Team 18F06 Sumobot

Final Proposal Report

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DISCLAIMER

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EXECUTIVE SUMMARY

The major purpose of this report is to document the progress of the design and manufacture of a remote controlled sumobot that is able to participate in the sumobot competitions. The purpose of this project is to make the participants to be able to participate in RoboGames by use of sumobots that are highly effective and operational such that in the end they emerge to be winners. There are a variety of sumobot designs in the market which have already been designed but in this case the sumobot that is being designed by the team is a unique one although it is related to the already existing ones. In fact, the already existing sumobots are used for purposes of benchmarking so that the team are able to design a sumobot that is far much effective. In order to complete the project in a successful manner, the team creates a sumobot that is able to send a command to move by use of a remote control. The signal is received by the Arduino Uno and then actuates it. However, the remote control is responsible for controlling the sumobot fully without use of any autonomous controls.

Before the start of the project, the checked the rules of competition in their website so as to get the customer requirements which were to be incorporated. Some of the customer requirements highlighted include: a device that is light in weight(3kg), durable, portable, easy to operate, has pausing capabilities, remote controlled, safe to other sumobots, and of low cost. A House of Quality was used to determine the significance of each customer and engineering requirement. The team conducted a research on already existing designs so as to get an idea on how the sumobot operates. A black box model and a functional model have been used to determine how the sumobot works in details. During the brainstorming process the team came up with 10 different designs based on the various customer and engineering requirements. A Pugh chart has been used to narrow down the designs into four. Then the decision matrix is used to determine the most appropriate design which meets the engineering requirements. The overall cost of this device is less than $1350. After several iterations of the design, the team was able to come up with the final device which was able to meet the given customer and engineering requirements. The device was thoroughly tested in a Sumo Match competition environment but is yet to be fully implemented. So far, all the requirements have been fully met and there are no any foreseen issues and hence the project is regarded as a success.

ACKNOWLEDGEMENTS

The team would like to give a vote of thanks to the entire crew of the engineering department in the Northern Arizona University for their ultimate support. The team also takes this chance to thank the fellow students who assisted them during the project. Moreover, the team would like to thank the instructor for providing the old designs of sumobots which were a great source. In addition, a lot of appreciation goes to the sponsor, that is the NAU.

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1 BACKGROUND

1.1 Introduction

In this project the team is required to participate and compete in a Sumo bot competition held by RoboGames. This competition has similar rules to traditional Japanese sumo sport which mainly aims to push the opponent outside the ring. In this competition there will be two robots competing instead of humans. The two robots enter the ring and compete head to head aiming to push the opponent out of the ring. The ring is circular in shape and have appropriate dimensions depending on the class, and each robot starts in a set line called shikari lines which are pained brown in a parallel manner inside the ring. The borderline is marked using a white circular line of a width appropriate for the given class on the outer edge of the playing surface. The ring area extends to the outside edge of this circular line [1]. Each match has three rounds, and the team wins a round when the opponent's sumo bot touches the outside ring of the arena. The team must follow the rules and regulation set by RoboGames whereas it is not allowed to damage in any way or flip the opponent. Moreover, the class this team is participating in is Mega Sumo – R/C which prohibits using any kind of autonomous movements. The sumo bot must be fully controlled using a remote control.

The sponsor of this project is Northern Arizona University's Mechanical Engineering Department, and the stakeholder for this project is RoboGames. Since the team does not have a client to get the customer needs, the team used RoboGames rules and regulations to get the customer needs and requirements. This project provides expertise of problem solving and building from scratch for the team. In addition, this project is a great way for the team to use their skills and problem-solving capabilities. Moreover, this project provides the team with electrical circuits experience and coding.

1.2 Project Description

In this project, the stakeholder is the RoboGames while the sponsor is the Northern Arizona University. The following is the original project description provided by RoboGames website:

> "Two robots compete in a head-to-head match following the basic system of traditional human sumo matches. Robots are allowed no weapons and are not allowed to flip each other. The sole purpose is a pushing match between the two robots to force the other from the arena. Multiple weight classes and control systems are allowed (autonomous compete against autonomous and R/C against R/C - they are separate classes and do not compete against each other.)". [2]

1.3 Original System

This project involved the design of a completely new Sumo bot. There was no original system when this project began.

2 REQUIREMENTS

This chapter will discuss the requirements of the project including customer and engineering requirements. These requirements will be implemented in the final design system to ensure that the device operates in an effective manner. However, they are weighted against each other in the House of Quality to determine the how important each requirement is. The chapter starts with the customer requirements explained in the following section.

2.1 Customer Requirements (CRs)

Customer requirements are regarded as the various forms of requests in which the clients and the users have regarding how the device can be designed so as to suit their needs. Details on the customer requirements were obtained from Robogames website [2]. Since the team does not have a client all requirements were obtained from the website rules and regulations. The gathered customer requirements are weighted on a scale of 1-5 based on what the team believed to be the most significant. In this regard, 1 means least significant while 5 is the most significant. The customer requirements are presented in the table below.

Table 1: Customer Requirements for RC Sumobot

Customer requirement	Weight
Light in weight	5
Durability	3
Portable	4
Easy to operate	2.5
Pausing capabilities	3
RC controlled	5
Safe to other sumobots	4
Low cost	2

Discussion

1. **Light in weight**

Weight is one of the major requirements that must be fulfilled. The design should ensure that the laid down regulations on weight have been met. This is crucial since it will facilitate movement of the device while it is in operation. The weight must not exceed 3kg to fulfill the class the team participating in.

2. **Durability**

The device should last for a long period of time to regard it as economically viable. At the same time is should be able to withstand the roughness and toughness associated with the game.

3. **Portable**

The device should be light in weight and this will enable the users to carry it from one position to another with ease. On a similar note the device should have a few assembly procedures so that less time can be taken to prepare it for the competitions.

4. Easy to operate

Simplicity is another key requirement which mainly focuses on the need of designing a device which is not complicated but is able to complete its intended task in an effective manner. in this manner a few components and linkages should be used.

5. Pausing capabilities

Sometimes there is need to stop a bit during the game so as to set some rules or to correct an error. In this instance the ability of the device to have a pausing capability is crucial since it will ensure that the device stops when requires and resumes play when needed to do so.

6. RC controlled

The sumobot will be controlled by a remote control since the players are supposed to be far away from the competition field. With a better remote-control system, maneuvers in the field will be easy and this will increase winning chances.

7. Safe to other sumobots

The device should ensure that it does not damage or destroy opponent sumobot. In this regard, it should not have sharp edges or protruding components which may inflict damage on the opponent sumobot. Otherwise, the team is going to be disqualified.

8. Low cost

The budget for making the sumobot should be pocket friendly and at the same time the team should ensure that the quality of the device is not comprised. In addition, the instructor provided the team with the previous project designs. The team can cut down the cost by using some of the parts in the old designs.

2.2 Engineering Requirements (ERs)

From the customer requirements the team formulated engineering requirements. The engineering requirements are specific and measurable hence making it easy for later analysis and interpretation. When all the engineering requirements are fully met, the deice will operate in an efficient manner. The engineering requirements are presented in in Table 2 below.

Table 2: Engineering Requirements for RC Sumobot

Engineering Requirements	**Target**
Maintenance	Once per competition
Remote Controlled	75Mhz
Assembly time	$\leq$ 60 min
Linkages	$\leq$ 4
Safety factor	$\leq$ 2
Cost efficient	<1000
Power source	12V
Weight	<3000
Size	20 x 20 cm
Motor	90 watts
Torque	TBD

Discussion

1. **Maintenance**

The maintenance of the device should be easy. Some of the areas which require maintenance are the moving parts such as the wheels and gears. These parts should be lubricated appropriately to ensure that they move with ease. Worn out parts and batteries should be replaced promptly.

2. **Remote Controlled**

The device should be controlled with the most appropriate remote control. In this case the effective remote control is the radio remote control since it has a higher sensitivity hence strong penetration ability.

3. **Assembly time**

The device should be assembled within a significant short period of time since it is made up of a few components. Specifically, the assembly time should not exceed 60 minutes if needed.

4. **Linkages**

The device should have a few linkages so as to reduce the time required for assembly and also to make it easy to operate. Specifically, it should have a maximum of 4 linkages.

5. **Safety factor**

The device should be made in such a manner that during operation it does not exceed dangerous capabilities. In case there are hazardous parts they should be modified or be covered with a non-hazardous material.

