Engineering Portfolio

Green Mountain Gears
Team 9721

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Executive Summary

During autonomous, our robot uses tensor flow to determine the size of the stack. The robot uses a PID algorithm and the IMU sensor to drive straight, using 4 motors geared at 20:1 with mecanum wheels, until it detects the image target using Vuforia. The robot uses the data from Vuforia to navigate to the launch line where it fires (3) donuts into the middle goal. The robot then drives to the correct location to release the wobble goal. During teleOp, the robot scores 4-7 donuts in the middle goal. During the end game, the robot delivers the wobble goal to the drop zone. The robot generally scores 50-82 points.

The team achieved several goals this year that were noteworthy. The team had wanted to navigate using Vuforia. The team also used timing belts and pulleys and corrected the drift with the mecanum wheels. The team also developed a roller intake system and corrected the long-standing problem of lifter arm motors slipping.

The team met in a combination of in-person and zoom meetings. In order to follow covid protocols, our in-person meetings were all outside. This limited the time we could work but years of working together made it easier to build and test prototypes and make collective decisions using zoom. Final builds were done in-person by one of the team members.

The team helped to found (2) new rookie teams (18641 and 18753) and supported those teams with a combination of in-person mentoring, zoom mentoring, tutorial videos, materials, programs and prototypes. The team provided support to team 16295, which an all-girls rookie team last year that we helped to form. New partnerships with John Cohen, Vermont Academy of Science and Technology, VT Maker Space and UVM CEMS lead to more than $3000 in grants that were used to support all (4) teams.

Our team added our first alumni mentor this year when one of our former team members returned to support the team. He acted as the Dean's List submitter and provided support on the design of the robot.

Video of Match 3 https://youtu.be/u9dshBo_rp0

Autonomous

3 rings into middle goal, dropped wobble in correct position and parked

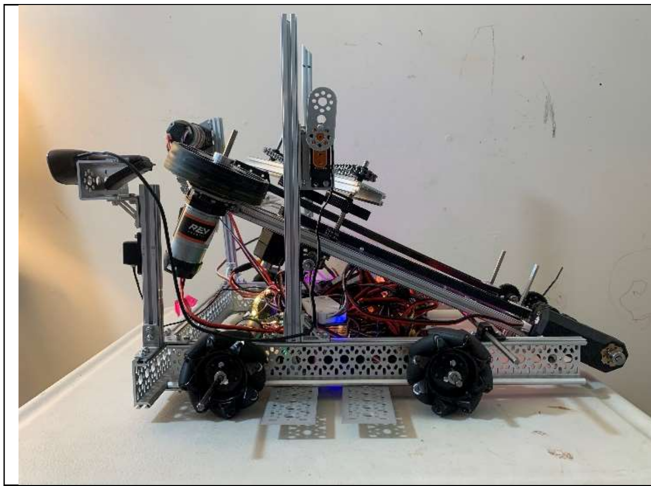
TeleOp

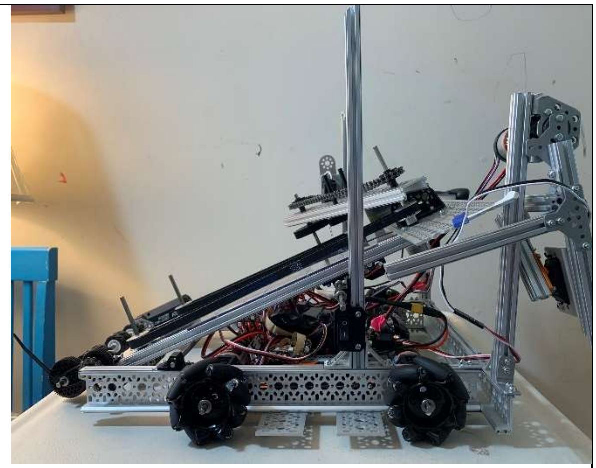
Scored 5 rings into mid goal

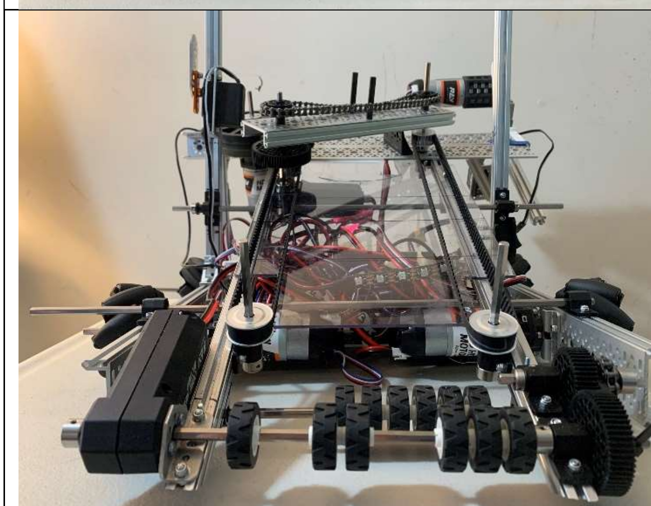
End Game

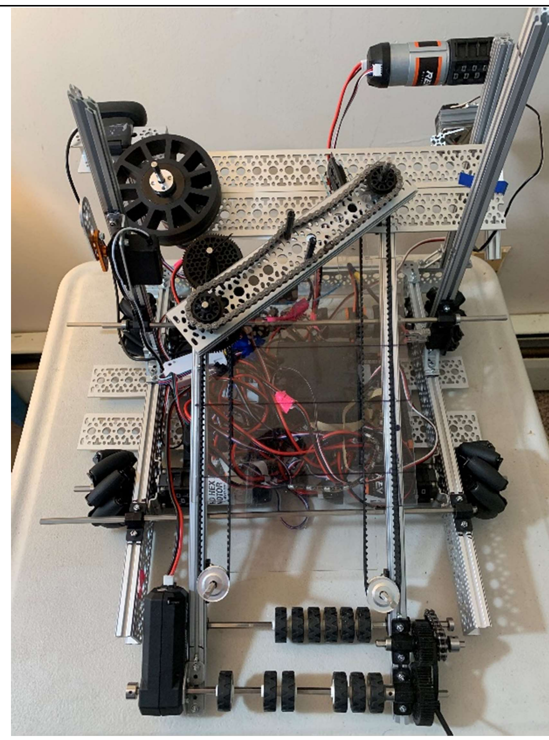
Placed wobble goal in drop zone

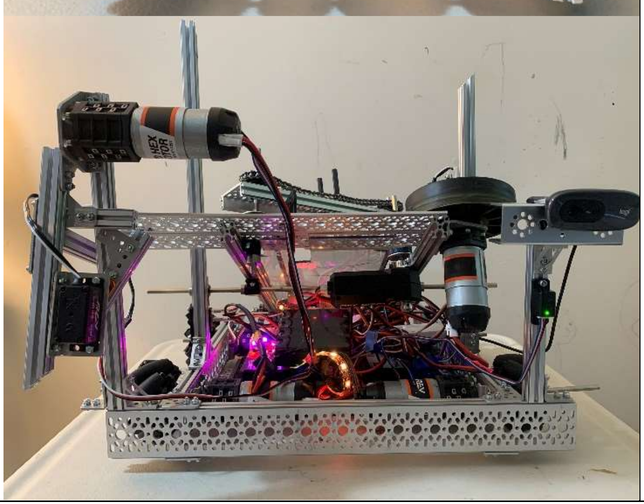
2020-21 Robot Photos











2018-19-Rover Ruckus

The team designed a robot that integrated tetrix and REV materials.
During autonomous, the robot lowered itself and used tensor flow to identify and deliver minerals using motor encoders.
During teleOp, the robot placed minerals in the correct location.
During end game, the robot lifted itself. The team won the "Best of Vermont" award for the 2nd year. The team was an Alliance Captain during the semi-finals.

