ASME Soccer Robot- Group V

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Executive Summary

Our senior design project was centered around this year's ASME design challenge, where the theme was robot soccer. The guidelines stated that the robot must be user-controlled, fit in a (50cm)^3 box and, as long as everything fit within the box, you could have multiple robots. Our final design was quite simple, comprising of a base plate, two DC motor-powered wheels, an unpowered support wheel, and two brackets that hold a rectangular plate that spins. We controlled the robot using an Arduino microcontroller, L293D motor driver, and an HC-06 Bluetooth module to give commands to the robot remotely using a phone app. Our kicking function was inspired by the game of foosball, where the kicking plate spun continuously at a constant RPM to smack the ball, which resulted in a consistent kicking ability that could make up to 90% of its shots on an open goal from 10 feet away. We wanted our robot to be able to play defense and offense against other robots competitively and thus we designed it to be able to rapidly change direction and move at roughly average walking speed. Throughout the semester we ran into two major problems, building a functioning circuit and crafting an app to control our robot through the Bluetooth module. We fried multiple circuit elements and even lost a laptop while testing the circuit's functionality with the app. But even with these incidents, we were able to successfully build a robot that achieved all of our performance goals while meeting the ASME requirements.

MEMS 411: Senior Design Project

Project Name

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION AND BACKGROUND INFORMATION

1.1 INITIAL PROJECT DESCRIPTION

The project that we have selected for our senior design is the topic of the 2018 ASME student design competition, robot football. Our proposed project will follow guidelines and restrictions provided by ASME while using our creativity and engineering knowledge to build robot(s) that could be mechanically controlled to interact with a tennis ball. The customers of this product will be us, and its function should be to perform well in a 4 way soccer match against 3 other teams' robot(s).

1.2 EXISTING PRODUCTS

2017 UBTECH Alpha 2 Intelligent Humanoid Robot[1]

A humanoid robot that can do a variety of things, one of which is play soccer. The price tag attached with this product is quite heavy. Although the main function of this robot seems to fit in more to the 'pet' category than soccer robot. It is programmed using a Samsung Exynos 5260 six core processor. This robot is supposed to have built in AI. In conclusion, the scope of this product is too high in comparison to what we want to achieve.

Fig. 1 Existing product 1

Roomba[2]

This product is available on the market is the famous Roomba vacuum cleaner. Although its function is not to play soccer, its can be altered to do so very easily. The current Roombas on the market function on its own, they are programmed to turn when approach walls. The preference for our robot would be to have them be controlled via a controller of some sort.

Fig. 2 Existing Product 2

[1] https://www.lightinthebox.com/ko/domestic-personal-robots-walking-sound-control-digital-bluetooth-aluminium-alloy-abs_p6119704.html?currency=USD&litb_from=bing_shopping&utm_source=bingshopping&utm_medium=cpc&utm_campaign=bingshopping

[2] http://store.irobot.com/default/robot-vacuum-roomba/?utm_medium=cpc&utm_source=bing_us&utm_campaign=&utm_term=roomba&utm_content=c41mSyRf|pcrid|84112645085219|pkw|roomba|pmt|be|pdv|c|

CMDragons - SSL soccer robot[3]

Fig. 3 Existing product 3

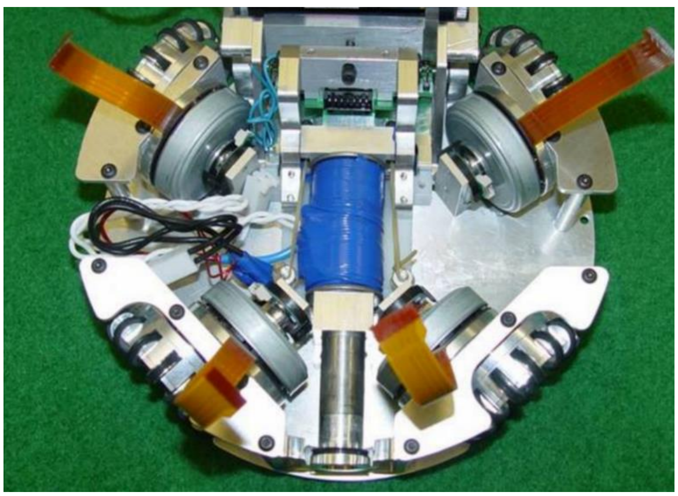


Fig. 4 Existing product 4

This robot is designed for the Robocup Small Size League robot soccer game. It is omnidirectional with 4 wheels, which is ideal type for active games. The CMDragons robot also has rubber-coated dribbling bar which is able to kicking function, chip-kicking device as well. Its mainboard is ARM7 core running at 58MHz linked to a Xilinx Spartan2 FPGA. This robot looks simple. However, it needs a server to get the visual information of a field, and cameras and software to scan the field. Moreover, this robot should move by itself without any remote controller.

[3] http://www.cs.cmu.edu/~robosoccer/small/#Hardware

iNOVA MICROSYSTEMS –iSoccerBot[4]

Fig. 5 Existing product 5

This robot is designed for FIRA RoboWorld Cup in MROSOT category. For the soccer game, just like SSL soccer robot, it needs a camera, a computer to give an order with a software, a transmitter to transmit the signals from the computer. This two wheeled machine has a high-speed motor with gyroscope electronic stability control system. Also, it's programmed by Borland C++.

OSU Swarm Soccer Robotics – Soccer Robot[5]

Fig. 6 Existing product 6

This robot is autonomous. Those parts were designed by the SolidWorks and programmed by C++. It doesn't have kicking function, but have a sound-activated sensor. The wheels of this are large enough not to require a gyroscope sensor to give stability. Dimensions are 7.5cm x 7.5cm x 7.5, and the weight is 650g.

[4] http://www.inovamicro.com/isoccerbot.html
[5] https://sites.google.com/site/swarmfirebots/

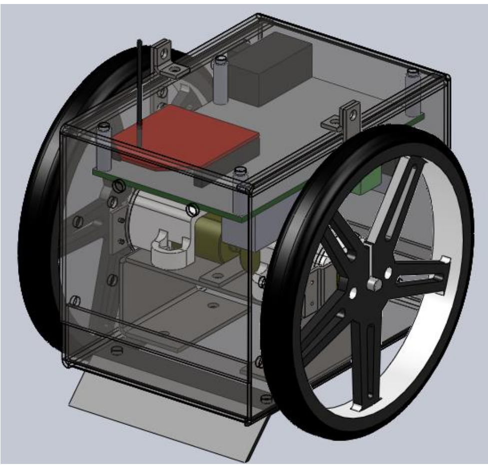


Fig. 7 Existing product 7

The design of this robot Is really similar to t the original idea, but we still need to downscale it because of the programming problem which could be hard to solve by ourselves.

1.3 RELEVANT PATENTS

1) **Soccer and fighting robot, and driving and operating device of the robot Patent (US 7463001 B2)[6]**

Fig. 1

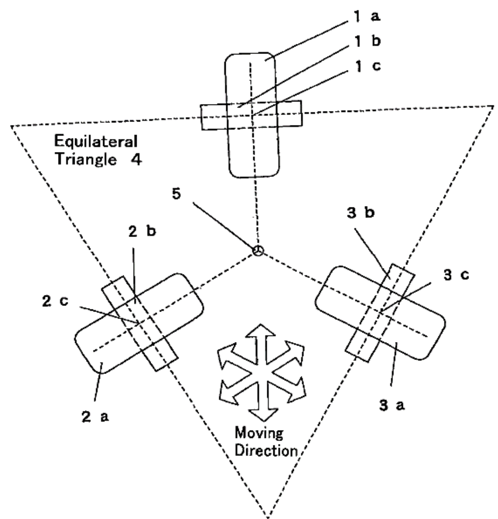


Fig. 8 Relevant Patent 1

Fig. 2

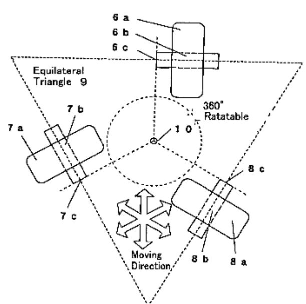


Fig. 3

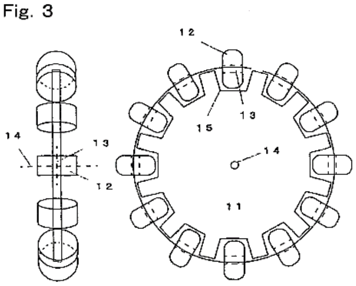


Fig. 9 Relevant patent 1

[6] https://www.google.com/patents/US7463001?dq=soccer+robot&hl=en&sa=X&ved=0ahUKEwjSm4eVkp7WAhWUwYMKHQy0DecQ6AEINDAB

Figure 7. Relevant Patent 1

This patent is an invented by Fumiaki Tsurukawa is a robot meant to play soccer and fight. It has a triangular body, and a drive wheel on each side of the triangle. The triangle body design was chosen so that the robot could move laterally. This robot is controlled by a six directional joystick.

2) Modular robotic teaching tool (US 6877574 B2)[7]

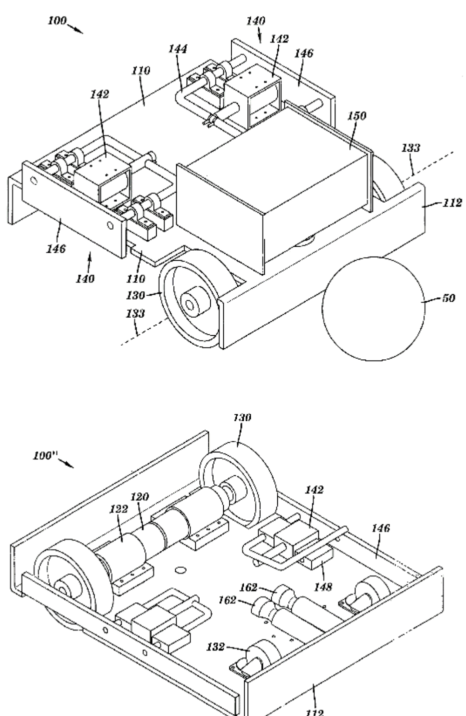


FIG. 6

The second patent is a modular robotic teaching kit filed in 2002 by MIT. This was a modular kit intended to be used for educational purposes; mainly to introduce students to mechanical engineering and robotics. The parts included are a body, motors and wheels. The robot could be configured to play robotic soccer.

Fig. 10 Relevant patent 2

7 https://www.google.com/patents/US6877574?dq=robotics+soccer&hl=en&sa=X&ved=0ahUKEwipq8zBpp7WAhWj4IMKHa6BBcMQ6wEIcjAI

3) Omni-directional toy vehicle (US7293790B2)[8]

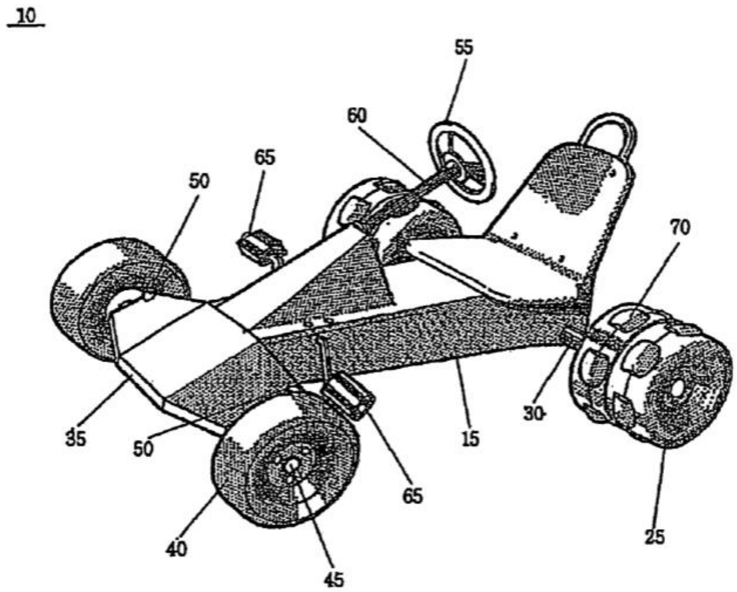


Fig. 11 Relevant patent 3

This patent is about the vehicle has more than 3 omnidirectional wheels, so it can be driven without any additional steering element. This patent could give me an idea to make an omnidirectional wheel for the soccer robot.

[8] http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=7293790.PN.&OS=PN/7293790&RS=PN/7293790

4) Driving component, robot and robot system (US 9682479 B2)[9]

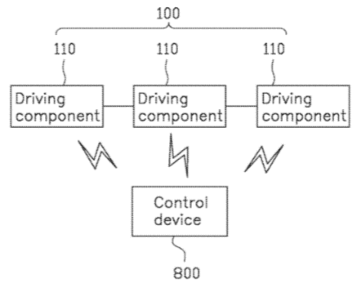


Fig. 12 Relevant patent 4

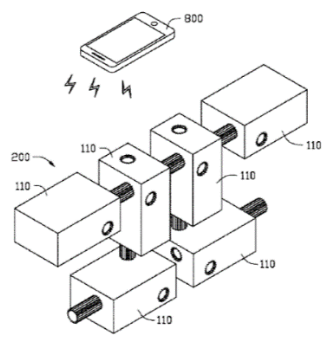


Fig. 13 Relevant patent 4

This has diffent kinds of components, such as communicating module, a motor, a sensor, and battery, etc. we can add or remove the components to fit the situation. This could help us to make our robot have flexibility in function.

[9] http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=46&f=G&l=50&co1=AND&d=PTXT&s1=arduino&OS=arduino&RS=arduino

1.4 CODES & STANDARDS

We incorporated a standard for kid toy hazards in our 'Target Specifications' because we determined our customer base to be students from elementary to middle school. The specific standard is ASTM F 963-16. This standard requires comprehensive testing on the product in order to ensure safety for customer use; these requires cover a wide range of areas including: use of heavy elements, labeling of small objects and parts, a test for sharp edges and points, wires, and electrical circuits. This is extremely applicable to our project should we choose to refine it for industry.

1.5 PROJECT SCOPE

Project Scope

1. Overview: The purpose of this project is to design and build a robot that can play soccer. Specifically, it needs to be remote controlled and should be able to shoot the ball at various speeds and directions.
2. Any kids age 8 and above, who are interested in robotic toys as well as soccer. Users don't necessarily have to be fans of the sport, they may just want a cool toy that shoots balls on command. Parents of kids will also be customers as this robot could make a great present.
3. Customers will benefit from the fun and joy provided by the robot as it will essentially be a toy for people to play with.
4. The soccer robot we build should be able to shoot a small soccer ball (tennis ball sized) accurately and on command, where shot velocity and distance are measurable parameters we will track and optimize. The robot will have to be maneuverable and thus its speed and ability to change direction will also be tracked. The robot should be able to move forwards, backwards, and turn. Lastly, the robot should be able to score on an open net.
5. Our project will follow the ASME competition guidelines, where the robot must be able to kick a ball using remote controlled commands. The robot should also be able to score an uncontested goal and be battery powered for portability.

