Stod Bot

10.14.16

Design Team 6
RBE 1001 Final Project Robot
Worcester Polytechnic Institute

Member	Signature	Contribution
Clayton Dembski		34%
Nicoli Liedtke	Nicoli Liedtke	31%
Floris van Rossum	F Rossum	35%

Grading:		
	Presentation	____/20
	Design Analysis	____/30
	Programming	____/30
	Accomplishment	____/20
	Total	____/100

Table of Contents

List of Figures:

List of Tables

1. Introduction:

Savage Soccer is a WPI held Robotics competition that is directed towards FIRST Robotics. The competition was created to give students an atypical yet engaging, condensed environment that both promoted collaboration and served as an introduction to mechanical engineering, electrical engineering, and computer science. Each year's specific task revolves around the manipulation of a particular object (or set of objects) into a set goal structure. This is further complicated by addition of a second coalition and the advent of side-objectives which enhance the complexity of the playing field.

In 2015, Savage Soccer 19 was unveiled and the next round of competition began. Foam Frenzy pits the two coalitions together in an 8 by 12 foot, rugged field of FOAMS. 6 FOAMS are placed in front of the Central Uber Block Element (CUBE, a 12’’ by 12’’ block with colored sides, that may be flipped, allowing for additional points to be scored) and one on each Gradual Accent Platform (GAP). Each of these Foams of Advanced Manipulation may be scored in 1 of 4 ways: into the Low Universal Goal Scoring (LUGS), a large trapezoidal frame lined anterior to the front wall and set between the teams, into the Middle Universal Goal Scoring (MUGS), a second, concentric trapezoid set behind the LUGS and extended 3 inches above the ground, into the High Universal Goal Scoring (HUGS), a third concentric trapezoid, set within the MUGS and raised 14 inches above the field, or into the Big Object With Little Sponges (BOWLS), set in the back corner of each teams sector. Once one FOAM is scored, more FOAMS will be poured into play in a select location, permitting for additional scoring.

A robotical design for this map must be integrated, yet adaptable, and capable of working both in the 20 second autonomous period, via sensors and the 2 minute user controlled period, via remote connection. It must include a transmission, a lifting device for FOAM Manipulation and must be under 10 pounds/ 15.25’’ by 15.25’’ by 18”. This leaves a high range of freedom for targeted creation: A robot must be made efficiently, as to cover as many tasks as possible, while still having high control for advanced manipulation.

2. Preliminary Discussion

The first thing that must be done as soon as a challenge is presented is an extensive analysis of the problem. A failure to do so will result in a flawed strategy which will snowball to become a massive problem in the future. Even with intensive rules analysis there will always be rules and limitations that were not correctly identified which will lead to mistakes that must be fixed in the future.

Our group started off by reading the rules and watching the reveal video independently this makes sure everyone can take their time to process the game. Soon after we held our first rules discussion where we started discussing the rules of the game. We started with fundamental rules such as the size limitations of the robot and the weight. We also paid special attention to the time each match took and what segments it was divided into (teleop and auton). We discussed the point values of all the goals that could be accomplished in the game and noted them in a document. Our group went over any parts of the rule that we were unsure about such as the scoring and moving of the bowl and interactions with opponents' game elements.

Once the rules were understood and everyone was on the same page we started developing strategies. A few of our group members, Nicoli and Floris, had previous experience with creating robots in high school for the FIRST programs. We were able to apply our knowledge of strategy and rules analysis to this challenge as well. We started listing any possible strategies in a Google Drive Doc. We listed the maximum possible point values and complexity for each strategy in autonomous, teleoperated and endgame periods.

Teleoperated Strategies:

Strategy	Description	Total Points	Difficulty (1-10)
BOWLS to RAP to MUGS	1. Carry the BOWLS under the RAP 2. Expel FOAM from autonomous period into the LUGS 3. RAP will tip into BOWLS 4. Carry BOWLS into MUGS 5. Score any additional FOAM into the MUGS	90 pts	7

BOWLS to RAP to HUGS	1. Carry the BOWLS under the RAP 2. Expel FOAM from autonomous period into the LUGS 3. RAP will tip into BOWLS 4. Carry BOWLS into HUGS 5. Score any additional FOAM into the MUGS	105pts	9.5
All MUGS	1. Score all possible FOAM into MUGS	87 pts	6

Table 2.1

Analysis and comparison of Teleoperated Period Strategies:

The teleoperated (teleop) period of the match is undoubtedly the most essential part of the match where the most points are likely to be scored by any team. Therefore it is important to have a solid strategy for this period.

The 1st strategy listed in Table 2.1, BOWLS to RAP to MUGS, is a strategy that is moderately difficult strategy to pursue and yet it earns a fair amount of points. Lifting the BOWL under the RAP is a significant challenge that other strategies may not have, i.e. the "All MUGS" strategy listed in 3rd in

The 2nd strategy, BOWLS to RAP to HUGS, is very comparable to the first strategy except that the BOWL is scored in the HUGS instead of the MUGS. The difference between the first and second strategies is, of course, the difference in points but also a great increase in risk and difficulty of the second strategy. Therefore a proper analysis must be done in order to judge whether it is worth it to follow a more difficult strategy for a greater reward. A problem with both strategies one and two in Table 2.1 is that it is most likely a strategy more teams are going to ensue. But since there is only one BOWLS per alliance that could cause some complications. A mix of different strategies may be required to ensure that the robot can be useful when paired with a robot with a similar strategy.

Autonomous Period Strategies:

Strategy	Description	Total Points	Difficulty (1-10)
Climb GAP and intake FOAM	1. Climb the GAP 2. Intake the FOAM at the top of the GAP	10 pts	7
Climb GAP and score FOAM in the BOWLS	1. Climb the GAP 2. Score the FOAMS at the top into the BOWLS below the GAP	15 pts	8
Insane (Pickup BOWLS, place under RAP and score a FOAM)	1. Pickup the BOWLS 2. Drive the BOWLS under the RAP 3. Score a FOAM into the LUGS	~75pts	10+

Table 2.2

Autonomous Period Strategies Analysis and Comparison:

The autonomous (auton) period provides a team the opportunity to gain an early advantage in a match. Still the auton objectives are often difficult to complete and have a high degree of uncertainty surrounding them. Auton strategies might be done for setup for the teleoperated period and not just for points.

The first strategy listed in Table 2.2 is the Climb the GAP and intake FOAM strategy. This strategy is straightforward (not literally of course), it requires the tracking of the line, then driving up the ramp and then intaking the FOAM in preparation for the teleoperated period. It is assumed that intaking the FOAM will be of some benefit in the future and save time. It will be difficult to drive up the ramp as it is not that wide. Special attention should be given to solve this and ensure that the robot does not fall off in the beginning of the match.

The second strategy in Table 2.2 is climbing the GAP and scoring the FOAM at the top into the BOWLS below. It should be noted that this strategy is likely to be paired with strategy 3 listed in Table 2.1, All MUGS. This is because scoring the FOAM into the BOWLS will cause the RAP to tip all the FOAMS on the floor which makes it virtually impossible to score all the FOAMS into the BOWLS and then into one of the UGGS. Overall this strategy might be slightly more difficult than strategy 1 in Table 2.2.

The third strategy, Insane, is a complete reach. It is put on the table because it is technically possible but insanely difficult and would have a tremendous degree of uncertainty.

Endgame Period Strategies:

Strategy	Description	Total Points	Difficulty (1-10)
No touch carpet	Be off the carpet at the end of the match	10 pts	7
Rotate CUBE	Rotate the CUBE to ensure that your alliance's color is facing upwards.	10 pts	8.5

Table 2.3

Analysis of Endgame Period Strategies:

At the end of each match it is preferable to be able to score a final few points because it allows you to get ahead of your opponents using a different strategy and game elements. This is the case in this game as well, neither the CUBE nor the GAP is a focal point in the game until the endgame period of the match. Therefore a careful analysis of possible endgame strategies is required in order to win.

