Team 9: RobotX Final Report

MCHE 201: Introduction to Mechanical Design
Fall 2016

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Abstract

This final RobotX project is based off of the Maritime RobotX contest held annually in Oahu, Hawaii. In the Maritime RobotX contest competitors are to create a robotic watercraft device that displays some major functions such as autonomously navigating, finding and retrieving beacons, detecting and delivering objects, and docking. The device that is to be constructed for this simplied version of this RobotX contest is to display the same basic functions on a much smaller scale. It must navigate autonomously, find and retrieve beacons in the form of small Tabasco bottles and bowling pins, detect and deliver ping-pong balls, and return to the start zone and dock. The main requirement for this device is to meet given dimensions, and the main characteristic for the device is to have the correct programming for the device to operate correctly. After evaluating several design concepts, a final design was chosen in order to effectively satisfy the most important customer requirements. The final design, named SIKTB 2.0, is a belt driven car with a mechanical ping pong ball dumping mechanism that also docks and ports. Before the contest took place judging was held based on aesthetics, ingenuity, and presentation. Results from the judging portion of the final contest concluded in an average of 8.01 points out of 10 for all three categories. Competition wise, the robot finished 9th place overall out of 21 participating teams.

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1 Introduction

The MCHE 201 final RobotX competition is based off of the actual Maritime RobotX contest held annually in Oahu, Hawaii. Teams from all over the world go to Hawaii to display their robotic watercraft device and to compete in a series of different skill competitions. The skills the robot must display in these competitions include autonomously navigating, finding and retrieving beacons, detecting and delivering objects, and self-docking and porting. For the MCHE 201 RobotX competition students must create a robotic device that performs and displays the same basic functions involved in the Maritime RobotX competition on a much smaller and simpler scale. The replica "competition waters" course for this competition, as seen in Figure 1, is a large square track broken down into color coded triangular zones for each team. Amongst each team's zone are cones that are not to be disturbed, beacons that are to be retrieved, and ping pong balls that are to be delivered to the inner or outer ring in the center of the track. The beacons include 4 mini Tabasco bottles evenly spaced around the outer ring of the competition track, and 2 large beacons placed along the edges of the individual triangular zones of the track. The beacons must be found, retrieved, and returned to the data center in order to obtain points for the task. The detect and deliver task includes delivering 3 ping-pong balls to either the outer ring or the rotating center hole. Returning to port and docking includes having your device completely return to the start area or "docking" after performing other functions. Each one of these tasks completed will be rewarded by a certain amount of points based on the diculty of each function. All of these tasks must be completed in a 30 second time span by the created robot, leaving it up to the teams to determine what tasks the device will be programmed to do based on the maximum amount of points attainable in that time period. The next section of this final report will first explain the final design in full detail. Next, in Section 3, the customer requirements and specifications for this project will be outlined. Then, in Section 4, alternate design concepts will be discussed and argued. Then, in Section 5, the overall performance of the final design in the final competition will be reviewed, and finally conclusions are presented in Section 6.

2 Final Design

After fully understanding the contest and key customer requirements, a final design with the name of "SIKTB 2.0" was selected. SIKTB 2.0 stands for "Simplicity is the Key to Brilliance" and the 2.0 was added after some minor changes were made. This design focuses on detecting the inner ring, delivering the ping pong balls to it, and docking and porting itself. The final design concept, as seen in Figures 2 and 3, stands at 17 inches tall, 22.5 inches long, and 10 inches wide. The dimensions of the final concept are just small enough to fit perfectly in the 18 by 24 by 12 inch size box. The final design concept operates autonomously via a simple drive belt, and delivers the ping pong balls by a mechanical dumping mechanism.

The device has a large DC motor mounted to the top of the base which powers the entire thing. A rubber O-ring used as a belt wraps around the DC motor drive shaft on one side, and wraps around the drive axle on the other. As the motor shaft rotates, the belt rotates the drive axle, and thus the system moves autonomously. The devices detect and deliver function includes a cup mounted at the top via a steel rod with a red tilt lever attached to the bottom. As the device rolls

up to the inner circle the tilt lever hits the outer edge, which causes the cup to rotate around the steel rod, thus dumping the ping pong balls into the inner circle. After about a 2 second delay the device begins moving backwards until it reaches the start zone. Once the device gets completely into the start zone it stops moving thus docking and porting itself.

