Team 18F06 SumoBot

Final Proposal Report

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DISCLAIMER

EXECUTIVE SUMMARY

The major purpose of this report is to document the progress of the design and manufacturing of a remote controlled SumoBot that is able to participate in the SumoBot competitions. The purpose of this project is to make the participants 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.

Before the start of the project, we checked the rules on the competition's website to get the customer requirements that should 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 existing designs to get an idea on how SumoBot operates. A black box model and a functional model had been used to determine how the SumoBot works in details. During the brainstorming the team came up with 10 different designs based on the various customer and engineering requirements. A Pugh chart had 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.

Already existing designs were used as benchmarks to design an effective SumoBot that meets the engineering requirements.

After reviewing many designs and many control methods, the team has decided to build a SumoBot with pyramid design controlled wirelessly by Bluetooth that can be controlled using any mobile phone that has a Bluetooth connection. Control signals are sent to Arduino Uno Controller that controls the motors on the robot.

So far, all the requirements have been fully met, and there are no foreseen issues, and hence the project is regarded as a success.

ACKNOWLEDGMENTS

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. Besides, a lot of appreciation goes to NAU our sponsor.

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1 BACKGROUND

1.1 Introduction

In this project, the team is required to participate and compete in a SumoBot competition held by RoboGames. This competition has similar rules to the traditional Japanese sumo sport which mainly aims to push the opponent outside the ring. Two robots are competing instead of humans. The ring is circular and has varying dimensions depending on the class, and each robot starts in a set line called shikari lines inside the ring. Each match has three rounds, and the team wins a round when the opponent's SumoBot touches the outside ring of the arena. The teams follow the rules and regulation set by RoboGames which states that it is not allowed to damage or flip the opponent Bot.

The sponsor of this project is Northern Arizona University's mechanical engineering department, and RoboGames may be considered as one of our stakeholders. This project provides expertise in problem-solving and building from scratch for the team. Besides, this project is an excellent 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

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 SumoBot. 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 how important each requirement is.

2.1 Customer Requirements (CRs)

Customer requirements are considered as the various forms of requests in which the clients and the users consider how the device can be designed to suit their needs. The customer requirements were obtained from RoboGames website [2]. The gathered customer requirements are weighted on a scale of 1-5 where 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
Reliable	4
Durable	3
Portable	4
Competitive	2
Pausing capabilities	2
RC controlled	3
Safe to other SumoBots	5
Low cost	4
Light in Weight	3

1. Reliable
A robot with poor reliability leads to many problems: unsafe conditions, inconvenience so robot should be designed in such a way that any single failure will not lead to a robot's hazardous motion.

2. Durable
The device should last for a long period and at the same time should be able to withstand the roughness and toughness associated with the game.

3. Portable
The device should be easy to carry which 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 and follows the size limit of 20x20 cm.

4. Competitive
The design must be competitive enough in the competition and has great defensive and offensive capabilities to ensure being competitive in the competition. Moreover, the team aimed to have great maneuver to have the ability to counter attack.

5. Pausing capabilities
Sometimes there is a 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. The team should focus on not exceeding the budget limit of $1500.

9. 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. 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.

2.2 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 device 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
Effective from all sides	All sides are equally powerful
Size	20x20cm
Competitive	Fast enough to maneuver in attack and defense.
Remote Controlled	Fully controlled and easy to operate.
No Autonomous Features	Does not have any sensors or autonomous codes.
Safety	Does not damage other SumoBots.
Cost Efficient	<$1500
Weight	<3kg

1. Maintenance
In order for the device to be reliable it should not require much maintenance. Some of robot parts which require maintenance are the moving parts. These parts should be lubricated appropriately to ensure that they move with ease. Worn out parts and batteries should be replaced promptly, parts maintenance should be once per competition just to check the proper functionality of the parts.

2. Effective from all sides.
The team aimed to have the design effective from all sides, unlike most other sumobots which only focused on one side only. As a result, these sumobots have a lot of weak points, and bad defensive capabilities from the sides.

3. 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 and the robot height is not a restriction, but 15 cm height is suitable for robot stability.

4. Competitive
The design must have a great competitive abilities to be able to win in the competition. Since the team aimed to have great defensive and offensive from all sides this will help to achieve this requirement.

5. Remote Controlled
Having fully remote controlled SumoBot, and the SumoBot controls must be easy and simple for anyone to use.

6. No Autonomous Features
Having fully controlled SumoBot is crucial in this competition since having any kind of autonomous will result in disqualifying.

7. Safety
One of rules of the competition is to not inflict any damage to other sumobots or flip them otherwise the team will get disqualified.

8. Cost efficient
The cost of the device should be minimized such that the amount of money spent building the final robot, prototype and the various parts is within the set budget limit of $1500. In addition, the team should try to use as much as they can from the previous capstone project designs if possible.

9. 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.

2.3 *Testing Procedures (TPs)*

After having the full design, the team will have a chain of tests to make sure that the sumobot functions properly. These testing procedures will ensure that the sumobot is functional and follows the rules and regulations of the competition.

1. Maintenance

The device will be disassembled to check whether the moving parts such as wheels are working properly, and all the bolts and nuts are fastened. Moreover, the maintenance should be done one time only before each competition. This will be checked using how long it takes to fully assemble the sumobot which will be discussed in the next point.

2. 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. The team will make sure to use a timer watch before assembling the sumobot to ensure it does not take a long time.

3. Cost efficient

The prices of all the components and services used in Robot building will be summed and they must not exceed the budget of $1500.

4. Weight

The weight of the device must be measured to determine that it does not exceed 3kg.

5. Size

The length, width and height of the device will be measured by use of a ruler calibrated in centimeters. The result must follow the rules and regulation which are 20x20 cm maximum base size and the height is unlimited.

6. Motor

Motor will be tested and make sure that it easily transmits its power through the wheels and provides its max power and to avoid using gears to avoid power loss.

7. Pushing Capabilities

The instructor provided the team with the old sumobots which will help to test the pushing capabilities to make sure that the motors are providing enough power.

8. Battery Life

The team will keep the sumobot running with timer watch while monitoring the performance level of the device to evaluate the time that the sumobot has full power. This will help to know when the team need to change the batteries during the competition.

9. Remote Control

All commands of the remote control must be tested and make sure that it perform as expected.

2.4 Design Links (DLs)

1. Easy Maintenance

The Pyramid design provide an easy access to each of the components in the robot which provide fast and easy maintenance and we moved the controller and the power source to the upper side of the robot to be easy accessed.

2. Assembly Time

All parts in our SumoBot have been fixed using bolts and nuts to be easily and fast assembled together.

3. Cost Efficient

Total prices of components and services used in our robot did not exceed the 1300$ budget.

4. Weight

Robot weight is about 2 kg which meets the determined weight, however, the team will try to increase the weight as much as possible.

5. Size

Robot dimensions are 20 cm x 20 cm x 15 cm which is within the determined dimensions and which will provide the required stability.

6. Motor

Motors used in the robot are of 8.8 kg/cm torque which will provide the required torque to push the opponent robot.

2.5 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**	**Effective from all sides**	**Size**	**Competitive**	**Remote Controlled**	**No Autonomous**	**Safety**	**Cost Efficient**	**Weight**
Reliable	4		9	3	3	9	3	1	3		3
Durable	3		9		3	9	3	1	3		3
Portable	4		9		9	3	3		9	1	9
Competetive	2		3	9	3	9	9	3	9	3	9
Pausing Capabilities	2		3	1		3	9	9	9	3	3
RC Controlled	3		9	3	9	3	9	9	3	3	3
Safety	5		3	3	3	9	9	1	9	3	1
Low cost	4				3	3	1		3	3	3
Light in Weight	3		1	9	9	3		1	3	3	9
Absolute Technical Importance (ATI)			156	83	144	174	145	66	165	61	134
Relative Technical Importance (RTI) (Rank)			3	7	5	1	4	8	2	9	6
Target unit of measurement			Per competition	No unit	Cm		Mhz	No unit	No unit	USD	Kg
Target ER values			1		20*20*20		75			1500	3
Tolerances of ERs			1		<<20*20*20		<75			<1500	<3

According to the House of Quality the most crucial engineering requirements that the team had to lay more emphasis on include competitive, safety and Maintenance. Being competitive is the key to be able to win and compete during the competition. Safety is a major thing in the competition as it is one of the rules and regulations and failing meeting this requirement will lead to elimination from the competition. 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 weight has to be limited to facilitate movement. 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 will be discussed. The team focused on designs which meet various customer requirements.

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 customer'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: 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.

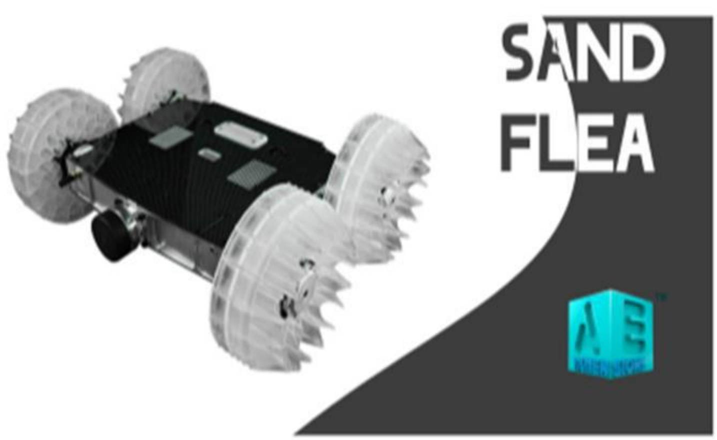


Figure 1: Sand Flea [3]

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.

