

AI SPECIALIZED FIRE FIGHTING ROBOT WITH FIRE SENSORS AND 6 WHEEL DRIVE

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechanical Engineering

By

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APRIL - 2024



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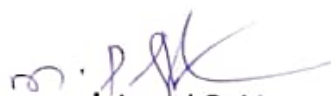
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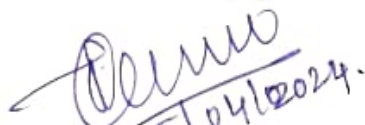
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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of JASON VALENTINE DOSS (Reg. No. 40150014) who carried out the project entitled "AI SPECIALIZED FIRE FIGHTING ROBOT WITH FIRE SENSORS AND 6 WHEEL DRIVE" under our supervision from December 2023 to April 2024.


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I, JASON VALENTINE DOSS (Reg. No.40150014) hereby declare that the Project Report entitled "**AI SPECIALIZED FIREFIGHTING ROBOT WITH FIRE SENSORS AND 6 WHEEL DRIVE**" done by me under the guidance of **Dr. M. PURUSOTHAMAN., M.E., Ph.D.** is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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ABSTRACT

Novel approaches to firefighting operations are required due to the rising frequency and intensity of flames in urban and industrial settings. In order to improve efficiency and safety in firefighting settings, this article outlines the design and development of an Automatic Firefighting Robot (AFR) outfitted with a 6-wheel drive system. The AFR is built to navigate through difficult terrains on its own, including locations that have been devastated by fire and areas that are frequently filled with debris and impediments. With the help of a sturdy 6-wheel drive system, the robot can move more steadily and maneuverable over rocky and uneven terrain, enabling efficient firefighting operations even in challenging terrain. The robotic platform integrates advanced sensors for environmental perception, including infrared cameras and gas sensors, enabling real-time detection of fire sources and hazardous gases. Through comprehensive simulations and field tests, the efficacy and reliability of the AFR in firefighting scenarios are evaluated. Results demonstrate the capability of the robot to autonomously navigate and suppress fires in challenging environments, highlighting its potential as a valuable tool for firefighting agencies in enhancing operational efficiency and protecting human lives.

TABLE OF CONTENTS

CHAPTER No.	TITLE	PAGE No.
	ABSTRACT	v
	LIST OF FIGURES	viii
	LIST OF TABLES	ix
	LIST OF SYMBOLS AND ABBREVIATIONS	x
1	INTRODUCTION	1
	1.1 BACKGROUND OF STUDY	1
	1.2 PROBLEM STATEMENT	2
	1.3 FEASIBILITY SIGNIFICANCE RELEVANCY	2
	1.3.1 Feasibility	3
	1.3.2 Significance	3
	1.3.3 Relevancy	3
2	LITERATURE SURVEY	5
	2.1 OVERVIEW OF AN AUTONOMOUS MOBILE PLATFORM	5
	2.2 LINE FOLLOWING	6
	2.3 FLAME DETECTION	7
	2.4 FIRE EXTINGUISHING	8
3	AIM AND SCOPE	10
	3.1 AIM AND SCOPE	10
	3.2 SCOPE OF THE PROJECT	11
	3.3 SALIENT FEATURES	12
4	MATERIALS AND EXPERIMENTAL METHOD	14
	4.1 RESEARCH METHODOLOGY	14
	4.2 MATERIALS	18

4.3	KEY MILESTONES	21
4.4	PROGRAMMING THROUGH ARDUINO	22
4.5	6 WHEEL ROBOT FRAME	23
4.6	ARDUINO BOARD	25
4.7	IR SENSOR	26
4.8	MOTOR DRIVER	28
4.9	POWER SOURCE	28
5	RESULTS AND DISCUSSION	30
5.1	RESULTS	30
5.2	DISCUSSION	30
6	SUMMARY AND CONCLUSION	32
6.1	SUMMARY	32
6.2	CONCLUSION	33
	REFERENCES	34

LIST OF FIGURES

FIGURE No	TITLE	PAGE No.
4.1	OVERFLOW OF PROJECT	15
4.2	WORKING OF AFFMP	16
4.3	MOTOR DRIVER	18
4.4	FLAME SENSOR	18
4.5	PLYWOOD	19
4.6	ARDUINO UNO	19
4.7	POWER SOURCE	20
4.8	FLAME SENSOR	20
4.9	METAL FRAME	24
4.10	ARDUINO BOARD	25
4.11	IR SENSORS	27
4.12	MOTOR DRIVER	28
4.13	POWER SOURCE	29
5.1	6 WHEEL ROBOT	30

LIST OF TABLES

TABLE No	TITLE	PAGE No.
2.1	FIRE CLASSES	8
2.2	FIRE EXTINGUISHING	9
4.1	MATERIALS	18

LIST OF SYMBOLS AND ABBEREVIATIONS

AFFMP	Autonomous Fire Fighting Mobile Platform
IR	Infrared sensors
PWM	Pulse Width Modulation
CO ₂	Carbon dioxide
O ₂	Oxygen
IDE	Integrated Development Environment

CHAPTER 1

INTRODUCTION

An employee's life is constantly in jeopardy when they are assigned a hazardous duty like fire detection and extinguishing. A mobile robot can help prevent unfortunate events or human casualties by carrying out this duty in a fire-prone location. The goal of this project is to create an autonomous firefighting mobile platform (AFFMP), which will be outfitted with basic firefighting tools and be able to patrol hazardous places using a guiding track in order to detect fires early. The fire extinguishing device positioned on its platform will be used to quickly put out the flames once the source of the fire has been located. A homing algorithm is added to a standard line-following algorithm to guide the patrolling movement along a set of lines. After leaving the patrol path, the AFFMP's responsibilities include avoiding obstacles, utilizing a front flame sensor to locate the fire source more precisely, and putting out the flames. Before the platform was deployed, the input from flame sensors was carefully calibrated based on the surrounding environment, outside interference, and the movement of the AFFMP in order to detect the source of the fire. The platform's ability to function as an independent device that can monitor a designated region, detect fire, and put out a flame has been demonstrated by the development work completed on it thus far.

1.1 BACKGROUND OF STUDY

Even though fighting fires is a very dangerous operation, human operators nevertheless perform it frequently, endangering human life, which is already precious. It is therefore highly desirable that AFFMP take over or at least partially help in executing the routine and fundamental firefighting tasks. AFFMP can be implemented in a number of methods, but the majority of them are used only when necessary. This project is rather unique in the way it is being implemented; the AFFMP will use the directing track to find fire sources and traverse through a region while on patrol, all while utilizing its continuous monitoring capability, which operates around the clock, seven days a week.

The work done to create an AFFMP that safely and quickly puts out fires in designated areas is described in this study. Patrolling inside a guiding track and continuously checking for fire using the flame sensors constitute monitoring. In the event that a fire is discovered, AFFMP will make an effort to pinpoint the exact location of the fire source. After determining the location, it will leave its guided track, approach towards the flame, and use the integrated fire extinguishing sub-system to put out the flames. It returns to the guiding track to resume the patrolling duties once the flame is totally extinguished. Because every step is entirely automated by employing a microcontroller system to execute the flame sensing system and the flame submission system, none of the operations require human control to occur. There is no denying that using robots to help humans complete their hazardous and everyday duties can help reduce the amount of risk involved. Put another way, a robot can be utilized to replace a human in any dangerous profession or duty that calls for accuracy, endurance, high efficiency, and repetition. Robots can be employed in nearly every industry, including manufacturing, agriculture, healthcare, assembly lines for parts and components, housework to improve human lives, and even entertainment. Time has shown the effectiveness, usefulness, and benefits that robot can make to society's citizens.