2019-20 Skystone

The robot can do the foundation and skystone during autonomous. During driver control, the robot can stack 4-5 stones using a cabinet slider and drive under the alliance bridge.During end game, the robot can place the end cap on a stack, move the foundation and park.The team was the first Vermont team to win the "Think" award and the team was a member of a Semi-Finals Alliance. The team also helped to form the first all-female FTC team in VT and they created a series of rookie tutorials to help new teams, including videos of robot design, robot fabrication, robot programming and robot operation during competition including several scrimmage events where both teams worked the fame field at the same time.

Team Members

Hi! I’m Andrew. I’m a senior at South Burlington High School and I’ve been with this team for eight years. Something I really enjoy to do in my free time is to write music. I write classical musical through the Music-COMP, a Vermont based mentoring program. I also make jazz and funk music with a couple of my close friends. I play the guitar in my jazz band and the clarinet in the high school Wind Ensemble. Another thing I enjoy is playing sports. My main sport is volleyball. I’ve played for the Vibe VC travel team and play for my high school varsity team.

Luke Fitzgerald

Luke Fitzgerald is from South Burlington and is currently a Junior who is home schooled and taking courses through the Center for Talented Youth at Johns Hopkins. In addition to robotics, Luke plays soccer and baseball, enjoys theater, loves skiing and being outdoors in nature, goes fishing, plays piano and clarinet, and participates in Odyssey of the Mind. This is his 9th year of FIRST but his 12th season. He did Junior FLL for 1 year, FLL for 5 years (3 of which he did while simultaneously doing FTC), and is now in his 7th season of FTC.

Kenny Chamberlain

Hi I am Kenny, this is my ninth season of FIRST and my seventh year with this team. I am a Junior at South Burlington High School. Something I enjoy doing is Math, I am on my school’s math league team and I made it to nationals for Math Counts two years ago. I am currently taking AP Calculus in school and I made it to ARML as one of the members of the Vermont team. Another thing I enjoy doing is sports. My favorite sport to play is currently Ultimate Frisbee where I play for my high school’s JV team, but I also enjoy playing ping pong and I am in the club that my school started up last year.

Mentors

Ethan Behr

Ethan is an alumni mentor of our team. He participated in FIRST programs for 9 years, 3 in FLL, and 6 in FTC. He enjoys other activities such as playing piano and trumpet for various musical groups and setting such as the FlynnArts Jazz Combo and the St. Michael's College Chapel Liturgical Chapel. He is currently a senior at Rice Memorial High School. His favorite author is Kurt Vonnegut. He was accepted to Boston College but deferred a year because of COVID but he plans to start in the fall.

Paul Fitzgerald

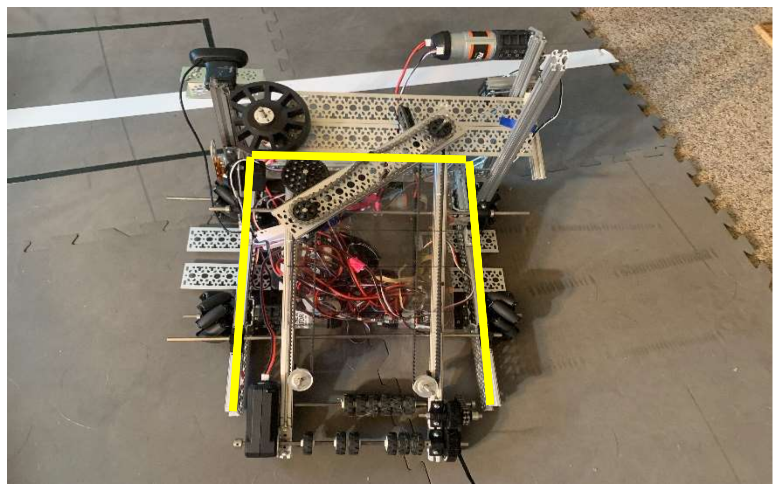
This marks my (3 season of Jr. FLL, 6 seasons of FLL, 7 seasons of FTC) 16th season of FIRST. I taught math and science for 16 years before founding Teams of Innovative Problem Solvers (TIPS).

I studied Applied Marine Ecology at UMass Boston and earned an M.Ed. in 1998. I earned a BS in Biology with a Minor in Chemistry from UNC-Chapel Hill in 1995.

I also coach chess, mathematics, baseball/softball, soccer, Odyssey of the Mind and I play both violin and guitar.

Our chassis this year is a U-frame assembled with C-channels. In past years, we have experimented with square-, H-, and U-shaped frames. While the new game each year requires differences in the robot, we've have found that a U-frame is often a good approach. This year was no exception. The U-frame easily enables the robot to have an area to interact with game elements (this year, rings), while maintaining a solid structure and allowing for the other part of the robot to push game elements (this year, the wobble goal).

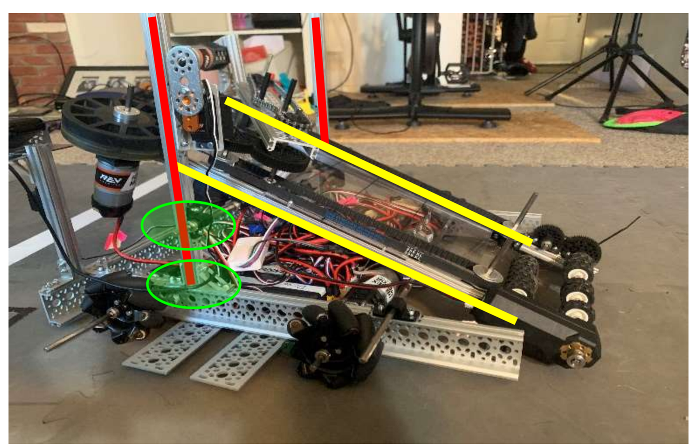
Image 1: U-Frame



Our decision to use C-channels came after deliberation about whether to use Tetrix channels, Rev extrusion or the Rev C-channels. The C-channels combine the fixed pitch system of the Tetrix with the extrusion of Rev, which is why we decided to use C-channels.