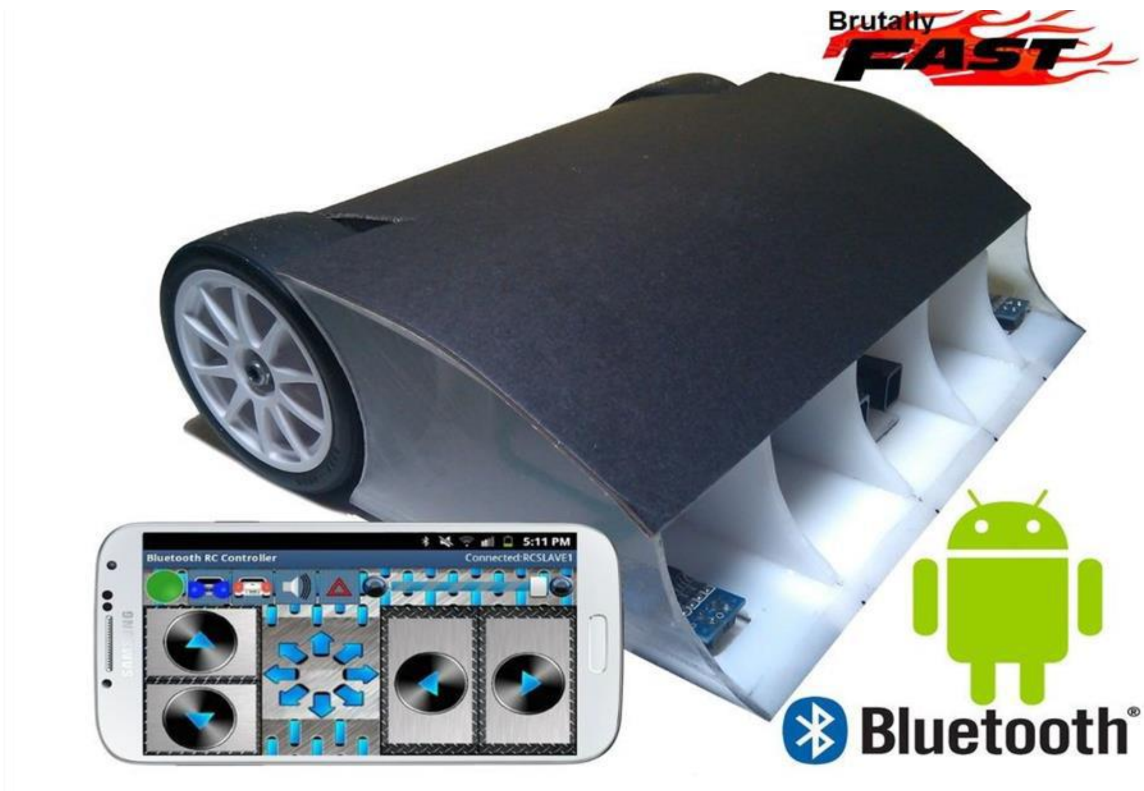


Figure 2: Bluetooth Powered SumoBot [4]

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 thin line and the dotted line represents energy and 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.

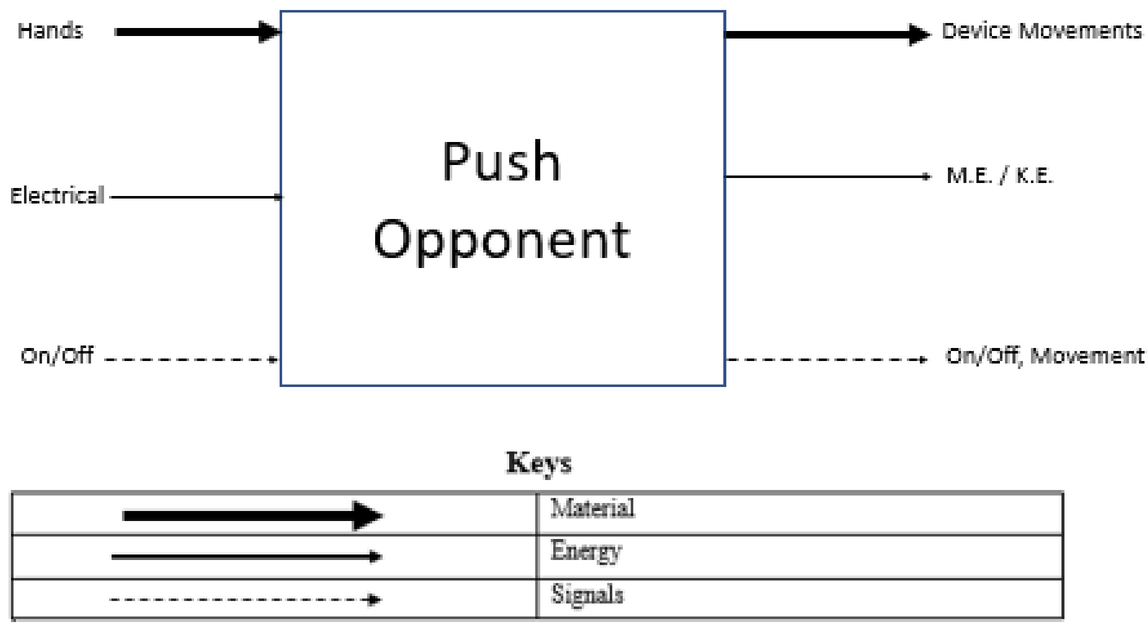


Figure 4: Black Box Model

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 different 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.

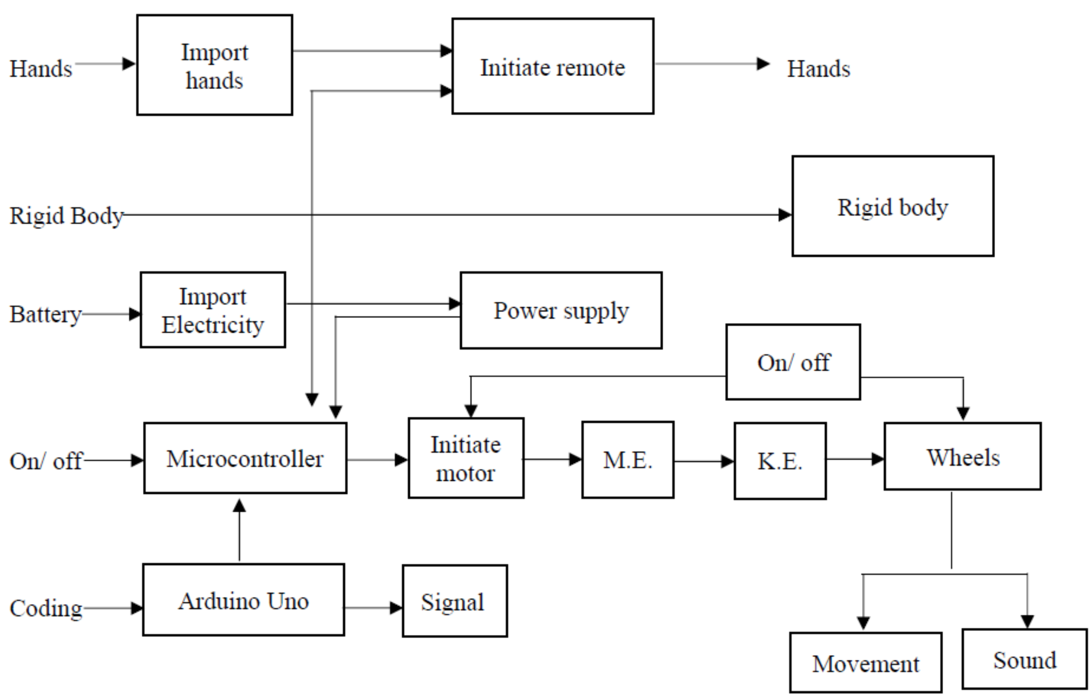


Figure 5: Functional Model

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, motor is relevant to the required function as it has high rate of acceleration and speed and relatively high torque which is highly required in the robot. [6].

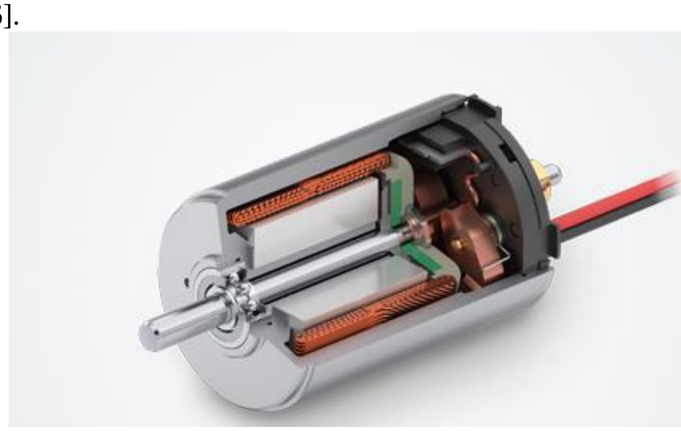


Figure 6: Brushed Maxon DC Motors [6]

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. Stepper motor may not be suitable for our robot as it is used tasks that required high accuracy in movement but in our design we do not need this type of accuracy as much as we need high speed and torque. [7].

