Design & Development of Firefighting Robot in the Scenario of Bangladesh

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CERTIFICATE OF RESEARCH

This thesis titled "DESIGN & DEVELOPMENT OF FIREFIGHTING ROBOT IN THE SCENARIO OF BANGLADESH" submitted by SHAH HASIBUL ALAM (170011020), REZWAN MAHMUD (170011033) and RAKIN ROBBANI RAAD (170011034) has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Bachelor of Science in Mechanical Engineering.

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DECLARATION

I hereby declare that this thesis entitled "Design & Development of Firefighting Robot in the scenario of Bangladesh" is an authentic report of study carried out as requirement for the award of degree B.Sc. in Mechanical Engineering at Islamic University of Technology, Gazipur, Dhaka, under the supervision of Dr. Md. Anayet Ullah Patwari, Professor, MPE, IUT in the year 2022.

The matter embodied in this thesis has not been submitted in part or full to any other institute for award of any degree.

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ABSTRACT

Firefighting is an essential yet hazardous profession. Technology has now crossed the gap between humans and machines, enabling for a much more effective and efficient firefighting strategy. Robots developed to locate a fire before it spreads out of control might one day collaborate with firefighters, drastically lowering the danger of human injury. These thesis focuses on different design and fabrication of a Firefighting robot. The reason behind every design of robot, cost analysis and its simplicity and effectively in the scenario of Bangladesh have also been discussed. A sample design has been finalized on the basis of the findings. It has also gone under simulations and other experiment and the flaws have been identified. The usual sensors for robot navigation do not operate well so an integrated semi-autonomous system is built here with the help of Raspberry pi microprocessor. Along with these the existing firefighting technologies are discussed and evaluated. In the end of these thesis a proper view of the future of the firefighting Robot has been drawn.

Keywords: Firefighting Robot, Raspberry pi, Robotic design, Fire hazards.

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Chapter-1

Introduction

These is the foremost chapter of the book where the introduction towards the fire incident is discussed. By reading these chapter one can know the exact reason of collaborating robots in the firefighting situation. Also, the objective of the thesis will be understandable through these theses.

1.1 Fire disaster

A fire is a disaster that can result in the loss of life, property devastation, and long-term disability for those affected. Firefighters have difficulties, especially when a fire breaks out in a restricted place, because they must explore the remnants of structures and overcome obstacles to extinguish the fire and save the sufferer.[1] Because of the numerous obstacles and dangers involved with firefighting operations, technology advancements might be beneficial.

1.2 Diseases faced by firefighter due to close contact of fire

On the job, firefighters encounter major hazards such as heat exhaustion, burns, and physical and emotional stress. Furthermore, they are regularly exposed to high quantities of carbon monoxide and other hazardous risks. With these hazardous exposures, this line of employment raises the risk of a variety of illnesses. Firefighters who smoke or indulge in other bad lifestyle practices are particularly vulnerable. Tobacco use raises the chance of developing heart disease, cancer, respiratory infections, stress, and poor treatment results for some diseases such as hepatitis.

I. Heart Disease

Most of the cases are not even taken into considerations. When materials burn, they emit a variety of carcinogens (cancer-causing agents), including polycyclic aromatic hydrocarbons (PAHs),[2] a class of over 100 compounds. Some PAHs can cause cancer if they are inhaled.[3]According to a National Institute for Occupational Safety and Health research, firemen are more than twice as likely as the general population to be diagnosed with invasive cancer. Other recognized carcinogens, like as asbestos and diesel exhaust, may also be encountered by firefighters. These carcinogens can enter the body through the skin or be breathed. [4], [5]heart disease is responsible for 45 percent of all work-related fatalities among firefighters. In the graph given below, we can see the number of deaths of firefighter. It can be caused by intense labor near hot flames, exposure to carbon monoxide, and other job-related stressors. These risks are increased by a lack of physical fitness, being overweight, and smoking.

Firefighters who also smoke are more likely to get CO and other respiratory disorders. High levels of physical and mental stress cause the heart to need more oxygen; yet, breathing in more CO lowers the quantity of oxygen received by a firefighter. This can result in heart attacks caused by both coronary artery disease and irregular cardiac rhythms.

II. Cancer

According to a National Institute for Occupational Safety and Health research, firemen are more than twice as likely as the general population to be diagnosed with invasive cancer. When fighting a fire, firefighters frequently come into touch with hazardous, cancer-causing elements. Firefighters are more likely than the general population to get malignancies of the colon, brain, bladder, kidney, and Hodgkin's lymphoma.

III. Chronic Respiratory Diseases

The most severe effects of lung sickness might befall seasoned firemen, particularly those who smoke. Firefighters are subjected to a variety of respiratory hazards that can result in substantial and irreversible lung damage. Aside from work-related exposure to burning chemical chemicals, a fireman who smokes cigarettes can be polluted by the same burning substances, increasing their risk of chronic respiratory illness considerably.

IV. Hepatitis B & C

Firefighters are frequently the first responders to a fire or medical emergency. They are then more likely to come into touch with blood that has been tainted with the hepatitis B and C viruses.

V. Stress

When comparing the most stressful jobs, those at the top of the list contain some type of personal danger. Career-Cast investigated stress elements in 200 jobs, such as needed travel, deadlines, working under public scrutiny, physical demands, environmental conditions, dangers, threats to one's own life, and contacts with the general public. Firefighting was ranked second most stressful job, trailing only enlisted military personnel. One of the most stressful aspects of becoming a fireman is the enormous responsibility of being entrusted with the protection and well-being of people. [6]

While potential firemen may be aware of some of the hazards of the job, they are unlikely to be aware that studies and evidence demonstrate that mismanaged stress may lead to anxiety, depression, and PTSD (Snyder, Sournier, Michelle, Pickel, & Cameron, 2011)[7][8]. Chronic stress hinders one's ability to think clearly and make sound decisions.

According to several studies, when stress becomes overwhelming, some firemen binge on alcohol at a rate 2-3 times that of the general population (Jahnke, 2015). According to the United States Firefighters Association, drug addiction among firefighters is estimated to be approximately 10%. Boxer and Wild (Boxer & D.A., 1993) discovered that more than 40% of firefighters reported serious psychological discomfort in 1993 research.

Standard stresses that most other employees endure add to firefighters' persistent stress. Linda F. Willing, a consultant, identifies nine reasons of firefighter stress (Willing, 2015), which include:

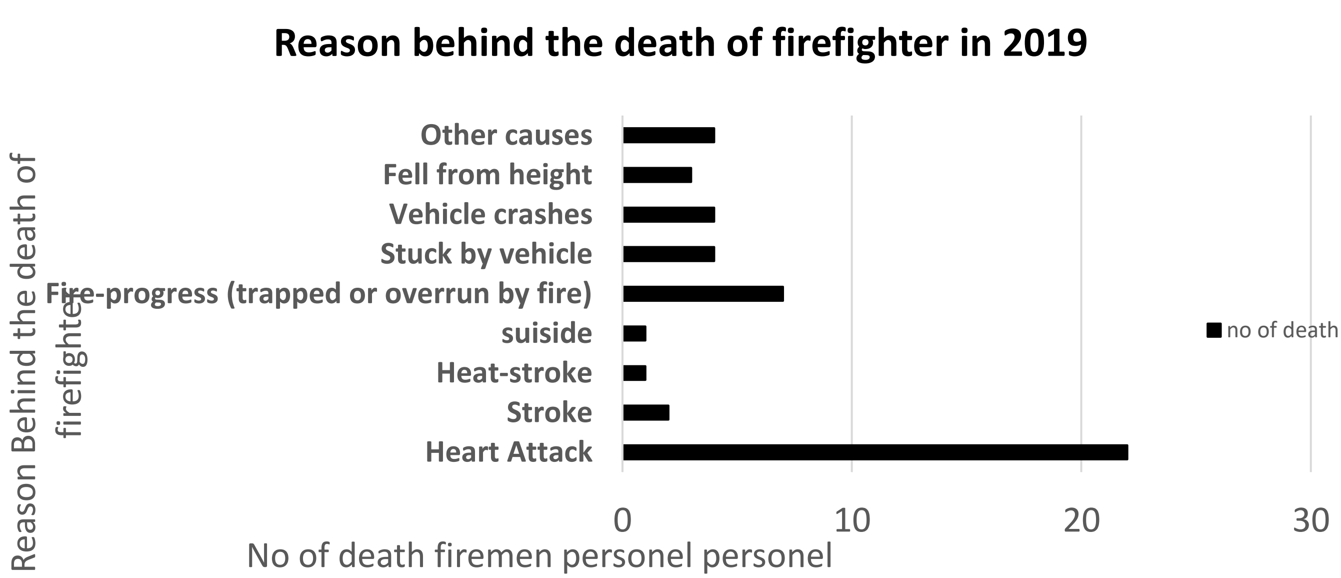
1. Work-stressed couples and children who are relocating
2. Sleep deprivation causes physical and emotional problems.
3. Inadequate training-fear leads to reluctance or failure to operate as a team.
4. Technical issues—issues with gear and safety equipment
5. Unpleasant behaviors and interpersonal clashes characterize bad teams.
6. Harassing or disrespectful coworkers are examples of malicious coworkers.
7. Policy inconsistency-uneven or unfair leadership behaviors

8. Poor leadership-lack of trust and respect for leadership
9. Rough calls-firefighters require appropriate action during a crisis

1.3 Study of National Fire Protection Association on the cause of firemen death

The National Fire Protection Association's published research of firefighter mortality focuses on deaths that occur while firefighters are on the job and covers both fatal traumatic injuries and deaths caused by medical problems. Of fact, this is only a portion of the entire danger to personnel of the fire service. Long-term health consequences, both physical and emotional, also contribute to job-related mortality, both for current firefighters and for those who have retired from the fire service. While it is impossible to name more than a handful of the fatalities as a result of long-term consequences, it is crucial to emphasize that the firefighter fatality picture is significantly more complex than what is depicted in this research of on-duty deaths.

Table 1: Reasons behind the death of firefighter



In 2019, 48 firemen died on the job in the United States as a consequence of injuries and illnesses sustained at particular occurrences that year. This is a significant decrease from former years, when fatalities averaged 65 each year. Of the 48 firefighters, 25 were volunteer firemen and 20 were professional firefighters; one was a state property management agency employee, one of which was a federal land offers the opportunity employee, and one was a civilian military personnel.

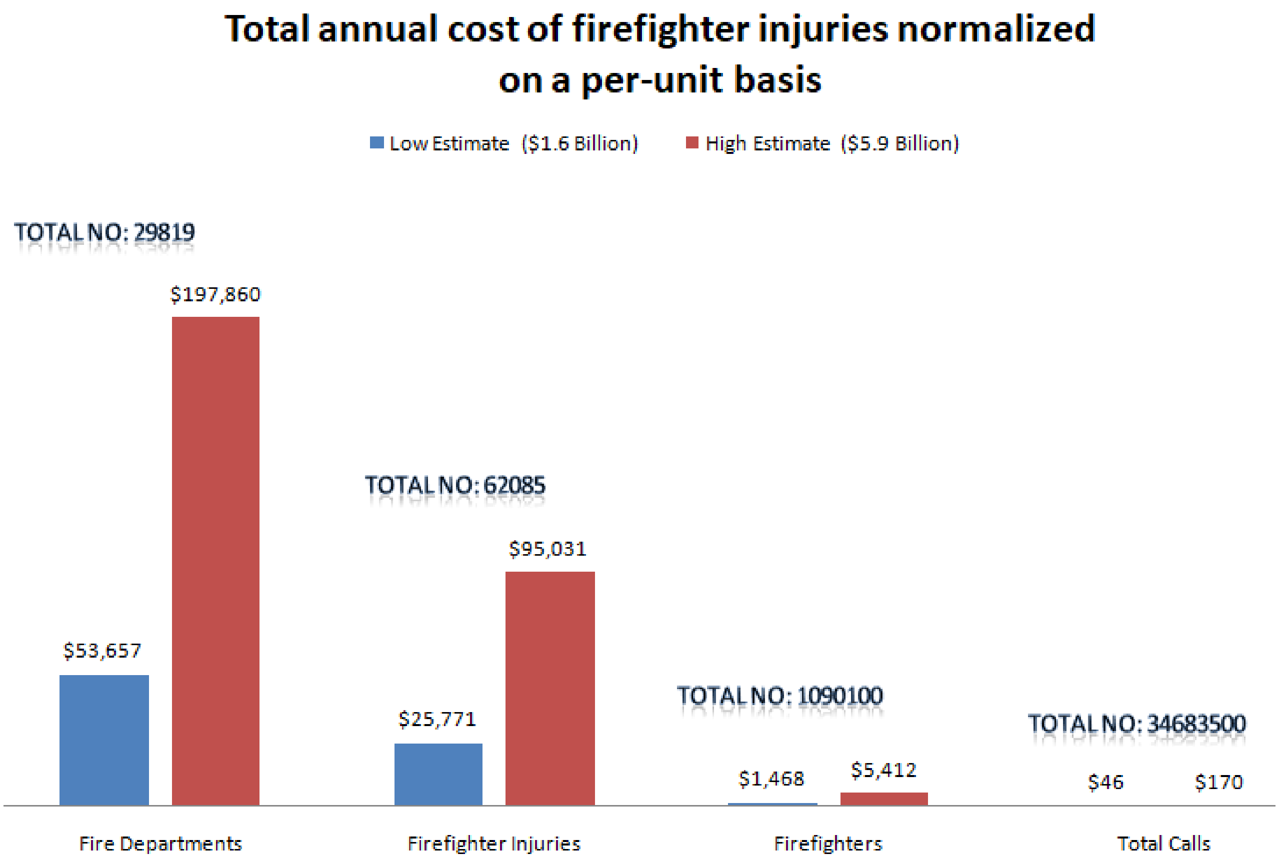
13 firemen were killed in fires and explosions, with ten of them dying in structure fires and three in wildland fires. This is the fewest number of deaths at fire sites ever documented in this survey, and it is the third time in the last four years that there have been less than 20 deaths. This maintains a definite declining trend that began in the late 1970s, when the number of fire ground deaths each year averaged more than 80.

Three of the structures were single-family residences or duplexes, while three were apartment complexes. For one tragic occurrence, the kind of residence was not disclosed. The additional structural fire fatalities happened in a hotel, a grain silo, and an empty furniture shop.

One fireman became trapped in a three-story apartment building during suppression operations; another became trapped in a three-story apartment building during a search for residents; and third fell from the roof of a grain silo following an explosion while using a handline. While attempting to reach a chimney fire, a firefighter fell from the snow-covered top of a four-story apartment building. When the stairs to the bottom floor fell while firefighters were fleeing the building, one fireman became trapped inside on the top floor of a vacant furniture business. Another perished after a brick gable wall fell on him as he was working at a fire scene.