6. This project will have to be relatively simple due to time and resource constraints. Due to cost concerns, our robot will have a more basic design with limited functionality, where our robot won't be able to play in the competitive robot soccer match. Also, instead of producing multiple robots we will focus on developing one working model that we could later attempt to replicate for competition.
7. For the project to be successful we should achieve the following points:
    a. Score a goal with the robot
    b. Ensure the robot consistently responds to controller input
    c. Stay within the allowed budget
    d. Produce an easy to use (user interface) robot
    e. Stay on schedule as outlined in a Gantt chart
8. We are assuming the parts are readily available. If, these assumptions are wrong, then the project will become more intensive as we'll have to machine our own parts for the project. This could put us behind schedule and over budget.'
9. The major project constraints are the allowed budget, availability of facilities like the machine shop, and scheduling since all of us are busy students and will struggle to find a time at which we're all available.
10. The main project deliverables will be that the robot acts as commanded and scores an uncontested goal.

1.6 PROJECT PLANNING

Group V Robotic Soccer

	ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION
1	**Body design**	1	1		
1.1	Sizing				
1.2	Material	1	1		
1.2	Shape	1	1		
2	**Wheels**	2	1		
2.1	Arrangement	2	1		
2.2	Number of Wheels	2	1		
3	**Motors**	3	1		
3.1	Type of motor	3	1		
3.2	Power	3	1		
4	**Kicking function- design**	4	2		
4.1	Lever arm	4	2		
4.2	motors	4	2		
5	**Kicking function-Shot variability**	5	1		
5.1	Angle of attack	5	1		
5.2	Power	5	1		
6	**Remote control-Connectivitiy**	6	1		
6.1	Range	6	1		
6.2	Response	6	1		
7	**Remote control-ease of use**	7	1		
7.1	layout	7	1		
7.2	platform(physical controler, app on iphone)	7	1		
8	**Remote control-functionality**	8	1		
8.1	Turning command	8	1		
8.2	Translation command	8	1		
8.3	Kicking command	8	1		
	Prototype Demo	9	0		
	Report	3	9		

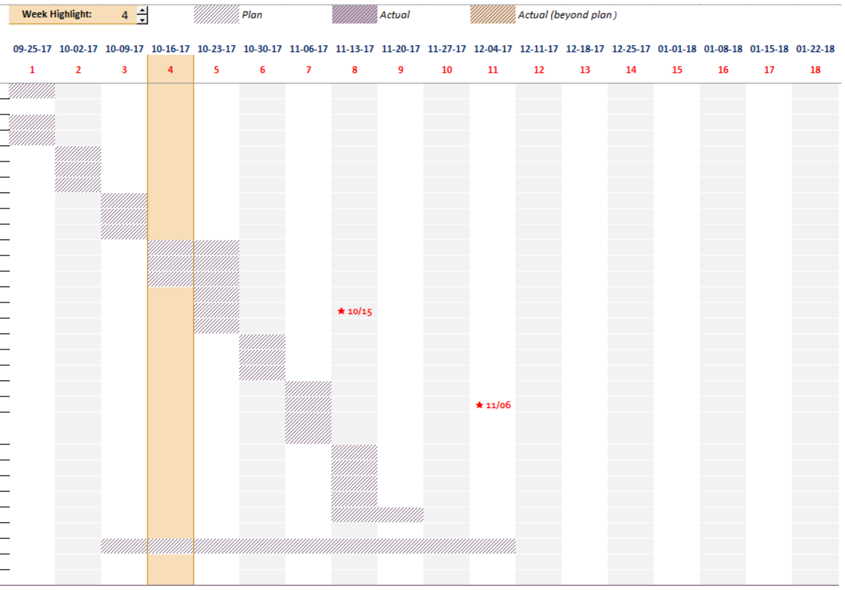


Table I. Gantt Chart for Project Planning

1.7 REALISTIC CONSTRAINTS

1.7.1 Functional

The current design of the soccer robot follows the 2018 ASME competition guidelines and have several restrictions including: size, cost, and time. The size constraint is limited to the requirement of the competition to have the robot fit within a 50cm cubic box. In terms of geometry, we are restricted to utilizing simple shapes such as cubes or spheres; this is mostly due to the time we have to build the robot and a more complex shape would require more time to implement. Furthermore, the main concern of the project is not its aesthetics, so we decided to just stick with simple geometry. Another section of constraint worth mentioning is those that pertain to the kicking function. While it is ideal to implement variation in shot velocity, angle and depth, it would require more components and a more sophisticated design; which are limited by our budget and time. In an ideal situation, implementing additional features to the kicking function should require additional motors, circuit elements, and thorough analysis and calculations.

1.7.2 Safety

The safety constraints related to our project could either be mitigated through careful planning. For example, many of the parts we ordered require further machining to obtain the desired dimensions. During this process, it is inevitable that sharp and unclean edges will present themselves. However, we plan to take precaution to file unclean sides, drill holes and sand down the sharp edges to create filets. In terms of customer usage, the standard for kid safety toy we have cited should cover the necessary warnings, labels and testing to make the product safe.

1.7.3 Quality

The quality constraints divide into three categories: quality assurance, quality control and reliability. In terms of quality assurance, the product will follow and comply with standard ASTM F 963-16. On quality control, we expect the usual inspection, testing and labeling procedures; there is no immediate concern that leads to constraint. Reliability is the section where we would see most of the constraints rise. For example, the designed life of the SR as of now is not expected to last very long. This is mainly due to the lack of failure testing and statistics. However, the function of the robot is to play soccer with other robots, which would require the SR to encounter infrequent collisions. During our design, we did not factor in durability and this could inversely impact our SR's reliability in the long run.

1.7.4 Manufacturing

There are not many constraints pertaining to manufacturing of the SR. The mechanical parts could be purchased on McMaster-Carr and there are detailed CAD drawings on how to machine. We do not anticipate a lot of waste in our production. Assembly of components include using nuts and bolts to fit the individual pieces together.

1.7.5 Timing

In the scope of the senior design timeline, our time constraint will most likely involve building the circuit and getting the Bluetooth controller to work. It will be a first for all of us working on a project requiring this magnitude of circuit building and coding; we estimate that this will take a long time since we have to learn as we build. In the scope of turning the SR into a customer product, we expect rather smooth production schedule since we have documented our building process in detailed CAD drawings. A bulk of the time constraint will come from design detailing to perfect the product in performance and aesthetics and compliance testing.

1.7.6 Economic

We incur no economic constraints building the SR for the purpose of senior design. However, if we expand that scope into production, a few constraints are worth noting. Firstly, we would have to estimate minimal initial funding; costs associated with marketing and design would be a luxury. The important costs such as manufacturing and distribution should be covered first. In initial stages, we could manufacture from WashU's machine shop which could help with cutting costs.

1.7.7 Ergonomic

Possible ergonomic constraints can arise in the controller. We plan to build an app that could remotely control the SR through Bluetooth on the android platform. Therefore, customers who do not have an android phone will be unable to control the SR until an IOS version is built. Furthermore, we currently have no on/off switch integrated into our design. To turn on the robot with the design we have, one would simply complete the circuit; however, this could be a source of confusion for people who have no experience with circuits, and it also makes for an unrefined product.

1.7.8 Ecological

The SR is constructed from 6061 aluminum, which makes up the base plate and kicking system and the housing is made from cardboard. These materials do not pose harm to the environment and could even contribute to sustainability if we use recycled cardboard. The SR is powered by 9V batteries, and with the motors drawing in a lot of power, they do not last a very long time. The ecological constraint in this case would be the use of 9 V batteries, and finding ways to safely dispose of them.

1.7.9 Aesthetic

The SR was designed with completing the senior design project in mind, therefore, not too many aesthetical values were put into consideration during the design process. In the current state, the SR has very little customer appeal as it is very simple and has an unrefined and raw appearance. Future expectations include a completely revamped appearance. This includes a completely new housing for the SR, a paint job a more complex body shape.

1.7.10 Life Cycle

This constraint is very out of scope and we have not thought too much about it. This definitely does not apply in the scope of senior design. The immediate concern seems to deal with disposal, because the SR contains many electrical parts as well as aluminum 6061, it can't simply be recycled; perhaps an instruction book on disassembly of the SR would have to come with the product.

1.7.11 Legal

We are following the cited standard for kid's toy when building the SR. In terms of ethics, our SR should be in the clear as long as we are meticulous in taking care of sharp edges and unclean drill holes. In terms of intellectual property, this is an original design we have come up with from scratch so that should steer us away from patents, trademarks and copyrights.

1.8 REVISED PROJECT DESCRIPTION

Our senior design project will follow the theme, guidelines and restrictions of the 2018 ASME student design competition. The theme for this year is robotic soccer. We plan to build a robot from mechanical and electronical parts to satisfy the function of kicking and defending a tennis ball. The robot will be remote controlled using a tether, or other secure methods, and not self-directed. The final product will not be as extensive nor complicated as a humanoid robot, but will be optimized in terms of shape and proportions to be a top contender in the ASME competition.

2 CUSTOMER NEEDS & PRODUCT SPECIFICATIONS

2.1 CUSTOMER INTERVIEWS

Customer Data: ASME soccer robot (SR)
Customer: Lyndon Zhao, Chan-hwi Cho, Gonzalo Berluzconi (Group V)

Address: Washington University in St. Louis
Date: 18 September 2017

Question	Customer Statement	Interpreted Need	Importance
What is the optimal size of the robot?	The robot, along with any external tools (controllers, batteries, repair kits) would need to fit inside a $(50\text{cm})^3$ box.	The SR is small	4
What would be the optimal method to control your robot?	The robot should not be autonomous, but have some sort of mechanical controller or smartphone application controller	The SR is remotely controlled	5
How many dimensions does the robot need to move in?	Robot needs to move in a x-y coordinate system.	-SR can move forward -SR can move backwards -SR can turn/rotate	5 4

Are there any safety considerations?	Robot should be safe for everyone, especially kids to use	SR follows kid toy safety standards (ASTM F 963-16)[10]	5
What material considerations do you have?	It has to be lightweight and durable, but not too expensive	SR made from light and durable material	3
Are there any other functions you would like on the robot?	The robot should be able to vary shot types	SR can vary shot velocity SR can vary angle	2 1

Table II. Customer Interview

2.2 INTERPRETED CUSTOMER NEEDS

Need Number	Need	Importance
1	Robot is smaller than $(30cm)^3$	4
2	Robot could be remotely controlled	5
3	Robot moves forwards and backwards	5
4	Robot could rotate	4
5	Robot follow safety guidelines	5
6	Robot is made of mostly plastics/polymers	3
7	Robot has varying shot velocity	2
8	Robt has varying azimuthal shot angle	1

Table III. Interpreted Needs

2.3 TARGET SPECIFICATIONS

Metric Number	Associated Needs	Metric	Units	Acceptable	Ideal
1	1	Length	cm	<40	<30
2	1	Width	cm	<40	<30
3	1	Height	cm	<40	<30
4	6	Total weight	kg	<8	<5
5	7	Shot velocity	m/s	>5	>12

[10] https://www.cpsc.gov/Business--Manufacturing/Business-Education/Toy-Safety

6	8	Angle range	degrees	>0º	>30º
7	4	Rotation range	degrees	>0º	>180º
8	5	Required labeling	yes/no	yes	yes
9	5	Safety testing by third party	yes/no	yes	yes

