RobotX: Final Design

MCHE 201: Intro to Engineering Design
Fall 2016

Team N

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Abstract

The challenge presented was to design and construct a robot to compete in the Fall 2016 MCHE 201 RobotX competition. Once a thorough understanding of the problem was achieved, three design concepts were developed and one was selected through concept evaluation. The chosen design consisted of a stationary metal tower with two extendable arms. These arms are used to complete various objectives of the RobotX competition. This design failed to meet its expectations in the competition earning only 3.2 out of 8 performance points and a rank of 17 out of 23 in the class.

Ok, but maybe a bit too team centric.

Don't number the title or abstract pages.

I Introduction

The main problem presented in this stage of the project was to properly execute the final design chosen during concept evaluation, along with using the problem understanding and concept evaluation tools and methods in order to continue improving the selected design. Additionally, another major challenge was to determine the best approach to take for the final competition, which had four main objectives. These objectives were to autonomously navigate, find and retrieve beacons, detect and deliver, and return to port and dock. The main focus of each team from the beginning of the project was to achieve the highest robot performance score, resulting in each and every team putting all of their efforts into conceiving and executing the best design with hopes of winning the final competition. The teams were required to come up with two alternative designs during concept evaluation, assuring that each team had considered multiple approaches before deciding on the one that that they considered the best. The next section of the report will describe in detail the final design chosen by team 18, followed by a review of the problem understanding in Section 3. Section 4 will describe the approach taken during concept evaluation, and Section 5 will serve as a final design review, where the results of the competition will be discussed. Finally, the conclusions will be found in Section 6.

Write this Intro as a standalone document. You can't assume people have read previous ones.

Stay formal

Avoid. It's basically 1st person.

Good

II Final Design

The final design, shown in Figures 1 and 2, consists of a stationary metal tower with two drawer sliders that act as arms. There is one arm at the top of the tower and one at the bottom. They are rigidly connected and are propelled forward and backward by a DC mounted to the bottom roller and is attached to a wheel which rolls along the base of the tower. Figure 1 shows a side view of the design, and a front view can be seen in Figure 2. As the arms extend outward, a rod with a PVC pipe holding the Ping-Pong balls rotates over the front end of the top arm, giving it the necessary length to reach the inner ring and drop the ping-pong balls into the hole. The dimensions of the arms when they are fully extended can be found in Figure 3. A servo motor is mounted near the mouth of the PVC and rotates a wire in the shape of a loop that covers the hole in order to prevent the balls from falling out of the pipe. The servo is controlled by an infrared sensor also mounted to the PVC, as seen in Figure 4. The infrared sensor detects when the hole is directly beneath the PVC, and tells the servo to rotate and drop the balls into the hole. ¶ Attached to the bottom slider is a shovel-like device that is designed to retrieve two small beacons and return them to the data center. A pulley wheel is rigidly mounted to the outside of the main wheel and attached to the rotating arm via a string. As the wheel is driven forward, the rope winds around the pulley, putting tension on the end of the arm causing it to rotate. Once the sliders are fully extended and the top arm has rotated and dropped the balls in the hole, the arm on the bottom slider rotates down 90° to grab two miniature beacons. The direction of the wheel is then reversed in order to return the sliders to their original position, while at the same time dragging the captured beacons back to the data center. The top arm is brought back to its original position by a windlass pulley system powered by a separate smaller motor. This motor rotates a spool to wind up a string that passes over another pulley wheel, and attached to the arm, pulling it back in a slower but similar manner in which it is rotated out. The code for the robot is written to a SparkFun RedBoard and is stacked with an Adafruit Motor Shield V2 to power the motors.

A major issue discovered during the design process was that the wheel did not generate enough traction, causing it to slip when subjected to the tension that was meant to rotate the top arm, preventing the rotation of the arm. This issue was resolved by modifying the wheel to act as a rack and pinion system, with the rack attached to the base of the tower. When the rubber tire was removed from the wheel, the exposed rim had ridges all the way around allowing it to act as a pinion. The rack was made by cutting the outer rim from an identical wheel and laying it flat along the path of the wheel. Figure 5 shows an overview of the motion of the robot.

You generally want to avoid tweaking discussion. Just present the design as is.

III Problem Understanding

Before any design specifics can be conceived, the problem being faced must be thoroughly understood. This thorough understanding was achieved through the use of design tools such as a house of quality, specification sheet, and function tree. A house of quality is a tool that is used to determine the strength of the relationship, if any, between the customer and functional requirements and also to establish a positive or negative correlation between the functional requirements. The middle section of the house of quality seen in Table 1 notes the relationships between the customer and functional requirements. The customer requirements that received the highest relative weight were those that were mandated by the competition. and these include fit inside of a 12" x 24" x 18" box", components cost no more than $100, can only run for 30 seconds, and no initial elastic potential energy. The reason why these were the most important is because without meeting these requirements, the robot would not be able to contend in the competition. The competition objectives with the highest relative weights are avoid buoys, deliver balls, and return within start zone.