Not only the number of death but also the economical casualties are a very important issue to taken in consideration. In the graph displayed below we get the idea about the total yearly expenses normalized (split by) the number of fire departments, firefighter injuries, firefighters, and total calls to offer context. According to the highest estimate ($5.9 billion), firefighter injuries cost $197 860 per fire department per year, $5412 per fireman per year, or $170 per call per year. The average monetary loss per injury is $95 031.[9][10]

Table 2:Total annual cost of firefighter injuries normalized on a per-unit basis [11][12]

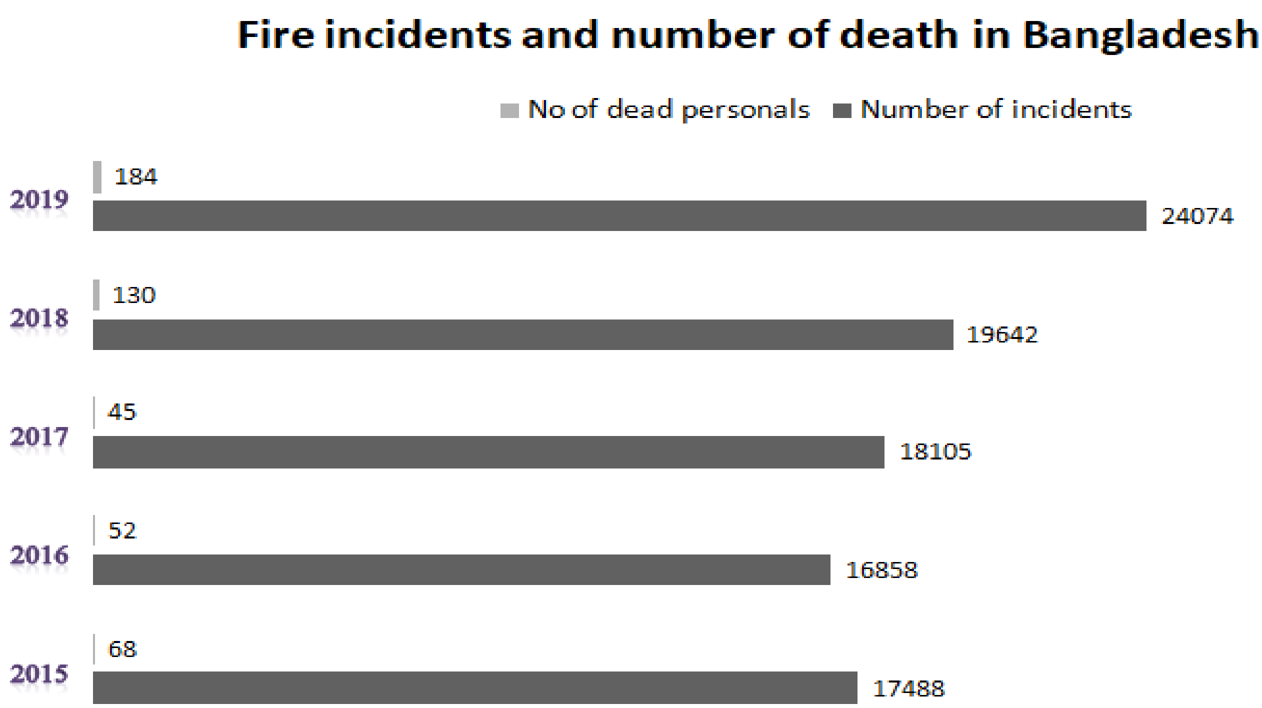


1.4 Fire incidents in Bangladesh and the number of deaths

Fire occurrences are one of the most serious risks in Bangladesh, especially in urban and industrial areas. In 2019, there were 24,078 documented fire incidents, with estimated losses of 330.04 million (in BDT) [13], resulting in 184 deaths and 560 injuries in Bangladesh [14] (BFSCD 2020). Fire occurrences in Bangladesh are becoming more common by the day. When compared to rural settlements, urban settlements have a higher danger of fire due to higher population density, concentration of wealth, and human activity (production, transportation, and service). The city of Dhaka and its neighboring areas have the highest number of incidences. Electrical short circuits and burner fires are the two most common causes of fires in Dhaka and throughout Bangladesh.

According to Alam and Baroi (2004), over 60% of fire incidents in Dhaka occur between noon and midnight, and the dry season (December to March) [15]is the riskiest time of year (Nearly twice fire 92 Sahebi et al. incident occur compared to the wet season). In Dhaka, commercial and mixed-use areas are more vulnerable to fires (Rahman and Islam 2019) [16][17][18]. According to BFSCD (2020), based on a survey of 31 slums in 2019, fire accidents inflict a massive amount of economic damage and take many lives; many people become homeless and lose all of their goods within a few hours, particularly those living in slum regions.

Table 3: No of people died in fire incident in Bangladesh [19][3][20][21]



1.5 Why Firefighting Robot

The high-profile applications of firefighting robots demonstrate their versatility. Of course, not every fire is as difficult and unusual as the one at Notre Dame in Paris, but it doesn't make these technical wonders any less helpful to departments around the country. Many of the following circumstances can benefit from the usage of firefighting robots:

i. On major business fire-fighting robot that it provides safe interior fire operations
ii. Putting out fires in wood-framed structures under construction.
iii. Putting in place a structural barrier against wildfires.
iv. Completing the huge animal rescue assisting in the extinguishment of fuel truck fires.
v. Putting out vehicle storage fire

1.6 Objectives

From the title of the thesis, it has already guessed about the main objective. Thus, the main objective of the project is given below:

- Studying about the condition of firefighters in Bangladesh
- Analyzing the reasons behind the death and post-fire incident death of the firemen
- Analyzing different design of firefighting robot
- Simulating and cost analyzing a perfect design of firefighting robot for fabrication.
- Construction of the robot based on the analytical findings which is affordable to small industries in the perspective of Bangladesh
- Running and analyzing the flaws in the constructed firefighting robot
- Finding the means to improve the firefighting robot
- Visualizing the future prospect and imbedded technologies of the firefighting robot

Besides these objectives, hand on experience had been achieved on the construction of firefighting robot alongside with the component procurements.

1.7 Thesis outcome

The expected outcome of the thesis is very much important in safety management of the industry and other sectors. The expected outcomes is given below:

- Finding out the exact condition of firefighting in Bangladesh
- Reviewing the existing technologies on the field of firefighting robots

- Identifying a proper design to fabricate which is cheap and easy alongside will give the maximum results in terms of static load, dynamic load and other factors.
- Construction of a perfect working model of the designed firefighting robot
- Finding out the future prospect of the work

1.8 Thesis organization

These have been divided into 6 chapters. In the 1st chapter the introduction parts along with the condition of firefighters has been discussed. The diseases oriented to the close fire contact has been found out. Also, the main focus of this chapter is to visualize the objectives of the project.

In the following 2nd chapter, all the existing technologies in the field of firefighting robot has been discussed. All major literature reviews has been done. Also, a table consisting of the commercially available firefighting robot has been shown.

In the 3rd chapter, the main thesis work and findings have been shown. Here different designs have been discussed with its different aspects. A finalized design has been chosen and the related simulations have been done. The key features of the selected design have been discussed. Also, the delicate arm design has been done along with all its parameters.

In the 4th chapter, the designed robot is manufactured. All the procedure has been mentioned and explained with all necessary reasons. Also, the cheap and low-cost material has been characterized.

In the 5th chapter the robotic control has been done. Here, all mechanism flow charts has been discussed and explained in details. Even the exact components have discussed along with their exact features.

In the last chapters, the conclusion along with some recommendations have been done. The future prospect and the summary of all the findings has been done.

Chapter- Two

Literature Review

Here, in these chapter we will be discussing the recent trends and inventories in the field of fire-fighting robot. All the discussed scientific projects have some unique features and characteristics and later some of them are summarized in the table below:

Kinematic and mathematical texture properties extracted from thermal images are the best qualities for effective classification, according to the paper 'Feature selection for intelligent firefighting robot classification of fire, smoke, and thermal reflections using thermal infrared images.'[22]. A Gaussian encoder is used to differentiate between multiple classes based on probabilities, and only a number of co evolutionary computation improvement is employed to find the optimal combination of features with the fewest errors and the best results. By analyzing the distributions of several selected features with an accuracy of 6.70 percent or less, the best technique for smoke and fire classification was determined.

Dual Infrared and Frequency - modulated radar sensor fusion was created and proven to improve object identification and position accuracy while retaining real-time processing. This sort of sensor fusion began with a stereo IR system acquiring an approximate estimate of object placement in 3-D space and FMCW radar obtaining independent 1-D object location. Components first from two devices were matched and utilized to upgrade the stereo IR picture with the more precise radar distances using a minimization approach.

The suggested solution addresses both sensor flaws while also improving item recognition and positioning. As a consequence, ghost objects formed by stereo IR mismatch were deleted, as were things discovered using the radar beyond the FOV. Furthermore, thanks to data acquisition with Frequency response, the stereo IR distance error was decreased from 1 percent to 19.0 percent to 1 percent to 2 percent while maintaining a duration of roughly 1.0 s. In both clear and limited visibility fire smoke settings, the trial findings showed the same accuracy. The robot is now being fitted with multispectral sensor technologies for obstacle avoidance, interior navigation, and mapping.

Systems including firefighting robots, transporting robots, and monitoring robots are being developed for disaster management applications. In the study [23], we propose a moveable emergency evacuation guide robot that can be tossed into a large fire to take environmental parameters, locate displaced individuals, and evacuate them. This spool-like tiny and light robot arm may be easily carried and controlled using a laptop-sized conferencing. It features a camera to capture the fire scene, sensors to record temperature readings, CO gas, and O 2 quantities, and microphones with speakers to allow firefighters and victims to communicate urgently.

This paper proposed the design of an autonomous fire-fighting robot in this work.
A body, thermal and ultrasound sensors for navigation, a flame sensor for fire detection, and a fan for fire extinguishment were among the robot's hardware components. In case any problems occurred, a live stream and map representation were supplied to allow the voyage of extinguishing fire to be seen to people as well as the robot.

This project seems to have plenty of potential for growth. Allowing the particles to move across numerous floors, for example, is a good idea because residences or structures on fire frequently have multiple levels. A room for survivors might also be provided, as well as human detection using image processing to detect such individuals and transport them to safety.

This study provided a fresh perspective on the principles that are employed in this sector. Its goal is to stimulate technological innovation so that the different instruments can produce dependable and efficient results. Experiments have been thoroughly carried out. The results reveal that the embedded system does really increase efficiency. These new tools will have more flexibility in control, operation, and growth thanks to an universal digitalized platform; they will also have embedded intelligence, which will help them to be more resilient.

Customers would eventually benefit from improved services, dependability, and convenience.
It won't be long until this technology infiltrates your home, making you even more lethargic. The key functions and features of the numerous ideas that might be applied in this sector are presented in depth in this article through several categories. Because this preliminary study cannot cover

everything within the suggested framework and vision, additional research and development activities are required to completely implement framework through a collaborative effort of multiple entities.
The fire-fighting machine[24] is programmed to locate a fire in the floor plan of a small house, extinguish the fire (via putting a cup over Led), and afterwards return towards the front residence. A line detector and ultrasonic transducers give data that allows the robot to navigate inside the house. A specialized arm driven by servos deploys the extinguishing device.

Using infrared photos, a real-time stochastic classification approach covering fire, smokes, their thermal reflections, and other objects was created. This algorithm was created for a robot that will independently locate fires inside a structure that are outside of the robot's range of view. Because long wavelength infrared imaging can image through zero visibility situations, thermal pictures were utilized to extract features. The suggested technique distinguished between desired qualities, such as flames and smoke, as well as those who may send the robot in the opposite direction, such as temperature reflection and other hot objects, for firefighting robots to autonomously travel toward fire.

The probabilistic classification approach presented in this research is a reliable, real-time algorithm that employs thermal pictures to accurately detect fire and smoke. To describe and classify the candidates, our approach comprised extracting applicants from 16 bits thermal pictures streamed from an infrared camera and assessing various statistical texture characteristics. The candidates were categorized using the highest precedence decision method after computing the posterior probability using Bayes' theorem.

About 75,000 pieces of information were generated using large-scale fire test footage and supervised machine learning to both train and evaluate the method. The most important very first two order statistical features extracted revealed by this study were mean & variance of intensity, as well as heterogeneity and inverse differential moment. Smaller flames (just under 15 kW) with less smoke and colder temperatures have worse categorization accuracy.

Based on validation using the test dataset that is not included in original training dataset, the classification performance error was estimated to be 6.4%.
Furthermore, the accuracy, remember, F-measure, and G-measure for categorizing smoke and flames using the test dataset were 93.5–99.9%, which are required in the algorithm for guiding the robot toward the fire.

This robot [25] is set to walk through the entrance and look for a source of extreme heat, such as with a fire. When the robot enters the room, it will use the color camera to find a bright spot. After the robot has been overinflated to the light source, the heat detector is activated to determine if there is a significant amount of heat being generated. If the temperature grows too high, then fan is engaged and spun quickly enough to extinguish the flame. If the flame is not put out, the fan will restart and continue to blow on it. The robot exits the home shortly after the flame is out.

Thermal pictures were used to evaluate the best combination of characteristics for reliably classifying fire, smoky, and their thermal reflections. Using a clustering-based, auto thresholding method, motion and texture features were extracted from grayscale 14-bit pictures from a single infrared camera. During real-time implementation, Bayesian classification is used to probabilistically identify numerous classes. A multi objective evolutionary algorithm optimization was used to discover the optimal combination of characteristics, with resubstituting & bridge errors as objective functions. To assess the feature combinations, huge fire tests with various fire sources were done to provide a variety of temperatures and smoke conditions.

The probabilities of 15 motion and texture characteristics were estimated using the statistical inference method. When compared to a single feature, a combination of numerous characteristics was shown to more effectively distinguish fire, smoke, and temperature reflections. SKE, ENT, DIS, STD, COR, VAR, and MNI had 77.8 percent or higher occurrence in the adaptive initial solution where feature combinations create fewer than 7% resubstituting & cross validation errors, whereas other features had 40.0 percent or less incidence. The feature combination of MNI, Brokenness, COR, SKE, and STD produced great classification results, with resubstituting and cross-validation errors of 6.68 percent and 6.70 percent, respectively, and accuracy, responsiveness, F-measure, and accuracy of 95.64 percent, 97.61 percent, 96.62 percent, and 93.45 percent

The categorization of flames, fog, and their heat reflections will be assessed on any classifiers and features in the near future in order to improve performance. Deep learning's convolution neural network, which has lately demonstrated great performance, might be investigated as a classifier, as will model-based visual characteristics like the discrete wavelet transform.

The goal of this project by ‘Autonomous Mobile Robot: Recognize and Respond to Fire: Nik Md Hafizul Hasmi & Md Suhaimi’ is to develop a mechanical controller which could be used to develop and control an autonomous multifunctional robot. Basic navigation skills, as well as the capacity to identify and extinguish flames, are taught. A PlC16F84A microcontroller controls the robot, with RC circuits functioning as DC motor and some other electronic component drivers. This robot has a flame sensor that can expand & attract, permitting it to detect and respond to flames while keeping the hydraulic pump system functioning. A monitoring system circuit is also included in this robot, making it simple to keeping track of the entire battery power.

The animal swarming connectivity study must address a number of novel issues. In GUARDIANS, the coupling of robotics swarming and base station aids the human in navigating when the human senses fail. Furthermore, this research seeks to build unique interface technologies to sustain swarm and human control and coordination.

Following that, a detailed conceptual design for human-robot swarm interactions will be provided, and the structural and organizational prototype will be tested in full scale tests with end users.

All energy & joint technology have been incorporated it in to an adaptive joint in this manner. Because to the enhanced 7 degree - of - freedom kinematics, the manipulator offers more flexibility. This mechatronic method, together with the resulting light-weight architecture, allowed for a weight-to-payload ratio of 17 to 8. Advanced control techniques for force sensors, sound absorption, and stiffness control may be implemented thanks to the integrated joint torque sensors.

The preceding findings indicate that if some vehicle factors like as needed grade capability and velocity are known, the engine power for an average vehicle may be calculated. Further, Modifications can be performed if the estimated torque is not provided by the available motor specs. Gross Automobile Mass, Wheel Size, and other vehicle characteristics Wheel and transmission system materials.