1.2 PROBLEM STATEMENT

One of the most difficult and dangerous jobs that people, in general, or firefighters in particular, must perform is battling fires. It is theoretically possible to use robots to help or partially replace humans in carrying out routine and fundamental firefighting tasks. As a result, this embedded project has the feasibility of being implemented in an actual industry. For this project, I have to create an autonomous firefighting mobile platform that appeals to my interests and draws attention, and that is also realistically applicable in actual hazardous locations. After this project is finished, it is intended that the AFFMP, which is prepared with the fundamentals of fighting fires, would greatly lessen the hazards involved in the firefighting activities that firefighters experience and share some of the load off the firefighters.

1.2 FEASIBILITY RELEVANCY AND SIGNIFICANCE OF PROJECT

1.3.1 Feasibility

The feasibility of developing an AI specialized firefighting robot with fire sensors and 6-wheel drive is supported by recent technological advancements across multiple domains. Advances in robotics, artificial intelligence, sensor technology, and mobility systems provide the necessary foundation for integrating these capabilities into a single platform. Furthermore, the existence of several prototypes of firefighting robots with diverse functionalities demonstrates the technical feasibility of such integration. Modular design principles offer an additional advantage, as they streamline development processes and enable seamless integration of various components, thereby enhancing the project's manageability and feasibility. These factors collectively contribute to the feasibility of creating an innovative firefighting robot equipped with advanced capabilities for enhanced emergency response.

1.3.2 Relevancy

Globally, the frequency and intensity of wildfires and urban fires are rising, which highlights the urgent need for creative ways to improve firefighting skills. Given this, the use of specialist firefighting robots becomes an essential tactic to deal with the problems brought on by these increasingly frequent fire events. The safety of human firefighters is of utmost importance. By using robots to do duties in dangerous settings remotely, firefighting operations can considerably reduce hazards. Additionally, these robots are more efficient at detecting and responding to fires than traditional methods since they are outfitted with cutting-edge AI and sensor technologies. This improved responsiveness could save property damage and, more significantly, save lives, highlighting how crucial it is to incorporate robotics into emergency response plans.

1.3.3 Significance

The significance of implementing AI specialized firefighting robots equipped with fire sensors and 6-wheel drive lies in their transformative impact on emergency response capabilities. By integrating fire sensors with AI algorithms, these robots gain the ability to autonomously detect and assess fire incidents, facilitating rapid and informed decision-making in dynamic firefighting scenarios. Moreover, their 6-wheel drive configuration ensures superior mobility, enabling navigation through challenging

terrain and obstacles commonly encountered in firefighting environments. This enhanced mobility not only improves the robot's effectiveness but also enhances the safety of responders by accessing otherwise inaccessible areas. Furthermore, the scalability of deploying such robots augments existing firefighting capabilities, enabling responders to cover larger areas more efficiently during emergencies. Ultimately, by automating certain firefighting tasks, these robots optimize resource allocation, allowing human firefighters to focus on strategic activities such as coordinating emergency response efforts and evacuations, thereby enhancing overall effectiveness and safety in firefighting operations.

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW OF AN AUTONOMOUS VEHICLE

In essence, many different concepts and applications for mobile robots that can function in dangerous environments, and these are always being developed, improved, and modified. A mobile robot is one example of a device which shall be used for rescue and to move people out of critical damage, such fires, earthquakes, and other situations. The sections that follow include descriptions of a few of the works. A robot called Fire Searcher is made to operate in harsh environments, such scorching heat or toxic fumes. It relays vital information to its operator at a remote location while keeping an eye on the victims' and fire site's internal conditions [1]. In the meantime, Tokyo Fire Department has created a new kind of autonomous firefighting mobile platform called Jet Fighter. It is capable of being operated and controlled remotely, and once the fire source has been located, it can put out the flames. It uses a wireless connection system and has a monitoring system installed. Its autonomous navigation system has an obstacle avoidance mechanism integrated into it[2]. Additionally, another kind of transportable Autonomous Fire Fighting Mobile Platform is made expressly to be hurled into a fire scene in order to gather information, look for victims, and remove them from the area [3].

In emergency situations, the victims can use the built-in speaker and microphone system to communicate with the operator, who can control it [3]. Additionally, this device has a camera to record the fire scene and sensors to measure temperature, CO₂ and O₂ concentrations [3]. It is impact resistant, waterproof, and specifically made to be thrown into a fire zone, meaning it can endure temperatures as high as 1500°C [3]. For intra-system communication, a mobile platform can also be constructed around a wireless sensor network, for example, by utilizing ZigBee wireless communication modules. Relatively large amounts of data, including audio and video from the robot to an off-site command hub. It also makes it possible to track the position of the robot using the wireless sensor network's signal strength [4]. Escharotics' BEAR (Battlefield Extraction-Assist Robot) is a sort of rescue robot designed to resemble a humanoid that can lift and carry victims for searching and

rescue operations, as well as for casualty extraction and unsafe building evacuation. But the price is too high [5]. Tehzeeb is a different kind of rescue robot that locates and navigates in visually challenging environments, like areas with a lot of smoke [3], using a laser scanner module, a manipulator, and map generating algorithms. All things considered, the primary methodology employed to create the AFFMP was rather traditional and uncomplicated. Its primary purpose was to detect the presence of walls, obstructions, and fires [2,4]. As a result, it needs to have a strong wall-following algorithm that takes into account factors like the brightness of the wall's colours—whether they are white or black [8]. The AFFMP unit may need to go closer to the fire source (about 30 cm away) and even close to the source if fire put it out in order to increase the accuracy of the flame detection system [2, 4]. The AFFMP was created to find fire (often represented by a candle flame), find its source, put it out as quickly as possible, and then find its way back to the starting point inside a predetermined maze of interconnecting passageways and chambers [2].