3 Problem Understanding

Based on the full understanding of the contest and what it entails, key customer requirements were deciphered and prioritized based on their level of importance via the House of Quality, as seen in Tables 1 and 2. The most important customer requirements include the main functions the device must display, the device must fit into the start size box, and the device must have the proper coding that correlates to its main functions. Key specifications that result from these main customer requirements are outlined by the Specification Sheet, as seen in Table 3. Based off the customer requirement of fitting inside the start sizing box, the device itself must have dimensions below 18 inches tall, 24 inches long, and 12 inches wide. If the device were to not meet this specification the device would not be allowed to participate whatsoever, making this spec the first main priority. Another vital requirement is the correct programming and coding that directly correlates to the devices main functions. The conceptual idea of a design can sound great on paper, but without the correct programming the device will be inert, making this customer requirement essential to the overall performance of the robot during the competition. The main functions that the robot must display are also very important customer requirements. These functions, as shown in Figure 4 by the Function Tree, include autonomously navigating, detecting and delivering ping pong balls, finding and retrieving beacons, and docking and porting. Points are scored in the competition based off of these main functions, therefore having a device that displays these main functions is vital to ensure good competition performance.

Each one of the main customer requirements and the specifications that result from them build off of one another and go hand in hand. The robot must meet dimension requirements in order to participate, the device must have the correct programming in order to display the main functions, and the device must display the main functions in order to perform well in the competition. All of the requirements, specifications, and functions come together to ultimately reach the goal of satisfying the customer and doing well in the RobotX competition.

4 Concept Evaluation

With programming and design capabilities in mind, the final concept design was chosen based on common sense and with the support of the Evaluation Matrix, as seen in Table 4. The evaluation matrix shows that out of all the customer requirements the final design chosen would be able to satisy the most requirements. SIKTB 2.0 was chosen in order to represent the basic theme that its name implies, simplicity. After undergoing several preliminary and qualifying rounds for this competition, it seemed as if most teams created such elaborate devices but when competing took place none of them actually worked. Although the final design was not projected to obtain as many points as other design concepts, the final design was more probable, more consistent, and more

reliable than any other design.

The first alternate design concept, seen in Figure 5, consists of a box structured device that mainly focuses on detecting and delivering the ping pong balls, and retrieving all 4 Tabasco bottle beacons. This device autonomously navigates using the small DC motor and a gear system. One gear is fastened to the motor drive shaft, and another gear is fastened to the rear axle. As the motor rotates its drive shaft, the gear rotates the other gear on the axle and the device moves forward. Once it approaches and hangs over the inner circle the ping pong balls housed in the PVC ball holder will remain in the holder until the flex sensor is triggered. The flex sensor is triggered when the rotating hole passes by and it senses the depth change, once the sensor is triggered it drops the ping pong balls into the inner circle. Meanwhile, a mini-servo rotates a long and curved beacon retriever arm downwards so that it sits behind all 4 beacons. After about a 2 second delay the device begins moving backwards, dragging the beacons until the beacons are placed in the data zone. This design concept was designed to obtain as many points as possible without thinking about any other limitations. Based on knowledge and skills with the Arduino programming system, this design was considered too complex and difficult to create. Another problem with this design is that its dimensions are exactly the same as the size box, thus making almost impossible to fit inside the start box so it can compete.

The second alternate design concept, seen in Figure 6, is a tank like device that mainly focuses on retrieving the beacons, and docking and porting. This system navigates autonomously via the small DC motor and a tank-like track system. As the DC motor shaft rotates, the tank tracks rotate thus moving the device forward and backwards. This device is designed to drive up to the edge of the outer ring, retrieve as many beacons as possible, and then dock and port itself. Since the very small overall size of the device limits the beacon retriever arm size, this device was deemed capable of only retrieving 2 beacons. Once it retrieved the beacons in the same fashion as the previous design, it drops them off in the data zone and docks and ports itself. This device would have been very simple to create and program but the very small amount of points that would result from it were unacceptable.

5 Design Performance Evaluation

The final robot design, SIKTB 2.0, finished in 9th place overall out of 21 participating teams. In the first round the robot finished 2nd out of the 4 teams by obtaining 80 total points for delivering all 3 ping pong balls into the center hole and docking itself. This advanced the device into the winners bracket. The next round did not go so well, being that there was another team whose robot covered the center hole, SIKTB 2.0 was not able to deliver any balls into the center hole, resulting in a 4th place finish. This put the robot into the losers bracket, and in the next round the robot delivered only 1 ball into the center hole and docked itself, resulting in a 3rd place finish for that round. The double loss resulted in SIKTB 2.0 being eliminated from the contest. Prior to the competition judging was held based off of aesthetics, ingenuity, and presentation. The final design resulted with an average of 8.01 points out of 10 for all three categories.

The main tendency for all teams in the contest seemed to be detecting and delivering the ping pong

balls, and docking and porting. This assumption was made during the design process and it was deemed correct being that the most points and the easiest points were achieved through detecting and delivering, and docking and porting. Another assumption made was that the beacons, being worth 5 points each, were deemed far less important than focusing on the ping pong balls which was also proved correct during the competition. The assumptions made during the design process were all proven correct, therefore arguing that the design chosen was the best fit for this final competition.

Point to design tools to support this.