In the paper of ‘Fire Fighting Autonomous Robotic System with Sensitive Sensors for Fire Alarm and Detection, Avoidance Behavior Mechanism, and SMS Messaging Capability Design and Fabrication’ Ai technologies used in robots have become a part of our working environment for a long time, but they are not limited to factory automation. Firefighting robots have recently been developed to assist reduce the risk of fires. This project creates a fire-fighting robot arm that has sensitive flame detectors, an avoiding mechanism, an alert, and SMS capabilities. A circuit design connects several elements to a microcontroller so that it can effectively do its planned task. The structural construction of the chassis is designed to accommodate all pieces for best performance. The codes were adjusted to evaluate which ones were the most dependable and fit for the job.

This work proposes and develops a remotely operated indoor tracked firefighting robot. When the robot is subjected to a 700°C fire for 60 minutes, it has an excellent thermal insulation system to retain the inner electrical parts at an acceptable temperature. It can ascend stairs and converse with confined and injured persons within the burning structure, as well as relay visuals info to the control board detailing the fire situation. Several of such firefighting robots might be utilized to put out fires in huge structures early on. When the chemical differentiating agent is gone, a water hose may be connected to the robot's back to continue battling the fire.

The latest DLR illumination robot is a significant step forward in the development of the next generation of light-weight robots. The concept resulted in a virtual robot prototype that includes crucial process variables and enables for effective integration of electronics into the arm.

To undertake early firefighting intervention, the study of Autonomous Fire Fighting Mobile Robot Based on the Internet of Robotic Things proposes adding an unmanned spraying mobile robot into a traditional fire prevention Internet of Things (IoT) architecture. If a fire occurs, the IoT gadget alerts the fire brigade and directs the robotic arm to respond.

The firefighting robot arrives at the fire site using a route mapping algorithm, performs firefighting activities, and transmits the video feed of a fire site to the control center.

This quick firefighting operation puts a stop to the fire's progress and alerts the fire department. Meanwhile, fire safety inspectors can create a better way to dealing with the fire crash after seeing the footage given by the firefighting robot.

The major focus of this research is to create an Internet of Robotic Things environment that really can respond quickly to fires in industries and save a lot of money. To conduct action as soon as possible, an autonomous fire-fighting robot arm has been incorporated to a typical fire safety IoT system. This technology might be used by industries that have a higher risk of fire accidents to avert big losses. Integration of specific computer artificial intelligence and computer vision frameworks, as well as more sensors, may be included in future work to improve the system's performance accuracy. Machine learning techniques for predicting fire accidents will be extremely useful in improving the end - to - end system's efficacy.

The computational domain and description of direct torque determination for a vehicle with autonomous drive train have been provided. The ideal solutions were compared to those of mechanical kind automobiles under a variety of driving scenarios. We came to the following findings.

- Automobile efficiency on a hill is increased by applying adequate torque to each wheel.
- When all four wheels are driven at the same speed in a straight line on flat ground, the power on each tire is automatically optimized.
- When tire traction and steering angles are combined properly, energy loss throughout turning motion may be reduced.
- The correct torque is applied to each wheel by determining the ratio of load applied on a wheel to the overall load on the automobile.

A intelligent fire-fighting robot system (LAHEEB) was proposed in this research to determine the origin of a flame, suppress it, and increase awareness of wildfires in the event environment. This is an illustration. The robot can put out A, B, C, D, F/K, electromechanical, and metal fires all without spreading. the smallest period of time This robot would lower the chance of firemen and other victims being injured, as well as the expense of operations. monetary losses that rise in proportion towards the duration of the fire LAHEEB is made up of an ultrasonic sensor placed on a servo motor that detects impediments and flame sensors that detect fire.

It also uses a liquid tank and a spray mechanism to put out the flames. To cover the most area, the sprayed nozzle is placed on a servo motor. A 12V pump is used to pump liquid extinguisher from of the main supply to the nose. The entire system is controlled by an Arduino Uno (At mega microcontroller), which serves as the system's brain.

According to the findings of the experiments, an intelligent fire-fighting robot has accomplished its goal and objective. The robot was created to assist firemen in their work. It provides many advantages such as the capacity to discover the cause of a fire, put it out, and learn further about fire activity from the event location.

This robot can suppress several forms of fire, including A, B, C, D, F/K, electric, and metal fires, in the lowest amount of time. This robot will lessen the danger of injury to firefighters and potential victims, as well as the financial damages that climb dramatically as the length of a fire increases.

Using sensors, this robot can also avoid colliding with barriers or other items. Because of its tiny construction, the robot may be employed in places with a small entry or in small areas.

In this article introduces and helps to establish model of interior fire-fighting robot. Inside buildings, it can walk upstairs and negotiate various sorts of floor surfaces. It can withstand high temperatures of excess to 700^{o}C for around 60 minutes using various thermal insulating techniques. It will make contact with stranded and injured victims within the building and provide audio and video data to a control unit explaining the fire situation. Some of these firefighting robots might be launched to work together with the aid of a remote-control device.

Thermal robot firefighters are among the most capable and lengthy robots on the market. To lessen life-threatening situations, these gadgets provide first responders with fire-restraint, situational awareness, and information. Past remote belly-pack controls, users are provided a real-time video stream that allows them to navigate through risks and clear blockages while enduring tough circumstances. This type of robotic firemen is essential in high-risk hazardous environments.

This study has provided a fresh perspective on the principles that are employed in this sector. Its goal is to stimulate technological innovation so that the different instruments can produce trustworthy and efficient results. Experiments have been thoroughly carried out. The results reveal that the embedded system does really increase efficiency. These new instruments will benefit customers with improved services thanks to a common digitalized platform that will empower additional mobility in control, implementation, and advancement; allow for embedded intelligence, essentially fostering the instruments' resilience; and eventually benefit customers with improved services.

This study ‘Human-Robot Swarm Interaction in Firefighting: Analysis and Design ’focuses on the collaborative usage of intelligent machines in firefighting scenarios. In particular, we consider why fire-fighters in the environment interact with a swarm of robots capable of jointly supporting and extending firefighting actions.
The key elements of this emergency scenario are discussed in this study. It discusses the many forms of swarm robotic interactions being researched with in GUARDIANS project. The application of supportive mobile robots to aid firemen in navigating and search and recovery missions is discussed in the study.

This project is about a real-time firefighting robot that runs at a steady pace, detects a fire, and then uses a pumping mechanism to extinguish it. The sensing element, gearbox, engine and its operator, relay driver, and other components were interfaced with Arduino to detect and extinguish the fire. The robot communicates with a smartphone through Bluetooth and uses the digital and analogue data from the sensors to identify whether or not there is a fire in the surroundings. This project was completed successfully on both equipment / software levels. The "Android operated fire-fighting robot" may be employed in a variety of settings, including houses, labs, parking spaces, marketplaces, stores, and shops, among others.

This analysis highlighted firefighters' PPE-related injuries as well as the shortcomings of current firefighting PPE. It highlighted the most significant obstacles to effective firefighter protection and efficient firefighting performance. The heavy or large turnout gear, notably thick rubber boots and thick SCBA, is the initial hurdle.

The second hurdle is an inefficient sizing system, namely a lack of gender-specific size for female firefighters and an inefficient glove sizing system [10]. Even if the harmful impact using PPE on females is greater than that on males, articles concentrating on male fire-fighters predominate the study on personal protective equipment. Absence of availability to female fire-fighters inside the firefighting profession is one of the causes for the lack of diversity.

This systematic assessment of the publications offers suggestions for enhancing future PPE design, fit, and functioning.

Human factor research, ergonomic features, functional design theory, framework, and methodologies, and valuing user feedback in the design and development phase of firefighter Gear are all improvements that can assist increase the safety, performance, and happiness of firefighters. Robot is a machine that looks like a human being and performs various complex tasks. Now, let’s have a good look at existing firefighting robots.

Virtual Reality Simulation of Fire Fighting Robot is a virtual adaptation of competition robot, that took part in Panitia Kontes Robot Cerdas Indonesia competition in 2006.[26] This system was developed in MATLAB/Simulink with the help of Virtual Reality Toolbox plug-in. It is oriented for initial testing of controlling algorithms. It’s important to notice, that even the robot itself doesn’t have enough level of functionality, because of low-detailed formalization of environment. The robot could operate only in corridor-room environment, without strange objects. Only one fire source is meant and there are auxiliary marks on floor, that mean for example room entrance. Pokey the Firefighting Robot is the firefighting robot[27], that made its way out of competitions, and became more “serious” than other systems. In there are detailed description of used equipment and basic algorithms of operating. Robots operating environment is a building, so the robot is equipped with necessary sensors, for example, with a line sensor, that could not be useful in conditions of dense smoke. The main advantages of robot are:

- using of two types of fire sensors, working in different ways;
- using of complex firefighting tool

The main disadvantages are:

- short distance of sensor's work. the fire could be recognized at the distance not more than 1.4 m. at longer distances the sensors works bad, ad developers say
- low efficiency of onboard computer, able only to carry main tasks, without its extension and complexation;
- Absence of optical means of environment perception.

The device is described as autonomous mean of firefighting in houses and any civil buildings. Fire Protection Robot - another competition project, developed for 15th Annual Trinity College [28] Fire Fighting Robot Competition. Robot has more complex organization, than one, shown above and is oriented for solving larger variety of tasks. The main system's advantages are:

- more complex algorithms, used for fire detection.
- using of sound sensor for activating.
- presence of some additional navigation sensors.

The main disadvantages are:

- low-efficiency computer;
- low-power chassis;
- absence of home-return algorithm;
- absence of mapping;

Firefighting Robot built developed by American Trinity College, that was only on early-prototype stage. It was supposed to this robot to be an autonomous device, with 15 minutes limited working time, after which it will return to the supply station. This approach is one of the best variants for firefighting in houses and non-industrial buildings. The main disadvantages in this project are:

- the little working time;
- low-stock of “water”;

The projects [31] have address the development of a mobile robot that may be used to train and run an autonomous robot with a variety of functions. The robot learns basic navigation skills as well as how to recognize and extinguish a fire. This robot is controlled by a microcontroller PlC16F84A, which is complemented by RC circuits that function as drivers for DC motors and other electrical components. This robot has a fire sensor that can be enlarged and attracted, allowing it to recognize and respond to flames while operating the water pump system. This robot also has a battery monitoring circuit that allows you to easily examine the entire battery power of the robot.

The robot designed in these project [24] to enter a room and look for regions of high heat, maybe caused by a fire. When the robot enters the room, it will use the color camera to choose a location with a high concentration of light. When the robot approaches the light source, the heat sensor detects whether there is a lot of heat being produced. If an excessive amount of heat is produced, the fan is engaged and rapidly spun using a servo motor to extinguish the flame. If the flame is not extinguished, the fan will resume and blow on it again.

Researchers propose a portable fire evacuation guide robot device [23] that can be thrown into a fire scene to collect environmental data, find displaced individuals, and evacuate them. This spool-like tiny and light mobile robot may be easily moved and operated remotely by a laptop-sized tele-operator. It has the following functional units: a camera to capture the fire scene; sensors to gather temperature data, CO gas concentrations, and O_2 concentrations; and a microphone with speaker for emergency voice communications between firefighter and victims. The design of the robot provides high-temperature protection, excellent waterproofing, and high impact resistance. Experiments in the lab were carried out to evaluate the performance of the proposed evacuation guide robot system.

The motion and mathematical texture characteristics taken from thermal pictures are investigated in this research[22][32] in order to discover the optimum features for proper categorization. A

Bayesian classifier is used to identify various classes probabilistically, and a multi-objective genetic algorithm optimization is used to determine the optimum combination of characteristics with the fewest mistakes and the best outcomes. The distributions of many function combinations were explored, and the optimal strategy for fire and smoke categorization was discovered.

A novel indoor firefighting robot model is introduced and established in the research work [33]. Within buildings, it can climb stairs and traverse various types of floor surfaces. Using different thermal insulating methods, it can resist temperatures of up to 700o C for around 60 minutes. It will connect with trapped and injured victims within the building, as well as provide visual and audio data to the control unit, explaining the fire situation. To operate together, some of these firefighting robots may be launched using a remote-control device.

The authors of [34] 'Robotic Force Estimation Using Motor Torques and Modeling of Low Velocity Friction Disturbances' demonstrated how to calculate contact forces from motor torques. For low velocities, the approach accurately predicts and combines Coulomb friction uncertainty. from a variety of joints, the estimate and confidence intervals are presented in the table below. real-time computation based on convex optimization issues time. The method was put to the test in a two-arm experiment.

Data from a wrist-mounted force sensor was used to corroborate the assembling procedure.
Tokyo Fire Department has a manipulator that can remove obstacles and handle drums.[35] Yokohama Fire Deponents also has a robot that moves with a double pair of crawlers, which is a characteristic of the robot. Some fire departments also have remote-controlled monitor nozzle vehicles. They even deployed a remote-control machine for rescues. Its operation board is movable, and the robot and operation board are carried by truck. The robot moves with a pair of crawlers and is driven hydraulically.

Again, from the paper 'Fire sensing technologies: A review'[36] provides an overview of state-of-the-art fire sensing and control practices, with the focus on excellent fire detection capabilities, the reduction in the detection of fake positive effects, the capacity to inform the occupants, the transmission of fire information and status to the fire department and the automatic inspection capacities of the occupant's operation. Main aspects of the fire instant including heat, flame, smoke and gas are addressed with their virtues, their demerits, their measuring benchmarks and their measurement of the span of the parameters.

The motives and criteria for the control of fire are also covered in commercial and residential structures. The aforesaid problems were also recognized by research papers on fire detecting technology. However, there are challenges and partial solutions to the necessity of sturdy systems which meet all or most of the above-mentioned standards. A modified fire detection and control system idea was presented to solve the deficiencies.

Table 4: Commercially available firefighting robots

Name of the fire-fighting robot	Special Features	Probable cost
ODE TOOLS BE-FR-01	Pan-tilt Thermal imaging binocular camera	$180000
RXR-M50D Fire-fighting Robot Firemen	Maintenance-free battery-driven, all-terrain tires, can load 300Kg.	$36000
FFR-1	Two steel tracks with optimal rubber tracks locomotion technique	$100000
Firemote 4800	protect tracks and sensitive parts by circulating water through chassis and using fixed nozzle to cool down the body.	$70000
Thermite RS1	24-hp diesel engine, 1250 gpm nozzle Standoff range of over 300 m	$90000

2.1 Overall Feedback from the papers reviewed

The papers we have reviewed mostly describes different technologies based on the firefighting techniques applied by different firefighting robots. Most of the technical papers mostly discussed the newly added features added to the firefighting robot. Already Thermite firefighting robot is in commercial use in the United States of America. Robot Colossus made by Shark Robotics has already been used in extinguishing fire accident in Notre Dame church in France. From those practical implementations we can get a conclusion are lot gaps where we can do more research and development.

Some of the errors in the existing technologies and improvement that can be obtained is given below:

- Can’t detect the type of fire accident and the way to approach the accident
- Can’t detect the epicenter of the fire
- Robots which are carrying water cannot carry huge amount of water
- Doesn’t have any features of rescuing
- Some of the Robots doesn’t have any features of camera and proper navigation
- Lack of proper flow power of water
- Lack of cooling system to the engine
- Low-efficiency of computing
- Low-power chassis
- Absence of home-return algorithm
- Absence of mapping

  Besides this there many other places where improvement and research can be done

Chapter- Three

Design Selection and Analysis

In the third chapter, the main thesis work and findings have been shown. Here different designs have been discussed with its different aspects. A finalized design has been chosen and the related simulations have been done. The key features of the selected design have been discussed. Also, the delicate arm design has been done along with all its parameters.

