles. This capability ensures that the robot can efficiently and autonomously navigate towards its destination without human intervention, enhancing its ability to operate effectively in complex and dynamic environments.

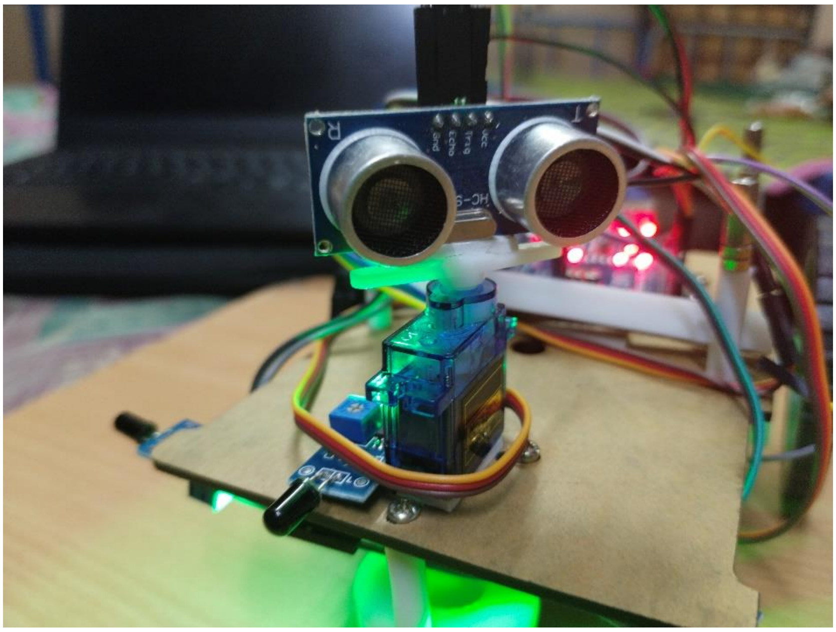

Figure 5.3.1.1: Obstacle Avoidance using Ultrasonic Sensor

5.3.2. FIRE DETECTION USING IR FLAME SENSOR

The IR Flame Sensor is designed to detect the specific wavelengths of infrared radiation emitted by flames. When a fire occurs, it emits infrared light that the sensor can pick up, triggering an alert to indicate the presence of a fire. This module enables the robot to quickly and accurately identify the location of a fire, allowing it to respond promptly. The sensitivity of the IR Flame Sensor ensures that even small fires can be detected early, which is crucial for preventing the fire from spreading and causing more significant damage. The ability to detect flames reliably is essential for the robot's effectiveness in fire-fighting scenarios, providing a crucial early warning that enables immediate action.