6 Conclusion

The final RobotX competition for the MCHE 201 design class involves creating a robotic device that autonomously navigates, finds and retrieves beacons, detects and delivers ping pong balls, and docks and ports itself. Each one of these tasks were rewarded with a certain amount of points based off the difficulty of each task. The competition consisted of multiple rounds of 4 teams competing at once. The winner of the competition was the team whose robot made it to the final round and scored the most points. A final design named "SIKTB 2.0" was chosen and created by Team 9 for this competition that would meet the most possible customer requirements, be the most reliable and consistent, and have the best chance for success in the final competition. This design consists of a DC motor driven car that uses a belt system to move forward and backwards, and a mechanical dumping mechanism that delivers the ping pong balls into the center hole. SIKTB 2.0 finished 9th place overall out of 21 total participating teams.

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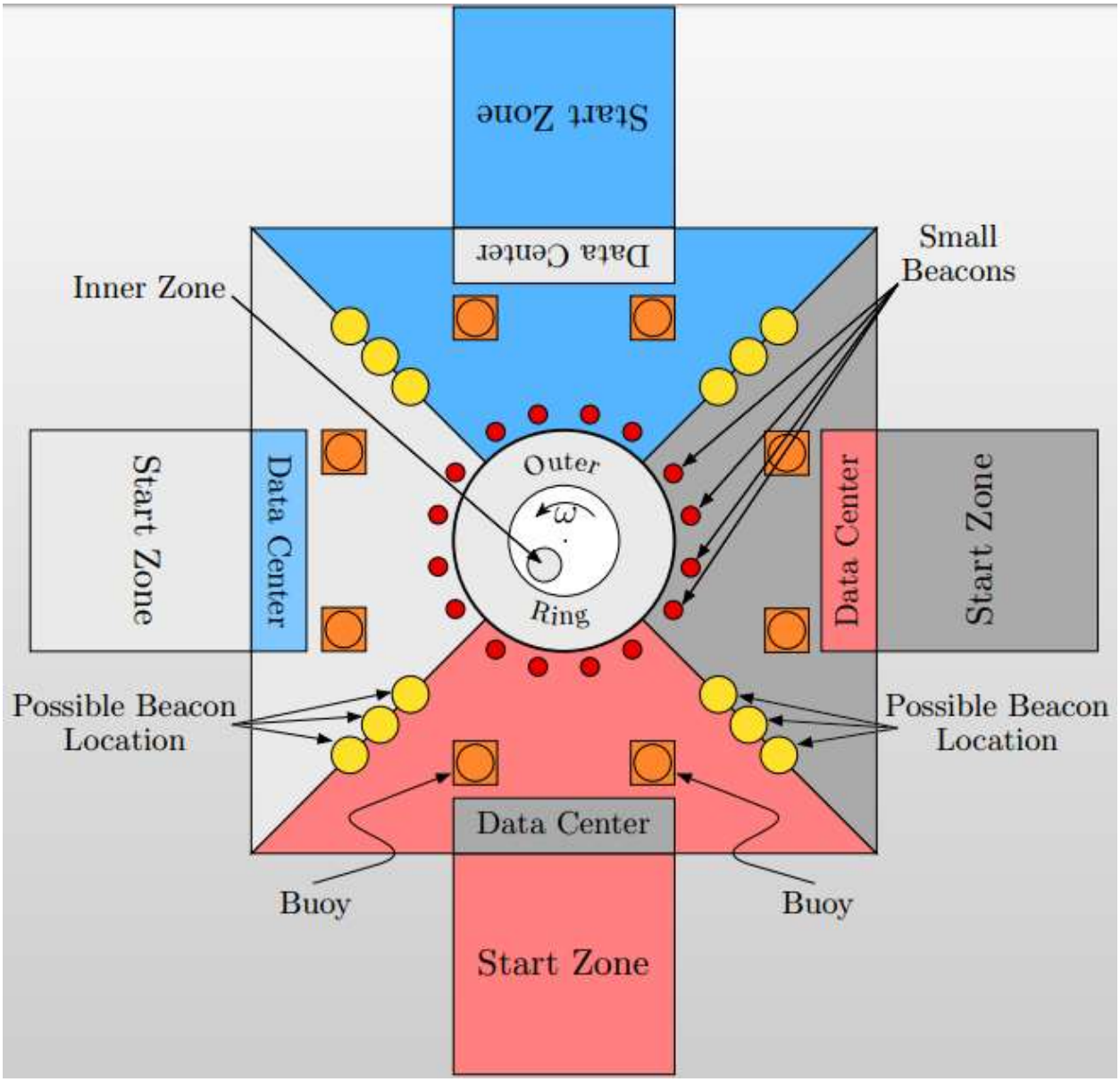


Figure 1 - "Competition Waters" Course [cite course] As is, this is plagiarized.