6. **Cost efficient**

The cost of the device should be minimized such that the amount of money spent on the various components making up the device is within the set budget limit of $1300. In addition, the team should try to use as much as they can from the previous capstone project designs if possible.

7. **Power source**

The Sumobot should be powered by use of a 12V rechargeable battery. However, the standby time of the battery should be long enough such that it is able to power the device throughout the game.

8. **Weight**

The device should have a maximum weight of 3000 grams. This is crucial since this is a requirement to be able to participate in the competition.

9. **Size**

The device should have a standard size of 20 cm x 20 cm, for the device must be able to fit inside a 20 cm x 20 cm box to be able to participate.

10. **Motor**

The design should make use of a powerful motor to enable the sumobot to push the competitor away from the arena. This is a very important part in the design because the more powerful the motor is the better it can push the opponent.

11. **Torque**

The design should ensure that it has a great force that will ensure that it is able to rotate about an axis. This is crucial since it will ensure that the sumobot is able to make fast rotational moves and hence push its opponent from the arena just in time. A torque of 40 N.m is the most appropriate.

2.3 Testing Procedures (TPs)

1. Maintenance

The device will be disassembled to check whether the moving parts such as wheels and gears are properly lubricated before each match.

2. Remote Controlled

Check how far the signal can travel, and each try each command after coding the sumo bot.

3. Assembly time

In order to determine that the assembly of the device does not exceed 60 minutes, the actual assembly of the device should be conducted to ensure that it remains within that time limit.

4. Linkages

The team restricted the number of linkages that were used in the making of the sumobot to four. Actual checking was conducted to ensure that the linkages were actually not more than four.

5. Safety factor

The device was checked for any protruding parts which could inflict damage to an opponent sumobot. The protruding parts and sharp areas will be filed and covered appropriately.

6. Cost efficient

The cost of the device should be minimized such that the amount of money spent on the various components making up the device is within the set budget of $1300

The prices of all the components and services used in its designing were summed up and they did not exceed the budget of $1300.

7. Power source

The batteries which were used to power the Sumobot were rechargeable one and had a maximum voltage of 12V. The voltage was measured using a voltmeter.

The bot will operate till the batteries runs out to check how long it can last to make sure the team knows how many rounds the sumo bot will be able to participate before recharging.

8. Weight

The weight of the device was determined using the weighing scale and it should not exceed 3 kgs.

9. Size

The length, width and height of the device were measured by use of a ruler calibrated in centimeters. The results of the sumo bot must be within the required size of 20 cm x 20 cm.

10. Motor

The team will make sure that the motor easily transmits its power through the tires and provide its max power. This will be determined after testing the pushing power and speed of the sumobot.

11. Torque

To make sure the sumo bot has enough torque. A 3kg weight will be placed to test if the sumo bot could easily push it.

2.4 House of Quality (HoQ)

This section discusses the House of Quality for the RC Sumobot, and its major aim is to determine the most important engineering requirements for this project. The customer requirements are listed on the left and weighted in order of their significance on a scale of 1 to 5. 1 is the least important whereas 5 is the most important. In the table 3 below, values 1, 3, and 9 are used to represent a weak, medium and strong correlation respectively between the customer requirements to the engineering requirements. Then the factor of weight is multiplied by the correlation value. The value obtained is then summed up at the bottom so as to obtain the absolute technical importance (ATI). The engineering requirement that will have the largest ATI number will be placed first in Relative Technical Importance (RTI) and the process will continue until the lowest ATI s obtained at last. The House of Quality is presented in table 3 below.

Table 3: House of Quality for the RC Sumobot

Customer Requirement	**Weight**	**Engineering Requirement**	**Maintenance**	**Remote Controlled**	**Assembly Time**	**Linkages**	**Safety Factor**	**Cost efficient**	**Power source**	**size**	**Weight**
Weight	5		1	3	9		3		9	9	3
Durability	3		9	3		9	9	3	3	1	3
Portable	4		9	1			1	3	9	3	3
Easy to use	2.5		9	3	3	3	1	3	3	9	9
Pausing Capabilities	3		3	9	1		3		3		3
RC Controlled	5		9	9	3	3	3	9	1		3
Safety	4		3		3	1	1	3	1	1	9
Absolute Technical Importance (ATI)			156.5	107.5	82.5	53.5	76.5	85.5	115.5	86.5	103.5
Relative Technical Importance (RTI)			20.30%	13.76%	10.56%	6.85%	9.8	10.95%	14.78%	11.07%	13.25%
Target unit of measurement			no unit	Mhz	Min	N*m	no unit	USD	Volts	cm	g
Target ER values			1	75	60	TBD	2	2500	12	20*20*20	3000
Tolerances of ERs			1	75	<60	± 0.1	<2	<2500	< 12	<20*20*20	<3000

Discussion

According to the House of Quality the most crucial engineering requirements that the team had to lay more emphasis on include maintenance, power source, remote control and weight. Maintenance is very crucial since it ensures that the device is able to operate in an efficient manner and for a longer period of time. Also, the power source ensured that the device have enough power to move around the arena. The remote control is crucial since it is the only way to control the sumo bot. Also, the weight has to be limited so as to ensure that the movement and carrying of device. Since these requirements had such a large correlation, both the customer and engineering requirements were strongly considered in the designing of the device.

3 EXISTING DESIGNS

In this chapter, the details of research of existing designs related to this project have been discussed. The team ensured that it focused on designs which met the various customer requirements. Specifically, the major focus will be on how research was conducted, resources which were utilized used, information found, and analysis which made a comparison between the existing designs at the design at hand. In addition, a functional decomposition including a black box model and a hypothesized functional model has been included. In order to get appropriate designs, the team researched in the internet.

3.1 Design Research

There are a variety of RC Sumobot designs which have been created ever since the first Sumobot was made. As years pass by customer requirements change and as a result designers and engineers make improvements so as to make the designs fulfill the user's needs. In order to ensure that the team came up with the most appropriate designs they first checked on the already existing designs which had specifications which were almost similar to the customers's requirements. They analyzed the designs by focusing on their pros and cons. The major resources that were used in this project include conducting web searches particularly on the RoboGames website. Also, benchmarking was conducted through observations of sumobot games on the YouTube channel. In addition, there were interviews which were conducted to people who have participated in the sumo matches before.

3.2 System Level

The following section describes existing designs which have requirements which are of relevance to the RC Sumobot design. Three designs which were selected have been discussed by focusing on their pros and cons.

3.2.1 Existing Design #1: Newest Generation Sumobot "Sand Flea"

The Newest Generation Sumobot "Sand Flea" was created by Boston dynamics [3] and is appropriate benchmarking design in relation to the project. This is because it has some specifications that can be applied in the current device that is being designed. Its specifications include: Battery and propane powered; has a weight of 5Kg, a height of 15cm, and 5 joints. It is able to make jumps of up to 10m and 25 bounces per charge. These specifications are appropriate for the device in our project. For instance, the battery used in the Sumobot Sand Flea can be incorporated into our design. The device does not have protruding edges and hence it is safe to the opponent sumobots. It also has an appropriate size which is within the range of 20x20cm hence making it easy to store and transport from one point to another. In addition is made up of high-quality materials which are strong hence making it to be highly durable. The only problem of this device in respect to the device which is to be made in our project is that it exceeds the weight of 3kgs since it weighs 5Kgs.