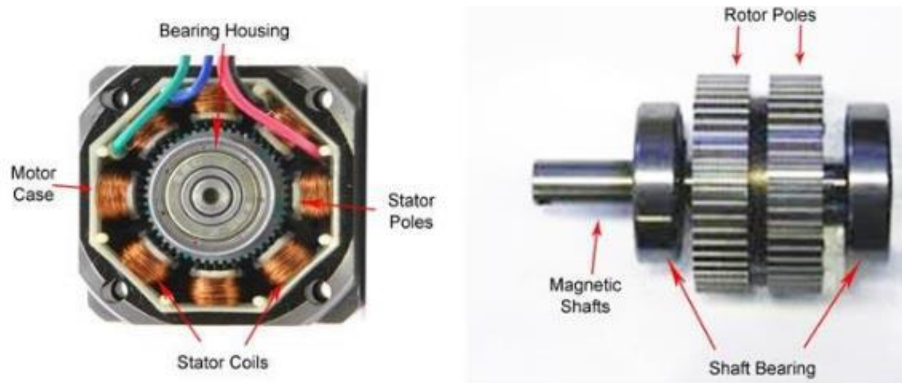


Figure 7: Stepper Motors [7]

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 and in our robot we do not need this kind of accuracy as much as we need speed and torque so servo motor may not be relevant to our robot. [8].

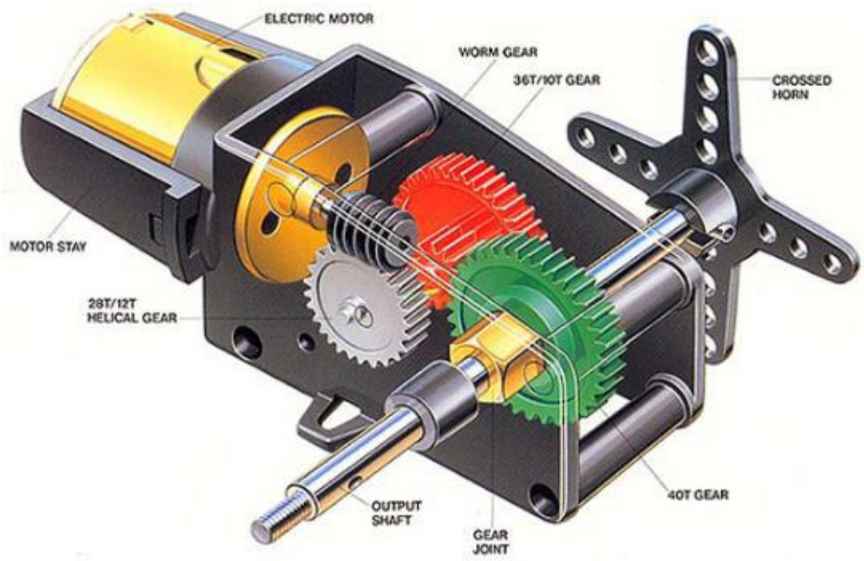


Figure 8: Servo Motor [8]

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 NiMH battery 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].

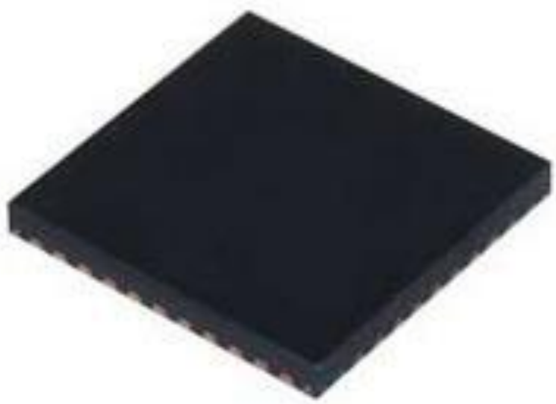


Figure 16: 16-bit Digital Signal Controller (DSC) [12]

3.4.5 Subsystem #4: Wheels

A Wheel system is crucial in the SumoBot as it translates the rotational motion of the motors into robot movement so the wheels should have high surface friction to be able to push opponents.

3.4.5.1 Existing Design #1: Omni Wheel

This Omni wheel provides 360° movement with rotational and sideways maneuverability and will make the robot able to rotate 360° but it is not relevant to our design as it require a totally different motors position design.

Figure 17: Omni Wheel

3.4.5.2 Existing Design #2: Rubber Wheel

This rubber wheel has high friction which makes it relevant to our robot.

Figure 18: Rubber Wheel

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. In this manner, it is able to make extremely tough tackles to its opponents. Its cons are that its wheels have to be inside the robot body and the distance between the collinear wheels will be less than the other designs as all wheels have to be inside the body which will give less stability.

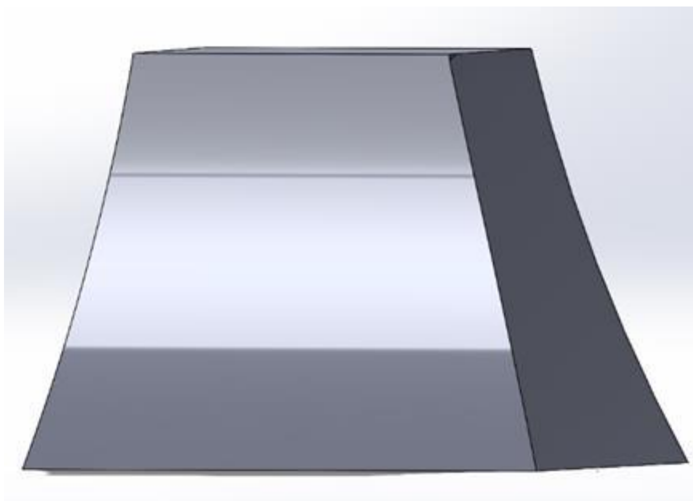


Figure 19: Pyramid design

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 higher weight than other design which may exceed our required weight hence it takes a lot of time to turn around and not easy to control.

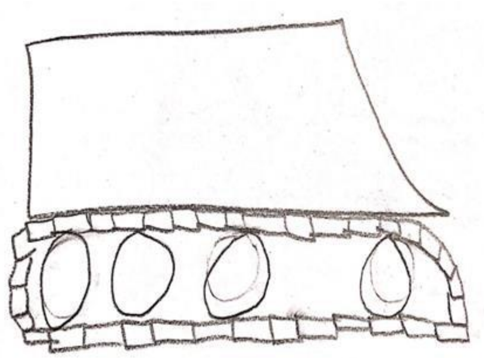


Figure 20: Tank bot

4.3 Design #3: Gripper

The 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 big tires on the side to prevent getting flipped. 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 be gripped easily and the team founds out that flipping is against the rules which makes this design useless.

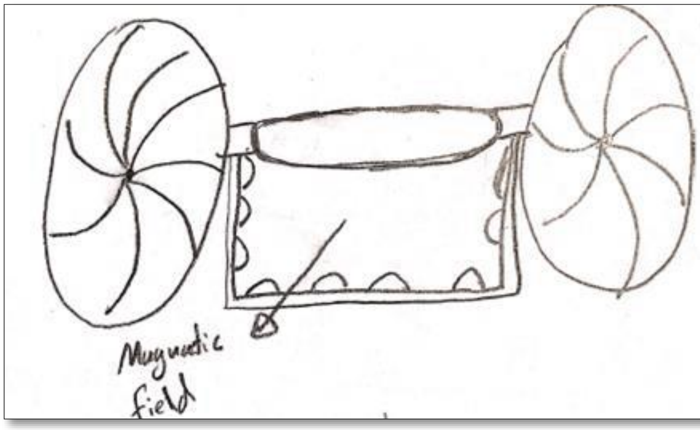


Figure 21: Gripper

4.4 Design #3: Seoi Nage

This design 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.

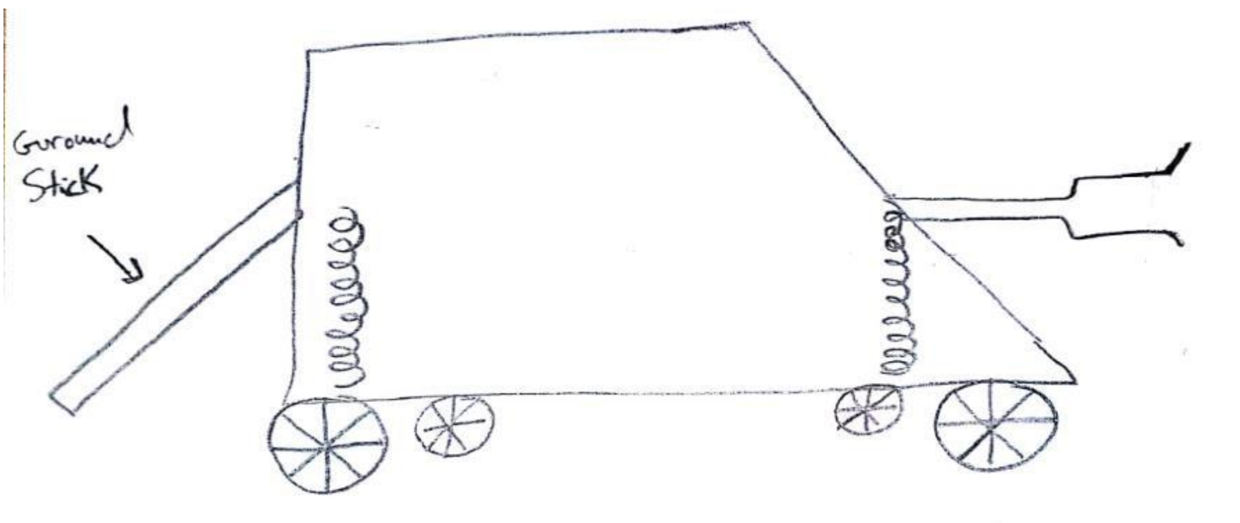


Figure 22: Seoi Nage

The rest of the 10 designs which were considered are presented in Appendix A

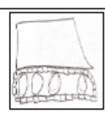
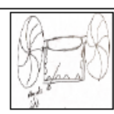
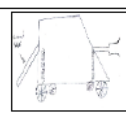
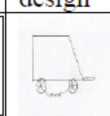
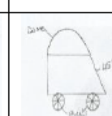
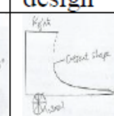
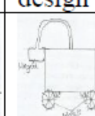
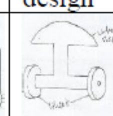
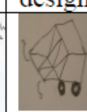
5 DESIGN SELECTED – First Semester

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.