2.2 LINE FOLLOWING

Utilizing three sets of Infrared Radiation (IR) sensors, the AFFMP's line following function was put into practice. For both the IR emitter and IR receiver, each set of IR sensors was placed side by side [9]. The line detector's operating principle is based on the varying levels of infrared reflection that the white and black lines create [9]. Depending on the IR receiver's output and whether any light is reflected from the reflecting lines, different voltage levels will be produced [9]. The IR sensor will output logic "1" as soon as it detects the line, and vice versa [7]. 4 In order for the AFFMP to automatically adjust itself to maintain its body within the line track at all times, the outputs from IR sensors are sent into the interrupt pin of the microcontroller [11]. The typical angle of an infrared sensor is 450 degrees from the x-axis of the infrared radiation beam [7]. IR sensors typically have a viewing angle of $\pm 15^\circ$ [6]. The total coverage of IR sensors is $150^\circ \pm 75^\circ$ if the AFFMP uses 5 of them [6]. As an alternative, IR phototransistors can be employed to detect flames [6, 8, 9]. It is recommended that the IR sensors be positioned symmetrically on the centreline of the AFFMP's body chassis for the best possible performance, stability, and dependability of the line tracking system [9]. AFFMP is outside the line when logic = "0" is applied, and inside the line when logic = "1" is applied

2.3 FLAME DETECTION

Flame sensors formed the foundation of the flame detection module. The microcontroller's analog to digital signal converter (ADC) input pin received the analog output from the flame sensors. There is a fire source in front of the AFFMP when the flame sensor's output exceeds the minimum predetermined threshold value. The intended sensitivity, overall performance, reduced interference, and AFFMP mobility were taken into consideration when setting the minimum threshold. The sensing mode will have less sensitivity if the minimum threshold value is set too high. Additionally, there will be a trade-off and compromise with the sensing mode's precision and stability. The Flame Sensors' output value will progressively rise as the AFFMP approaches the fire source. The area that the AFFMP covers may be fairly small if there is only one flame sensor on the mobile platform. Nonetheless, the AFFMP's coverage greatly expands if it is designed to rotate 360 degrees [6, 9]. Additionally, the AFFMP was made to adjust to a range of situations with varying light intensity levels by setting the minimum threshold value using the Dynamic Method, as explained below [9]:

1. The Autonomous Fire Fighting Mobile Platform (AFFMP) systematically records environmental intensity readings from the Flame Sensors on ten occasions, specifically in the absence of any fire source, ensuring a comprehensive assessment of ambient conditions.

2. Subsequently, employing the Median Average Filtering Method, the dataset undergoes processing whereby the maximum and minimum values are disregarded as outliers. This step is crucial for refining accuracy in flame detection.

3. Following outlier elimination, the remaining eight values are utilized to compute the average intensity level, providing a representative measure of the environmental condition.

4. To mitigate the influence of random interference and account for potential fluctuations, an offset value ($\Delta T = 4$) is added to the average intensity level, thus enhancing the robustness of the detection mechanism.

2.4 FIRE EXTINGUISHING

Upon detection of Flame sources and confirmation of an appropriate proximity between (AFFMP) and the flame [6], the fire extinguishing system is swiftly activated. Typically, the AFFMP employs a DC fan as its primary fire suppression mechanism, adept at extinguishing candle flames [8, 11]. Nonetheless, alternative tools such as robotic snuffers or computer-controlled CO₂ streams present viable options for combating fire hazards [8]. Tables 2.1 and 2.2 provide a comprehensive overview of the different classes of fires and the corresponding types of fire extinguishers tailored to address each class. This classification system aids in selecting the most effective fire extinguishing method for specific fire scenarios encountered, thereby enhancing the AFFMP's adaptability and efficacy in fire suppression endeavors.

Table :2.1: Class of Fires

Class of Fires	Materials
A	Solids (Paper, Wood, Plastic).
B	Liquids (Paraffin, Petrol, Oil).
C	Gases (Propane, Butane, Methane).
D	Metals (Sodium, Lithium, Manganese, Titanium in the form of swarf). Magnesium,
E	Electrical Apparatus.
F	Cooking oil & fat.

Table :2.2: Types of extinguishers

Types of Fire Extinguisher	Characteristics
Water	-Cheapest and commonly used to put off Class A fire. -Not suitable for Class B fire.
Foam	-Slightly expensive than water type. -Used to put off Class A and B fires. -Not suitable for fire involves electricity.
Dry Powder	-Multipurpose Extinguisher. -Used for Class A, B, and C fires. -Best for running liquid fires (Class B). -Effectively extinguishes Class C Gas fire.
Carbon dioxide	-Ideal for fires involves electrical apparatus. -Disadvantages: Fire might re-ignite for Class B liquid fire.
Wet chemical	-Used to put off Class F fire.
Metal	-Used to put off Class D fire.

CHAPTER 3

AIM AND SCOPE

3.1 AIM OF PROJECT

The development of an automated firefighting robot equipped with a 6-wheel drive system represents a groundbreaking leap forward in firefighting technology, poised to revolutionize emergency response operations in challenging and hazardous conditions. By offering enhanced mobility, autonomy, and efficiency, this innovative robot aims to transform traditional firefighting methodologies, mitigating risks to human responders and minimizing damage to infrastructure and communities. At the heart of this transformative technology lies the objective of enabling the robot to autonomously navigate through diverse terrains, including rough terrain and debris-filled areas where conventional firefighting methods may prove unsafe or impractical for human responders. This ambitious goal is achieved through the seamless integration of sophisticated sensors, advanced algorithms, and a sturdy mechanical design.

The utilization of a 6-wheel drive system serves as a cornerstone of the robot's capability to overcome barriers with unparalleled stability and agility. This innovative drive system empowers the robot to swiftly maneuver through challenging environments, ensuring quick response times and efficient fire suppression efforts. By seamlessly traversing various terrains, the robot enhances its operational versatility, enabling it to reach remote or inaccessible areas swiftly and effectively. Moreover, the incorporation of sophisticated sensors enables the robot to autonomously identify and extinguish flames, significantly reducing the risks faced by human firefighters and civilians. By leveraging state-of-the-art technologies for fire detection and suppression, the robot operates with precision and efficiency, minimizing the spread of fires and protecting both lives and property.

The overarching goal of developing this cutting-edge firefighting technology extends beyond immediate response capabilities. It aims to drastically enhance operating capabilities, accelerate reaction times, and ultimately mitigate the devastating impact of fires on infrastructure and communities. Through continuous

innovation and refinement, the automated firefighting robot with a 6-wheel drive system strives to redefine the landscape of emergency response, ushering in a new era of safety, efficiency, and resilience in firefighting operation

3.2 SCOPE OF PROJECT

The scope of this ambitious project spans across multiple engineering disciplines, including mechanical, electrical, and software engineering, all converging towards the construction of an autonomous firefighting robot, specifically engineered with a robust 6-wheel drive system. To ensure the effectiveness and reliability of such a sophisticated system, the project initiates with an extensive investigation phase, delving deep into the intricacies of firefighting operations across diverse locations. This initial phase entails thorough research and analysis, which serves as the cornerstone for the project's subsequent development stages. Comprehensive studies are conducted to understand the nuanced needs and challenges inherent in firefighting scenarios, taking into account factors such as varying terrain types, environmental conditions, and operational constraints. By examining current firefighting strategies and practices, the project aims to glean insights into the shortcomings of existing methodologies and identify areas ripe for innovation. Moreover, a critical aspect of this investigative phase involves the evaluation of available sensing systems, including their capabilities and limitations in accurately detecting and assessing fire-related hazards. By comprehensively assessing the performance and suitability of different sensor technologies, the project endeavours to integrate the most advanced and effective sensing solutions into the firefighting robot's design.

The multidisciplinary nature of the project is emphasized as engineers from diverse backgrounds collaborate to synthesize their expertise and insights. Mechanical engineers focus on designing a rugged and versatile chassis capable of withstanding the rigors of firefighting operations in challenging environments. Electrical engineers tackle the intricate task of integrating power systems and motor controls to ensure seamless operation of the robot's 6-wheel drive mechanism. Meanwhile, software engineers develop sophisticated algorithms for autonomous navigation, sensor data processing, and decision-making, leveraging cutting-edge artificial intelligence techniques to enable the robot to navigate and respond to dynamic firefighting scenarios with agility and precision.