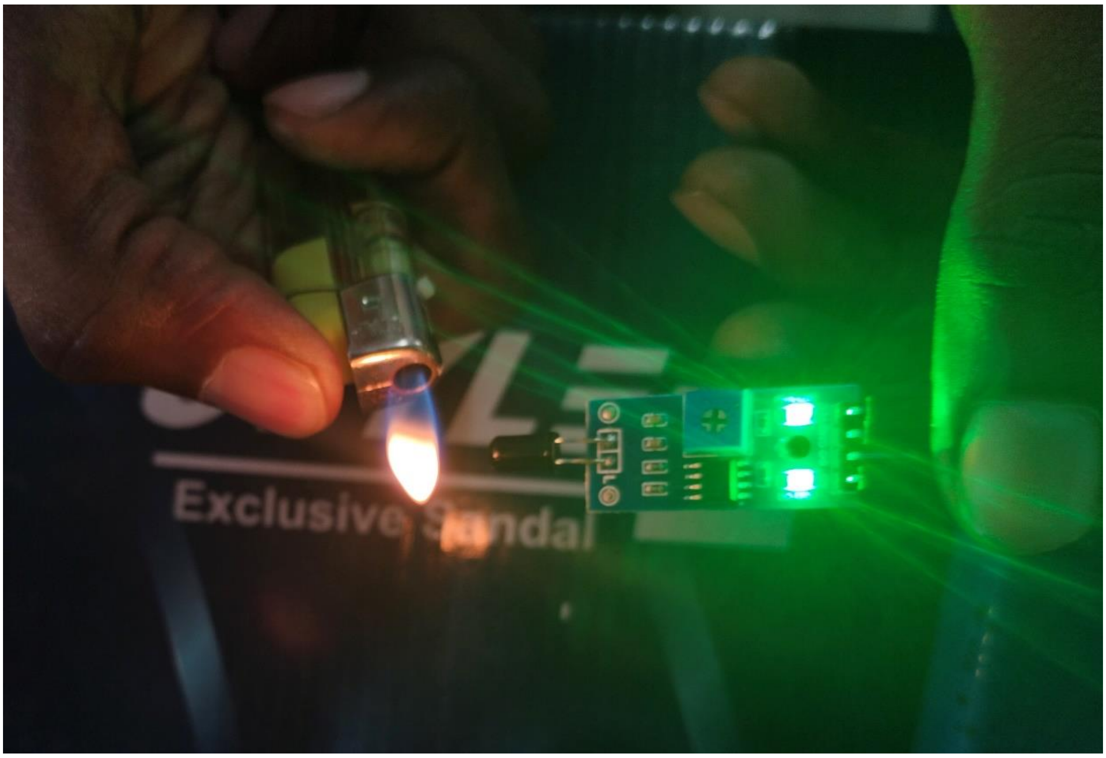

Figure 5.3.2.1: Fire Detection IR Flame Sensor

5.3.3. WATER SUPPRESSION SYSTEM USING WATER MOTOR

The Water Motor is the component responsible for delivering the fire-suppressing agent to the detected fire. Upon receiving a signal from the IR Flame Sensor indicating the presence of a fire, the robot activates the Water Motor. The motor then pumps water from an onboard reservoir through hoses or nozzles, directing it at the flames to extinguish them. This automated system ensures a swift and targeted response to fires, minimizing damage and preventing the fire from spreading. The integration of the Water Motor with the fire detection system allows the robot to operate autonomously, effectively tackling fire incidents without the need for human intervention. This capability is essential for rapid and effective fire suppression, enhancing the safety and security of indoor environments.