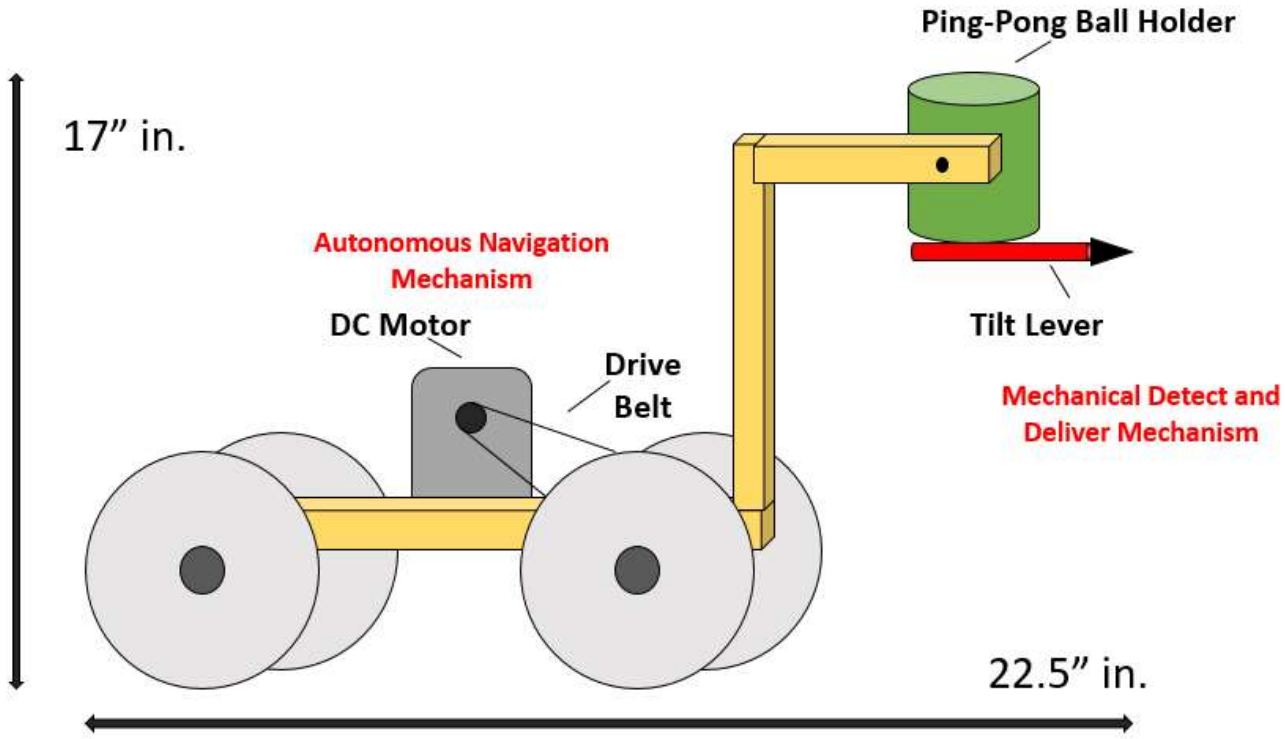


Figure 2 - Final Design

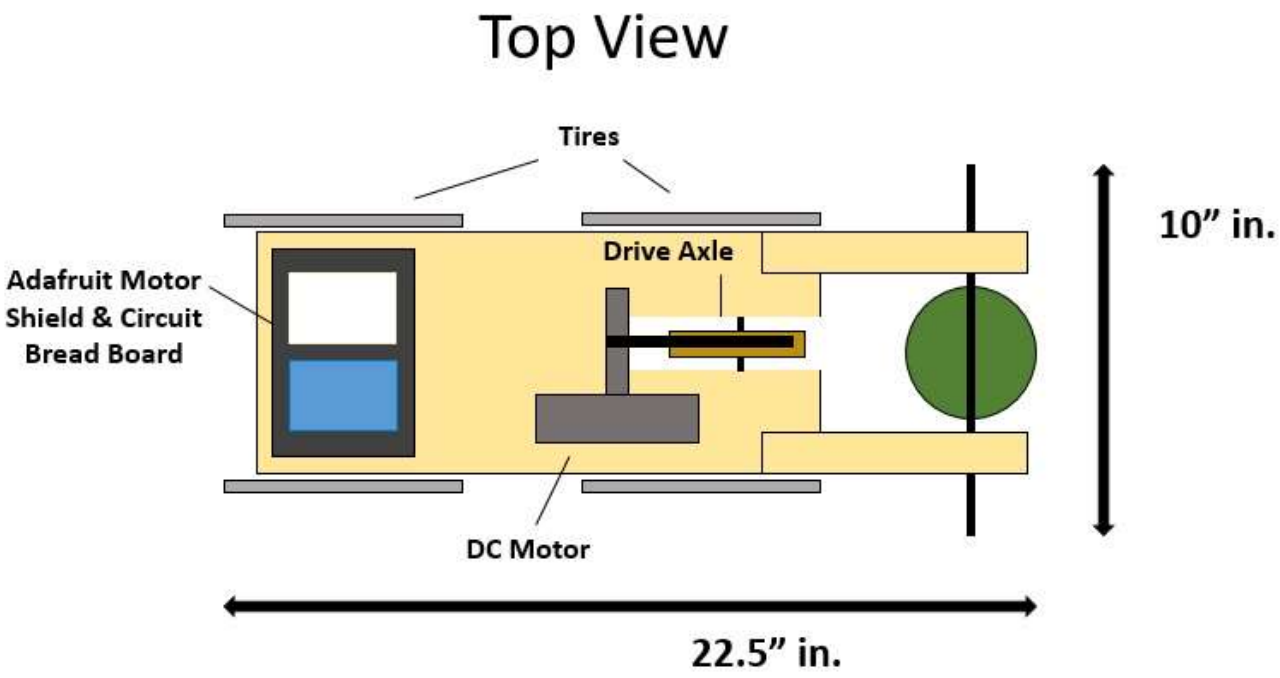


Figure 3 - Final Design (Top)