Through this comprehensive and holistic approach, the project aims to culminate in

the development of a sophisticated and reliable automatic firefighting robot with unparalleled capabilities. By enhancing firefighting capabilities and improving safety outcomes in hazardous environments, the envisioned robot stands poised to make a significant impact in the field of emergency response and disaster management.

3.3 SALIENT FEATURES

Advanced Fire Detection System: Equipped with highly sensitive fire sensors, the firefighting robot can swiftly detect the presence of flames, smoke, and heat signatures, enabling rapid response to fire outbreaks in diverse environments. **Intelligent Autonomous Navigation:** Leveraging cutting-edge artificial intelligence algorithms, the robot autonomously navigates through complex terrain and obstacle-laden environments with precision and agility. Its 6-wheel drive system ensures stability and maneuverability over various surfaces, including rough terrain and debris-strewn areas. **Real-time Fire Assessment:** The robot's onboard sensors continuously monitor environmental conditions, providing real-time data on fire intensity, temperature fluctuations, and smoke levels. This information enables firefighters to assess the situation remotely and strategize accordingly. **Efficient Fire Suppression Mechanism:** Equipped with advanced firefighting tools such as water cannons, foam dispensers, and extinguisher modules, the robot swiftly extinguishes flames while minimizing collateral damage. Its precise targeting capabilities ensure effective firefighting without endangering nearby structures or personnel.

Firefighters can remotely operate and control the firefighting robot from a safe distance using intuitive interfaces. This feature allows for strategic deployment of resources and enhances situational awareness during firefighting operations. **Scalability and Customization:** The modular design of the firefighting robot allows for easy customization and integration of additional features and functionalities as per specific firefighting requirements. It can be equipped with interchangeable tools and sensors to address a wide range of fire scenarios and emergency situations. Built to withstand harsh operating conditions, the firefighting robot features a ruggedized chassis and reinforced components that ensure durability and longevity in demanding firefighting environments. Safety is paramount, and the firefighting robot is equipped with multiple fail-safe mechanisms and emergency shutdown procedures to prevent accidents and ensure the well-being of both responders and bystanders.

The robot logs and analyzes firefighting data in real-time, providing valuable insights into fire dynamics, response times, and operational effectiveness. This data can be used for post-incident analysis and continuous improvement of firefighting strategies.

Environmental Sensitivity: In addition to its firefighting capabilities, the robot is designed to minimize its environmental footprint, incorporating energy-efficient components and eco-friendly materials wherever possible.

CHAPTER 4

MATERIALS AND EXPERIMENTAL METHOD

4.1 RESEARCH METHODOLOGY

The execution of this prototype involves a series of pivotal steps, each playing a crucial role in the development of an advanced AI specialized firefighting robot. The journey begins with the meticulous construction of the robot itself, meticulously assembling and integrating various hardware components. This includes the intricate wiring and assembly of motor driver circuitry, the implementation of Light Dependent Resistor (LDR) sensors circuitry for navigation and obstacle detection, the integration of Flame Sensors to detect fires, and the incorporation of Heat/Temperature Sensors for assessing the intensity of the blaze. Concurrently, the focal point of this endeavour revolves around the development of a highly sophisticated algorithm specifically tailored for the microcontroller at the heart of the firefighting robot. This algorithm serves as the brain of the Artificially Intelligent Firefighting Microcontroller Platform (AFFMP), enabling it to make real-time decisions and respond effectively to dynamic firefighting scenarios.

Through meticulous programming and iterative refinement, the algorithm is designed to analyse sensor data, interpret environmental cues, and execute precise manoeuvres to combat fires with efficiency and precision. Moreover, the development process encompasses rigorous testing and validation procedures to ensure the reliability, efficacy, and safety of the AI firefighting robot. This includes simulated fire scenarios to evaluate the robot's responsiveness and performance under various conditions, as well as stress testing to assess its durability and robustness in demanding firefighting environments. As the project progresses, collaboration between multidisciplinary teams of engineers, programmers, and domain experts is essential to synergize diverse expertise and perspectives towards achieving the overarching goal of creating a cutting-edge AI firefighting solution. Through innovation, ingenuity, and perseverance, this prototype aims to revolutionize firefighting techniques, ushering in a new era of autonomous firefighting technology capable of safeguarding lives and property with unprecedented efficiency and effectiveness. Flow of the project is indicated in Fig 4.1.