Table IV. Target Specifications

3 CONCEPT GENERATION

3.1 FUNCTIONAL DECOMPOSITION

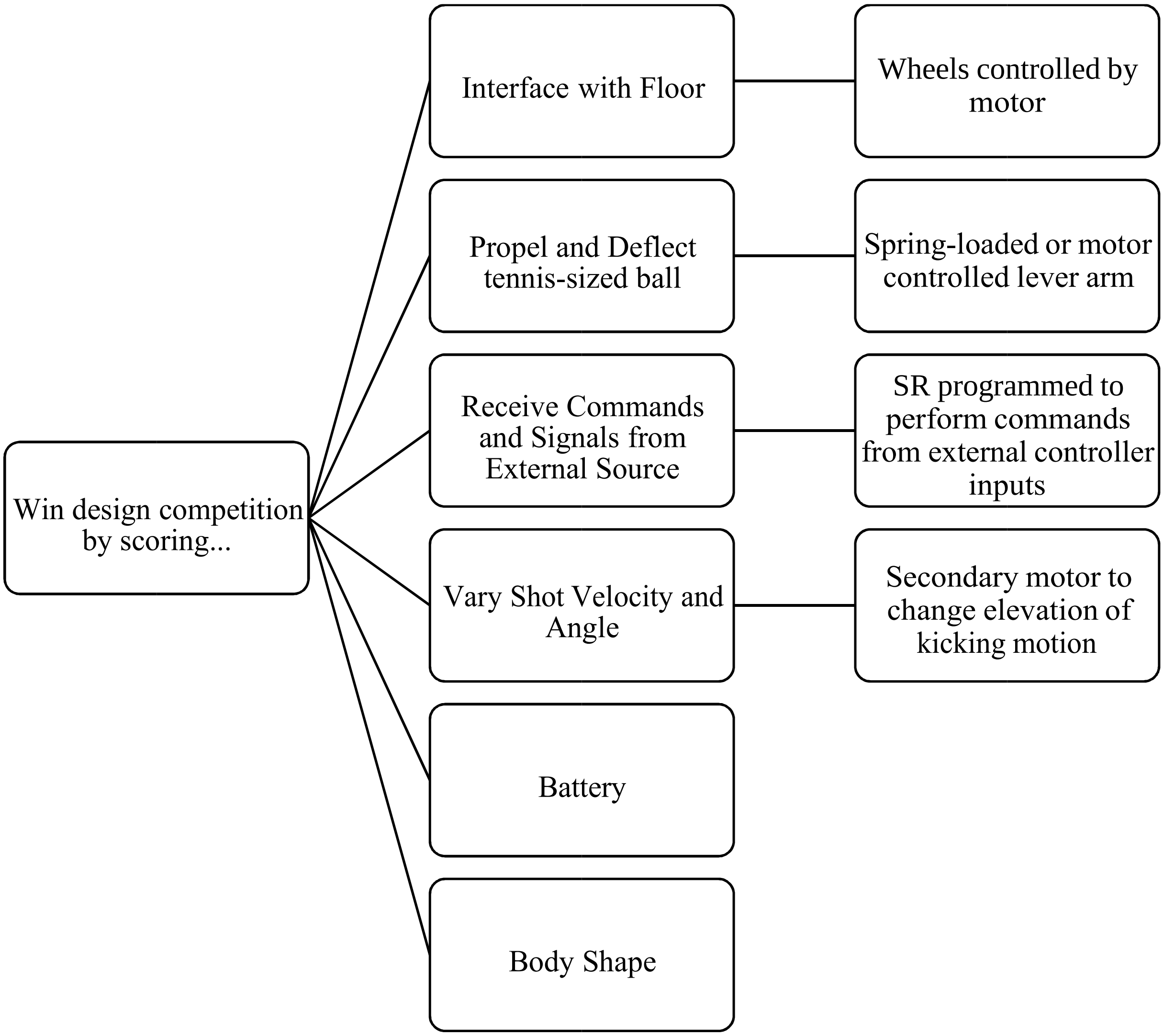


Fig. 14 Function Tree

3.2 MORPHOLOGICAL CHART

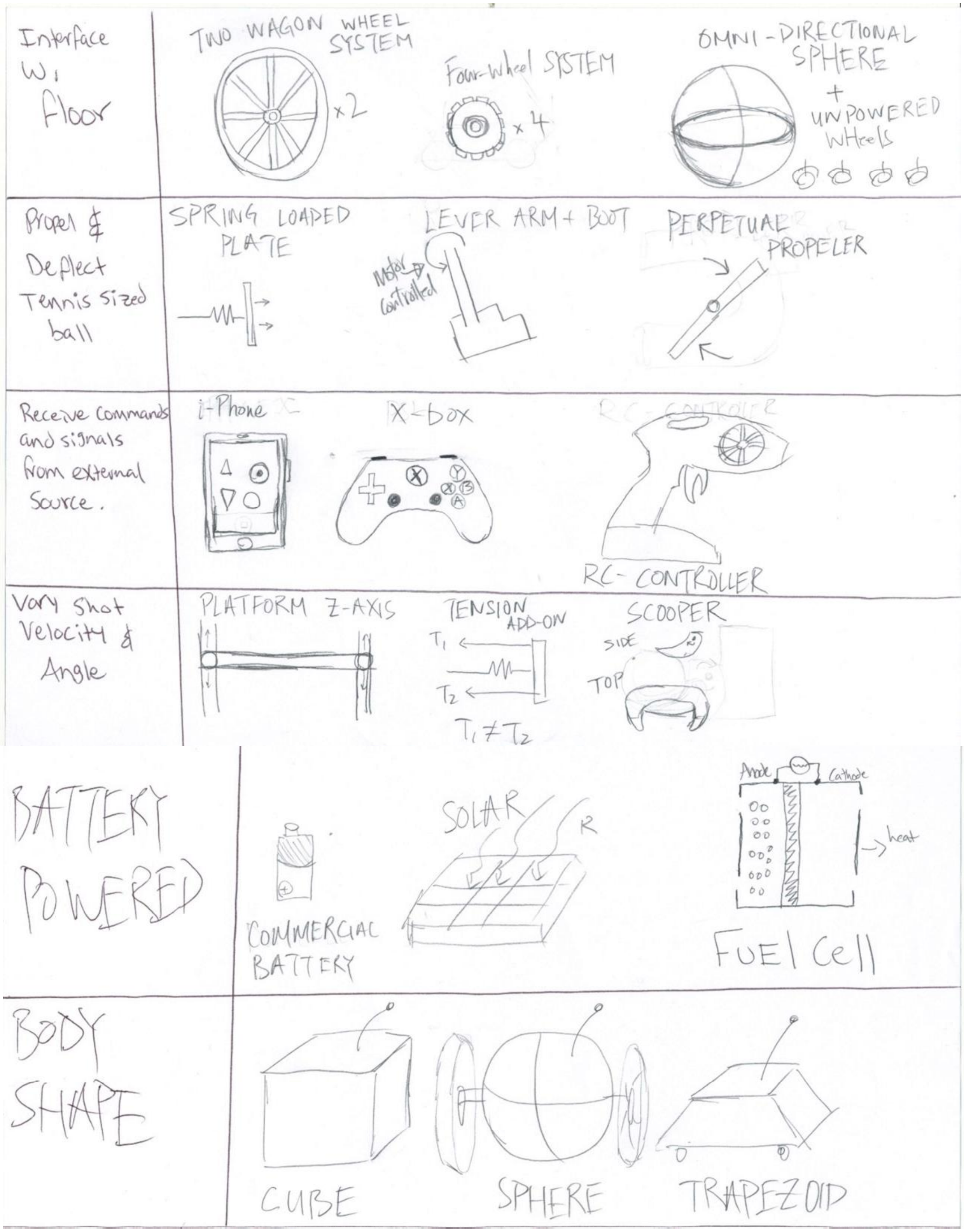


Fig. 15 Morphological Chart

3.3 CONCEPT #1 – "SOMETHING FROM STAR WARS"

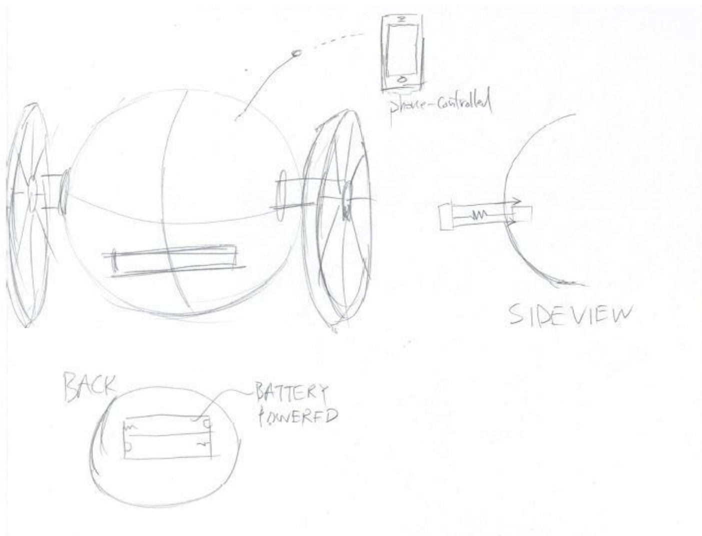


Fig. 16 Concept 1

Description: A spherical body with a two wagon wheel system. This robot will be powered by commercially available batteries and controlled via an i-phone app. The kicking function consists of a spring loaded plate with tension add-ons to vary the angle of kicking.

Components: Spherical body, two wagon wheel, spring loaded plate, tension add-ons, commercial battery

Downsides: BALANCE.

3.4 CONCEPT #2 – "THE BARBEQUE GRILL"

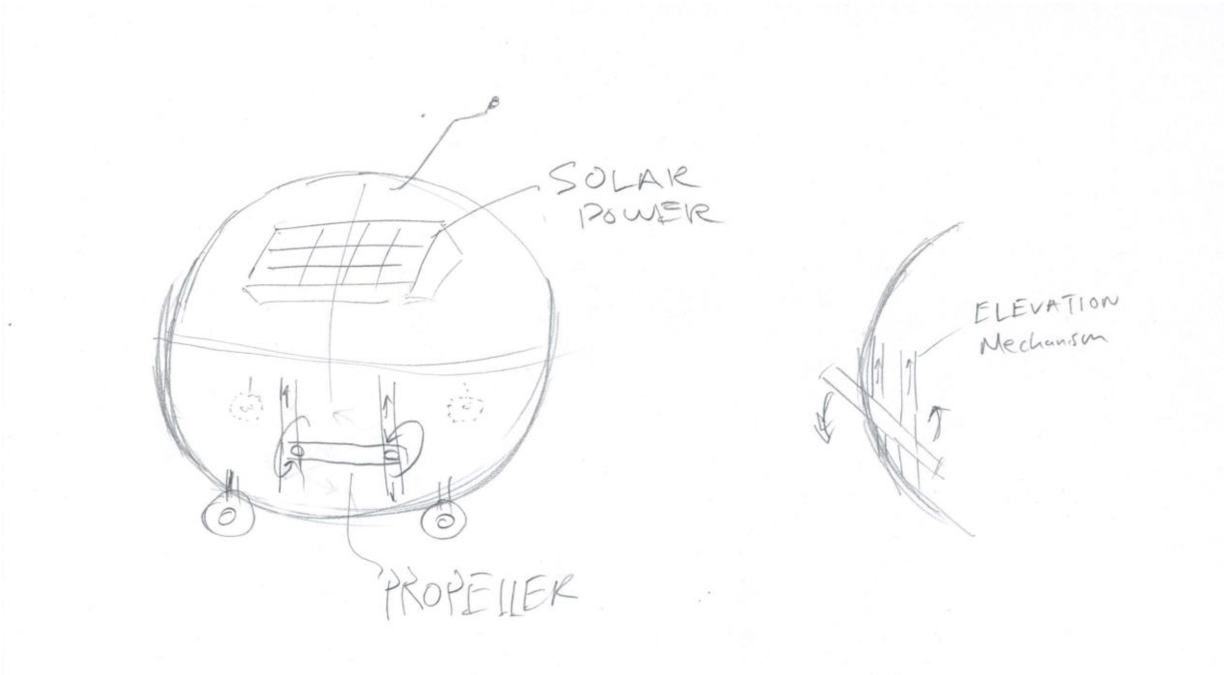


Fig. 17 Concept 2

Description: A spherical body with four wheel drive. The Grill will be solar powered. The kicking function consists of a propeller with the platform Z-axis for elevation.

Components: Spherical body, solar powered battery, propeller, four wheel system, z-axis platform

Downsides: Looks like a barbeque grill. Solar cell is difficult to work with and requires prior charging using THE SUN.

Upside: Can grill meat if hungry during competition.

3.5 CONCEPT #3 – "TORNADO OF DEATH"

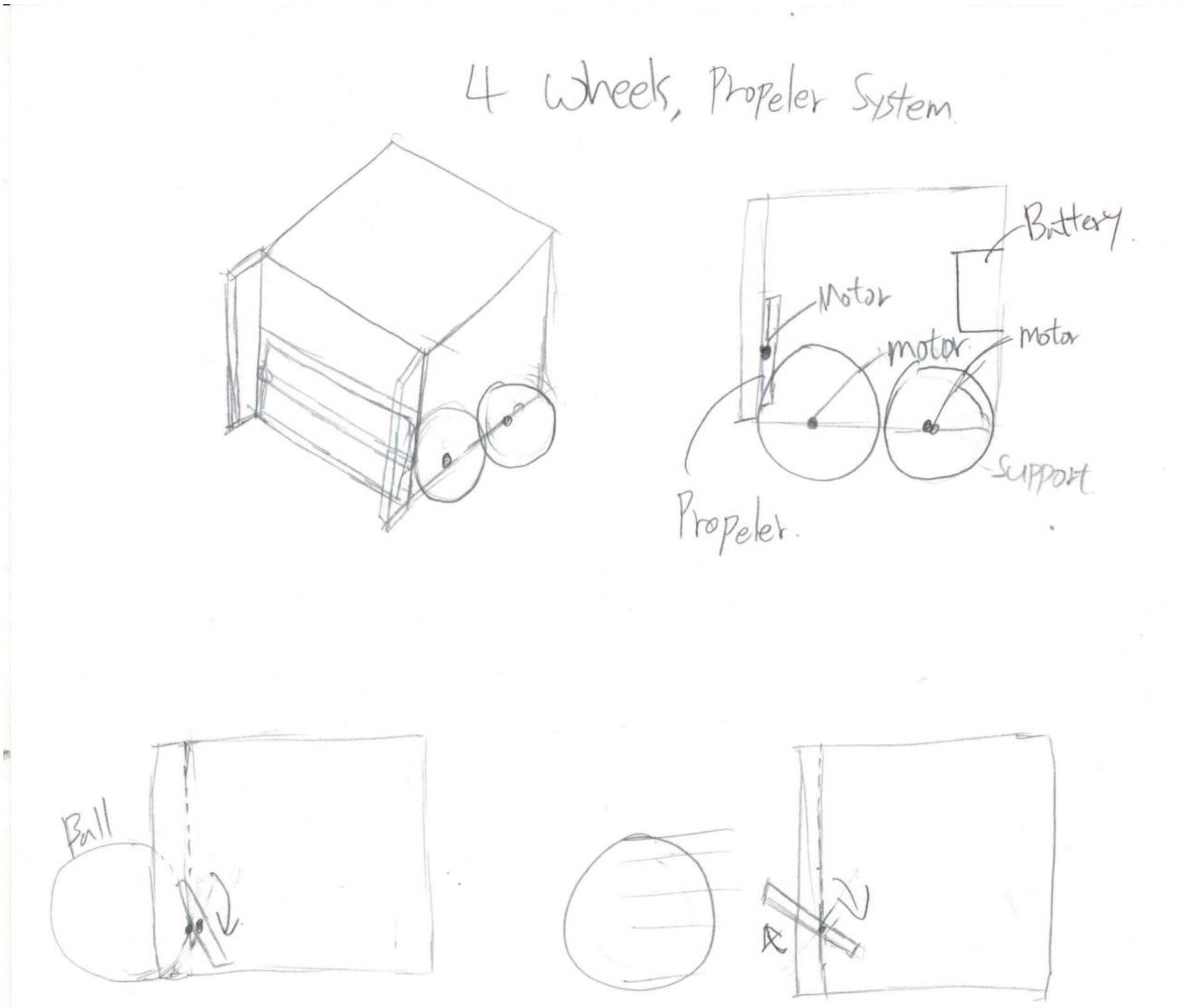


Fig. 18 Concept 3

Description: A cubic body with four wheels system. The kicking function, powered by a commercial battery, consists of the perpetual propeller and guiding plates, which was inspired by the game of foosball.

Components: Cubic body, propeller kicking function, four wheel system, a commercial battery, guiding plate.

Downsides: It cannot change all the direction of shooting. Four wheel system might hinder the turning ability.