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 narrow the number of designs down to four which are represented below. Then from the four designs a selection was made 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; reliable; 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. 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 lower section is 20 cm square while the upper part is 10 cm square. 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 mobile phone with Bluetooth connection. The signal is received by Arduino which then actuates the command. The remote control fully controls the SumoBot without any autonomous controls.

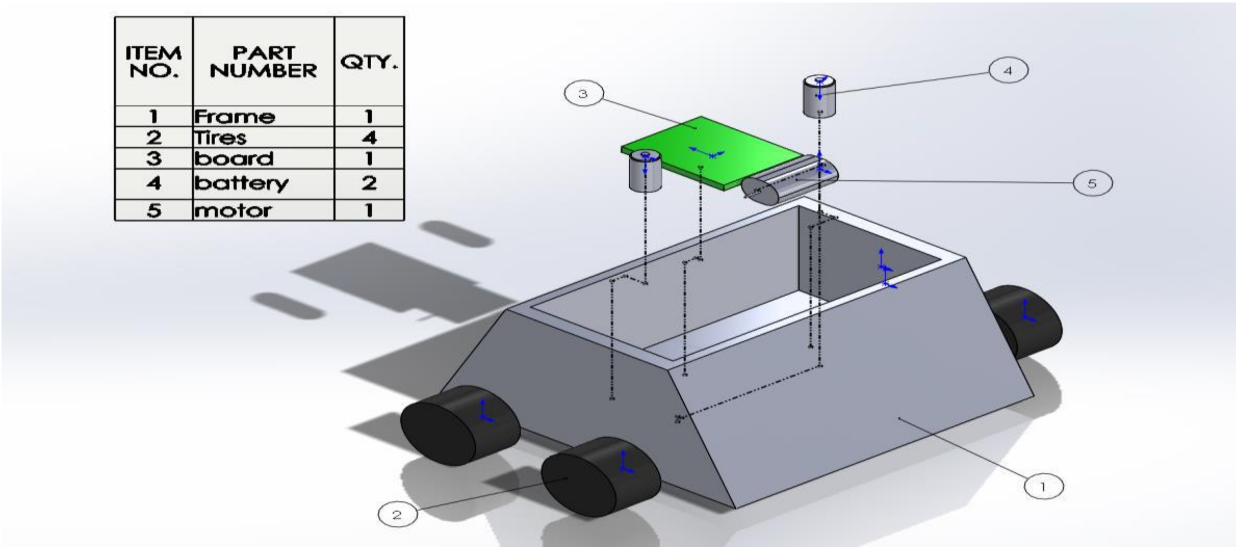


Figure 23: CAD Draft of the pyramid SumoBot

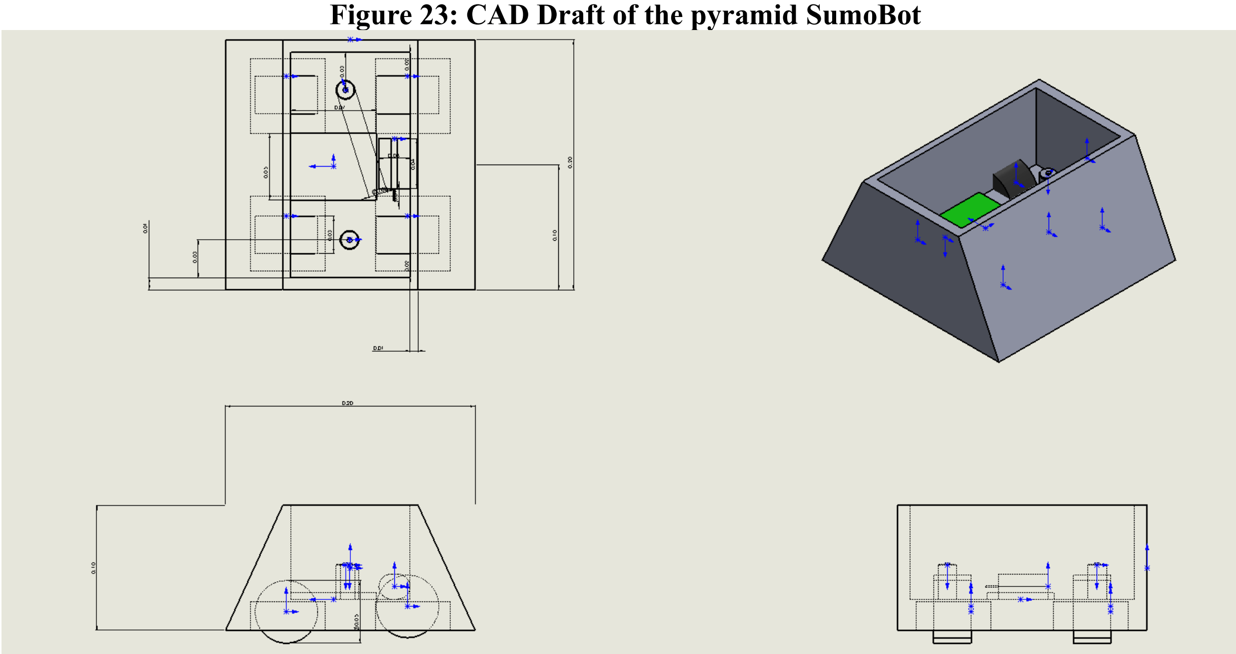


Figure 24: Multiple view CAD of the pyramid SumoBot

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 Proposed 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. The bill of materials which is presented in table 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	

6.3 Proposed 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.

6.4 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 table 8 Appendix B.

7 IMPLEMENTATION – Second Semester

Final design was changed to fit the manufacturing processes and assembly processes which was done to the design, so the complete final design of the robot has changed as follow after replacing some of the parts and after building the exterior body. The figure below shows the result of the changes with a CAD model and details will be discussed in this chapter.

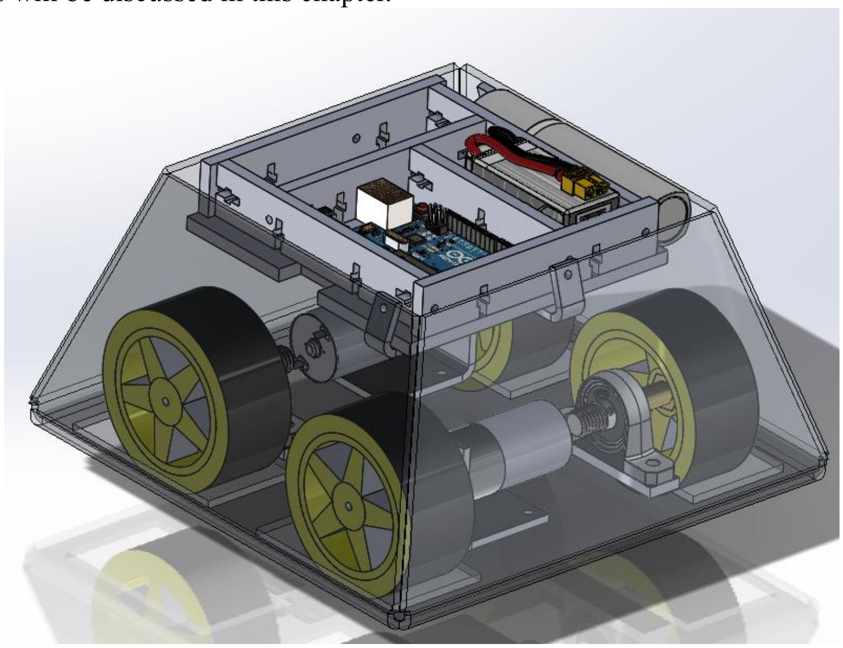


Figure 25: Final CAD draft of SumoBot

7.1 Manufacturing

Most of the SumoBot will be assembled of many components that was bought but the exterior body and the second layer to be manufactured based on the design and each was based on calculations that was done to make sure the best material were used. The process of manufacturing started during winter break between the semesters which gave the team a better machines to use in the Kuwait Scientific Club.

7.1.1. Exterior Body:

The exterior body was made of aluminum sheet metal which was cut using **Laser cutting machine** available in the Kuwait Scientific Club based on the designed flatten sheet metal as seen below. The aluminum 6061 was used as the body material after comparing it to Mild Steel and Brass. The aluminum had enough strength to with stand impacts with lighter weight. The Calculations are presented in Appendix C.

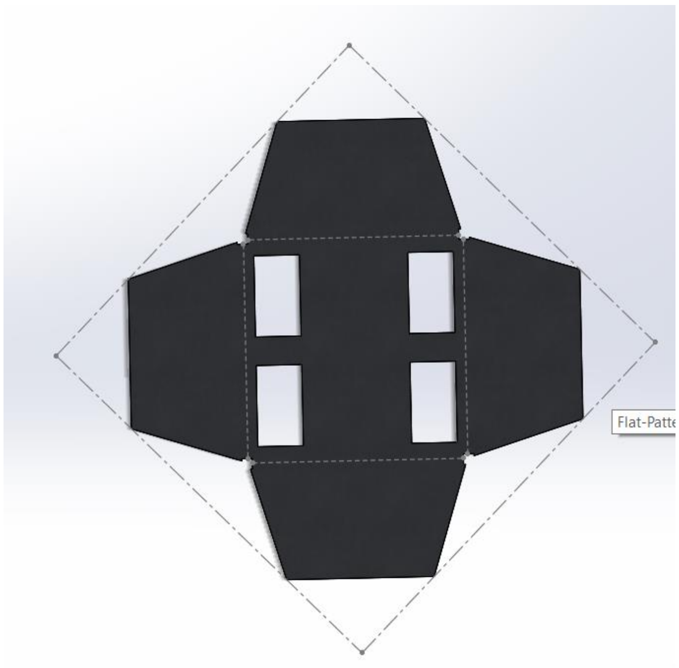


Figure 27: Flatten exterior body aluminum sheet

After cutting the aluminum sheet using the laser cutting machine a hydraulic sheet metal bending machine was used to bend the sides of the cut aluminum sheet which was also available in the Kuwait Scientific Club to make the pyramid shape as seen below.