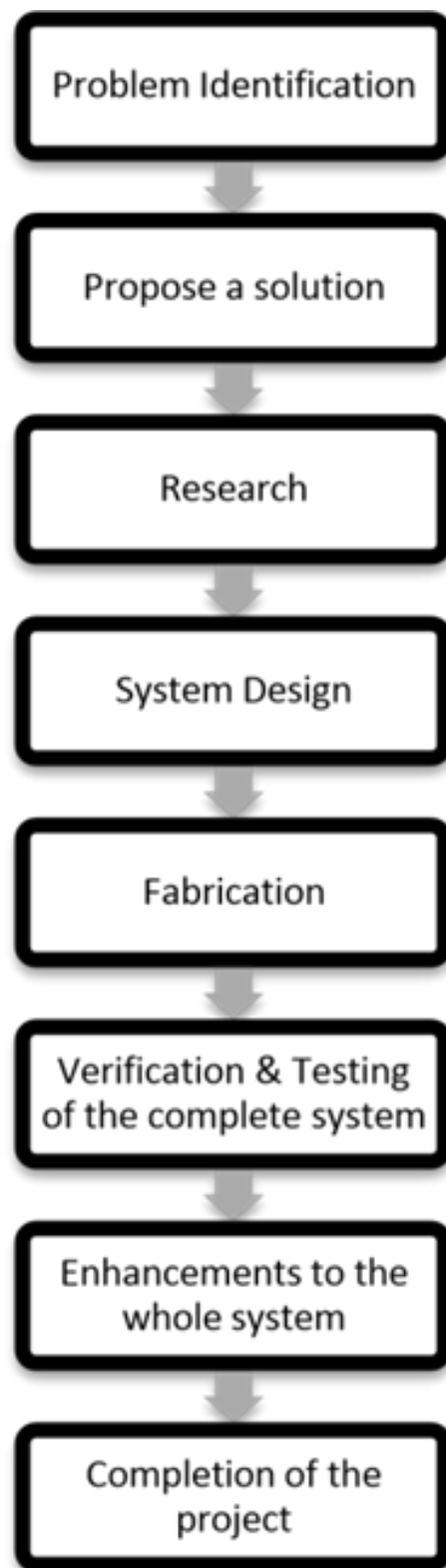


Fig:4.1: Flow of the project

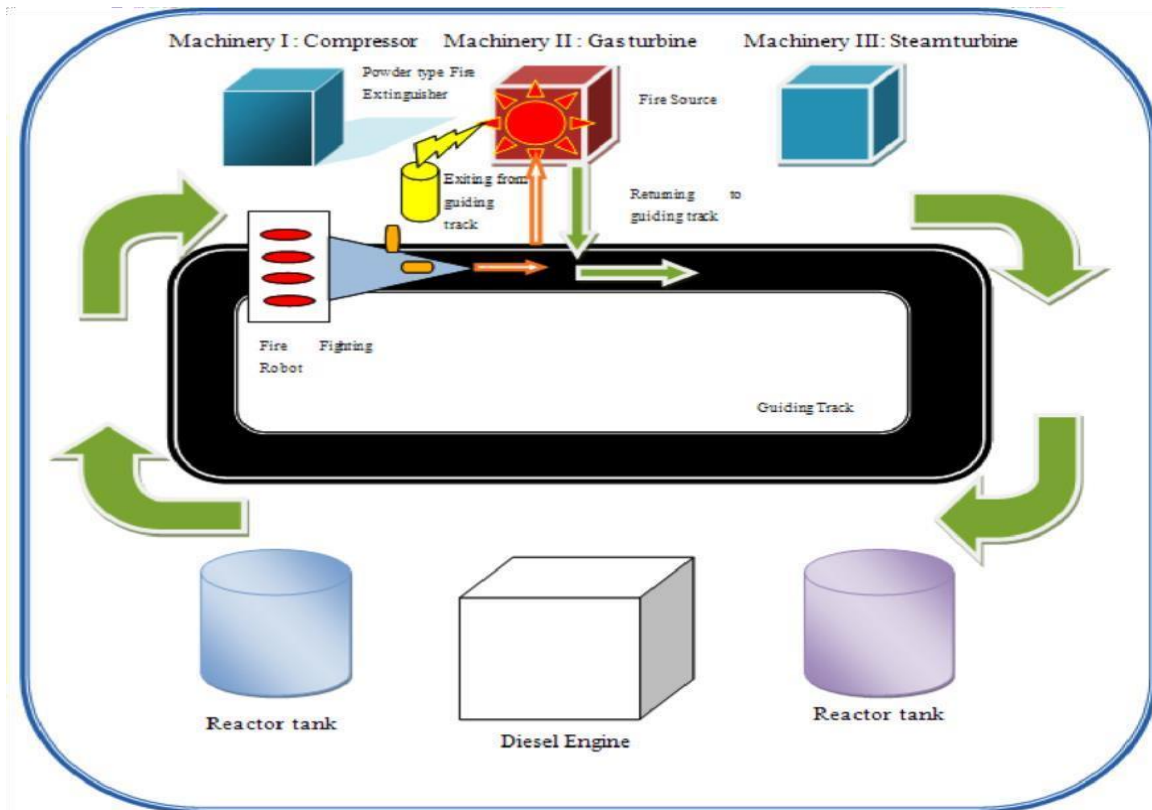


Fig:4.2: The working principle of AFFMP.

Fig 4.2 provides a visual representation of the operational workflow of the Autonomous Fire Fighting Mobile Platform (AFFMP). The microcontroller chip is seamlessly integrated into the Arduino board, serving as the core processing unit. To imbue the AFFMP with intelligence, C algorithms are developed using the MPLAB Integrated Development Environment (IDE). These algorithms are meticulously structured into separate sub-functions, each contributing to specific functionalities, and are subsequently invoked.

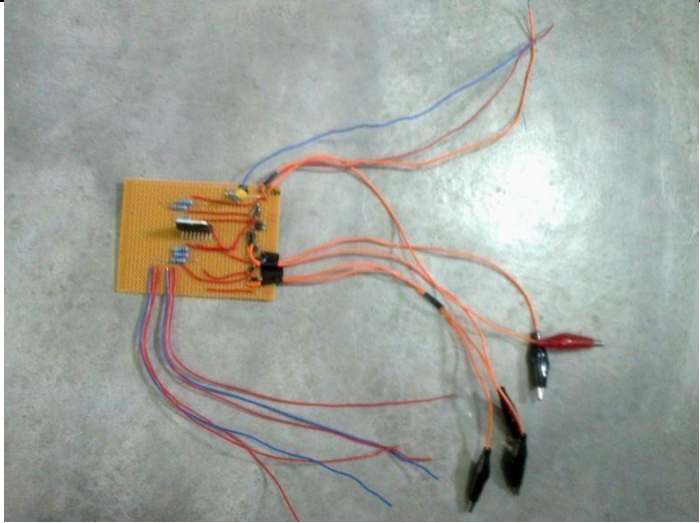
The research progresses with the design and prototyping of the robot, integrating fire sensors, developing AI algorithms, and implementing the 6-wheel drive system. Controlled experiments are conducted to evaluate the robot's performance in simulated fire scenarios, with data collected and analyzed systematically to validate research hypotheses. The results obtained are interpreted to draw conclusions regarding the robot's effectiveness and feasibility in real-world firefighting applications. Discussions center around the contributions, limitations, and implications of the research, concluding with recommendations for future studies. Ultimately, the research findings are documented and disseminated through various channels, contributing to advancements in firefighting technology and practices.

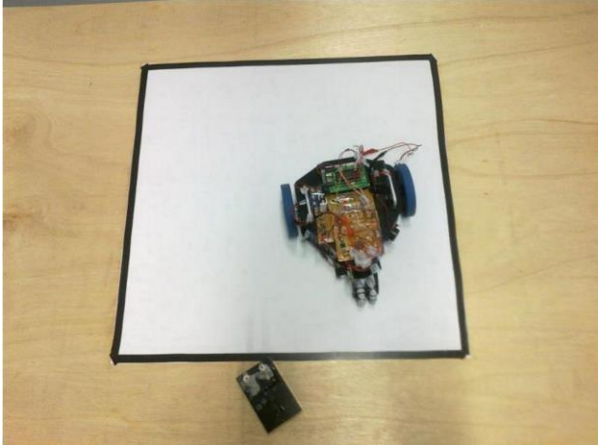
The developed Autonomous Fire Fighting Mobile Platform (AFFMP) boasts the capability to autonomously patrol hazardous sites along guiding tracks while concurrently conducting real-time fire source checks. The fire extinguishing system initially intended for the AFFMP comprises a lightweight 1kg powder-type fire extinguisher, renowned for its effectiveness across various classes of fires. However, owing to budgetary constraints and the absence of collaboration with fire extinguisher distributors during project development, a pragmatic alternative has been adopted. In lieu of the fire extinguishing system, a 6V DC fan has been integrated to extinguish candle flames by blowing them out. Four pairs of high-intensity white LEDs (emitters) and corresponding sensors (receivers), serve the crucial function of enabling the line-following feature within the AFFMP. This feature ensures precise alignment within the guiding track in the absence of a detected fire source. The sensors are strategically positioned between the emitters, symmetrically distributed across the front part of the AFFMP chassis. These sensors include the left sensor, middle left sensor, middle right sensor, and right sensor. Analog outputs generated by the sensors are first directed to a comparator before being relayed to the digital pins of the microcontroller for processing.

4.2 MATERIALS

To develop an AI-specialized firefighting robot equipped with fire sensors and 6-wheel drive, you would require a variety of materials to ensure its functionality and effectiveness in emergency situations. Table 4.1 shows the list of materials needed.

