MENG 411 Capstone Team Project

Eastern Mediterranean University

Faculty of Engineering

Department of Mechanical Engineering

Autonomous Fire Detection and Extinguishing Vehicle

Course Coordinator
Assist. Prof. Dr. Mostafa Ranjbar

Supervisor
Assist. Prof. Dr. Davut Solyalı

Team Members

Paul Ogunniran	127645
Aliyu Abdulkadir Muazu	128407
Akunne Chisom	128484

Group Name: Blazers

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JURY MEMBERS

Assist. Prof. Dr. Davut Solyalı (Supervisor)	
Lec. Cafer Kızılörs	
Assoc. Prof. Dr. Qasim Zeeshan	

ABSTRACT

This report is about the design and manufacturing of fire detecting and extinguishing vehicle. Fire accident which is a global devastating problem leads to loss of lives and properties on a daily basis. Although there are different types of fire suppression systems, they are mostly very expensive and difficult to implement, hereby discouraging people from using them. The traditional 'wall attached' fire extinguisher which people often resort to is mostly ineffective in a situation of fire outbreak as people may not be around to use them or flee the scene at the sight of a fire. This calls for a more effective and cheaper approach to how fire accidents are been handled especially at their early stages.

This report gives background information, design specifications and manufacturing method of a fire detecting and extinguishing vehicle by; defining fire, its types and different conventional fire suppression systems. Furthermore, it explains the detecting, extinguishing and general operational principle of the vehicle. After the design and manufacturing of the system, it was tested in an obstacle filled environment, it was able to successfully avoid the obstacle, track down and extinguish a fire that started at more than 400cm away. This proofs that a cheaper and effective method can be used to combat fire accident.

TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1

INTRODUCTION

1.1 General information about fire damage

Fire outbreak is a global problem that has the most diverse causes and devastating effects mainly because they can cause loss of lives, environmental pollution and destruction of properties. Fire damages are the accidents that occur most frequently and their causes can be attributed to (although not limited to) faulty electrical wiring or outlets, negligence like gas leakage, improper handling of inflammable materials (cigarettes, fuel, matches, etc.), inappropriate or unsafe use of appliances and arson usually to cover up criminal activities. The advantageous purposes of fire causes people to keep its sources around them, so unfortunately, the occurrence of fire-related accidents are often inevitable**,** despite the presence of fire safety measures and because of this intervention methods and firefighting devices are necessary.

1.2 Fire triangle

In order to know and understand the elements necessary for a fire and how fire burns, a simple figure as shown in (Figure 1.2.1) called the fire triangle is used. The triangle shows the three elements needed to ignite a fire and their mutual dependence on each other. Each side represents one of the three elements. They are oxygen, fuel and heat. **Oxygen** is required because it supports the chemical processes of fire through oxidation; when fuel burns it reacts with oxygen thereby releasing heat and generating combustion products (smoke, gases and ashes). About 16% of oxygen is needed for fire to burn. **Fuel** is any type of inflammable substance and it is classified based on its size and shape, quantity and its moisture content (the wetness). Moisture content is important because it dictates how easily or fast the fuel will burn. **Heat** is responsible for raising the material to its ignition temperature and maintaining the fire; allowing it to spread. It lets the fire travel easily by reducing the wetness of the fuel, preheating the air and warming the path of the fuel. A fire will occur when all the elements are available and combined in the right mixture thus the removal of any one of the elements can prevent or suppress the fire.

Without adequate *oxygen*, a fire can neither start nor continue because the oxidation stops and combustion becomes slow. Oxygen can be reduced by using a carbon dioxide extinguisher, pouring water or covering the area of the fire with flame retardant material (e.g. fire blanket). Absence of sufficient *heat* available to the chemical reaction will quench a fire and it can be removed by using water or specific powders or gases. Removing ashes extinguishes the heat source and turning off the electricity in the event of an electric fire removes the ignition source. Fire will stop without *fuel*. After all the fuel has been burned it will naturally end but it can be manually eliminated by mechanical means; water reduces the temperature of the fuel below the ignition point and disperses the fuel.

Figure 1.2.1: Fire Triangle. It depicts the ingredients necessary for a fire [1]

1.3 Classes of fire

Fire has been classified into different categories based on the kind of inflammable material that triggers them. Fires are grouped into class A-D and K.

1) Class A: These are fires started by ordinary materials like paper wood, cloth, trash and plastics.

2) Class B: are fires caused by inflammable liquids such as paint, paraffin, gasoline and petrol or inflammable gases such as methane, propane and butane. They do not include fires from cooking oils and grease

3) Class C: fires involving faulty electrical equipment such as motors, transformers, and other appliances.

4) Class D: fires caused by inflammable metals such as potassium, sodium, aluminum, magnesium, titanium etc.

5) Class K: These are usually kitchen fires; triggered by cooking oils and greases such as animals fats and vegetable fats.

Due to the variety of fuels, different types of extinguishing agents are required. Some extinguishing agents can be used for more than one class of fire. Others have warnings instructions where it would be dangerous for the individual to use a particular extinguishing agent.

1) **Water:** For use on class A fires only. Not for use on flammable liquid (class B) and live electrical equipment (class C)
2) **Dry Powder:** For use on class A, B and C fires. It is the most used extinguishing agent.
3) **Foam:** For use on class A and B fires. It should not be used on class C fire
4) **Carbon dioxide:** For use on class B and C. Do not use in confined space.
5) **Wet chemical:** For use class A and K

1.4 Objective of the project

The main aim of our project is to design and manufacture a cheaper, more precise and smarter fire extinguishing mechanism that can detect any fire in its early stages, go to the source of the fire and put it out. Fire extinguishing robot incorporates the various branches of a mechatronics system which are electrical, mechanical and computer. The identification of the direction of the fire is done by the smoke sensor and flame sensor (electrical), the microcontroller (computer) acts on the flame and smoke sensor values to activate the vehicle motors (mechanical) which tracks the fire and put it out. The operational process starts by identifying the direction of the incoming fire by the flame sensor and smoke detector. The microcontroller (Arduino) acts on this flame sensor and smoke sensor values to track the fire. .There are 6 flame sensors and 2 smoke sensors mounted on the pentagonal shaped vehicle. Their values are processed by the microcontroller at short intervals. During an event of a fire outbreak, the fire is identified first by one of the six flame sensors. These sensors values are interpreted by the microcontroller and it activates the motor to move the vehicle in the direction of the sensor with the highest value. While in motion, it avoids obstacle using 3 distance sensors and activates the extinguisher when close to the fire.

1.5 Contents of the report

Chapter 1 gave a brief introduction to fire damages, its effects and its causes then highlighted the purpose of our project. The subsequent chapter comprises of the literature review which talks about previous published works concerning this project, different models of firefighting equipment and its development. Chapter 3 illustrates the project's design and the manufacturing analysis. Chapter 4 and 5 gives in-depth information about the system manufacturing, assembly, testing, results and discussion, and also the difference between the proposed operational mechanism and the implemented mechanism. Chapter 6 talks on the conclusion and future work that can be carried out to improve the project. The concluding section will includes the references and appendices.

Chapter 2

LITERATURE REVIEW

Fire outbreak is a major concern and problem. It has been responsible for a large amount of loss of lives and properties. According to National Fire Protection Association in the US, a total estimate of 328 billion dollars was lost with 3,275 deaths and 12,775 injuries in 2013 due to fire accident and based on the World Fire Statistic (Figure 2.1), about 50% of fire accidents occurs in building structures therefore this report will focus on designing a fire detection and extinguishing vehicle that can be used to fight structural fire.

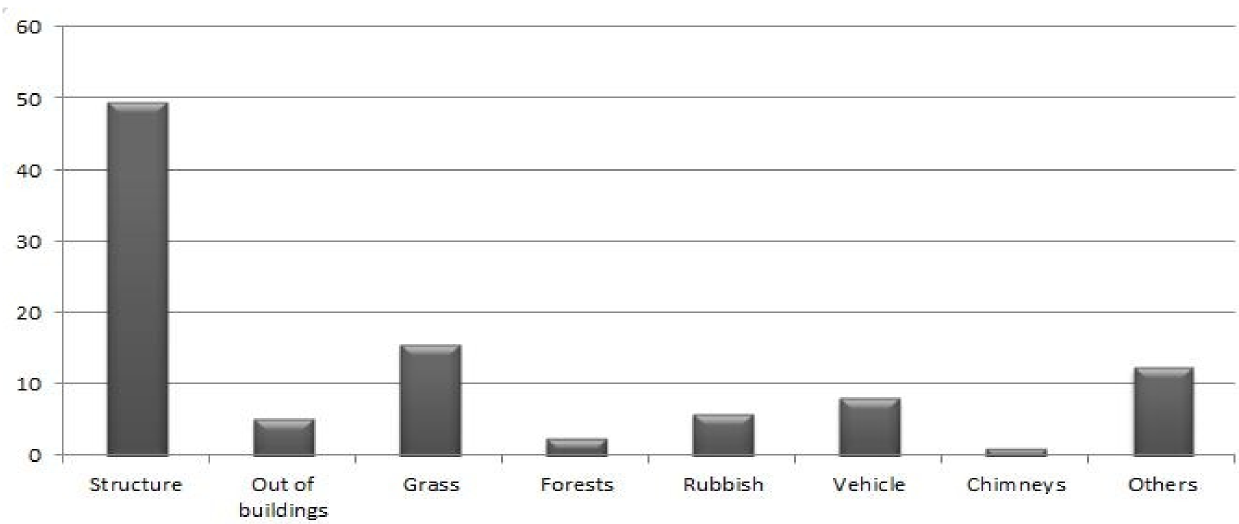


Figure 2.1: 2013 World Fire Statistic Chart [2]

2.1 Structural firefighting mechanisms:

Eliminating fire outbreak can be a tough task and it requires reducing the area of the burning region by suppressing the fire through depriving it of fuel, heat, or oxygen. There are various ways and instruments designed to douse a fire but the most common ones are the fire extinguisher, fire suppression systems and sprinkler systems.

2.1.1 Portable fire extinguisher:

This is the a portable and widely used fire control device which is made up of a pressurized cylindrical container housing an agent in liquid or powder form that can be discharged to put off a fire. The portable fire extinguisher (Figure 2.1.1) is used generally at the inception stage of the fire, when the fire is not out of control. It can be found in most building structures. Different types of the extinguisher include water based, foam based, CO2 based, CFC based and dry chemical based (mostly used) and they are applied according to the type of fire (class A-D).

Figure 2.1.1: Portable Fire Extinguisher [12]

2.1.2 Fire suppression systems

Fire suppression Systems (Figure 2.1.2) are used to control or extinguish, either manually (firefighting) or automatically. Manual control involves the using a standpipe system or fire extinguisher. Automatic control involves using a gaseous clean agent, or firefighting foam system. Automatic suppression systems are usually used in high risk areas such as a restaurant’s kitchen.

Figure 2.1.2: Fire suppression systems [13]

2.1.3 Sprinkler systems

Sprinkler systems (Figure 2.1.3) basically sprinkles anti-fire agent when fire is sensed. According to Wikipedia (2015), “They are usually located at ceiling level and are connected to a reliable water source, most commonly city water”. Wikipedia further explains that, “A typical sprinkler system operates when heat at the site of a fire causes a glass component in the sprinkler head to fail, thereby releasing the water from the sprinkler head”. It is incorporated in all types of buildings, commercial and residential.

Figure 2.1.3: Sprinkler systems [14]

2.2 Firefighting systems restrictions

Although this systems are quite important in combating fire, they still have limited technlogy or disadvantages. We hope to tackle this problems in our project. They are:

1) First extinguisher- in a fire outbreak, most people panic and try to leave the place instead of fighting the fire, allowing it to spread and cause more damage. Also, if the fire is situated at the area where the device has been kept, it will be unreachable and therefore pointless

2) Fire suppression and sprinklers systems- They are very expensive, complex to implement and the shower anti-fire agent sprinkled around has a high chance of destroying documents and machineries in that environment.

2.3 Firefighter robot solution

As a result of these limitations researches are been made into the possibilities of firefighting robots. Information about published researches will be discussed; however, fire detection and extinguishing robot cannot be fully discussed directly unless the term robot is explained. Robot describes any man-made mechanical, usually electro mechanical system that is programmed, guided or commanded by an electronic-circuitry or a computer to perform some specific functions ranging from light duties such as vacuum cleaning to heavy duties such as moving an airplane. Before going into the researches and projects carried out in this field, firstly how robots came into existence would be discussed.

2.4 Brief history and development of robots:

The first robot was created by achytas in the year 347BC it was bird shaped machine called pigeon it flies about 200 yards on average, propelled by steam like fluid. Through various researches and developments in physics and mathematics in the year 1790 Pierre Jaquet Droz and his son invented animated robots that help them sell accessories like watches; this is the oldest famously known example of computer. With the bloom of steam engines in 1865 John Brainerd created the Steam Man which was used to pull wheeled carts. In 1942 Willard Pollard and Harold Roselund designed he first re- programmable mechanism, a paint-sprayer for the DeVilbiss Company.

Following the development of transistors, robot started becoming less complex and more functional more researches were conducted starting off with Victor Scheinman creation of the Stanford Arm in 1969, which is notably the first successful electrically powered, computer-controlled robot arm. Consequently, in the year 1977, William Grey Walter developed the robot that uses a sensor giving birth to the idea which has become a key feature of a robot. This robot was called Elsie or Bristol Tortoise (Figure 2.4.1). It uses light and contact with objects as stimuli.

