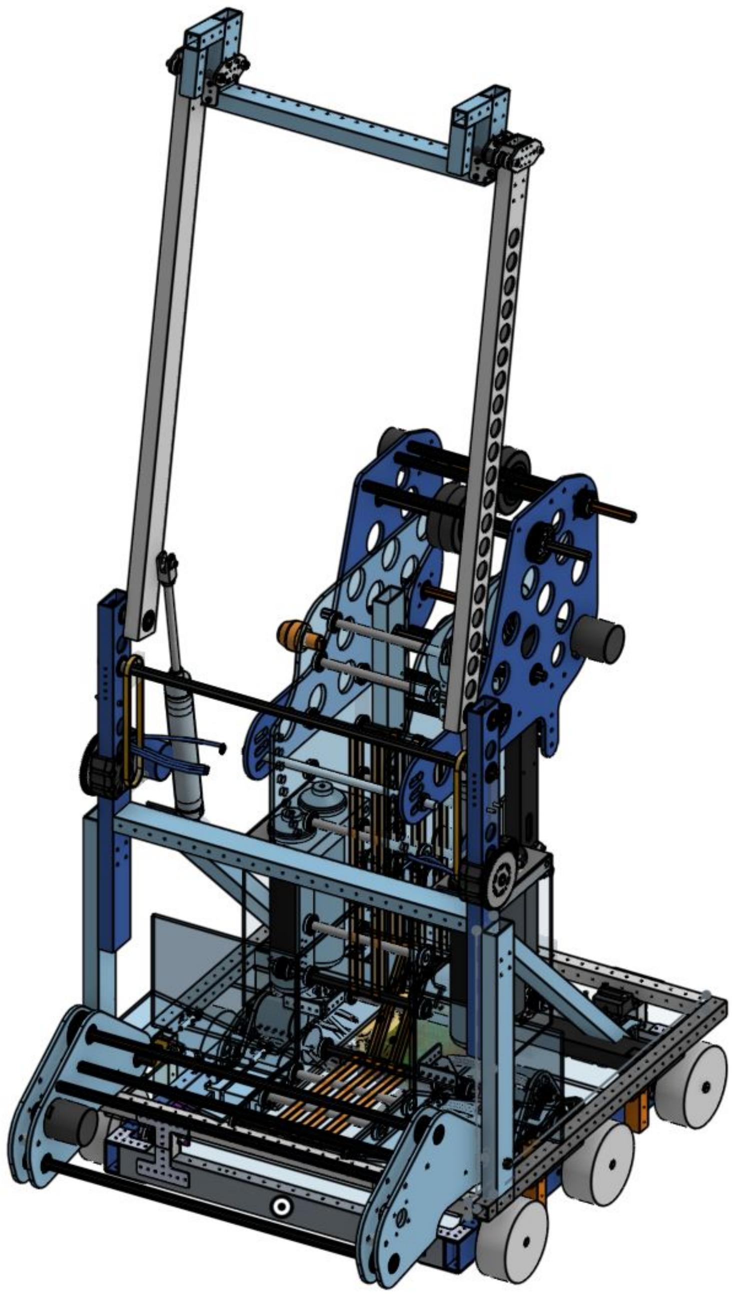
Team 1389

Technical Binder



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Game Analysis

On January 4, 2020, Team 1389 traveled to Woodrow Wilson High School in Tenleytown, DC, to view the live-streamed game reveal for Infinite Recharge with many other teams. After the reveal, we headed back to our lab to break down the game and start coming up with strategies for the season.

In the following analytic discussions, the team sought to identify the best way to score points. We attempted to predict how other teams in the Chesapeake District would perform in order to best set the design requirements and role of our robot. We broke up the different ways to score in FIRST Infinite Recharge and assigned each method a ranking: Common, Uncommon, Rare, and Impossible. At each level of competition, from Districts to the World Championship, we tried to predict what strategies we would see so we could set a goal for our own team's minimum score requirement. After this, we had to decide which goals would be our priorities and which would be less important to us. At the end of this long day, the team set our design requirements and decisions and began working to bring each initial concept to life.

