RBE 1001

Final Project: Report

Contributions

Max: My main contributions to the robot were designing and building our drive train, designing the forklift on our first iteration of the robot. In the final version, I helped to design and construct our four bar lift, and the screw to let us park on the ramp.

Pranav: My main contributions to the robot were designing and building the drive train, and also designing and building the cascading slides in our first iteration of the robot. In the final version, I designed and constructed the four bar lift and also the claw that I attached in front of the lift mechanism. I also helped to stabilize the robot and edited the parts of the robot, where needed.

Ethan: My contribution to the project was mostly organization. I kept track of what we did and what we still needed to get done, as well as organize our idea generation and concept selection. I also designed and built our original claw, which was changed in favor of a design capable of picking up more balls, and our autonomous program.

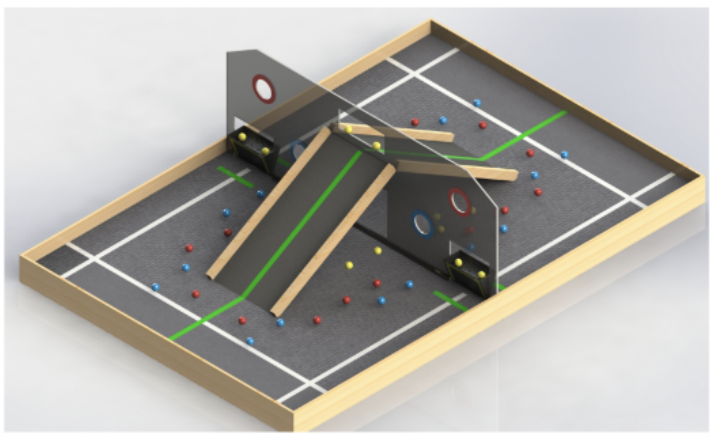
Max Williams

Pranav Jain

Ethan Ford

Introduction and Problem Statement

For this project, the goal is to deliver differently colored plastic LEGO balls through various holes in the plexiglass. Other, secondary objectives are to cross a 1” tall metal barricade in the center of the field, and to climb and park on a plexiglass ramp. For this project, we are given a limited set of VEX hardware and electronics, as well as a small budget to custom make parts, such as 3D printing. Below is an image of the field for the project.



There are several challenges associated with this project. First, while the blue hole is reachable within the starting height limit of 18 inches, the red hole is significantly higher off of the ground, forcing the robot to extend well past its original height. Another challenge is staying in place on the ramp. For the robot to be considered “parked”, it must remain in place after all the motors have been powered off. Given the steep incline and relatively low friction of plexiglass, the robot must have an external tool to hook onto the ramp. Finally, the limited design time for this project is another major challenge, as we only have four weeks to build, program, and test our robot.

We hope to build a robot capable of autonomously collecting plastic LEGO balls and delivering them through the four different circular holes in the plexiglass divider, and capable to driving up the ramp and parking on it, no bigger than 15.25” X 15.25” X 18”, and no heavier than 10 pounds.

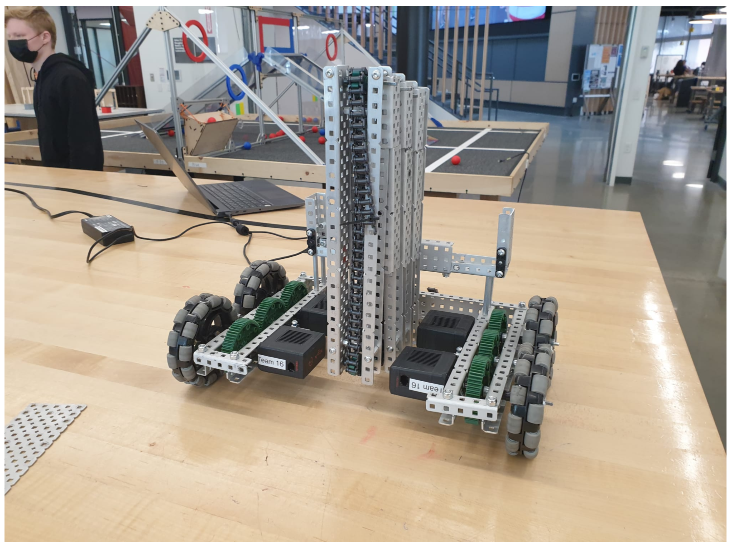
System Design

In designing this system, we had a few specifications for our robot that it needed to meet. It needed to pick up balls and deliver them through the plexiglass barrier both effectively and efficiently. During our idea generation and concept selection, we rated each of our ideas based on a few criteria. First, our delivery system needed to be built feasibly in the seven-week period we had. Some of our ideas would have taken much too long to build to work reliably than the time we had. Second, our delivery system needed to be consistent delivering balls. This is the main way to score points, so we wanted to be as reliable as possible in this area.