The rotation of the CUBE strategy, which is worth 10 points (pts), is an unusual aspect in the game because it allows you to deny your opponent points directly. This is because they would receive 10 pts if their respective alliance color is facing upwards. So the rotation of the CUBE in effect is worth 20 pts because it denies the enemy their 10 pts. However, because the CUBE is a point of interest for both alliances it complicates things. A battle can ensue around the CUBE which can result in neither of the two teams getting any points or the opposing team getting the CUBE points. The uncertainty surrounding this strategy is what makes it difficult to pursue this.

The other endgame strategy where the robot is off the carpet grants just as many points as moving the cube. Presumably in this strategy the robot would make its way onto the GAP. This strategy depends solely on your robot and driver’s performance that makes this task easier to accomplish and more dependable.

It is possible to turn both the CUBE and climb the GAP although this will take more time and an opponent robot can always rotate the CUBE to their alliances color in the time that your alliance climbs the GAP.

The Final Strategy:

Our strategy selected for the teleoperated period was to score the BOWLS in the MUGS once we filled it up at the RAP. So this is strategy 1 listed in Table 2.1. We went with this because scoring the BOWLS in the MUGS because it balances maximum points and complexity quite well. Aside from that we also chose to implement part of strategy 3 in Table 2.1. This is because we assumed that most people will attempt to move the BOWLS, and if they are more effective at it then our robot is virtually useless. Being able to intake FOAM and score them in the MUGS or elsewhere is a great advantage and gives us versatility that we need. In the autonomous period we hope to be able to climb the GAP for extra points but not score the FOAM as it will dump them on the floor instead of in the BOWLS. As endgame strategy we hope to be able to climb the GAP again to get the final points.

Additional Strategies:

Our final strategy allows for room for expansion, if we determine that we can do all of our primary strategy we might be able to add additional strategies such as flipping the CUBE or scoring in the HUGS. More on this topic in Problem Statement (Chapter 3).

3. Problem Statement

The robot will be designed and built to collect and deliver FOAMS to scoring areas and collect and the deliver the BOWLS to scoring areas. Goals have been separated into three focuses differing in level.

1. Primary Focus - The designs in this focus are most important. All goals in this focus need to be accomplished. Effort and materials should be put into the goals for this focus first.

- Collect FOAMS
- Store at least 3 FOAMS
- Be able to expel FOAMS
- Be able to move BOWLS
- Have an autonomous gives positional advantage
- Weigh less than 10 lbs
- Fit inside a 15.25” x 15.25” x 18” box
- Be able to traverse over the carpet.
- Have control over robot using remote control.

2. Secondary Focus - These goals must be tried. Effort and materials should be allocated to these goals, but without sacrificing any Primary Focuses. All goals in Secondary Focus should be completed, but the robot can still be successful if a few goals are not completed.
    - Expel foams into MUGS
    - Move BOWLS into MUGS
    - Have autonomous that scores points
    - Climb the GAP
    - Store at least 5 FOAMS
3. Tertiary Focus - These goals are only attempted after completion of all Primary Focuses and most Secondary Focuses. Tertiary Focuses can also only be attempted with ample time and resources. These focuses can be considered in design, but should not greatly influence design.
    - Store at least 7 FOAMS
    - Score FOAMS in HUGS
    - Score BOWLS in HUGS
    - Flip CUBE to team color
    - Move CUBE in front of opposing team’s GAP

4. Preliminary Designs

Overall Design Calculations:

As we want to be able to climb up the GAP in the autonomous period we need to have a low center of gravity. The following calculation shows the distance from the ground that our center of gravity can be. Although it is hard to be able to incorporate the center of gravity in our design at this point. It is something that needs to be remembered when designing and building the robot.

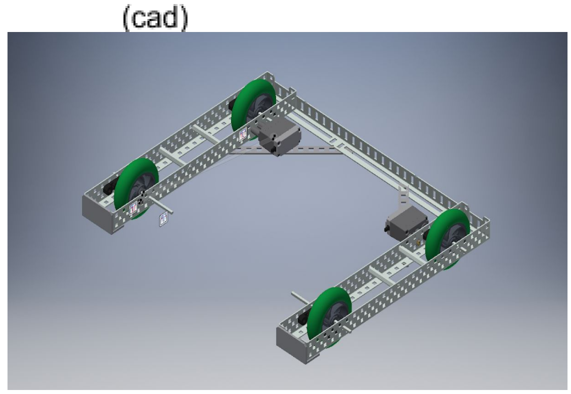
Assuming the CG_x *is located halfway along the length of our robot .*

$CG_x = 6in \ \ \theta_{ramp} = 8.39^\circ \ CG_y \ = 14.88in$

So the max height of our Center of Gravity is 14.88 inches. Although this does not incorporate acceleration forces, therefore it will be better to have a much lower CGy.

Drivebase:

Fig 4.1: Initial Drive Base (cad)

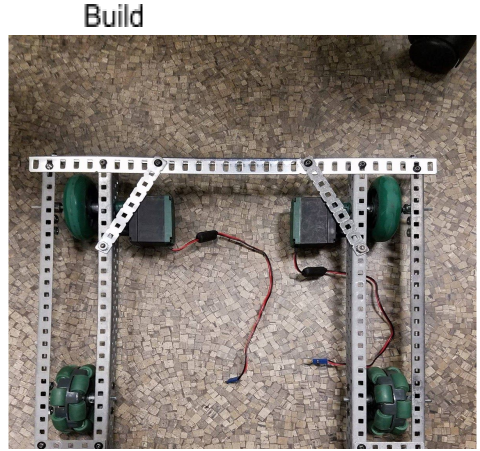


The drive base is the core of a robot, it helps your robot get from point A to B. In most games movement is essential to score points. The drive base is important for moving translationally but also determines what orientation you are in, something that is often underrated and disregarded.[1]

Initially we wanted to build a holonomic drive, but that was more because of the "wow" factor than anything else. We soon moved on and started thinking of a drive-base that met our needs.

The First Iteration of the Drive Base:

Fig 4.2 Initial Design Build



We started with a CAD model of the drive base (Figure 4.1). We came up with a U-shaped frame as it allowed us to put the

[1] Figure 4.1

bowl inside our robot and thus be less likely to tip over as we lifted the bowl inside our robot. We built the frame shortly and discovered that it was very prone to torqueing, even with the added cross-bars at the back. We were going to need a proper superstructure in the final robot that could make the drive-base more rigid. The CAD model is not completely accurate as the front wheels would be omni-wheels and not the basic vex wheels.[2]

Vex Basic Motor Calculations at 1:1 Gear Ratio
Assumed motor running speed: 90 rpm
Wheel D: 2.75in
(90*2π)/60= 8.9 rad/sec
V = r*w = 8.9 * (2.75)/2 = 12.86 in/s
Linear Speed: 12.86in/s
Torque max assuming efficiency of 90%: 3lbf

Powering the Drive Base:

We determined that we would power the wheels with a simple VEX motor module, as shown in Figure 4.1. But because we determined that we would meet our opponents directly on the field we would need more torque. So we added two 393 motors to the parts list and added them onto our robot. We were going to use the vex basic wheels as the drive wheels in order to make sure we have enough traction. As you can see in Figures 4.3 and 4.4 it is more advantageous to have the 393 as the drive motor as it will give our robot all the possible traction force that it could possibly have while still maintaining a fast speed.