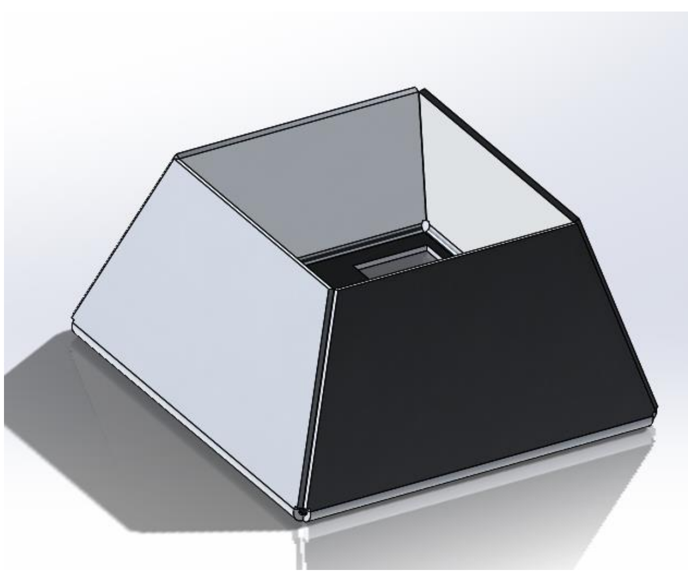


Figure 28: Exterior aluminum body after bending

7.1.2 Control wooden frame:

Wooden Frame will be used to carry the electronic parts in the upper side of the sumobot and we chose to use wood as it helps to control the heat generated from the electronic parts. Moreover, the wood was used as it does not conduct the heat generated by the motors inside the design. The wood was bought from Home Depot and the manufacturing process was done in Ace Hardware workshop. The frame was cut based on the design below.

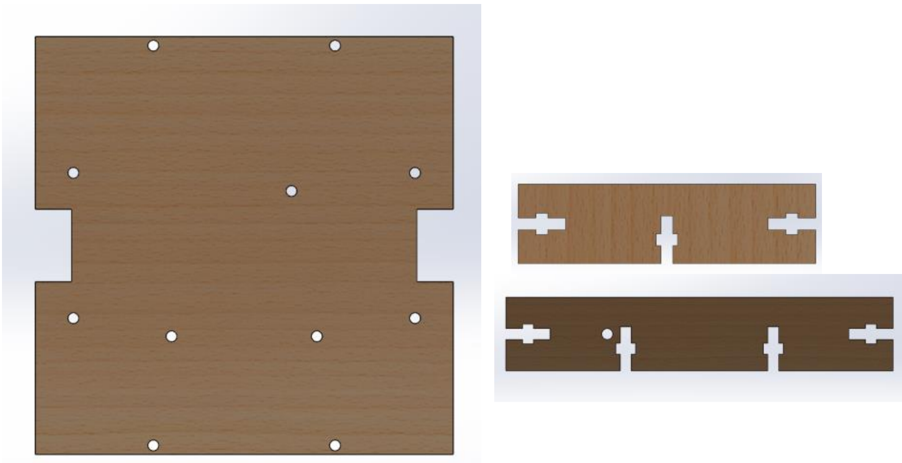


Figure 29: Wooden frame parts

After Cutting off the wooden frame the wooden parts will be assembled using bolts and nuts to form the wooden frame as the figure shows below.

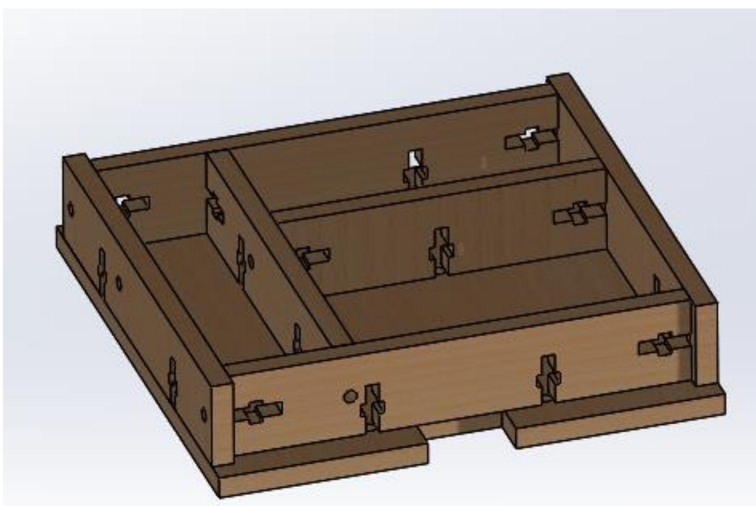


Figure 29: Wooden frame after assembly

7.2 Design Changes

The design went through some changes after the first semester which helped improving the design and achieving the goals of the design. The changes focused in having the best possible power from the motors by avoiding the use of gears and to control the heat inside the design.

7.2.1 Design change #1

Based on the calculations the team did about the gears, the team found out that some of the speed will be lost from the gears with a lot more space required to mount them properly. As a result, the team tried their best to find a relative solution to avoid using gears. This changed to plan to fix 2 motors on the robot: one motor on the rear left wheel and the other on the right front wheel and to leave the other 2 wheels idle, which gave the team a problem in fixing the idle wheels while maintaining the robot balance as in the design each wheel has to be fixed separately. The calculations are presented in Appendix C.

So to fix the idle wheel we had to manufacture some sort of support using wood and a ball bearing but it failed to maintain balance of the robot because we manufactured this support manually.

After many tries the team found a pillow block bearing that had fixed our problem by fixing the idle wheel directly of the bearing of the pillow block and fix the pillow block bearing on the frame of the robot, below is the pillow block bearing KP08.

Based on the calculations the team did about the gears, the team found out that some of the speed will be lost from the gears with a lot more space required to mount them properly. As a result, the team tried their best to find a relative solution to avoid using gears which lead to using a bearing.

Figure 30: KP08 Pillow block bearing

7.2.2 Design change #2

We had in our design that the body should be as low to ground as possible to avoid being flipped by any of the opponents and in the same time to maintain stability but we used wheel had about 65 mm diameter so in order to lower the frame to ground we had to lift the wheel a little up, in which we used some aluminum spacers which are shown in figure below to be put under the KP08 pillow block bearing and under the motor frame to lift them up in order to lower the frame to the ground.

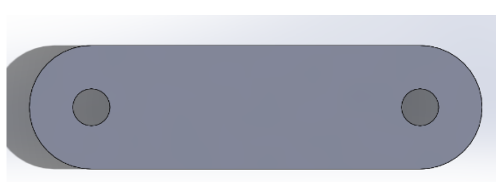


Figure 31: Aluminum spacers

7.2.3 Design change #3

In our first design we had a flat aluminum second floor to hold the control parts. However, considering the heat caused by the parts while operating the team decided to change the material to wood. In addition, each component will be separate with wooden walls to make sure the heat is controlled and does not cause any problems.

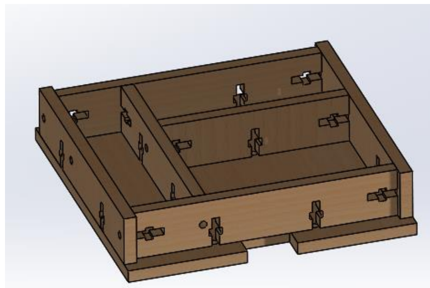


Figure 32: Wooden frame of the 2nd floor.

7.3 *Final Budget*

The estimated total cost of the project was actually lower than estimated in the first semester. It went down to $1226 from $1309.27. This was a result of changing some of the parts. The team was not able to salvage any parts from the old sumobots provided by the instructor. The following Table shows the total cost breakdown.

Table 7: Budget

Part	Quantity	Price
Li-po Battery	2	$137
Hc-05 Bluetooth module	2	$21
Arduino uno	2	$40
Breadboard	1	$3
Rubber Wheels	6	$35
Motors	2	$400
Battery Charger	1	$69
Monstershield Motor Driver	2	$86
Power Bank	1	$15
Bearings	4	$20
Manufacturing	-	$85
Screws and nuts	-	$10
Wires	-	$5
Laser Cutting	-	$20
Shipping	-	$270
Wooden board	1	$10
Total Cost		$1226

7.4 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 for both ME 476C and ME 486C.

7.5 Final Bill of Materials

The proposed Bill of materials was changed after changing the design because of unavailability of the parts and to fit the manufacturing processes and assembly processes of some parts. Below is the table of the components used in the final design.

Part No.	Part Name	Qty.	Description
1	Arduino UNO	1	Microcontroller
2	Battery	1	LIPO battery 1100 mAh
3	Motor	2	Motor 250 rpm and 8.8 kg/cm torque
4	Wheel	4	Rubber Wheel
5	Driver	1	Monster motor shield VNH2SP30
6	Bluetooth Module	1	HC05 Bluetooth Module
7	Aluminum Body	1	Metal Body
8	Power Bank	1	2000 mAh power bank
9	Block bearing	2	KP08 housing pillow block bearing
10	Wooden Frame	1	Controlling electronic parts on top of the device
11	Coupler	4	Connect the tires to the bearings and motors.
12	Motor fixation	2	Holds the motors in place.
13	Control Fixation	4	Holds the wooden frame in place.
14	Shaft	2	Shafts are connected from the bearing to the tires through the couplers.
15	Spacers	2	A spacer beneath each bearing to hold in place and to keep it high enough.