Good

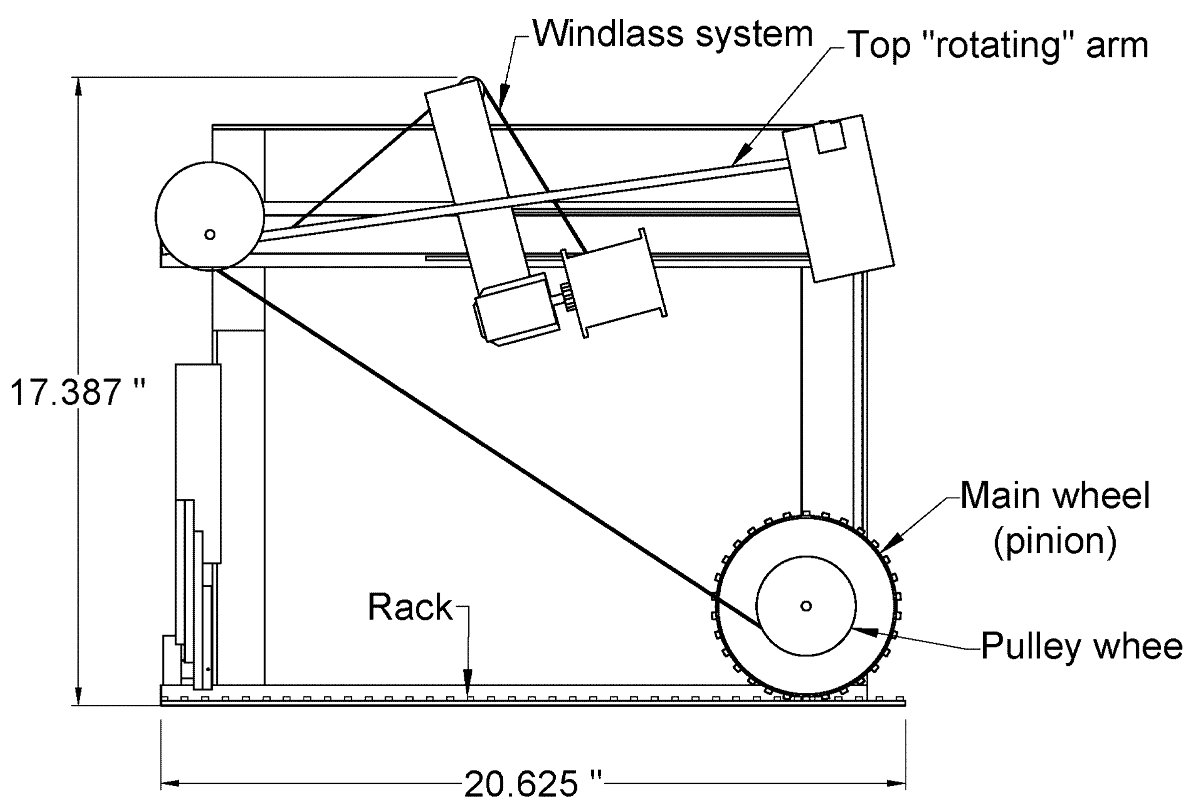

Figure 1 - Side view of final design

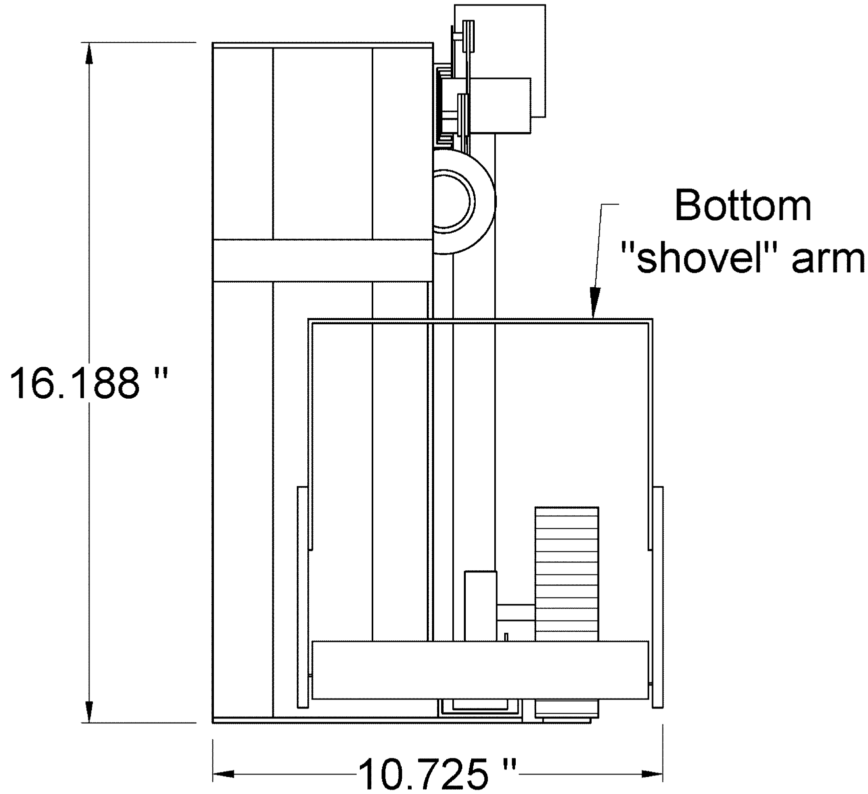

Figure 2 - Front view

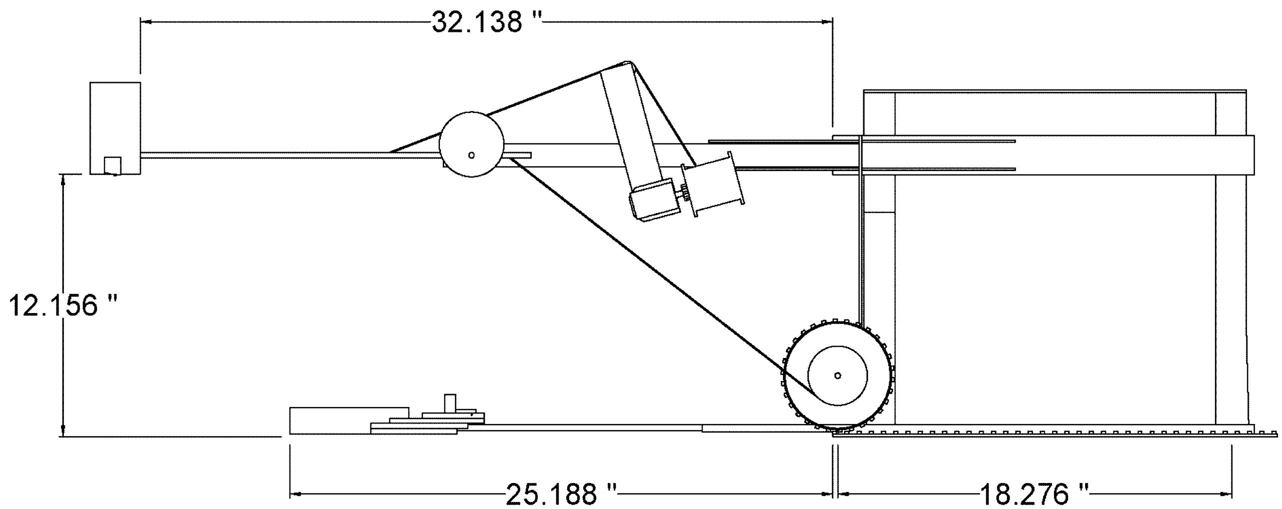

Figure 3 - Dimensions of fully extended arms