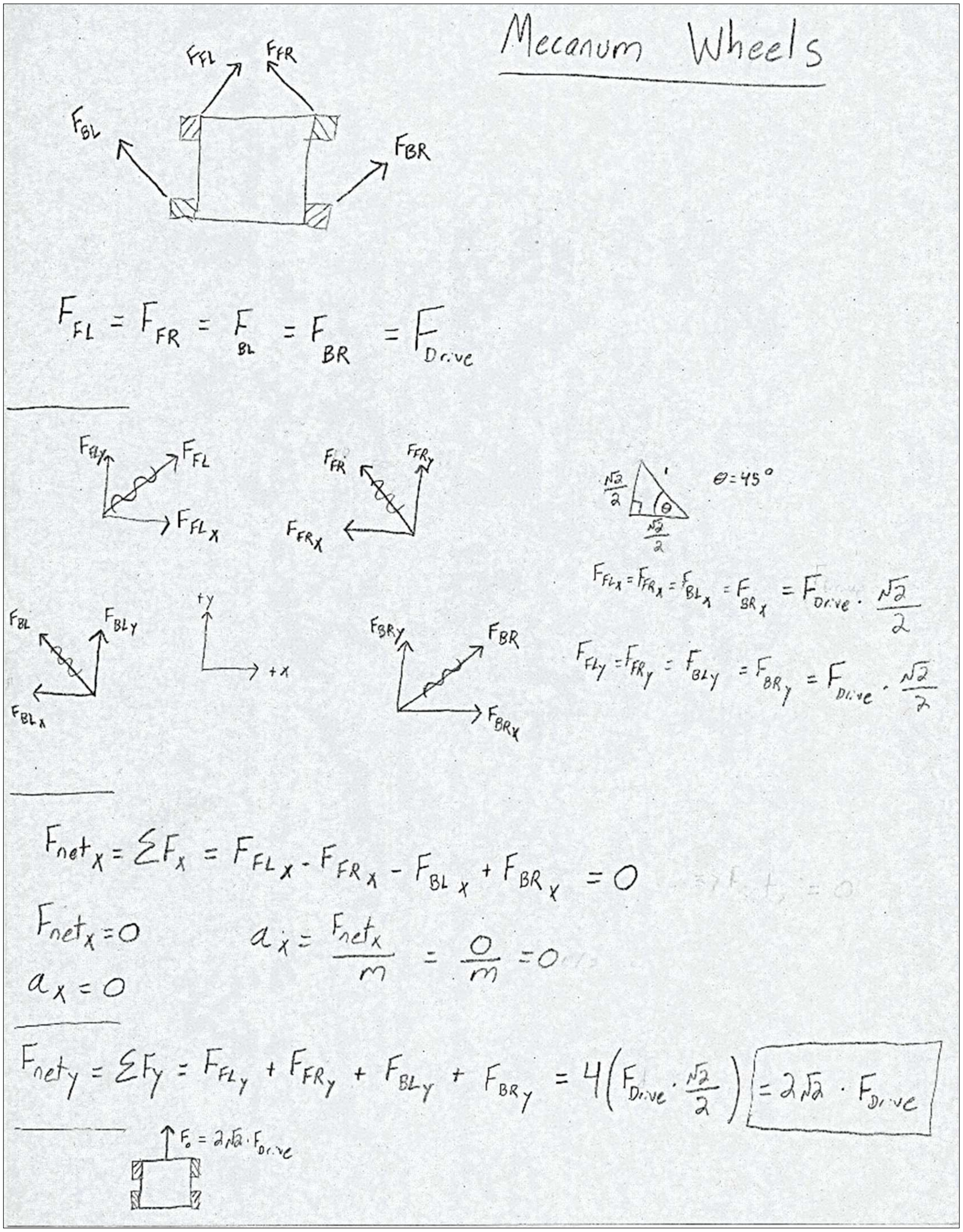
Initially, we were hoping to build a bumper system around our wheels so that the wheels would not directly interact with the game elements – in past years, our robot has gotten stuck on certain game elements, such as plastic cubes. We did not end up creating a full bumper system, but did create bumpers so that the wheels in the front were protected from game elements. With more time, we may have experimented with adding a bumper to the sides as well, though we did not feel this was necessary.

Image 2: Conveyor and Vertical Extrusion



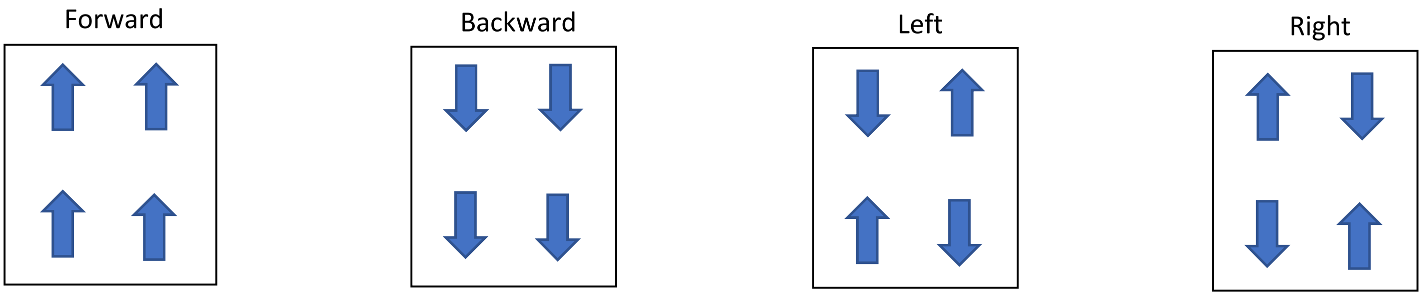
Our conveyor system is directly related to the chassis. It is held up by two vertical rev extrusions mounted to the C-channels (of the U frame). Since the extrusion part of the C-channel enables the vertical extrusions to slide back and forth (in addition to the ability for the conveyor to be slid up and down on the vertical extrusions) the shooter launch angle can be adjusted. However, for out intake system to work properly, there is a very limited range for which the conveyor system can be angled.

The Physics Behind Mecanum Wheels



Despite none of the wheels pushing the robot forward individually, when all spinning forwards, the net force on the robot is forward. This is due to all the side to side forces canceling each other out and all of the forward backward forces being in the forward direction.

So, the robot can go forward, left, backward and right while facing the same direction depending on which direction the wheels are turning in. Below is a diagram showing the needed turning direction for the wheels for the different directions of motion.



Intake System Kenny Chamberlain 03/10/21

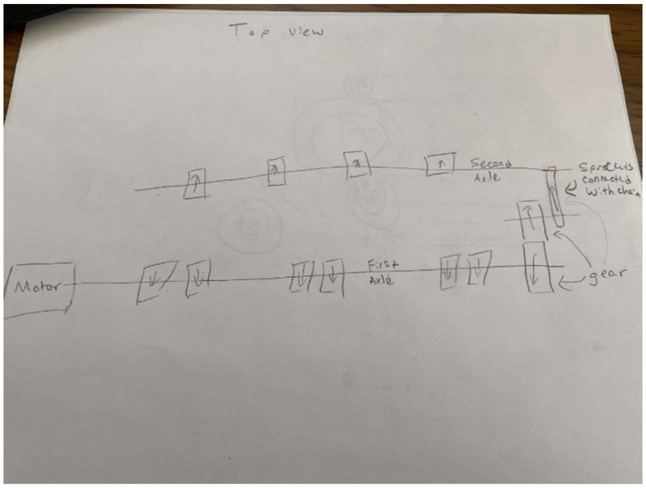
- Intake System
    - Move 32 gram donut from ground into conveyor system, which is 1-2” off the ground.
- Conveyor System
    - Move donut to the shooter, along a ramp at a 45 degree angle for a distance of 14” and a height of 10”