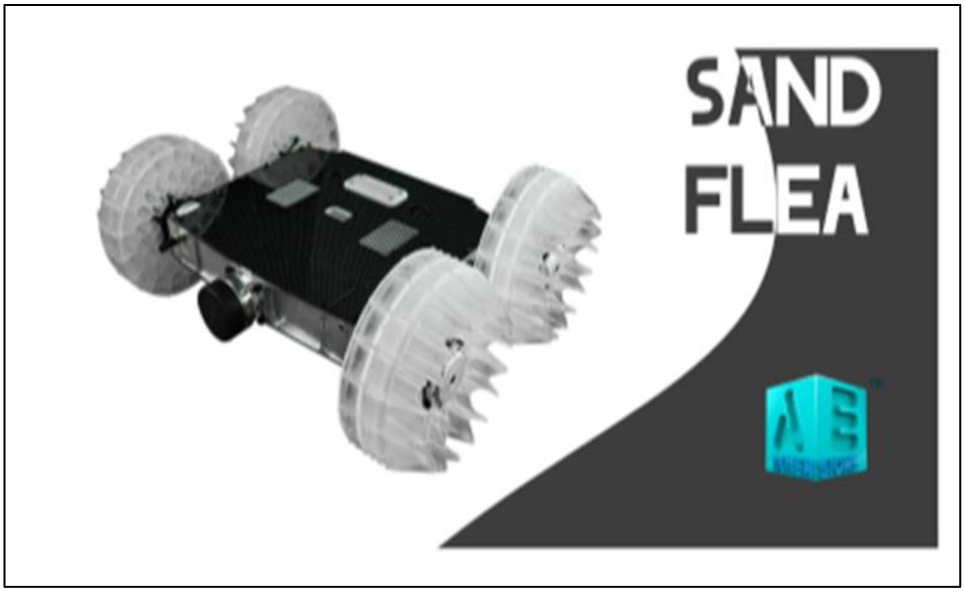


Figure 1: Newest Generation Sumobot "Sand Flea" [3]

3.2.2 Existing Design #2: Bluetooth Powered Sumobot

The Bluetooth Powered Sumobot is a recent technology which enables the users to operate it using Bluetooth. The design has some specifications which are beneficial to our design such as a low cost of 90$. This is because it is made up of a few components which are cheap. Also, the device has a few linkages and hence this specification can be incorporated in our device so as to reduce the time taken for assembly. The few linkages translate into a few components which makes the device to be light in weight hence can be carried from one point to another with ease [4]. The fact that it is Bluetooth controlled makes it to qualify as a device which is RC controlled. That is why it has been given the name Bluetooth Powered Sumobot. The microprocessor which have been applied to facilitate its effectiveness in use of Bluetooth can be incorporated in our sumobot device. However, its cons are that it is not hardy enough since it is made up of materials which are light in weight and not of low quality. In this manner the device is not able to last for a long period of time. In addition, the sharp edges which are on its sides make the device to be highly hazardous.

Figure 2: Bluetooth Powered Sumobot [4]

3.2.3 Existing Design #3: Parallax SumoBot

Parallax SumoBot is manufactured by Trossen Robotics and has specifications which are useful to our design. The sumobot is controlled by use of a remote control, a 4AA power pack and servo motors. The 4AA power pack ensures that the device is supplied with the right amount of power to facilitate effective operation. In addition, it has 2 module and infrared sensors to detect your opponent and the edge of the Sumo Ring. As a result, it enables the player to detect when opponent is ready to strike and hence prepare in advance how to make an appropriate move or counter attack. The device has high levels of safety since it has sensor inputs [5]. The major cons are that the device is made up of numerous components hence making its assembly to be too complicated. This also makes the device to have a lot of linkages hence making its assembly to be difficult. The device is not hardy and hence it cannot last for a long period of time.

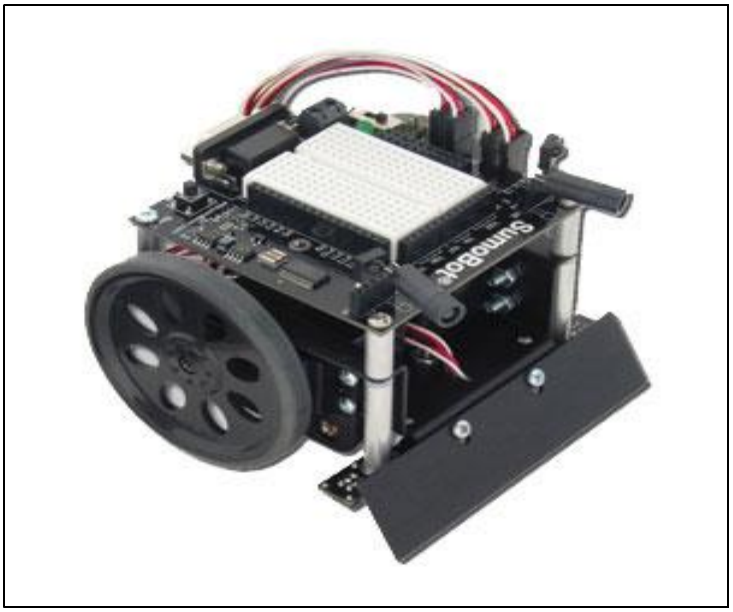


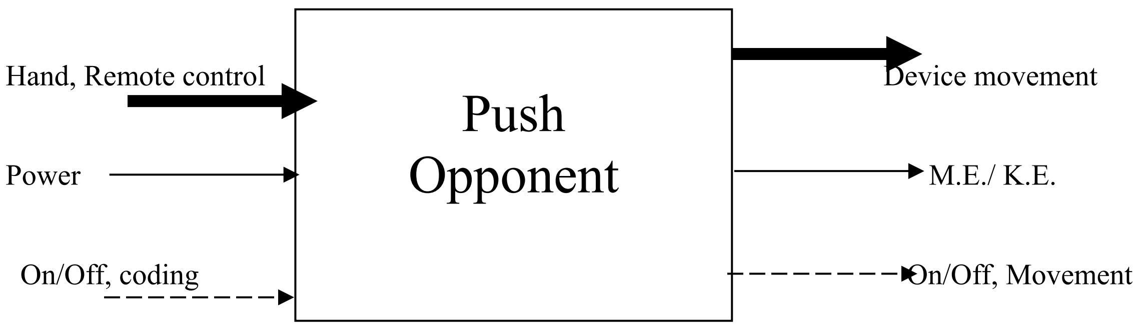
Figure 3: Parallax SumoBot by Trossen Robotics [5]

3.3 Functional Decomposition

In this section, there is a description of the black box model and the functional model. The black box gives a simplified analysis of the functioning of the sumobot in terms of inputs and outputs while the functional model gives details of the various steps which are involved in various components to ensure that the sumobot operates in an efficient manner.

3.3.1 Black Box Model

Black Box model entails a general overview of how the sumobot functions. At the centralized box the general functioning of the device is given. On the left-hand side, inputs were indicated whereas on the right-hand side the outputs were indicated. The thick black line, the thin line and the dotted line represents materials, energy, signals respectively. After using the black box model, the team were able to learn that all materials that enter, exit the system, hence, there are no materials that stay in the system. the black box model also enabled the team to focus on the fundamental elements and make sure that the device addresses the requirements in a successful manner.



KEY

━━━━━▶	Materials
─────▶	Energy
– – – – ▶	Signals
M.E.	Mechanical Energy
K.E.	Kinetic Energy

Figure 4: A black box model

3.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

The functional model is a breakdown of how the team theorized the sumobot system would operate. The model is derived from the black box model through analysis of the energy, material, and signal imports and exports. In this manner one gets a deeper understanding of how the device operates. Detailed presentation of how various forms of energy interact with various components of the sumobot have been shown. In order to operate the sumobot power is put on using a switch so that power can flow through the multi controller and initiate the motor. The movement of the sumobot is controlled by use of two pre-modified parallax continuous rotation servo motors by use of a process known as differential drive. The modification is able to trick the feedback circuitry to ensure that the device stops on receiving a centering command. It also enables the device to rotate in a continuous manner in either direction. However, the movement of the sumobot is controlled by use of a remote control using human hands. The remote control sends signals to the multi-controller. The Arduino receives the signal and actuate the command, which in turn initiate the motor which makes the wheels to rotate thus moving the device. When both motors are rotating in the same direction, then the sumobot moves in that direction. On the other hand, when the sumobot motors turn in varying directions, then the chassis will rotate. The rate of movement is determined by the speed in which the motor is moving. The functional model is presented in the figure below. However, the sumobot is fully controlled by use of a remote control.