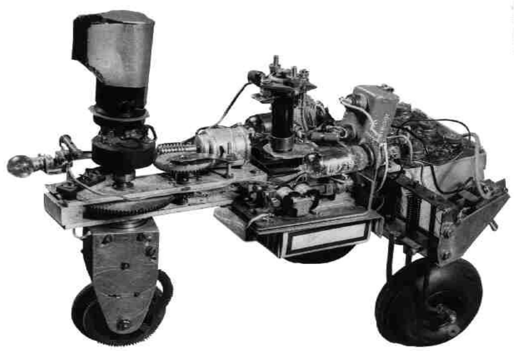


Figure 2.4.1 Elsie

Robot started becoming more incorporated in human lives with the introduction of iRobot; the first generation of Roomba robotic vacuum cleaners in 2002. Also space missions which couldn't be carried out by humans was accomplished with the use of NASA's launched twin robot in the 2003 mission's to explore Mars. Furthermore, Robonaut 2 (Figure 2.4.2), the latest generation of the astronaut helpers was launched to the space station aboard Space Shuttle Discovery on the STS-133 mission.

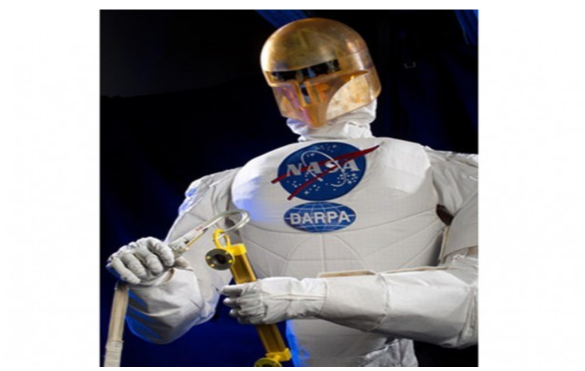


Figure 2.4.2 Robonaut 2[5]

In this modern era, commercial and industrial robots are now widely used in jobs to reduce overall cost and ensure greater accuracy and reliability.

2.5 Types of fire detection robots:

Various researches has been conducted on fire detection and extinguishing robots. Different types have also been modeled. Based on the studies, different mechanisms have been discovered to achieve the common goal of detecting a fire and putting it out.

An easy and fairly simple method was introduced by William Dubel, Hector Gengora, Kevin Bechtold and Daisy Diaz. The fire detection and extinguishing robot called rolly firefighter (Figure 2.5.1) uses a transducer and a line tracker for its movement and navigation. It follows the line to the position of the fire and extinguishes it by the use of a cup mounted on a custom arm. However this robot won't be able to function properly in an event of large fire outbreak due to its heavy dependence on line tracker and cup extinguisher mechanism.

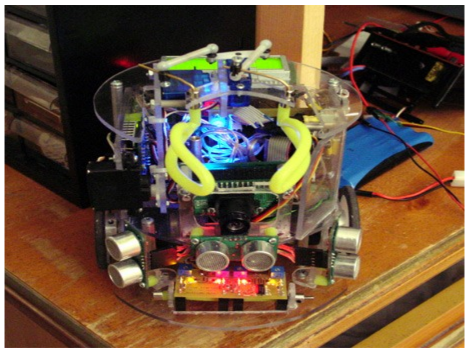


Figure 2.5.1 Rolly firefighter [11]

Viet Do, Ryan Norder and Ryan Spreatz noted that concentration of heat can also be a fire detection mechanism. They developed a robot (Figure 2.5.2) that can detect a certain amount of heat that could possibly lead to fire. In this method a color camera continuously monitor its surrounding to detect a spot or an area that has a large concentration of light it then move to the place and takes its heat value with a temperature sensor. If an excess temperature excessively greater than the normal room temperature is detected, a servo motor controlled fan will be turned on and will be left to continue blowing quickly until the fire is blown away. This method also wouldn't be reliable due to the fact that there are many other light sources apart from fire and a fan cannot put out a big fire, the most it can do is provide oxygen which propagates fire.

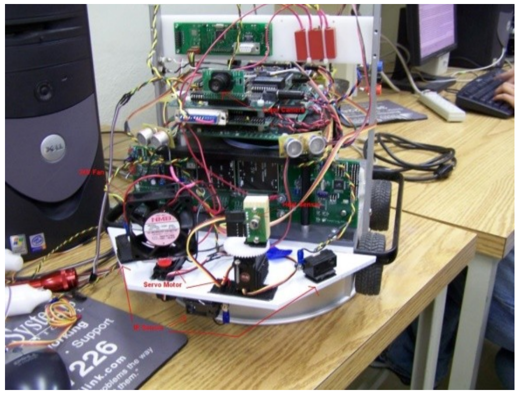


Figure 2.5.2 fire extinguishing robot by Viet Do and Ryan Norder [11]

More developed ‘fire fighter robots’ have subsequently been studied and developed. A notable example can be found in the research of Taiser T. T. and Walter F. L. (2012). They proposed that PLC can be used as the control system of robots. According to them, “To use industrial components, a PLC was chosen. A PLC is equipment with many capabilities like network communication and complex calculation.” Also they employed a rather different extinguishing mechanism by using a pneumatic system which ejects compressed air. [3]

U.Jyostna S. P. and M.V.D.Prasad (2013), however suggested the possibility of a simpler but equally functional mechanism through the use of a microcontroller instead of a PLC. In their research, they used a AT89C51 which is a low-power, high-performance microcontroller. They claimed that “Microcontroller is the heart of the project”. Also they utilized 4 amplified flame sensors for the fire detection and additionally incorporated the ‘fire fighter’ robot system with a GSM module that contacts the nearest Fire station when a fire is detected.[4]

Chapter 3

DESIGN AND MANUFACTURING

3.1 Calculations:

It is a known fact that fire propagates and spread very fast within a short period of time, therefore we have to design a system that would respond fast and move quickly towards the fire. To do this, a few parameters that the vehicle must possess will be stated.

3.1.1 Speed: This is a very important factor, to achieve a minimum desired speed of 20cm/s, a motor that can provide such RPM has to be selected, 20cm/s can be converted to RPM in the following steps:

$$V = r * \omega \text{ --------------------- (equ 1)}$$

V = Velocity

r = Radius of the tire

ω = Angular velocity

Minimum desired velocity = 20cm/s.

Chosen radius = 3cm. (radius of the desired wheels)

$$\omega = \frac{20\,cm/s}{3\,cm}$$

$$\omega = 6.67 rad/s.$$

$$\omega = 400 rad/min$$

Radian to revolution per minute conversion:

$$RPS = \frac{rad/s}{2\pi}$$

RPS = Revolution per second

Rad/s = Radians per second

$$RPS = \frac{6.67\, rad/s}{2\pi} = 1.06$$

$$RPM = RPS * 60s$$

Revolution per minute needed to achieve a minimum of 20cm/s = 63.9RPM

Therefore a motor that can provide more than 63.9RPM would be selected.

3.1.3 Torque: More importantly, the motor should be able to carry the total weight (Sprung weight) of the system (i.e. the body, fire extinguisher and components. Therefore the torque the system will produce needs to be known so that a motor can be selected to handle such torque. The torque is calculated in the following steps:

$$F = \mu_r * N \text{ ---------------------- (equ 2)}$$

F = Force

μ_r = Rotational frictional coefficient

N = Normal Force = M*g

Total Estimated Weight of the Vehicle is 15kg.

$$N = 15 * 9.8 = 147N$$

Rotational frictional of rubber to hard surface: μ_r = 0.015 (Appendix D2)

$$F = 0.015 * 147 = 2.2N$$

Torque:

$$T = Distance * Force \text{ -------------------------- (equ 3)}$$

$$= 2.2 * 3cm = 6.6N.cm$$

= 0.667kg.cm

Therefore a motor that can provide at least 60.3RPM at a torque of 0.667kg.cm will be selected.

3.2 Proposed Electrical Component

This involves the parts that are incorporated in whole electrical aspect of the design. They work together as a unit in bringing about the detection, navigation and extinguishing process. These components can be sub-divided into:

3.2.1 Microcontroller

The selected controller for the vehicle is the **Arduino MEGA 2560** (Figure 3.2.1). It is the brain of the system and it coordinates all the activities of the vehicle. It was chosen because it's more suitable for complex robotics projects. It consists of some technical specifications beneficial to this project. They include: **16 analog input pins**; we are using many sensors so that amount is adequate for the project, **256kb flash memory**; this space is enough for our program code which requires lot of bits. It is can be configured using the Arduino software and automatically selects its power source which can either USB connection or an external power supply.

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

Figure 3.2.1 Arduino Mega [15]

3.2.2 Sensors

The use of different types of sensors is incorporated in this project. They are mounted on the front, right and left side of the vehicle. They are responsible for the detection of fire outbreak. They include: flame sensors, smoke sensors and ultrasonic sensors.

1) Flame sensors:

The flame sensor module as seen in Figure 3.2.2 is sensitive and designed to detect and respond to the presence of a flame or fire. Due to its flame detection mechanisms, it often responds quicker and more accurately than a smoke or heat detector. It can be used as a flame alarm or in firefighting robots.

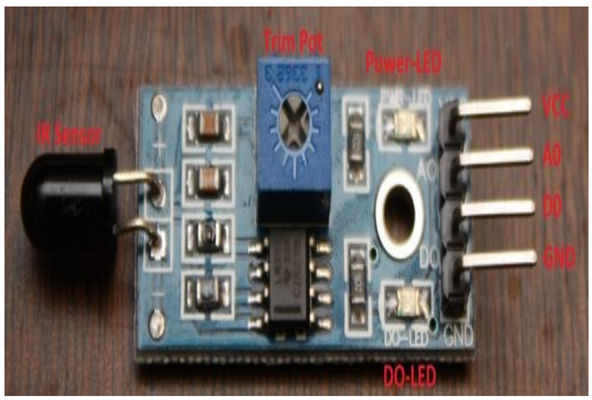


Figure 3.2.2 Flame Sensor [16]

Characteristics

• Detects a flame or a light source of a wavelength in the range of 760nm-1100 nm
• Detection distance: 20cm (4.8V) ~ 100cm (1V)
• Detection angle about 60 degrees, it is sensitive to the flame spectrum.
• Comparator chip LM393 makes module readings stable.
• Adjustable detection range.
• Operating voltage 3.3V-5V
• Digital and Analog Output
" DO digital switch outputs (0 and 1)
" AO analog voltage output
• Power indicator and digital switch output indicator

Schematic

1) VCC -- 3.3V-5V voltage
2) GND -- GND
3) DO -- board digital output interface (0 and 1)
4) AO -- board analog output interface

2) Smoke sensor (MQ-2):

The MQ-2 gas sensor module (Figure 3.2.3) is not only sensitive to smoke but to inflammable gases. It can detect LPG, i-butane, propane, methane, alcohol, hydrogen and smoke. It gives off analog output signal. The MQ-2 smoke sensor reports smoke according to the voltage level that it outputs. Increase in smoke causes a greater output voltage and vice versa. It also has a built-in potentiometer to calibrate the sensitivity to smoke.

Schematic

- VCC to Arduino 5V pin
- GNG to Arduino GND pin
- Output to Arduino Analog A0 pin

Figure 3.2.3 Smoke Sensor [17]

3) Ultrasonic sensors:

The ultrasonic sensor shown in Figure 3.2.4 is a non-contact distance measurement module that uses sonar to sense the presence of materials and determine distance between them. It provides accurate range detection and with stable readings.

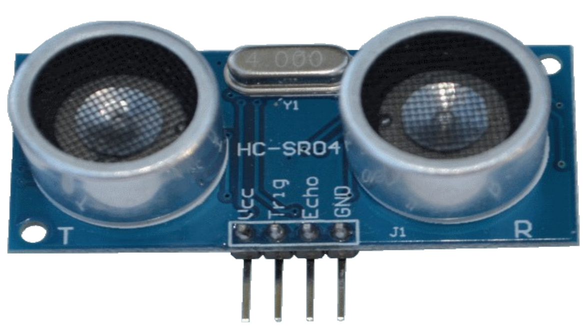


Figure 3.2.4 Ultrasonic sensors [18]

Features

-Power Supply: +5V DC

-Working Current: 15mA

-Ranging Distance: 2cm – 400cm

Measuring Angle: 30 degree

Schematic

VCC: +5VDC

Trig: Trigger (INPUT)

Echo: Echo (OUTPUT)

GND: GND

3.2.3 Actuators:

An actuator is a type of motor that is operated by a sou hydraulic fluid pressure, pneumatic pressure and converts this source of energy into motion which is used for controlling a mechanism or a moving part. The following actuators would be used in the vehicle:

1) DC Motor:

DC Motor is an electrical device that converts the electrical power gotten from a direct current directly into mechanical power. DC motor (Figure 3.2.5) works based on the principle of electromagnetism, Where a magnetic field is generated by a current carrying conductor, it is then placed in another external magnetic field, when this is done, it will experience a force or energy that it's magnitude is directly proportional to both the external magnetic field and to the current in the current carrying conductor. [6]

Two DC motors will be used as the main motion provider for the vehicle, based on the calculation that 63.9RMP is needed to achieve the desired minimum speed of 20cm/s, for optimum performance, 2 12V square geared gearhead high torque dc motors was chosen, one for each wheel.

Specifications

-Operating voltage: 12VDC

-Speed: 128 RPM

-Torque: 0.7kg.cm

- Current: 250ma

-Power: 1.3W

Figure 3.2.5 square geared gearhead dc motor [Appendix C1]

2) DC Motor driver:

This device will be used in controlling the direction and speed of the DC motors. It will act as a medium between the motor and the Microcontroller. Due to its PWM ability, high current, high voltage power amplifier, and ability to act like a relay (Switch between ground and positive) while changing the direction of the motor. Ln298 dual h-bridge motor driver (Figure 3.2.6) has been selected.