Table 1 - House of Quality (Top)

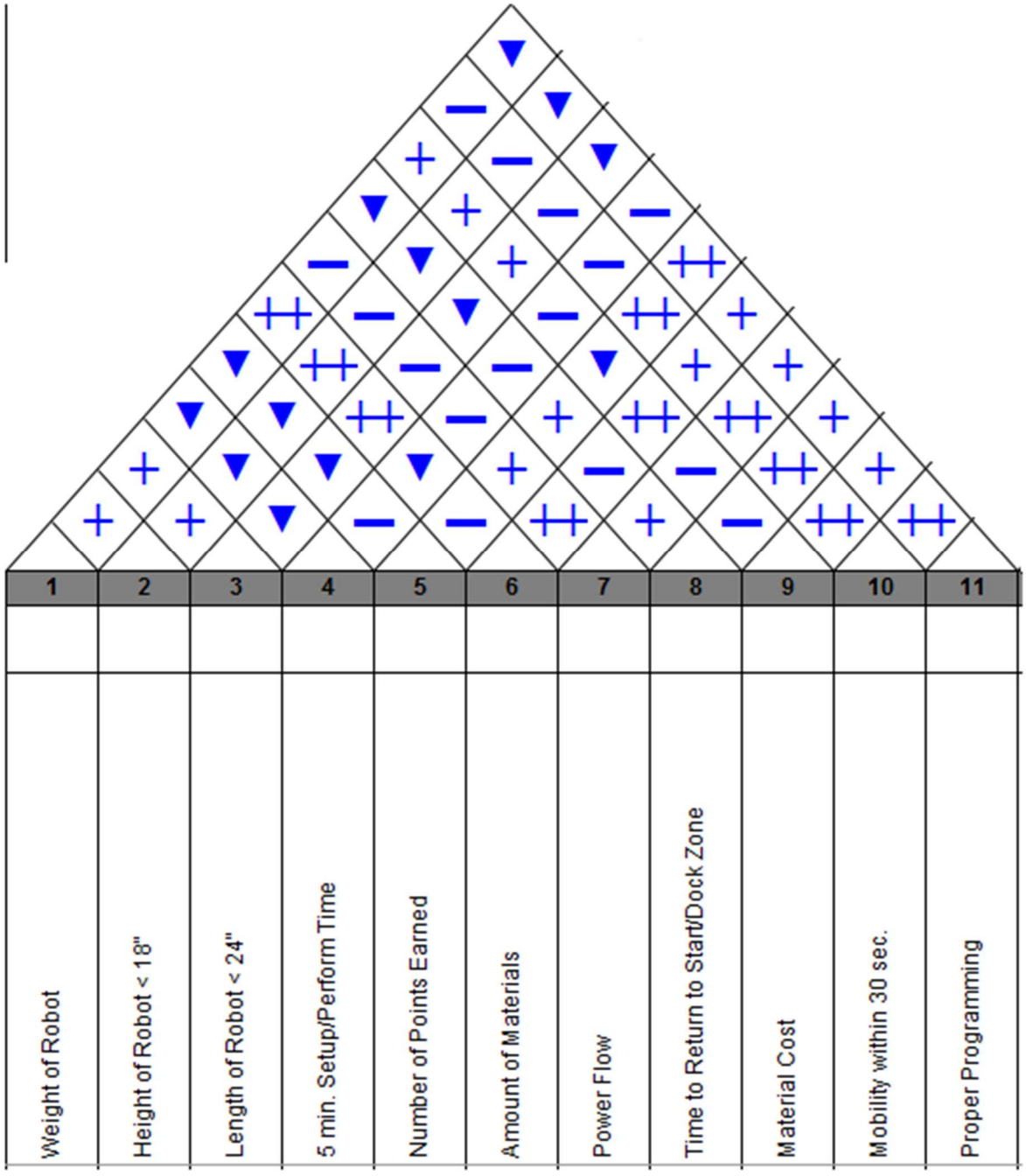


Table 2 - House of Quality (Middle)