393 Motor Calculations:
Wheel Diameter: 2.75in
Running speed: 85 rpm
((85*2π)/60)*(2.75/2)=12.24 in/s
Linear speed = 12.24in/s
Stall torque = 13.5 in*lb
13.5*0.9/1.365 = 8.84 lbf
8.84*2= 17.67 lbf pushing force from motors

Max force of friction: 12 lbf
(Assuming a robot weight of 10 lbf and a coefficient of friction of 1.2 and all weight on drive wheels)

So traction force = 12 lbf

The Virtual Turning Center

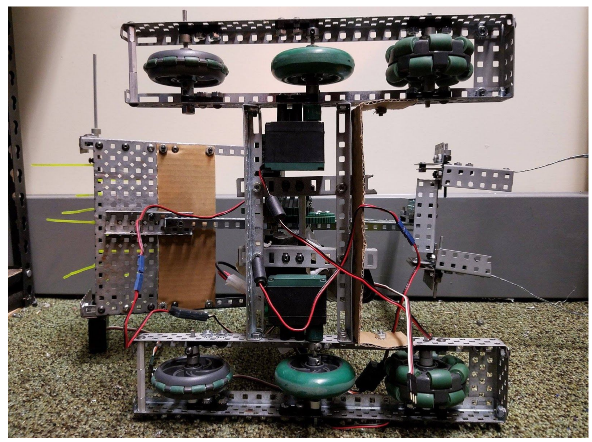
We identified early on that picking up the bowl was a challenge, even though we had not finalized the bowl lifting mechanism nor the intake, we knew that lining up was going to be a problem. So we chose to put our Virtual Turning Center (VTC) at the back so that we could put a mechanism there

[2] Figure 4.2

which the robot would turn around, making it easier to line up. Another benefit of having omni-wheels at the front of the robot was a reduced resistance to turning. In fact if we assume the omni wheels have no friction when rolling perpendicular to their axis of rotation around an axle, our robot will have no resistance to turning. So it should be easier for our robot to turn especially when hindered by FOAM.

Fig 4.3: Double U Drop Drive Base

The Second Iteration of the Drive Base



Shortly after we had finished prototyping the first drive base we found out that we would need an H-shaped frame to make room for both the Bowl Lifter and the Intake as they were both on an arm that could swivel. (More info under Intake and Bowl Lifter). This resulted in taking the first drive base apart and building the second one.

The second drive base inherited a lot of the characteristics of the first drive base. It was still powered by 393's but this time had omni-wheels on either side as shown in Figure 4.5 Because we had two sets of omni wheels on either side our VTC was now in the center which meant that it was easier to line up while intaking FOAM and lifting up the BOWLS on the other side. In order to make sure we have enough robot weight on the center drive wheels we had to drop down our center wheels making our drive base a drop center.

Overall our drive base is well designed around our selected strategy. Our drive base lets our robot move effectively across the field and interact with other robots and game elements.

Intake:

[3] Figure 4.3

The initial design of the intake (Fig 4.4-4.6) displays it as our most important accessory item. It is meant to perform consistently throughout every trial, and its allowance for imperfection allows for a high reliability and a failsafe for the four bar design. The intake is made up of 2 sets 6 rubber spoked wheels, set roughly a cubes length behind one another. Spinning clockwise, the spokes pull in a FOAM, cycling it into the base of the cage. To remove the foams, one may continue to spin both sets of intakes clockwise. The foam will travel to the rounded back of the cage, up, and around to the top of the rollers. This top is elevated a little over 3 inches, so that, as the intake rollers continue to spin, the foams are brought out over the height displacement of the MUGS. If the four bar fails or if the bowl is not placed in front of the RAP in time, the intake should be able to pick up the FOAMS in front of the CUBE and GAP, and any misc. FOAMS to score in the mugs. That way, they will at least be scored, even if not in the preferable way.[4]

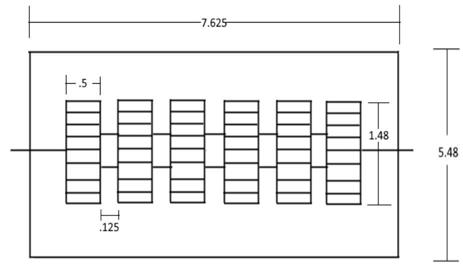


Fig 4.4 Intake: Front Veiw

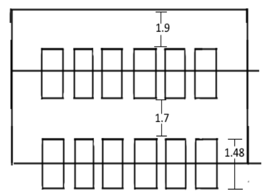


Fig 4.5 Intake: Top Veiw

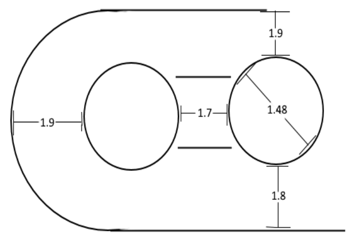


Fig 4.6 Intake: Side Veiw

$$FOAM_{max} = \frac{L_{IE}}{L_{cube}} = \frac{7.625''}{2''} = 3$$

The maximum number of FOAMs that may be accepted at one time by the intake driver is the length of the effective drive shaft (Fig 4.4) divided by the individual length of the FOAM

$$\tau = Ff * R * FOAM_{max} =$$

$$1.65N * .74'' * \frac{2.71cm}{1''} * \frac{10^{-2}m}{1cm} * 3$$

$$= 0.0993Nm$$

[4] Figure 4.4-Figure 4.6

The torque needed to intake the 3 cubes is the force of friction of the cubes when compressed .1 inches (experimentally determined), multiplied by half the diameter of the intake roller (fig 4.6) then multiplied by the number of cubes to be moved.

From the motor data given at a torque of ~.01N/m, the motor may operate without a gear train at 22% efficiency and a power of 0.9. The motor is in acceptable ranges to drive the intake at a ratio of 1:1.

Bowl Lifter: [5]

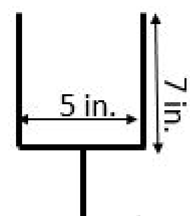
Our bowl lifter is designed to place the bowl in the MUGS. The BOWLS is held by two horizontal bars that when lifted will squeeze the BOWLS up with the mechanism. Our mechanism passively gets into position to lift the bowl by driving into the bowl. From a vertical view the mechanism looks like a "U." The bowl will slide into the "U."

Our bowl lifter mechanism is based off of a four bar. The four bar will be in a parallelogram configuration to ensure the coupler stays perpendicular to the ground at all times. Attached to the coupler will be the "U" mechanism. The four bar will be small with only a four inch crank and follower. The four bar is small, because it only needs to lift the bowl over the short 3.5 inch lip into the MUGS

In order for this design to fit inside the initial size parameters, the "U" mechanism has additional parts. The "U" mechanism is attached to bearing and freely rotates around the axis

Fig 4.7

Perspective from above



Fid 4.8

Perspective from side

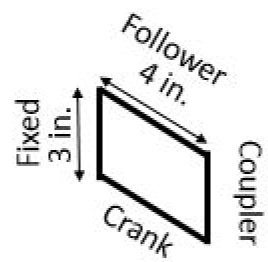
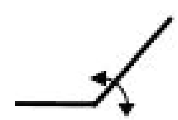


Fig 4.9

"U" mechanism from side

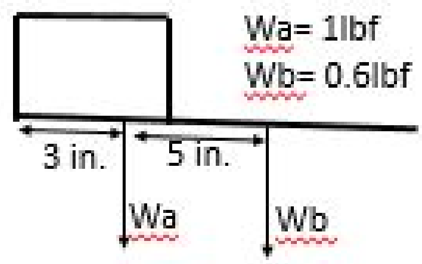


[5] Figure 4.7-Figure 4.91

seen in figure 4.9. The "U" mechanism will start in a vertical position to fit in the size constraints. Then the "U" mechanism will fall horizontal for the remainder of the game. The "U" mechanism is released by a servo with a hook.