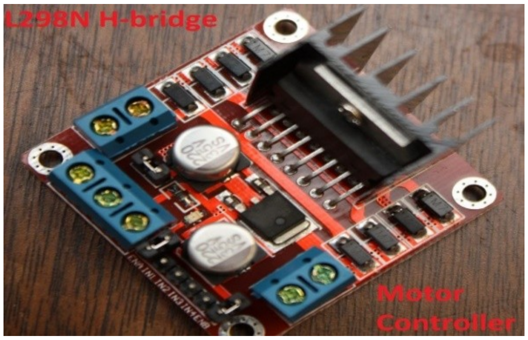


Figure 3.2.6 ln298 dual h-bridge motor driver [7]

Specifications

-Driver power supply: +5v ~ +46v

-Driver Peak Current: 2A

-Logic Power Output Vss: +5v ~ +7v

-Logic Current: 0 ~ 36mA

-Controlling Level: low -0.3v~1.5v, high: 2.3v~Vss

3) Buzzer:

Also called a beeper, this device is used for signaling a sound. The sound produced from this buzzer is mostly used to indicate a button is pressed which can be a click, a ring or a beep. In the Fire Detection and Extinguishing Vehicle (FDEV), a piezoelectric buzzer (Figure 3.2.7) will be used. It would beep continuously after fire has been sensed.

Figure 3.2.7 piezoelectric buzzer

4) Fire extinguisher actuator:

The linear actuator (Figure 3.2.8) works with dc solenoid electromagnetic principle, it goes in or out depending on the direction of the applied voltage. It will be used to activate the fire extinguisher by pressing the valve stem.

The specifications of the dc solenoid electromagnet are show below:

Figure 3.2.8 dc solenoid electromagnet

Specifications

Rated voltage: DC 12V

Type: push /pull

Force and stroke: 500G/10mm

Energized rate: 50%

5) **Relays:**

A relay is known as an electrically controlled switch. Two relays will be used to control the push and pull movement of the Fire extinguisher actuators. A SPDT (Single Pole Double Throw) sealed relay (Figure 3.2.9) is suitable for controlling the actuator due to its high voltage or high current capability. The coils of the spdt relays have a minimum switching voltage of 5V which would be provided by the microcontroller and by alternating the voltage passed to each relay, the push and pull motion of the actuator can be achieved.

Figure 3.2.9 spdt relay

3.2.4 Electrical power

This highlights the second stage of the electrical components. Power is important as it serves as the backbone of the system. Batteries will be the main used of power in the FDEV. Batteries converts stored chemical energy to electrical energy. It consists of more than one electrochemical cell and each cell has a negative terminal called the cathode and a positive terminal called the anode. They would supply electric current or voltage to run the actuators, sensors and microcontroller. 2 different categories of batteries would be used:

1) **Battery for motors:**

A 6v 4.5Ah/20hr battery will be used as the power source of the actuators. CP 645 6v 4.5Ah/20hr battery is a lead-lead system rechargeable battery (see Figure 3.2.10). It uses dilute sulphuric acid as an electrolyte which is absorbed by the separators and the plated inside the battery thus immobilized.

Specifications:

Nominal Voltage 6v

Number of cell 3

Max. Discharge Current: 67.5A (5s)

Short Circuit Current: 225A

Maximum charging current: 1.8mA

Standby use 6.8-6.9v

Figure 3.2.10 cp645 battery

This battery was chosen because of its high power life at high current. It would be able to provide enough power to run the motors for a long while. It is also rechargeable.

2) Sensors and microcontroller battery

When the actuators are active, noise will be generated in the circuit, in order to prevent this noise from affecting the sensor value and the MCU stability, another power source need to be used. The battery type that will be used for the Arduino and the sensors is the 9v battery (Figure 3.2.11) .Most 9v batteries are alkaline and are constructed of mostly six individual 1.5v lR61 cells that are covered in an enclosed wrapper-like manner.

Figure 3.2.11: 9v battery [9]

Specifications

Nominal Voltage: 9v

Impedance: 1700 m-ohm @1khz

Terminals: Miniature Snap

3.3 Proposed design of mechanical part

This part of the report gives detailed information on the design of mechanical components of the vehicle.

3.3.1 Body

The fire detecting and extinguishing vehicle was designed in such a way that it can be lightweight and have a simple body structure that facilitates an easy manufacturing and assembly process. The steel body design gives it strength to withstand the fire extinguisher load, while the shape allows support of the different parts mounted on it. The vehicle design (Figure 3.3.1) makes it portable enabling it to move around effortlessly and quickly thereby increasing its performance and effectiveness in attending to fires.

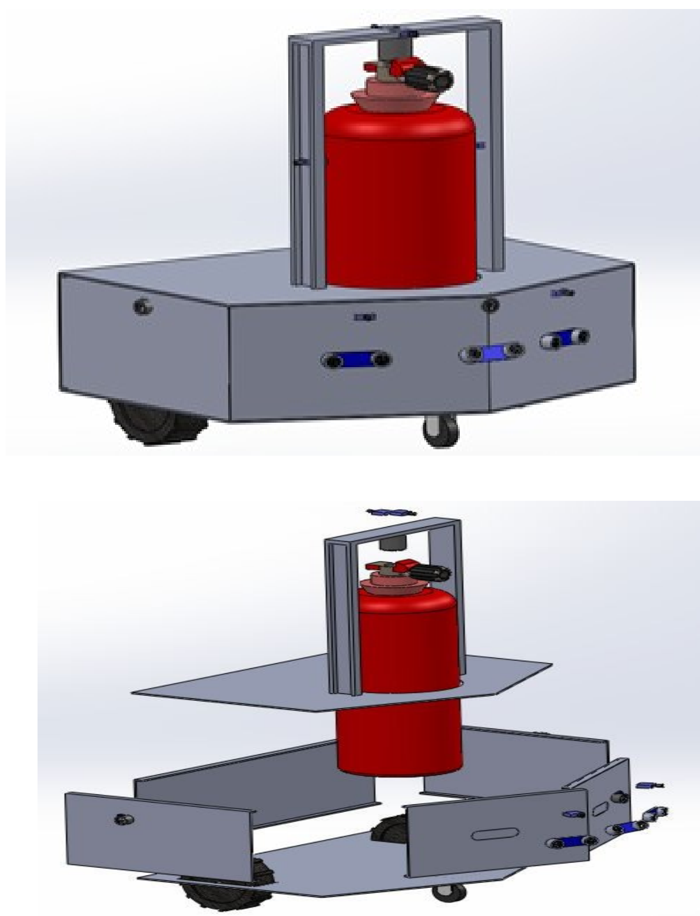


Figure 3.3.1: Body Design. Full Assembly (Top) and Exploded full assembly (bottom). [Appendix B]

3.3.2 Tires

Tread tires are the type of tires we will use for the side wheels of the vehicle. According to Wikipedia (2015), “the tread of a tire or track refers to the rubber on its circumference that makes contact with the road or the ground”. (para.1).This type of tire (Figure 3.3.2) was chosen because of its benefits to the vehicle. The grooves which make up the tread pattern in the rubber, disperses water from beneath the tire and provides adequate traction with the ground. The traction allows for smoother acceleration and quick braking. It is less noisy when in motion and can be retreaded often if it wears out. The diameter of the side wheel is 6cm

Figure 3.3.2 Tread Wheels [Appendix B]

The front wheel of the vehicle is a universal wheel (Figure 3.3.3). This was chosen because the front wheel is responsible for the direction of the motion and the universal wheel has the ability to turn in any angle.

Figure 3.3.3 Universal Wheels [10]

3.3.3 Fire extinguisher

The type of extinguisher selected for our project is the dry chemical fire extinguisher (Figure 3.3.4). It is the most common and versatile firefighting equipment and can be used to quench most classes of fire. The powder substance used in the extinguisher is called ABC dry chemical also known as Monoammonium phosphate.

Uses

1) It insulates class A fires (wood, paper, plastic, etc.) by melting at about 350–400 degrees Fahrenheit when sprayed on it.

2) It coats the surface when applied to the area of the fire and breaks the chain reaction of class B and C fires (petrol, gasoline, propane, etc.)

3) The powder doesn’t conduct electricity so it is therefore safe for the user (prevents electric shock) and very effective for class C fires (electrical fires). This is important because electric fires can cause other classes of fire.

Figure 3.3.4 ABC Fire Extinguisher [12]

3.4 Proposed component integration and operation principles

The working principle of the fire detection and extinguishing vehicle can be divided into 3 stages:

3.4.1 Fire detection

This begins the overall process of the system. The sensors connected to the microprocessor constantly searches for fire from the surrounding using two main methods:

1) Long range detection: This is achieved with the use of the smoke sensors. It is known that smoke fills up the environment of the fire a little while after the outbreak therefore, even if the FDEV isn't in the immediate vicinity of the fire (more than 100cm away), the smoke in the air will be sensed by the smoke sensors.

2) Short range detection: This is achieved with the use of the flame sensors. When the vehicle is less than100cm away from the fire, the flame sensor senses it. And all the values are analyzed by the microcontroller to determine the highest. In the neutral state, the smoke sensors and flame sensors operate simultaneously but depending on which sensor senses the fire, the vehicle operate on either long range or short range detection.

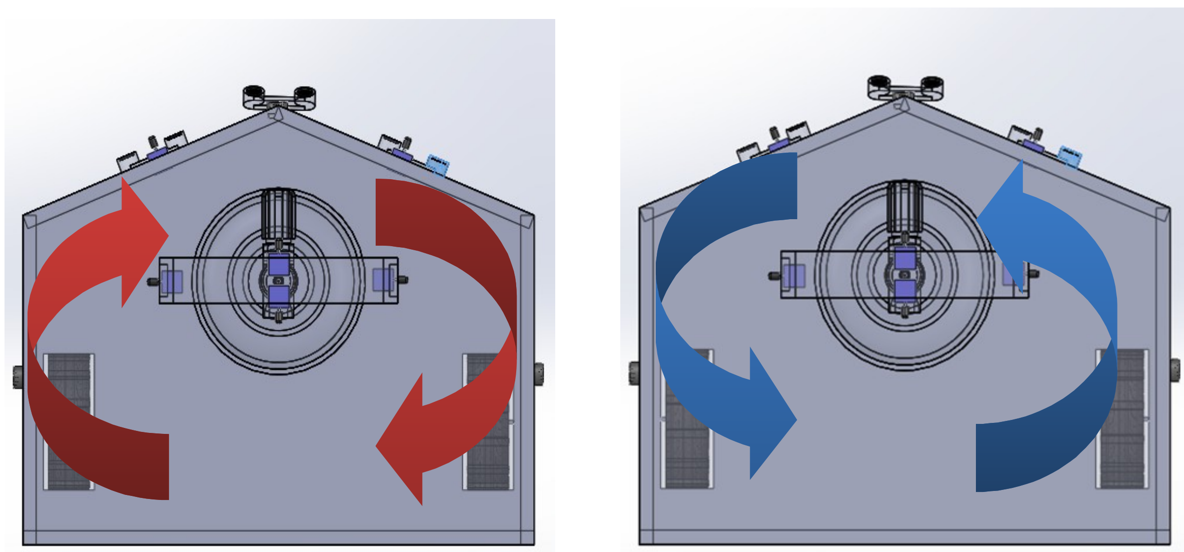
3.4.2 Fire position tracking

This is the second operational stage. After the detection of the fire by the sensors, the next task is for the vehicle to navigate to the position of the fire. This navigation process moves the vehicle towards the sensor with the highest smoke or flame value; right, left, back or front.

If smoke is sensed by the smoke sensor (long range detection), the microcontroller analyses the received values based on which it activates the motors to move towards the sensor with the highest smoke concentration measurement. So if the highest is the front smoke sensor, the microcontroller activates the motor to move forward, this applies to the right and left also. As the vehicle moves towards that direction, the flame sensors are continuously searches for the fire. However during this navigation process to prevent the vehicle from going off course, the smoke sensor values are re-measured every 5 seconds. When fire is sensed by the flame sensor (short range detection), this implies that the fire is nearby. Through the principle of the vehicle moving in the direction of the flame sensor with the highest flame value, the fire will be located.

3.4.3 Movement features

1) Steering Mechanism: Point turning will be applied as the steering mechanism. Point turning is achieved by moving the wheels in opposite direction of each other (see Figure 3.4.1). This concept is chosen because it requires less space to turn left or right because the vehicle would rotate around its center of gravity.



Turns Right Turns Left

Figure 3.4.1 Steering Mechanism

3) Obstacle Avoidance Mechanism: This is an important feature because the path to the fire is not predictable and can be littered with objects. The vehicle has to be able to maneuver around such objects.

According to the specification of the ultrasonic sensors that would act as the eyes of the FDEV, it can be deduced that it covers 4m and measures best an angle of 30°. But for optimum performance the FDEV was designed is a way that the 3 ultrasonic distance sensor are positioned to cover a range of 1.2m in length and collectively 1.6m width at 30° each as seen in Figure 3.4.2.