Collection Ideas		**Reason**
Pincer		Easy but not super precise
Scoop		Really efficient but not
Vertical Spinner		Fast intake and capable of intaking multiple balls
Vacuum		Not feasable
Claw Arm		Same as pincer
Forklift		Slow and not super precise
Trained Squirrels		No. Just no.
Lifting Ideas		
Forklift		Reliable and adjustable, not fast
Flywheels		Efficient, but may shoot it off of the edge
Delivery Arm		Same as forklift
Conveyor Belt		Like forklift but slower
Shooter via Spring		Less efficient than flywheel, but less powerful
Linear Slides		Same as forklift
Pulley		Not consistent
Scissor Lift		More complicated forklift
Trebuchet		not feasable but really cool
Catapult		Same as shooter via spring

Our concept selection chart with ratings and reasoning

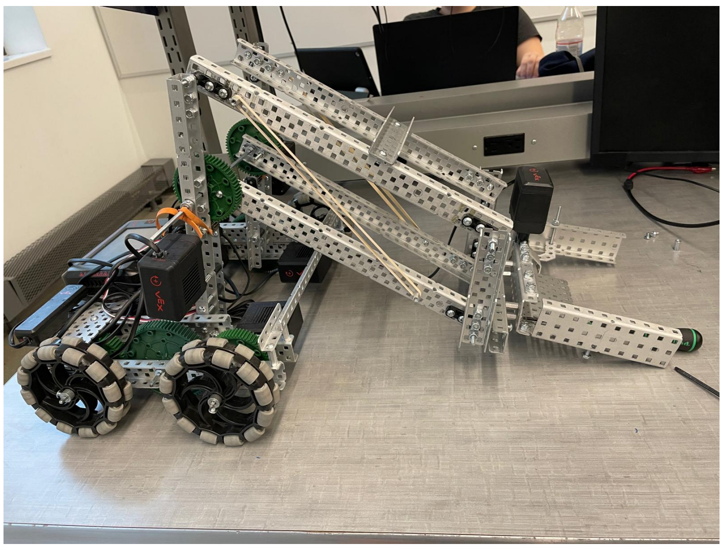
After sorting through our ideas, we settled on using a forklift that was lifted by linear slides as our delivery mechanism. Since we evaluated the forklift as not precise to collect the ball, we designed the forks to have rails which allows the balls to rest on the rails and not slip off. We also chose linear slides since Pranav had prior experience building linear slides, so we were confident in his abilities to build us the system that we wanted.



Original Robot

We went through our stages of testing, which included being able to drive around the area, pick up balls, and climb the ramp. This is where we ran into a few problems, the first being the weight distribution of the robot. Because of our linear slides being so heavy, it shifted the weight to the back causing us to tip whenever we attempted to drive the robot. This problem also made climbing the ramp much more difficult, since we tipped over as soon as we reached the steep part of the ramp. This could be solved by going backwards, however we lost traction on one side of the drivetrain when climbing backwards. We attempted multiple solutions to this problem, including switching our omnidirectional wheels to high-traction wheels and lowering the slides to lower our center of mass.

Despite our efforts, nothing changed, so we switched our design to a claw mechanism that was lifted using a 4-bar arm. This increased stability and traction compared to the linear slides in exchange for less reach of the lifting mechanism for the robot's final design.



Final Robot

Solutions / Justifications

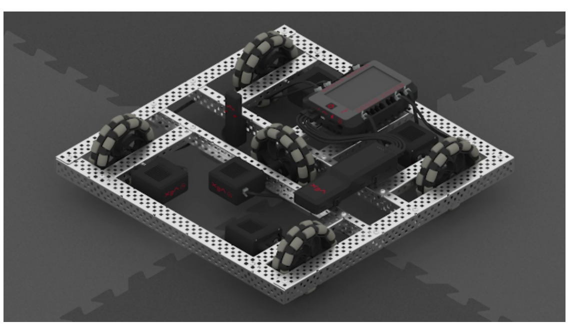
For our robot, there were four main functions that it had to perform.