Table 10: Current Bill of Materials

Final Design exploded view:

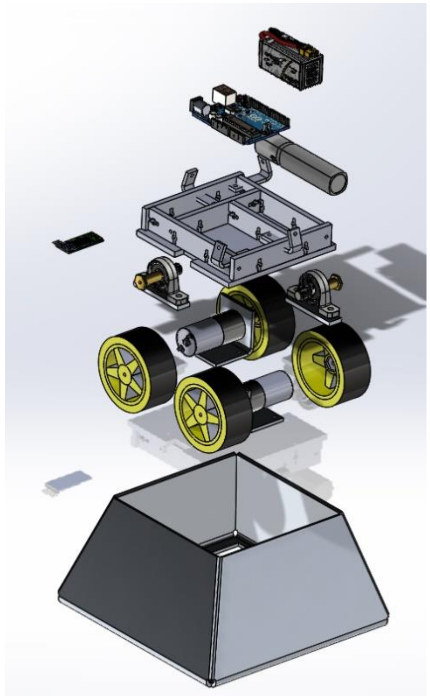


Figure 26: Final exploded CAD draft of SumoBot

8 TESTING

After the full design was manufactured the team went through a testing procedure to make sure all the engineering requirement went as intended. This will help the team to figure out any changes needed for the design to get the best possible final product.

Table 8: Testing procedure and results

Testing Procedure	Result
Assembly Time	~55mins
Tough Exterior Body	Strong and withstood impacts.
Dimensions	Length 20cm Width 20cm Height 15cm
Battery Life	10 mins and 15 seconds of full performance.
Weight	2.5kg
Remote Control	Fully remote controlled and easy to operate.
Pushing Capabilities	Had enough speed and torque to easily push old sumobots.

Safe to other SumoBots	Did not inflict any damages to other sumbots during testing.
Pausing Capabilities	Completely stops when needed.
Cost	$1226
Competitive	Great Maneuver abilities and effective from all sides.

1. Assembly time
During the manufacturing process the team had to disassemble and reassemble the design from scratch multiple times. Each time the team made sure to have a timer watch to check how long it takes to fully assemble the sumobot, and each time it takes around 55 minutes.
2. Tough Exterior Body
The team tested the sumobot against the old sumobots provided by the team instructor. The sumobot was able to withstand all the impacts during the testing without any deformations.
3.Dimensions
The length, width and height of the device were measured by using a measure tape in centimeters. The results of the SumoBot size was 20 cm x 20 cm x 15 cm.
4.Battery Life
The team managed to check how long the sumobot have the performance possible before starting to lose power gradually. The team found out it takes 10 mins and 15 seconds before the sumobot starts to lose full performance. This will help the team know when to change the batteries during the competition.
3. Cost efficient
The prices of all the components and services used in Robot building were summed up and they did not exceed the budget of $1500.
4. Weight
The weight of the device was determined, and it was 2.5kg which does not exceed the limit of 3kg.
5. Remote Control
After the team completed the codes, the team tested all the commands to check that everything worked as intended. Moreover, the team made sure that the sumo bot is easy to control and achieved 360° rotation.
6.Pushing Capabilities
By using the old sumobots provided by the instructor, the team were able to test out the pushing capabilities to make sure that the sumobot has enough torque and speed as intended. The test was successful as the sumobot managed to easily push the old sumobots.
7. Safe to Other Sumobots
During the pushing capabilities testing the team made sure to check if there was any damage inflicted to the old sumobots, for this is against the rules and regulations of the competition. Moreover, the sumobot did not flip the sumobots or damage the floor which are also in the rules.
8.Pausing Capabilities
Whenever the team stops sending commands the sumobot comes to an immediate stop while still connected to the remote control. This meets the requirement as having the ability of pausing and resuming since the judge can stop the match anytime needed and resume it.
9. Cost efficient
The prices of all the components and services used in Robot building were summed up and they did not exceed the budget of $1500. In fact, the team was able to be $274 below the budget as the cost was $1226.
10. Competitive

After achieving the 360° rotation, this helped to have great maneuver ability while having enough torque to push the opponent from the sides. Moreover, the design has great offensive and defensive abilities from all sides. These abilities give a lot of advantages in the competition.

9 CONCLUSIONS

In conclusion there were several factors that contributed to the success of the project and areas of development that needs to be looked at to enhance the success of the project. The contributors to the success of the project are the team strength which should be utilized to enhance the project performance while the areas of development are the opportunities that will be capitalized to enhance product's success and competitiveness. Some of the success factors that will be discussed in this report include, adherence to ground rules and coping strategies stipulated in the team charter, methodologies and practices applied as well as the product quality. On the other hand, the areas of development that will be discussed include time management, team challenges and organizational actions that will be employed to enhance the success of the project.

9.1 Contributors to Project Success

At the end of the semester the team finally achieved the purpose and goal stated in the team charter which is designing a 3Kg Remote controlled sumobot to compete in the sumobot competition and overcame the identified mistakes that were made by previous teams such as depending on the power in pushing the opponent without maneuvering, and having a cubic shape which has a lot of weak points. The team now has a 3Kg sumobot that has a unique design and remotely controlled by mobile phone application instead of the physical remote control and the sumobot that the team built is able to compete in the competition, but unfortunately the Robogame canceled the competition for this year. But the team is positive that if the competition was held this year the sumobot that the team built would be competitive. In addition, one of the most important contributors of the project success was the ground rules and coping strategies that was formulated by the group. The team followed and respected the rules to the latter these rules helped the group to resolve conflicts. One of the ground rules stated that the group meetings were held on Sundays at 5 pm this rule was followed and helped the group to be consistent in building the project, the group met more than once a week in order to work on the project, but the meeting on Sundays was mandatory to follow up with the work. The main rule that made everyone submit their work on time and prevented submitting the work otherwise there is a $100 fee for anyone who turn in his work late. This rule made everyone think about turn in their work early to avoid paying 100$. Another rule that was followed is solving conflictions by voting, since the group has 5 members it made it easier to vote for different ideas. Thankfully the team never experienced any tension between the team members. Furthermore, there were several aspects of project performance were positive. Started with time management the team was planning to be ahead of schedule just in case of anything goes wrong, and that was useful and helped a lot in building the sumobot on time. In addition another aspect of the project performance that was positive the project quality. Quality can be defined as the standard of an item as measured against other items (Stevenson, Hojati and Cao, 2007). Also quality refers to the degree of excellence of something (Stevenson, Hojati and Cao, 2007). The team designed their sumobot with high level of quality because they identified previous failures and worked on improving and solving them. The researches and brainstorming of the group members contributed in solving these failures and coming up with unique ideas that focuses on maneuvering and counter attack instead of focusing on the most powerful motor in the market to meet the engineering requirements of cost efficient and weight. The success of this project can be attributed to the tools used in the design phase, and the different team member's team member's skills. Solid works played a big role in the designing phase of the project. Since solid works gives the opportunity to easily edit on the design and makes the manufacturing process easier. Additionally to the solid works the team members were skilled differently, so every person in the group played an important role in contributing to the success of the device. One of the group members was responsible for group meeting and dividing the work equally, another team member is expert in Solid Works his abilities helped to improve the design and solve the design problems before even building the device by analyzing the design through solid works. The team hired one of the team as a financial advisor, his main role was to control the budget and make it cost effective. However, the team was very flexible on changing the tasks between themselves, so technically every member of the group was able to perform every task in the project. Team work was the main methodology that helped in designing a competitive sumobot, keeps the budget down and keeps the members of the group motivated and finished the building process on time.

9.2 Opportunities/areas for improvement

Despite all the positive aspects mentioned above the project had few negative aspects that the group faced, such as coding the group took long time and did many tests to improve their coding for the device, but that was expected since no one in the group have a basic knowledge for coding. Especially that the group wanted a 360 degrees rotational movement and that was not easy to code. The team did their best to overcome the problem with great determination. This issue was not avoidable since the group members assigned coding to two student only, but the team was flexible to help anytime with the coding. Finally the problem was solved and the team members were able to successfully code the device and the project was built on scheduled time. In addition the team planned to reuse some of the previous team's parts, but unfortunately this was waste of time because most of the parts were difficult to take off from the devices and some of them were not able to reuse due to permanent wear. Furthermore the previous devices has common cubic shape which made it more impossible to the group members to test different shapes of the devices to make their decision. Despite all of this the team was able to build a competitive device. Ensuring that the tasks are well divided between the team members, sometimes equal dividing is not effective but assigning each task to the quality strength of the team member will ensure that the task will be delivered with quality. Furthermore, collaborating and working as a team and sharing ideas and thoughts, as well as researching definitely will improve the performance of team. Moreover, scheduling ahead of time and monitoring the schedule planned is the key to success. The key for every successful team is respect and collaboration between team members. Far from the respect between the team members the team learned multiple skills during this project. None of the team members had any experience in manufacturing, coding or setting up electronic parts. But, with research and communicating with experts the team gained the skills to build the device properly. For example in manufacturing the team had the advantage to work in Kuwait during the winter break, which gave the team the opportunity to use machines that may not be available or hard to find in university machine shop such as laser cutting machine and hydraulic bending machine, these two machines are the main reason to achieve the unique design of pyramid. For coding and setting up the electronic parts the team never had a chance before to perform those kind of skills, but with research and practicing the team was able to success in those tasks.

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11 APPENDICES

11.1 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.