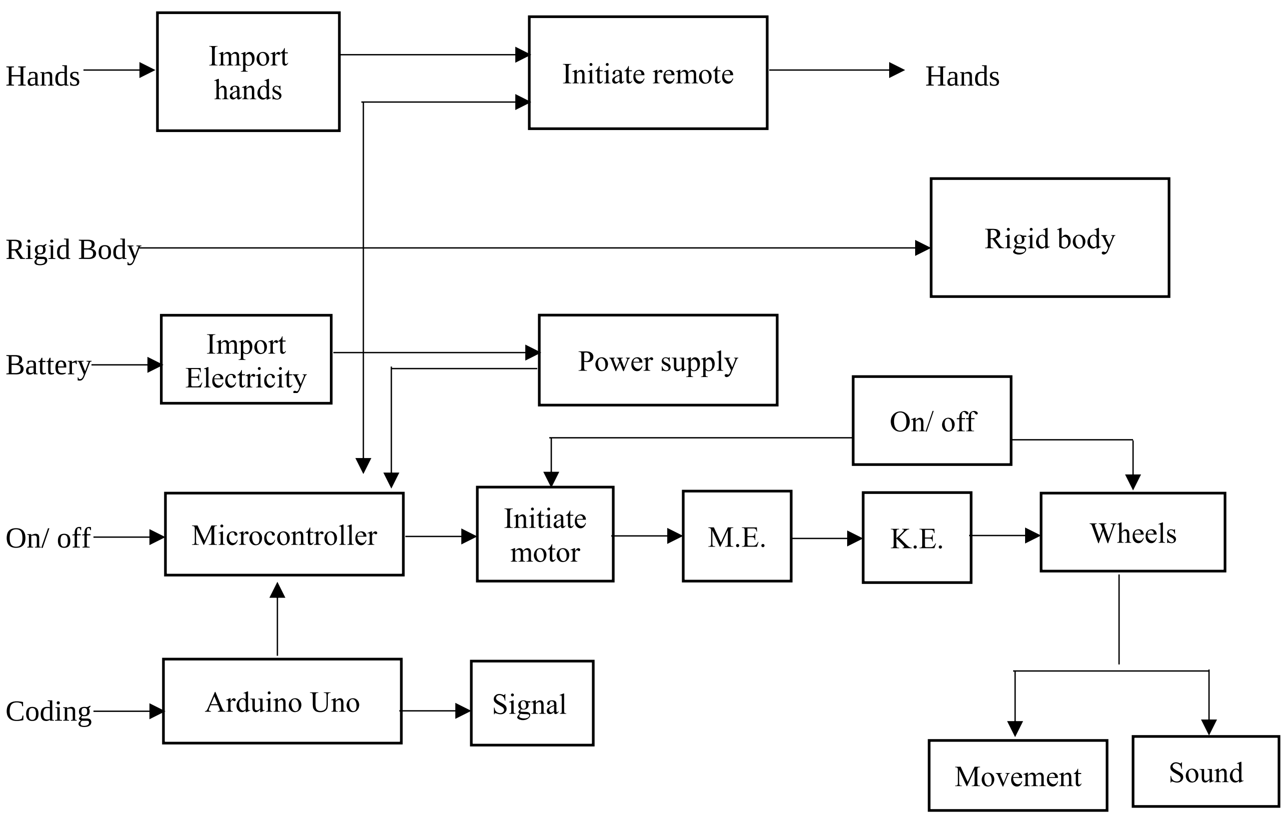


Figure 5: Functional Model

3.4 Subsystem Level

The main function of this project is to create an RC sumobot that capable of participating in the sumobot competition that include two R/C bots to compete against each other to win the battle. In order to power the sumobot it must have a battery which is placed in a certain compartment. The motors facilitate movement of the robot by use of wheels fixed on the sides. The movements of the sumobot are controlled by use of a remote control. The content of the section below will be discussing the existing designs for (1) motors, (2) batteries, (3) remote control system and (4) microprocessor system.

3.4.1 Subsystem #1: Motor

Motors are crucial in the sumobots since they facilitate effectiveness in movements within the device. Motors in the device also helps in improving the quality use as the sumobot is able to move freely while being operated.

3.4.1.1 Existing Design #1: Brushed Maxon DC Motors

Brushed Maxon DC motors are high-quality DC motors and are comprised of powerful permanent magnets. The motor is made using the ironless rotor cutting-edge technology which ensure that the motor has powerful drives and low inertia. In addition, it has a high rate of acceleration [6].

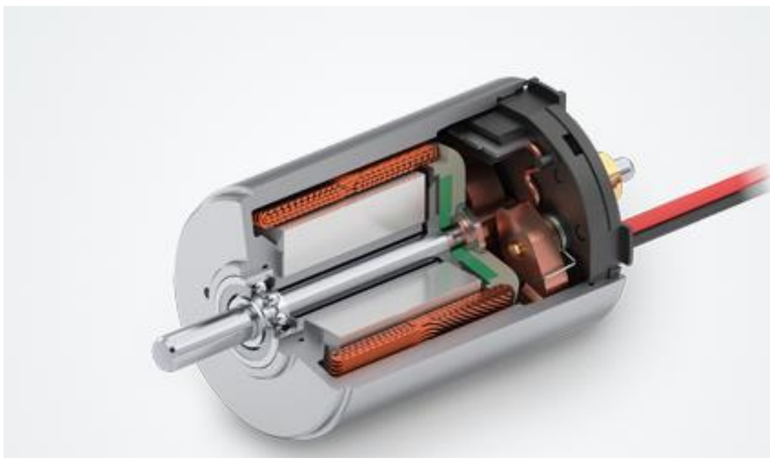


Figure 5: Brushed Maxon DC Motors [6]

3.4.1.2 Existing Design #2: Stepper Motor

This is a kind of motor which makes the shaft to rotate in a few degrees and then stop. In order to ensure that there is a continuous rotation, the stepper motors make use of numerous notched electromagnets which are arranged around a central equipment [7].

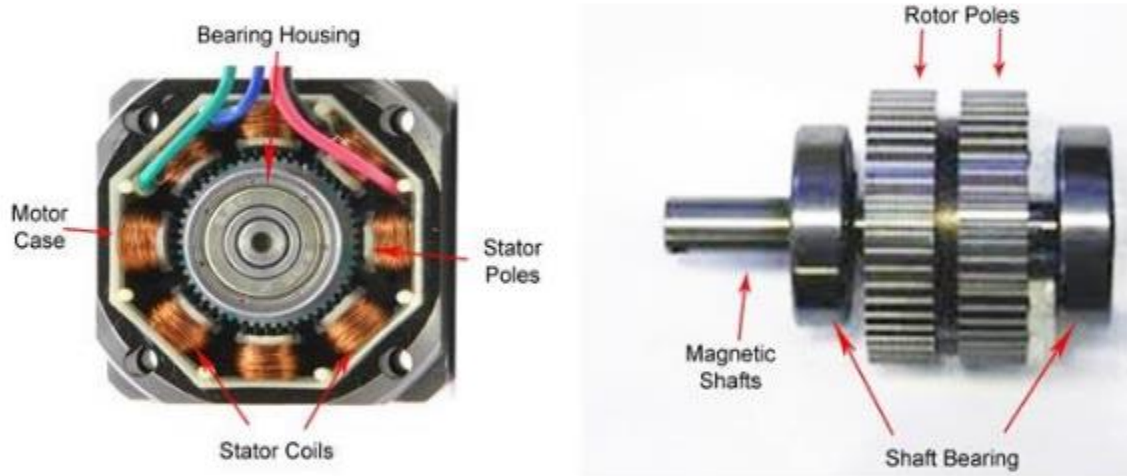


Figure 7: Stepper Motors [7]

3.4.1.3 Existing Design #3: Servo Motor

This is a kind of motor that is used for accurate positioning of the sumobot. It combines a continuous DC motor with a “feedback loop” to facilitate accurate positioning. This motor is designed for specific tasks where a motor position requires to be clear like moving various parts of the sumobot [8].

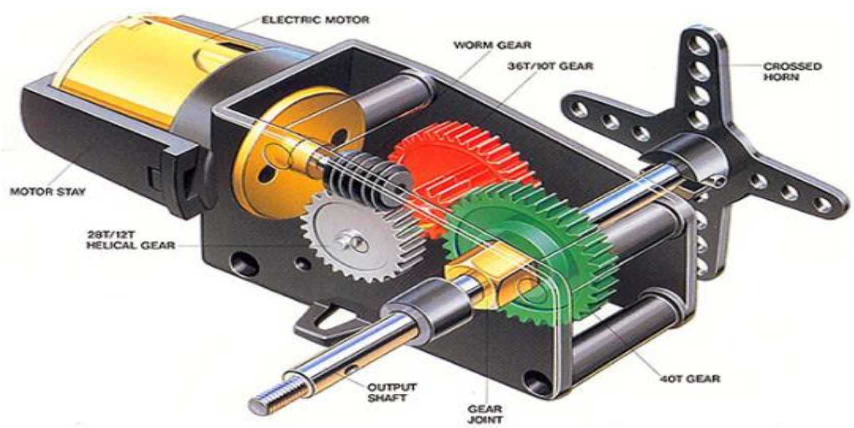


Figure 8: Servo Motor [8]

3.4.2 Subsystem #2: Batteries

Batteries are very crucial in sumobot device since they provide energy that is needed to power the device. There are a number of existing battery designs such as Cylindrical18650” batteries, Pouch Li-Poly battery, and Prismatic NiMHbattery which are as discussed below.