To power the crank of the four bar we calculated a desired gear ratio to power the crank using a 393 motor. The gear ratio must provide enough torque to lift the four bar, while also ensuring a slow steady movement of the four bar. Moving the four bar quickly will likely cause the BOWLS to fall. The maximum torque applied on the motor will occur when the four bar is parallel to the ground. The torque applied on the crank axle is 7.8 in lb. Knowing this crank torque, the stall torque of the motor, and the no load RPM, we can find a desired gear ratio. The desired gear ratio we found was 1:5. With the gear ratio the motor has ample torque to power the four bar. The four bar will turn at rate of 17.78 RPM. There is concern about how fast the four bar will rotate, but we believe it could still turn in a slow enough range. The four bar will be given a greater gear reduction if 17.78 RPM is too fast.

Figure 4.91
Fourbar Lift Diagram



$$Tcrank = 3(1) + 8(0.6)$$
$$Tcrank = 7.8inlb$$

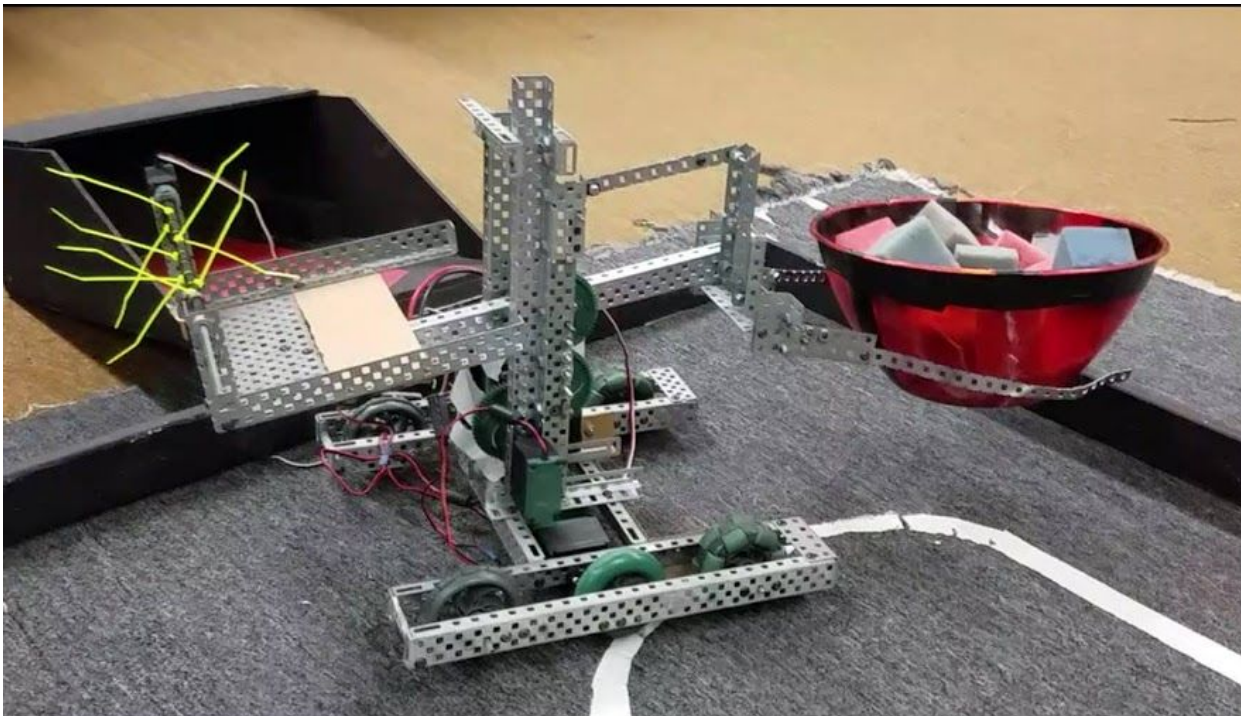
$$Tstall = 14.76inlbs$$
$$RPMnoload = 100RPM$$

$$Tmotor(\frac{1}{e})(efficiency) = Tcrank$$
$$Tmotor(5)(0.95) = 7.8$$
$$Tmotor = 1.64inlb$$

$$RPM = (RPMnoload)(\frac{Tstall - Tmotor}{Tstall})$$
$$RPM = (100)(\frac{14.76 - 1.64}{14.76})$$
$$RPM = 88.89RPM$$

$$RPMcrank = RPM(e)$$
$$RPMcrank = 88.89(0.2)$$
$$RPMcrank = 17.778$$

Final Preliminary Design:



The robot at the end of the preliminary design phase

Figure 4.10

5. Selection of Final Design

Drive Train

As a design analysis we made a design matrix which compares all the different designs for the drivetrain.

Designs\Factors	Complexity	Maneuverability	Center of Gravity	Rigidity	Virtual Turning Center
U-Shaped	4	6	7	3	7

Drivetrain (Fig. 4.1)					
H-Shaped Drivetrain (Fig. 4.2)	5	9	5	8	9

Table 5.1

This matrix still does not describe all the design decisions we made and went through. After building both drives and testing them vigorously we determined that we were going to select the H-shaped drivetrain. This was mainly because it turned out to be most compatible with the superstructure on top of the drive train. Still there were factors other factors and characteristics of the drivetrain that went into the selection of the final design.

The U-shaped drivetrain was initially built to allow for a large intake or bowl-grabber. But because of its shape it was prone to torquing which was one of the main weaknesses. The H-shaped drivetrain, on the other hand, was very rigid. In terms of complexity both drivetrains were very similar, they both utilized wheel bays and a crossbar connecting the two. So their complexity was very similar. Although the H-drive is slightly more complex because of its drop-center. The drop-center is what gave the H-drivetrain a considerable amount more maneuverability as it could change its virtual turning center depending on where the Center of Gravity was as we moved mechanisms and picked up game elements. This brings us to the next factor, Center of gravity, the first design had its center of gravity located all the way at the back, which was good because it would offset picking up the bowl. Aside from that it also had a very wide and stable base and so was not prone to tipping. The H shaped drive is more likely to tip because of its drop-center which makes it unstable. This was definitely a reason not to select this drive and we still notice this problem when testing. Because we selected the H drivetrain we will have to keep our center of gravity low. Both designs had the same gear ratio and drive wheels so speed, torque and traction were the same for both designs.

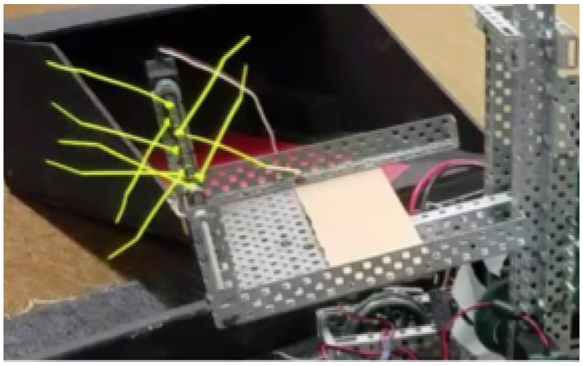
Overall we are satisfied with the selection of the H-shaped drivetrain because of its maneuverability because of its drop center as well as its rigidity and flexibility with the superstructure.