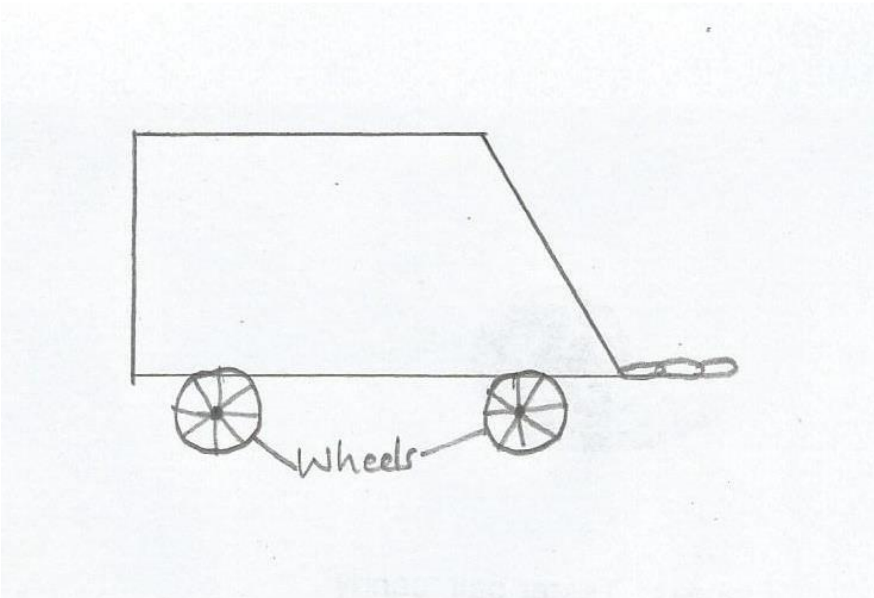


Figure 23: Trapezoid design

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 unflappable. 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.

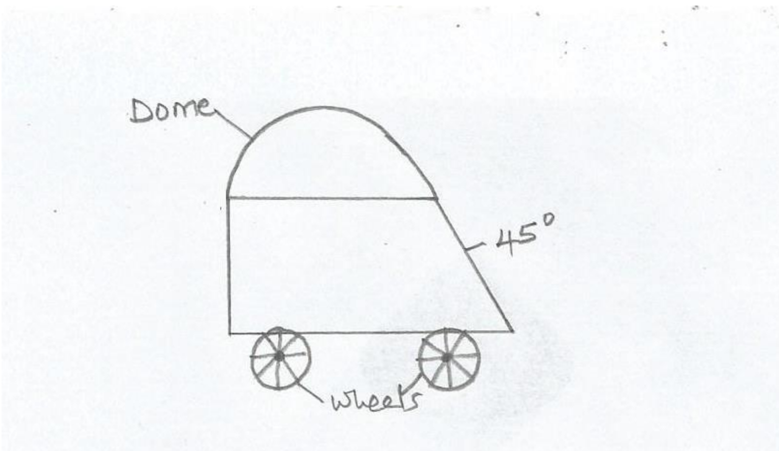


Figure 24: Dome design

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.

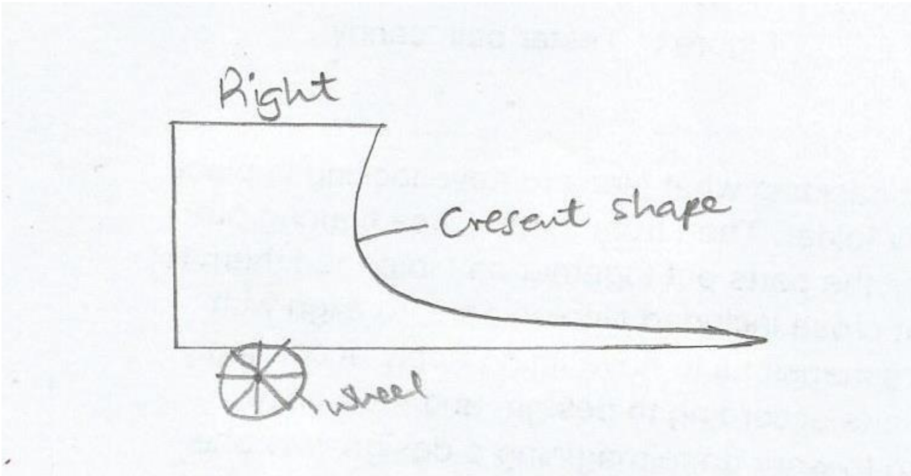


Figure 25: Crescent design

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.

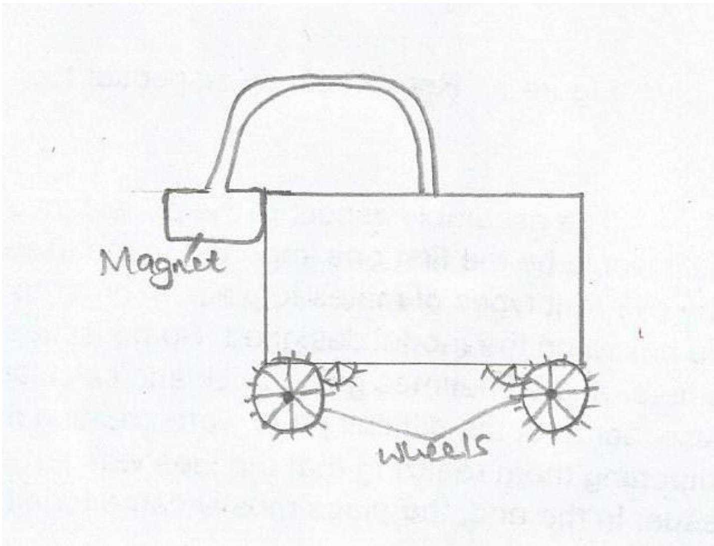


Figure 26: Cuboid design

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.

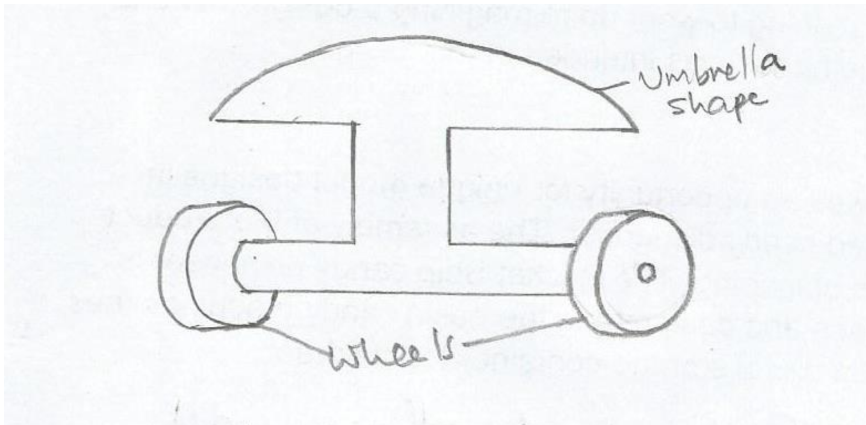


Figure 27: Umbrella design

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.