3.4.2.1 Existing Design #1: Cylindrical18650” batteries

These batteries are crucial since they provide a maximum voltage of 4.7 volts. The cells have an 18mm diameter and are 65mm long. There are some which have a flat “+” terminal which makes it ready for welding cells in a group to form battery packs. Others have a raised “+” terminal for easy insertion and removal from a battery holder [9].

Figure 9: Cylindrical18650” batteries [9]

3.4.2.2 Existing Design #2: Pouch Li-Poly battery

These are batteries which are produced in form of thin, elastic slices, that are stacked and inserted into the pouches instead of being can-rolled. Lack of metal packaging makes them light and hence crucial for the device as they will not add a lot of weight. Their slim nature makes them to be easily fitted into the device [9].

Figure 10: Li-Poly—lithium polymer battery [8]

3.4.2.3 Existing Design #3: Prismatic NiMH battery

This battery is enclosed in a metal can hence making it to be strong and free from explosion. The enclosure makes the battery to be a bit heavier hence can add onto the weight of the device. However, it is weather resistant due to the coating [9].

Figure 10: Prismatic NiMH battery [9]

3.4.3 Subsystem #3: Remote Control

A remote control system is crucial in the sumobot as it facilitates easy control by the operator when they are at a distance. The remote control systems discussed include voice remote control, infra-red remote control and radio remote control.

3.4.3.1 Existing Design #1: Ultrasonic remote control

This remote control system makes use of voice control. It is complicated and only requires a light tap, a whistle or a voice input [10].

Figure 11: Ultrasonic remote control [10]

3.4.3.2 Existing Design #2: Infrared remote control

Infrared remote control makes use of light in order to operate a device. It also requires a line of sight to operate the device and hence there is need to aim to the direction of receiver. However, it is cheap and easy to encode with a multi-function remote control [10].

Figure 12: Infrared remote control [10]

3.4.3.3 Existing Design #3: Radio remote control

Radio remote control is used to control distant objects by use of radio signals which are transmitted using the remote control device. This kind of remote control has a complex circuit; is expensive but has the best performance since it has farthest control distance and strong penetration ability [10].

Figure 13: Radio remote control [10]

3.4.4 Subsystem #4: Microcontroller

A microcontroller system is crucial in the sumobot as it translate the signal to the motors. As a result, it enables easier and efficient operation of the device.

3.4.4.1 Existing Design #1: Arduino Uno R3 USB Microcontroller

This microcontroller is of significant in this device since it has some specifications which are appropriate. It has a wide variety of accessory "Shields" which are available. It also has a variety of I/O pins including analog and digital. It also has an USB connection which facilitate connection to other devices [11].

Figure 14: Arduino Uno R3 USB Microcontroller [11].

3.4.4.2 Existing Design #1: Arduino Uno R3 USB Microcontroller

This design is characterized by a versatile, programmable robot tank kit, a complete Arduino board built-in Arduino Uno, and is compatible with a variety of shields. Also, it has a Dual H-bridge and onboard voltage regulator and hence there is only one battery which is required. In addition, it has an onboard LiPo battery charger and solder prototyping area hence there is no need of soldering[11].

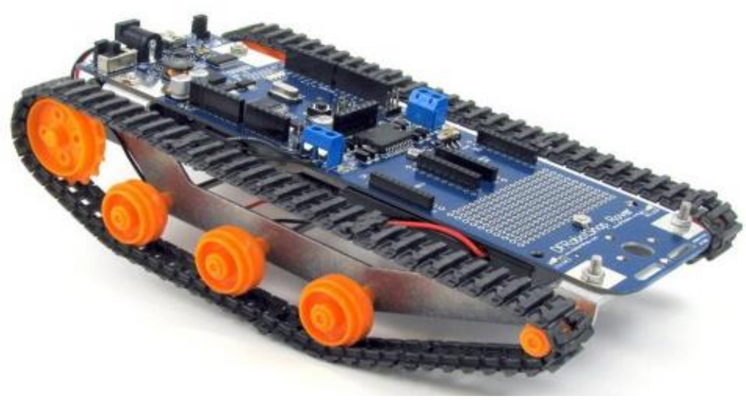


Figure 15: Arduino Uno R3 USB Microcontroller [11]

3.4.4.3 Existing Design #1: 16-bit Digital Signal Controller (DSC)

This design is crucial since it provides seamless operation while at the same time reducing power consumption. It is also characterized by a self-contained system with memory, a processor and peripherals. This design is highly appropriate in motor control, sensor processing and power conversion applications [12].

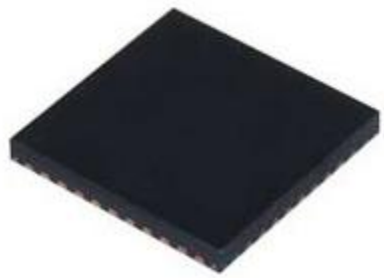


Figure 16: 16-bit Digital Signal Controller (DSC) [12]

4 DESIGNS CONSIDERED

The team generated a total of 10 different designs during the brainstorming process based on the various customer and engineering requirements. The first four designs which were considered are as discussed below and the rest are presented in the appendix

4.1 Design #1: Pyramid design

This design resembles a pyramid in its appearance. The pyramid shape increases the stability of the device since the lower part is wider than the upper part. Its pros are that it is able to move at a faster speed and make sharp turns while attacking the opponent sumobots. Also, it has less weak points hence making it to be very strong and durable. In this manner, it is able to make extremely tough tackles to its opponents. Its cons are that it has weak axels and a complicated coding.

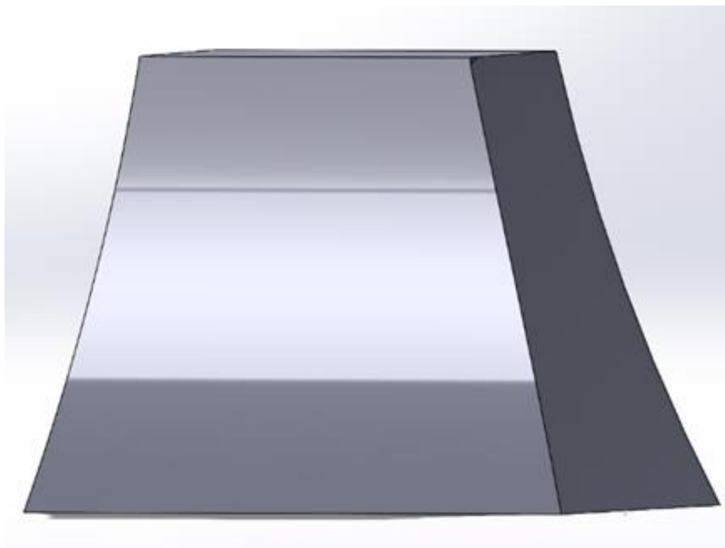


Figure 17: Pyramid design

4.2 Design #2: Tank bot

This design resembles a military tank. It has a pair of four wheels which are connected to a conveyor belt. Its pros are that it has a large contact area with the ground hence increasing its stability while it is in action. Also, the stability is increased by the conveyed wheels due to the high grip on the ground. In addition, it has defenses capabilities. Its major cons are that it has a high weight hence it takes a lot of time to turn around. At the same time its control mechanism is hard hence making the player to be filled with a lot of anxiety.

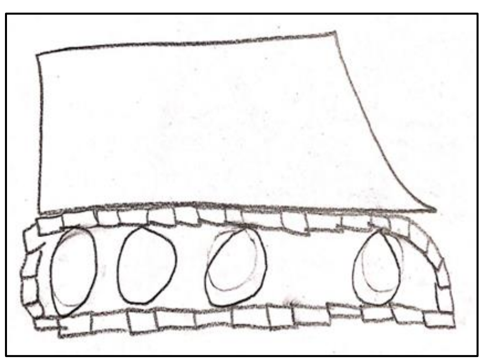


Figure 18: Tank bot

4.3 Design #3: Gripper

This design is made in such a manner that it has a magnetic field which results into a firm grip. Its major pros are a strong magnetic field and anti-flip tires. This ensures that the device is stable on the ground and it does not slide easily when attacked by an opponent sumobot. Its major cons are that it has tires which can break easily and an opponent sumobot may not fit.