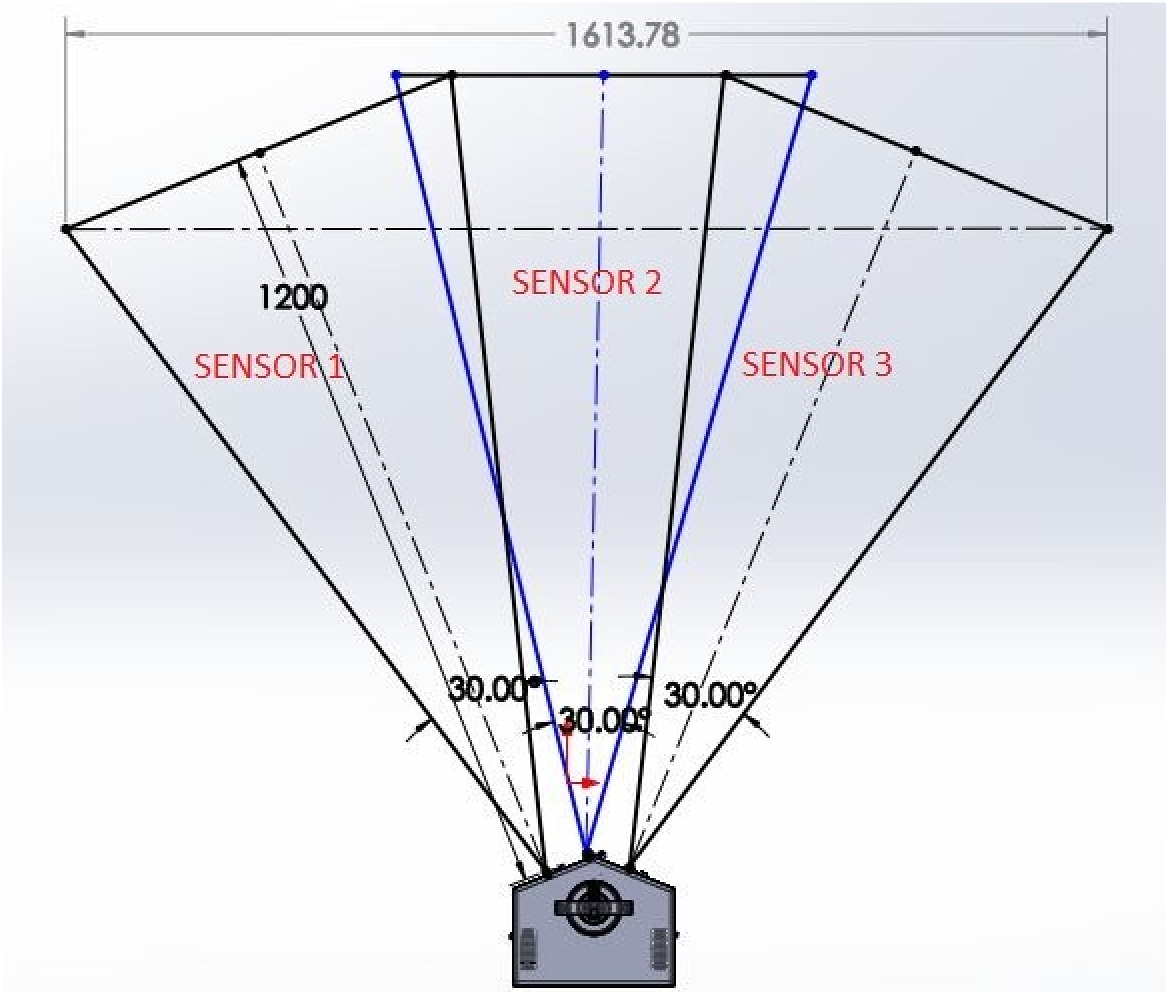
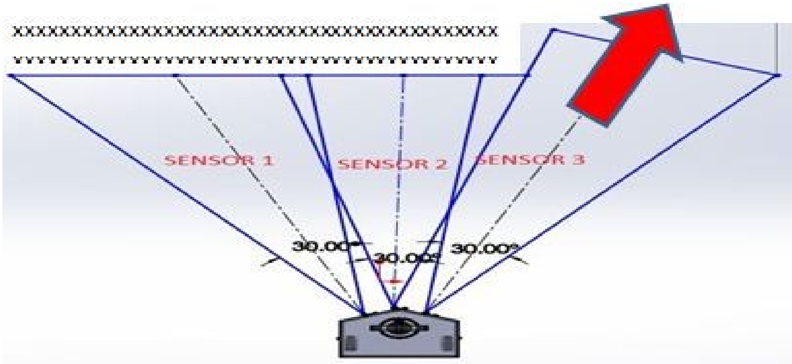


Figure 3.4.2 View of the 3 Ultrasonic Sensors

2) General Obstacle Avoidance Overview: Normally, the vehicle will always move in response to the sensors value when there is no obstacle at its front. But when it senses an obstacle it has to maneuver around it. Let’s consider 3 common cases in which the vehicle encounters an obstacle.

CASE1:



SENSOR 1PATH: OBSTACLE

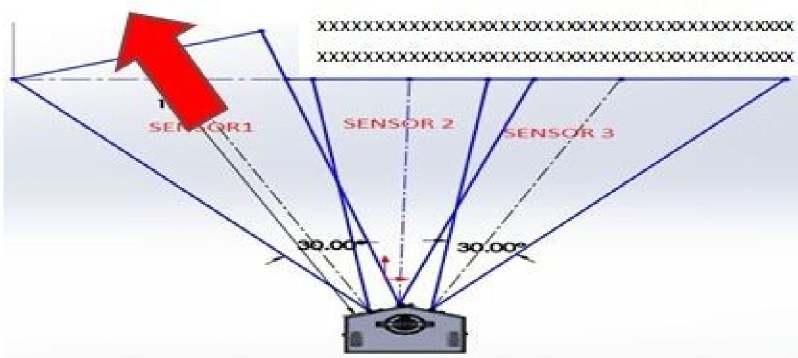
SENSOR 2 PATH: OBSTACLE

SENSOR 3 PATH: FREE.

ACTION: Vehicle turns and moves to the right

Figure 3.4.2 CASE 1

CASE 2:



SENSOR 1PATH: FREE

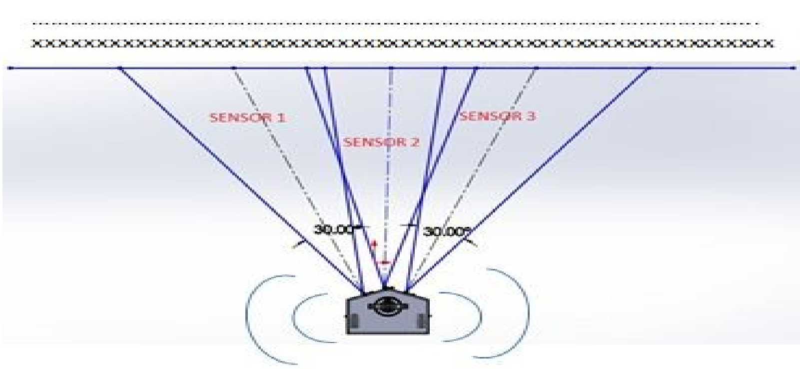
SENSOR 2 PATH: OBSTACLE

SENSOR 3 PATH: OBSTACLE

ACTION: Vehicle turns and moves to the left

Figure 3.4.3 CASE 2

CASE 3:



SENSOR 1PATH: OBSTACLE

SENSOR 2 PATH: OBSTACLE

SENSOR 3 PATH: OBSTACLE

ACTION: Takes reading from the left and right smoke and flame sensors and turn towards the highest

Figure 3.4.4 CASE 3

3.4.4 Proposed Fire Extinguishing Process

This is the final stage of the overall process. In this stage the vehicle has located the fire and is near the fire. An electromagnetic actuator is used to press against the valve stem of the fire extinguisher (Figure 3.4.5) thereby opening the fire extinguisher. The fire extinguisher is activated for few seconds and to confirm that the fire is out, the flame sensor takes another measurement, if a high value is recorded, the process is repeated again until the fire is out.

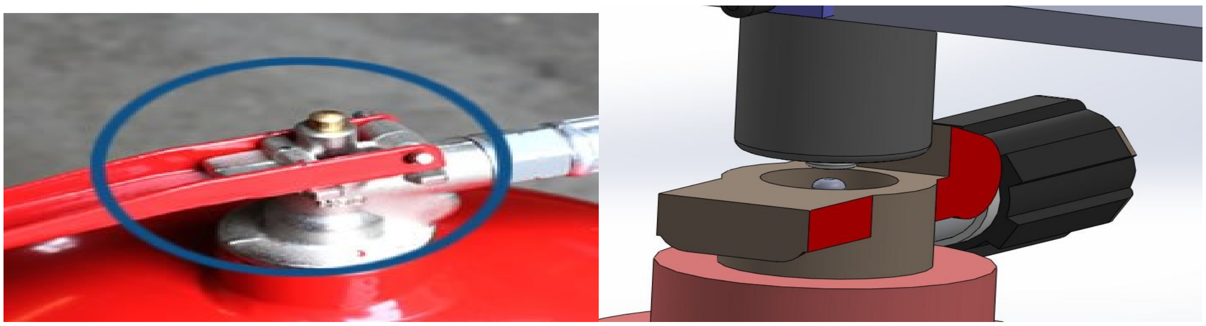


Figure 3.4.5 Valve Stem and Extinguishing Mechanism [Appendix C3]

3.5 Proposed Manufacturing processes

This is the final process of any design. It involves the transformation and combination of materials and components to produce the required finished system. Manufacturing Process is divided into mechanical and electrical.

3.5.1 Mechanical process: This involves the selection of material type, applying machining operations on the material to shape it into the designed body of the system and finally assembling of the distinct parts.

3.5.2 Material type: The material chosen for the FDEV is steel. Steel was chosen because of many reasons. Firstly, it can withstand high tensile stress and it gives warning before failure, this means that even if the robot accidentally falls or hits a hard surface with high force, it will not break easily, this ability is known as ductility. Steel also have high strength, uniformity, light weight and high temperature endurance limit also known as melting point.

3.5.3 Machining operations: These involve the making of raw material into the required shape, thickness, texture and size. To produce the required vehicle body, cutting, drilling and tapping of thread holes and milling will be used as the machining operations.

1) Cutting**:** The selected material which is steel will be cut into the required shape and size by the use of a tool called the saw.

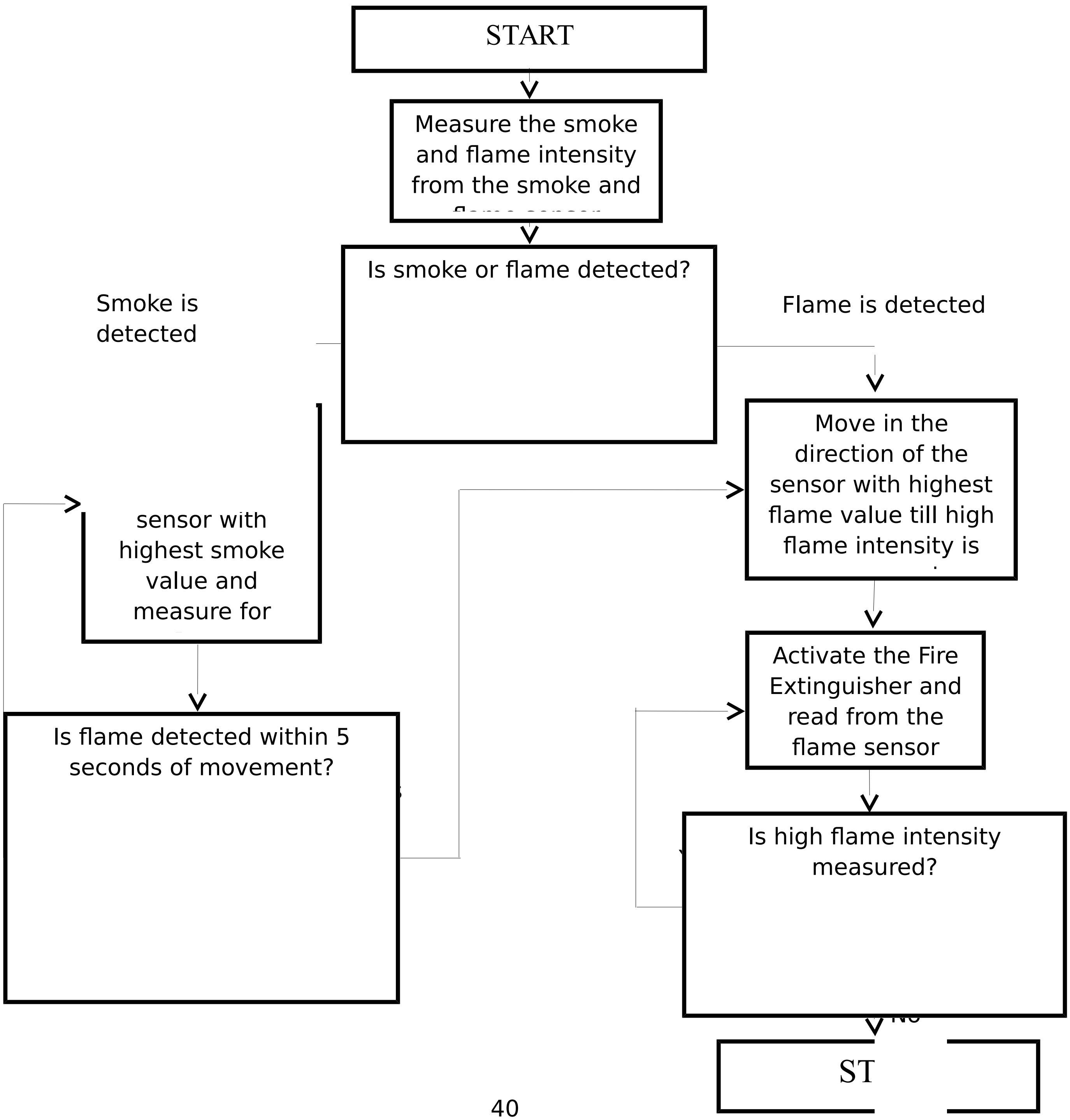
2) Drilling and tapping: Drilling is a method of perforating or making holes on a material. And tapping is the process of making thread like shape in a drilled hole. These processes will be used in making the bolt tread hole.