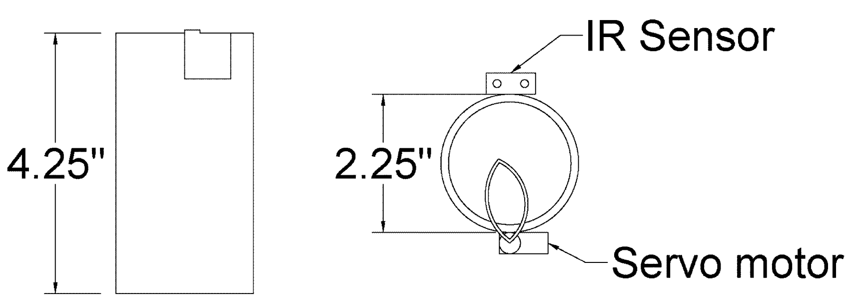

Figure 4 - Device used to hold and release ping-pong balls

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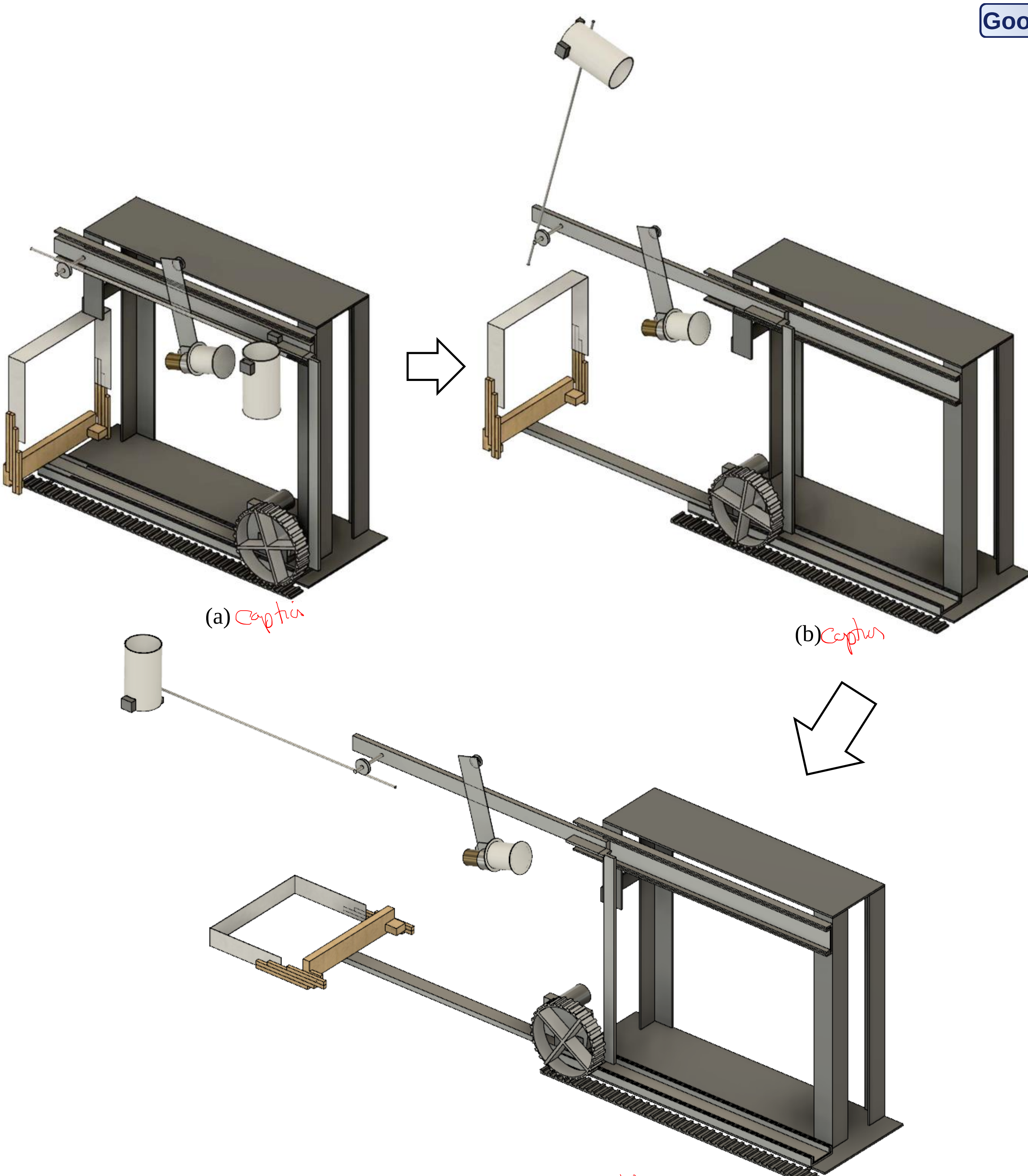