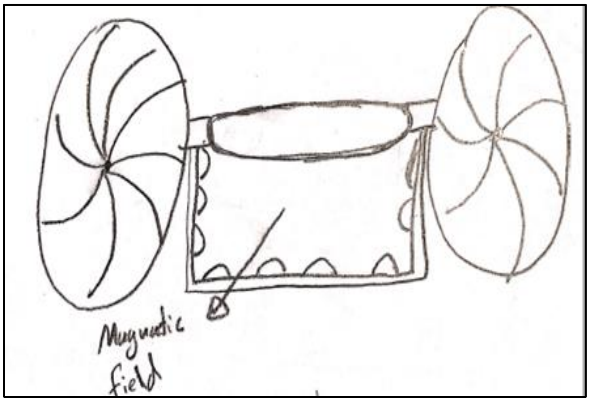


Figure 19: Gripper

4.4 Design #3: Seoi Nage

The design is comprised of rear and front protrusions for attacking the enemy bot. The components are controlled by use of hydraulic springs. Its major pros are that it has a rear stick which acts as a stabilizer. In this manner, the device is able to have a lot of stability while attacking or being attacked by an opponent sumobot. Its major con is that the hydraulic springs tend to make the device to be highly bouncy while it is in real operations. Also, its big size makes it hard to operate especially when it is made to turn.

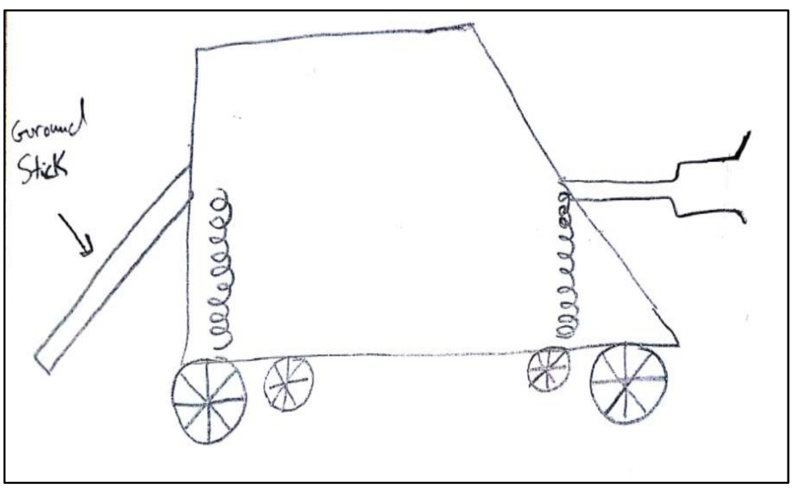


Figure 20: Seoi Nage

The rest six designs which were considered are presented in Appendix A.

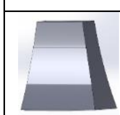
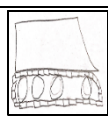
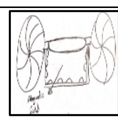
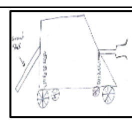
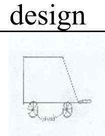
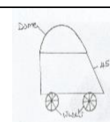
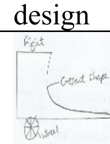
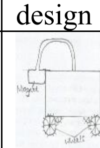
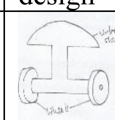
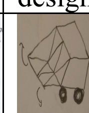
5 DESIGN SELECTED – First Semester

This section gives the explanation of the rationale that was used to select the most appropriate design for the sumobot that met the customer and engineering requirements. The design was carefully selected after evaluations of the designs using a Pugh chart and a decision matrix. The way in which the two rationales were used have been described in the sections below.

5.1 Rationale for Design Selection

The first rationale which was used in the process of design process was use of a Pugh Chart, which enabled the team to enabled narrowing down of used first to narrow the number of designs down to four. Then from the four designs a selection was done so as to get the design which meets most of the customer requirements. The customer requirements which were considered in this selection process include a design that is: light in weight; durable; portable; easy to operate; has pausing capabilities; remote controlled; safe to other sumobots and has low cost. The design which met a majority of the customer and engineering requirements in all scenarios was set as the datum. In this case the design which was selected as the DATUM is the Trapezoid design. In case a certain design exceeded the datum in a customer requirement, it was given a plus (+), whereas the design which did not exceed the datum in a customer requirement was given a minus (–). For designs which had a similarity in customer requirement were given an “S”. Then, a summation of the pluses, minuses and “S” was done below each design. After using the Pugh chart, the four designs which were selected so that they could be analyzed further in the decision matrix include: tank bot, pyramid, dome, and umbrella designs. After using the Pugh chart, the following four designs emerged the best including: pyramid, tank bot, dome, and umbrella designs. The Pugh chart which was used in narrowing down the ten designs into four is represented in the table below.

Table 4: Pugh Chart

CONCEPTS/ CRITERIA	Pyramid	Tank bot	Gripper	Seoi Nage	Trapezoid design	Dome design	Crescent design	Cuboid design	Umbrella design	Scissors design
										
Light in weight	-	+	-	-	DATUM	+	+	+	+	+
Durable	+	+	-	-		+	+	+	+	+
Portable	+	-	+	+		-	-	-	-	-
Easy to operate	+	+	-	-		+	-	-	+	-
Pausing capabilities	-	+	+	+		+	+	+	+	-
Remote controlled	+	-	S	-		-	-	-	-	S
Safe	S	-	-	-		+	S	S	S	+
Low cost	+	S	S	-		S	-	S	+	S
Σ+	5	4	2	2		5	3	3	5	3
Σ-	2	3	4	6		2	4	3	2	3
ΣS	1	1	1	0		1	1	2	1	2

A decision matrix was used in order to decide on the most appropriate design after being narrowed down by the Pugh chart. In the table, the customer requirements are listed on the left and weighted in terms of importance on a scale of 1 to 5. In this case, 1 is the least important whereas 5 is the most important. The same scale is used in rating the designs in respect to the customer requirements. For instance, 1 is awarded to the design which least fulfills the intended customer requirement; 3 is for the one which averagely fulfills whereas 5 is for the one which fully fulfills the respective customer requirement. Then, each rating on every design is multiplied by the customer requirement weighting and added together so as to get the total score. After using the decision matrix, the pyramid design emerged the best with a score of 62 and hence was selected since it had met most of the customer and engineering requirements.

Table 5: Decision Matrix

Criteria	Weight	Design 1 Pyramid		Design 2 Tank bot		Design 6 Dome		Design 9 Umbrella	
		Score	WS	Score	WS	Score	WS	Score	WS
Weight	5	5	**25**	2	**10**	3	**15**	4	**20**
Durability	4	4	**16**	4	**16**	3	**12**	2	**8**
Safety	3	3	**9**	3	**9**	4	**12**	3	**9**
Simplicity	2	4	**8**	1	**2**	3	**6**	4	**8**
Cost	1	4	**4**	2	**2**	3	**3**	3	**3**
Total			**62**		**39**		**48**		**48**

5.2 Design Description

The design which emerged the best in the project is the Pyramid design. The design resembles a pyramid in its appearance. The length of the device on the lower section is 20 cm while on the upper part it is 10 cm. the overall design resembles a pyramid and hence has been given the name of the pyramid. The pyramid shape increases the stability of the device and hence it is able to make quick and stable maneuvers as it pushes its opponent. The design has four wheels which are made up of rubber and this is crucial since it helps to increase the grip of the device. The outer casing of the device is made up of aluminum 6061 hence making it to be strong and highly durable.

In order to operate the device; it is first of all powered on by using a switch. This powers the motors hence making it ready for movement. Commands for moving the device are sent by use of a remote control. The signal is received by Arduino which then actuates the command. The remote control fully controls the sumobot without any autonomous controls.