3.1 Reason behind taking different design configurations

Lots of designs are available in different research and projects related to firefighting robots. Analyzing most of them it is found that all the designs are pretty much complex and hard to manufacture. Most of designs doesn't have any basis of calculation. but with the consideration of different features based under the literature review of different thesis papers we have summarized the designs into 5 sample designs. All the designs are authentic and created within the consideration of designing details and other basis considerations which will be discussed further on.

3.2 Obstacles in mechanical designing

While designing many calculations and parameters are considered and the designs are done. Some of the major obstacles that any designer might face is given below:

i. Managing the overall weight:

   The weight is a very important factor needed to be considered while designing. If the designed is such that it requires more material than it will easily increase the weight of the robot. Increased weight will result in more horsepower of the motor, which will eventually increase the price of the motor and other related inventories.

ii. Finding out the center of mass:

   For proper placement of the four wheels and the even mass distribution on them, the calculation of center of mass and COG (Centre of gravity) is very much needed. Even the weight of the arm (which includes the weight of the arm along with the flowing water weight) is needed to be placed according to the calculations of the center of mass and COG.

iii. Height of the robot body:

The height of the robot body is also crucial. It contains the height of the wheel which includes the damper it requires. In real-time action situation of the firefighting robot the maximum height will give more motor torque and eventually will result in more efficiently crossing the obstacles on the road.

iv. Proper simulation analysis:

Different simulations including static force analysis, dynamic force analysis, crush test is required for proper analysis of the design. Nodal analysis with different sizes of mesh is recommended, but more the small the mesh more the accurate value will come. But fine mesh will require more time and money for simulation. For this purpose, standard design with less complexities are taken and the mesh size is standardized for the purpose of easy calculations.

v. Hose-pipe diameter:

The diameter or area of the hose-pipe is very important for the calculation of the amount of water flow. The less the area of the hose-pipe the more the force of the flow. Thus, the water will go to a long range. Again, this will result in a backward torque that will be faced by the whole robotic body. So, an average and proper calculated hose pipe area is needed.

vi. Gear calculation:

The power of the motor is transferred from the electromagnetic mechanisms through the gears for proper torque and rotational speed. Gear is most importantly needed in the designing of the arm.

vii. Aero-dynamics:

The calculation of the aero-dynamics is not needed as there is no requirement of high speed. But there is a huge scope of water flow calculations i.e., the water pipe dynamics.

These are some of the main features that are needed to be considered while designing the robotic body. All these parameters are very much needed and precisely to be followed and in this paper all the designs that are discussed have gone through all these criterions.

3.3 Sample design of firefighting robot-1

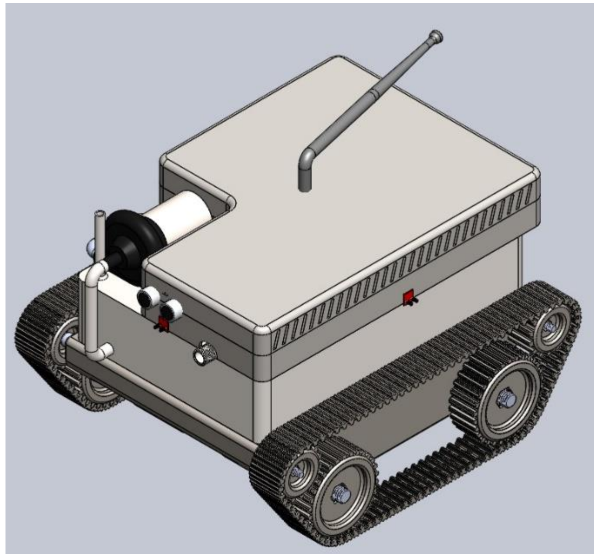


Figure 1: Sample Fire-fighting Robot design

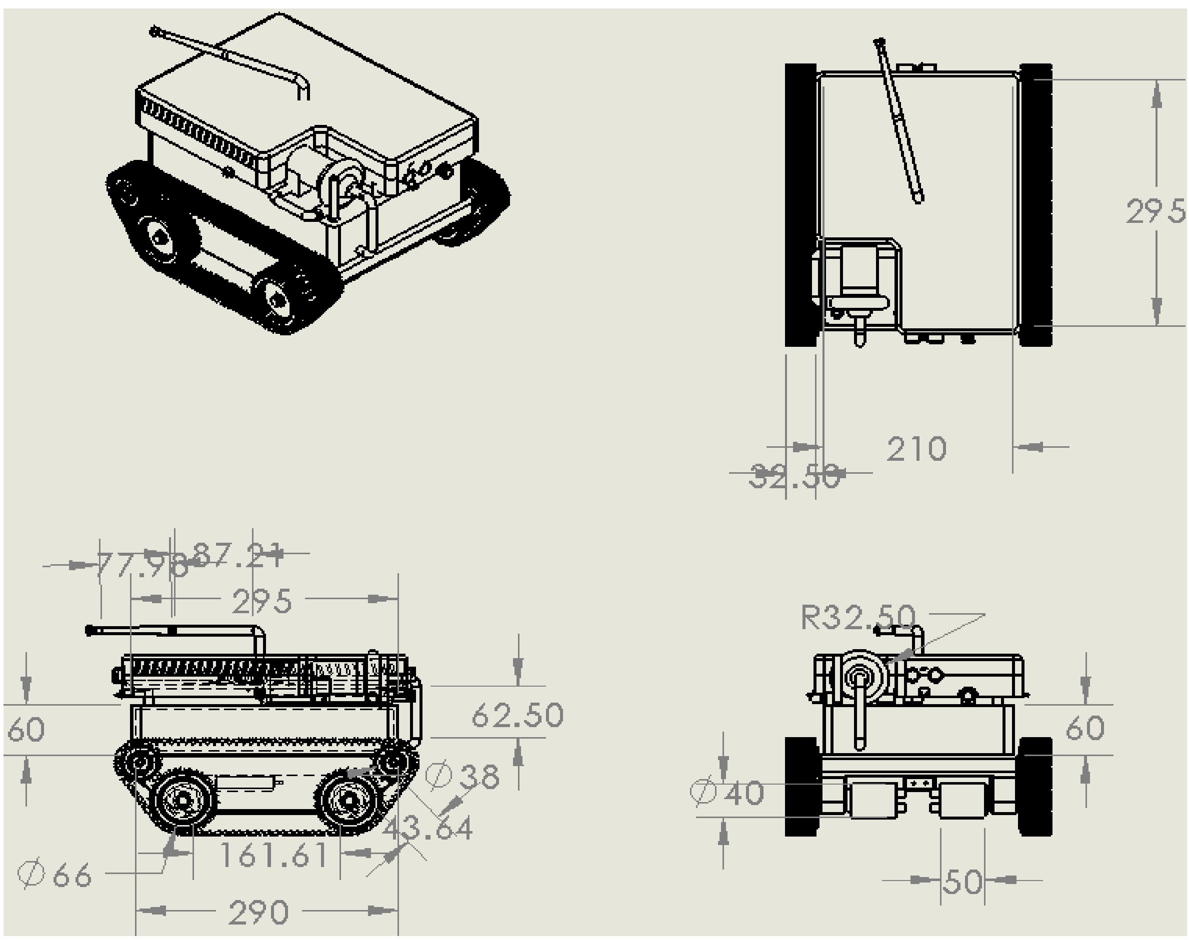


Figure 2: 2D drawing and sketch of the sample firefighting robot with water carrying capacity

3.3.1 Some of the features of these designed firefighting robot is given below:

i. It has a water holding capacity of 20L. Which results in an increase of more than 20kg weight.
ii. The shape of the firefighting robot is compact and have the capacity to enter the furthest most place in a real time fire incident.
iii. The robot is designed with two pairs of continuous wheels. The pair of continuous wheels have an inclination which gives it the capacity of climbing the obstacles more easily.
iv. Different compartment for electrical devices which are completely sealed from the water carry compartment. This portion of the robot is fully water-proved.

3.3.2 Reason behind not considering this design:

i. Continuous wheel production is costly including the production of gears and the inside gears which are very much costly. The sprocket teeth attached to grooves in the continuous wheel is linked metal rails, down which these firefighting robot wheels run. Thus it is easily understood the complexity of the production of these wheel.
ii. Water carrying capacity is only 20L which is very much inadequate in any fire accident scenario
iii. Due to the feature of water carry the weight automatically increased and thus resulting in the requirement of more powerful torque motor.
iv. Due to the increased amount of motor torque, it is preferable to use piston engine which is runed by diesel or other burning natural oil or gas. Thus, it is inevitable that these petrol or diesel oil is very dangerous in the scenario of firefighting.

3.4 Sample design of firefighting robot-2

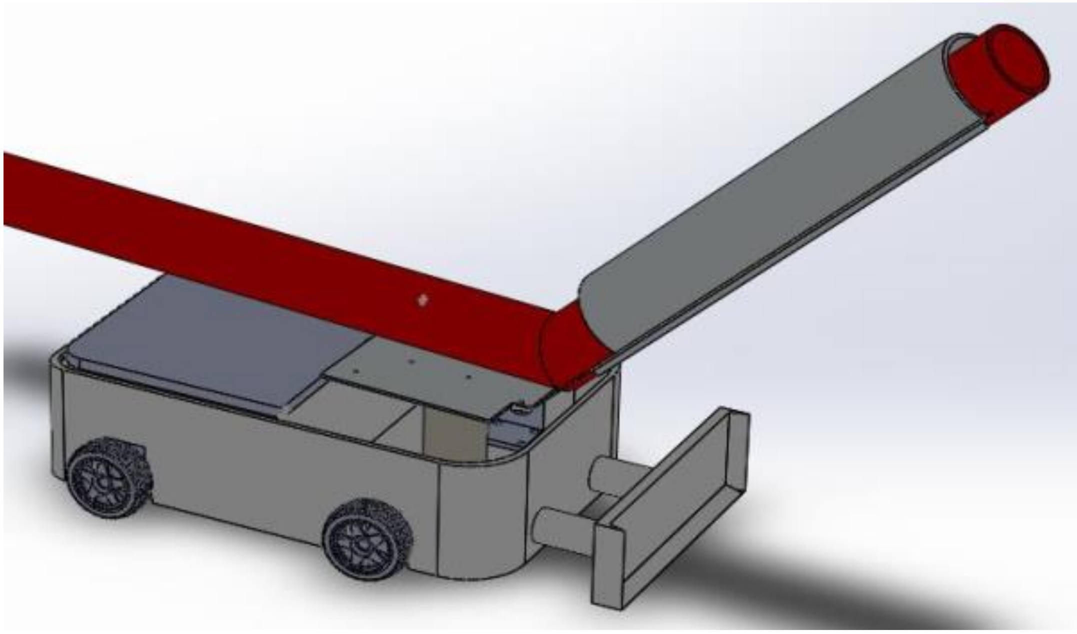


Figure 3: Sample firefighting robot- II

3.4.1 Some of the features of these designed firefighting robot is given below:

i. It has a long hose-pipe
ii. Single degree of freedom of the arm which carries the main hose-pipe.
iii. Separate compartment for the electrical components
iv. A front shovel mechanism is installed which has the capacity to clear any sorts of obstacles. The frontal part of the shovel is very sharp is that it cut down the obstacle.
v. Four wheel is installed which gives a separate control system

3.4.2 Reason behind not considering this design:

i. The frontal shovel is very weak and under simulation it can withhold only a force of 10N.In real time fire situation the shovel is in endangered to be broken
ii. The long hose-pipe makes the firefighting robot in an imbalanced situation.
iii. Only one axis of rotation is obtained which is very old fashioned and cannot reach the water in the exact location.

3.5 Sample design of firefighting robot-3

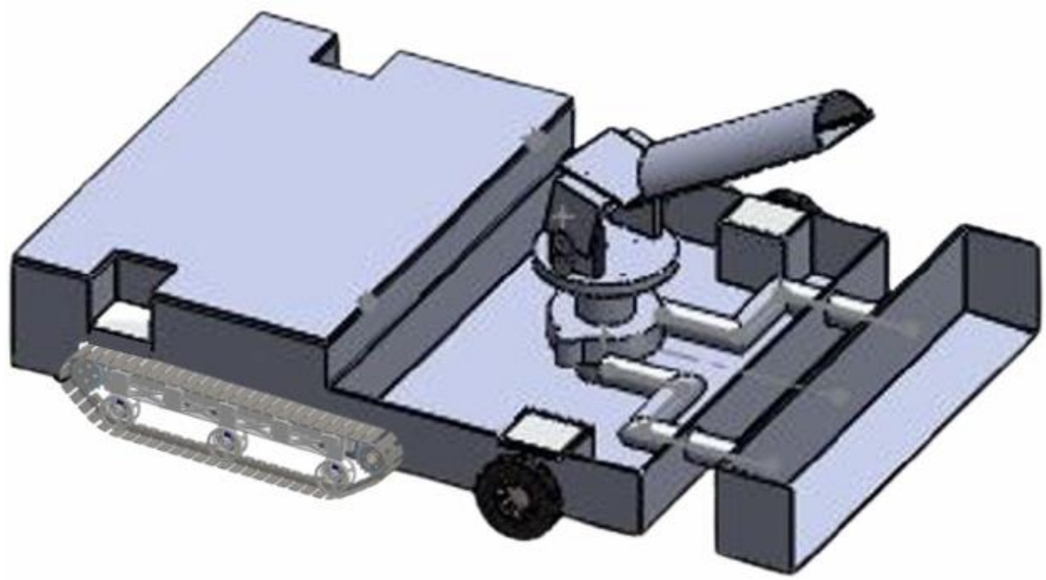


Figure 4: Sample design of firefighting Robot

3.5.1 Some of the features of these designed firefighting robot is given below:

i. It is the most delicately designed firefighting robot with a numerous feature.

ii. It is having a moveable shovel. The frontal part of the shovel is very sharp like a blade and has the capacity to remove the obstacles in the sideward direction. The cam profile attached to it has the capacity of continuous movement and will be rotating the shovel mechanism in sideways.

iii. The arm has two degrees of freedom. And can exactly be moved so that the water can reach the exact destination. The bottom part of the arm is connected with a stepper motor with a high torque .and the upper part is connected with another stepper motor.

iv. The continuous wheel is designed in the most efficient way. There are two gears and three inner wheels. The inner platform of the continuous wheel is attached with the main frame of the firefighting robot. Under another simulating study, it is seen that 5 inner wheels will give much stable configuration to the continuous wheel rather than the three inner wheel configuration.

v. Other than the continuous wheel there are two directional wheels for exactly defining the direction of the robot which makes its driving mechanism more efficient and easier.

vi. There is inner electric cover have heat-exchanger type mechanism for reducing its heat or to protect it from the outer heat in real time fire scenario.