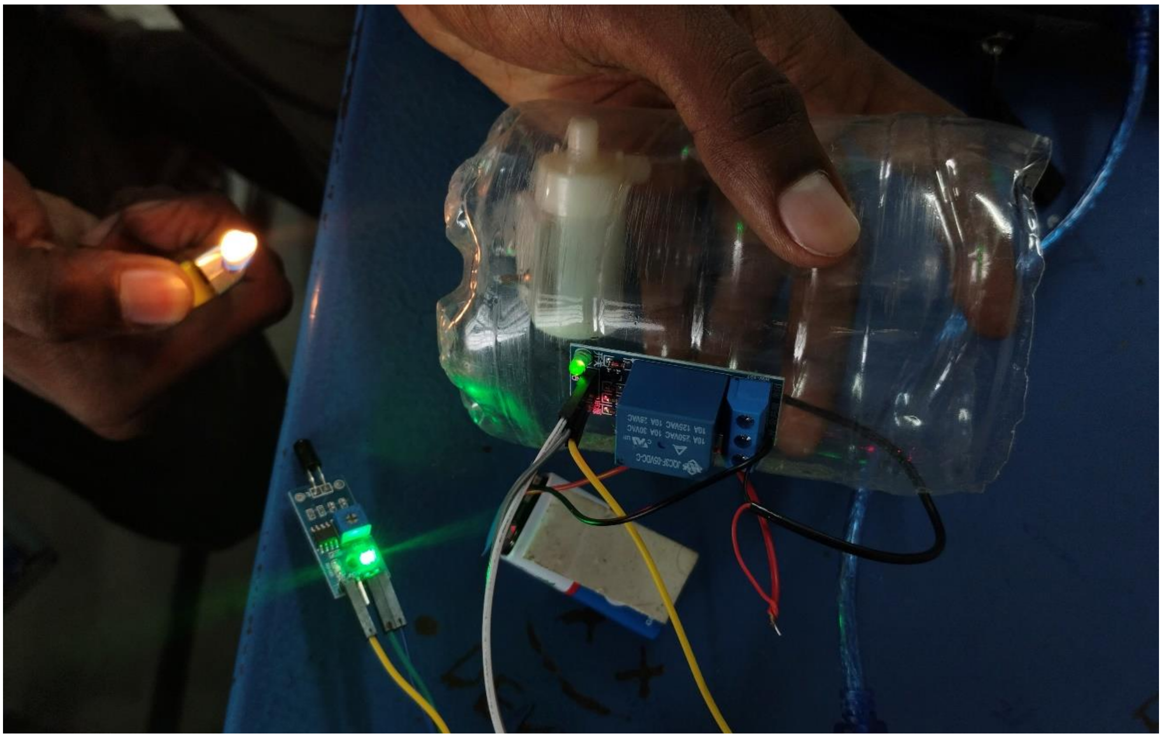

Figure 5.3.3.1: Water Suppression System using Water Motor

5.4 RESULT

The experimental setup features a fire-extinguishing robot designed to autonomously detect and extinguish fires. The robot integrates various components, including sensors, actuators, and a control unit, to perform its functions efficiently.

The image shows the robot equipped with a water bottle for holding the fire-suppressing agent, an actuator for dispensing the agent, multiple sensors, and a power supply unit. The robot uses ultrasonic sensors for obstacle detection and infrared sensors for fire detection. These sensors are strategically placed to ensure comprehensive coverage and accurate detection in various directions.

The water bottle is connected to a dispensing actuator, likely a pump or servo motor, which controls the flow of water. This setup allows the robot to effectively aim and deploy the water towards the detected fire. The wheels and motor system are configured to enable autonomous movement. The sensors provide real-time data to the control unit, allowing the robot to navigate through the environment, avoid obstacles, and approach the fire source.

The central control board, likely an Arduino or similar microcontroller, is connected to the various sensors, actuators, and power sources. This board processes sensor data, executes navigation algorithms, and controls the dispensing mechanism. The 9V battery provides the necessary power to the system, ensuring mobility and operational functionality. The components are mounted on a multi-tiered chassis, providing stability and easy access for maintenance and adjustments. The wiring is organized to minimize interference and ensure reliable connections.

The integration of advanced sensors allows the robot to detect fires quickly and accurately, enhancing response time. The autonomous navigation system ensures the robot can move efficiently through different environments, avoiding obstacles and reaching fire sources with precision. The water dispensing mechanism is designed to target and suppress fires effectively, demonstrating the robot's capability to handle fire emergencies. The fire-extinguishing robot, as depicted in the image, showcases a functional prototype with essential features for autonomous fire detection and suppression. The successful integration of sensors, navigation systems, and dispensing mechanisms highlights the robot's potential for improving fire safety in various settings. Future enhancements could focus on optimizing sensor accuracy, improving mobility in complex terrains, and increasing the capacity of the fire-suppressing agent.

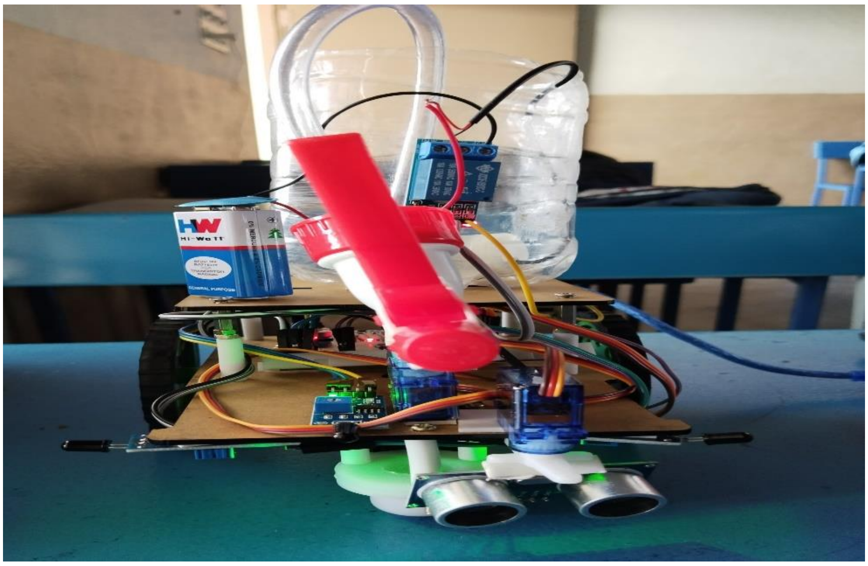

Figure 5.3: Result

CHAPTER 6

CONCLUSION AND FUTURE ENHANCEMENT

6.1 CONCLUSION

In conclusion, The PyroPatrol project marks a significant advancement in firefighting robotics, providing an autonomous solution to enhance indoor fire safety. Through its innovative design and autonomous capabilities, PyroPatrol can effectively detect and locate fires, navigate through indoor environments, and deploy fire-suppressing agents, thereby reducing response times and minimizing risks to occupants and firefighters.