(a) Caption

(b) Caption

(c) Caption

Figure 5 - Overview of motion

Spell out

Another tool utilized to better understand the problem at hand is the specification (spec) sheet seen in Table 2. The spec sheet lists all important customer and functional requirements plus any other targets and constraints that the design must meet. It also shows the most recent date that each requirement was modified, determines if each requirement is a demand or a wish, and tells who the source of the requirement is and who is responsible for it. For example, the requirement to reach the inner ring is a wish, the design team is responsible for the requirement, and the design team is also the source of the requirement. This spec sheet starts off by listing all of the requirements that are mandated by the competition, followed by categories of operation, geometry, kinematics, assembly, actuators, electronics, sensors, consistency, power, and safety.

more of this & less discussion of the tool itself

The final problem understanding tool used is the function tree seen in Figure 6. The purpose of a function tree is to break down a large and complicated process into many small and much simpler processes. This function tree starts with the main function being “win the competition”, which is then broken down into the sub-functions, “score the most points” and “sabotage other teams”. Branching from the function “score the most points” are the four main objectives of the competition, which are then broken down further into simpler functions required to complete each objective. The same process was performed for the sub-function of sabotaging the other teams.

move to top

Table 1 - House of quality

Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Production cost	Mechanical operating footprint	Obsticle clearance	Stability	Run time	Power consumtion	Function timing	Electrical operating footprint	Mechatronics operating footprint	Complete multiple tasks	Number of motors/sensors	Operating Speed	# of Ping-Pong balls delivered	# of beacons collected
7.9	9.0	Fit inside of a 12" x 24" x 18" box	Θ	Θ	Θ	Θ			O		O	▲				
7.9	9.0	Components cost no more than $100	Θ	▲								▲	O			
7.9	9.0	Can only run for 30 seconds					Θ	O	Θ	O	Θ	Θ	▲	Θ	O	O
7.9	9.0	No initial elastic potential energy						▲	O	O	O	▲	O			
7.0	8.0	Avoid buoys		Θ	Θ	▲	O	O	Θ	O	Θ	Θ				
7.0	8.0	Deliver balls		Θ	O	▲	O	O	Θ	O	Θ	Θ	▲		Θ	
6.1	7.0	Retreave and deliver beacons		Θ	Θ	▲	O	O	Θ	O	Θ	Θ	▲			Θ
5.3	6.0	Operate autonomously					Θ	O	Θ	Θ	Θ	Θ	O		Θ	Θ
5.3	6.0	Initiated by track					▲		O	Θ	Θ	▲			O	O
7.0	8.0	Return within start zone		Θ	▲	▲	Θ	▲	Θ	Θ	Θ	Θ		O		
5.3	6.0	Cannot break mechatronics kit components	▲	Θ		O		O	Θ	O	Θ	▲	O	Θ		
6.1	7.0	Start via pushbutton					▲	▲	O	Θ	▲	O				
6.1	7.0	Maximim 2 motors	▲	O			O	Θ	Θ	O	O	O	Θ	Θ	▲	▲
7.0	8.0	Score > 60 points per round		O	O	O	Θ		Θ	Θ	O	Θ		▲	O	O
6.1	7.0	Easily repeatable functions		O					Θ		▲	Θ				