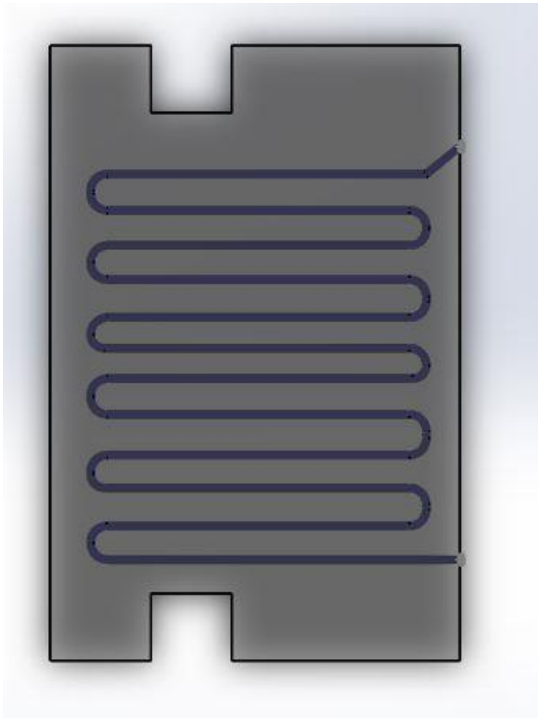


Figure 5: Inner heat-exchanger mechanism to cool the electric box.

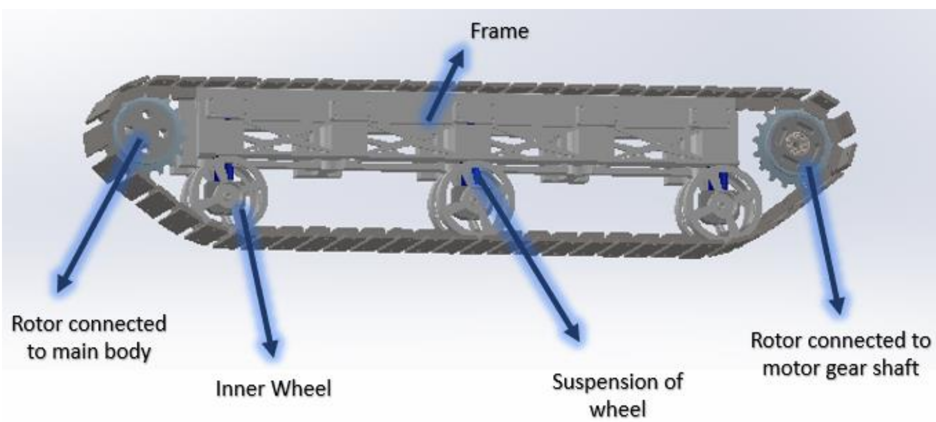


Figure 6: Different components of a continuous wheel.

3.5.2 Reason behind not considering this design:

i. The frontal shovel is very weak and under simulation it can withhold only a force of 10N.In real time fire situation the shovel is in endangered to be broken.

ii. The cam profile mechanism is very tough to create and the efficiency of it is not so good in the scenario of removing obstacle and withstand the high force that is going to be exerted on it.

iii. All the weight of the arm is fallen exactly on the single stepper motor. So, it is obvious that the stepper is prompt to fail or it might not work to its exact capacity.

iv. Also, the damping system of the continuous wheel is not so good.

v. 3D printer is needed to make the inner heat-exchanger type mechanism. This is pretty much complex and the rate of heat exchange is not so praiseworthy in the perspective of the required heat change needed.

vi. Continuous wheel production is costly including the production of gears and the inside gears which are very much costly. The sprocket teeth attached to grooves in the continuous wheel is linked metal rails, down which these firefighting robot wheels run. Thus, it is easily understood the complexity of the production of these wheels.

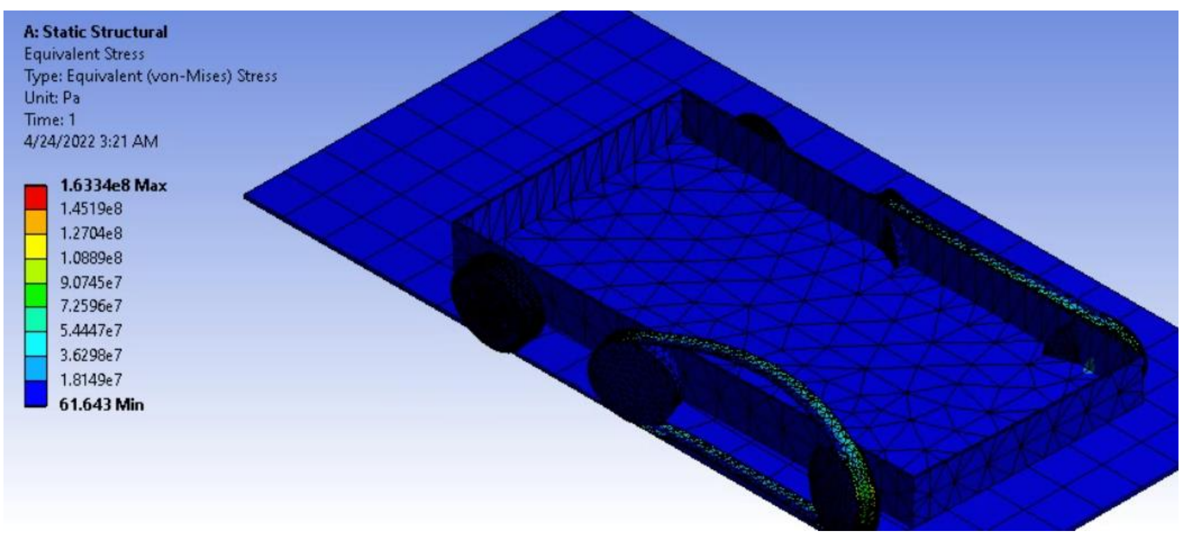


Figure 7: Von-Moses stress on 2 Wheel and Continuous wheel configuration

The following things are considered while this simulation:

- The environmental Temperature is 50^{o}C
- Mesh element size 0.2213m
- In close vertices mesh size 4.5e^{-003}
- The ground part of the road is considered as fixed support
- As the Robot body weight is fallen on the road, thus we have given the opposite force of (49N) from the road to the robot wheel.
- The weight of the Robot body is considered as 5*2 kg

From the simulation it can easily be observed that the continuous wheel is enable to take the load endorsed on it.

3.6 Sample design of firefighting robot-4

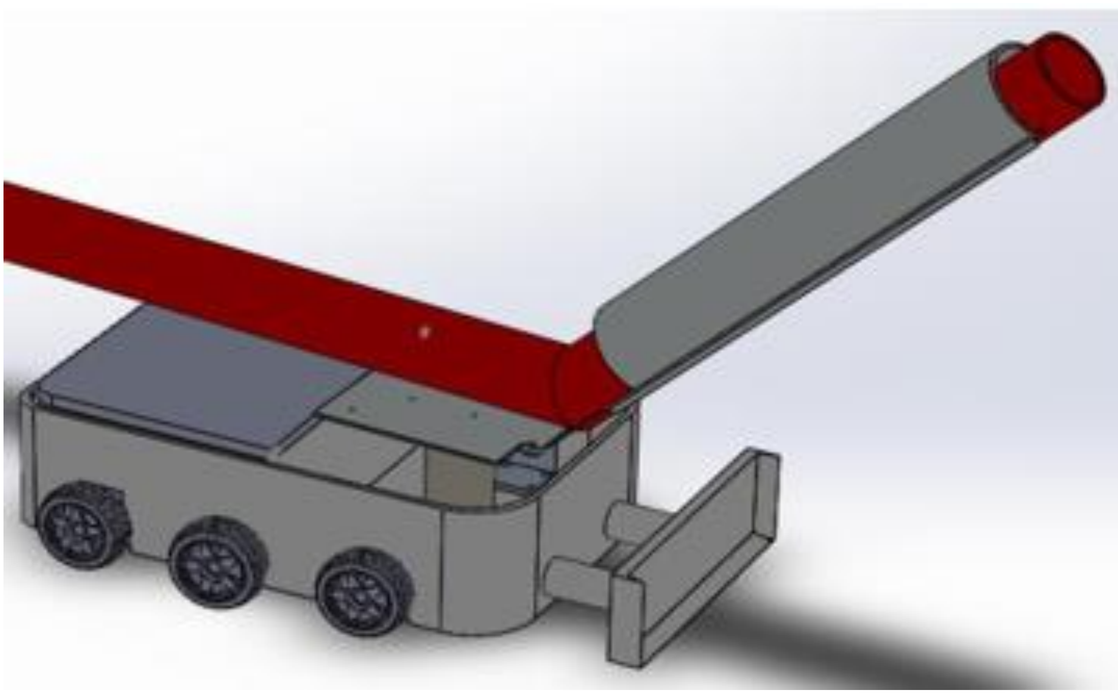


Figure 8: Sample design of firefighting robot with 6-wheel configurations

3.6.1 Some of the features of these designed firefighting robot is given below:

The design has similar features of that of the sample design -2 but it has a configuration of 6-wheels.

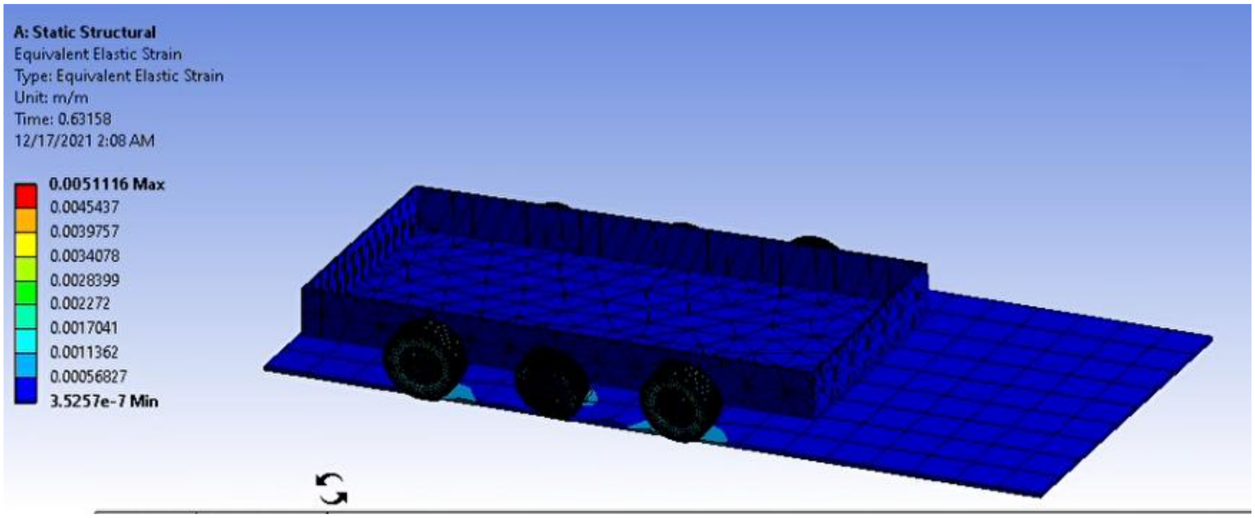


Figure 9: Equivalent elastic strain of the sample design with 6-wheel configurations

Thus, from different structural simulation scenario we found that this 6-wheel configurations is the most stable and gives the demanded result in any simulation.

The 6 wheels are placed exactly in accordance with the calculation of center of mass.

Parameters considered for this simulation:

- The environmental Temperature is 50°C
- Mesh element size 0.2213m
- In close vertices mesh size $4.5e^{-003}$
- The ground part of the road is considered as fixed support
- As the Robot body weight is fallen on the road, thus we have given the opposite force of (49N) from the road to the robot wheel.
- The weight of the Robot body is considered as 10kg

3.6.2 Reason behind not considering this design:

Due to the addition of 6-wheels the cost of the production of this robot has increased manifold. Thus, it will require a pair of wheels, motors, damper and other related materials. Again, the control mechanism of the 6-wheel is quite difficult and the rotation of the wheel is not exactly obtained. Thus, this design is discarded with having only these issues.

3.7 Selected Design:

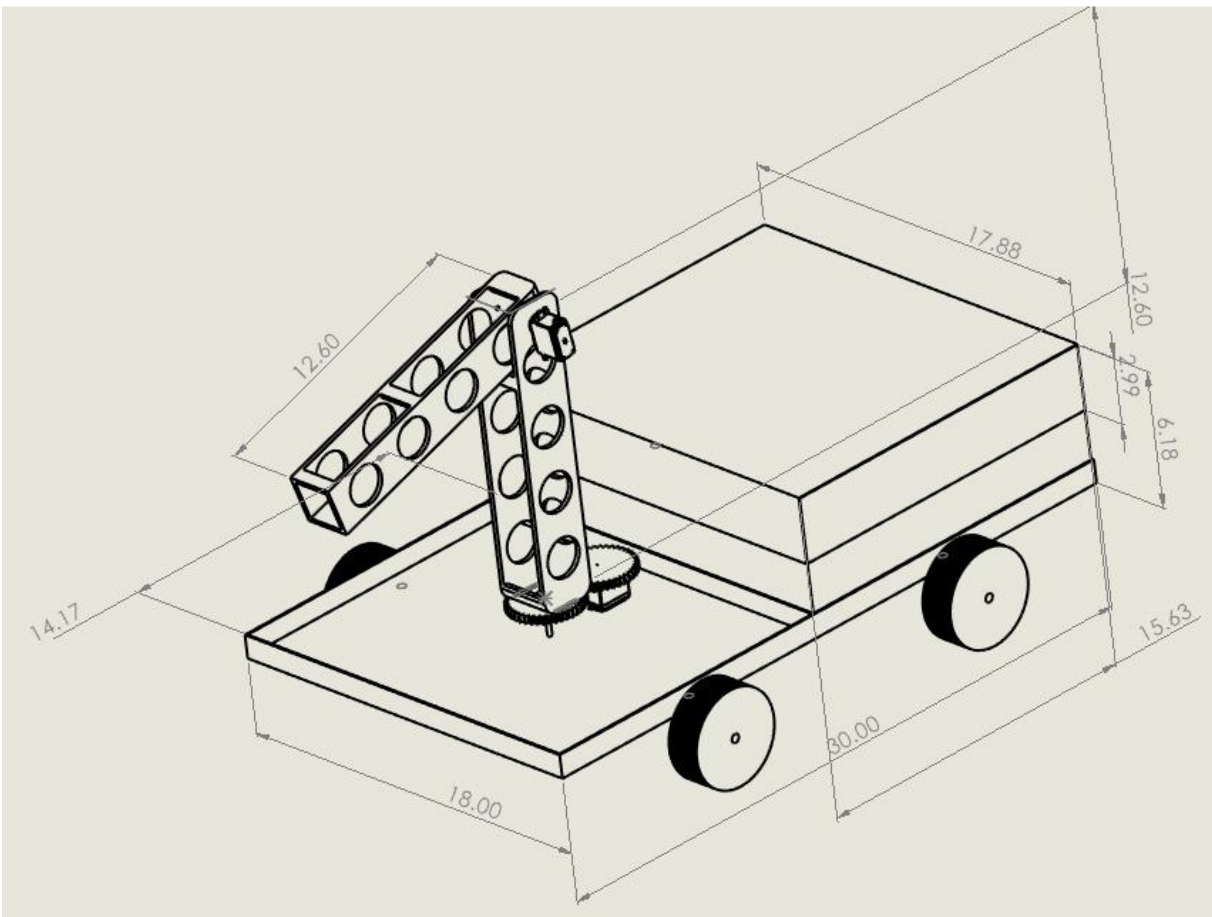


Figure 10: Selected design of fire-fighting robot

These is the selected design of the fire-fighting robot, which is then fabricated.

Table 5: Mechanical design parameter of the selected firefighting robot

Design Features	Measurement
Length	30 inches
Width	18 inches
Height	6.18 inch
Arm Height	12.6 inch
Electric Box	Length- 17.88 inch
	Breadth- 15.63 inch

3.7.1 Key Features for selecting this design:

- These is a very compact design and can be easily replicable
- The cost of manufacturing robot with this design is pretty low
- There is no need of any advance machinery including 3-d printer to manufacture these design
- The weight of the electric box is distributed on the rear pair of wheels and the weight of the arm along with the sprayed water weight is distributed in the front pair of wheels under the calculation of center of mass
- It contains 4 wheels which is not so stable like the other configured designs previously discussed.