Table :4.1: The main components

No.	Hardware	Illustrations
1	Motor Driver	 Function: To drive the DC motors on the AI firefighting robot. <i>Fig:4.3: Motor drive</i>
2	Flammable Sensor	 Function: To detect for hot or thermal sources. <i>Fig:4.4: Flammable sensor</i>

3	Plywood for the circuits	 Function: acts as a holder for the circuits <i>Fig:4.5: Plywood</i>
4	Arduino uno board	 <i>Fig:4.6: Arduino Board</i> Function: To provide intelligence

5	Power Supply	 Fig:4.7: Power supply Function: Acts as a power supply for the circuitry
6	Flaming hot source	 Fig:4.8: Flame source

logic „1“ since opposite of black background reflects back all the light being emitted and the sensor’s output will be logic „0“ if dark shade strip line is detected as black line absorbs all the emitted lights. Since every environment has a slightly different level of light, be adjusted to set the side Flame Sensor's minimum threshold value during the platform's initial startup to prevent false positive fire flame detection by adjusting the adjustable resistor [2]. It is possible to prevent false positive flame detection by fine-tuning or pre-calibrating the AFFMP before it is configured to carry out the firefighting operations. For example, during the redeployment, ambient factors such light intensity will be gathered using the Dynamic Method, evaluated, and filtered. The flame sensor utilized in this study has a wavelength range of 760 to 1100 nm, which allows it to detect fires in the visible and partially infrared regions of the spectrum. The Flame Sensor performs the initial examination of the fire source by passing its analog output to a comparator, which compares it to a

predetermined threshold value, and then to a digital pin on the microcontroller. The AFFMP has two additional secondary inspection features for fire sources in addition to the primary examination: the smoke sensor and the heat/temperature sensor. The AFFMP will halt its forward motion and turn 90 degrees out of the guiding track in the direction of the fire source if it detects any fire. The mounted fire extinguishing system will begin automatically extinguishing the flames as soon as the AFFMP leaves the guiding track. After putting out the fire, the AFFMP will retrace their steps and enter the guiding track to resume their patrolling duties. If the timeframe for FYP allows, the obstacle avoidance capability can also be added to the system to stop the AI specialized firefighting robot from running into or colliding with any objects by employing the ultrasonic sensor and challenging environments. Furthermore, advancements in AI algorithms have facilitated the robot's autonomous navigation capabilities, enabling it to swiftly respond to emergency situations and efficiently navigate through complex firefighting scenarios. These milestones mark significant progress towards the deployment of an agile, intelligent, and effective robotic solution for combating fires and safeguarding human lives and proper.

4.3 KEY MILESTONES

The development of an AI specialized firefighting robot equipped with advanced fire sensors and a robust 6-wheel drive system has reached several key milestones. Initial stages involved the successful integration of state-of-the-art fire detection technology, enabling real-time monitoring of environmental conditions and prompt identification of fire outbreaks. Subsequent milestones included the optimization of the robot's mobility through the implementation of a reliable 6-wheel drive mechanism, ensuring enhanced maneuverability across diverse terrains. Programming an AI specialized firefighting robot with fire sensors and 6-wheel drive entails a multifaceted approach that encompasses hardware control, sensor data processing, decision-making algorithms, autonomous navigation, communication protocols, safety measures, integration, testing, and iterative optimization. The foundational step involves coding to regulate the motors governing the robot's 6-wheel drive system, enabling nuanced movements crucial for firefighting tasks. Additionally, interfacing with auxiliary hardware components such as water cannons or foam dispensers necessitates meticulous programming to ensure seamless.

Decision-making algorithms play a pivotal role in analyzing sensor data, employing AI techniques like machine learning to enhance the robot's ability to make informed judgments in dynamic firefighting scenarios. For autonomous navigation, integrating GPS and mapping data enables the robot to navigate predefined paths or reach designated targets while incorporating obstacle avoidance algorithms ensures safe maneuvering around impediments encountered during operations. Establishing wireless communication protocols facilitates remote control and monitoring by firefighters or operators, necessitating the development of user-friendly interfaces for seamless interaction with the robot's functionalities. Safety protocols are imperative, integrated into the software to maintain operational integrity within predefined parameters, encompassing emergency shutdown mechanisms and fail-safe procedures to preempt accidents or malfunctions during firefighting endeavors. Integration and testing involve amalgamating programming components into a cohesive software system, subjecting it to rigorous testing in simulated firefighting scenarios to validate performance, reliability, and safety. Continuous optimization and iteration are fundamental, leveraging testing feedback and operational experience to refine software algorithms, enhance efficiency, accuracy, and responsiveness in detecting and suppressing fires, ultimately ensuring the efficacy and safety of the AI specialized firefighting robot in real-world deployments.

4.4 PROGRAMMING THROUGH ARDUINO

Programming an AI specialized firefighting robot with fire sensors and 6-wheel drive entails a multifaceted approach that encompasses hardware control, sensor data processing, decision-making algorithms, autonomous navigation, communication protocols, safety measures, integration, testing, and iterative optimization. The foundational step involves coding to regulate the motors governing the robot's 6-wheel drive system, enabling nuanced movements crucial for firefighting tasks. Additionally, interfacing with auxiliary hardware components such as water cannons or foam dispensers necessitates meticulous programming to ensure seamless integration and operation. Sensor data processing involves developing algorithms to interpret inputs from fire sensors, discerning heat, smoke, or flame signatures indicative of potential fire incidents and triggering appropriate responses. Decision-making algorithms play a pivotal role in analyzing sensor data,

employing AI techniques like machine learning to enhance the robot's ability to make informed judgments in dynamic firefighting scenarios. For autonomous navigation, integrating GPS and mapping data enables the robot to navigate predefined paths or reach designated targets while incorporating obstacle avoidance algorithms ensures safe maneuvering around impediments encountered during operations. Establishing wireless communication protocols facilitates remote control and monitoring by firefighters or operators, necessitating the development of user-friendly interfaces for seamless interaction with the robot's functionalities. Safety protocols are imperative, integrated into the software to maintain operational integrity within predefined parameters, encompassing emergency shutdown mechanisms and fail-safe procedures to preempt accidents or malfunctions during firefighting endeavors. Integration and testing involve amalgamating programming components into a cohesive software system, subjecting it to rigorous testing in simulated firefighting scenarios to validate performance, reliability, and safety. Continuous optimization and iteration are fundamental, leveraging testing feedback and operational experience to refine software algorithms, enhance efficiency, accuracy, and responsiveness in detecting and suppressing fires, ultimately ensuring the efficacy and safety of the AI specialized firefighting robot in real-world deployments.

4.5 6 WHEEL ROBOT METAL FRAME

The integration of a 6-wheel drive system within the framework of an AI specialized firefighting robot represents a monumental leap forward in the realm of robotics engineering, epitomizing innovation at its zenith. This pioneering endeavour aims to revolutionize the capabilities of firefighting technology, enhancing not only mobility and stability but also adaptability to the myriad challenges presented by the volatile and unpredictable nature of firefighting scenarios. Crafted meticulously from high-strength steel, the frame stands as a testament to resilience and durability, fortified to withstand the unforgiving environments characteristic of emergency situations. Imbued with unparalleled strength, the steel chassis serves as the indomitable fortress upon which the firefighting robot relies, steadfast and unwavering in the face of adversity.