3) Milling: This is a machining operation for removal of unwanted parts of the material. The metal must be properly milled for the accurate insertion of sensors.

4) Assembly: Bolt and nut will be used as the assembly method because of its flexibility; it can be easily removed and fitted together unlike other assembly processes such as welding

3.6 Proposed Electrical Operation:

The electrical connection would be between the electrical components (Flame sensor, smoke sensors, ultrasonic sensor, motors and actuator) with the brain been the microcontroller (Arduino Mega 2560). The sensors will supply input values to the microcontroller and based on this values it will activate the motors or actuator. The Arduino Mega will be programmed using the Arduino IDE. The following algorithm would be used in the programing



FLAME

SMOKE

LTRASONIC SENSORS

CHAPTER 4

IMPLEMENTED MANUFACTURING AND ASSEMBLY PROCESSES, ELECTRICAL OPERATION AND TESTING

4.1 Prototype implementation

Based on the proposed and accepted project, a prototype was made. A prototype is defined as a model or an early sample of a product that is built strictly to test and try a concept or a process to act as a thing to be replicated or learned from to enhance precision by the user in making of the main product. The prototype (Figure 4) was built using light material, cardboard paper. The batteries, sensors, motors were all mounted on this cardboard paper. It was discovered that the weight of the battery is substantial as it slows the movement even though the vehicle was made of cardboard and also that there is need for more spacing within the vehicle because the fire extinguisher couldn't fit in properly with the electrical components. Considering this, 20mm was added to all the dimensions of the vehicle before proceeding to implement the real vehicle.

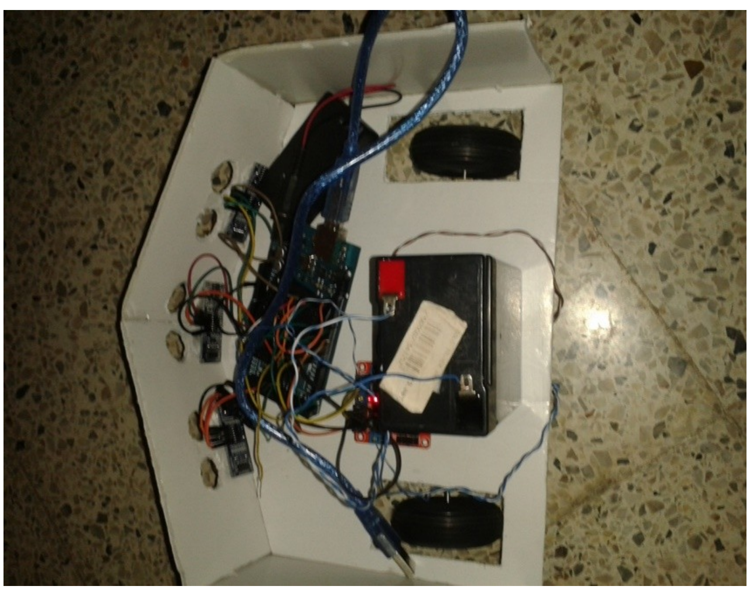


Figure 4.0: Prototype of the fire detection and extinguishing vehicle

4.2 Manufacturing of the parts

Different manufacturing processes were used in the production of the vehicle. The processes include cutting, bending, drilling, and painting. First, the parts of the project are cut from the big metal sheet. This is made possible by the use of a metal cutting machine in the workshop. The flat metal is placed between the sharp blades of the machine in alignment with the already dimensioned line on the metal sheet then the metal sheet is held firmly by the user to avoid shaking of the metal sheet as this may result in wrong cutting of the required parts. After that, pressure is applied on the pads of the machine by the use of leg allowing the blades to cut the metal sheet into the required dimensions. The picture (Figure 4.1) shows the already cut flat metals sheets

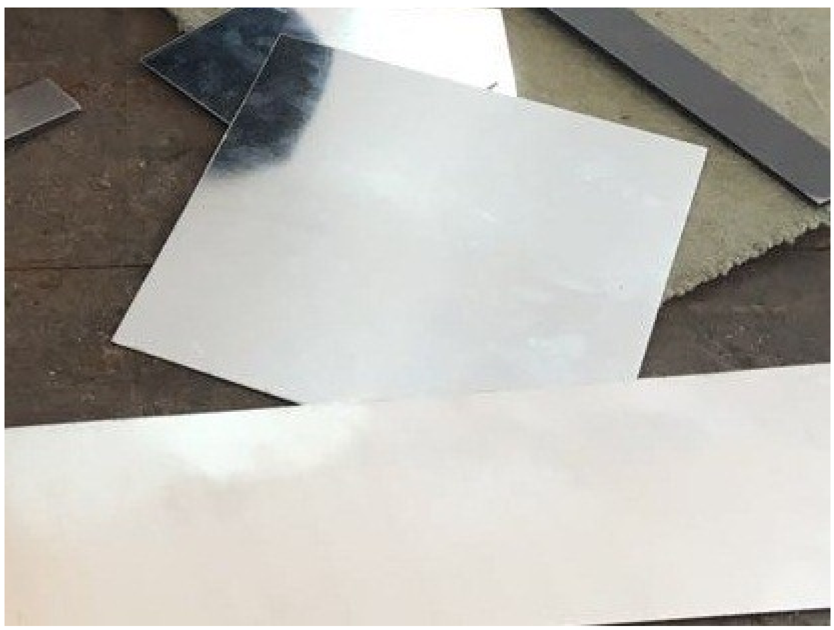


Figure 4.1 Aluminum material used

Next step involved in the manufacturing is the bending of the already cut flat metal parts using the bending machine. The metal piece is inserted in the machine and the handle of the machine when raised by the user applies pressure to the metal piece at a certain angle and the required bent part (Figure 4.3) is gotten.

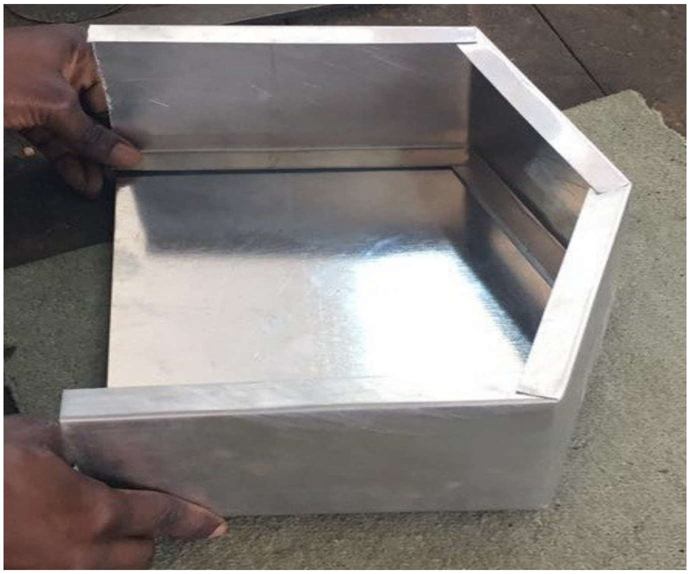


Figure 4.3 Bent metal part

The next step is the drilling of the holes on the bent metal parts. The holes will be the means for the insertion of different types of sensors; smoke, flame and distance sensors each having different dimensions. The flame sensors are 6mm in diameter so a small electronic hand drill was used to drill the holes.

An attempt was made to drill the holes of the ultrasonic distance sensors using the hand drill but the holes were too big, the drilling machine available (Figure 4.5) in the mechanical engineering workshop was used instead.

Figure 4.5 drilling the bigger holes using the drilling machine

4.2.1 Assembly of the parts

The methods of assembly used for the project was performed manually in the workshop of mechanical engineering department. The major process involved here is screwing. For the assembly the parts, points already drilled are joined together by the use of screws. Screws were chosen as they are easy to disassemble, hereby making troubleshooting easier to perform. A detachable holder (Figure 4.7) is attached to the fire extinguisher with the aid of the screws to help hold the extinguisher firm together with the robot when in motion. This also makes it possible for easy replacement of the fire extinguisher when it is finished without causing damage to the materials of the robot.

Figure 4.7 Extinguisher attached to the holder with the aid of screws

4.3 Electrical operation

4.3.1 Sensor testing

To get the best result from the sensors and for the purpose of selecting the appropriate sensor to carry out assigned duties, test were carried out on all the sensors to be used

1) FLAME SENSOR TEST

The purpose of the flame sensor is to detect fire. To test this, the flame sensors (Figure 4.3.1) were attached to the Arduino and a small candle was placed at different distances from it.

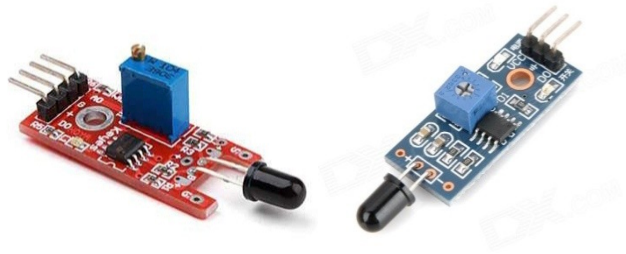


Figure 4.3.1: KEYES KY-026 IR flame sensor (left) and MH flame sensor (right)

Two common types of flame sensors were tested to select the best for long range and short range detection.

Conclusion from test

- Based on the above test. The KY-026 is better for long range detection therefore will be used at the top of the robot, while the MH is more stable and will be used at the lower side of the robot
- Also it is observed that the flame sensor is sensitive to changes in the light of the environment, therefore this would be compensated for in the general programming phase

2) SMOKE SENSOR TEST

MQ2 Gas sensor is used to detect smoke. It was proposed to be the primary detection sensor.

Conclusion from test

- Based on the above test. The smoke sensor can be observed to be less sensitive to far way smoke. It is only sensitive when in contact with smoke
- However, it was observed that the smoke sensor is very sensitive to gas.
- As a result of the poor sensitivity of the smoke sensor, the flame sensors will be used as the primary fire detection sensors

3) DISTANCE SENSOR TEST

Ultrasonic sensor is used to measure the robot’s distance to the fire. For the robot to cruise smoothly and not get stuck at a place, it must be able to have a good and fast sense of the objects around it.

Conclusion from test

- Based on the above test. The ultrasonic distance sensor is ideal to be used for distance detection.

4.4 Electrical component connection

After the completion of the sensor tests and the appropriate conclusions were made, the electrical components were connected together based on the schematic (Figure 4.4.1). The components includes 1 Arduino mega, 6 flame sensor, 2 smoke sensors, 2 motors, 1l293d Motor driver, 1 servo motor, one sound buzzer and switches.

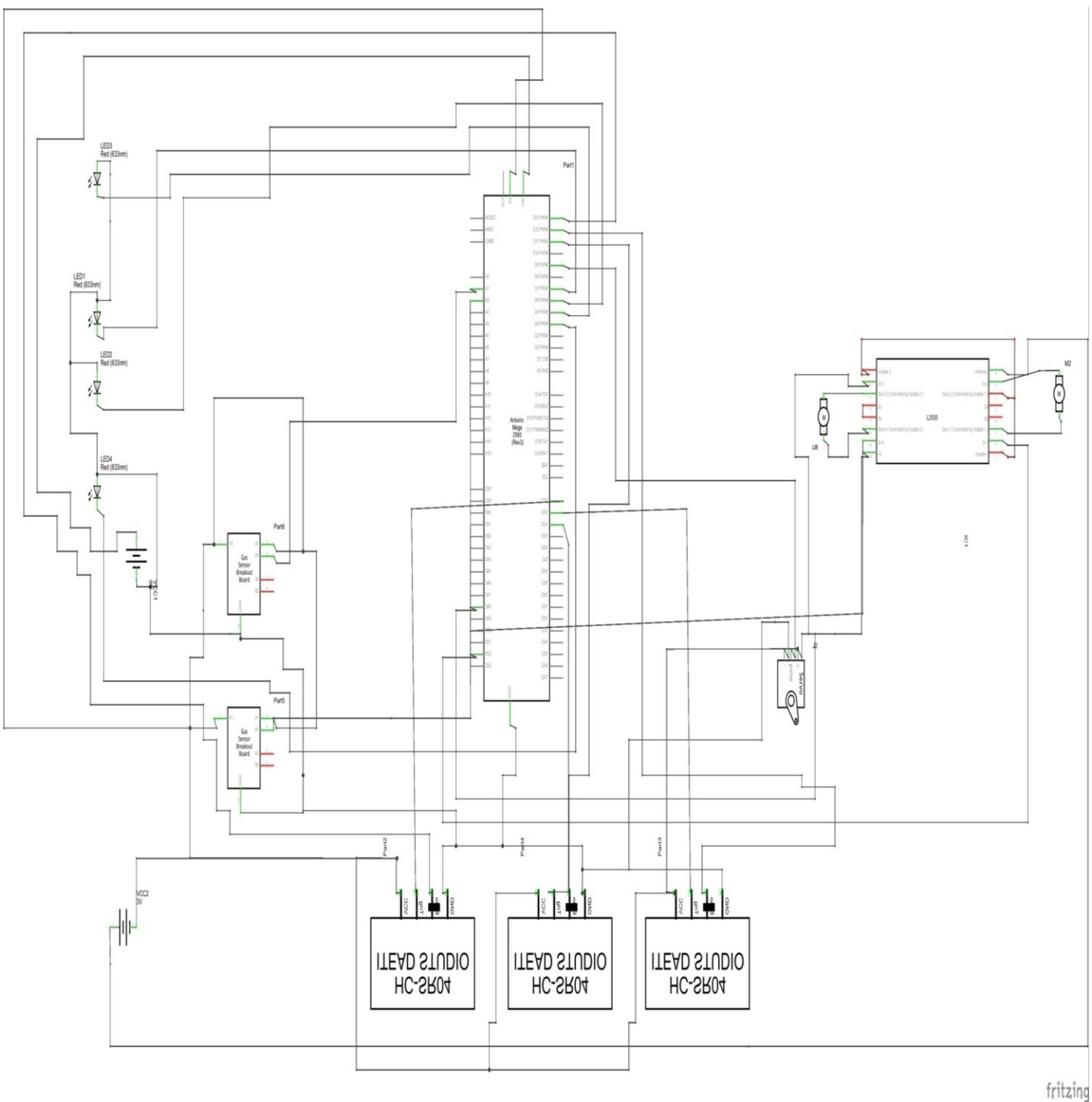


Figure 4.4.1 General circuit schematic

4.5 Operation principles modifications

As a result of the sensor test carried out. The following modifications were made to the proposed operation principle

1) Long range detection: The KY-026 flame sensor was used for long range detection due to the low sensitivity of the smoke sensor.