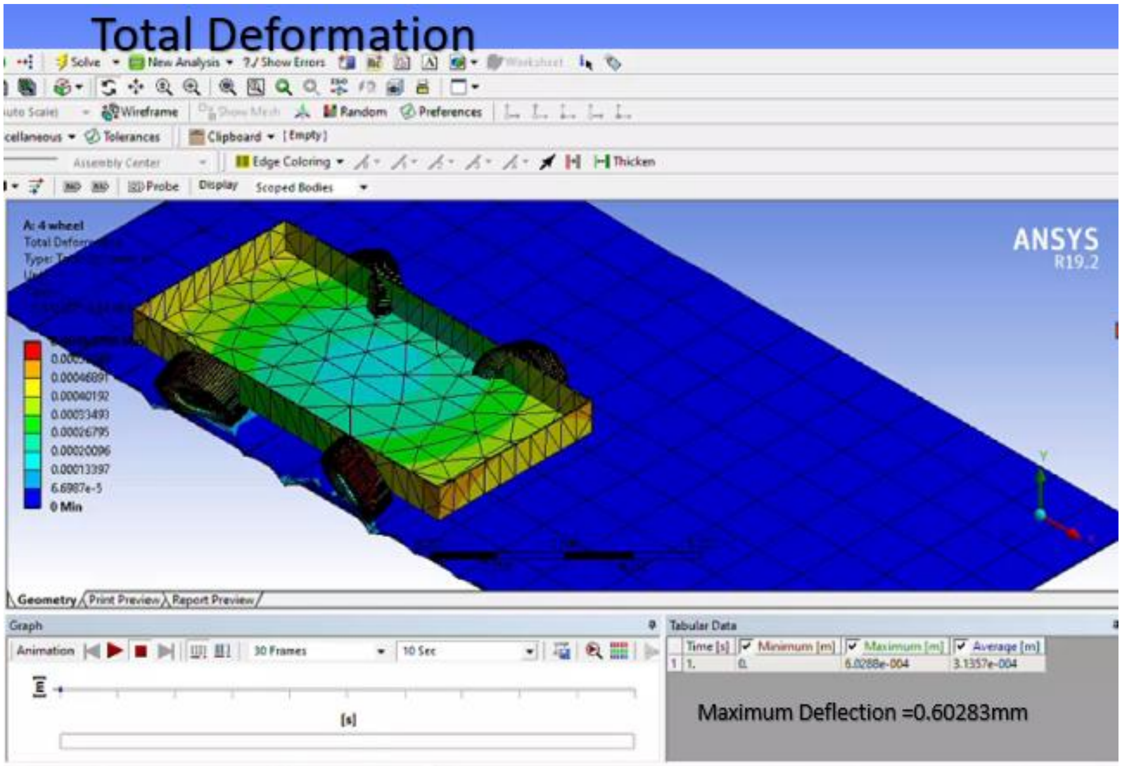


Figure 11: Total deformation on the selected design with 4 wheels configurations

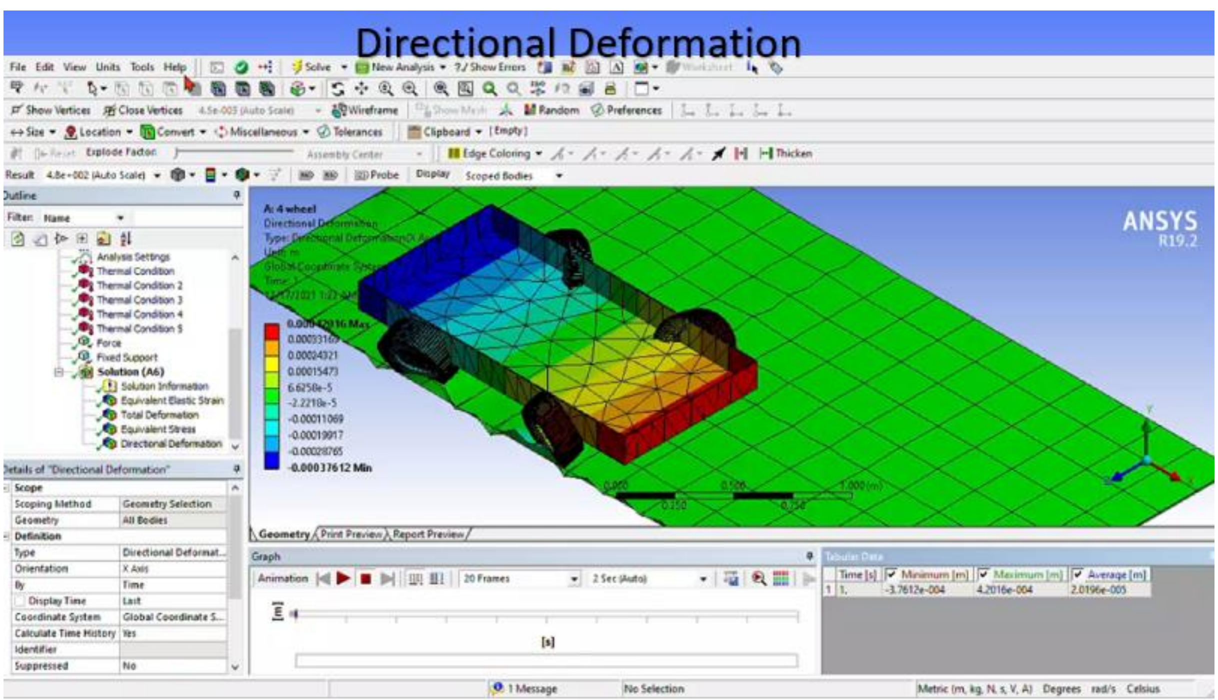


Figure 12: Directional deformation on the selected design

Considered parameters for the simulations:

- The environmental Temperature is 50^{o}C
- Mesh element size 0.2213m
- In close vertices mesh size 4.5e^{-003}
- The ground part of the road is considered as fixed support
- As the Robot body weight is fallen on the road, thus we have given the opposite force of (49N) from the road to the robot wheel.
- The weight of the Robot body is considered as 10kg

3.8 Arm design

The arm is designed into two parts. One is the upper arm and the other is the lower arm. The upper part is attached with the lower part with a revolving joint which is connected with the help of a stepper motor. The lower arm is connected with a gear, which directly connected with another stepper motor powered gear. Thus a 2 degree of freedom (DOF) movement is achieved. The designing of the arm is done considering the low weight. The grooves are given on the arm so that the material needed is significantly reduced and weight is reduced. Under simulation we get the arm with grooves can with-hold the weight that will be exerted on it due to the moving water weight.

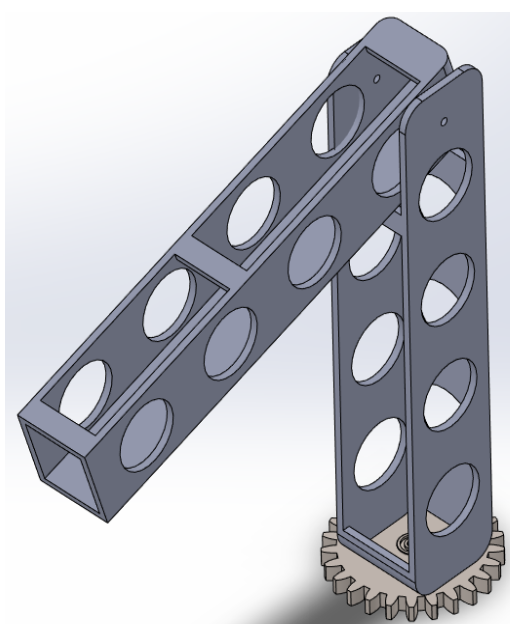


Figure 13: 2DOF arm of the firefighting robot

Chapter- Four

Manufacture & build-up of the robot

In these chapter, the designed robot is manufactured. All the procedure has been mentioned and explained with all necessary reasons. Also, the cheap and low-cost material has been characterized. The selected firefighting robot is fabricated with sheet metal and the frame work is done with Aluminium. The robot is built exactly as per the final draft design. The work has been cheap and easy as there is no need of any advanced mechanical work.

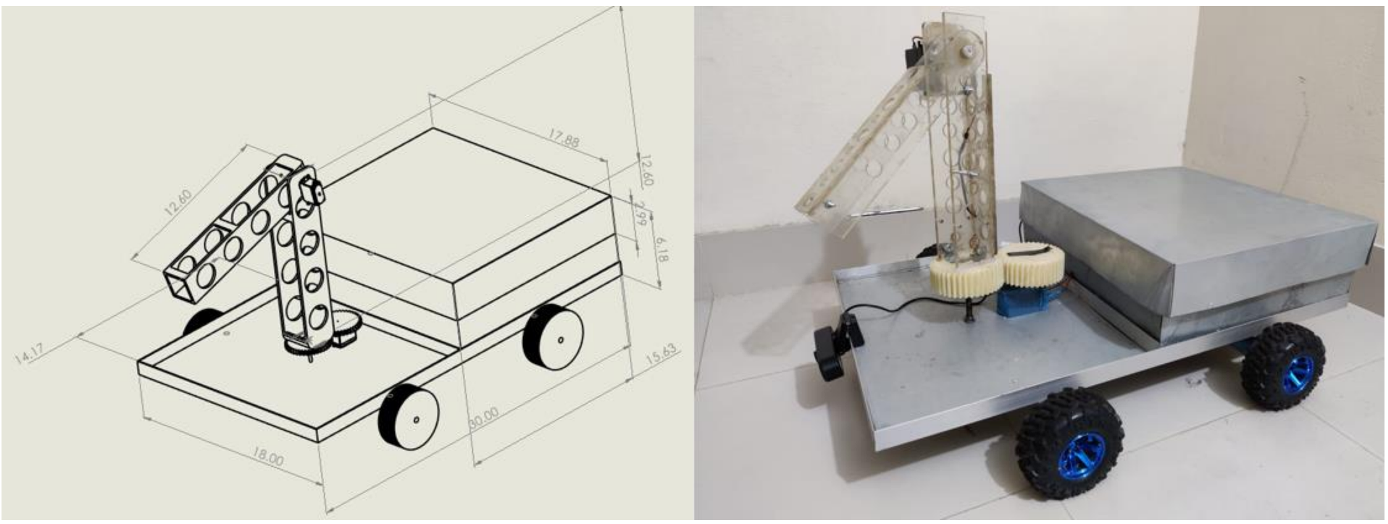


Figure 14: Design to exact manufacture of the firefighting robot

4.1 Frame-work

The frame is given to give extra rigid support to robot body. Due to the frame the weight of the whole robot is equally distributed throughout the whole robot body. Before the Manufacture of the frame, it is designed and simulated many times.

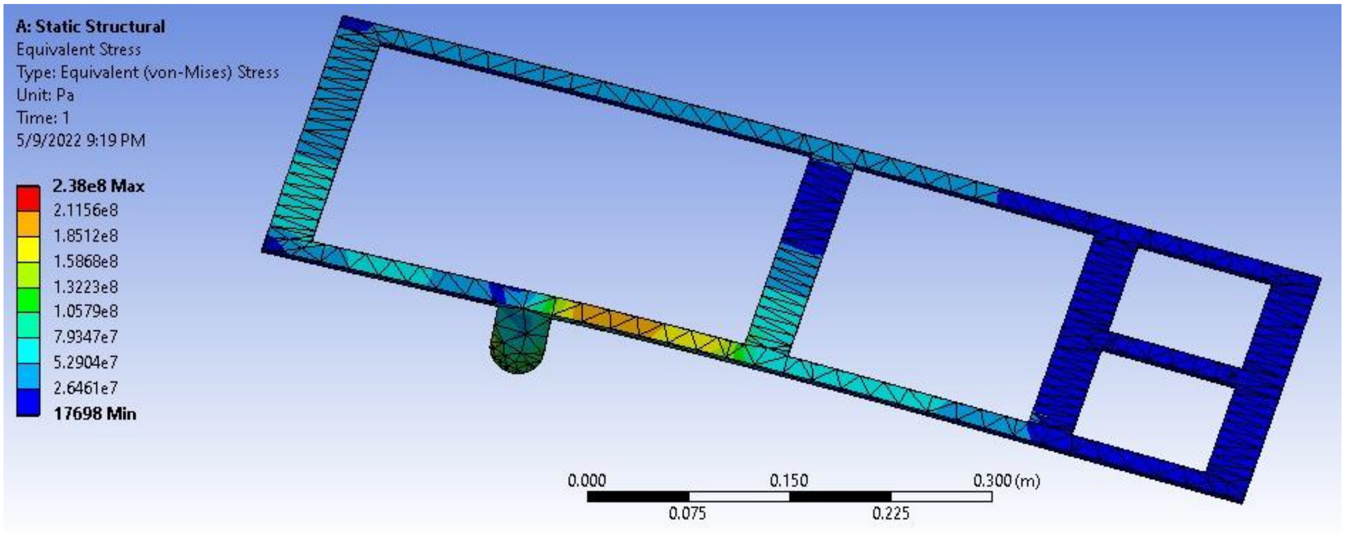


Figure 15: Von-Mises equivalent stress on the frame of the firefighting robot

Assumptions for the simulation

- The environmental Temperature is 50^{o}C
- Mesh element size 0.2213m
- In close vertices mesh size 4.5e^{-003}
- The weight of the Robot body is considered as 10kg
- For ease of the simulation only one motor mount has been shown.

In this simulation, mainly one motor mount has been considered and the stresses oriented to that has been observed. The shape of the overall frame has been taken rectangular shape as the force here is equally distributed and it gives the most stable weight balance.

The frame has been internally joined with rivet pin. A rivet is a physical attachment that looks like a metal pin with a head on one end. At first the desired rivet location is drilled than the rivet pin is attached to it with the help of a rivet gun. Due to this the frame work works become more strong and rigid. Rivets are vibration-resistant and can fix connections with short clamp lengths. They are, however, more complex and time consuming to install and remove than threaded bolts, and their clamp load is limited.

The arm and the wheel motors are attached firmly with the main frame as per simulation they will be exerting the maximum amount of force

4.2 Electric Box and base

The other parts including the electric box and the base are made with sheet metal as it will withstand less force and distribute the force on the frame.