Table 2 - Specification sheet

Changes	D/W	Requirements	Responsibility	Source
		Mandated by competition		
10/27/2016	D	Base fits inside of a 12" x 24" footprint	Design team	Standard
10/27/2016	D	Height < 18"	Design team	Standard
10/27/2016	D	Run time < 30 seconds	Design team	Standard
10/27/2016	D	Cost < $100	Design team	Standard
10/27/2016	D	Initial elastic energy = 0	Design team	Standard
		Operation		
11/20/2016	D	Operates autonomously	Design team	Standard
11/20/2016	W	Operate multiple times without manual reset	Design team	Design team
11/20/2016	W	Stop all functions < 30 seconds after starting	Design team	Design team
11/20/2016	W	Deliver all 3 balls into inner ring	Design team	Design team
11/20/2016	W	Retrieve at least 2 small beacons	Design team	Design team
11/20/2016	W	Robot 100% inside start zone before 30 seconds has expired	Design team	Design team
11/20/2016	W	Reach inner ring within 4 seconds	Design team	Design team
11/20/2016	W	Initiate return to start zone within 24 seconds	Design team	Design team
		Geometry	Design team	
10/27/2016	W	Base < 10" x 23"	Design team	Team
10/27/2016	W	Height of < 17"	Design team	Team
10/27/2016	W	Move table tennis balls 28" to center circle	Design team	Team
10/27/2016	D	Start zone to acoustic beacons 21"	Design team	Standard
10/27/2016	D	Start zone to inner ring 33.9"	Design team	Standard
11/20/2016	D	6" x 2' data center	Design team	Standard
11/20/2016	D	2' x 2' start zone	Design team	Standard
10/27/2016	D	Center of start zone to top big beacons 28.77"	Design team	Standard
		Kinematics		
11/20/2016	W	Stationary base	Design team	Design team
		Assembly		
11/20/2016	W	< 30 second set up time per run	Design team	Design team
		Actuators	Design team	
11/5/2016	D	≤ 2 DC motors	Design team	MCHE 201 kit
11/5/2016	D	≤ 3 servo motors	Design team	SparkFun kit
11/5/2016	D	Solenoid	Design team	MCHE 201 kit
		Electronics		
11/20/2016	D	Use 1 Arduino controller	Design team	Sparkfun kit
11/20/2016	D	Use 1 motor driver shield	Design team	MCHE 201 kit
		Sensors	Design team	
11/5/2016	W	Infrared sensor	Design team	MCHE 201 kit
11/5/2016	W	≤ 3 Flex Sensors	Design team	SparkFun kit
		Consistency		
10/27/2016	W	Achieve minimum score of 60 points per round	Design team	Team
10/27/2016	W	Run time between 25-28 seconds	Design team	Team
		Power	Design team	
10/27/2016	D	5 V potential difference	Design team	Standard
		Safety	Design team	
10/27/2016	D	Maximum operating temperature for DC motor 50°C	Design team	Standard

Some of these are solution priciples/ ideas, not subfunctions.