- Maneuverability
    - Drive around the field
    - Be able to climb ramp
    - Speed and turning
- Intaking

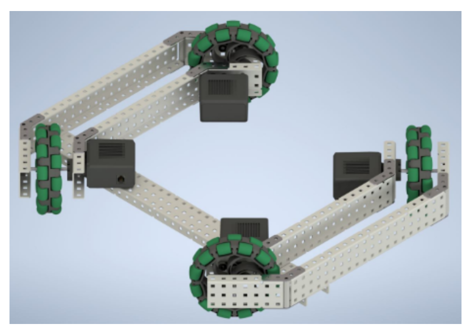
    - Collect balls
    - Able to pick up over one ball
    - Intake to a delivery / lift mechanism
- Delivery
    - Elevation to correct holes
    - Release ball at correct point
- Parking
    - Climb + Stay on ramp
    - Work without motor power

In terms of driving, there were several types of drive trains we considered.

We considered holonomic drive trains such as H-Drive (Image 1), four wheels shaped in a "H" pattern to allow for holonomic movement, and X-Drive (Image 2), which uses a sideways drive wheel to allow for strafing.

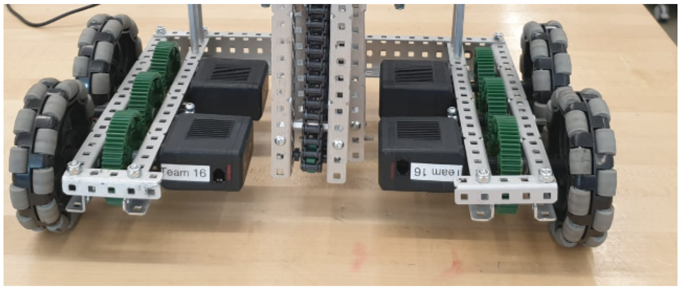


H-Drive



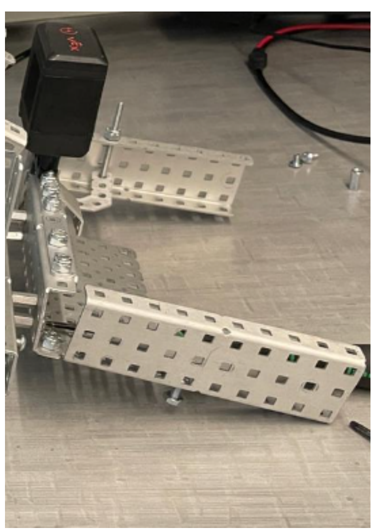
X-Drive

However, we felt that both were difficult, and the time needed to implement them would outweigh the benefits of maneuverability. So, we built our drive train using 4 driver omni-directional wheels, each linked via an 84-toothed gear. We kept the standard ratio of 18:1, since we felt that would provide sufficient torque while allowing us to drive around fast.



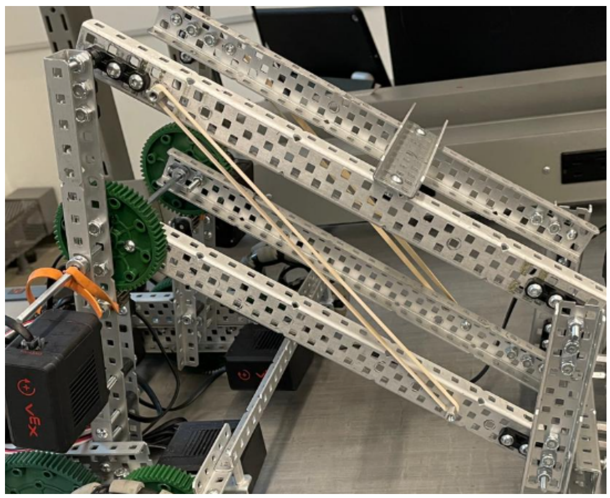
Our Drive Train

For intake, our three main ideas were a lift, a vertical spinner, and a claw. We chose not to use a vertical spinner because of concerns of the difficulty to design a delivery mechanism for it. On the first version of our robot, we attempted to use a forklift-like attachment to scoop the balls before raising them into the hole. However, this idea ended up failing because the balls did not have enough friction to allow the lift to slide underneath it. So, for our final design, we used a claw capable of picking up three balls at once. Finally, the claw was easy to attach to a lift, given its small size. Additionally, the screw on the bottom of one side of the claw allowed us to remain hanging on to the plexiglass divider to park after the robot powered off.


Claw + Parking Screw

For the lifting mechanism, we had two main ideas. Our first idea was a series of cascading linear slides powered by two motors at a torque of 36:1.