Steps taken to manufacture these is given below:

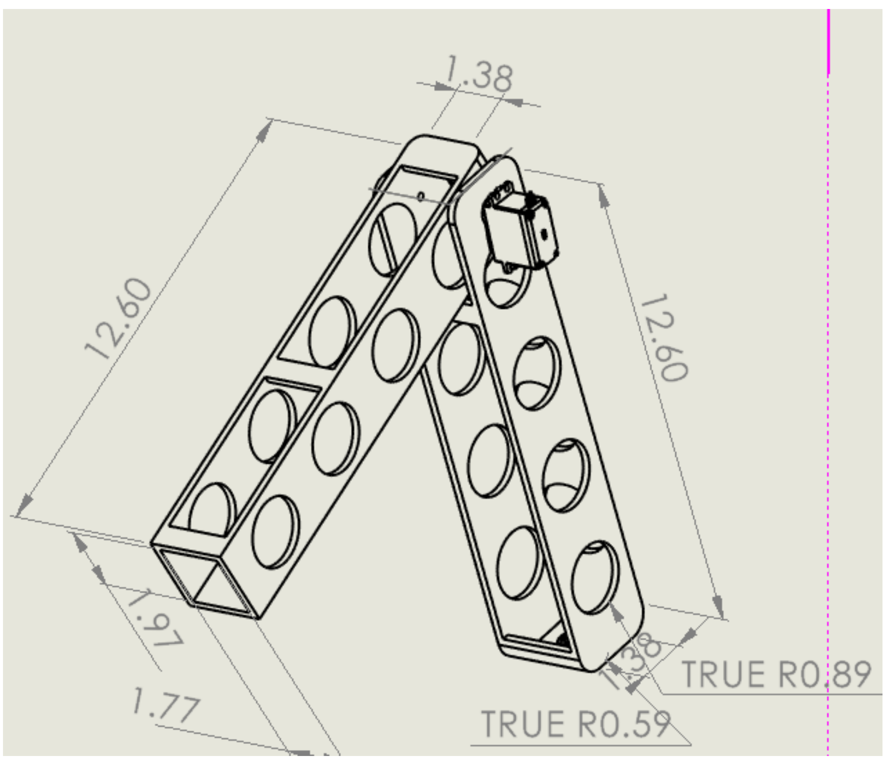
- At first the designed is taken and an exact long metal sheet has been cut off from it
- Then the sheet metal is folded to make a box like structure exactly as per design
- The side wards extra metal sheet is folded with each other and this part is hammered so that the shape is firmly attached and it becomes water proved.
- Now we get the exact electric box as per the design
- At last, the water proof test is done on it, so that no water can enter this place.
- After these a exact electric box cover is made which is exact fit to the upper part of the electric box.
- For safety issues the sharp ends are again folded and made blunt.
- The base are very easy to make with the cut of the sheet metal and they are rigidly fitted with the frame with rivet pins.

4.3 2-DOF Robotic arm

The robotic arm is delicately designed and the done with simulation analysis. The robotic arm is made of two parts, the upper arm and the lower arm. The material of both of it is made of nylon. The thermal conductivity of the nylon-6 material is very less, i.e., 0.200 - 0.330 W/m-K. The manufacturing process of the Robotic arm is given below:

- Nylon material is at first cut down made into 8 small flat rectangular shape
- In milling machine, the parts are exactly cut down according to the design
- Then four of the parts are attached in a box type structure to form both the upper and lower parts of the arm
- For extra rigidity of the arms, nut and bolt is added and they are firmly attached by drilling a through hole through the parts of the arm.
- As per designs different holes are made on the arms so that it will lose some weight.

- Two arms are connected through a revolving rod which is fabricated with the help of a lathe machine. These connecting rod is drilled inside to fit the motor shaft of the stepper motor.
- With the help of milling machine two exactly meshed gears are made on which the arm will be placed on.
- One of the gears will be holding the arm weight and the other will be revolving with the power of the motor.
- The arm which will hold the weight of the arm is attached with the frame with the help of nut and bolt along with the springs to absorb the shocks.
- The other gear is attached with the stepper motor with the help of the stepper motor mount. This stepper motor mount is made exactly with motor shaft fittings and it can rotate with the rotation of the motors.
- A long metallic pipe is attached with upper arm, which is again connected with main water supply source.
- Thus, the Robotic arm is finished manufacturing.



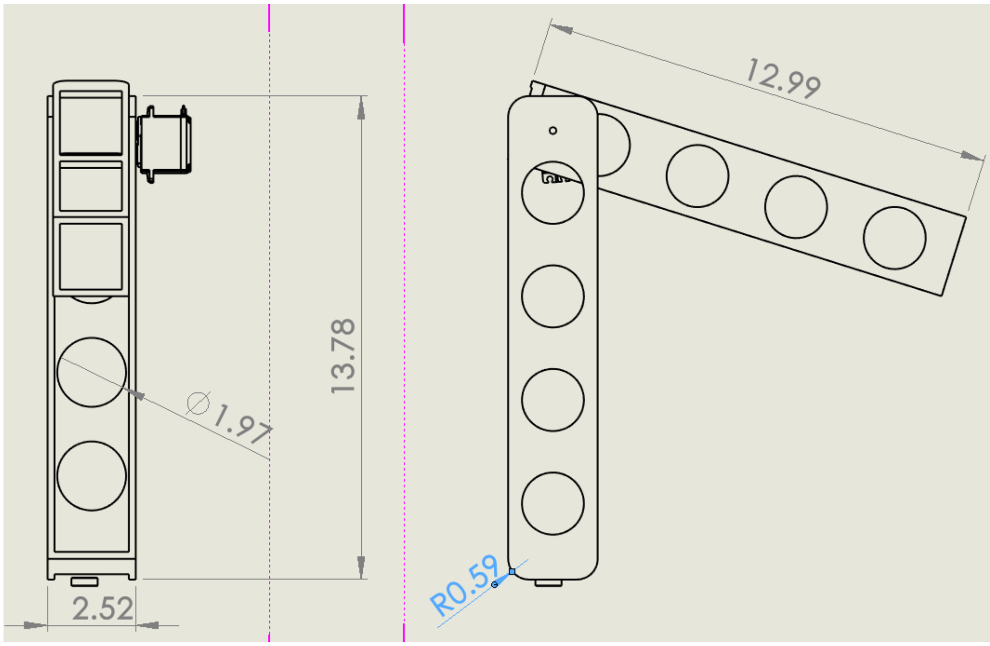


Figure 16: 2DOF robotic arm with dimensions

4.4 Wheels

Though in these project market available wheels are used. But as per our design metallic wheels are mostly fitted for this work. The manufacturing process of these wheel is given below:

- Exactly circular structure is cut off from the metal scarp with the help of lathe machine.
- A central whole is created for the purpose of holding these circular pieces in the late machine. Later in these whole a nut system should be introduced so that the motor shaft can be firmly attached.
- On the outer part of the wheel a circular thick rubber is attached so that it can hold the expansion of the metallic wheels
- Before the installation of the wheels to the main frame it should be examined carefully about its performance while revolving
- While running the firefighting robot, if the wheels does not work properly or it seems to vibrate a lot, then the screw attached to the wheel and the motor shaft should be tighten again or else the no-2 process should be done.

4.5 Material analysis for the firefighting Robot

Different materials have been analyzed in order to get an idea to use the perfect material for the firefighting robot. Even the idea of mixing the different materials or use of complex material can be get from these table.

Table 6: Comparison between different materials that can be used in the firefighting robot.

Features	Brass	Copper (Cu)	Bronze	Aluminum	Stainless Steel
Melting Temperature	1073-1113 K	1357.6 K	1367 K	933K	1793K
Cost analysis	Very expensive	Very expensive	More than brass	Low cost	Low cost
Strength	Better than Cu	Low	Moderate	High	High
Resistance to fire	Low	High	Moderate	Moderate	High
Thermal conductivity	Around 43% of the copper thermal conductivity. These is also high	Highest conductivity	Moderate	High	Poor

Thus, analyzing these data and information we have chosen steel which is used as sheet-metal in these projects.

4.6 Mechanical works to be done after Robot crushes

It is usual that the firefighting robot will operating might get crush or collusion with walls or other large obstacle. After this type of collisions, the immediate mechanical works that should be done is given below:

- The overall structure of the firefighting robot should be checked. If any parts is damaged then immediately it should be changed.
- The motor mount should be changed. As simulation data the maximum stress is fallen upon the mount and also while using the robot after the crush the motor mount experiences the most force.
- The lower part of the robotic arm should be checked if it is firmly attached with the gear.
- For minor crush, it is advised to color the whole robot structure so that the minor crush can be easily identified with the damp color conditions.
- If massive crush happens, i.e. the robot electric box and arm is completely destroyed then the robotic frame should be extracted and the robot can be easily rebuild.
- Finally after rebuilding from the crush, again before going to action the firefighting robot should be thoroughly checked and run.

Chapter-Five

Robot control & Programming

In the main focus of these following chapter is the robotic control. Here, all mechanism flow charts has been discussed and explained in details. Even the exact components have discussed along with their exact features.

5.1 Driving mechanism

The driving mechanism of the firefighting robot is pretty easy. Previously discussed 4 wheels are used in this robot model. The Raspberry pi-4 is used as the micro-processor. And BTS-7960 is used as motor driver. 300 rpm DC motor is connected with the motor driver.

5.1.1 Raspberry pi as microprocessor

The Raspberry Pi is made up of several small single-board computers that are often used in a variety of applications. It contains a quad-core ARM Cortex-A7 CPU (Central Processing Unit) running at 900 MHz and 2 GB of RAM (Random Access Memory). The Arm Cortex-A7 is built on an energy-efficient 8-stage pipeline and has a low-power, low-latency L2 cache. It includes 100 MBPS Ethernet capability, 4 USB connectors, and 40 GPIO pins. Quad-core Cortex-A72 64 bit. It's Wi-Fi has the capacity of Dual band signal with a speed of 2.4 GHz .It has also high band Camera serial interface (CSI) and Display Serial Interface (DSI) .

Raspberry Pi is chosen over Arduino for a variety of reasons. To begin, an Arduino is a microcontroller that can only run one system at a time, but a Raspberry Pi appears to be a microprocessor or general-purpose computer that can run many programs at the same time, which is crucial for our project. Second, while the Arduino is simpler and easier to use than the Raspberry Pi, it is usually used for simple tasks like temperature sensing, door unlocking, and so on. When we need to perform several tasks, such as calculations and decision making, the Raspberry Pi is suitable. The Raspberry Pi is better suited for controlling appliances from several users in our system. Furthermore, there is scope of adding a SD card slot in the raspberry and a large number of GPIO pins makes it suitable for the project to use a large number of features directly connected to the Arduino.

5.1.2 Motor driver

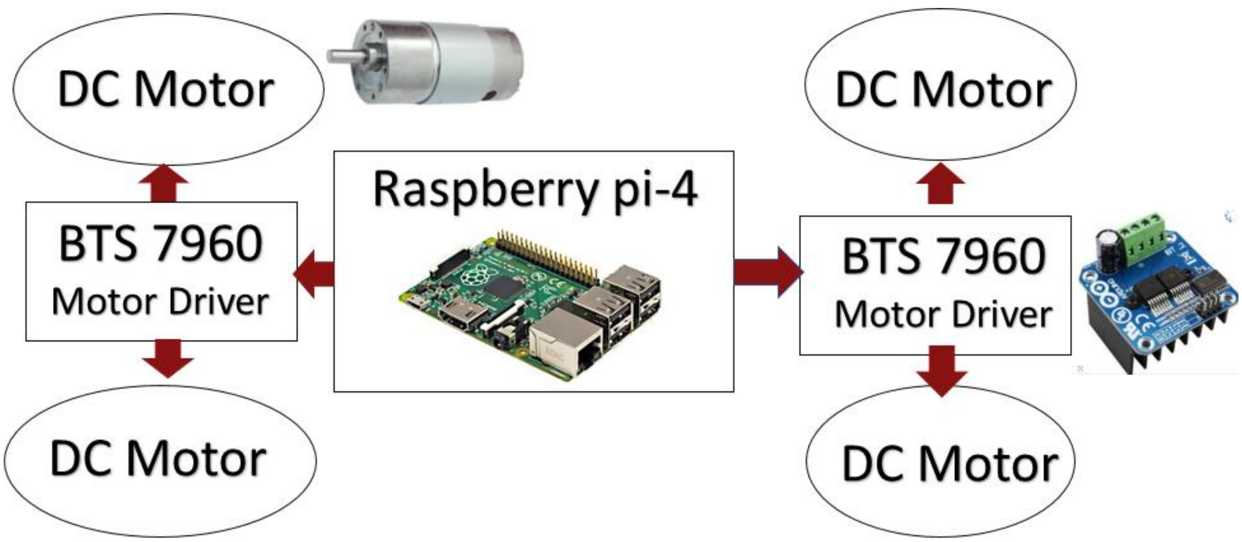
The BTS7960 is a high-current full-bridge motor driver module. The following are the main characteristics: The voltage range is 6V to 27V. The maximum permitted current is 43 amps. The frequency range of PWM is up to 25 kHz. Then, like a bidirectional Converter, an H-bridge is utilized to drive a load in both directions. It also regulates the flow of electricity to the lift capacity. The most common among the motor drivers is the L298n motor driver .But, it is not used since its current flowing capacity is very less (less than 2A) .Thus BTS-7960 is the perfect motor driver.

5.1.3 DC Motor

High torque geared DC motor is used. This motor has the capacity of 300rpm. The working range of current is 4.5- 5 A current. Small gears are meshed in accordance with mathematical calculation to give the right amount of torque.

The DC motor is directly connected with the motor driver. Motor driver is connected with both the power supply (Battery) and the micro-processor (raspberry pi). The flow chart given below can give an easy visualization towards process and connectivity.

Table 7: Driving mechanism flow chart of the firefighting robot



5.1.4 Motor control:

The motor driver controls the power to the motor .For forward movement all the 4 motors are activated .similarly for the reverse movement all the 4 motors are rotated in the opposite manner .But in case of the right and left turn ,differential type mechanism is used .Here one of the motor driver is switched off, resulting in the movement of the other two motors .Thus the motor will rotate the whole robot body in one direction might be left or right .Again for the rotation in the other direction opposite mannerly the motor driver is activated .But, these movement is sometimes not so precise and results in more turning .

5.2 Arm control

As per design, the arm is divided into two parts, the upper arm and the lower arm. Here the microprocessor Raspberry pi gives the order of the movement of the servo motors and thus it rotates the arms accordingly.

5.2.1 Servo motor:

Servo motor is a special type of motor that generates torque and velocity dependent on the current and voltage supply. It is a part of the closed loop system controlled by the servo controller and is eventually closed by a feedback device.

The servo motor is mainly controlled by the PWM (Pulse with Modulation) signal sent through the control wires. There's a minimum pulse, a maximum pulse, and a repetition rate in every servo motor. It may turn 90 degrees in any direction from its initial state. It usually anticipates seeing a pulse every 20 milliseconds (ms), and the length of the pulse affects where the motor rotates. A 1.5ms pulse, for instance, will force the motor to rotate 90 degrees. If the pulse is less than 1.5ms, the shaft moves to 0°; if it is larger than 1.5ms, the servo turns 180°.

In these projects we have used Carson Mega EVO Servo-motor whose model no: 502003.These servo motor has a maximum capacity of 19.62 Nm Torque. It can mainly work within an operational voltage of 6.8 to 7.6v. The more the torque needed the more it will take the voltage. For the rotation of only 60^0 degrees, it requires only 0.17 second time. Though due to continuous use this value may degrade. The servo motor is very compact in shape with a length of only 38.5

mm, breadth of 19mm and a height of 32mm. The weight of the motor is only 39gm. Graupner/JR wire system is used in the motor for external connectivity (connection with the raspberry pi).

5.2.2 Buck Converter

The buck converter is a special type of step-down converter which has the capability of degrading the voltage of a DC (direct current) to DC power supply. For instance, in these projects the servo motor requires a voltage range of 6.8 to 7.6v. But the power supply (Lithium ion battery) gives a voltage around 11.5v. So, it obvious that these direct connect of battery with the servo motor will certainly be massacre. For particularly this reason buck converter is used. we have reduced the voltage of 11.5 to 7v. And thus, the servo motor is working perfectly.

The input current varies unexpectedly due to the inductor in the input resistance. When the switch is set to high (on), the inductor receives energy from the input and stores it as magnetic energy. As a result, the adoption of MOSFETs has enabled this.