Resilience and robustness are crucial for the reliability of firefighting robots in unpredictable conditions. Research into fault-tolerant control algorithms, self-repair mechanisms, and resilient communication networks will further enhance their effectiveness.

In summary, ongoing innovation in firefighting robotics promises to revolutionize fire safety measures, making them more efficient, reliable, and responsive. By leveraging advanced technologies and interdisciplinary approaches, these systems can save lives and minimize the impact of fire emergencies on human lives and property.

6.2 FUTURE ENHANCEMENT

One enhancement for PyroPatrol involves integrating advanced sensors to improve fire detection and environmental assessment. Adding thermal imaging cameras can provide detailed heat maps, enabling the robot to identify hotspots and monitor fire spread more accurately. Gas detectors can detect hazardous gases, and LiDAR sensors can enhance obstacle detection and path planning, allowing the robot to navigate more precisely.

Leveraging machine learning and artificial intelligence (AI) can significantly enhance PyroPatrol's capabilities. Implementing machine learning algorithms can help predict fire spread patterns and optimize firefighting strategies. AI can improve decision-making, allowing the robot to adapt to complex fire scenarios and operate more autonomously, reducing the need for human intervention.

Developing collaborative robotics is another promising enhancement. Creating a multi-robot system where PyroPatrol units and drones communicate and coordinate can improve firefighting efficiency. Drones can provide aerial views and identify hotspots, enhancing situational awareness and allowing for more effective and coordinated firefighting efforts.

Improving PyroPatrol's mobility is also essential. Enhancements could include designing robots that can navigate various terrains, such as stairs and uneven surfaces. Developing more compact and agile designs would allow PyroPatrol to maneuver through tight spaces, making it suitable for a wider range of indoor applications.

Lastly, focusing on resilience and robustness is crucial for the reliability of PyroPatrol. Future research should explore fault-tolerant control algorithms, self-repair mechanisms, and resilient communication networks to ensure the robot can perform reliably under adverse conditions. These enhancements will increase the robot's operational lifespan and effectiveness, making it a more dependable tool in fire safety and emergency response.

APPENDIX

PROGRAM:

```
int motor1pin1 = 2;
int motor1pin2 = 3;
int motor2pin1 = 4;
int motor2pin2 = 5;
const int sensorMin = 0;     //  sensor minimum
const int sensorMax = 1024;  // sensor maximum
void setup() {
  Serial.begin(9600);
  pinMode(motor1pin1, OUTPUT);
  pinMode(motor1pin2, OUTPUT);
  pinMode(motor2pin1,   OUTPUT);
  pinMode(motor2pin2, OUTPUT);
  pinMode(6, OUTPUT);
}
void loop() {
  int sensorReading  = analogRead(A0);
  int range = map(sensorReading,  sensorMin, sensorMax, 0, 3);
  digitalWrite(6, LOW);
  delay(500);
  switch (range) {
  case 0:    // A fire closer than 1.5 feet away.
    digitalWrite(motor1pin1, LOW);
```

```
    digitalWrite(motor1pin2, LOW);
    digitalWrite(motor2pin1, LOW);
    digitalWrite(motor2pin2, LOW);
    break;
  case 1:    // A fire between 1-3 feet away.
    digitalWrite(motor1pin1, LOW);
    digitalWrite(motor1pin2, HIGH);
    digitalWrite(motor2pin1, HIGH);
    digitalWrite(motor2pin2, LOW);
    break;
  case 2:    // No fire detected.
    digitalWrite(motor1pin1, HIGH);
    digitalWrite(motor1pin2, LOW);
    digitalWrite(motor2pin1, LOW);
    digitalWrite(motor2pin2, HIGH);
    digitalWrite(6, LOW);
    break;
  }
  delay(1);
}
```

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