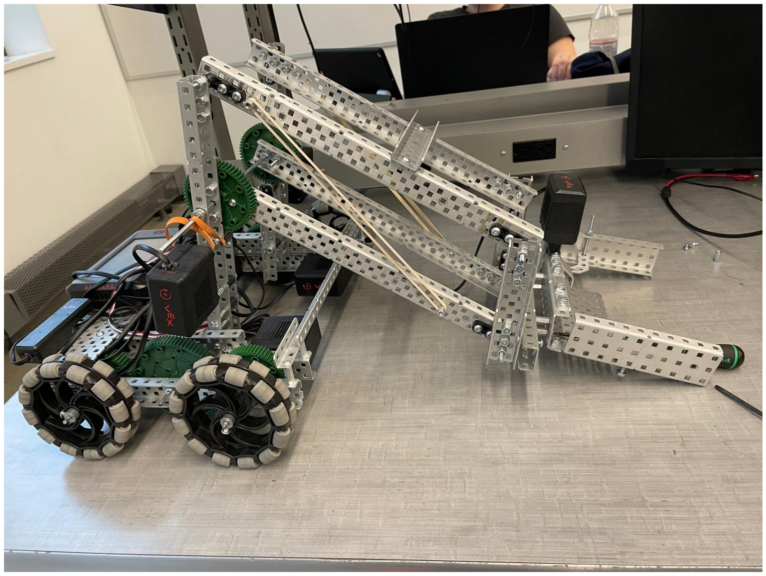
While the robot could reach both sets of holes, the poor weight distribution combined with the weight of the lift led to a series of mechanical issues. We could not climb the ramp, and we were very prone to tipping. So, we decided to use a four bar instead.



4 Bar Lift

By positioning the support towards the middle of our robot, we could have a much better center of mass, and be much more stable. In order to give the lift enough power, we used a 90:1 gear ratio combined with rubber bands for additional power. Although we could not reach the highest red holes, the improved stability was easily worth the tradeoff.

Systems Integration



Final Robot

Overall, we have designed the whole system in such a way that completes most of the requirements and tasks set out by the testing table. We designed the various robotics parts perfectly to make sure that they work to our expectations. However, when we combined all these parts to make the robot, we found out that our robot was significantly over the size limit (around 13cm) which eventually led to a deduction of 2 points. We allowed the robot to be oversized as we planned to have a second autonomous program that would allow us to get 2 bonus points. This meant that we could use our time effectively in completing the robot and creating the autonomous program.

During the autonomous period, we could successfully collect 3 out of the maximum 5 balls from the corner of the field, deliver it 100% of the time through the ramp, and then, park the robot on the ramp. This allowed us to not only get full points for delivering the balls but also allowed us to use the 10 minute time more effectively on Demo Day as we didn’t need to deliver the balls through the hole and then, just go up the ramp to park. By delivering 3 ball at a time, we could reduce the number of trips that we had to make to deliver the balls.

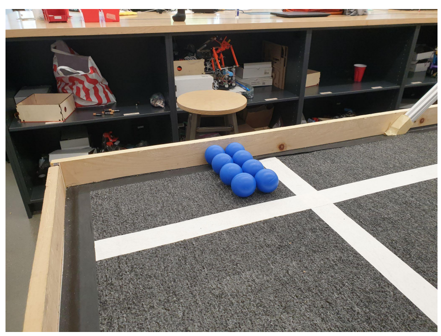
During the tele-operation period, we collected one ball at a time and then delivered it through the hole and the V-bucket. We could deliver two blue balls through the hole and a blue and red ball through the V-bucket. Then, we climbed the ramp and parked. This was effective as we could align the claw exactly with hole and then deliver the balls. Collecting one ball at a time seemed more productive as we were usually losing the first ball on the claw while trying to collect the second ball.

We also had a second autonomous code that basically did the same tasks as the previous autonomous program but it started from the other side of the field. This was a very simple but creative idea that allowed us to gain 2 bonus points for only changing the distance that the robot had to travel to collect the balls.

For the robot to complete these tasks, we went through some testing. We tested the robot for how long it took to climb the ramp. We saw it took us around 6.59 seconds on average which was much faster than 10-15 seconds that we were hoping to achieve. Because of the low gear ratio and four motor drive, our robot was quite fast at maneuvering around the field. It took us around 3.46 seconds on average to get the robot across the field which was faster than 5 seconds that we were hoping to achieve. Unfortunately, because of a last minute redesign of our lifting and delivery mechanism, we could not collect any data with our newly redesigned lift mechanism and the claw. However, while testing our autonomous program and tele-operating the robot, we found our claw and lifting mechanism to be quite effective at collecting and delivering 3 balls.