3.6 CONCEPT #4 – "CHANNY SCOOPER"

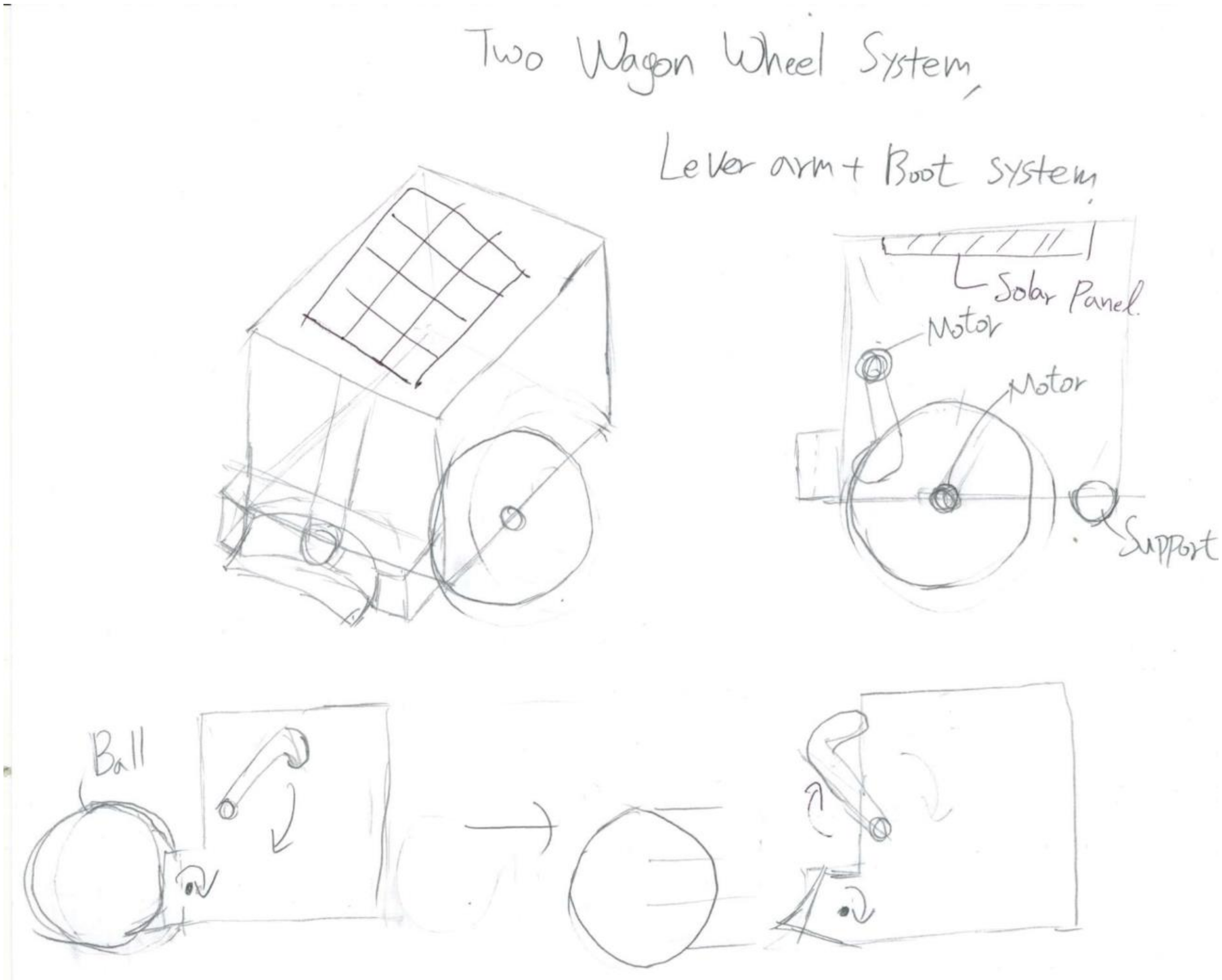


Fig. 19 Concept 4

Description: A cubic body with two wagon wheel system. The kicking function, powered by a Solar powered battery, consists of the scooper and lever arm. When the scooper holds a ball, it varies the kicking angle through its own rotation. The support will be included to help the robot keep its balance.

Components: Cubic body, Lever arm + Boot, Scooper, Two wagon wheel system, Solar-powered battery, Support

Downsides: It cannot change the direction of shooting. The battery will be weaker than commercial battery powered robots.

3.7 CONCEPT #5 – "THE MESSI HAMMER BOT"

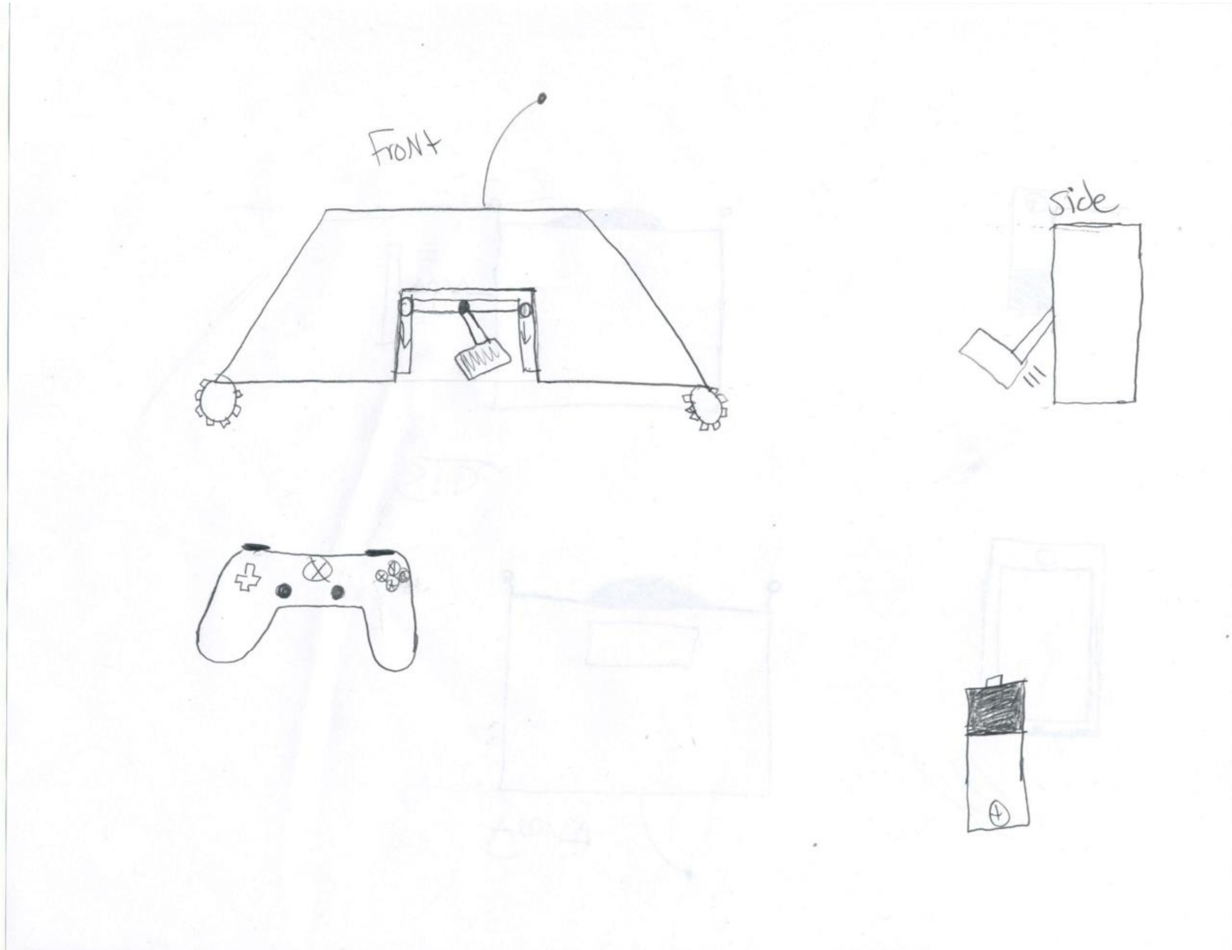


Fig. 20 Concept 5

Description: A trapezoid-shaped body with four powered wheels. The kicking action comes from a hammer lever arm that's driven by a motor. The lever arm can be lowered or raised by the platform, allowing for variation in the shot trajectory.

Components: Battery, motor controlled lever arm, trapezoid body, xbox controller, z-axis platform, and four powered wheels (differential will be used to turn).

Downsides: Lever arm kicking motion is slow and could be difficult to get right. Xbox controller for sending commands to the robot will also be hard to integrate.

3.8 CONCEPT #6 – "OMNIPOTENT OMNIDIRECTIONAL O'BOT"

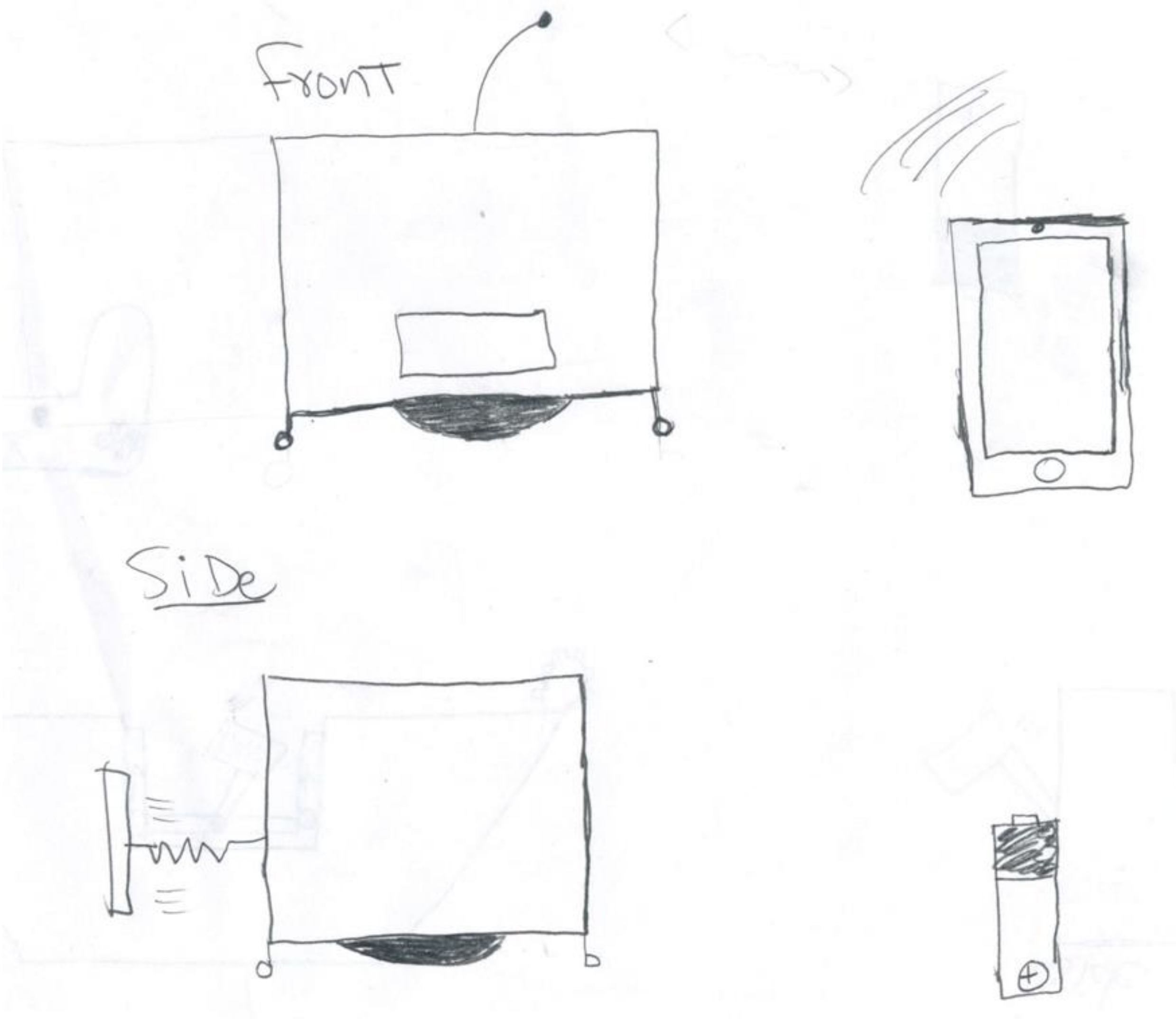


Fig. 21 Concept 6

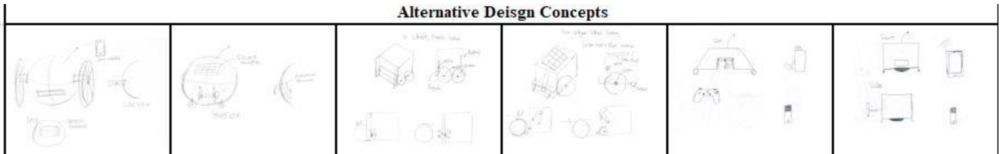
Description: A simple cube shaped body driven by a powered sphere, allowing for multidirectional motion. Four office chair-type wheels will be used for support and balance. THe robot will "kick" the ball using the spring platform design and can be controlled with an iphone app.

Components: Battery powered, spherical wheel, spring loaded plate, iphone integrated controls, cube shaped body.

Downsides: Very difficult to create an omnidirectional spherical wheel.