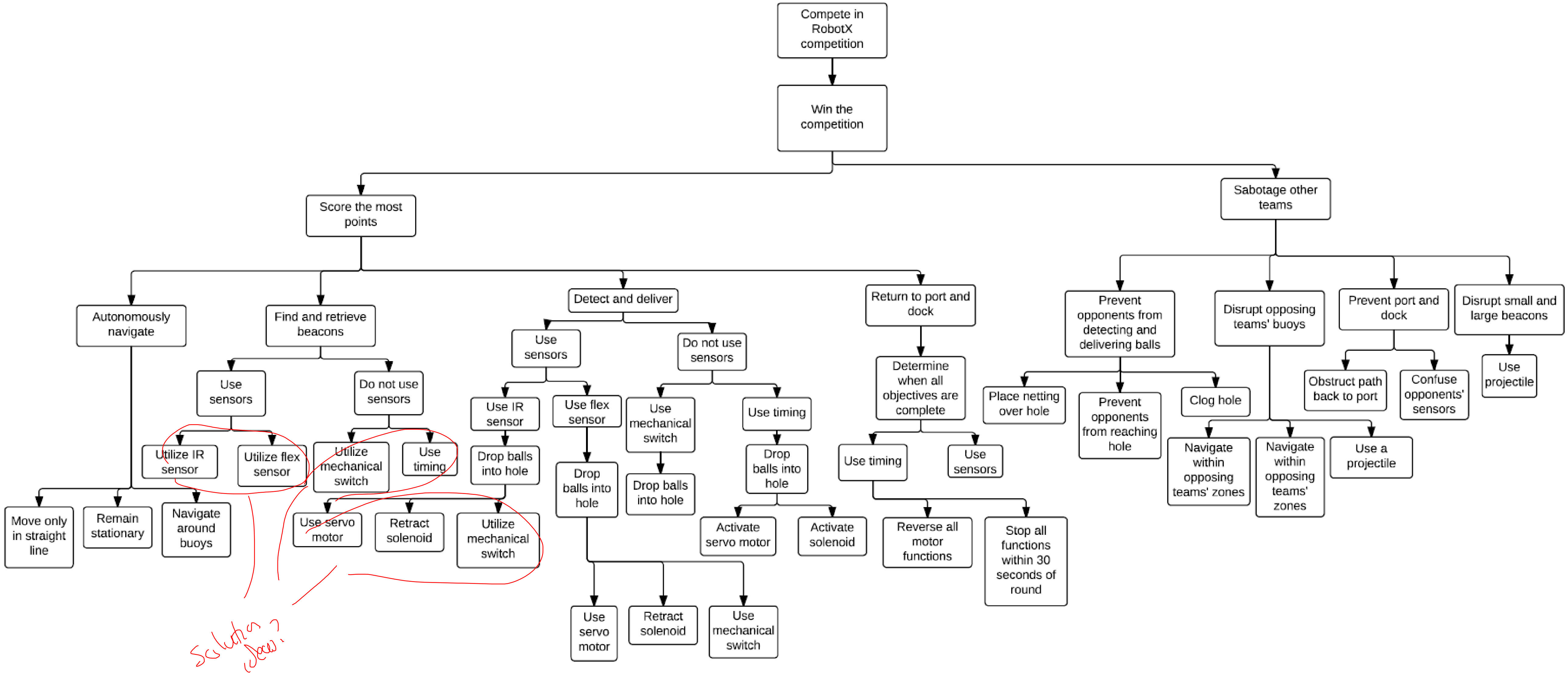

Figure 6 - Function tree

IV Concept Evaluation

Before a final design can be chosen, a concept evaluation process must take place to ensure that the best design is selected. There were two alternative designs considered for this project. Alternative design 1 is a car type device designed to drop the balls in the inner ring and grab two smaller beacons. Alternative design 2 is another car type device, and is designed to grab the small and large beacons. The first alternative design rolls on five wheels. A side view can be seen in Figure 7 and a top view in Figure 8. One wheel is powered by a motor, while the other four are free to spin. A PVC pipe is mounted vertically and then extends outward, forming the shape of a “7”. This vertical arm is used to drop the ping pong balls in the hole. Mounted to the lower part of the vertical arm is a rotating arm that is used to grab two of the small beacons. After the balls are delivered, the drive motor begins to drive backwards and the rotation of the lower arm is powered by a servo motor, rotating it downward 90° to drag the beacons back to the data processing center and then rotating it back up 90° to its original position.

The second alternative design rolls on four wheels which are powered by the larger motor. A side view can be seen in Figure 9 and a top view in Figure 10. Mounted to the front of the device is a rotating arm used to grab the small beacons, similar to the one in the previous alternative design. The smaller motor is mounted vertically in the center of the device and is connected to an arm with a claw on the end. This arm is able to rotate a full 360° and is used to grab the large beacons. As each large beacon is grabbed, the arm rotates and places them inside the arm used to grab the small beacons. Once all of the beacons are collected, the robot rolls back to the start zone and then retracts the front arm back to its original position.

The first level evaluation matrix seen in Table 3 sets the drawer slide tower as the datum and compares it with the two alternative designs by saying if it is better (+), worse (-), or the same (S) for each requirement. The selected design was better than or the same as each alternative design for every requirement besides the requirement to “retrieve and deliver beacons”. The second level evaluation matrix in Table 4 gives the designs a ranking for each customer requirement, and then calculates a relative and absolute total for each design. The chosen design received the highest relative total, 0.88, compared to alternative design 1, 0.68, and alternative design 2, 0.62. These results support the selection of the final design.

The main advantage of this design is the fact that the main body of the robot never moves out of the start zone. This makes the task of returning to the start zone much simpler, because it limits the motion of the robot to a straight line, eliminating the possibility of it getting “lost” or moved off course by an external factor. This is why the chosen design received a higher score for the requirement to “return within start zone” on the 2nd level evaluation matrix. Another key advantage is that the top arm extends out a total of 32.1 inches and only requires the motor to move 18.3 inches, as seen in Figure 3. This greatly reduces the time that it takes to reach the inner circle and allows the robot to deliver the balls into the hole faster than any other robot. The final design was chosen because it excelled at delivering ping-pong balls, avoiding the navigation buoys, and returning to the start zone, even though both alternative designs outperformed it at retrieving both the small and large beacons.

Use a 3rd level matrix for "final" evaluations.