Intake

Design	Complexity	Storage	Size (horizontal)	Size (vertical)	Intake-ing FOAMS	Expelling FOAMS
Cycling intake (Fig 4.4 - 4.6)	5	4	6	5	4	2
Horizontal mounted intake	4	3	8	3	2	2
Vertical four-bar intake	7	7	3	7	8	4

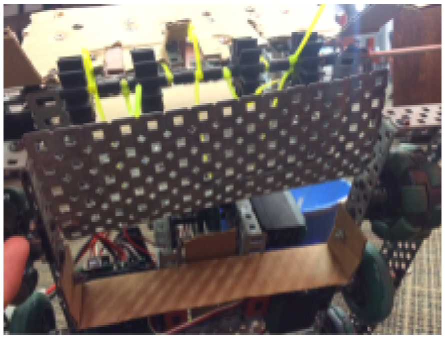
Table 5.2

The intake went through 2 separate iterations before landing on the vertically mounted four-bar design, set opposite to the BOWLS lifter. The first "⊂" shaped intake reduced the functionality of the robot, and reduced the net FOAMS that could be scored. The Cycling intake extended 3 inches past the edge of our already 15 inch robot. This alone caused the robot to be limited to the x direction for additional expansion. The BOWLS lifter was directly affected by this, and its length was hence compromised. Any chance of scoring in the HUGS was invalid, and the MUGS became far less feasible, due to the limited mobility. A second problem was generated by the top height of the intake: 3 inches. This meant that the cycling intake output was high enough to place FOAMS into the MUGS, but not into the BOWLS, which could be utilized for far more points. As the FOAMS were compressed within this variation, only a few foams could be collected before reaching max torque, reducing our efficiency. The design ultimately failed when it simultaneously became not rigid enough, and too heavy for ease of use.



The first intake prototype
Fig. 5.1

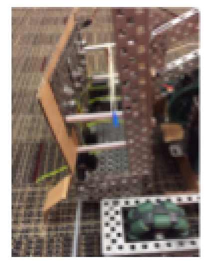
An overextension of the back of the initial four-bar's BOWLS-lifter led to the advent of the second intake design. The obstacle of height was negated by the mobility of the intake across the z axis. By replacing the intake roller of the first design with a collection of zip ties, the system was no longer able to reach max torque, The zip ties would bend and flex out of the way at an experimentally determined force of ~.03N. In this way, the zip ties worked most effectively by rotating and rolling the foam into the carriage. The carriage, however, developed a few problems. First and foremost, the back half of the carriage was a dead zone. FOAMS, on occasion, were able to slip from the intake and get trapped in the gear system of the four-bar. Once a foam moved to the back of the carriage, the zip ties were no longer long enough to extract a FOAM. The limit of FOAMS thus then becomes how many FOAMS may directly fit underneath the zip ties: 3. These FOAMS must be perfectly underneath, or else they will not



The second intake prototype
Fig. 5.2

be expelled. The arm was also bulky. Being so far from the front, the intake would cause massive amounts of unbalanced rotational inertia , causing the robot to jostle while turning.

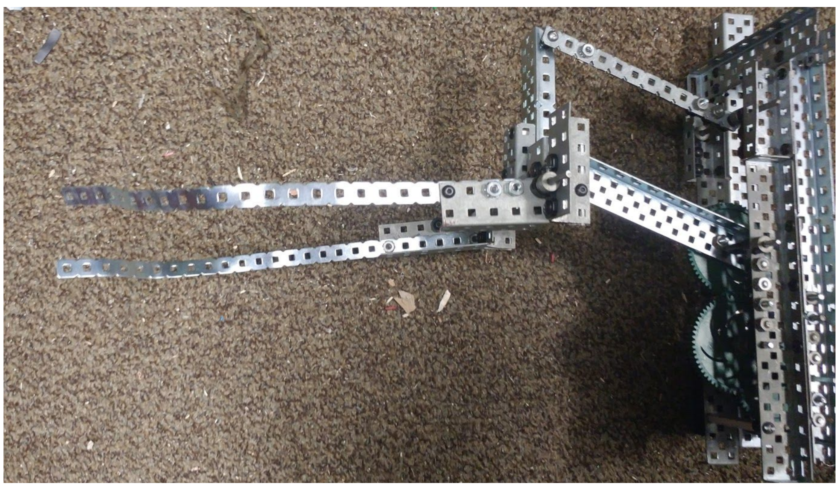
To fix these errors, a third and final intake was created. This took the "⊂" portion of cycling intake, and placed it below the intake mechanism, which was flipped vertically. This lead to a much more compact vehicle, however, if the intake was merely reattached, then there would be play as to the orientation of the intake, which would cause reduce the angle of usability of the BOWLS lifter. The intake was then mounted on a mini four-bar. A front panel was created to stop FOAMs from being removed, and slits in the front panel were cut to allow the zip ties through. Intake rollers were re-added to the system to allow for a greater removal force in addition to gravity and the zip ties. The new system is able to hold a maximum of 7 foams before a loss of functionality, and only then due to foams creating too high of friction for the foams to come back down by gravity. The system's weight, less than the cycling intake and more than the horizontal intake, allows it to act as a counterbalance for the newest lanky BOWLS lifter. The four-bar attachment allows for the intake to be raised just above the BOWLS and to lightly place the foams within, rather than shoot the foams out. Although it is less effective at removing FOAMS than intaking them, sometimes requiring some jostling, the intake is far more effective than all previous iterations.



The final intake
Fig. 5.3

BOWLS Lifter

The preliminary design was a single four bar arm that would lift a "U" shaped mechanism. The "U" mechanism would slide around the bowl and lift the BOWLS while the mechanism was lifted. This design was fairly simple and effective at positioning the robot to lift the BOWLS. While the BOWLS was lifted however, the BOWLS was unsteady while driving the robot around the field. The unsteadiness could lead to the BOWLS falling out of the "U" mechanism. Our preliminary design called for a 5:1 gear ratio. In design we calculated the speed at which the four bar would rotate and we were unsure whether the four bar would rotate too quickly. After building the four bar, we found that the mechanism did rotate too quickly. The design quickly changed to have a 25:1 gear ratio instead, to ensure a slow steady lift.

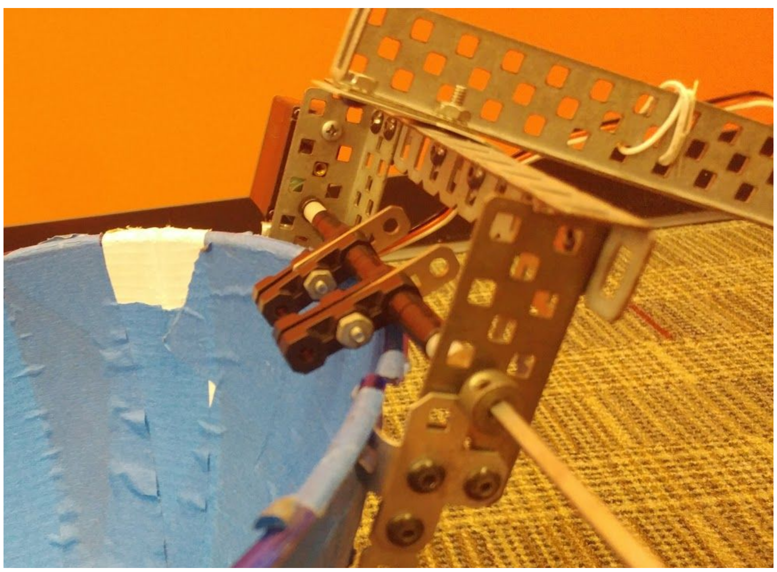


The first prototype of the bowl lifter

Fig. 5.4

After prototyping our initial design we quickly found an easy way to mount our intake onto the four bar. Mounting the intake would allow us more versatility in scoring FOAMS. THe new design added a bar on opposite side of the four bar to act as an arm for the intake. Everything else about this new design is exactly the same as our preliminary design. This 2nd design was better or equal in all aspects making the preliminary design obsolete.