Initial Design Requirements

On the first day of build, after a strategic analysis of the game manual, we set the design requirements for our robot as follows:

Given

- Inline Drop-six drivetrain
- 6 motors in drive train
  - We decided on our drivetrain early to ensure we would have as much time to design, fabricate, test, and modify the mechanisms on the robot as possible.

Primary:

- Have a ground intake that can do the high goal
- Be able to score three Power Cells in Auton
- Cross the line in Auton
- Be able to score 10 balls total in Teleop within two cycles
- Climb

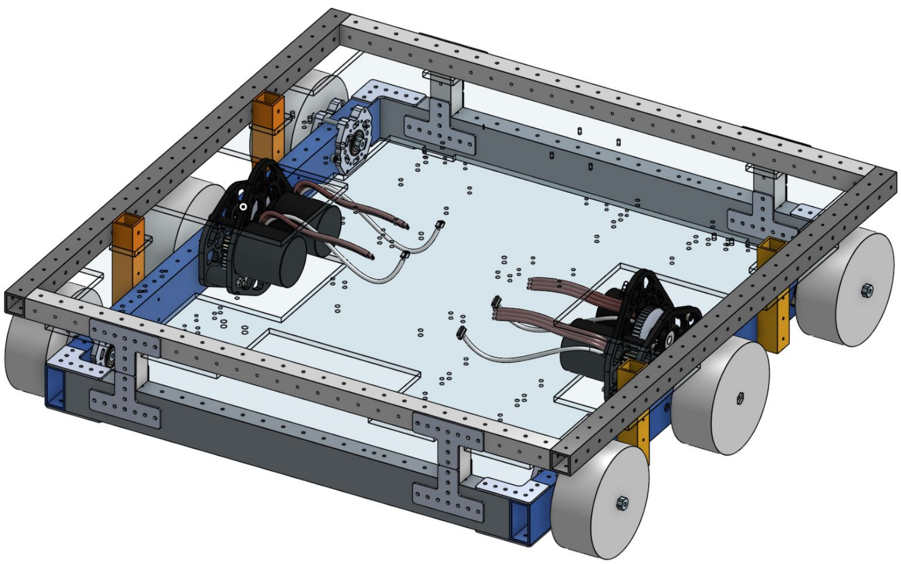
Secondary:

- Wheel Rotation
- Scoring in the high goals
- Have vision working

Tertiary:

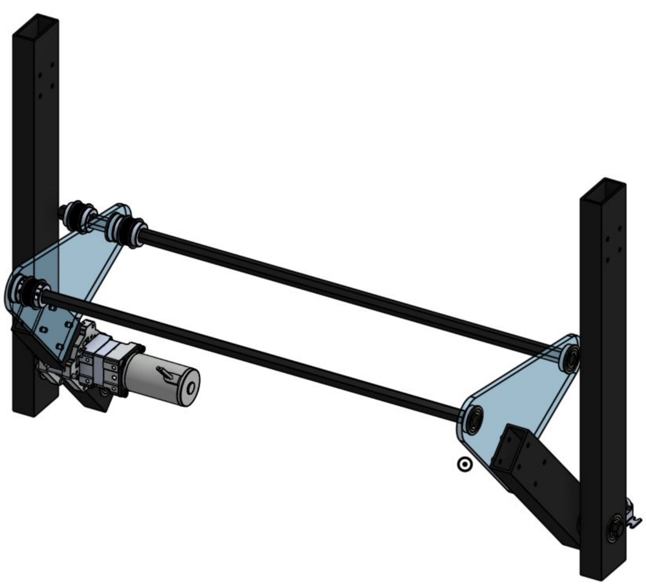
- Wheel Position Control

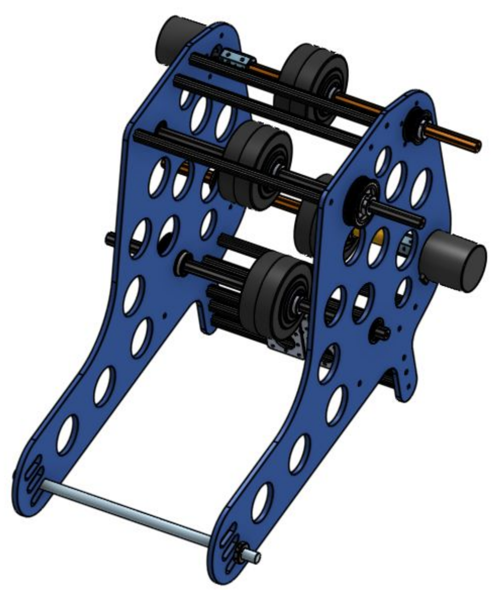
Mechanical Design



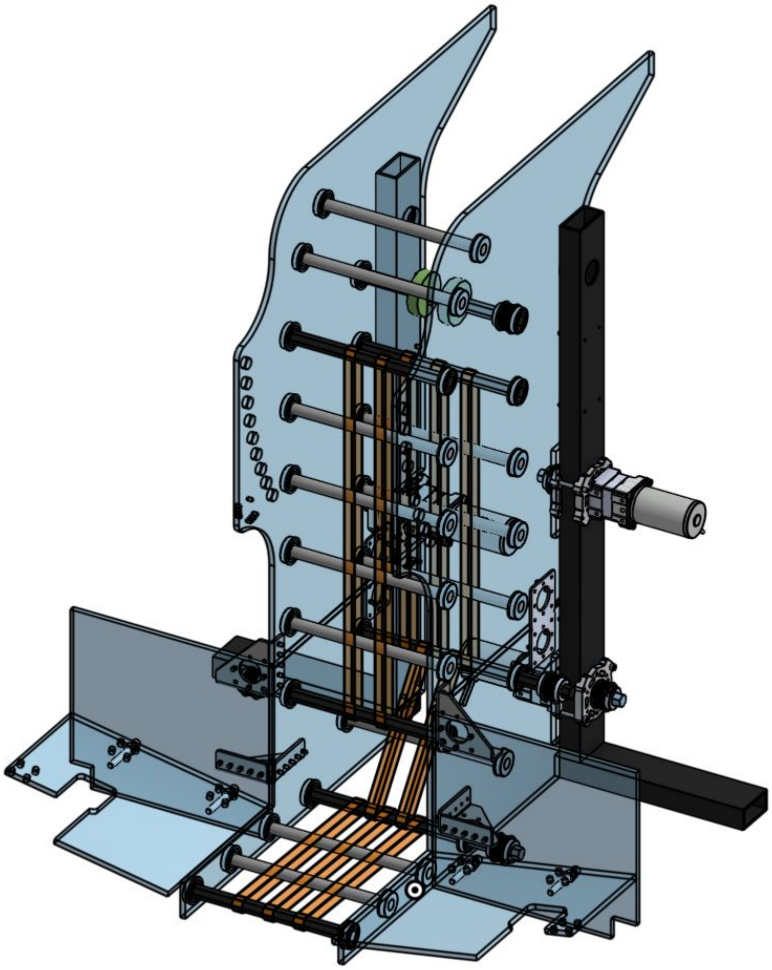
← Drivetrain

↓ Shooter



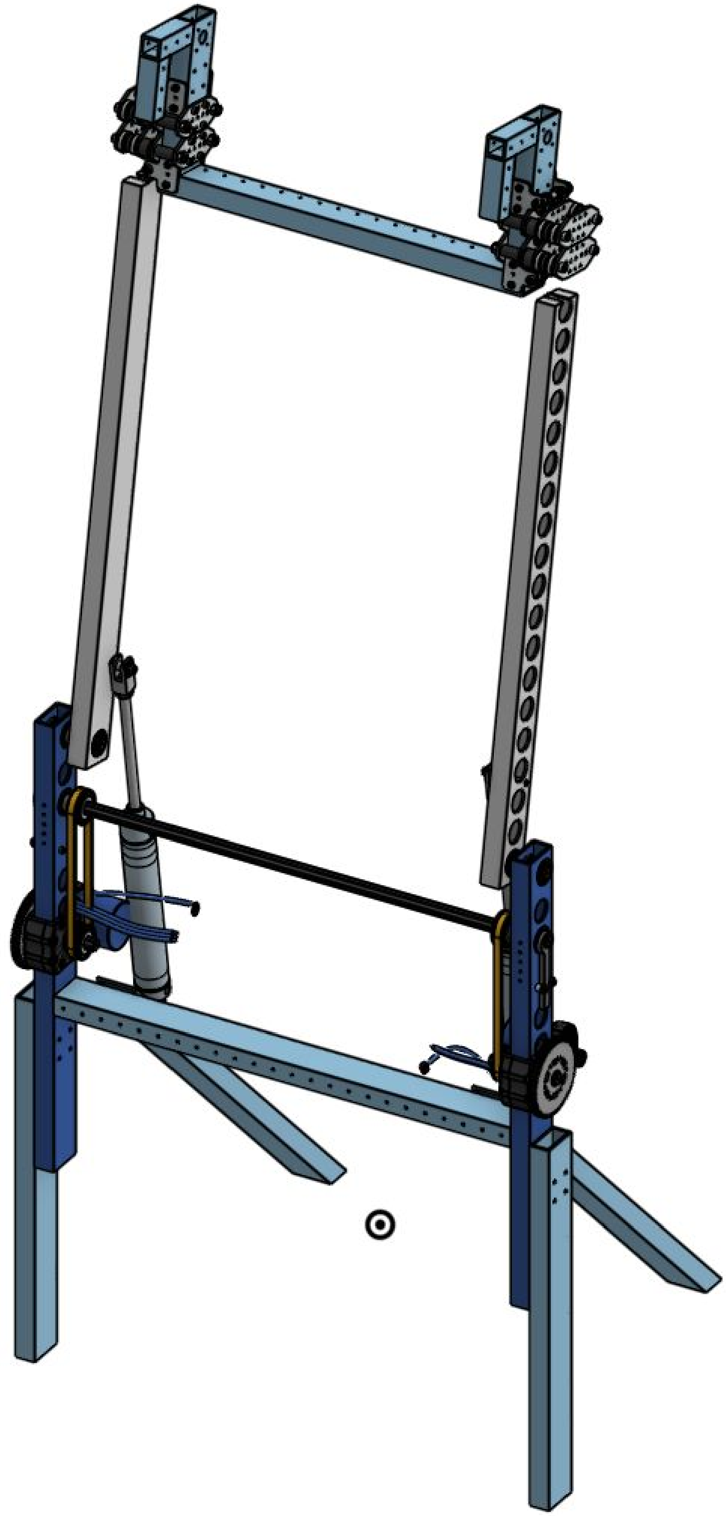


↑ Intake



↑ Conveyor

Climber →



Drivetrain

Goal for system: We decided upon a six-wheel tank drive last May in order to go into this season with a reliable drivetrain. This year we chose to put our chain in-tube so that there would be less interference with the electrical board. However, knowing that in-tube was unfamiliar, we built a practice drivetrain in the weeks leading up to kickoff. Originally, the drivetrain had six NEOs, but after a couple driver practices we realized that that was excessive and switched down to four motors.

Design: Andromeda has a six wheel tank drive system with chain-in-tube. It is powered by four NEOs and has 5 in Colson wheels.