1	9	10.6	10.0	Navigate Autonomously	○	○	○		⊙		○	⊙	⊙	⊙	⊙
2	3	2.1	2.0	Force of Gravity	○										▲
3	3	10.6	10.0	Fit inside Start Zone/Size Box	○	○	○			○			▲		
4	9	8.5	8.0	Setup within 3 minutes				⊙						▲	
5	9	9.5	9.0	Complete All Tasks				○	○			⊙	▲	○	⊙
6	9	7.4	7.0	Find and Retrieve Beacons	▲	○	○		⊙	⊙	⊙	⊙	⊙	⊙	⊙
7	9	10.6	10.0	Deliver Ping-Pong Balls		○	○		⊙		▲	▲		○	⊙
8	9	10.6	10.0	Return to Start Zone/Dock							○	⊙	▲	⊙	⊙
9	9	2.6	2.5	Aesthetically Pleasing	▲	▲	▲	⊙	○	▲			⊙		
10	3	8.5	8.0	Easily Manufactured	▲	▲	▲	○	▲	○	○	○	○	○	▲
11	3	5.3	5.0	Start at Equilibrium	○	○	○	▲		▲			▲		○
12	9	4.2	4.0	Locate Beacons			▲		⊙	○	▲	▲	○	⊙	⊙
13	9	9.5	9.0	Correct Coding				▲	○		○	○	▲	⊙	⊙
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)											
				Max Relationship Value in Column	3	3	3	9	9	9	9	9	9	9	9
				Weight / Importance	104.2	144.4	148.7	168.8	368.8	144.4	198.9	411.6	269.3	475.1	588.4
				Relative Weight	3.4	4.8	4.9	5.6	12.2	4.8	6.6	13.6	8.9	15.7	19.5

Table 3 – Specification Sheet

changes	D/W	Requirements	responsibility	source
	D	Deliver 3 balls	Design team	Comp. rules
	W	Retrieve 4 small beacons	Design team	Comp. rules
	W	Retrieve 3 large beacons	Design team	Comp. rules
	D	Return to start zone 30 sec	Design team	Comp. rules
		Geometry		
	D	12 x 18 x24 start box	Design team	Comp. rules
	D	Fit between buoys 14 in	Design team	Design team
	D	23 inches from start to edge of big circle	Design team	Design team
	D	Outer Ring diameter 22 inch	Dr. Vaughn	Comp. rules
	D	Inner zone diameter 12 inch	Dr. Vaughn	Comp. rules
	D	Small circle inside Inner zone 3 inch	Dr. Vaughn	Comp. rules
	D	Start zone 2 x 2 ft.	Dr. Vaughn	Comp. rules
	D	5 inch between beacons	Dr. Vaughn	Comp. rules
	D	1 inch between data center and buoys	Dr. Vaughn	Comp. rules
	D	Data center 6 inch	Dr. Vaughn	Comp. rules
		Materials		
	D	Cost less than 100 $	Design team	Comp. rules
	D	Arduino board	Design team	Comp. rules
	D	Large and small DC motor	Design team	Comp. rules
	D	servo	Design team	Comp. rules
	W	Wood < $20	Design team	Design team
	W	Plastic < $10	Design team	Design team
	W	String < $10	Design team	Design team
	W	Tires < $10	Design team	Design team
		Energy		
	D	Potential (gravity)	Design team	Comp. rules
	D	Electric (Arduino board) 5v	Design team	Comp. rules
	D	Motors	Design team	Comp. rules
		Cost		
	D	Less than 100 $	Dr. Vaughn	Comp. rules
	W	Cost 40 $	Design team	Design team