The choice of steel as the primary material for the frame is a testament to meticulous engineering foresight, offering a harmonious fusion of strength, endurance, and resistance to impact. In the crucible of fire and chaos, where debris, jagged terrain,

and unforeseen obstacles abound, the steel chassis remains an unyielding bastion of stability and support, ensuring the seamless operation of critical firefighting functions. The symphony of six wheels, intricately choreographed in a carefully orchestrated dance of precision and power, imbues the robot with unparalleled mobility and agility, transcending the confines of conventional terrain. The metal frame of the robot is as shown in Fig 4.9.



Fig:4.9: Metal frame

With the strategic arrangement of wheels, whether in a symmetrical 6x6 configuration or the versatile 4x2+2x2 layout, the firefighting robot navigates with unparalleled grace and poise, effortlessly surmounting obstacles and traversing diverse landscapes with consummate ease. Moreover, the steel frame serves as the linchpin of weight distribution and centre of gravity management, a cornerstone of stability essential for averting the spectre of rollovers and tilting in the heat of action. In the crucible of innovation and ingenuity, the steel-based 6-wheel drive frame emerges as a paragon of engineering excellence, a testament to the indomitable spirit of human endeavour. Through meticulous design and fabrication processes, each weld and rivet bears witness to the unyielding commitment to perfection, forging an unbreakable bond between man and machine. It is within the crucible of adversity that

the true mettle of the firefighting robot is revealed, empowered by the robustness of its steel chassis to navigate hazardous environments and fulfil its solemn duty of safeguarding lives and property against the ravages of fire.

4.6 ARDUINO BOARD

Arduino boards represent a pivotal innovation in modern electronics, embodying a fusion of creativity, accessibility, and adaptability that has transformed the landscape of hobbyist tinkering, prototyping, and professional engineering endeavours. Originating from a group of visionary engineers at the Interaction Design Institute Ivrea in Italy during the early 2000s, Arduino emerged as an open-source microcontroller platform designed to democratize electronics education and empower individuals regardless of their technical background. Characterized by its simplicity, flexibility, and user-friendly design, Arduino quickly gained widespread adoption among hobbyists, educators, and professionals alike, thanks to its intuitive programming environment and extensive online resources and community support. At the core of Arduino's appeal lies its modular architecture, comprising a compact yet powerful microcontroller unit (MCU) integrated with an array of input/output (I/O) pins, analogue-to-digital converters (ADCs), and communication interfaces on a single printed circuit board (PCB). This modular design enables seamless integration with a diverse range of sensors, actuators, displays, and other electronic components, allowing users to create an infinite variety of interactive projects, from basic LED blinkers to sophisticated robotics systems and Internet of Things (IoT) devices. Fig 4.10 shows the Arduino board.



Fig:4.10: Arduino board

The key to Arduino's success lies in its accessibility and ease of use, exemplified by the Arduino Integrated Development Environment (IDE), a cross-platform software tool that simplifies the process of writing, compiling, and uploading code to Arduino boards. Leveraging the open-source Wiring framework, the Arduino IDE provides a user-friendly interface and an extensive library of code examples, enabling even novice programmers to quickly learn and experiment with embedded systems development. Furthermore, Arduino's commitment to openness and community collaboration has fostered a vibrant ecosystem of enthusiasts, educators, and professionals who freely share their knowledge, code, and project designs through online forums, tutorials, and collaborative platforms such as GitHub. This culture of sharing and collaboration accelerates innovation and fosters a sense of camaraderie and inclusivity within the Arduino community, welcoming newcomers and seasoned veterans alike to embark on a journey of exploration and discovery.

From its humble beginnings as an educational tool, Arduino has evolved into a ubiquitous presence in electronics, robotics, art, and beyond. Its versatility and adaptability make it a preferred platform for prototyping and proof-of-concept development across industries ranging from aerospace and automotive engineering to home automation and wearable technology. Whether utilized by hobbyists in their workshops, students in laboratories, or professionals in high-tech startups, Arduino boards inspire creativity, innovation, and ingenuity worldwide. Looking forward, Arduino's future remains bright, fuelled by ongoing advancements in hardware technology, software development, and community engagement. With the introduction of next-generation Arduino boards like the Arduino Uno WIFI Rev2 and Arduino Nano Every, featuring built-in wireless connectivity and enhanced processing capabilities, the platform continues to evolve to meet the evolving needs and aspirations of its diverse user base. As we enter a new era of digital innovation, Arduino stands as a beacon of inspiration and opportunity, empowering individuals of all backgrounds to unleash their creativity and shape the world around them, one project at a time.

4.7 IR SENSORS

Within the domain of AI specialized firefighting robots outfitted with fire sensors and 6-wheel drive, the incorporation of infrared (IR) sensors for flame detection stands as a revolutionary milestone in the arena of fire prevention and control. These

IR sensors function on the fundamental principle of identifying infrared radiation emitted by flames, endowing the robot with the capacity to promptly discern and pinpoint potential fire sources with exceptional precision and efficiency. Painstakingly engineered to recognize the distinct spectral signatures emitted by flames, these sensors serve as the vanguard against the pernicious menace of fire, tirelessly operating across a diverse spectrum of environmental conditions, ranging from smoke-laden interiors to expansive outdoor terrains. Fig 4.11 contains the IR sensors for the robot.



Fig:4.11: IR sensors

Characterized by their exacting craftsmanship and acute sensitivity, IR sensors bestow upon the firefighting robot a decisive edge, enabling it to detect flames even amidst low-light environments or obstructed surroundings where conventional visual detection methods may falter. Furthermore, the seamless integration of IR sensors into the robot's sensor suite amplifies its overarching capabilities, furnishing it with the capacity to swiftly analyse and address fire incidents with unparalleled celerity and precision. In the crucible of exigent circumstances, wherein every moment is of paramount significance, the deployment of IR sensors furnishes the firefighting robot with a formidable instrument for combatting the devastating impact of fire, thereby safeguarding lives and fortifying property against the relentless onslaught of flames.

4.8 MOTOR DRIVER

The motor driver plays a crucial role in the functionality of an AI specialized firefighting robot equipped with fire sensors and 6-wheel drive. It serves as the intermediary between the robot's control system and its motors, regulating the power and direction supplied to each wheel. With the aid of the motor driver, the robot can navigate various terrains encountered during firefighting operations efficiently. Fig 4.12 shows the Motor driver used. Additionally, the motor driver enables precise control over the robot's movements, allowing it to maneuver with accuracy and agility, crucial for reaching and extinguishing fires swiftly. Moreover, in emergency situations, the motor driver ensures the coordinated movement of all six wheels, enhancing the robot's stability and traction on uneven surfaces or debris-filled environments, thereby maximizing its effectiveness in combating fires and ensuring the safety of both property and lives.