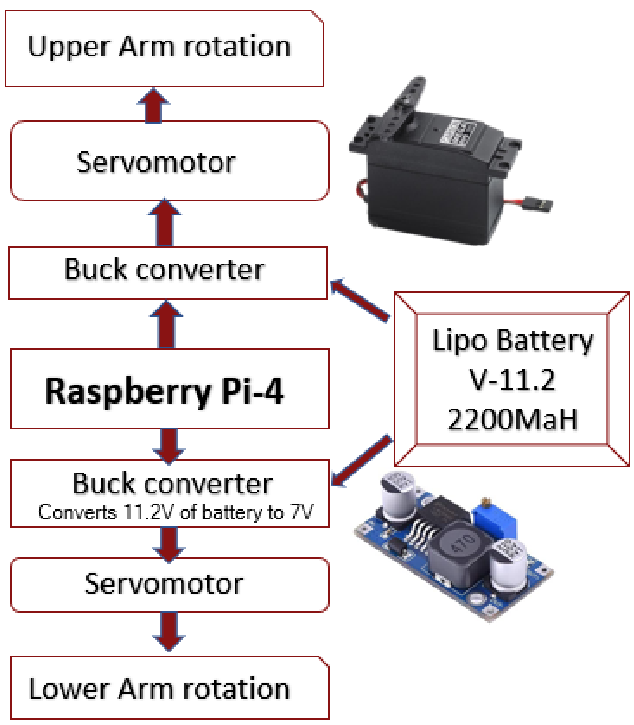


Figure 17: Flowchart of arm-control of the firefighting robot

5.3 Camera connectivity flow-chart

Camera is an essential component of every distant robot control. In these projects a widely available USB camera is used. Camera is in direct contract with the micro-processor. After lots of analysis and experiment to get the perfect the feedback the image quality should be 640 x 480 pixels. The frame rate should be 350. If this is not maintained then the inbuilt wireless WIFI of the raspberry will buffer the video feedback. The trigger motion threshold should be 1500 and the noise threshold for motion detection level should be 32. Using the motion library of the raspberry pi a local port is created in the pi-address. Thus, open video feedback is created which can be accessed by anyone who is connected in the similar network. Motion is a free open-source platform which is developed for Linux operating system. This library is used to detect the motion and to record or to fetch the video stream online.

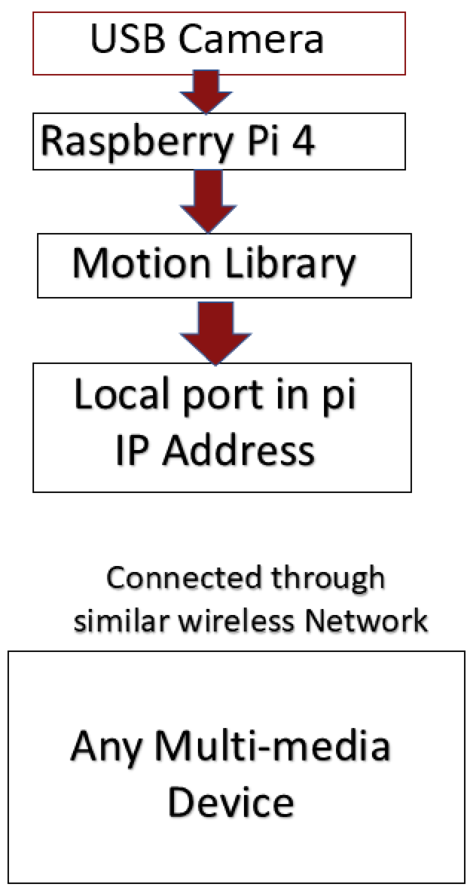


Figure 18: Wireless camera connectivity flowchart

5.4 Flame sensor

Nowadays flame sensor are widely in use to detect the flame. It used IR (infrared ray) to detect flame and gives signal. The module features a straightforward three-pin male berg connection with V_{cc}, ground, and an output pin. To alter the threshold level, a potentiometer is supplied. The D0 pin to a GPIO pin is connected to activate the sensor. It gives only the data of on and off. The flame sensor is small and compact in size. It has a adjustable threshold value with a 2 state binary output (0 and 1). It also has a feature of easy screwing. The working voltage of the sensor is 3.3 to 5V.

This sensor is added with the raspberry pi and the logical output is wirelessly obtained.

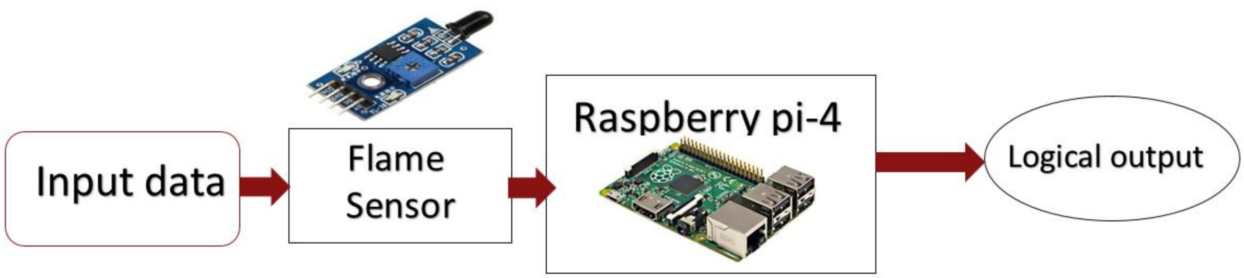


Figure 19: Flame sensor flow-chart

Chapter-Six

Conclusion and Recommendation

This is the last chapter of the book which comprises the summary of the whole book along with it the conclusion and some recommendations have been done. The future prospect of these thesis has been elaborately discussed in this part.

6.1 Conclusion:

A fire event is a calamity that can result in loss of life, damage to property, and lasting handicap of the victims. Firefighters face challenges, especially when fire breaks out in confined spaces, as they must investigate the ruins of structures and overcome obstructions to stop the flames and save sufferer. Because of the significant hurdles and risks involved with firefighting, technology developments can be used to help. The training sessions obtained via the design, manufacture, and contest of a robot will be discussed in this article. Firefighting is an essential yet hazardous profession. A firefighter has to be able to respond swiftly to a fire and safely put it out, avoiding more damage and reducing casualties. Technology has now crossed the gap between humans and machines, enabling for a much more effective and efficient firefighting strategy. Robots developed to locate a fire before it spreads out of control might one day collaborate with firefighters, drastically lowering the danger of human injury.

This thesis topic focuses on the creation of a fire-fighting robot that can put out fires without exposing firefighters to undue danger. The robot would be smaller than other typical fire-fighting bots in order to allow for easy accessibility into tight spaces and a longer reach for extinguishing fires. As a consequence, robots were able to locate fire sites automatically and extinguish fires remotely at a certain distance. The robot is trained to locate the fire and halt at a distance of up to 50 cm from it. It will be operated remotely.

This study provides a way for operating a robotic arm with an Android application. Wi-Fi connects the Android phone to the Raspberry Pi board. The robotic arm, as the name implies, is meant to do the same tasks as a human hand. The android app sends out a signal, which is intercepted mostly by Raspberry Pi 3, and also the robotic arm follows the predetermined program. The robotic arm's command center is an Android application. The Raspberry Pi software is created in the Python programming language. The arm rotation and movement will be controlled by various data.

Industrial accidents would result in huge losses and pose a significant risk to human life. Early fire detection and small-scale fire-fighting actions can save lives and prevent massive losses. Most fire mishaps will not result in significant losses if firefighting action is performed quickly. The notion of incorporating an automated firefighting mobile robot into a typical fire protection Internet of Things network to execute early firefighting action is proposed in this study. If a fire is detected, the system sends an alarm to the fire department and instructs the mobile robot to take action.

Hardware, electronics, and programming are the three parts that make up robot development. The robot is equipped with three DC motors: two for the driving system and one for the ball suction and fire blowing subsystems. Photoelectric detectors, fiber optic sensors, and RGB color sensors are all interfaced with the Pic microcontroller to provide feedback to the robot. The user may also see graphical information about the robot's status on the LCD display. The robot activity gain is determined from the devices input using the C programming language.

This fast-firefighting activity puts out the flames and informs the fire department. Meanwhile, by analyzing the footage transmitted by the firefighting robot, fire safety authorities may better prepare how to tackle the fire mishap.
Industries with a high risk of fire may combine a fire-fighting robotic arm with their preexisting fire suppression system.

The qualitative investigations conducted in this study are a first step toward better understanding firefighters' attitude, ideas, and views about cancer risk, and also how organizational transformations affect disease health and the prevention improvement among members of the organization. This study focuses on fire-fighters' views of cancer risk in order to contribute to the literature on health education and occupational accidents, especially to the knowledge on firefighters' perceptions of their health risks. The architects of health promotion strategies and treatments aimed at the emergency services and other high-risk job groups will benefit from an assessment of these issues. This paper offers findings from group sessions and 150 hours of direct participant observation.

Firefighting robots are currently being investigated in order to prevent firefighter injuries and deaths while also increasing their work performance. The usual sensors for robot navigation do not operate well in fire smoke-filled conditions with limited vision and high temperatures, making it challenging to make firefighting robots autonomous. To overcome these restrictions, a multi-spectral recognition system was created that combines sensor fusion between stereo infrared light vision and frequency modulated-continuous wave radar to find objects in real-time through zero visibility smoke.

Electric vehicles are becoming more popular as popular awareness of environmental issues grows. The determination of wheel torque is an important aspect for efficient driving in vehicles with controlled motor on every individual wheel. The variation principle was used in this study to create an optimal torque determination approach that minimizes friction jobs performed either by wheels with the ground contact.

The equations were numerically solved under various driving situations to find the optimal torque upon every wheel for a multiple vehicle. The numerical simulation's outcome can be used as a reference for controlling overall torques of electric cars for more efficient driving.

The two most significant hurdles to efficient and effective fire-fighting performance were discovered to be a large and bulky turnout outfit and an inadequate sizing method. In addition, while research on female firefighters' PPE is sparse, it is in great demand. As a result, this study offers suggestions for enhancing the form, fit, & performance of future personal protective equipment. It outlines present PPE product design and size difficulties, giving a vital guidance to the business in enhancing sufficiently quickly design and manufacturing of PPE. It also highlights significant information gaps in firefighting and recommends future research possibilities, such as enhancing firefighter design depending on gender, size, experience, and firefighter classification.

The motor is a critical element that is found in all electric cars. The motor torque delivered by the driving motor is critical in determining an electric vehicle's speed, acceleration, and performance. The following study tries to make the computations necessary to determine the motor capacity that should be utilized to operate a vehicle with given characteristics easier.

6.2 Future Scope:

Soldiers in war are rotated off of the "front lines" after just a length of time to lower stress levels, while first responders can serve for up to thirty years, reacting to a range of horrific incidents on a regular basis. Understanding the predisposing characteristics, background, and/or personality traits that may make firefighter candidates more resilient or vulnerable once they have been implemented in the field and have experienced traumatic occurrences is critical. Which was before screening tests to choose and de-select individuals based on their capacity to endure the high stress atmosphere of a first responder profession may be doable and successful. Future study should also look at evaluating and adapting proven treatment approaches for war as well as other injury reactions to the unique demands and circumstances of firefighter/EMS workers, a group that's also known to just be treatment resistant.

The elevated implementations of firefighting robots show that they may be used in a number of situations. In fact, not that every fire is as difficult and unusual as the one at Notre Dame in Paris, but that does not diminish the importance of these technical wonders to fire departments across the country. Several of the following circumstances can be benefited from the usage of fire-fighting robots:

- Putting out fires in wood-framed structures that can be being built
- Putting in place a fire-fighting infrastructure
- completing the massive animal rescue
- assisting in the extinguishment of fuel truck fires
- Putting out flames in auto storage

The fire-fighting robot will indeed be able to collaborate with firemen in the future, drastically reducing the risk of damage to victims. It is a groundbreaking robotics project that aims to provide a practical and accessible means of saving lives and preventing property damage.

This study offers a fresh perspective on the principles employed in this subject. Its goal is to encourage technological innovation so that the different instruments can provide a dependable and efficient result. The research was meticulously carried out. The outcome demonstrates that the embedded system does really increase efficiency. These new instruments will benefit customers with improved services thanks to a common digitalized launch pad that will result in increasing flexibility in control, operation, and expansion; embedded intelligence, which will essentially foster the instruments' resilience; and, finally, improved control, operation, and expansion.

This is being addressed by researchers. A bunch of university students constructed among the most economical automatons to date using readily accessible off-the-shelf parts. It's a simple contraption that looks like a proxied, canary yellow take and carries a water reservoir as well as a shoebox-size PC that utilizes data from sensing devices to avoid colliding with objects. A slender arm protrudes from the chassis and therefore can bend in many locations, including an upper "elbow" that twists at angles that a human leg could not withstand. A thermally sensor, another camera that detects distance and brightness, and a nozzle are all attached to the arm.

- The demand for a technology that really can identify fires & take appropriate action without human intervention drove this idea.
- . This helps us move forward with robotic tasks that were previously performed by humans but were inherently dangerous.
- The mechanization of firefighting is an obvious candidate.
- It may be improved by connecting it to a camera system so the person in charge can monitor the robot's operation on a display from afar.

Water was being used to put out the fire, which was done by a pumping system. Blowing wind using fans, tightening fire extinguisher gel with servo motors, and other solutions are available in these areas. Nonetheless, in this construction, the fire is put out with water, which is the most efficient in terms of the time and materials.

This robot pauses at a doorway to collect its surroundings, then slides gently into position to evaluate the environment in a recent demonstration. The tip of something like the arm spins as it searches the walls for a heat source. When it discovers one, it points the nozzle at the hotspot and frees up, pouring water in a regular grid over it.

The existing data and literature showing the economic expenses associated with the non-fire-fighter injuries, illnesses, health exposures, and occupational disease arising from line-of-duty activities are identified, summarized, and evaluated in this paper. The complete assessment of the financial impact of these unfavorable health outcomes is hampered by major data problems. There are data gaps in capturing the prevalence and cost effects of firefighter cancer and other occupational disorders, such as post-traumatic significant, due to latency concerns.

The goal to build a system which can detect flames and intervene drove some study. It can only extinguish fire in the way at the moment, not in all of the rooms. It may be turned into a true fire extinguisher by substituting the fan with a carbon-di-oxide carrier and microprogramming it to suppress flames across the room. This enables us to delegate duties to robots that were formerly performed by people but were fundamentally dangerous.
The automation of firefighting is an obvious choice.
Given the number of lives lost in firefighting on a regular basis, the method we foresee is begging to be adopted. This effort, of course, has barely scratched the surface.

This effort, of course, has barely scratched the surface. Our work has become a proof-of-concept, as the design simplifications and implementation limits reveal. A functional autonomy fire-fighting system must, in particular, also provide a gathering of robots that communicate and cooperate in the mission; additionally, such a system must have the ability to navigate obstacles in the presence of fire, as well as the opportunity to absorb directions on-the-fly during an operation. All of these issues were outside the focus of this research.

Many of these components, however, have been studied in many settings, such as mobile agent coordination, obstacle detection and avoidance approaches, on-the-fly messaging between individuals and movable agents, and so on. Putting all of this together into a viable, self-contained firefighting service will be both exciting and demanding. So overall it can be said that for the next steps of improvement will be:

- Use of thermal Camera (FLIR ~ $1000 or other types of thermal camera)
- Automation using AI optimized sensor data
- Use of only customized continuous wheel and improved suspension system
- Greater improvement in the material selection
- Use of efficient heat exchanger to reduce temperature in controlling chamber

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