Performance

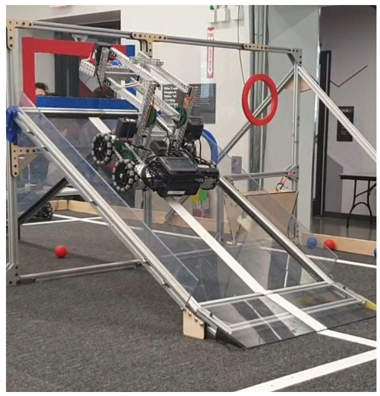
Our robot performed very well. We had to use dead reckoning because of the time constraints as we had to change the robot's configuration at the last minute. As we used dead reckoning, we had to test many iterations of the autonomous program with different ball arrangements to make sure that the robot picked up 3 balls 90% of the time.



Final Ball Configuration

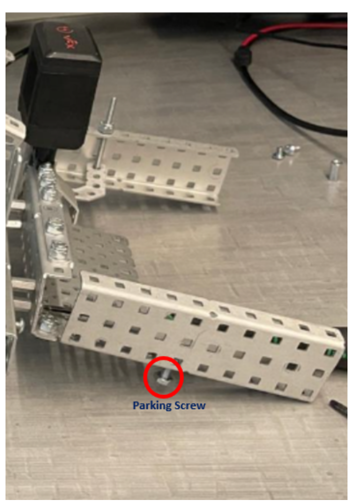
The final ball configuration was a 2 X 4 ball grid that helped the robot push the balls at the back wall and helped the robot pick up the balls. As there were more balls than the robot could pick up, there was a higher probability of the robot picking up 3 balls. As the robot couldn't physically pick up over 3 balls, we weren't worried about the robot picking up over 5 balls, causing us to get some or our points deducted. Although this worked for our robot, by adding a camera to the front of the robot, we would have been able to get 3 balls 100% of the time and the balls wouldn't need to be placed perfectly or in a specific configuration for the robot to work.

The robot was quite effective in getting up the ramp because of the robot being quite stable, had enough traction and was a four-wheel drive which gave it enough power. The addition of the 3 balls didn't impact the robot a lot as each ball only weighed 12g which became negligible when compared to the robot which weighed around 4.2kg.



Climbing the Ramp

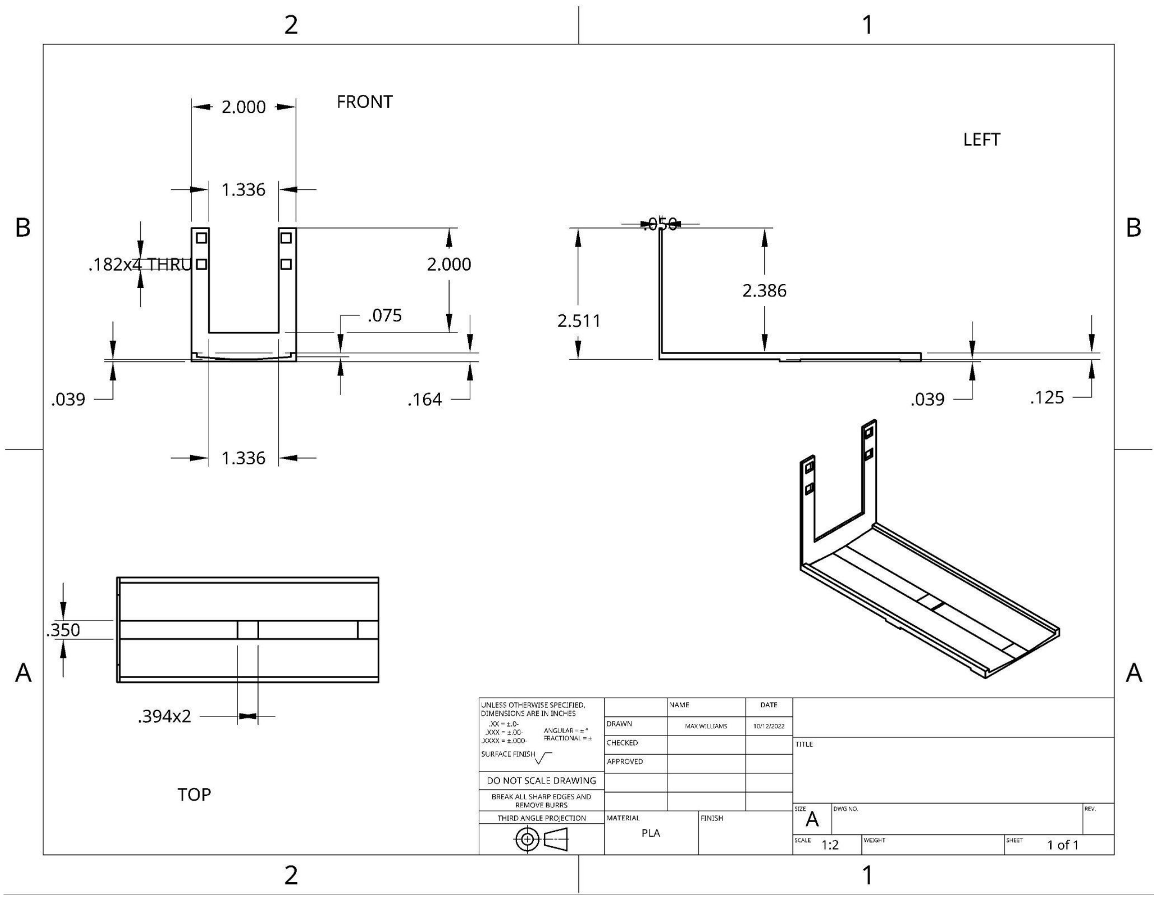
The robot's innovative parking strategy involved a loose screw that was attached to the claw of the robot. Though it seemed that the screw wouldn't be able to hold the weight of the robot on the ramp, especially when the motors were turned off, it actually did a very good job of keeping the robot up the ramp.