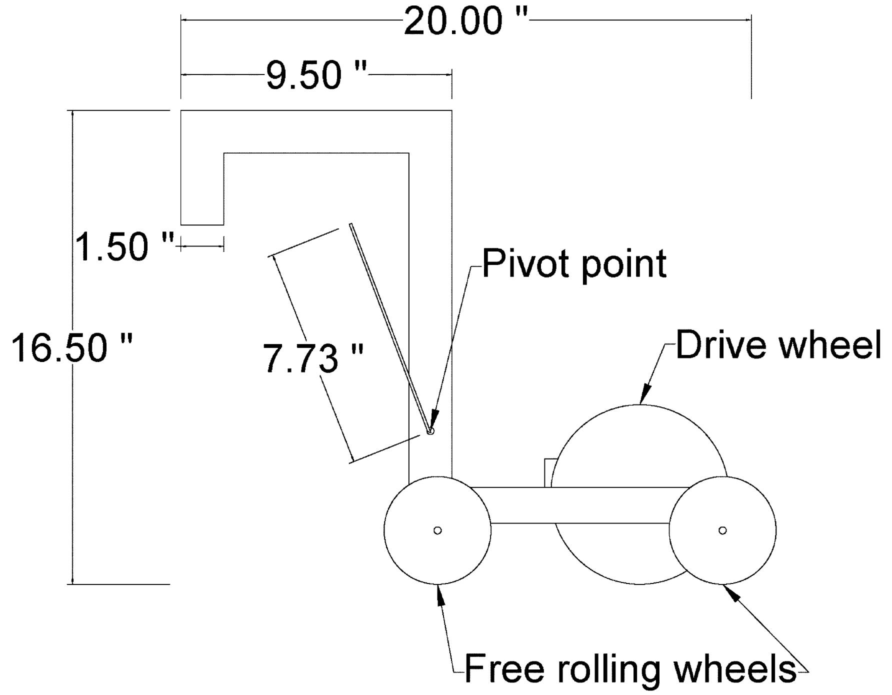

Figure 7 - Side view of alternative design 1

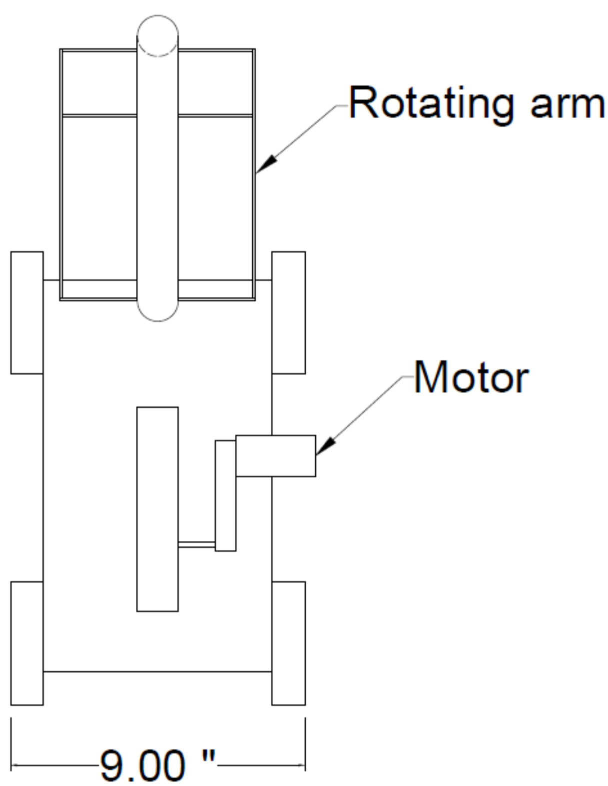

Figure 8 - Top view of alternative design 1

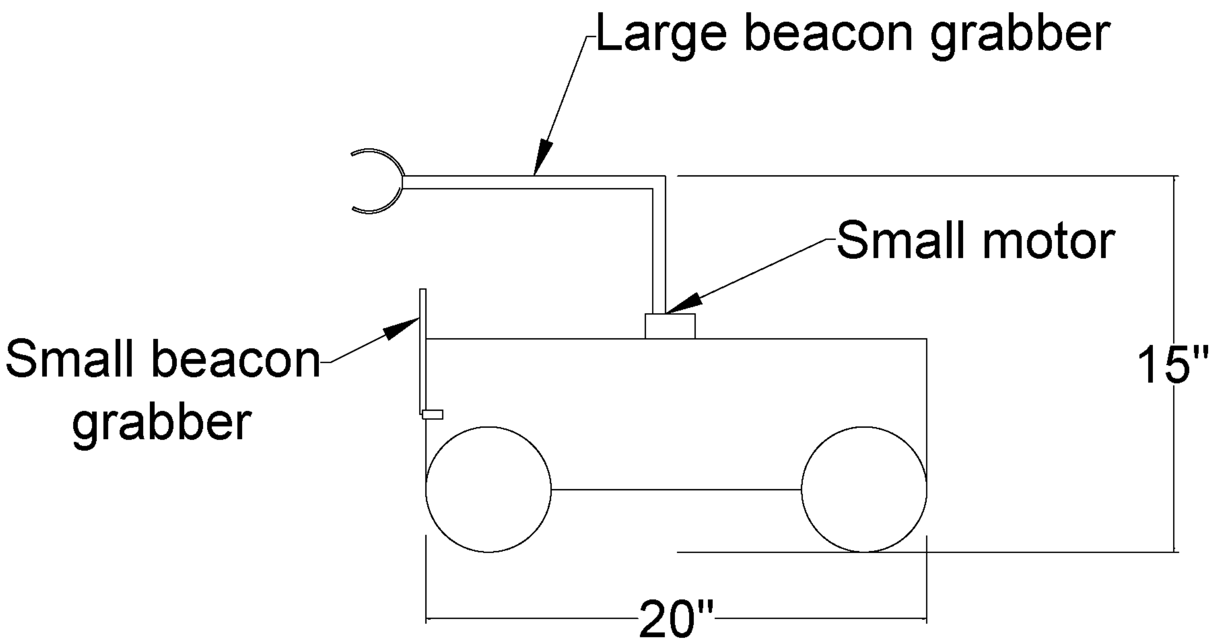

Figure 9 - Side view of alternative design 2

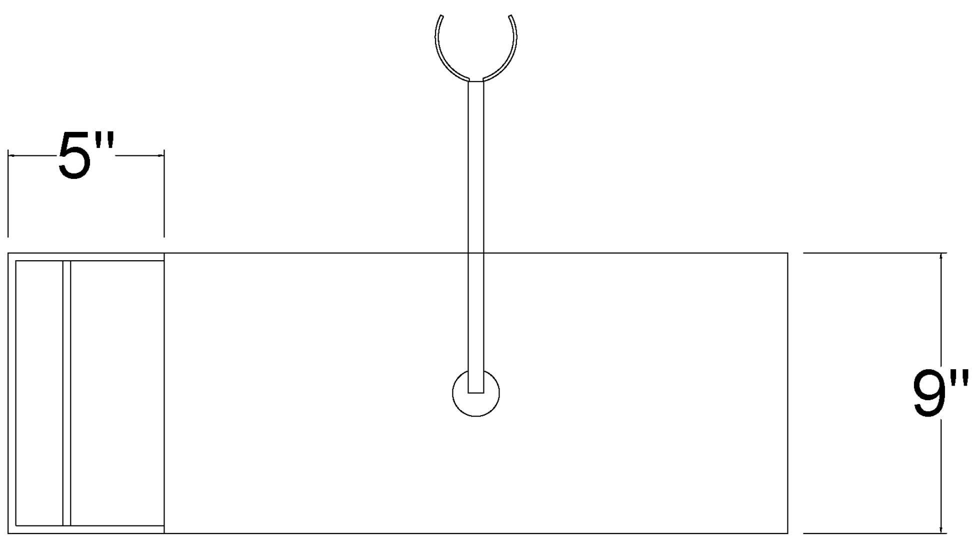

Figure 10 - Top view of alternative design 2

These should match the HoQ

Table 3 – 1st level evaluation matrix

Customer Requirements	Drawer Slide Tower	Alternative Design 1	Alternative Design 2
Fit inside of a 12" x 24" x 18" box	Datum	S	S
Components cost no more than $100		S	-
Can only run for 30 seconds		-	-
No initial elastic potential energy		S	S
Avoid buoys		-	+
Deliver balls		-	+
Retrieve and deliver beacons		+	-
Operate autonomously		-	-
Initiated by track		S	-
Return within start zone		-	-

These should match the HoQ

Table 4 – 2nd level evaluation matrix

Customer Requirements	Drawer Slide Tower	Alternative Design 1	Alternative Design 2
Fit inside of a 12" x 24" x 18" box	5	5	5
Components cost no more than $100	5	4	2
Can only run for 30 seconds	4	3	3
No initial elastic potential energy	4	4	4
Avoid buoys	5	2	5
Deliver balls	4	3	5
Retrieve and deliver beacons	2	4	1
Operate autonomously	5	3	3
Initiated by track	5	3	1
Return within start zone	5	3	2
Absolute Total	44	34	31
Relative Total	**0.88**	**0.68**	**0.62**

V Design Performance Evaluation

This design tied for 17th out of 23 teams in the final contest, earning a robot performance score of 3.2 out of 8. It earned 3.49 out of 5 grade points for the design review. It advanced past one round and lost two rounds. These results did not meet the expectations of the design team, and resulted from insufficient testing of the design along with malfunctioning sensors and faulty coding. The first two rounds resulted in 15 points for delivering the balls over the outer ring. The servo used to drop the balls did not initiate either round due to the infrared sensor malfunctioning, preventing the robot from returning to port. The final round resulted in 35 points for returning to port. The code malfunctioned and the robot went forward five inches and returned to the start zone.