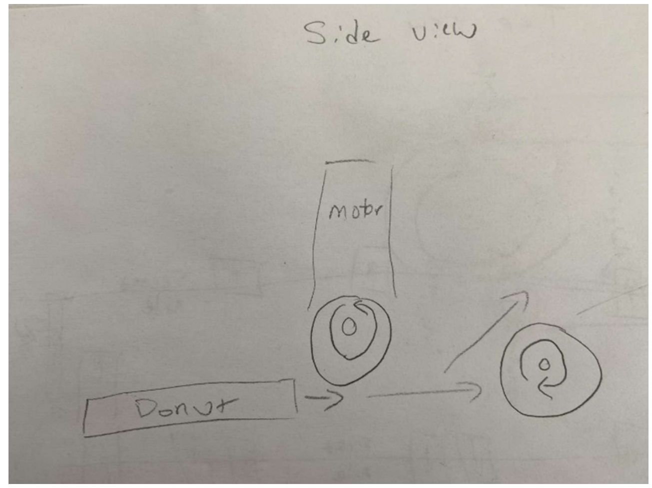
Intake System

The first axle is directly connected to a medium motor. REV intake wheels are placed on the axle, which rotates counterclockwise, which draws the donut into the robot. The Intake wheel make contact with the donut at the front of the donut, and then on the sides of the donut as the donut moves through the system. The force pushing the donut inside the robot must be greater than the inertia of the donut. Inertia=m*g or weight which is 32 g. The donut moves at least its full diameter to enter the robot, which is 5”. This means the axle must be able to do W=F*d or 32 g * 5” for 160 g “ of work.

The dummy axle is connected to the first axle through a spur gear. This connection changes the direction of rotation, which allows a single motor to power the two axles in opposite directions. These gears are not in a 1:1 ratio, which was desired. They were not 1:1 because the geometry would not work for the sizes of gears produced by REV. The gears needed to maintain the connection between the axles at a specific distance while keeping the second axle a specific distance above the ground did not exist. The dummy axle is connected to the second axle through a chain and two sprockets. This is necessary because the two main axles need to be at different elevations, very close to the ground, and need to rotate in the same direction.

The second axle is slightly above the ground and it rotates clockwise. This causes a force that pushed the donut upward and into the conveyor. The total force of the two axles together must be sufficient to lift the donut about an inch off the ground. This would require work equal W=F*d or 32 g * 1"



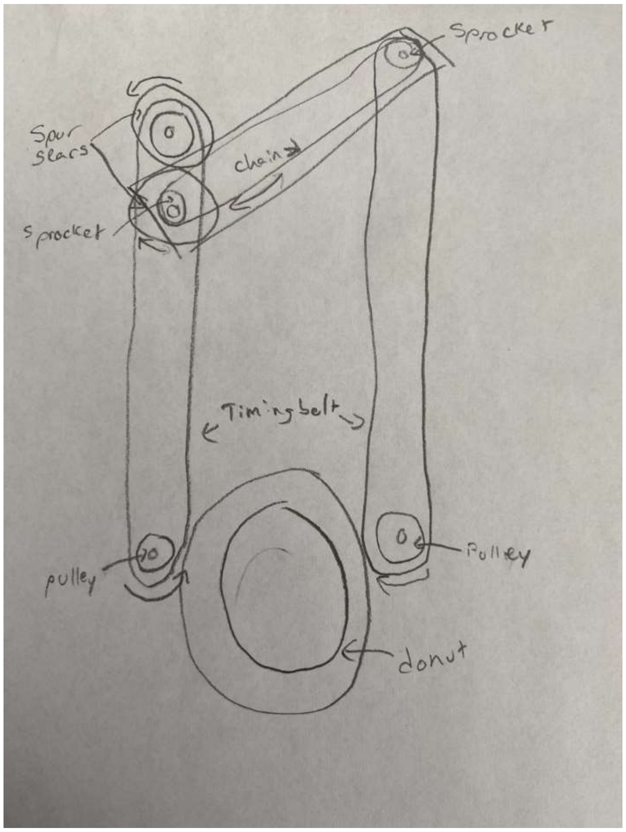


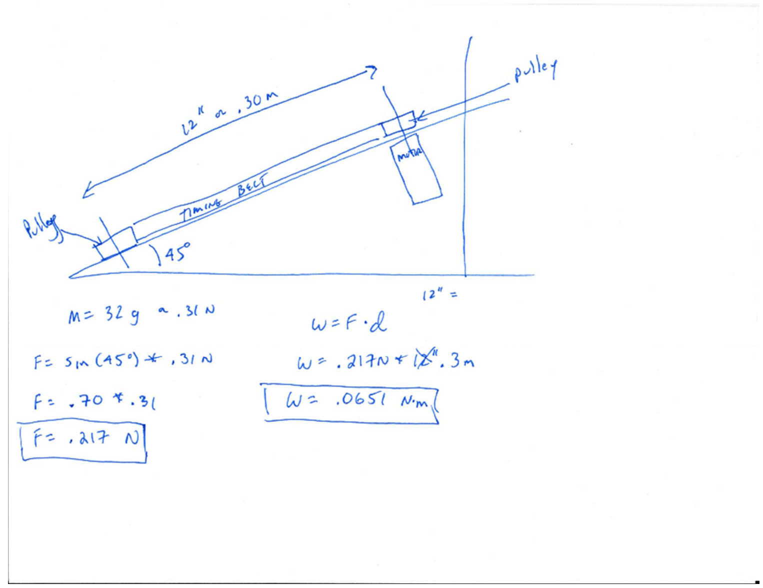
Conveyor

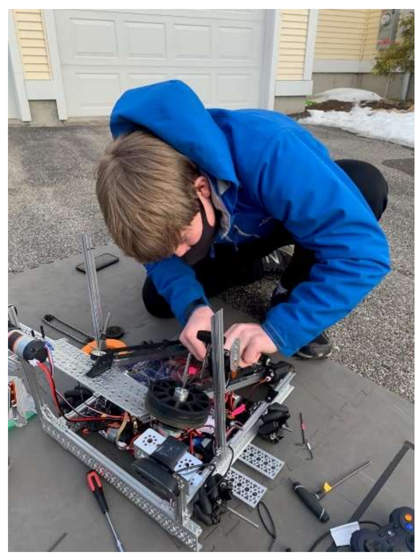
The conveyor pulls the donut up a ramp at an angle of 45 degrees. The force is applied by two timing belts, that come into contact with the donut along its sides. The conveyor is powered by a single motor. The first axle rotates counterclockwise. This axle is connected to a pulley, which is connected to another pulley through a timing belt that is about 23" long which draws the donut up the ramp.

The dummy axle is connected to the first axle using a spur gear which changes the direction. This is done above the pulley and timing belt. The dummy axle has a sprocket on the top of it. With a chain connects the sprocket to another sprocket on the opposite side of the conveyor without changing direction.

The second axle is connected to the dummy axle via a chain and sprocket in a 1:1 ratio, so that the axles rotate at the same rate. The second axle has a pully on it which is connected to another pully by a longer timing belt which is 29", this rotates clockwise to bring the donut up the ramp. It is longer than the first one so that the donut continues to get pushed into the shooter wheel which is at the end of the first belt opposite the second one.