2) Short range detection: Smoke sensor and MH flame sensor was used for short range detection

3) Fire position tracking: The vehicle moves towards the sensor with the highest flame value; right, left, or front. However flame sensors was used for the long range detection unlike the proposed method in which the tracking was based on the smoke sensor.

4) Obstacle avoidance and steering Mechanism: Same as proposed written in chapter 3 (see page 33-35). However to achieve smoother cruising of the vehicle, variation in the speed of the wheels (Figure 4.5.1) was used in addition to the proposed point turning mechanism to turn left and right.

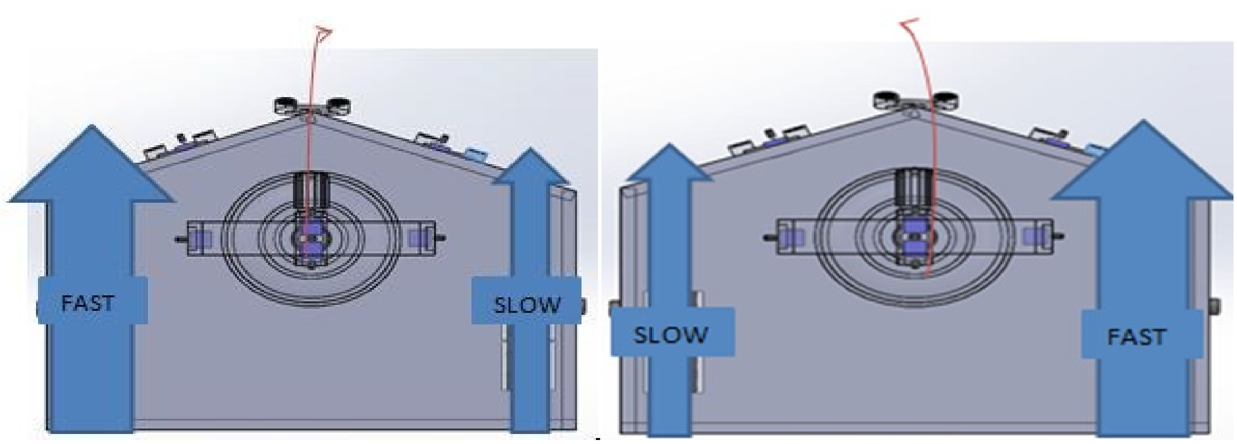


Figure 4.5.1: Speed Variation. a) vehicle moves leftwards b) vehicle moves rightwards

5) Proposed Fire Extinguishing Process: As a result of the low torque of the linear actuator and due to our modification to use spray extinguisher, Servo motor was used for the extinguisher activation

4.6 Programming

The programming was done on Arduino IDE, with c++ language. The aim of the program is guard the robot to autonomously detect the fire, autonomously approach the fire while avoiding obstacle and autonomously put out the fire. It has more than 800 lines of codes and tries to assign an action to every possible combination of fire sensing and obstacle avoidance scenarios possible.

Two different modes were programmed to the vehicle:

1) Standby Mode: This mode compensates for the sensitivity of the flame sensor to changes in surrounding light. This is the default mode and it's used if there is no fire when the robot was switched on. In the mode the sensors calibrates after a given period continuously and set the threshold of the sensors to the light condition of the room. It therefore stays immobile until there is a fire. In case of a fire, it becomes active and goes after the fire.

2) Attack Mode: In this mode the sensors values are compared to their default threshold value. Based on this, the robot tracks the fire. This mode is used if the fire is already on before the robot was switched on. Immediately the robot is switched on, it goes after the fire.

CHAPTER 5

5.1 Results

After the combination of various rigorous processes formerly discussed (i.e. manufacturing, assembly and testing procedures, programming and electrical connections) the finalization of the project produced the robotic vehicle (mechatronic system). The robot was tested with various obstacle arrangements in both standby and attack mode. The robot was able to sense fire more than 300cm away, track it while avoiding obstacles and turn it off.

5.2 Technical difficulties encountered

In the duration of the conduction of this project, there were a few factors that were present as a challenge to its progress and completion. They include:

- *Shipment problems:* Most of the items required for the project could not be found and obtained in this environment and so we had no choice but to resort to online purchasing measures from various available sites (i.e. Amazon, eBay, etc.). We experienced variety of problems from them (third party sellers); misleading details, late response from sellers when more product information was required, late shipment and arrival of items, difficulties in tracking items and loss of products in transit. This created a delay in acquisitions of the goods and subsequent waste of time and disorganization of plans.
- *Workshop availability:* The workshop was not always open at our free period considering the fact that we were individually taking different courses and had different timetables making it difficult to meet and work together. We each made compromises in order to get the work done.
- *Flame sensor:* The values read by the flame sensor (Figure 3.2.2) were influenced by its sensitivity to light thereby causing inaccuracy in the measurements and affecting the robotic vehicle output performance. A solution was to create two modes; standby and attack mode. In standby mode the sensor calibrate to continuously meet up with the changing environment light and in attack mode it goes to the fire’s position

- *Smoke sensor:* The sensor's (Figure 3.2.3) operation is smoke detection; it usually takes a big fire to generate enough smoke to be detected by it and because of this it functions as an assisting sensor to flame sensor.
- *Motor:* At first we purchased a miniature 100RPM-6V-0.4A (no load) DC motor (Figure 5.2.1) as a result of image deception and misleading information. Despite its specifications, the weight of the robotic vehicle caused it to move in a struggling manner and at a very low speed. We then decided to carefully order another one; motor speed: 8300RPM / gear box speed: 120RPM / Torque: 0.8 Kg.cm (no load) 12V DC motor (Figure 5.2.2) that never arrived.

Figure 5.2.1: The tiny DC motor.

Figure 5.2.2: The second purchased DC motor

- *Fire extinguisher:* A small sized stored-pressure ABC extinguisher (Figure 5.2.3) was purchased from a company in lefkosia. The expellant is stored in the same chamber as the dousing agent permitting its utilization only once before a need to refill the pressure. This was unproductive for us because we could not be refilling it each time a test is carried out. It was also heavy which caused reduction in speed. We ordered for a more expensive and effective different type of extinguisher.

Figure 5.2.3: The ABC extinguisher

5.3Improvements

As successions of experiments and testing of the project were performed, observations of the results led to execution of new ideas and change of some items we previously used. In the course of its production, we made some modifications to improve the project. They include:

- *Body improvements:* Initially, a very thick aluminum sheet was purchased and prepared (i.e. dimensioning and cutting) to be used as it was the only material found but our supervisor suggested and presented a thinner aluminum for the body which not only provided ease in machining operations but also caused a great reduction in weight and subsequently increase of the speed of the vehicle. The thicker sheet is still used at the base since that area is required to be rigid as it carries and supports the entire items and devices incorporated in the robotic vehicle. The height, length and the width of the vehicle was also increased by 2cm.

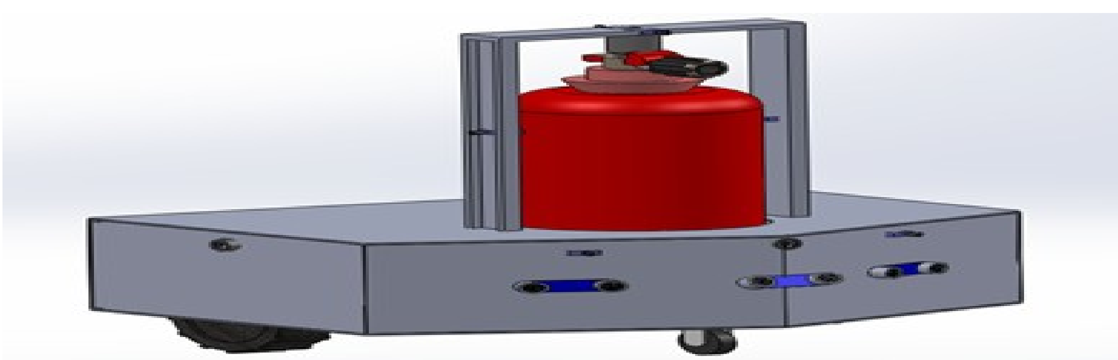


Figure 5.3.1: Proposed Design

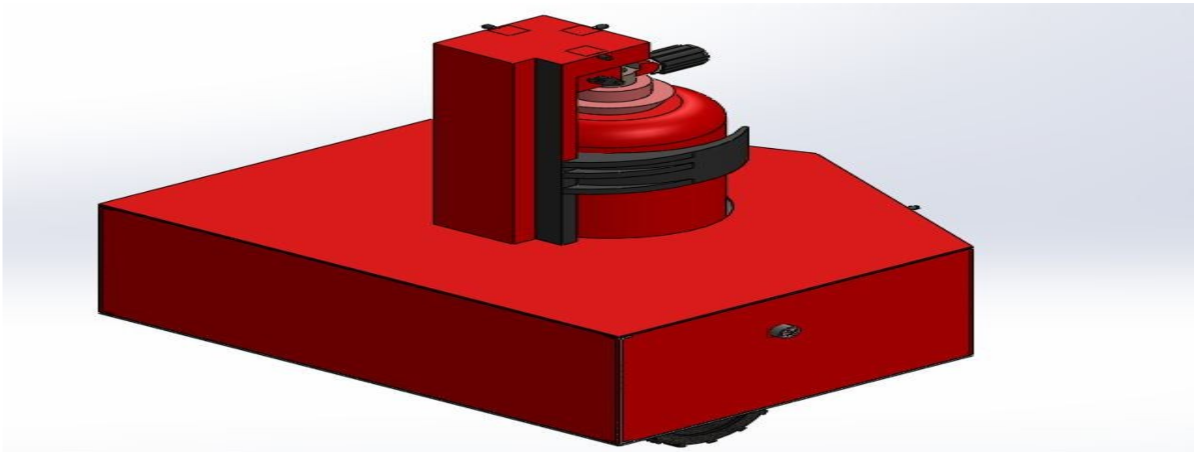


Figure 5.3.2: Final Design

Figure 5.3.3: Implemented Design

- *Use of a servo motor*: At the project's early stages, we intended on using a linear actuator (Figure 3.2.8) for the job of activating the fire extinguisher in the presence of a fire but the torque was small and therefore made it slow in triggering the extinguisher so we opted for a servo motor (Figure 5.3.3) which does the work successfully.

Figure 5.3.3: Servo motor

- *Change of battery:* A 6V lead acid rechargeable battery (Figure 3.2.10) was used as power supply for the motors at first but it was heavy and contributed to the reduction of the speed of the vehicle so an idea was proposed to buy a much lighter and more expensive nickel metal hydride 6V rechargeable battery. The pack is made up of 5 pieces of 1.5V batteries connected in series

Figure 5.3.4: Nickel metal hydride battery

- *Change of fire extinguisher:* The new type of fire extinguisher we chose was an aerosol spray aluminum can having monoammonium phosphate foam quenching agent that had many more advantages than the old extinguisher (Figure 5.2.3). They include:

1) It was much lighter in weight permitting effortless carriage and increase in speed.

2) Easier use: it didn’t require pin unlocking and lever squeezing unlike the old one. It has just a spray nozzle design that could be faced in the direction of the fire and pressed.

3) It claims to have four times greater agent discharge time and three times surface area coverage than the actuator of the old one

5) The aerosol can is safer to use as it is biodegradable and would not cause destruction to sprayed areas (i.e. appliances, equipment, etc.) unlike the chemicals from the old one.

5.4 Cost analysis

COST OF IMPLEMENNTED COMPONENTS

Flame Sensor	$22
Wheels	$10
Switches	$3.16
Servo motor	$10
Ni Mh Battery + Charger	140TL
2 Pieces of 9v batteries	30TL
Motor	30TL
Wire	$3.96
Arduino	$34
Distance Sensor	$5.15
Gas Sensor	$6.93
Spray Extinguisher	$60
Metal Sheet	20TL

TOTAL: $160+220TL

ADDITIONAL COST BASED ON PROPOSED DESIGN AND SHIPPING ISSUES

Wheels	$10
Actuator	$15.42
Charger	$6.19
Motor	$34.44
Initial Fire Extinguisher	35TL
Gas Sensor	$6.93
Batteries	30TL

TOTAL: $72 + 65TL

According to the cost of purchased components, the implemented system cost about $250 with spray type fire extinguisher.