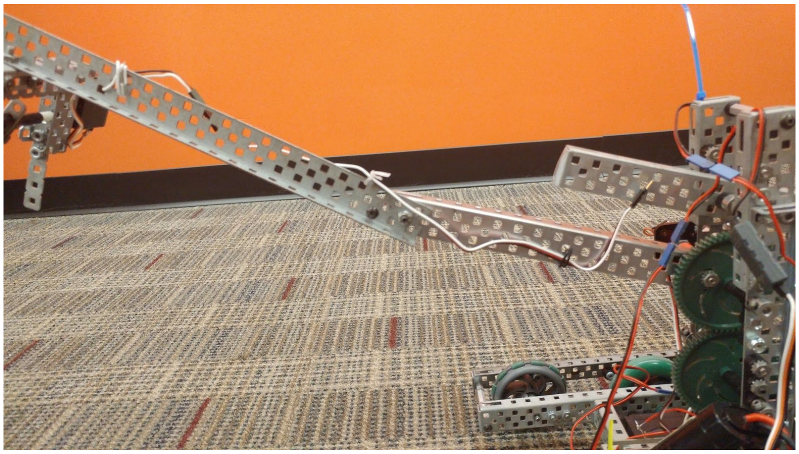
The first two designs struggled at ensuring the BOWLS did not fall out of the mechanism. We prototyped a different mechanism to make holding the BOWLS more reliable. This new mechanism would grasp the side of the BOWLS rather than support the bottom of the BOWLS. The mechanism has to slide over the lip of the BOWLS. Then a servo moves into a position that presses the plastic pieces into the side of the BOWLS. The BOWLS lip is squeezed in between the powered plastic pieces and metal brackets. The plastic pieces are powered by one normal vex motor. This new mechanism is better at keeping the BOWLS from falling back down to the floor. The mechanism is also much smaller and lighter than the previous two lifting mechanisms. However driving the robot into position to grasp onto the BOWLS was slightly hard than with the "U" mechanism.



The BOWLS clamping mechanism

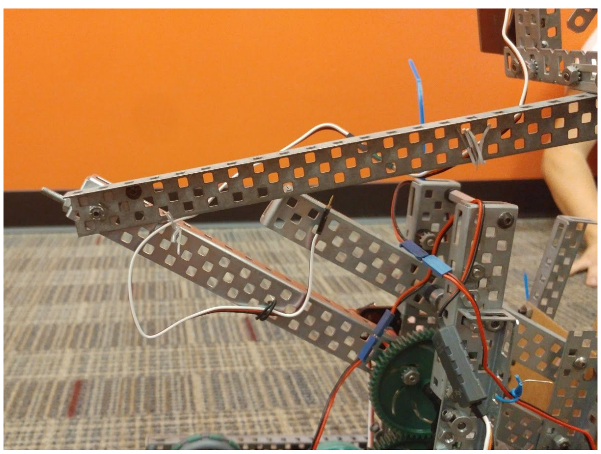
Figure 5.5

The four bar liter only allowed the robot to put the BOWLS in the MUGS. The lifter was very close to reaching the HUGS, but could never get close enough. We prototyped and extension to the lifter that eliminated the four bar system, but made the reach of the arm for placing the BOWLS much longer. The longer arm would allow us to reach the HUGS. In order to have the longer arm and still fit in initial size constraints the long arm needed to be folded at the start of the game. Overall this long arm design greatly increases the scoring ability of the robot.



The arm extended

Figure 5.6



The arm in a stowed position

Figure 5.7

The following matrix was used in deciding which design to use for scoring the BOWLS. The mechanisms considered were the “U” mechanism and the gripper mechanism along with the four bar lifter and the long arm lifter. Every combination of these two sets of mechanisms was used in the matrix.

Designs	Complexity of build (1 - most complex and 10 - least complex)	BOWLS Scoring difficulty (1 - hardest and 10 - easiest)	BOWLS Scoring reliability (1- least reliable and 10 - most reliable)	BOWLS Scoring Ability	Total
"U"mechanism with four bar	4	5	5	4	18
"U" mechanism with long arm	5	3	2	9	19
Grabber mechanism with four bar	5	4	9	4	22
Grabber mechanism with long arm	6	2	6	9	23

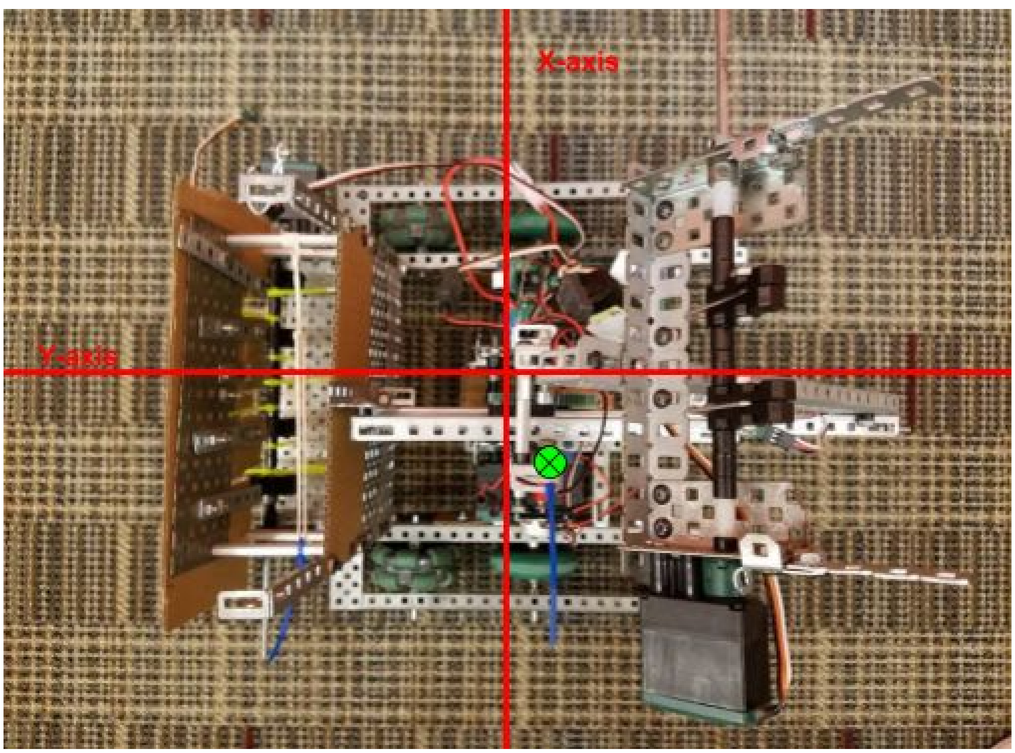
Table 5.3

The conclusion from the matrix was that the grabber mechanism with the long arm was the best combination to use for the robot. There was also ample time to construct this combination which is slightly more difficult to build.