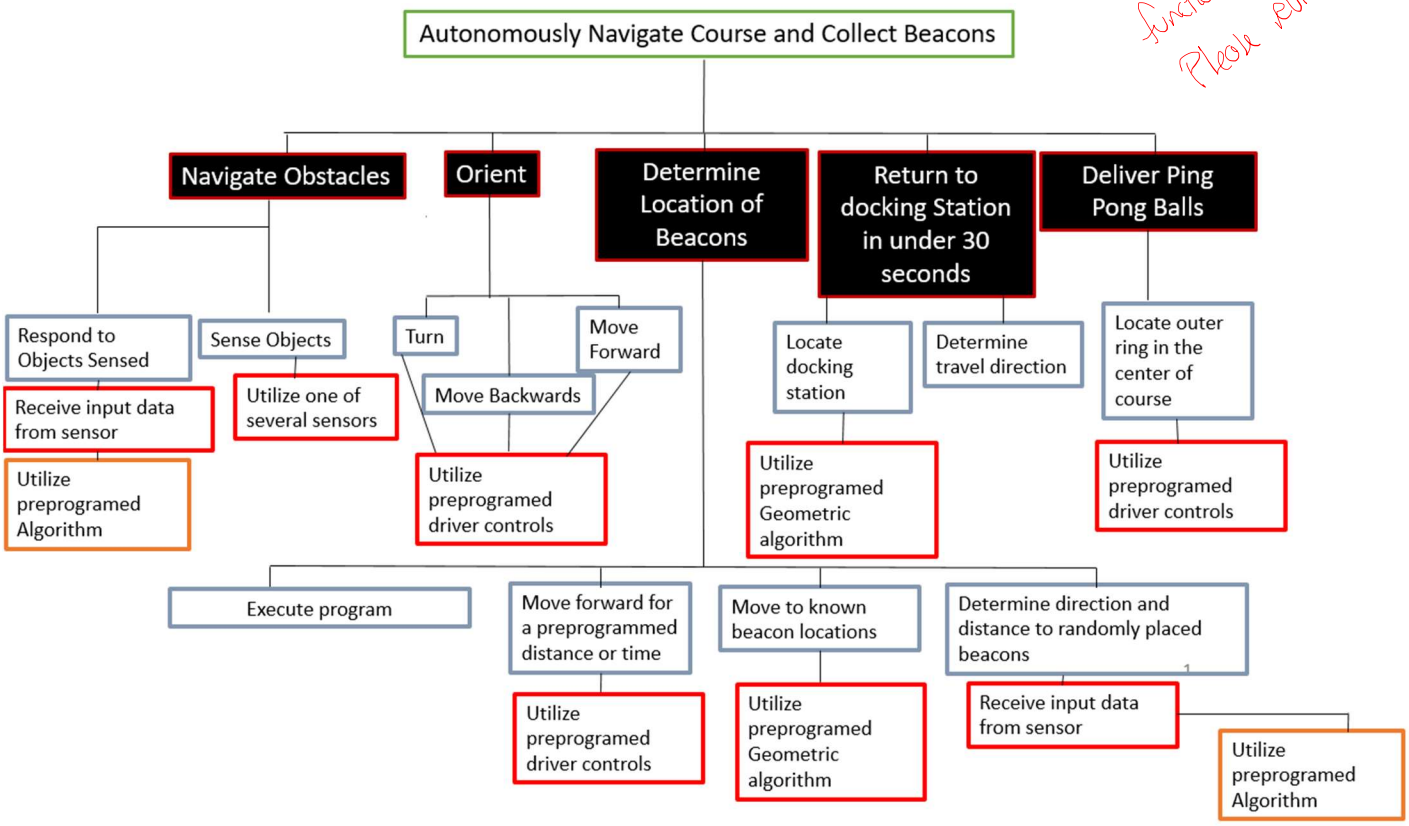
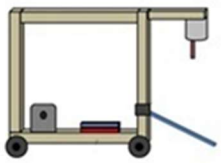
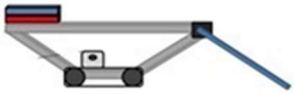
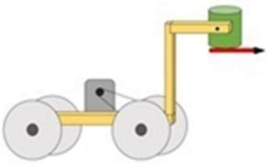


Figure 4 - Function Tree

Table 4 - Concept Evaluation Matrix

Customer Requirements	Importance (1-10)	 Concept 1	 Concept 2	 Final Design
Autonomously Navigate	10	4	4	4
Retrieve Beacons	9	3	3	3
Fit Inside Start Box	10	0	4	3
Setup and Perform within 6 minutes	10	3	3	4
Complete all Tasks	8	2	2	2
Locate and Retrieve Beacons	9	3	3	3
Detect and Deliver Ping Pong Balls	9	3	0	4
Return to Start Zone (Dock and Port)	9	2	3	4
Aesthetically Pleasing	5	2	2	3
Easily Manufactured	8	1	2	3
Proper Coding/Programming	10	1	3	4
Absolute Total		213	263	331
Relative Total		0.549	0.678	0.853