CHAPTER 6

CONCLUSION AND FUTURE WORK

In summary, the main aim of this project was to design, manufacture and assemble a robotic vehicle with the ability to not only accurately detect a fire but to successfully extinguish it, especially at its early stages. This project in its entirety has discussed general information about fire; its causes, effects, triangle, classes and their corresponding extinguishing agents. A comprehensive review on previously existing firefighting mechanisms and robots was also stated. In relation to our robotic vehicle a lot of aspects; calculation and operation principles, design of both mechanical and electrical components, manufacturing processes, assembly, testing, results, cost analysis, improvements and technical difficulties encountered where each thoroughly and meticulously covered.

Advancement to this project would be to implement interfacing of a GSM module and the microcontroller, Arduino Mega 2560. GSM module is used to initiate communication between a computer and a GSM-GPRS system. This development involves establishing a connection using a GSM/GPRS Modem and USB or RSR232 serial port with the microcontroller. The modem is the device that will generate, transmit or decode data from a cellular network allowing interaction between the microcontroller and the GSM and GPRS network so it requires a SIM subscribed to a network operator. Application of this GSM module to our robotic vehicle will allow the system notify an individual by calling or sending a message immediately after it detects a fire. This will be a very beneficial addition in view of the fact that in the event of an outbreak, the owner if present in the environment can be alerted about the situation in order to either flee the scene or assist in the quenching or if absence can be made aware and decide appropriate measures to be taken.

The completion of this project has given an increased in knowledge on various engineering principles and mechanisms as a result of in-depth and exhaustive research and experimentation. In addition, the importance of team cooperation; putting heads together and job sharing has been greatly understood as we faced challenges and difficulties and overcame them and also gathered new ideas that stemmed improvements.

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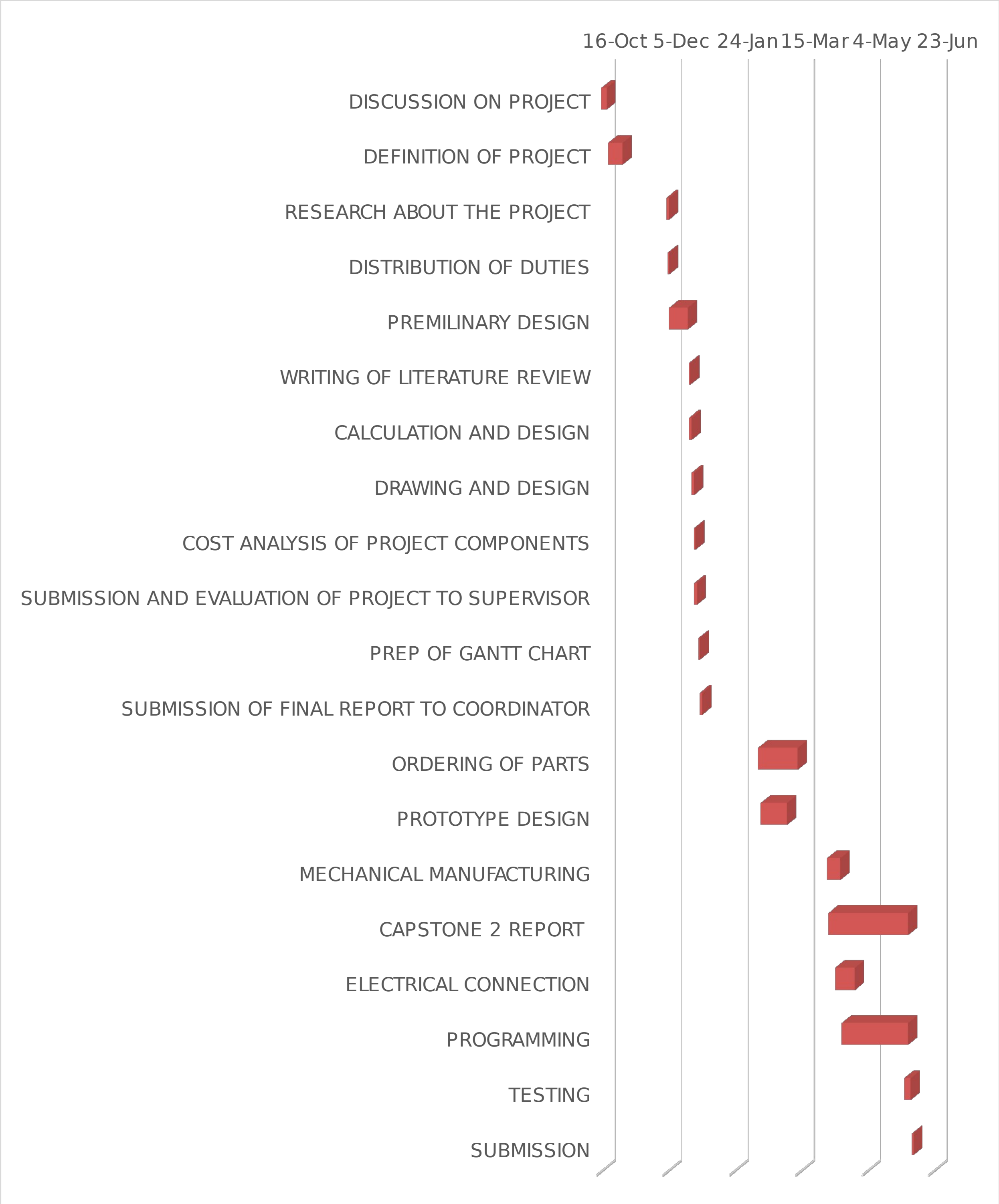
APPENDIX A

GANTT CHART



LOG BOOK

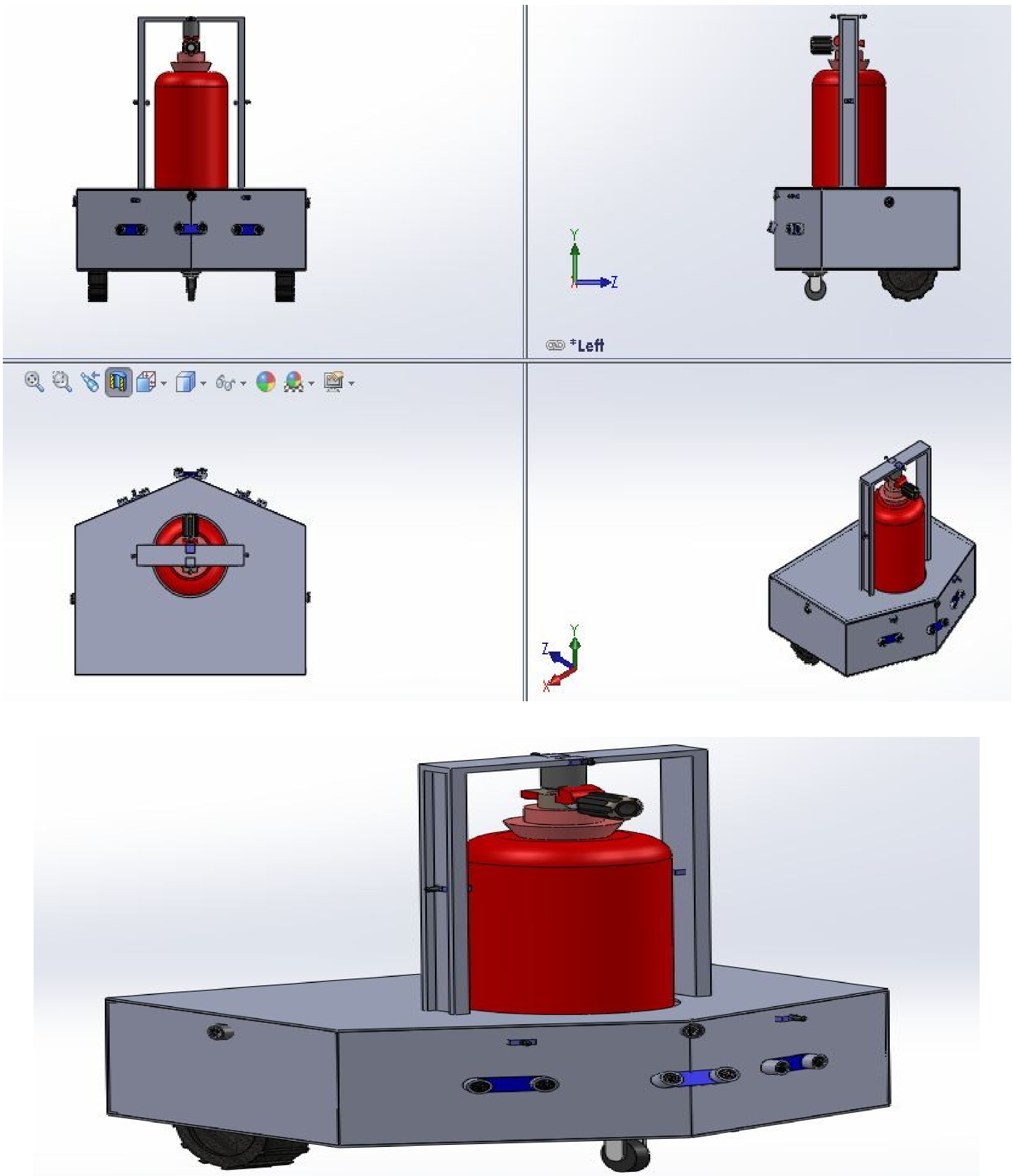
Date	Report Timeline	Member
13.10.2015	Meeting with supervisor for discussion on project topic	All
16.10.2015	Submission of proposal: defining the project objectives with supervisor	All
21.10.2015	Research on project components and designing of fire detecting and extinguish vehicle on solidworks	Paul
10.11.2015	Preparation of chapter 1 (Introduction)	Chisom
1.12.2015	Completion of chapter 2 (Literature review)	Aliyu
11.12.2015	Assessment and correction of chapter 1 and 2 by supervisor	All
12.12.2015	Discussion on the parts of chapter 3 (job sharing & team cooperation)	All
20.12.2015	Additional content for chapter 3	All
21.12.2015	Derivation of calculations and equations and creation of algorithm used for programming	Paul
21.12.2015	Remake of chapter 1	Chisom
21.12.2015	Correction of chapter 2	Aliyu
23.12.2015	Chapter 3 - connections and operational principles of electrical parts	Paul
23.12.2015	Chapter 3 - Design of the mechanical components and design of half of the electrical components	Chisom
23.12.2015	Chapter 3 - Manufacturing of mechanical components and design of remaining parts of electrical components	Aliyu
24.12.2015	Appendix: Pictures (solidworks, AutoCAD, charts, etc.)	Paul
24.12.2015	Appendix: Logbook	Chisom
24.12.2015	Appendix: Cost analysis of project components	Aliyu
25.12.2015	Submission of final report to supervisor	All
26/27.12.15	Evaluation of full report by supervisor	-
28.12.2015	Modification according to the correction	All
28.12.2015	Submission of report to the coordinator of course	All
26.1.2016	Ordering of linear actuator, flame sensors, wheels (front and back)	All

11.2.2016	Ordering of lead acid battery charger, jumper cables, DC power connector adapter and led toggle switch	All
13.2.2016	Prototype creation and testing	All
22.2.2016	Purchase of the first DC motor	All
29.2.2016	Arrival of ordered items; linear actuator, flame sensors, wheels (front and back)	-
3.3.2016	Purchase of the thick aluminium sheets	All
7.3.2016	Dimensioning and cutting of the thick sheets	All
10.3.2016	Arrival of ordered items; lead acid battery charger, jumper cables, DC power connector adapter and led toggle switch	-
11.3.2016	Purchase of old fire extinguisher from lefkosia	All
16.3.2016	Arrival and collection of the first DC motor	All
18.3.2016	Provision of the thinner sheet by supervisor	-
24.3.2016	Measurement and cutting of the thin sheets	All
28.3.2016	Bending of the thin sheets and drilling of screw holes	All
29.3.2016	Drilling of screw holes in the thick sheet base in order to be joined with the thin aluminium body & cutting operations for the wheels	All
31.3.2016	Drilling of different sizes of holes on the thin aluminium body for the fitting of the different types of sensors	All
1.4.2016	Joining of the base to the body	All
4.4.2016	Attachment of the wheels to the base	All
6.4.2016	Testing of the first motor using the two side wheels	All
11.4.2016	Connection of electrical components	All
12.4.2016	Ordering of second DC motor	All
20.4.2016	Creation of Arduino programs	All
23.4.2016	Testing of connection of electrical parts	All
27.4.2016	Testing of old extinguisher	All
1.5.2016	Ordering of the aerosol spray fire extinguisher	All