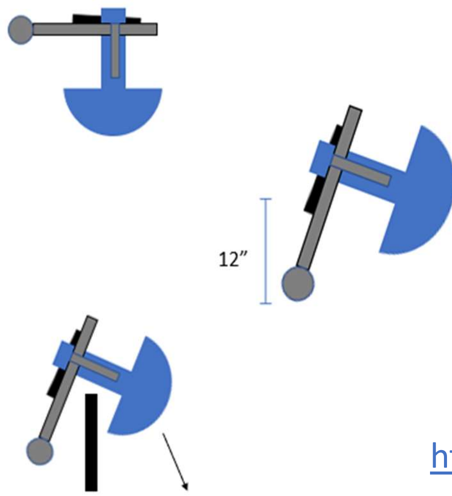


Physics of Lifter/Gripper System

Andrew Kim 3/10/21

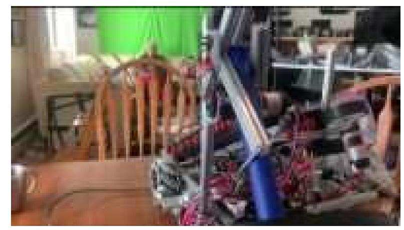
Objectives

- Grab the wobble goal and hold it
- Lift wobble goal to a height of at least 12”
- Drop wobble goal on the opposite side of the competition wall



Lifter/Gripper Demonstratio

https://youtu.be/2G-byR3ryeY

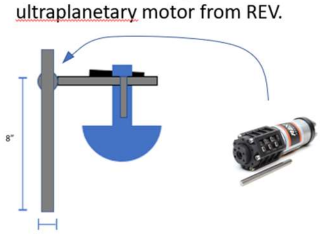


Lifter/Gripper Tour

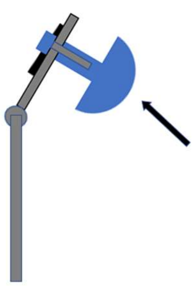
https://youtu.be/bS6KF92qmvs

Lifter/Gripper

The lifter gripper is based on a 15 mm REV extrusion system. The system has a stand, which is the mounting place for an ultraplanetary motor from REV.

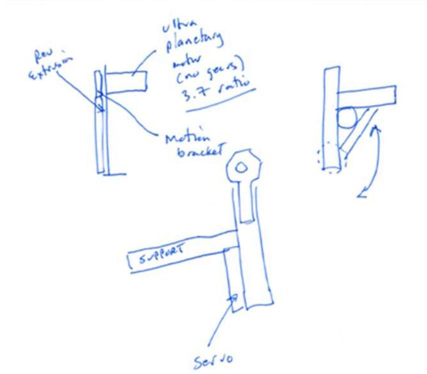


The lifter works by grabbing the wobble goal and rotating it into the robot.



The arm rotates to hide inside the robot when not in use.

Wobble Goal Parts

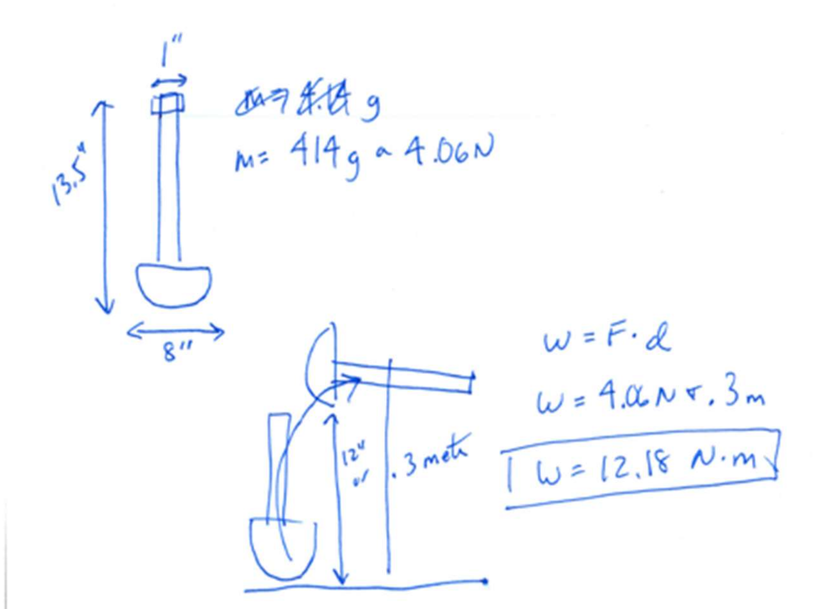


A servo was used to reduce the mass of the lifter

Ultra Planetary Motor

The ultra planetary motor was geared 5:1, 5:1, 5:1 or 125:1. This makes the motor have the greatest torque possible but the slowest speed. This allows the motor to not only lift the wobble goal but to hold its position while the robot is moving. This has been a problem for the team for the past 5 years and it was corrected for the first time this year!!!

Wobble Goal Calculations



The lifter arm was made as small as possible to reduce the "lever effect" of rotating the goal. This means that the longer the arm, the greater the force needed to move the goal.

Autonomous Wobble Goal Release

Luke Fitzgerald

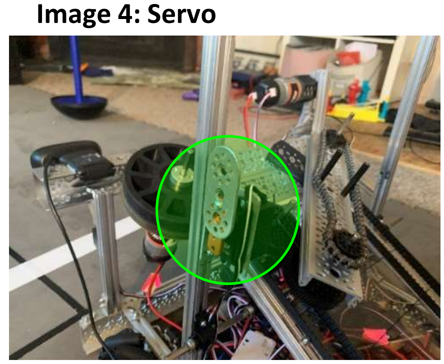
March 11, 2021

Servo Analysis

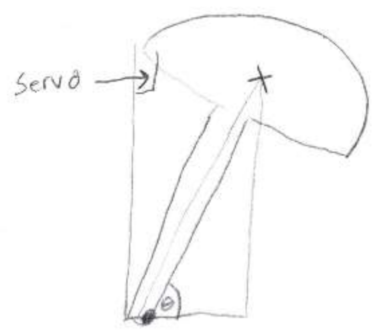
Servo

There is a servo mounted to the left vertical extrusion. This servo enables the robot to carry the wobble goal and drop it off in the drop zone during autonomous.

Image 4: Servo



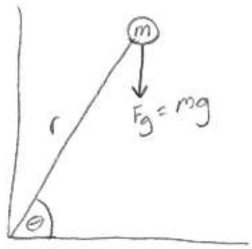
Servo and Wobble Goal



X ≈ center of mass

$\theta \approx 70^\circ$

Simplified:



$\tau = -F_g r \cos(\theta)$

$\tau = -mgr\cos(\theta)$

$\tau = -(0.414\,kg)(9.8\,N/kg)(0.305\,m)\cos(70^\circ)$

$\boxed{\tau = -0.423\,N}$

$m = 414\,g$

$r = 12\,in. = 12\,in.\left(\frac{1\,ft}{12\,in.}\right)\left(\frac{1\,m}{3.28\,ft}\right)$

$= 0.305\,m$

By applying a torque that counteracts this torque, the wobble goal is in static equilibrium. When this counteractive torque is removed, there is a net torque on the wobble goal and it acceleraties (i.e. falls) to the ground.