4 CONCEPT SELECTION

4.1 CONCEPT SCORING MATRIX



		Alternative Deisgn Concepts											
		Star Wars		BBQ Grill		Tornado		Channy		Messi		O'Bot	
Selection Criterion	Weight (%)	Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted
Mechanical safety	24.6	4	0.98	3	0.74	3	0.74	4	0.98	4	0.98	4	0.98
Cost of components	10.34	3	0.31	1	0.10	5	0.52	2	0.21	2	0.21	1	0.10
Weight	14.19	2	0.28	1	0.14	4	0.57	1	0.14	1	0.14	3	0.43
Manuverability	15.68	4	0.63	3	0.47	3	0.47	4	0.63	3	0.47	5	0.78
Size	2.54	3	0.08	3	0.08	3	0.08	3	0.08	3	0.08	3	0.08
Kicking Accuracy	2.46	4	0.10	2	0.05	2	0.05	5	0.12	5	0.12	4	0.10
Kicking Power	2.54	5	0.13	3	0.08	3	0.08	4	0.10	4	0.10	5	0.13
Battery Performance	7.06	5	0.35	1	0.07	5	0.35	1	0.07	5	0.35	5	0.35
Controllability	8.84	3	0.27	3	0.27	3	0.27	3	0.27	3	0.27	3	0.27
Manufacturability	11.76	1	0.12	1	0.12	5	0.59	2	0.24	3	0.35	1	0.12
	Total score	3.243		2.109		3.701		2.832		3.075		3.335	
	Rank	**3**		**6**		**1**		**5**		**4**		**2**	

	Mechanical Safety	Cost of components	Weight	Manuverability	Size	Kicking Accuracy	Kicking Power	Battery Performance	Controllability	Manufacturability	Row Total	Weight Value	Weight (%)
Mechanical safety	1.00	3.00	5.00	3.00	7.00	7.00	7.00	5.00	5.00	3.00	46.00	0.25	24.60%
Cost of components	0.33	1.00	0.33	0.33	3.00	5.00	3.00	3.00	0.33	3.00	19.33	0.10	10.34%
Weight	0.20	3.00	1.00	1.00	5.00	5.00	5.00	3.00	0.33	3.00	26.53	0.14	14.19%
Manuverability	0.33	3.00	1.00	1.00	5.00	5.00	5.00	3.00	3.00	3.00	29.33	0.16	15.68%
Size	0.14	0.33	0.20	0.20	1.00	1.00	1.00	0.33	0.33	0.20	4.74	0.03	2.54%
Kicking Accuracy	0.14	0.20	0.20	0.20	1.00	1.00	1.00	0.33	0.33	0.20	4.61	0.02	2.46%
Kicking Power	0.14	0.33	0.20	0.20	1.00	1.00	1.00	0.33	0.33	0.20	4.74	0.03	2.54%
Battery Performance	0.20	0.33	0.33	0.33	3.00	3.00	3.00	1.00	1.00	1.00	13.20	0.07	7.06%
Controllability	0.20	3.00	1.00	1.00	3.00	3.00	3.00	1.00	1.00	0.33	16.53	0.09	8.84%
Manufacturability	0.33	1.00	0.33	0.33	5.00	5.00	5.00	1.00	3.00	1.00	22.00	0.12	11.76%
										Column Total:	**187.03**	**1.00**	**100%**

Row criterion is _______ than/as column criterion

Numerical ratings: 9 -- Extremely more important
7 -- Very strongly more important
5 -- Strongly more important
3 -- Moderately more important
1 -- Equally important
1/3 -- Moderately less important
1/5 -- Strongly less important
1/7 -- Very strongly less important
1/9 -- Extremely less important

Table V. Scoring Matrix

4.2 EXPLANATION OF WINNING CONCEPT SCORES

Our winner for the concept selection is the 'Tornado', with a aggregate score of 3.701. It incorporates a simple cubic body, a four-wheel drive system, and a propeller mechanism for kicking. This concept is also battery powered. This concept simple and is able to hit all of our project goals. The simplicity of the 'Tornado' makes the purchasing, and manufacturing process fit within our monetary and time budget. This concept is an all-rounder, coming in the medium of the pack in terms of functionality (i.e. kicking power, kicking accuracy, maneuverability). The major upside to picking this concept is that it fits within the scope of the project and does not have any logistical conflicts.

4.3 EXPLANATION OF SECOND-PLACE CONCEPT SCORES

Ranking second is the O'Bot. The O'Bot features a cubic body with an omnidirectional spherical wheel along with four supporting wheels. The kicking function is performed by a spring-loaded plate. This concept is battery powered and was proposed to be controlled through a smartphone platform. With the spring-loaded plate, the O'Bot is able to achieve a very good kicking power and accuracy. Another great benefit of this concept design is the excellent maneuverability that the omnidirectional spherical wheel could provide. Similar to the 'Star Wars', manufacturability is a big hurdle for this concept due to the spherical wheel. Another large problem with this concept is the cost of components will most likely be out of budget. Taking everything else into consideration, a spherical omnidirectional wheel sounds cool, but is a premium that we cannot afford in terms of both time and money.

4.4 EXPLANATION OF THIRD-PLACE CONCEPT SCORES

Ranking third, the 'Star Wars' had a total weighted score of 3.243. This design has a spherical body complimented by a two-large-wheel wagon system for mobility. The kicking function relies on a spring loaded plate, which give it a great kicking power and accuracy as compared to some of our other kicking mechanism concepts. This concept's strongest performing criteria were its kicking power and battery performance, while its greatest downfall is the manufacturability due to its spherical body. Observing other criteria of this concept, it seems manufacturability is limiting its potential. Theoretically, this design has the capability to perform all of the defined goals; however, since manufacturability was defined as a very important criterion in our analytic hierarchy process, this design did not come out on top. There are many difficulties that come with creating a spherical body, such as machining or finding the right material in that shape. A cubic shape, in comparison, is much easier to achieve and gives up only on aesthetic value (which we do not value highly).

4.5 SUMMARY OF EVALUATION RESULTS

Utilizing both an analytic hierarchy process and the corresponding weighted scoring matrix, our top three design concepts were determined as: Tornado, O'Bot and Star Wars. We identified the most important factors as 1) mechanical safety 2)weight 3) manufacturability and 4) maneuverability. Each concept will be discussed in regards to these important factors.

5 EMBODIMENT & FABRICATION PLAN

5.1 ISOMETRIC DRAWING WITH BILL OF MATERIALS

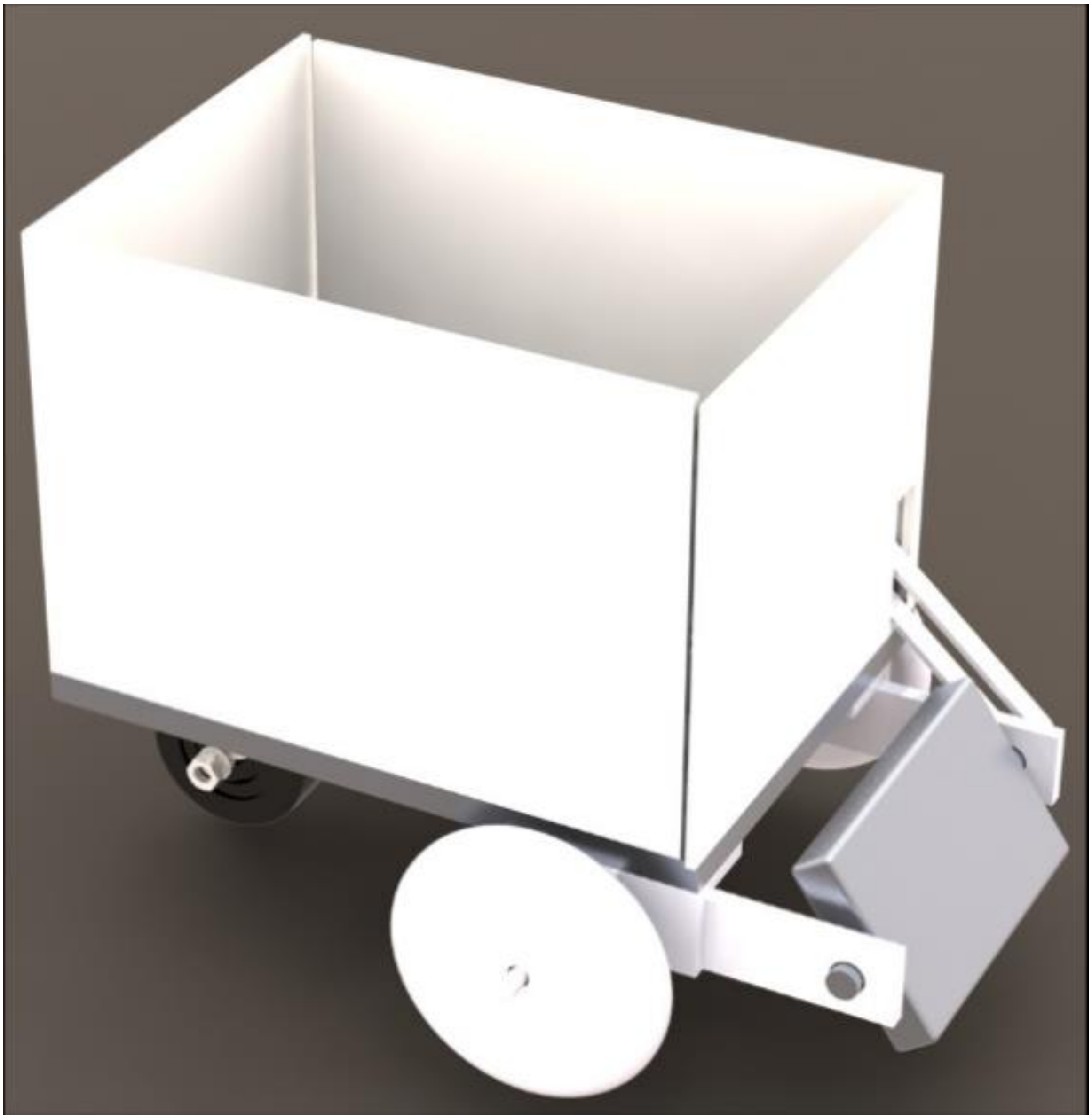
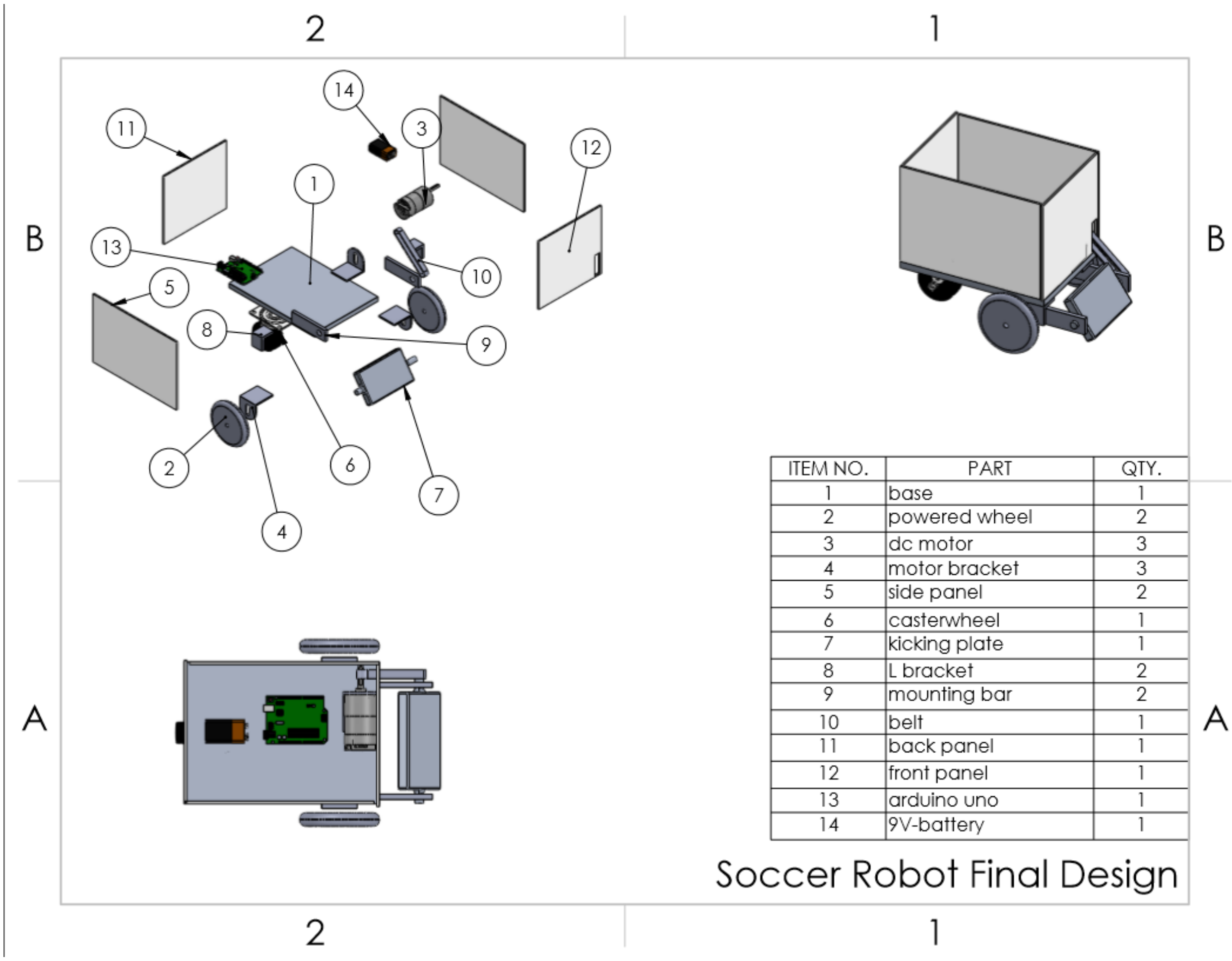


Fig. 22 Final Design

5.2 EXPLODED VIEW



ITEM NO.	PART	QTY.
1	base	1
2	powered wheel	2
3	dc motor	3
4	motor bracket	3
5	side panel	2
6	casterwheel	1
7	kicking plate	1
8	L bracket	2
9	mounting bar	2
10	belt	1
11	back panel	1
12	front panel	1
13	arduino uno	1
14	9V-battery	1