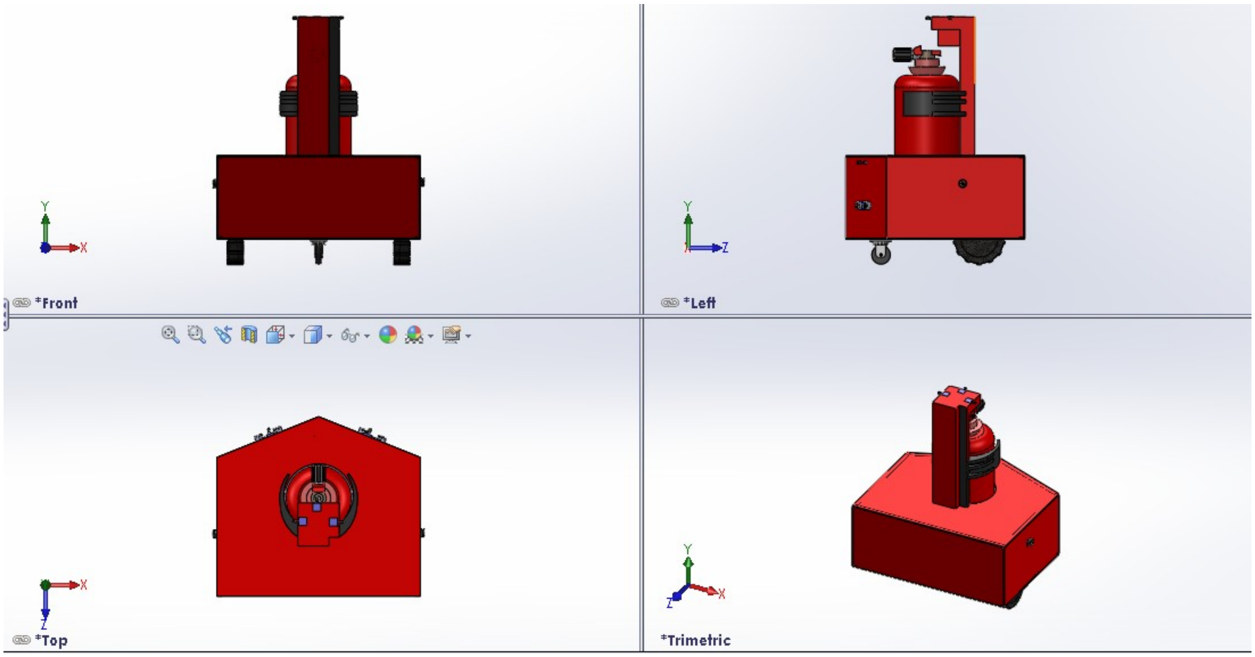
10.5.2016	Shipment of aerosol spray fire extinguisher	-
2.5.2016	Edition of program for the sensors according to testing results	All
5.5.2016	Purchase of servo motor to replace the less effective linear actuator	All
9.5.2016	Painting of the body of the vehicle	All
11.5.2016	Purchase of DC motors from Ozcan Electronics shop as a result of late-no arrival of second motor	All
13.5.2016	Change of program for the servo motor	All
16.5.2016	Machining operations performed in order to attached the motors to the wheels	All
18.5.2016	Correction of program for the DC motor	All
23.5.2016	Collection of the new extinguisher from the post office	All
24.5.2016	Replacement of rechargeable battery: 6V lead acid with (1.5V) 5 nickel metal hydride connected in series & testing operations	All
25.5.2016	Purchase of third DC motor as a result of its better specs	All
26.5.2016	Modification of program for the new motor	All
27.5.2016	Full assembly of the robotic vehicle	All
29/30.5.2016	Chapter 4	Aliyu
29/30.5.2016	Chapter 5	Chisom
30.5.2016	Chapter 6	Paul
31.5.2016	Completion of logbook	Chisom
31.5.2016	Gantt Chart finalization	Aliyu
31.5.2016	Edition and conclusion of programming	Paul
7.6.2016	Presentation of capstone 2 report to supervisor for signing	All
7.6.2016	Submission to course coordinator	All

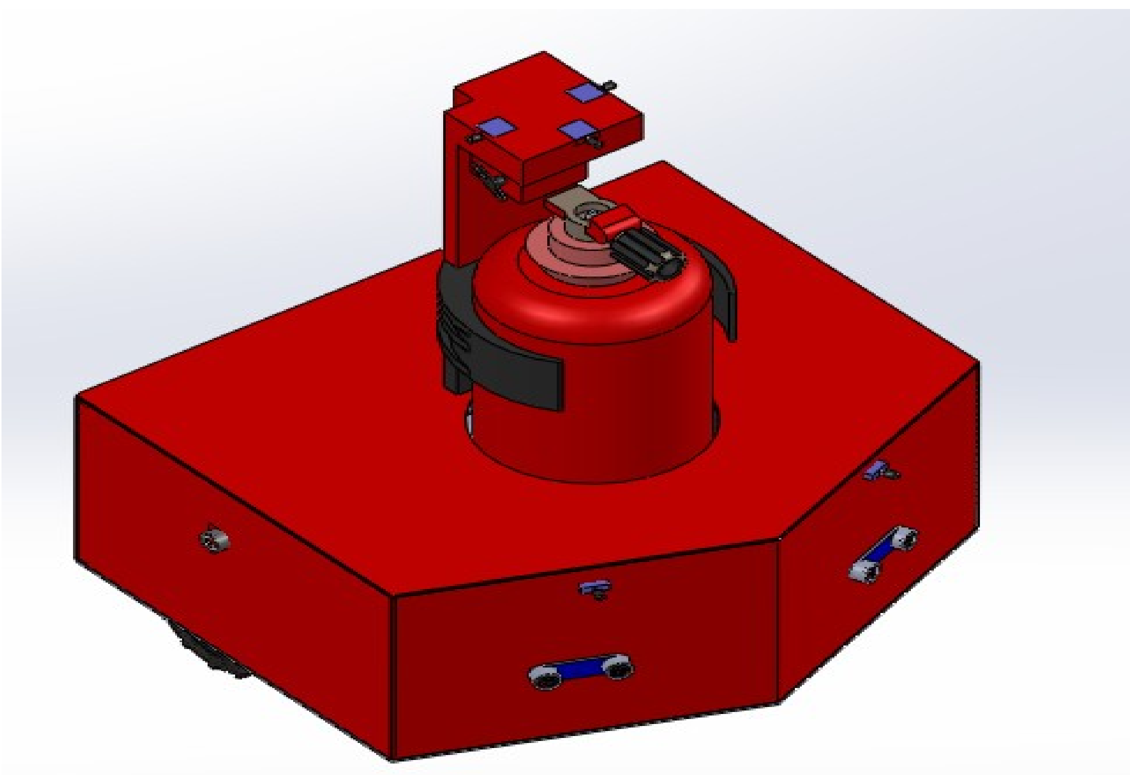
APPENDIX-B

SOLIDWORK DRAWING



Appendix B1- Proposed Design





Appendix B2- Modified Design

APPENDIX-C

6V:160rpm/min 40rpm/min 18rpm/min 10rpm/min 6rpm/min
12V:160rpm/min 40rpm/min 18rpm/min 10rpm/min 6rpm/min 3rpm/min
24V:101rpm/min 25rpm/min 12rpm/min 6rpm/min 4rpm/min

型号：JGY-370					参数表						
电压Voltage		空载No Load		负载转矩Load Torque				堵转Stall		减速器 Reducer	重量
范围	额定	转速	电流	转速	电流	扭矩	功率	扭矩	电流	减速比	Weight
Workable	Rated	Speed	Current	Speed	Current	Torque	Output	Torque	Current	Ratio	单位
Range	Volt.V	rpm	ma	rpm	ma	kg.cm	W	kg.cm	A	1:00	g
3-9V	6	160	40	128	250	0.7	1.3	2.8	1.7	37.3	165
3-9V	6	40	40	32	250	2.5	1.3	10	1.7	150	167
3-9V	6	18	40	14	250	5	1.3	20	1.7	324	168
3-9V	6	10	40	8	250	10	1.3	40	1.7	588	170
3-9V	6	6	40	4	250	15	1.3	60	1.7	972	170
6-15V	12	160	35	128	180	0.55	1.1	2.2	1	37.3	165
6-15V	12	40	35	32	80	2.2	1.1	8	1	150	167
6-15V	12	18	35	14	180	4.8	1.1	16	1	324	168
6-15V	12	10	35	8	180	8	1.1	32	1	588	170
6-15V	12	6	35	4	180	14	1.1	56	1	972	170
6-15V	12	3	15	2.4	60	10	0.5	40	0.4	972	170
12-26V	24	101	15	80	60	0.5	0.5	2	0.3	37.3	165
12-26V	24	25	15	20	60	1.5	0.5	6	0.3	150	167
12-26V	24	12	15	9	60	3	0.5	12	0.3	324	168
12-26V	24	6	15	4	60	6	0.5	24	0.3	588	170
12-26V	24	4	15	3	60	14	0.5	56	0.3	972	170

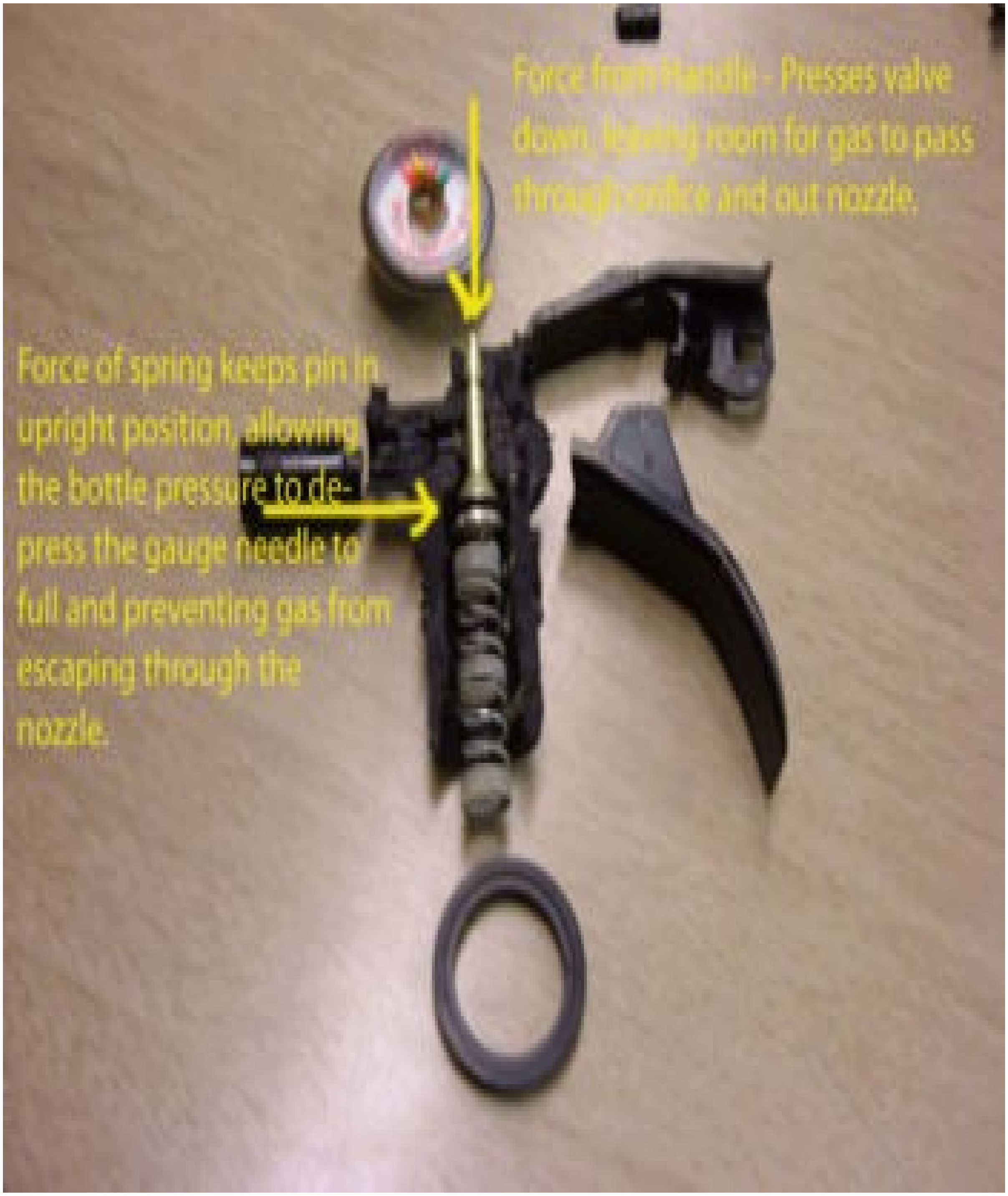
Appendix C1- Motor Properties

Typical values for rolling friction

Material	Rolling friction
Steel on Steel	0.0005m
Wood on Steel	0.0012m
Wood on Wood	0.0015m
Iron on Iron	0.00051m
Iron on Granite	0.0021m
Iron on Wood	0.0056m
Polymer on Steel	0.002m
Hard rubber on Steel	0.0077m
Hard rubber on Concrete	0.01 - 0.02m
Rubber on Concrete	0.015 - 0.035m

Note: Values for rolling friction from various sources are not consistent and these values should only be used for approximate calculations. Remember also the coefficient of rolling friction is dependent on the cylinder radius and therefore has units of length (metres).

Appendix C2- Coefficient of friction table



Appendix C3- Dissected fire extinguisher head showing the valve stem

APPENDIX-D

ENGINEERING STANDARDS

Few engineering standards were used in this project because immense complexity is not required in its design and implementation. This section contains some standards used:

IEEE:

1872-2015 - IEEE Standard Ontologies for Robotics and Automation

ASME:

ASME Standardization & Testing Codes and Standards B18 Standardization of Bolts, Nuts, Rivets, Screws, Washers, and Similar Fasteners Standardization of dimensional, physical, and performance requirements for the specification and manufacture of bolts, nut, rivets, screws, washers, and similar fasteners.

APPENDIX E

POSTER

APPENDIX F

WEB PAGE: http://students.emu.edu.tr/127645/

APPENDIX G

2D DRAWINGS