Shooter Analysis

Luke Fitzgerald

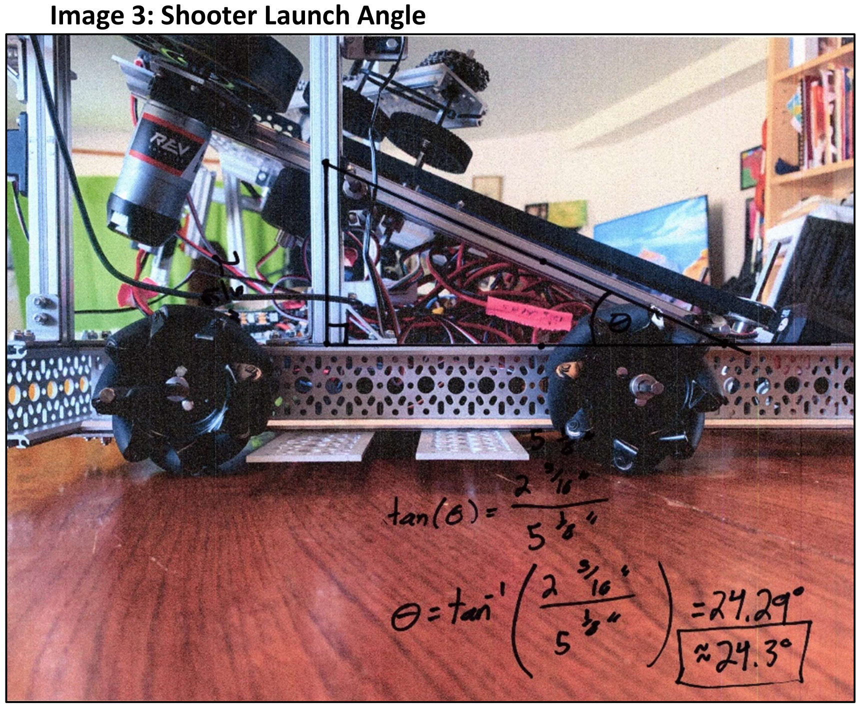
March 11, 2021

Shooter Analysis

The shooter takes inspiration from a pitching machine. To get started, we looked at some YoutTube videos and found one by the Bulldogs that looked like a good place to start. It involved one wheel spinning at a high rate with a conveyor system pushing rings into the shooter. To get the wheel spinning quickly, we used a planetary motor without any cartridges yielding a gear ratio of 3.7:1. This was the fastest the motor could be geared, and when we attached a wheel, it sounded like a little airplane – it went really fast. The next decision we had to make was what kind of wheel to use: a firm wheel or a flexible (or something in the middle). The first wheel we used was firm, and it worked pretty well. We decided we might as well try a softer wheel, and tried the shooter with various AndyMark compliant wheels. The smaller wheels didn't work as well because the tangential velocity at the edge of the wheel was less due to the smaller radius. The softer wheels didn't work as well. We believe that his was in part because the rings were flexible, and, similar to a bouncy ball on a trampoline, having two flexible materials wouldn't quite work as well. We ended up using a large, firm AndyMark compliant wheel (durometer: 60A). The speed of the motor along with the stiffness and greater radius of the wheel resulted in a shooting mechanism capable of shooting rings at about 20mph.

To find the relationship between motor power and exit velocity of the rings, we collected some data. The lowest power at which the shooter would successfully shoot the ring was around 0.4; at this power, however, the ring barely left the launcher. Therefore, it seemed that the lowest motor power at which the motor could operate within reason was 0.6. We placed a ruler on a wall and backed the robot up 60" from the wall. We then ran three trials of the shooter shooting the ring at the wall at power 0.6, 0.8, and 1.0. We recorded a slow-motion video of the rings hitting the wall so that we could clearly see what height they made contact with the wall. We used this height (along with the launch angle and distance to the wall) to calculate exit velocity for each power. We graph this data and added a linear trendline. It was determined that $Velocity_{initial} = 495(Motor\ Power) - 90.2$.

Image 3: Shooter Launch Angle

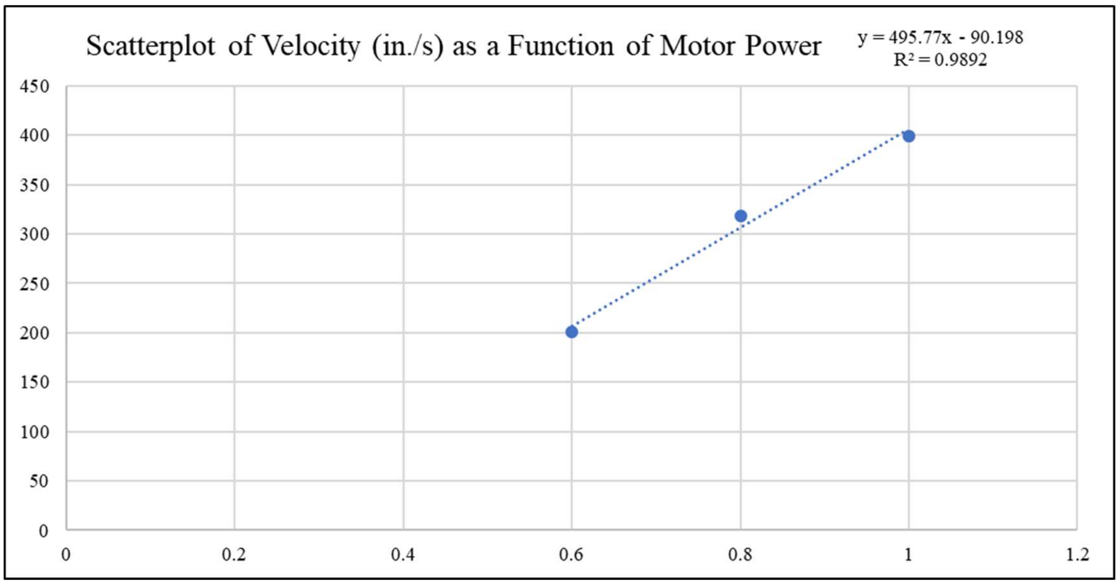


[Link to Video]

Table 1: Data Relating Exit Velocity (in./s) to Motor Power

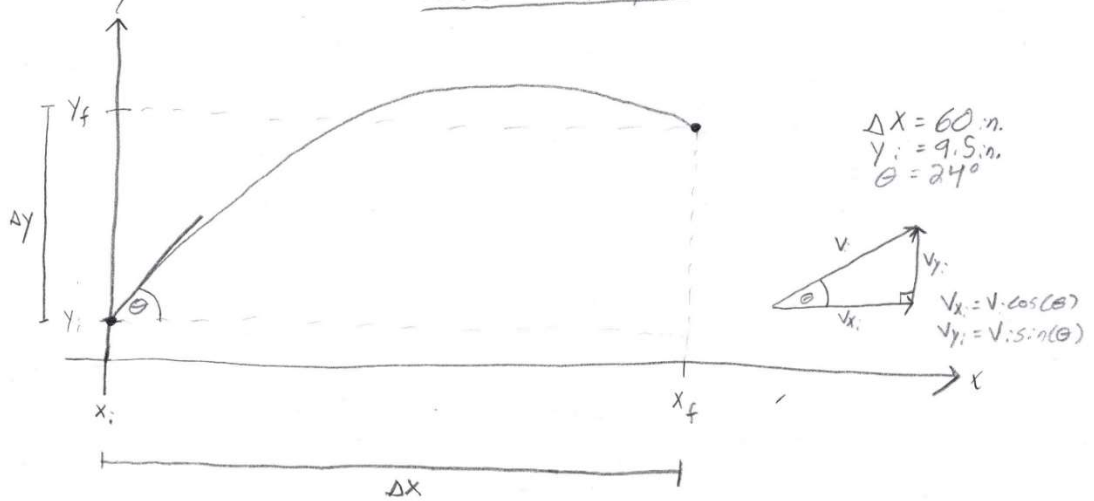
	Height (inches)				Distance (inches):	60
	Trial			Average	Launch Angle (degrees):	24
Power	**1**	**2**	**3**		**Exit Velocity (in./s)**	
0.6	18	12	17	15.7	201	
0.8	27	28	29	28.0	318	
1.0	31	30	32	31.0	400	

Graph 1: Relationship Between Initial Velocity (in./s) and Motor Power



The following contains the calculations used to solve for the exit velocities in table 1. It also uses the relationship found between motor power and exit velocity to determine the necessary motor power to shoot a ring at a target of a given height (h) a given distance away (Δx).