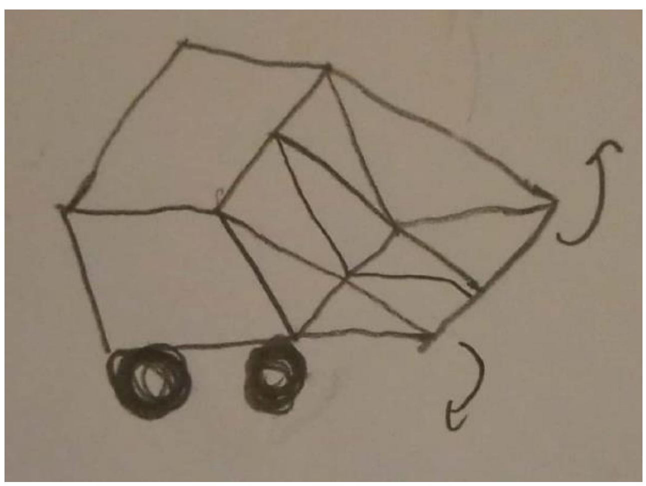


Figure 28: Scissors design

11.2 Appendix B: Gantt chart

Table 8: Gantt chart

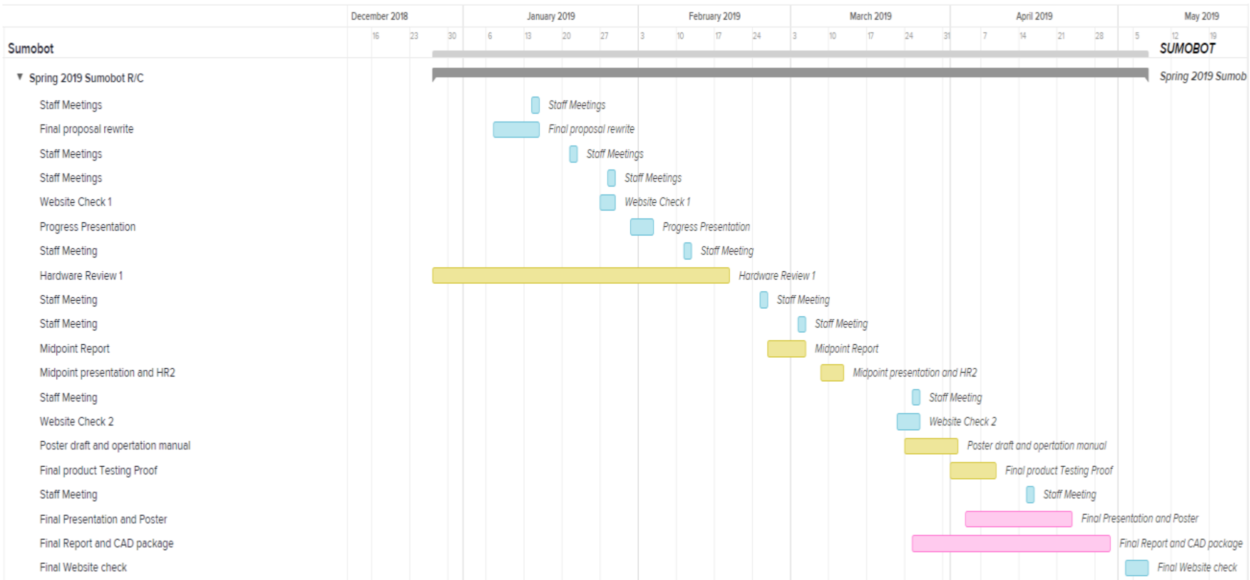
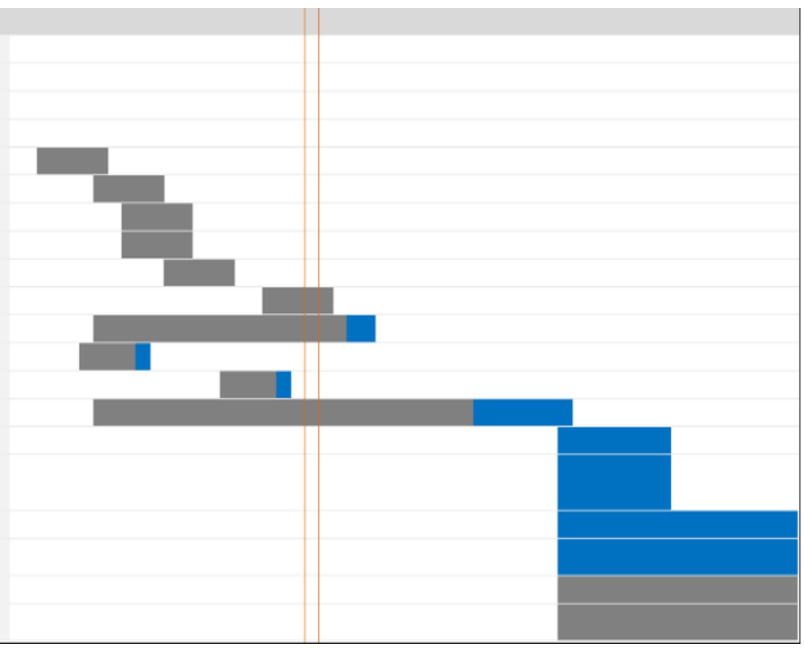


Table 9: 2nd -semester Gantt chart

1	[Task Category]						
1.1	Individual Post Mortem	[Name]	Sun 1/13/19	Thu 1/17/19	5	100%	4
1.2	Action Item week 4		Fri 2/01/19	Tue 2/05/19	5	100%	3
1.3	Website Check 1		Sat 2/09/19	Wed 2/13/19	5	100%	3
1.4	Action Item week 5		Fri 2/08/19	Tue 2/12/19	5	100%	3
1.5	Action Item week 6		Wed 2/20/19	Sun 2/24/19	5	100%	3
1.6	Hardware Review 1		Sun 2/24/19	Thu 2/28/19	5	100%	4
1.7	Peer Evaluation 1		Tue 2/26/19	Sat 3/02/19	5	100%	4
0.1	Action Item week 7		Tue 2/26/19	Sat 3/02/19	5	100%	4
0.2	Action Item week 8		Fri 3/01/19	Tue 3/05/19	5	100%	3
0.3	Midpoint Presentation		Fri 3/08/19	Tue 3/12/19	5	100%	3
0.4	Midpoint Report		Sun 2/24/19	Fri 3/15/19	20	90%	15
0.5	Peer Evaluation 2		Sat 2/23/19	Wed 2/27/19	5	90%	3
1.1	Action Item week 9		Tue 3/05/19	Sat 3/09/19	5	80%	4
1.2	Harddware Review 2		Sun 2/24/19	Fri 3/29/19	34	80%	25
1.3	Draft Poster		Fri 3/29/19	Fri 4/05/19	8	0%	6
1.4	Draft of operation manual and assembly manual		Fri 3/29/19	Fri 4/05/19	8	0%	6
2.1	Final Draft of Poster		Fri 3/29/19	Fri 4/19/19	22	0%	16
2.2	Final Operation and Assmebly Manual		Fri 3/29/19	Fri 4/26/19	29	0%	21
2.3	Final Report		Fri 3/29/19	Fri 5/03/19	36	60%	26
2.4	Final CAD package and BOM		Fri 3/29/19	Fri 5/03/19	36	100%	26



11.3 *Appendix C: Calculations*

11.3.1 Exterior Body Material Calculations

ASSUMPTIONS

Table 1: Variables used

Variable	Units	Value
Mass	Kilograms (kg)	3
Time	Seconds (s)	2
Acceleration a	(m/s^2)	0.05
Length L	Meters (m)	0.2
Width w	Meters (m)	0.2
Thickness b	Meters (m)	0.003
Impact Area A	(m^2)	0.002
Density ρ	(kg/m^3)	2700

The volume of the pyramid assuming a uniform sheet thickness of 3mm with an open top is given by:

$$v = \frac{lwh}{3} = \frac{l_1 w_1 h_1}{3} - \frac{l_2 w_2 h_2}{3} = \frac{0.2x0.2x0.1}{3} - \frac{0.194x0.194x0.097}{3} = 3.49x\ 10^{-4} m^3$$

Table 2: Masses of different frame materials of the same volume [14]

Material	Density kg/m^3	Mass kg
Mild steel	7850	2.74
Aluminum	2720	0.94
Brass	8470	2.96

A. *Impact Resistance*

$$E_k = \frac{1}{2} m v_0^2 = \frac{1}{2} x\ 3\ x\ 0.1^2 = 0.015J$$

Impact resistance is the amount of energy that the frame could absorb on impact without permanent deformation.

The amount of energy absorbed by the frame on impact (U) is a factor of the yield stress σ, Area A, thickness b, and elastic modulus E as given by [15]:

$$U = \frac{\sigma^2 A b}{2E} = \frac{(276\ x\ 10^6)^2\ x\ 0.002\ x\ 0.003}{2\ x\ 69\ x\ 10^9} = 3.312\ J$$

Since the impact energy is much higher than the kinetic energy on impact, the design would be able to withstand the impact.

B. *Yield Strength*

The force imparted on the sumobot when the opponent robot moving at an initial velocity v_0 collides with it is given by:

$$F = ma = 3\ x\ 0.05 = 0.15N$$

The normal stress of the material after collision due to a force F on impact cross sectional area A is given by:

$$Stress, \sigma = \frac{F}{A} = \frac{0.15}{0.002} = 75\ N/m^2$$

The normal strain of the material after collision measures the deformation of the frame due to impact.

$$F = \sigma A = 240\ x\ 10^6 \frac{N}{m^2} x\ 0.002\ m^2 = 480{,}000N$$

The safety factor is the ratio between the frame ultimate strength and the force applied to the body.

$$Safety\ factor = \frac{480\ x\ 10^6}{75} = 6.4\ x\ 10^6$$

RESULTS

The frame of the robot meets the specifications required for the competition including the weight and safety. The structure is sturdy enough to withstand impact on collisions and offers high maneuverability. The opponent robot of 3kg with an acceleration of 0.05m/s^2 imparts a stress of 75 Pa. Since the yield strength of aluminum is 276 MPa [15], this design is safe from yield due to impacts in the competition. This makes the robot efficient in competing and winning against other sumobots of the same class.

11.3.2 Gears Calculations

The team have used a motor with 8.8 kg.cm torque which will produce a force and speed of:

$$Torque = force * radius$$
$$8.8Kg.cm = force * 2.7\ cm$$
$$force = \frac{8.8\ Kg.cm}{2.7cm}$$
$$force = 3.25\ Kg$$
$$Linear\ speed = Motor\ rpm * circumference\ of\ the\ wheel$$
$$Speed = 250 * (2 * \pi * 2.7)$$
$$Speed = 4242\ cm/\min = 70.6\ cm/s = 0.706\ m/s$$

If gears were used with our motor we would have two options for our gears:

1. Gears have a 1:1 ratio which would only transmit the torque and speed as they are from the motor to the wheels
2. Gears with a 2:1 ratio as the gears on the wheels would be limited to 30 mm diameter due to wheel shaft height from the base which cannot be increased.

In case of 1:1 gear ratios:

$$\frac{D1}{D2} = \frac{T1}{T2} = \frac{N2}{N1} = 1$$
$$\frac{30}{30} = \frac{8.8}{8.8} = \frac{250}{250} = 1$$

But we must consider the gears efficiency in our calculations, so we can assume a 10% gears efficiency which would result in about (0.9*8.8=7.9 kg.cm) which will lower our torque which is a disadvantage for our robot in the competition.

In case of 2:1 gear ratios:

$$\frac{D1}{D2} = \frac{T1}{T2} = \frac{N2}{N1} = 1$$
$$\frac{60}{30} = \frac{17.6}{8.8} = \frac{125}{250} = 2$$
$$Linear\ speed = gears\ rpm * circumference\ of\ the\ wheel$$
$$Speed = 125 * (2 * \pi * 2.7)$$
$$Speed = 2121\ cm/\min = 35.3\ cm/s = 0.353\ m/s$$

But we must consider the gears efficiency in our calculations, so we can assume a 10% gears efficiency which would result in about (0.9*17.6=15.8 kg.cm), this will give us a significant advantage with the increase of torque but it lowered the speed to the half, and the speed is an important thing.