During the problem understanding process, the design team failed to focus on testing the device prior to the competition. Doing so would have given the team a chance discover and attempt to fix the faulty sensor. This should have been listed on the specification sheet under the category of consistency and/or as a functional requirement on the house of quality. Another requirement the design team should have included is a fail-safe in the code that would force the servo to activate and return process to initiate if the IR sensor had not been triggered by a certain time. This should have been included in the house of quality and the function tree, and would have resulted in additional points for releasing the balls into the inner zone and retuning to port in each of the first two rounds. If these issues had been addressed in problem solving process, the selected design would have remained the same. Addressing these issues would have helped to improve the execution the selected design, resulting in a better performance during the competition.

VI Conclusions

Spell out to start a sentence.

23 teams were challenged to design and construct a robot to compete in the RobotX competition. The selected design was a stationary metal tower with two drawer sliders that act as arms. This design was selected by using problem understanding tools such as a house of quality, specification sheet, and function tree along with evaluation matrices for concept evaluation. During problem understanding, it was determined that the key requirements to focus on were delivering the balls, returning to the start zone, and avoiding the navigation buoys. Despite high expectations, the robot scored only 3.2 out of a possible 8 performance points and 3.49 out of 5 points for the design review.

Avoid. It's basically 1st person.

The design team achieved a thorough understanding of the problem at hand through the use of design tools such as a house of quality, specification sheet, and function tree. Using this understanding, the team then conceived three conceptual designs and selected the best one through concept evaluation. The selected design was a stationary metal tower with two drawer sliders that act as arms. Despite high expectations, the robot scored only 3.2 out of a possible 8 performance points and 3.49 out of 5 points for the design review.

Too team-centric

Redundant with previous paragraph.