Fig. 23 Final Design BOM

5.3 ADDITIONAL VIEWS

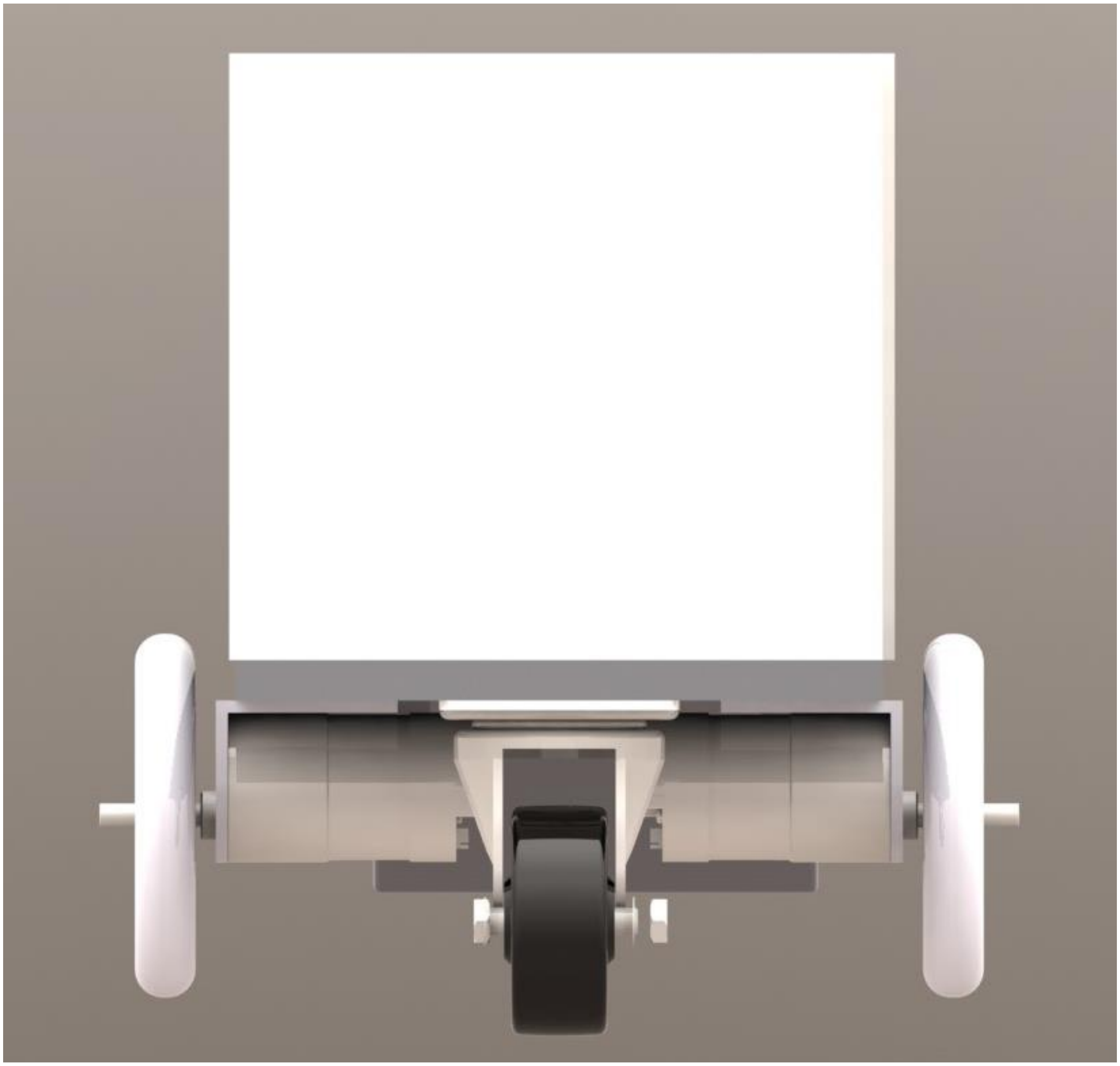


Fig. 24 Final Design Rear View

Rear View

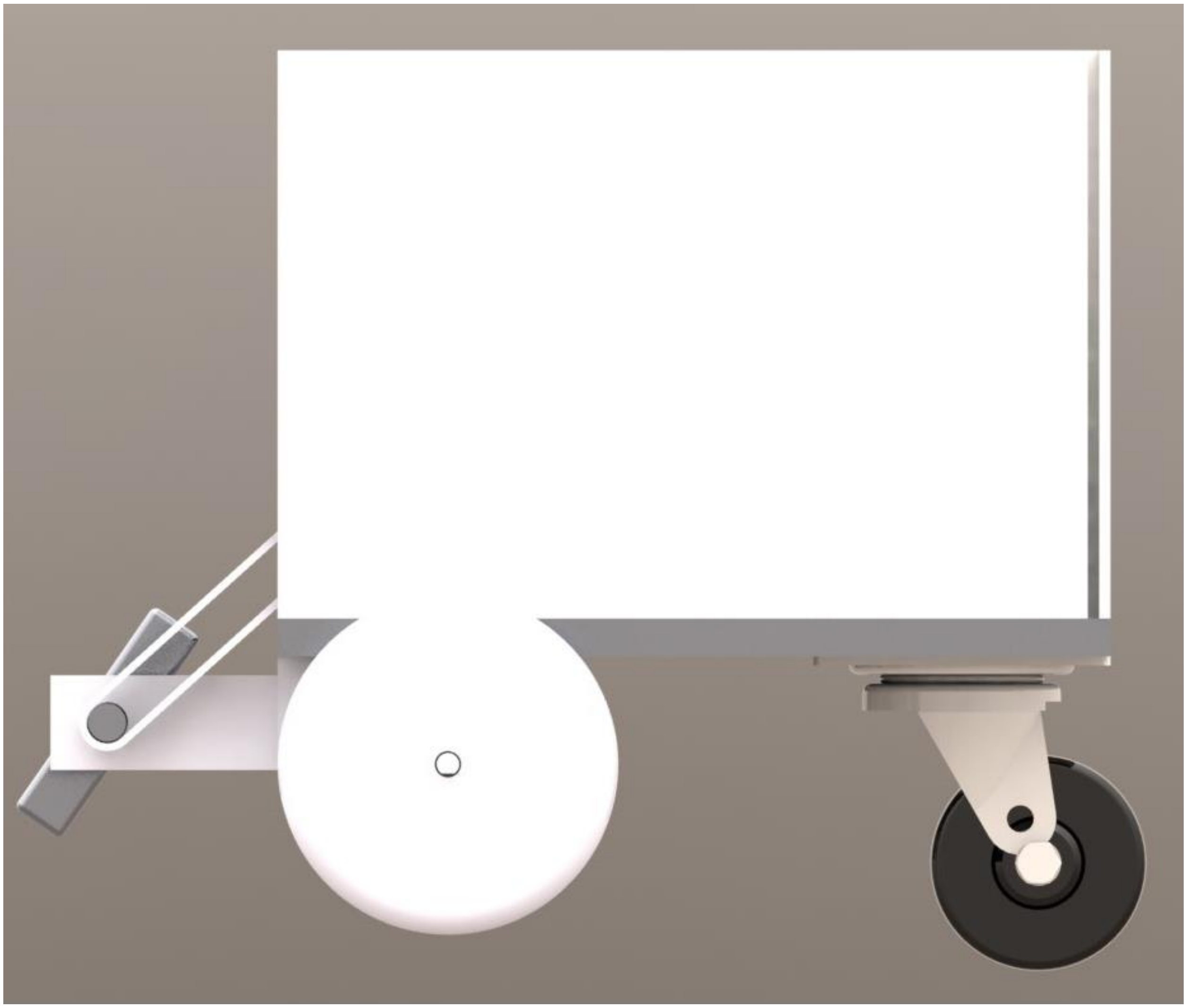


Fig. 25 Final Design side view

Side View

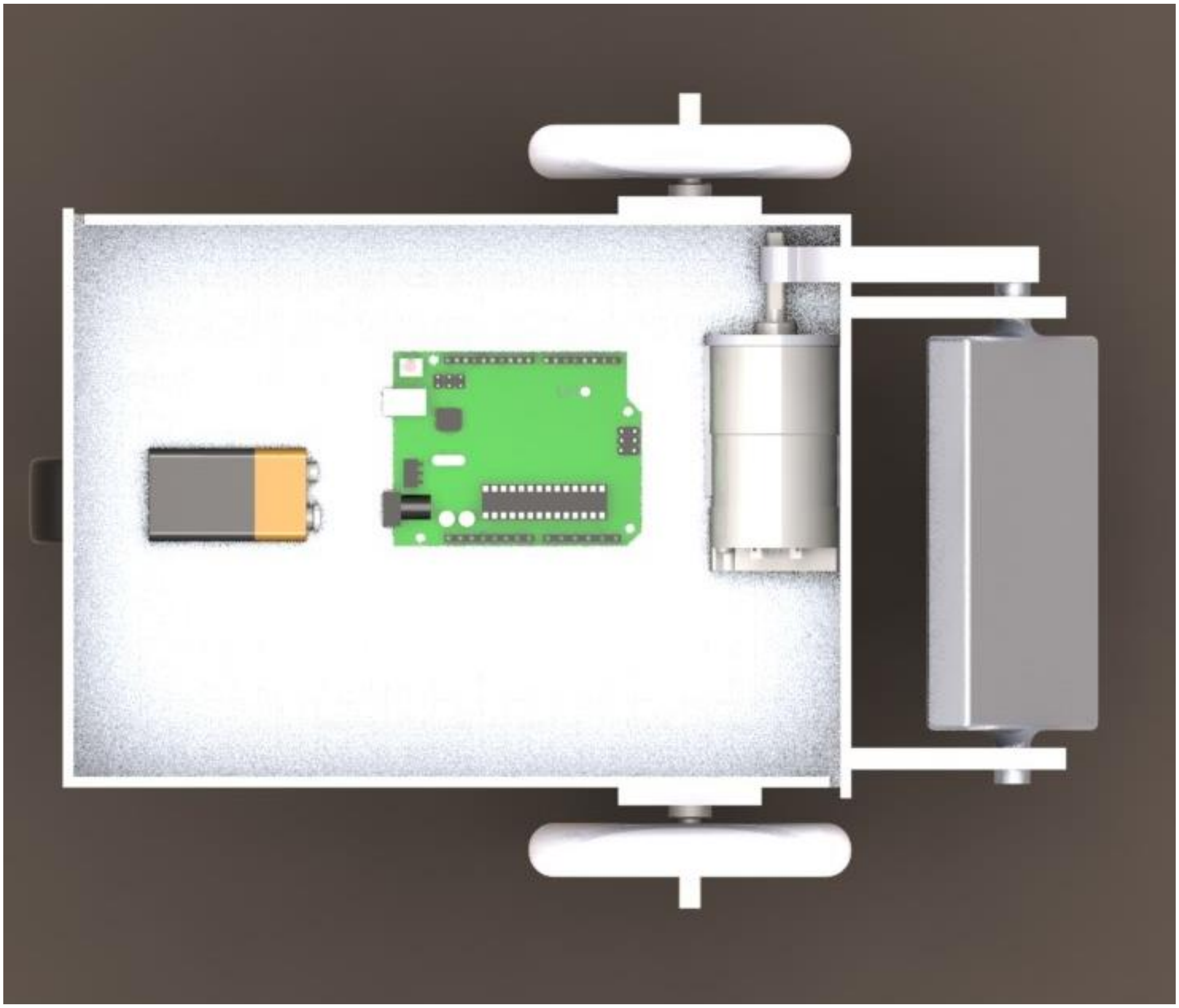


Fig. 26 Final Design Top View

6 ENGINEERING ANALYSIS

6.1 ENGINEERING ANALYSIS RESULTS

6.1.1 Motivation

We decided to analyze the required RPM of our kicking plate to score a goal using a tennis ball on a target at least 10 feet away. The resulting information would allow us to determine the motor size required to successfully kick the ball as we conceptualized. This analysis will also tell us whether or not this design was realistic and the correct one to choose. We used conservation of energy along with the assumption that all of the ball's kinetic energy would come from the kicking plate alone.

6.1.2 Summary Statement of the Analysis

Our analysis followed the physics behind foosball where the kicking tool will have a given rotational velocity and will end at rest, giving all of its energy to the ball in the form of kinetic energy. This approximation made the calculation more straight forward, but was a bit incorrect as the motor would also provide work on the ball when it hit the plate. We obtained our mass and inertia values from solidoworks after updating our model with the final dimensions of our machined part. We used these values in our calculations to obtain the following:

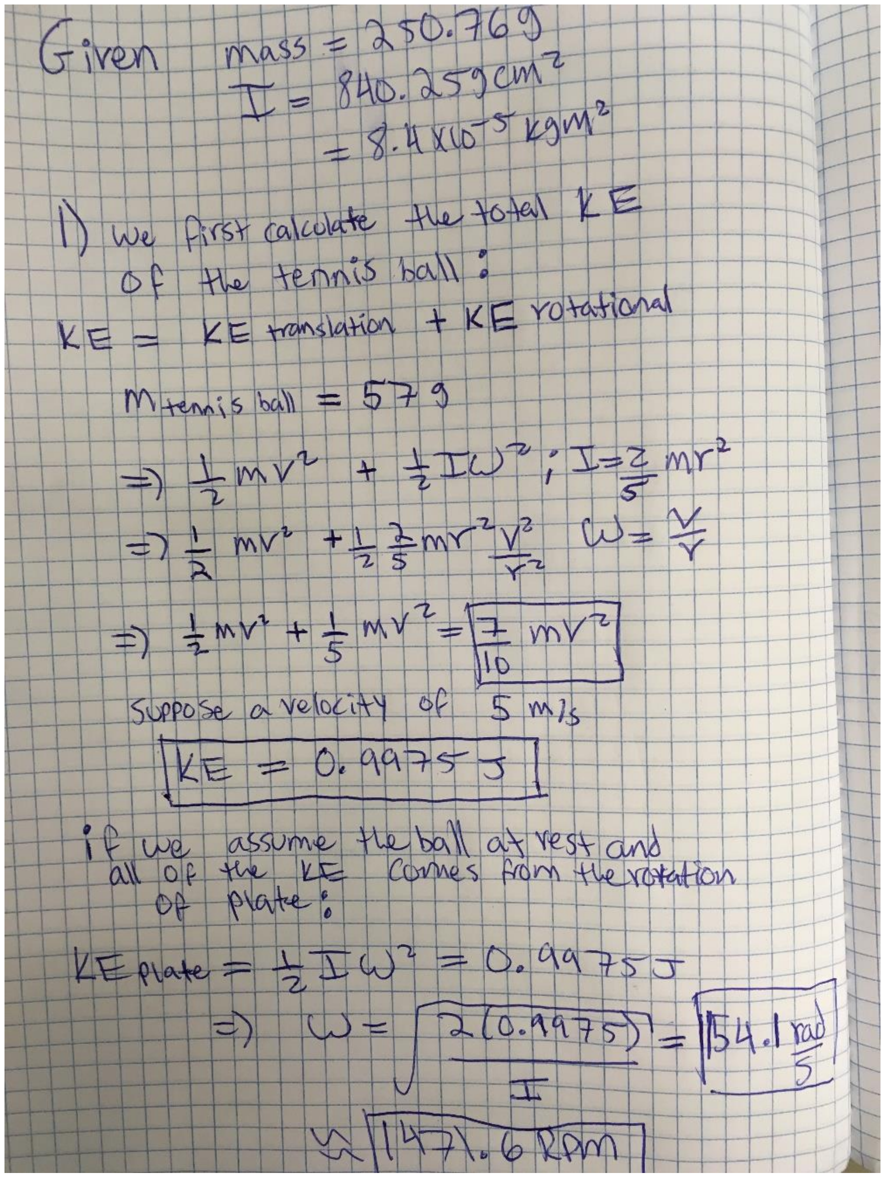


Fig. 27 Engineering Analysis

6.1.3 Methodology

The analysis was initially theoretical, however as we are currently in the process of building our kicking function, we will get to test our predictions and compare them to the experimental results we obtain. Through many test trials we hope to optimize this function so that our robot can successfully complete our goal of making 8 out 10 shots on goal from 10 feet away.