6. Final Design Analysis

Overall Robot Analysis

Robot Center of Gravity:

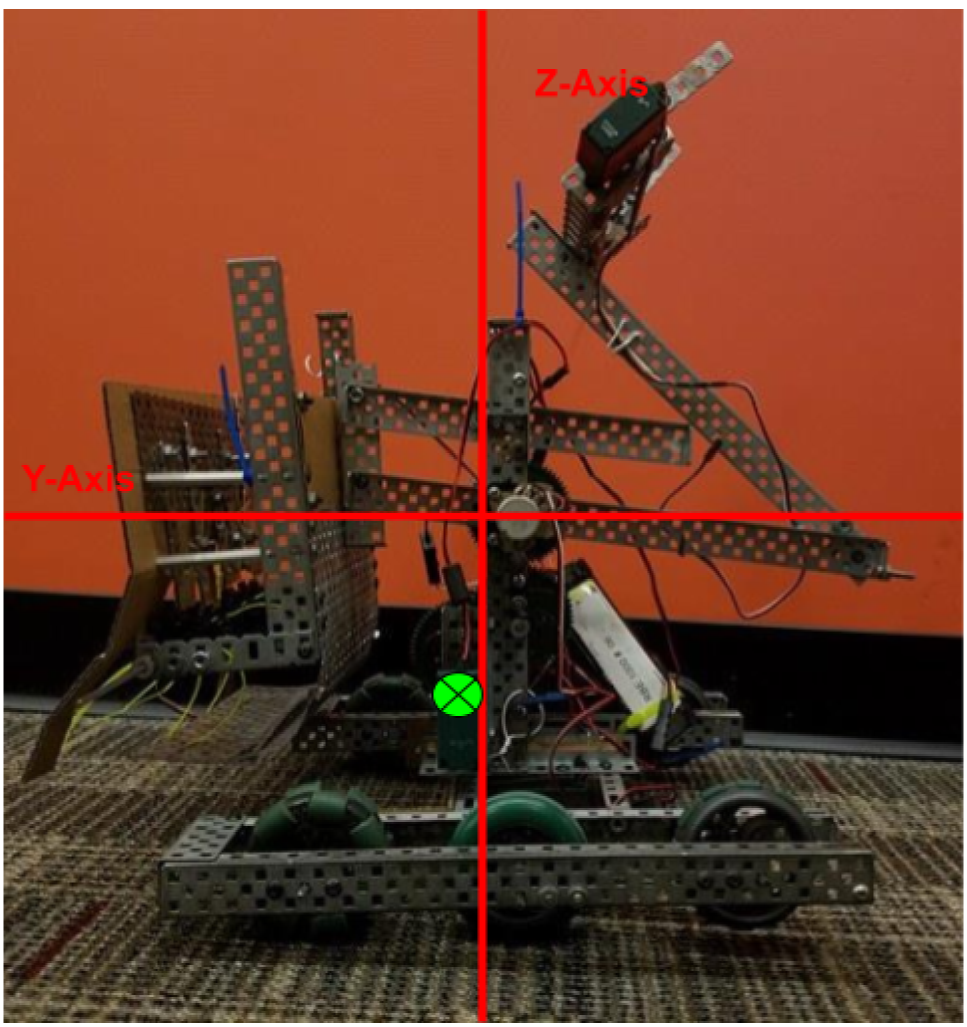


This picture shows the approximate location of the center of gravity of the final robot (the green dot).

Figure 6.1

The center of gravity in the y -direction is located 5.25 in away from the left side of our robot. This offset is likely caused by the BOWLS grabber motor as well as the arduino and battery which weigh about a pound.

The center of gravity in the x-direction is located about 7.5 in away from the front of our robot, which is the intake. As you can see on the picture the center of gravity in the x-direction is relatively in the center. This allows us to move easily in auton. However when we extend our bowl lifter arm and lift the bowl, our center of gravity in the x-direction will change significantly.

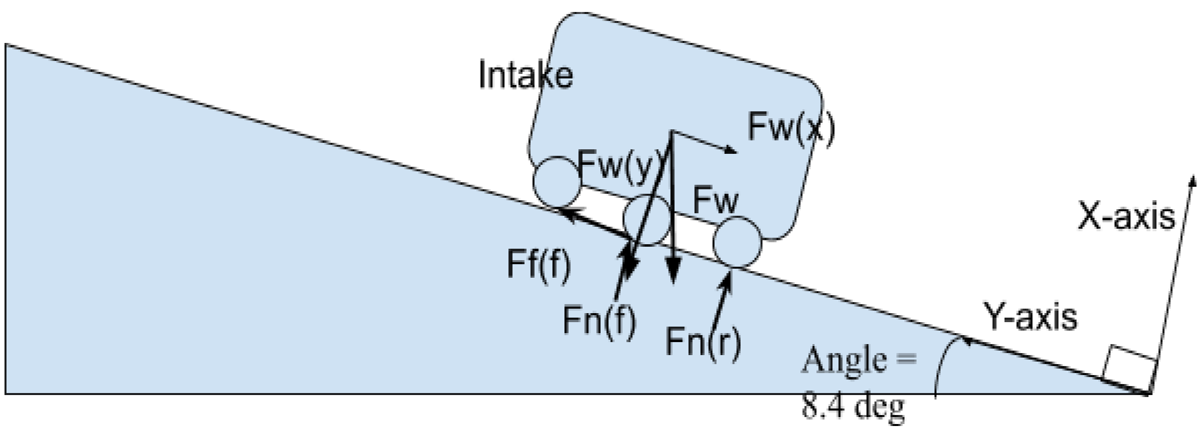


The location of the center of gravity of our final robot on the Z-axis and the Y-axis

Figure 6.2

The center of gravity on our robot along the z-axis is located 4.25 inches off the ground. However when if we would pick-up a BOWLS that would raise the center of gravity. As shown in the preliminary design calculations (Chapter 4, page 12) the center of gravity is far below the maximum, which means our robot should be able to climb up the GAP without tipping over.

Drivetrain Analysis



A FBD of the robot going up the ramp

Figure 6.3

Assumption:

When the robot is going up the GAP the drop center drivetrain will cause the robot to tip back onto its back wheels. This means that there is no normal force on the front wheels and so our robot is effectively is a front-wheel drive robot.

The following calculation shows the motor torque and traction force required when going up the GAP.

$X_{cg} = 4.75in \mid Y_{CG} = 4.25\ in \mid \theta = 8.4^{\circ} \mid Robot\ Weight:\ 8.1\ lbf \mid D_{wheel} = 2.75\ in \mid \eta\ (efficiency) = 0.9$

$R_w sin(\theta) = Fw_x = 1.1833\ lbf \mid \Sigma F_x = 0 = -Fw_x + Ff_{(f)} \mid Fw_x = Ff_{(f)} \mid Ff_{(f)} = 1.1833 lbf$

$\tau_m = ((\frac{D}{2}) * Ff_{(f)})/\eta \mid \tau_m = 1.808\ in * lb$

The next calculation shows the current draw as the robot climbs up the GAP

$\tau_m = 1.808\ in * lb \mid ((0.668 - 0.495)/(2.025 - 1.350)) * (1.808 - 1.350) + 0.495 = 0.612\ A$

As you can see when our robot ascends the GAP our motors are running at maximum efficiency and our current draw is quite low.

The speed and traction calculations can be found in chapter 4 on page 13. The gear ratio and motors have not changed since the design phase.

Intake Analysis

$\tau = Ff * R * FOAM_{max} + 6 * F_{zip\ tie} R$

$FOAM_{max} = 6$

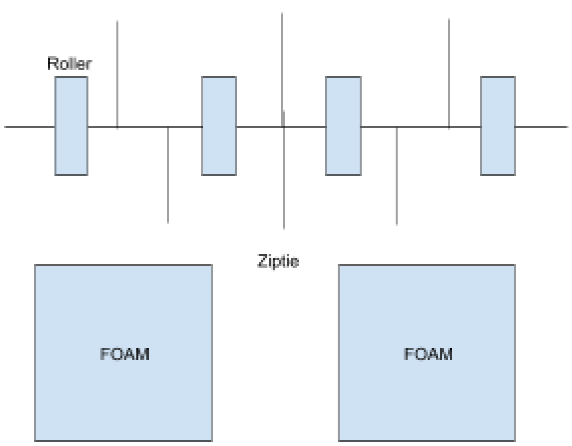
2 in front, 2 behind and 2 on top.

$R = .74'' * \frac{2.71cm}{1''} * \frac{10^{-2}m}{1cm}$

Radius of intake, distance where foams are closest, thereby same distance as zip tie's applied force.