Fabrication: The Monday following kickoff, we started fabricating our final competition drivetrain. Because we had built an exact replica a few weeks before, we were able to finish all of the fabrication and assembly by the end of the week. One of the most important things we learned from doing our practice drivetrain was how to put the chain inside the 2x1. Most teams that do chain-in-tube use 2x1.5 because the sprockets barely fit inside the 2x1. For our practice, it took a team of four people almost two whole days to put the four chains inside the metal, but for the real robot it took one person a mere 30 minutes. We also discovered later in fabrication, that the drivetrain that had been designed to be a drop six, was not in fact fabricated as a drop six, with all wheels instead being vertically aligned.

Intake

Goal for system: We aimed to create an over-the-bumper intake that would be "touch it, own it" so that we wouldn't waste cycle time trying to chase balls that we couldn't get on the first try.

Design: The intake starts inside the frame perimeter and is brought outside at the beginning of auto by shaking our robot back and forth. The intake covers most of the front of the robot, and consists of eighteen 35 durometer compliant wheels spread evenly along two axles, which guide the balls from the ground into our hopper. Both axles run at the same speed and are powered by a 775 Pro motor, geared 15:1.

Fabrication: The intake was one of the first things fabricated because the CNCed side plates are relatively small and the system is uncomplicated. After some testing, we decreased our gear ratio from 30:1 to 15:1, because intaking was wasting too much time. At this point, we also chose to switch from a BAG motor to a 775 in order to permit this change in speed while not sacrificing the torque we need to intake. We also decided against using pistons to lower the intake down, as we discovered gravity worked well enough that extra systems were unnecessary.

Conveyor

Goal for system: We chose to design a tall robot because of concerns towards building a conveyor that would wrap around itself. We also wanted the space for a hopper in the event that our intake broke, we still wanted to be able to do a five Power Cell cycle.

Design: We have a hopper to store balls between the intake and the conveyor. There are a set of polyurethane belts that run along the bottom of the hopper to move balls from the hopper to the conveyor. The conveyor itself is vertical and uses a set of belts to move the balls up through it. It is two-sided, and each side is powered individually by a BAG motor geared 15:1.

Fabrication: The conveyor was the most CNC-dependent because its massive side plates are all polycarbonate that needed to be precisely cut to have the holes for axles line up between both sides. The conveyor has been adjusted a couple times because of trouble when the conveyor runs with multiple balls in it for extended periods of time. During its first iteration, instead of the Vex belts that are currently on the robot, there were a set of polyurethane belts that our team custom made. While we left some of those on the bottom of the hopper, we had trouble with them walking and getting tangled over short periods of time, and over a period of a week they stretched and became less effective. We tried replacing belts, and 3D printed spacers to prevent walking, but eventually found that the Vex toothed, aluminum-reinforced belts worked far better. Additionally, we changed the positioning of one of our belts after testing and having balls get stuck at the top of our conveyor. We extended the length of a belt to over the indexer, so that balls cannot get stuck, instead they just pop into our shooter.

Shooter

Goal for system: We wanted to be able to shoot from a variety of positions on the field, and be able to adjust our shooter to fill whatever role our alliance partners needed.

Design: We designed a vertical flywheel shooter that can be manually adjusted to a variety of angles. We also mounted our Limelight beneath the shooter so that vision could be as accurate as possible. The shooter is connected to the conveyor by two compliant wheels that index the ball into the first set of wheels, which get it up to speed. The indexing wheels ensure we only send one power cell into the shooter at a time. The second, outer set of flywheels then shoot the ball outwards. The two sets of wheels are connected by a pulley that allows the inner set to spin at half the speed of the outer flywheels. The outer wheels are directly driven by two NEOs, which, when speeds are adjusted, allow us to shoot from a variety of positions on the field.

Fabrication: The first iteration of the shooter began to be built mid-way through week three, and was found to be durable but heavy. Originally, the sides of the shooter were made of metal 2x1, but was soon replaced because of weight concerns. The second shooter design had a set of CNCed plates. However, after intense shooter testing, they started to crack at points of high stress. The third shooter design increased the amount of material near those areas that had previously cracked, and further decreased the overall size of the side plates. Even with these adjustments, the shooter has remained reliably powerful and accurate throughout our testing.