6.1.4 Results

The results were a bit high as they stated that we would need to have an angular velocity of over 1000 RPM, a speed that isn't achievable with the dc motors we currently have. We hope to test our kicking function with real tennis balls and hopefully obtain a "kick" that is satisfactory. We stated that a good velocity for the kick would be 5 m/s, but we could lower this bar, which would in turn lower the required angular velocity for the plate. Also, if we wanted to pursue a shot velocity of 20 m/s, a velocity we thought to be fitting for the competition, then we'd need an angular velocity of almost 6000 RPM.

6.1.5 Significance

These results impact our choice in motors. At first, we wanted to use a small dc motor we found from old parts along with a belt to drive our plate. But, if our calculations are correct, we will have to use a substantially more powerful motor to achieve the function we want. For our final design this could mean incorporating a more expensive DC motor and thus strain our allotted budget. The AMPFlow E30-150 brushless electric motor can achieve RPMs of 5600, which could be a promising replacement for our design.

6.2 PRODUCT RISK ASSESSMENT

6.2.1 Risk Identification

6.3 RISK 1

Risk Name: Sharp edges

Description: The kicking plate system, along with the brackets and stabilizers were manufactured from 6061 aluminum. The finishing on the edges on the aluminum when they arrived were sharp, and given the speed that our robot would be traveling (roughly 3.5miles/ hour) this could pose a threat to children playing with the soccer robot.

Impact=2: We foresaw this risk and took extra caution while machining the parts and sanded down the sharp edges to a filet. As a result of the steps we took, the severity of this risk has gone down. Upon contact with children operating the device, the kicking plate system would no longer pose serious threats such as cutting or heavily scratching their skin.

Likelihood=5: Since the kicking plate system is mounted in the front of the bot, it is highly likely that the kicking plate will be in contact with other objects or people.

6.4 RISK 2

Risk Name: Body walls

Description: The body walls of the soccer robot are made from layered cardboard and attached via hot glue. The incentive behind this design was simply to minimize the weight of the entire robot to achieve higher motor speeds. While the body walls are sturdy for the purpose of kicking a tennis ball and maneuvering through space; in event of collision, a risk of the walls breaking down is inherent.

Impact = 1: Since the body walls are a feature for aesthetics, the risk of them breaking is minimal, and they can easily be replaced.

Likelihood=2: The event of a collision strong enough to break the walls is rather unlikely. First of all, the robot is leveled off the ground a good few inches, allowing it to avoid immediate hazards on the ground; secondly the hot glue is sturdy enough to withstand anything but a fatal collision for the robot.

6.5 RISK 3

Risk Name: Unclean drill holes

Description: All of the mechanical parts of the robot; kicking plate, motors, and wheels are all attached with nuts and bolts. While we took steps to clean up holes after drilling to take away sharp grooves and edges formed, not all the holes were cleaned up perfectly. As a result, this poses a certain danger to people handling the device to get scraped or hurt. However, the nut used to fasten the bolts are large enough to cover most of the hole.

Impact = 1: As stated above, the nut should be plenty protection against any uneven edges; however the edges have a chance of cutting fingers during the building process.

Likelihood=1: It is highly unlikely for there to be anything rough edges outstanding.

6.6 RISK 4

Risk Name: Wheels

Description: The wheels of the device pose a possible threat of running over infants' and pets' limbs when used in household settings.

Impact=3: The total weight of the soccer robot is roughly 2-3kg, a weight that is rather negligible for an adult. However, this weight on an infant or small pet could cause discomfort, but fortunately nothing long lasting.

Likelihood=4: The chance of this event happening is rather high since infants and small pets spend a good amount of time on the floor and the soccer robot has rather large wheels.

6.7 RISK 5

Risk Name: Kicking belt

Description: In the current design of the kicking system, a belt connected to a DC motor is used to drive the kicking plate continuously. The belt is simply latched on to the protruding portion of the pin that was forced fitted into the kicking plate. The potentially hazard here is that there is no safety mechanism to prevent the belt from slipping and eventually flying off.

Impact = 2: The impact of the belt flying off is rather low since it does not introduce other risks. Once it flies off, the plate will stop spinning. The belt is also lightweight enough that should it hit something, it would not produce a strong enough force to cause injuries.

Likelihood =3: We are still working on the kicking plate and have not had a chance to test this event yet. However, we predict that the event is equally likely as it is unlikely.

6.8 RISK 6

Risk Name: Loosening of screws

Description: The individual components of the soccer robot were assembled onto a main place using nuts and bolts. Over time, the nuts and bolts could become loose and could lead to larger problems such as wobbliness of the kicking plate system and wheels. As a result, the robot would not function optimally. However, the more concerning outcome is that the nuts get lost somewhere and gets picked up by infants and small pets. Small parts like the nut is a dangerous hazard to infant, young children and small pets because they could swallow it.

Impact = 5: The impact of this risk is very high if the small pieces gets swallowed by infants, young children or small pets. It is not very clean and could lead to other health issues.

Likelihood=1: The likelihood of the event described above happening is very low. Loosening of bolts and nuts should be visible way before it reaches the point of falling off the robot.

6.9 RISK 7

Risk Name: Electrical hazards

Description: The electrical portion of the robot requires a circuit to be built. As with any electrical component, this runs the risk of damaging electrical parts if the circuit is not built correctly or running the correct power.

Impact= 5: The impact of the risk is very high as it can cause components to be fried and impacting the completion of the project.

Likelihood=2 The likelihood should be rather low as long as we are careful with building the circuit.

6.9.1 Risk Heat Map

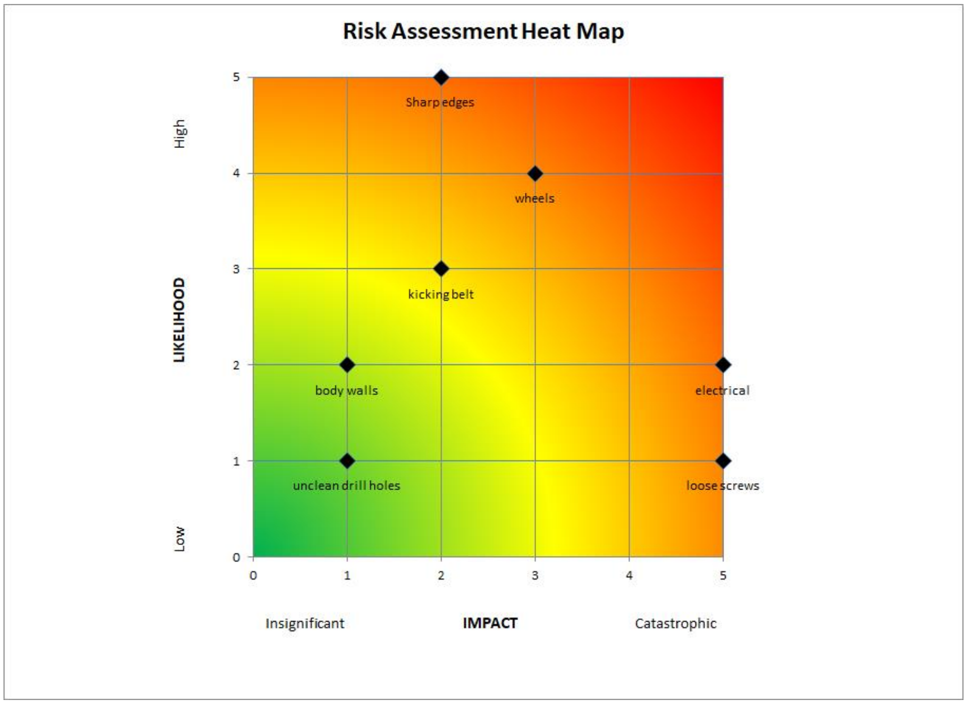


Fig. 28 Risk Heat Map

6.9.2 Risk Prioritization

According to the heat map, the order of risk prioritization should be: wheels, sharp edges/ electrical hazard, kicking belt, loose screws, body walls, unclean drill holes. The risk of wheels come in at aa risk score of 12. Sharp edges and electrical hazard are tied at a risk score of 10. Moving down, we have the kicking plate coming in at medium impact and medium likelihood. Next, we have the loose screws which create a large impact but have a low chance of materializing. Finally, we have the body wall and unclean drill holes; both with the same impact level but the likelihood of the body walls breaking down is higher than unclean drill holes risk materializing.

7 DESIGN DOCUMENTATION

7.1 PERFORMANCE GOALS

- Should be able to travel the perimeter of of a 5ft x 5ft box in less than 7s, with a linear velocity of about 5 ft/s (roughly 3.5 mph, or walking speed).
- Should be able to last for 5 sessions of use, 10 minutes each, before changing the battery.
- Should be able to score a goal on an open net from 10 ft away, 8 out of 10 times.

- Controller response lag should be less than 0.2s. (we can track this using the Arduino time function for executing a set of commands)
- The robot shouldn't be larger than $(30\text{ cm})^3$.

7.2 WORKING PROTOTYPE DEMONSTRATION

7.2.1 Performance Evaluation

We tested the robot for functionality in its translational motion and its kicking ability. We were able to successfully control the robot using a phone app, allowing us to move forward, backward, and side to side with a great response time, whose lag was virtually non-existent. While testing the kicking function, we made 9 out of 10 shots on an open goal from 10 feet away, which satisfied our performance goal of making at least 8 out of 10. Our robot was (30cm)^2 in area with a height of less than 15 cm, but this was also because we had to remove the plastic housing that went around the outside. Although we did have to use a lot of 9v batteries, we could play and test the robot around 5 times for roughly 10 minutes and thus satisfied our battery performance goal as well. Lastly, our robot was able to move at roughly walking speed and thus we accomplished all of the goals we hoped to meet.