Shooter Analysis



$$a_x(t) = 0 \Rightarrow V_x(t) = V_{x_i} \Rightarrow x(t) = V_{x_i} t + x_i$$

$$\Rightarrow x_f = V_{x_i} t + x_i$$

$$\Rightarrow \Delta x = V_{x_i} t$$

$$\Rightarrow t = \frac{\Delta x}{V_{x_i}}$$

$$V_{x_i} = V_{x_f} = V_x$$

$$\Rightarrow t = \frac{\Delta x}{V_x}$$

$$\Rightarrow \boxed{t = \frac{\Delta x}{V_i \cos(\theta)}}$$

$$a_y(t) = -g \Rightarrow V_y(t) = -gt + V_{y_i} \Rightarrow y(t) = -\frac{1}{2}gt^2 + V_{y_i} t + y_i$$

$$\Rightarrow y_f = -\frac{1}{2}gt^2 + V_{y_i} t + y_i$$

$$\Rightarrow \Delta y = -\frac{1}{2}gt^2 + V_{y_i} t$$

$$\Rightarrow \boxed{\Delta y = -\frac{1}{2}gt^2 + V_i \sin(\theta)\, t}$$

$$\Delta y = \frac{-1}{2} g \left(\frac{\Delta x}{v_i \cos(\theta)} \right)^2 + v_i \sin(\theta) \left(\frac{\Delta x}{v_i \cos(\theta)} \right)$$

$$\Delta y = \frac{-1}{2} g \frac{\Delta x^2}{v_i^2 \cos^2(\theta)} + \frac{\cancel{v_i} \sin(\theta) \Delta x}{\cancel{v_i} \cos(\theta)}$$

$$\Delta y = \frac{-1}{2} g \frac{\Delta x^2}{v_i^2 \cos^2(\theta)} + \tan(\theta) \Delta x$$

$$\Delta y - \tan(\theta)\Delta x = \frac{-1}{2} g \frac{\Delta x^2}{v_i^2 \cos^2(\theta)}$$

$$v_i^2 = \frac{-1}{2} g \frac{\Delta x^2}{\cos^2(\theta)} \left(\frac{1}{\Delta y - \tan(\theta)\Delta x} \right)$$

$$v_i = \pm \sqrt{\frac{-1}{2} g \frac{\Delta x^2}{\cos^2(\theta)} \left(\frac{1}{\Delta y - \tan(\theta)\Delta x} \right)}$$

$$v_i = \pm \frac{\Delta x}{\cos(\theta)} \sqrt{-\frac{1}{2} g \frac{1}{\Delta y - \tan(\theta)\Delta x}}$$

$$\boxed{v_i = \pm \frac{\Delta x}{\cos(\theta)} \sqrt{\frac{-1}{2} \frac{g}{\Delta y - \tan(\theta)\Delta x}}}$$

$$g = \frac{9.8m}{s^2} \left(\frac{3.284}{1m} \right) \left(\frac{12 in}{1 ft} \right) \approx 386 \, in/s^2$$

$$v_i = \pm \frac{60 \, in.}{\cos(24^\circ)} \sqrt{\frac{-1}{2} \left(\frac{386 \, in./s^2}{\Delta y - \tan(24^\circ) 60 in.} \right)}$$

$$V_i = \pm \frac{60\,in.}{\cos(24^\circ)} \sqrt{\frac{-1}{2}\left(\frac{386\,in./s^2}{h - 9.5\,in. - \tan(24^\circ)60\,in.}\right)}$$

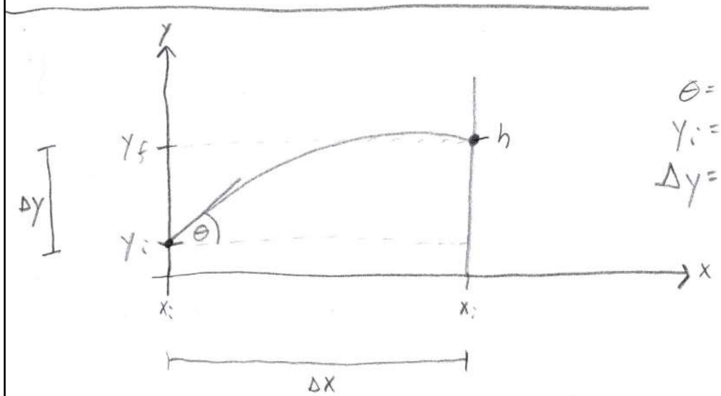
$$\Delta y = y_f - y_i = h - 9.5\,in.$$

since $h_{max} = 32\,in.$, $h - 9.5\,in. - \tan(24^\circ)60\,in. < 0$

and

$V_i > 0$,

$$V_i = \frac{60\,in.}{\cos(24^\circ)} \sqrt{\frac{-1}{2}\left(\frac{386\,in./s^2}{h - 9.5\,in. - \tan(24^\circ)60\,in.}\right)}$$



$\theta = 24^\circ$

$y_i = 9.5\,in.$

$\Delta y = y_f - y_i = h - 9.5\,in.$

$V_i(in/s^2) = 495.77(\text{motor power}) - 90.918$

$$V_i = \pm \frac{\Delta x}{\cos(\theta)} \sqrt{\frac{-1}{2} \frac{g}{\Delta y - \tan(\theta)\,\Delta x}}$$

$$= \pm \frac{\Delta X}{\cos(\theta)} \sqrt{\frac{-1}{2} \frac{g}{h - 9.5\text{in.} - \tan(\theta)\Delta X}}$$