Climber

Goal for system: After week one, there had been a number of game breakdowns from other teams and mentors, and climbing was consistently mentioned as being relatively easy, and a must for events beyond the district level. This led us to designing a climber that would be able to climb every match, at any position along the shield generator and even when the shield generator is not level.

Design: Our climber is actuated upwards by two 7 in stroke pistons that swing an arm about 120 degrees from its down position inside the frame perimeter to its up position perpendicular to the base of the robot. Two hooks used to attach to the shield generator are connected to an axle by a set of ropes. The axle is covered in high-strength hook tape, which holds the rope securely at one end. This axle is powered through two pulleys that each connect to NEO motors that are geared 72:11 and winch the hooks down. When the axles turn, the rope wraps around them and pulls down the hooks, therefore raising the entire robot. In order to prevent the robot from lowering back down once disabled, a ratchet was placed on the end of the axle so the rope would not unwind.

Fabrication: This is the only major mechanism besides the drivetrain that is made mostly of metal, which made weight a major concern. Therefore, we took time to make sure that there were lots of lightening holes, while still making it structurally stable. After initial testing, we noticed that the clamping gearboxes that held the NEOs in place slipped after a couple climbs. While there is no permanent solution to the loss of tension in belts, we have added it to our pre-match checklist to ensure that every match we could climb.

Control System

Overview

This season our electrical team designed the electrical board with the idea of mounting a majority of our components on the underside of our robot. Even with motors on the other side of the robot, the team was able to neatly wire the robot, allowing enough room for troubleshooting. Additionally, our team decided to use a pneumatics system for our climber. With large pistons strong enough to support the weight of our robot, we concluded that pneumatics would be able to bring our winch-and-climb mechanism to winch upwards in order to climb.

Our Design

This year, our team was much more organized, which allowed us to minimize our time with the robot while making conscious decisions when designing the electrical board. We decided to keep our robot simple in terms of wiring since the majority of the components are right next to the PDB. In order to make that happen, we decided that an electrical board on the underside of our robot would help all of our components stay close together. So far, our robot does not have any major electrical problems, which proves that a simple design is quite effective. With these constraints, our electrical team was able to create a design that resolved issues regarding space and logically placed components near the mechanisms that they control. Last year, our team faced issues regarding access to the electrical board. As a result, if a wire was disconnected during the competition, tracing and fixing the issue proved to be very difficult. In order to improve this, our electrical board was placed so it was easily accessible. Now, when the robot is placed on its side, our team had instant access to the electrical board. However, there were some disadvantages to placing the electrical board underneath our robot, including a large number of wire extensions that would be needed to reach motors and other components at the top of our robot. However, our team took this learning opportunity to teach new electrical members how to precisely crimp wires in order to bring wires all the way to the top of our robot.

Another hurdle that our team had to overcome was routing our wires, as well as distinguishing wires in order to help the pit team trace wires to their components. This year, our leadership team wanted to encourage the learning of our new members by giving them as much time with the robot as possible. As a result, there was a learning curve of ensuring that no loose wires were near the conveyor or gear boxes to prevent the wires from ripping.

In terms of the drivetrain, our team used six neos since these motors provide enough speed with a lighter weight. Additionally, our team used two neos for our shooter. We also used five victors in order to power the conveyor system. For the conveyor system, we are using two bag motors that are controlled by victors. For the indexer, our team used the 775 motor that would provide a steady control of the flow of Power Cells from the conveyor to the shooter. Furthermore, we decided to place the RoboRIO on the top of the drivetrain because sensors such as beam breaks and cameras would be at the top of the robot, so the convenient location of the RoboRIO would allow for the team to easily trace our wires.

Our team also started a new concept: the electrical journal. In this journal, our team documented the progress of our electrical board, the order of the CAN loop to help troubleshoot individual components, as well as the ports that our team used. This valuable resource has dramatically improved the organization of our team as all the electrical members would be on the same page. It would also help with troubleshooting the robot knowing exactly where any disconnections may occur.