Fig:4.12: Motor driver

4.9 POWER SOURCE

The use of a 12V battery as a primary power source in an AI specialized firefighting robot is fundamental, underpinning its functionality and enabling its mobility across diverse operational terrains. Serving as the central energy reservoir,

the 12V battery stands as the lifeline for the robot's operations, providing the essential power required to propel its motors, activate its suite of sensors, and sustain the computational systems critical for autonomous decision-making. This dependable power source is pivotal in ensuring the robot's autonomy, enabling it to function continuously throughout firefighting missions without the need for external power connections, thus bolstering its reliability and effectiveness in dynamic emergency scenarios. Moreover, the versatility and convenience offered by the 12V battery facilitate seamless recharging between deployments, ensuring minimal downtime and maximum readiness for subsequent missions. With the assurance of a robust and dependable power source like the 12V battery, the AI specialized firefighting robot can adeptly navigate hazardous environments, swiftly detect fires, and execute firefighting tasks with precision, ultimately culminating in significantly enhanced safety and operational efficiency during critical emergency situations. Fig 4.13 shows the power source used in the robot.



Fig:4.13: power source 12v battery

CHAPTER 5

RESULTS AND DISCUSSION

5.1 RESULTS

The AI specialized firefighting robot, equipped with advanced fire sensors and a robust 6-wheel drive system, represents a cutting-edge innovation in emergency response technology. Engineered to swiftly and autonomously detect, assess, and combat fires in hazardous environments, this sophisticated robot integrates state-of-the-art artificial intelligence algorithms with precision fire detection capabilities. Through its specialized sensors, the robot can swiftly identify the presence of heat, smoke, and flames, enabling rapid response and effective suppression of fires before they escalate. The 6-wheel drive system ensures optimal maneuverability across diverse terrains, allowing the robot to navigate through debris-filled or uneven surfaces with agility and stability. With its seamless integration of AI, fire sensors, and advanced mobility, this firefighting robot stands as a pioneering solution, promising enhanced safety and efficiency in critical firefighting operations. The end result and the first prototype is shown in Fig 5.1.



Fig:5.1: 6 wheel firefighting robot

5.2 DISCUSSION

In the context of developing an automatic firefighting robot equipped with a 6-wheel drive system, several crucial discussions emerge, ranging from technical feasibility to practical implementation and societal implications. Firstly, the discussion

revolves around the efficacy of the 6-wheel drive system in providing enhanced mobility and maneuverability over diverse terrains encountered in firefighting scenarios. This involves assessing the trade-offs between traction, stability, and energy efficiency to ensure optimal performance.

Additionally, the discussion encompasses the integration of advanced sensors and algorithms for autonomous navigation and firefighting capabilities, addressing challenges such as sensor fusion, real-time data processing, and decision-making algorithms. Furthermore, considerations regarding the robot's size, weight, and physical footprint are discussed to ensure compatibility with firefighting infrastructure and operational constraints. Ethical considerations regarding the deployment of autonomous systems in high-stakes environments and the potential impact on human firefighting personnel are also addressed. Overall, the discussion encompasses technical, operational, and ethical dimensions, aiming to foster informed decision. In the realm of contemporary firefighting technology, the integration of artificial intelligence (AI) into specialized firefighting robots equipped with fire sensors and a robust 6-wheel drive system represents a monumental advancement in the field of emergency response. These sophisticated robots, meticulously engineered to navigate treacherous environments with unparalleled agility and precision, herald a new era of firefighting capabilities.

At their core, these AI-driven robots are designed to detect and combat fires swiftly and effectively, leveraging a suite of cutting-edge fire sensors to identify and assess fire hazards in real-time. The integration of a 6-wheel drive system further enhances their mobility, allowing them to traverse a wide range of terrains, from urban streets to rugged wilderness areas, with ease and efficiency. The incorporation of fire sensors within these specialized robots is crucial for early fire detection and mitigation. These sensors operate on various principles, including infrared (IR) radiation detection, flame ionization, and smoke particle detection, enabling the robots to detect fires in their incipient stages. By detecting the presence of heat, flames, or smoke, these sensors provide invaluable data to the AI system onboard the robot, allowing it to analyse the severity and spread of the fire and formulate an appropriate response strategy. Moreover, the integration of advanced machine learning algorithms enables these robots to continuously learn and adapt their firefighting tactics

CHAPTER 6

SUMMARY AND RECOMMENDATIONS

6.1 SUMMARY

To sum up, the creation of an automated firefighting robot with a six-wheel drive system is a complex project meant to improve firefighting abilities in difficult situations. The project involves a thorough investigation of the mechanical, electrical, and software engineering domains with an emphasis on developing an advanced sensor integration, building a sturdy chassis, and putting autonomous navigation and firefighting algorithms into practice. Key issues like mobility, sensor integration, size limitations, and human safety are covered in discussions that cover technical viability, operational considerations, and ethical consequences. Through rigorous testing and validation procedures, the project aims to deliver a reliable and effective firefighting solution capable of autonomously navigating diverse terrains, detecting and suppressing fires, and ultimately mitigating fire-related risks to communities and infrastructure. The development of an AI specialized firefighting robot equipped with fire sensors and a robust 6-wheel drive system represents a significant advancement in modern emergency response technology.

This sophisticated robot has been meticulously engineered to navigate challenging environments with agility and precision, enhancing firefighting capabilities in diverse scenarios. By integrating cutting-edge fire sensors, the robot can detect and assess fire hazards in real-time, allowing for swift and effective mitigation strategies. The inclusion of a 6-wheel drive system further enhances mobility, enabling the robot to traverse various terrains with ease and efficiency. Despite encountering challenges such as power supply issues and circuitry inconsistencies, innovative solutions have been proposed to overcome these obstacles and ensure the robot's reliability in firefighting operations. Overall, the AI specialized firefighting robot promises to revolutionize firefighting practices by distributing workload, enhancing safety, and providing invaluable support to firefighters in hazardous situations.

6.1 CONCLUSION

The development of the AI specialized firefighting robot, equipped with fire sensors and a 6-wheel drive system, represents a tangible and practical project poised to revolutionize firefighting operations. With successful integration of essential hardware components such as fire sensors and motor driver circuits, the robot is primed to execute its anticipated patrolling and fire extinguishing duties with minimal margin for error. By shouldering the responsibility of patrolling hazardous sites, the AFFMP effectively lightens the workload of human firefighters, enabling them to allocate firefighting tasks safely and efficiently. However, amidst the progress, significant challenges have emerged, particularly concerning the system's power supplies. The inadequacy of the shared power supply's voltage level poses a formidable obstacle, rendering Pulse Width Modulation (PWM) for AFFMP speed control inoperable. In response, a workaround has been devised, involving the utilization of five distinct power supplies with common grounding to circumvent this issue.

Additionally, complications have arisen with the circuitry of the Light Dependent Resistor (LDR) sensors and yellow LEDs (Emitter), resulting in inconsistent or malfunctioning performance. While initial testing on a breadboard yielded promising results, the transition to Verwood and soldering has led to operational failures. To rectify this issue, a strategic solution has been proposed: substituting the yellow LEDs with intensely bright white LEDs and fine-tuning the comparator settings to optimize functionality, particularly in line-following applications. These challenges underscore the iterative nature of the project, requiring diligent troubleshooting and innovative problem-solving to ensure the successful realization of the AI specialized firefighting robot's capabilities. Through perseverance and adaptation, the project team remains steadfast in their commitment to overcoming obstacles and delivering a reliable and effective firefighting solution that enhances safety and efficiency in hazardous environments.

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