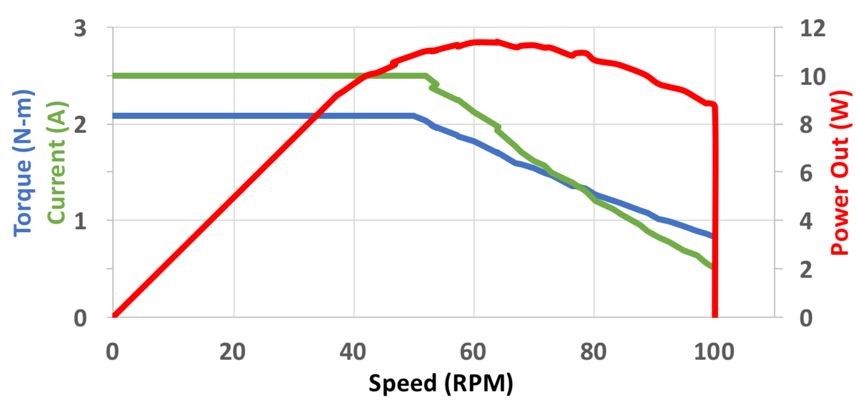
Parking Screw

Appendices (Calculations, Experimental Results, State Machines, etc..)

Lift Specifications



VEX V5 Motor Curve



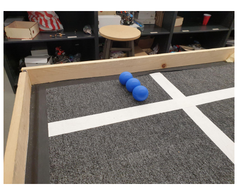
Ramp Climbing Test Results

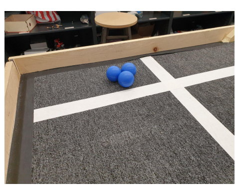
Trial 1	4.3 seconds
Trial 2	4.7 seconds
Trial 3	12.1 seconds (Driver Error)
Trial 4	6.5 seconds
Trial 5	5.3 seconds
Average	6.59 seconds (4.98 without error)

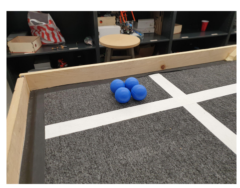
Speed of the Robot Across the Field Test Results

Trial 1	3.3 seconds
Trial 2	3.6 seconds
Trial 3	3.7 seconds
Trial 4	3.3 seconds
Trial 5	3.4 seconds
Average	3.46 seconds

Ball Configurations


Iteration 1


Iteration 2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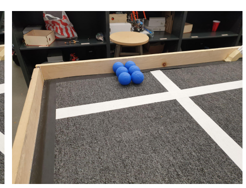
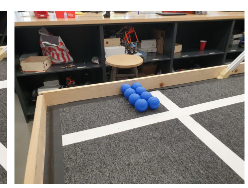

Iteration 4


Iteration 5