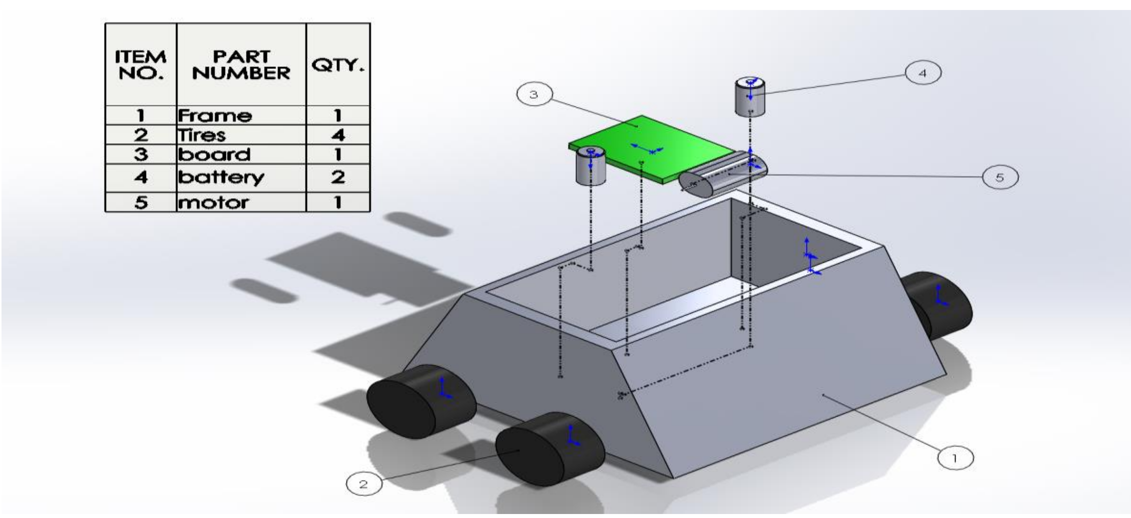


Figure 21: CAD Draft of the pyramid sumobot

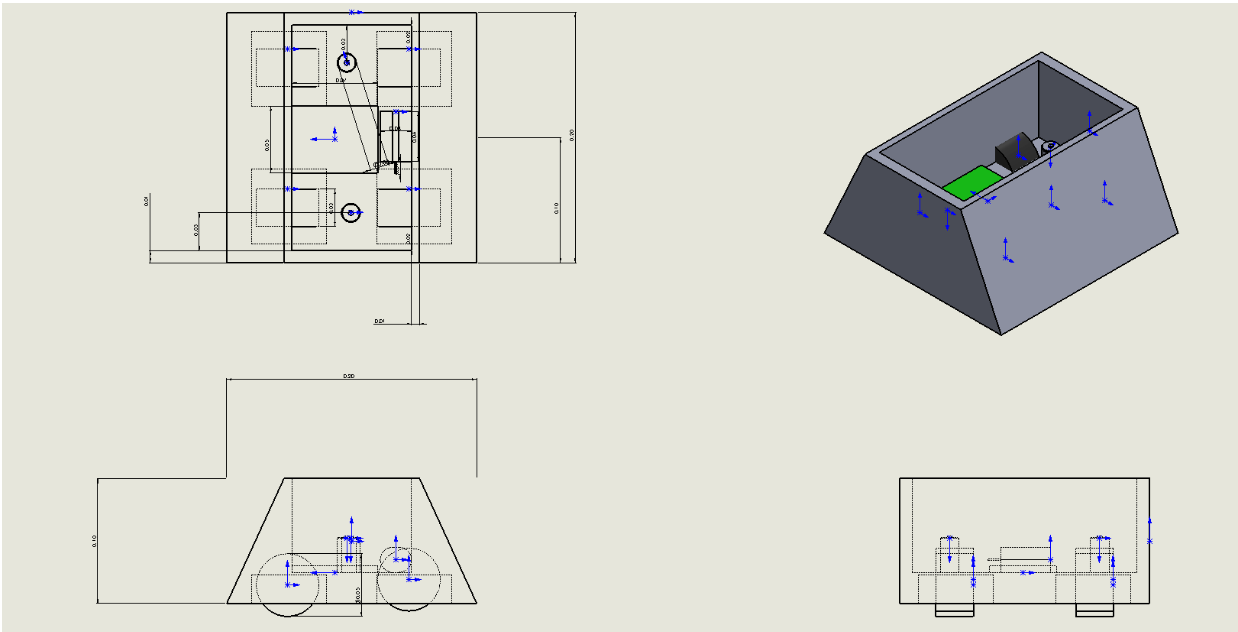


Figure 22: Multiple view CAD of the pyramid sumobot

6 PROPOSED DESIGN – First Semester

The implementation and fabrication of the sumobot has been described in this section.

6.1 Intended construction of the design

After selecting the pyramid design which have been discussed in section 5.2, the team made a decision of printing a 3D prototype for a proof of concept. The team hopes to discover possible problems in the designed from the prototype. This will help team to fix any problem and resketch if needed before starting to manufacture the design. This will help to make the manufacturing process much easier and reliable. This was to help in easy maintenance of the device in case some part failed or there was need of improvement. After prototyping, the team will look forward to full incorporation. Lastly, prototyping is a really important process since it confirms that everything works as intended and gives an idea of improvements and changes needed.

6.2 Materials

In this project, it was crucial to select the appropriate materials that could be used in the making of the pyramid sumobot. The components which were selected were to be of high quality, strong, light in weight, and durable. The strength of the materials was crucial since it ensured that the device was able to withstand strong forces from the opponent sumobots. Moreover, it facilitated easy operation and movement of the device while it is in operation. Durability will enable the device to sustain numerous tackles without breaking. The major materials that will be used in making the device include: Arduino Uno; battery; motor, wheels; motor driver; transmitter and receiver; and the frame will be made of aluminum 6061.

6.3 Bill of material

The bill of materials which is presented in table x below was made depending on the materials that were selected. However, the prices that have been indicated are the relative prices which are currently in the market.

Table 6: Proposed Design Bill of Materials

		Team 18F06			
Part #	Part Name	Qty	Description	Cost	Manufacturer
1	Arduino Uno	1	Microcontroller	$26	Adafruit
2	Battery	2	Li-Po Battery 2000mAh	$29.99	Robotmarketplace
3	Motor	2	RE 35 Ø35 mm, Graphite Brushes, 90 Watt	369.75	Maxon
4	Wheels	4	Aluminum Omni Wheel	$13.95	Robotshop
5	Motor driver	1	Sabertooth dual 32A motor driver	$124.99	dimensionengineering
6	Transmitter & Reciever	1	Transmitter and Reciever	$103	ebay
7	Aluminum T6	1	Metal Body	$200	Machine shop
		Total Cost Estimate:		$1,309.27	

6.4 Budget

The estimated total cost for the project so far is $1309.27, and this covers everything needed to build the sumobot from scratch. However, the price could be as low as $341.78 if the team were able to recycle the old sumobots provided by the instructor. If the team were able to recycle all the parts, they would only need to buy the frame material, machining, Arduino Uno, batteries, and wheels. The following table shows the cost breakdown of the initial prototype.

Table 7: Budget

	Available Balance	Anticipated Expenses	Actual Expenses	Result Balance
R/C Sumobot	$ 2500	$ 341.78	$ 1309.273	$ 1190.73

Schedule

In order to make sure that the team meets the deadlines of the project, other team set up a Gantt chart.in this manner, the team was able to organize themselves on significant milestones and deadlines. The Gantt chart that was used is presented in Appendix B.

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8 APPENDICES

8.1 Appendix A: Designs considered

Trapezoid design

This design resembles a trapezoid. Its major pros are that it has a strong wheel base, and a crane in the front to lift the opponent to make it easier to push them outside the ring. However, the cons were that the crane could be useless since most sumobots were very low in the front and made it hard to utilize the crane.

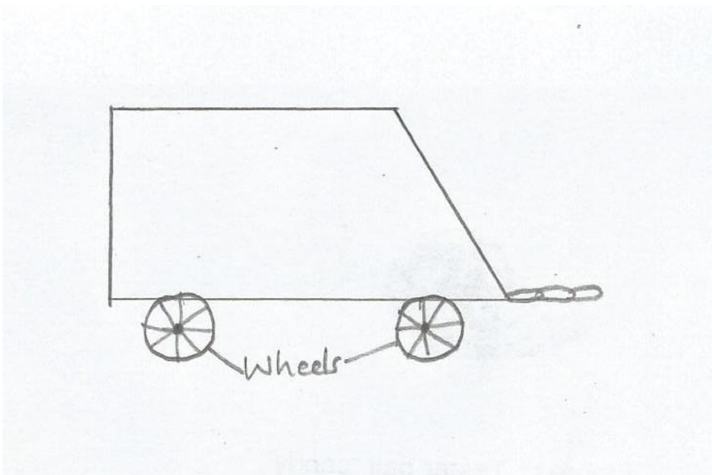

Figure 23: Trapezoid design

Dome design

This design mimics a dome on its upper part. On the lower section it is wide to facilitate stability. Its pros are that it is has higher levels of safety, durable, and its unflippable. Its cons are that it is hard to create it within the weight limit. In addition, the team found out its not allowed to flip the opponents which makes this design impractical which makes the team avoid thinking about how to counter getting flipped.