7.2.2 Working Prototype – Video Link

https://youtu.be/sL8zwB6Bydo

7.2.3 Working Prototype – Additional Photos-Final Presentation – Video Link

https://youtu.be/CC3EdvGuJjc

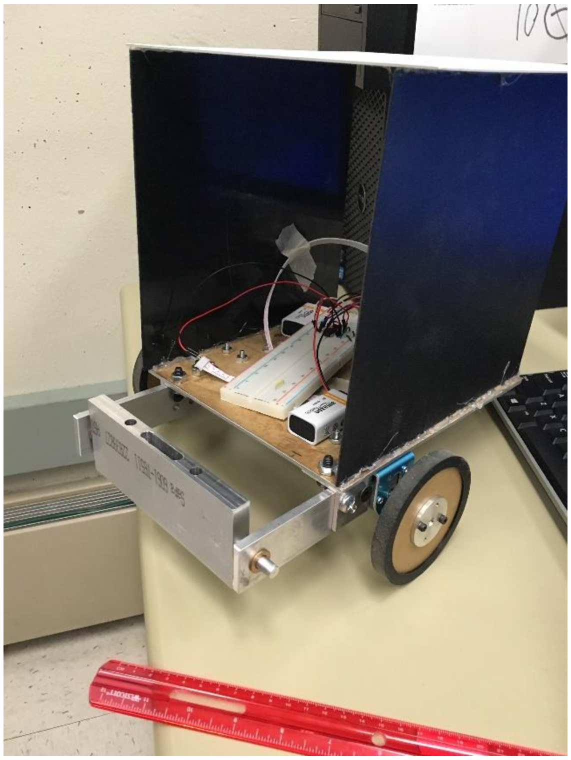


Fig. 29 Working Prototype

8 DISCUSSION

8.1 DESIGN FOR MANUFACTURING – PART REDESIGN FOR INJECTION MOLDING

8.1.1 Draft Analysis Results

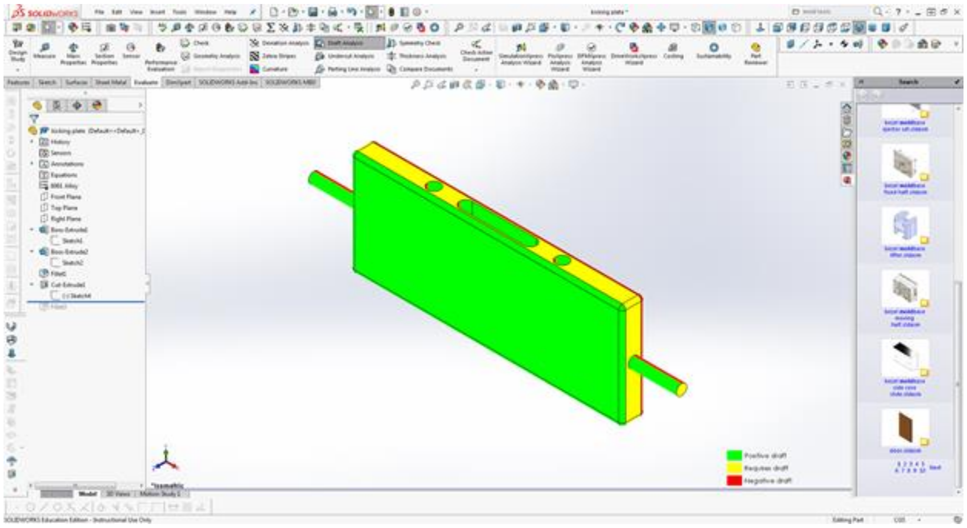


Fig. 30 Design for Manufacturing Initial Draft

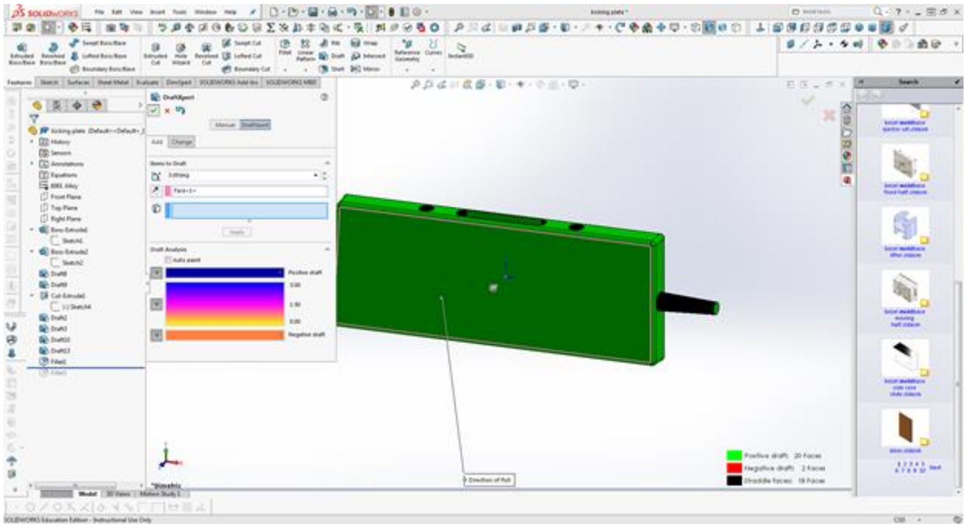


Fig. 31 Design for Manufacturing

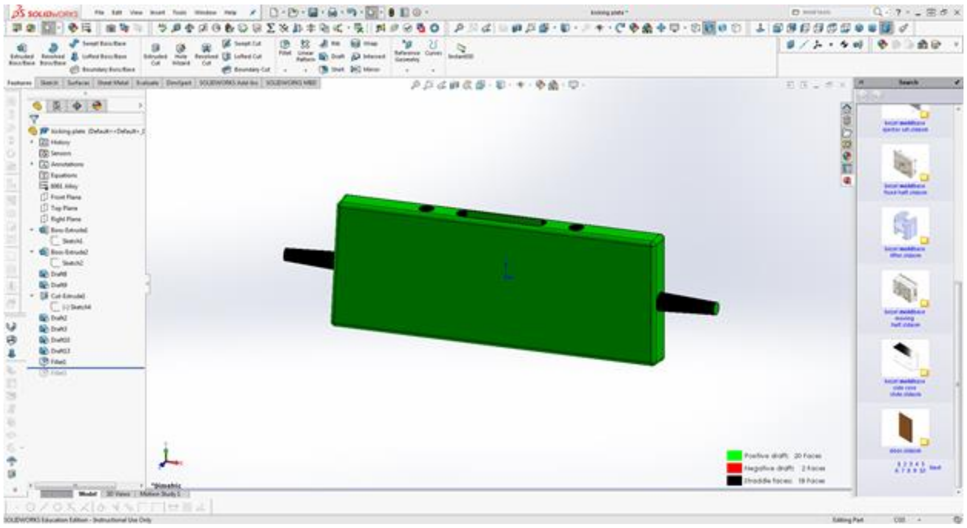


Fig. 32 Result of adding 3% draft on pins

8.1.2 Explanation of Design Changes

Changes made include adding a 3º draft on both of the pins. This reduced the area of yellow on the surface of the pin. Further, a draft to each vertical wall of the plate was added to decrease the number of yellow faces.

8.2 DESIGN FOR USABILITY – EFFECT OF IMPAIRMENTS ON USABILITY

8.2.1 Vision

Vision Impairment: A vision impairment will not affect the usability of our device. Our robot will be controlled remotely using smartphones and Bluetooth technology. The controls are not designed color coded.

8.2.2 Hearing

Hearing impairment: A hearing impairment will not affect the usability of our device. The soccer robot does not provide feedback in the form of sound that users have to listen for. However, persons with a hearing impairment will not be able to identify mechanical problems such as the motor running too hard or wheels grinding. In which case, a further design goal would be to incorporate a monitoring system on the Bluetooth controller than warns of problems arising in the robot.

8.2.3 Physical

Physical Impairment: Physical impairment will also have no effect on how our device will be used. The beauty of Bluetooth control is that it will be wire free and so the device could operate within a prespecified range and the user does not need to move at all. Persons with arthritis should have no problem operating the controller.

8.2.4 Language

Language impairment: The controls are designed in a universal language, a basic joystick for controlling movement of the robot. The kicking function is powered continuously by a DC motor. We may add a button to switch on/off this DC motor, in which case language impairment may play a role. However, the English words “ON” and “OFF” are universal enough where this should not be a problem.

8.3 OVERALL EXPERIENCE

8.3.1 Does your final project result align with the initial project description?

The version of the SR used in the final presentation aligned perfectly with the project description. We were able to create a SR that satisfies all the performance goals we had identified in order to be a contender in the ASME design competition. This includes being able to move freely in four directions, and a functional kicking system.

8.3.2 Was the project more or less difficult than you had expected?

The project was more difficult than expected due to the inclusion of circuitry and coding; both of which were required to build the Bluetooth controller. This was not totally unexpected, but we didn’t imagine the circuit and coding would take so long and pose this many challenges while working on it. This increase in difficultly comes from the fact that we were all learning as we went, and we had no one to guide us through the electrical portion of the project.

8.3.3 In what ways do you wish your final prototype would have performed better?

In terms of performance, we were completely satisfied with how it performed. One area of improvement was the aesthetics of the SR. As mentioned in the report, the current prototype of the SR appears unrefined; all the electronic parts are visible.

8.3.4 Was your group missing any critical information when you evaluated concepts?

There was no critical information missing as we evaluated the different concepts. Perhaps one thing worth mentioning is that we did not know in depth how the different controller systems or power sources would be integrated. Although, we already had in mind that we wanted to go with Bluetooth and battery powered.

8.3.5 Were there additional engineering analyses that could have helped guide your design?

Additional engineering analysis that should have been put into consideration is the weight balance of the entire SR. During building and testing, we noticed that when driving the SR at high RPMS or when batteries started running dry, it was hard to keep the SR going in a straight line. This was due to the fact that the robot was heavier on one side than the other, which impacted performance on one of the motors as it had a larger load over it.

8.3.6 How did you identify your most relevant codes and standards and how they influence revision of the design?

The code and standard we chose did not exactly influence our design decisions; however, we chose it because we would need to follow such guidelines should we try to make a product (kid toy) from the project. There were no codes and standards cited for the ASME challenge, so the only guidelines we had to follow were those outlined in the competition description.

8.3.7 What ethical considerations (from the Engineering Ethics and Design for Environment seminar) are relevant to your device? How could these considerations be addressed?

We think that the battery power source is one area where major environmental considerations could be made. For our prototype, we used 9 V batteries, and the SR ran these things dry quick. In the future, the use of rechargeable batteries should be integrated to lessen the environmental impact.

8.3.8 On which part(s) of the design process should your group have spent more time? Which parts required less time?

We should have spent more time designing circuit and how all the electric elements (motors) would fit together. This would have made the building process a lot smoother. This would also mean front loading the research and learning part instead of learning as we built.

8.3.9 Was there a task on your Gantt chart that was much harder than expected? Were there any that were much easier?

The engineering analysis, building of the kicking function and building of the Bluetooth controller were all things that were harder than expected. Many of the planning tasks such as concept generation and customers interview took less time than anticipated.

8.3.10 Was there a component of your prototype that was significantly easier or harder to make/assemble than you expected?

The kicking function posed a challenge as we could not find a suitable belt to drive the plate initially. We had to research and call around and eventually found a vacuum repair shop in St. Charles that had the right belt. Another difficult component to build was the Bluetooth controller, there were a lot of challenges with coding, building the app and transferring the code over to the Arduino; we even fried one of our member's computers during this process.

8.3.11 If your budget were increased to 10x its original amount, would your approach have changed? If so, in what specific ways?

Yes, but we do not know to what extent. For example, while we were shopping around for motors, we always had price in mind. So, with a larger budget, we could opt for the strongest and most refined motor on the market. In terms of the kicking system; we would probably stick with McMaster-Carr. Another area of improvement could be the material used for the housing of the SR. Therefore, with the larger budget, everything could be upgraded on the SR, but even so, there would still be plenty of budget remaining. This could help with prototyping as we could build multiple SRs with that budget. The budget could also be used to integrate cool, but unnecessary features such as sound and lights on the SR; or perhaps even an autonomous SR.

8.3.12 If you were able to take the course again with the same project and group, what would you have done differently the second time around?

We would start the building process sooner and account for unexpected issues such as breaks and circuits frying. Many times, we found ourselves working through the night as parts failed, which led to a lot of stress.

8.3.13 Were your team member's skills complementary?

Yes, we all had our strengths. Some were more proficient in mechanical design and analysis, and others more in coding and circuit building. This led to clearly defined roles that meshed well together.

8.3.14 Was any needed skill missing from the group?

Although our skills were satisfactory, more coding experience would've been helpful. This may not actually be an issue for other groups since you don't have to choose a project with such coding and electronic emphasis.

8.3.15 Has the project enhanced your design skills?

Yes, exposure to planning techniques such as the Gantt chart, customer interview, and going through the process of concept generation, selection and setting performance goals have definitely enhanced our design skills. Our biggest take away is actually to attempt to find the aspects of the project that could possibly fail or break ahead of time, so we can plan accordingly. We could then have backup parts and not have to redesign with such limited time.

8.3.16 Would you now feel more comfortable accepting a design project assignment at a job?

Yes, after taking this course and going through the process of design and building a project, we now know what tools we have at my disposal to tackle another design task.

8.3.17 Are there projects you would attempt now that you would not have attempted before?

There are no projects that come to mind. But, should any come up, I would definitely be confident in attempting.

9 APPENDIX A - PARTS LIST

Table 6 Parts List

	Part	Source Link	Supplier Part Number	Color, TPI, other part IDs	Unit price	Tax ($0.00 if tax exemption applied)	Shipping	Quantity	Total price
1	Wheel with motor	Trossenrobotics	KIT-MTR-WHL			$0.00		1	$59.95
2	Arduino Zero	Arduino	ABX00003					1	$39.00
3	9 V batteries				$5.00			6	$30.00
4	belt	got from vacuum store			$0.00			1	$0.00
5	base	jolly basement			$0.00			1	$0.00
6	housing	jolly basement			$0.00			1	$0.00
7	Kicking plate	mcmaster-carr			$8.92			2	$17.84
8	L-bracket	mcmaster-carr			$5.68			1	$5.68
9	support plate	mcmaster-carr			$3.00			1	$3.00
10	dowel pins	mcmaster-carr			$14.20			1	$14.20
12	bearings	mcmaster-carr			$1.01			4	$4.04
13	motor (kicking function)				$30.00			1	$30.00
Total:									$203.71

10 APPENDIX C - CAD MODELS

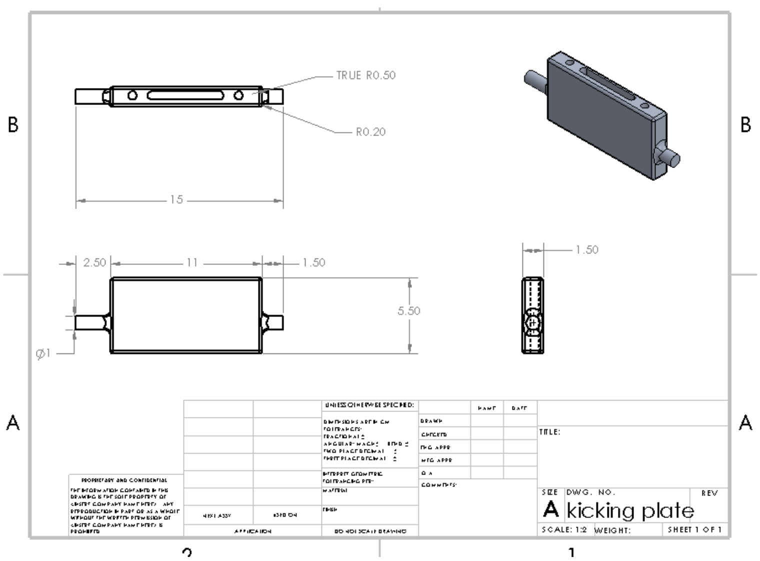


Fig. 33 Kicking Plate model

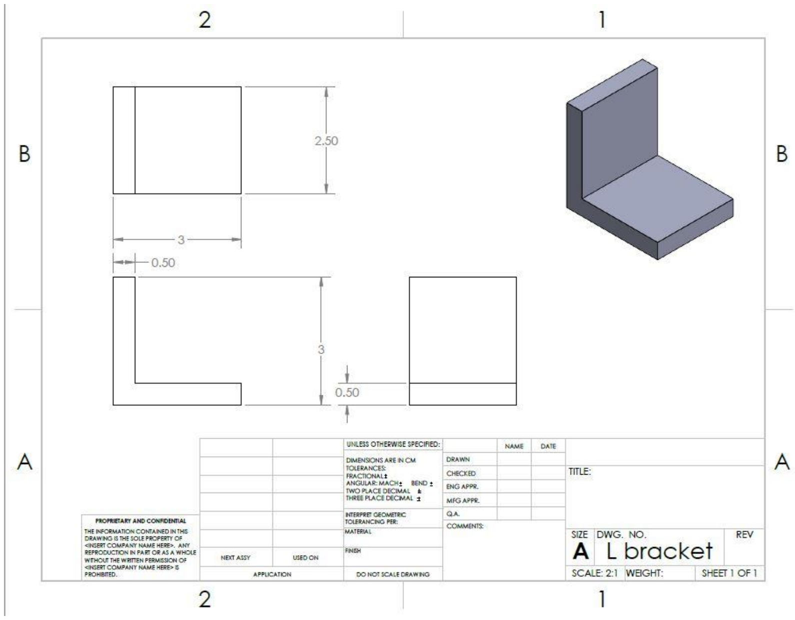


Fig. 34 L-Bracket Model

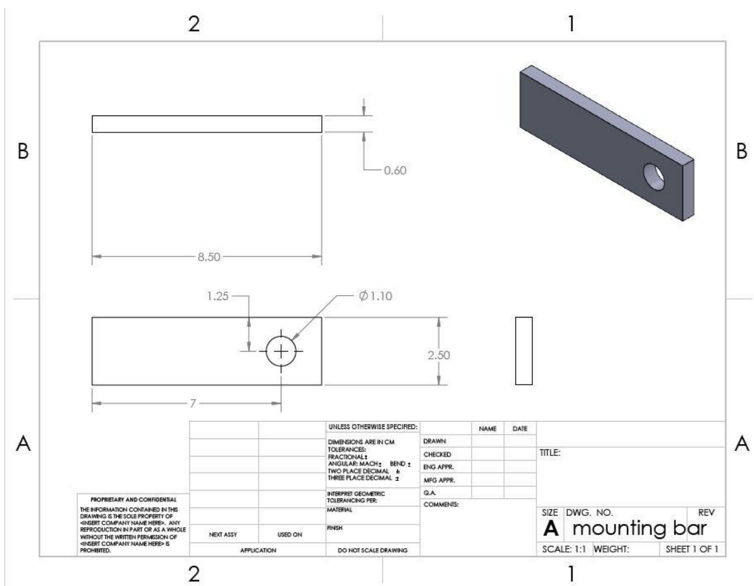


Fig. 35 Mounting Bar model

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3. http://store.irobot.com/default/robot-vacuum-roomba/?utm_medium=cpc&utm_source=bing_us&utm_campaign=&utm_term=roomba&utm_content=c41mSyRf|pcrid|84112645085219|pkw|roomba|pmt|be|pdv|c|
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