Even with this new sense of organization, there were also many technical issues, such as powering components on top of the drivetrain such as the radio. Through repetitive testing, our team determined that power over ethernet was much more stable and reliable than the direct power connection to the radio. Additionally, our team found that aligning the beam breaks was difficult as they were needed to be accurate to determine whether a power cell is in the conveyor system. In order to resolve this issue, our team used a ruler and string to make sure that the bream breakers are in alignment.

Mentors

This year one of our alumni from the team, Landon Perlman, came back and joined us as a mentor. He was the head of electrical four years ago for the team and has always been helpful whenever we had FRC robot questions. Unlike in previous years, we had a mentor who had extensive knowledge of the FRC components and the general functions of each subsystem. Through his past experiences with the team, he understood the capabilities of the team and always encouraged everyone. He understood the stress and the hard work that each student went through in order to build our final robot. Also, another mentor we have is David Swearingen, who was also a mentor last year to help the electrical team. With a year of experience mentoring our team, David was able to assist students in learning the basics such as soldering wires as well as how to organize wires on the robot. He was helpful with the technical aspects of electrical and ensured that we used the proper techniques when wiring things. He helped us get better at soldering and learn about the why's of electrical.

Improvement

This year, our team has made a significant improvement in terms of time management. Unlike last year, we set realistic goals in terms of what goals need to be accomplished at the end of the week. Our team also used Trello, which is an organizing tool that helps us keep track and tasks while setting goals for when they need to be done. This year, trello has been much more organized and detailed making day to day tasks much more streamline. Additionally, new members were able to learn about both the electrical and pneumatics system, thus improving their knowledge towards troubleshooting. Through resources such as the electrical journal, troubleshooting the robot has become a much more linear process that increases the efficiency of the pit team.

Programming Design

Overview

- **Identifying and Autonomously aligning with Power Cells**
- **Autonomous Routines**
- **Identifying and Aligning with the Power Port**
- **Mentor Support**

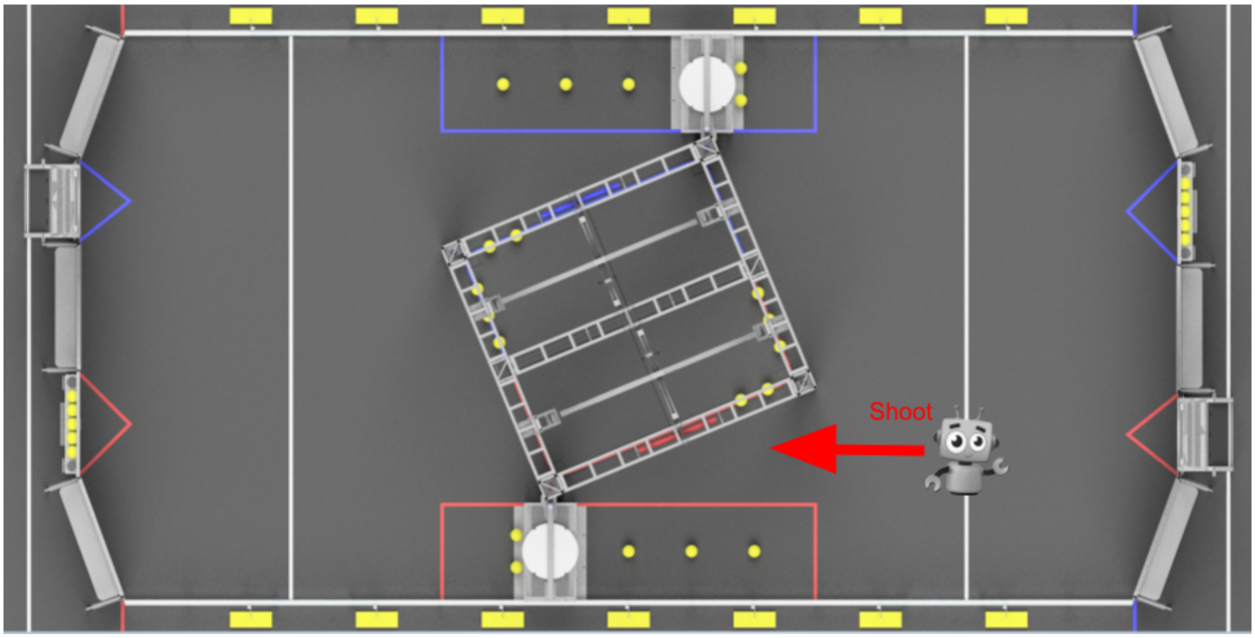
Identifying and Autonomously Aligning with Power Cells