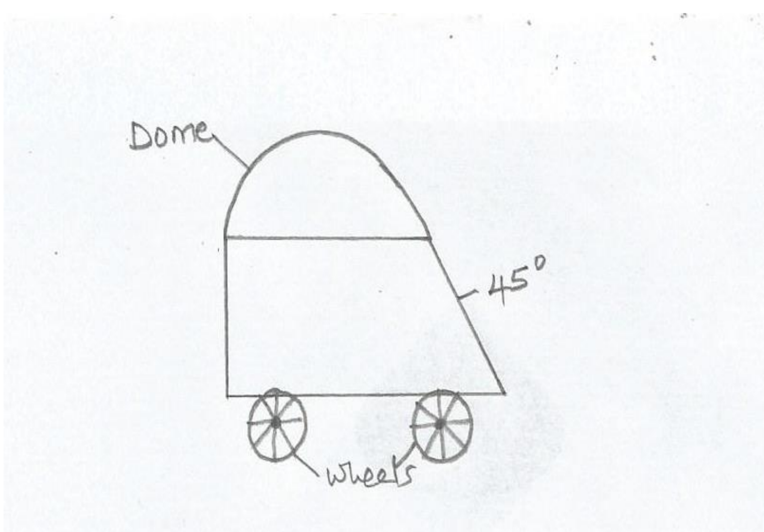

Figure 24: Dome design

Crescent design

This design resembles the crescents moon on one side where there is a magnetic attraction. The design has several pros including having sharp and very low blade to be able to lift the opponent easily. In addition, it has a magnetic field in the body to hold the opponent after lifting them. On the other hand, its cons were having lower than average defensive capabilities since it's hard to get enough weight with this design.

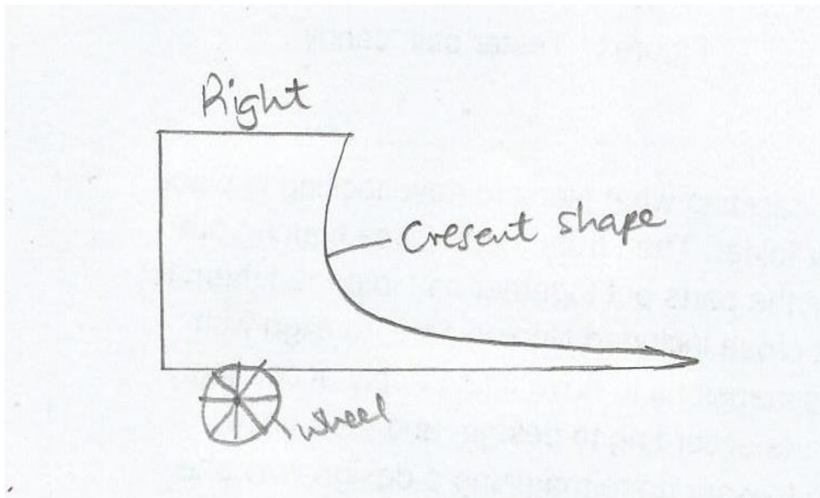

Figure 25: Crescent design

Cuboid design

This design is composed of a cuboid with four wheels. While the upper part has a curved arm, which has a magnetic edge. The pros associate with the device is that it has a high level of stability. However, the cons were that it was hard to fit this design in the required size. Moreover, it was hard to find a strong enough magnet to be able to lift the opponents from above.

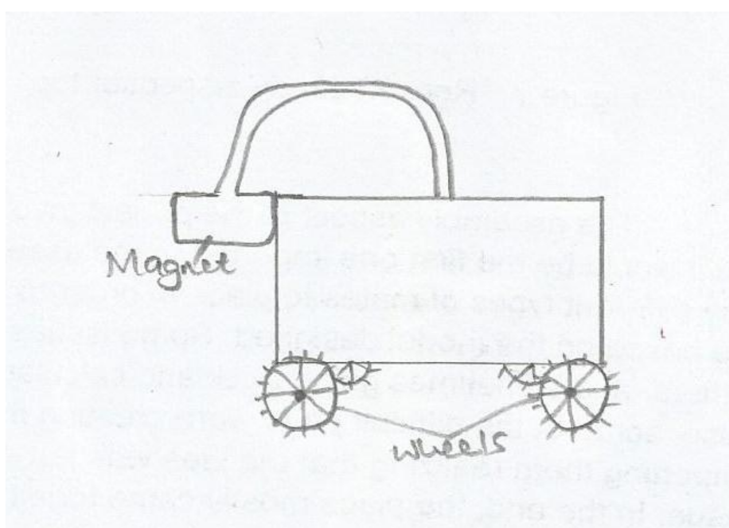

Figure 26: Cuboid design

Shovel design

The major pros in this design that it has two stances which were from utilizing the shovel shape. For attacking the shovel will lean forward and act as the design blade to push the opponent. In addition, the shovel is also used in a defensive way as the shovel will lean back to act as a drag mechanism to make it hard for the opponent to push the design. The cons for this design were begin light weight and having only two wheels which makes it unstable.

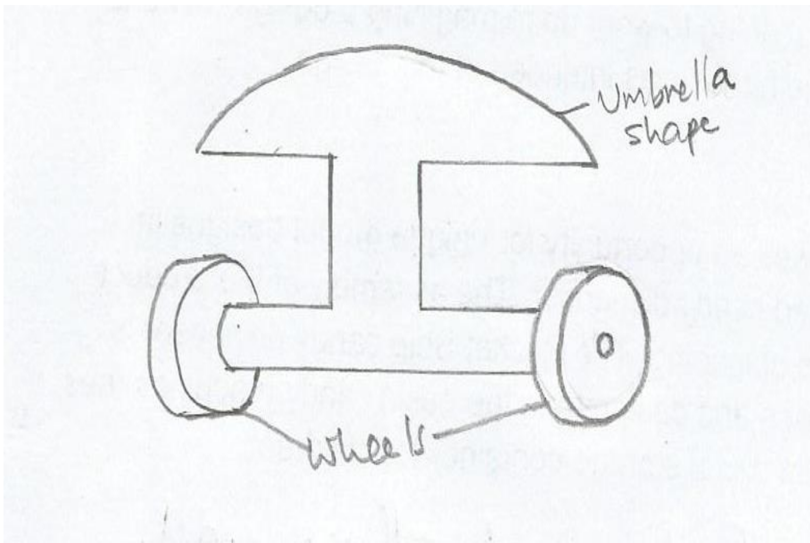

Figure 27: Umbrella design

Scissors design

This design utilizes a unique mechanism to counter being lifted. The front blades will be able to move sideways as a defensive technique which helps getting recovered after getting lifted from the opponent. However, the cons of this design are the weight limit in the competition since the design will get a lot of weight to accomplish this idea.

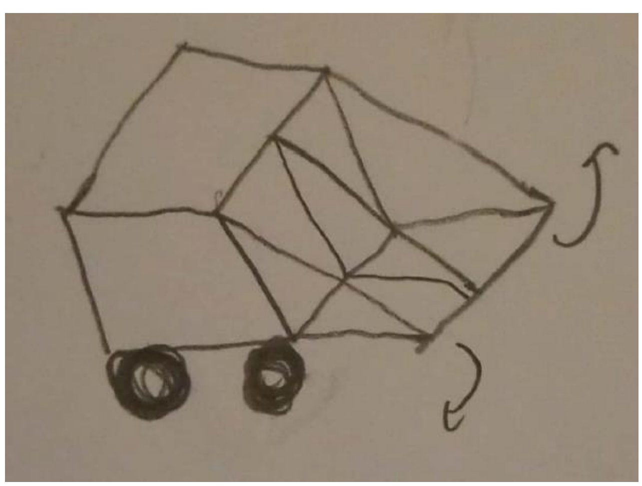

Figure 28: Scissors design

8.2 Appendix A: Gantt Chart

Table 8: Gantt Chart