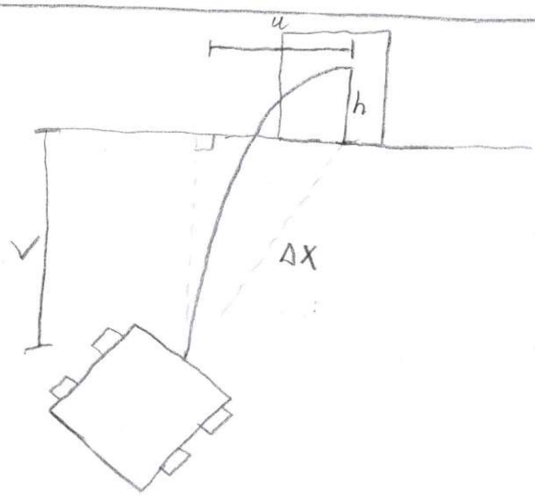
$$495.77(\text{motor power}) - 90.918 = \pm \frac{\Delta X}{\cos(\theta)} \sqrt{\frac{-1}{2} \frac{g}{h - 9.5\text{in.} - \tan(\theta)\Delta X}}$$

$$495.77(\text{motor power}) = \pm \frac{\Delta X}{\cos(\theta)} \sqrt{\frac{-1}{2} \frac{g}{h - 9.5\text{in.} - \tan(\theta)\Delta X}} + 90.918$$

$$\text{motor power} = \frac{\pm \frac{\Delta X}{\cos(\theta)} \sqrt{\frac{-1}{2} \frac{g}{h - 9.5\text{in.} - \tan(\theta)\Delta X}} + 90.918}{495.77}$$

for a ΔX and h,

$$\text{motor power} = \frac{\left| \frac{\Delta X}{\cos(24^\circ)} \sqrt{\frac{-1}{2} \frac{g}{h - 9.5\text{in.} - \tan(24^\circ)\Delta X}} \right| + 90.918}{495.77}$$



$$\Delta X = \sqrt{u^2 + v^2}$$

PID Algorithm

Luke Fitzgerald

March 11, 2021

PID Algorithm Analysis

This year, we used a Proportional Integral Derivative (PID) algorithm to have the robot drive true. We use the IMU in the Control Hub to get the initial heading of the robot. While the robot drives, any change in the heading of the robot results in a proportional power change in the drive motors.

The following is the method for the PID algorithm:

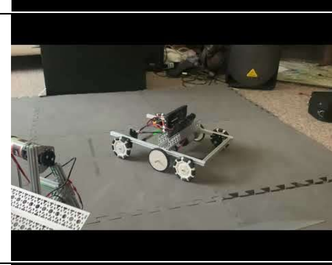
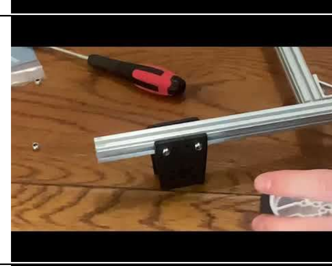
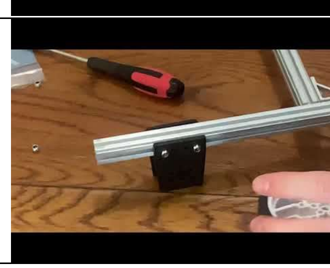
```
public void mecHoldHeading(double heading, double power)
{

    //Power Adjustment Proportional to Change in Heading
    double powerAdjustment = (heading) * (power / 15);

    double leftPower = power - (powerAdjustment);
    double rightPower = -power - (powerAdjustment);

    //Left Motors
    driveFL.setPower(leftPower);
    driveBL.setPower(leftPower);

    //Right Motors
    driveFR.setPower(rightPower);
    driveBR.setPower(rightPower);

    telemetry.addLine( s: "Left Power: " + leftPower);
    telemetry.addLine( s: "Right Power: " + rightPower);
    telemetry.update();

}
```

Since the initial value of the heading is always set to 0.0, the change in the heading is equal to the current heading. The “power adjustment” variable is proportional to the change in heading. The proportionality constant is power / 15. We initially tried power / 100, but this adjustment was too small. We gradually reduced the denominator so that larger adjustments would occur to correct drifting and it was found that 15 worked with a high degree of accuracy (with about 1-degree error for the full length of the game field). We made the proportionality constant dependent on power so that the PID algorithm would work regardless of what we set the power to. If we had made the program to operate at only one power level, iit would have been less flexible.

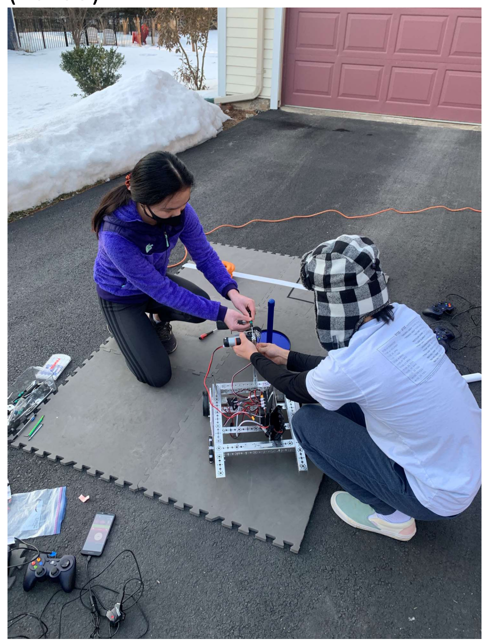
Outreach and Mentoring

The team helped to found (2) new rookie teams (18641 and 18753) and supported those teams with a combination of in-person mentoring, zoom mentoring, tutorial videos, materials, programs and prototypes. The team also provided support to team 16295, which an all-girls rookie team last year that we helped to form. New partnerships with John Cohen, Vermont Academy of Science and Technology, VT Maker Space and UVM CEMS lead to more than $3000 in grants that were used to support all (4) teams.

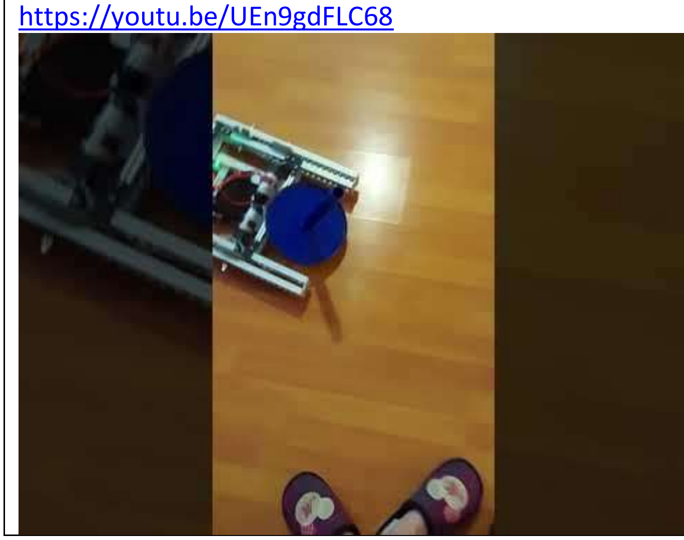
New Tutorial Videos

REV Bracket Tutorial https://youtu.be/ZAHqZFTkYdM		
Operating Rookie Robot Tutorial https://youtu.be/EOfIdiymGJU		
Programming Rookie Robot https://youtu.be/Mz92gxIldEk		
Mounting wheel tutorial https://youtu.be/zFBtZg7xYGU		
Wobble Goal Tutorial https://youtu.be/zFBtZg7xYGU		

In Person Sessions

2/24/21 Andrew Kim (9721) working with Kayla Kim (16295) 	3/8/21 Andrew Kim (9721) working with Emma Xia (16295) 

Rookie Teams using Prototype Robots

Team 18641 Driving with their wobble goal https://youtu.be/UEn9gdFLC68 	Team 18753 https://youtu.be/nUuN7O9Moi0