Scale	Score
0	Unsatisfactory
1	Tolerable
2	Average
3	Good
4	Excellent

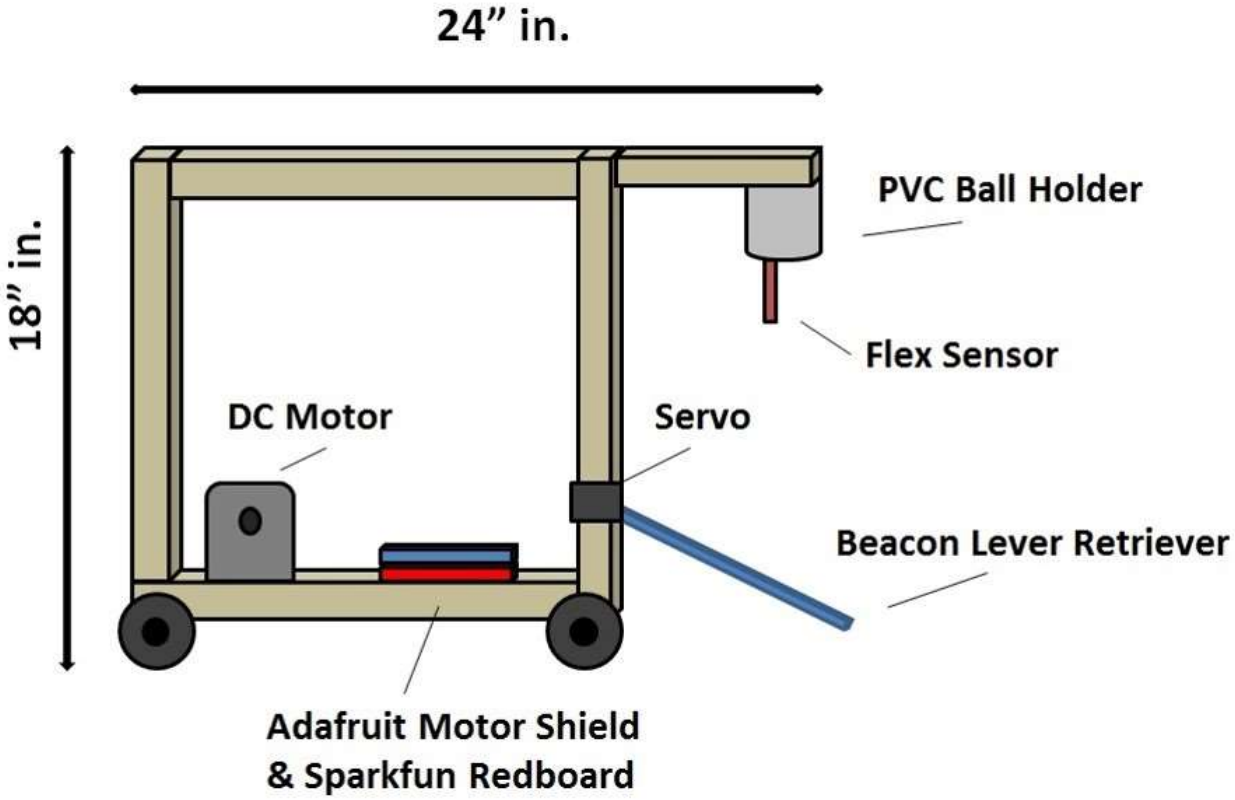


Figure 5 - Alternate Design 1

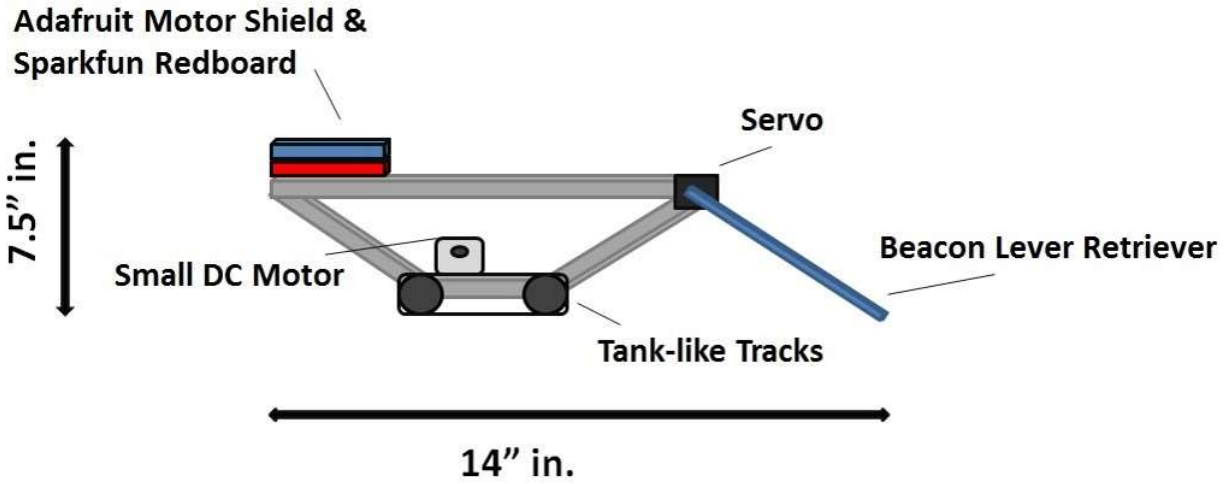


Figure 6 - Alternate Design 2