$Ff = 1.65N$

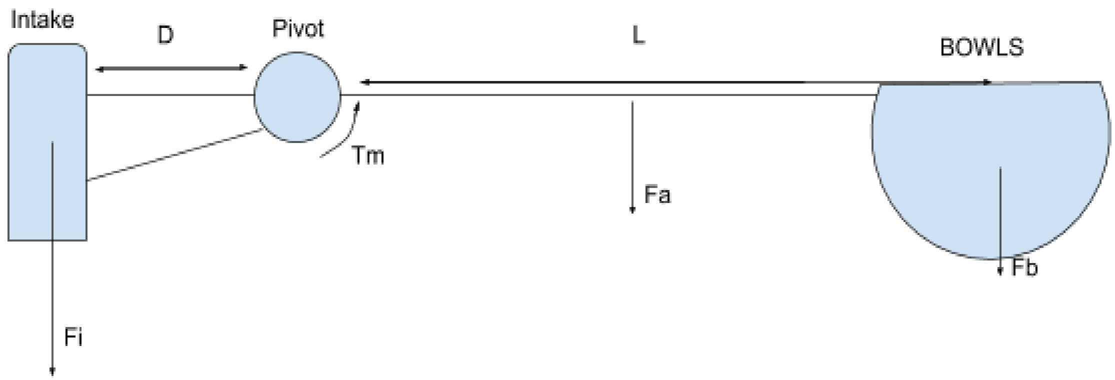
Fig 6.4



$\tau = 1.65N * .74'' * \frac{2.71cm}{1''} * \frac{10^{-2}m}{1cm} * 6 + 6 * .03 * .74'' * \frac{2.71cm}{1''} * \frac{10^{-2}m}{1cm} = 0.202'' LBS$

$\frac{0.202}{4.31} * (1.9 - 0.16) + 0.16 = 0.242\ Amps$

Bowl Lifter Analysis



An FBD of the arm

Figure 6.5

$\Sigma T_{max} = 0 = Tm + FiD - Fa\frac{L}{2} - FbL$

$Tm =- FiD + Fa\frac{L}{2} + FbL$

$D = 6.5'' \qquad L = 15''$

$Fi \ = \ 1.89\ LBS \qquad Fa = 2.2\ LBS \qquad Fb \ = \ .8\ LBS$

$Tm_{max} =- 1.89LBS * 6.5'' + 1.2LBS * 7.5'' + .8LBS * 15'' = 8.715''LBS$

The max force that must be applied on the motor gear train is 8.715’’lbs, when the arm is at max extension, holding the bowl and directly horizontal.

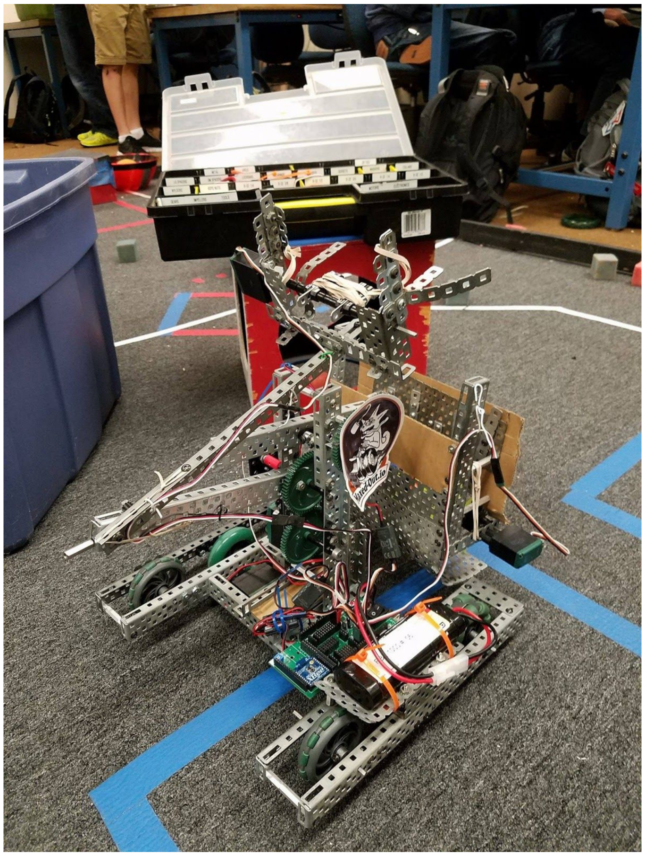
$Tm = Tmax * es/.95^2) = 8.715''LBS/(25 * 95^2) = .386''LBS$

The required torque from the motor is .386 “LBS.

The current drawn from this motor is equal to

$$\frac{0.386}{14.76} * (4.8 - 0.37) + 0.37 = 0.49\ Amps$$

7. Summary/Evaluation



The final iteration of our robot

Figure 7.1

Building the robot

Our team functioned differently than other teams. In total we built our robot three times over and were continuously trying to add and remove parts and systems from it. This allowed our team and robot to be more effective and adaptable although it was time consuming and led to other problems. Building our robot over and over allowed us to realize that our strategy, both of achieving rap dump during auton, and collecting all foams into the intake at one time, was not as feasible and so we altered it to be more effective and feasible. We also were able to test out more systems and realize their problems and improve, such as altering the long arms of the first bowl holder to the bowl grabber, and creating a guide for the bowl grabber. The fact that some teams did not have this capability was apparent as they built their robot without ever testing it. The problem with the way we built our robot is that it went with less planning. While some teams plan extensively and CAD their robot completely, we just evolved continuously. This made our robot more fit for the game but caused slight oversights and led to a worse looking robot, a "jankbot" as we added and removed components when convenient.

Changing Our Strategy

Halfway throughout our build period we looked at the development of the other teams and saw that our strategy would not nearly get as many points as they would. So we adapted and implemented a new strategy where we would try and put the BOWLS in the HUGS. We created a new design where we had a foldable arm that could reach the HUGS. Later we realized that this strategy change might have been a mistake that led to us wasting valuable time creating a new robot for a new strategy that replaced an already working strategy. Once we saw that the other robots were not nearly as effective as we expected we could have stuck to our old strategy and have won all the matches.

Autonomous

We focused mainly on the construction of our robot, which was a slight mistake. We should have realized the importance of autonomous. If we had planned out the construction of our robot better we might have been able to implement a better and more effective auton such as the one listed in our strategy. We did try to make a good auton but the line followers we got in the parts bidding process were not what we expected. Even after extensive testing of the line followers, both by fiddling mechanically with the positioning and distance of the sensors, and electronically, with the code that read the followers, the sensors were not sensitive enough to pick up on the change of line without dragging on the floor. If we had more time and planned better we would have been able to recreate the photoresistor line follower and build a better auton.

Conclusion

The robot created performed to the set expectations and goals. The final strategy was radically different from the initial causing multiple rebuilds of multiple parts of our robot. The initial goals of scoring the bowl into the MUGS was abandoned as there was more time than anticipated, and other teams were attempting more ambitious goals, and the objective of the HUGS was implemented. We accomplished all primary focuses, all but one secondary focus, and some tertiary focuses that were very effective in the game, gaining the high score of 108, nearly by our selves. Although there are many improvements that could have made the robot more effective, such as tweaking the intake or fixing the potentiometer from drifting, this would have reduced our time spent building and advancing the robot to its final iteration. A tremendous accomplishment was a tertiary focus of placing the BOWLS in the HUGS. Our bowl grabber and lifter were fairly consistent. More driver practice would have allowed us to more consistently score in the HUGS during the limited time. Our largest failure, however was our autonomous. The autonomous did not contain enough sensing, and did not have a large operational functionality. Still programming as a whole was successful by automating tasks and functions, like the P control section, which moved the arm to optimal bowl grabbing height, or the motor switch speed to make driving easier. Overall we evolved our perspectives on teamwork, and heavily improved our mechanical design process, both of which will be crucial for our future in robotics.

8. Appendix

Robot code and comments included in zip file attachment