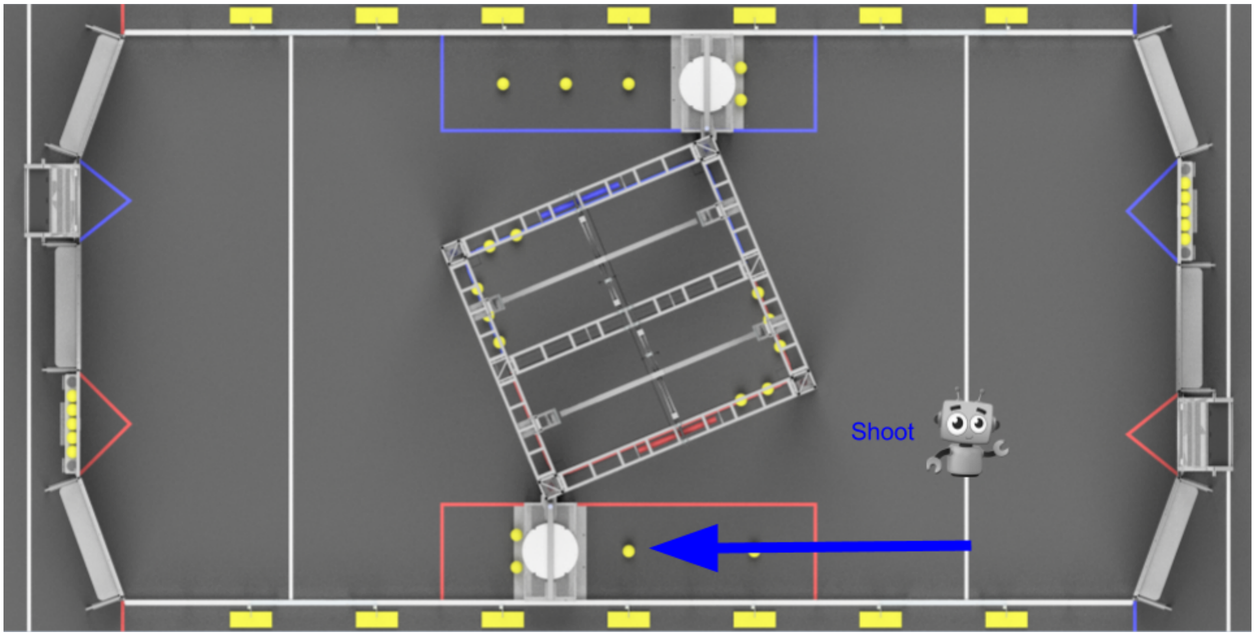
This year we created a machine learning algorithm that identifies where a Power Cell is relative to our robot and then leveraged this algorithm to create a routine that autonomously picks up Power Cells. Our machine-learning algorithm uses the scripts provided by WPILIB to feed images from the camera into our machine learning model. We annotated the remaining images in the WPI-provided image set that were not labeled, identifying which parts of the image were Power Cells. We then fed this data into Google Cloud Vision, using our own script to avoid an error that stopped teams from successfully completing the tutorial as it stated in the instructions. On the hardware end of things, our model is running on a Raspberry Pi 3B+ with a Microsoft

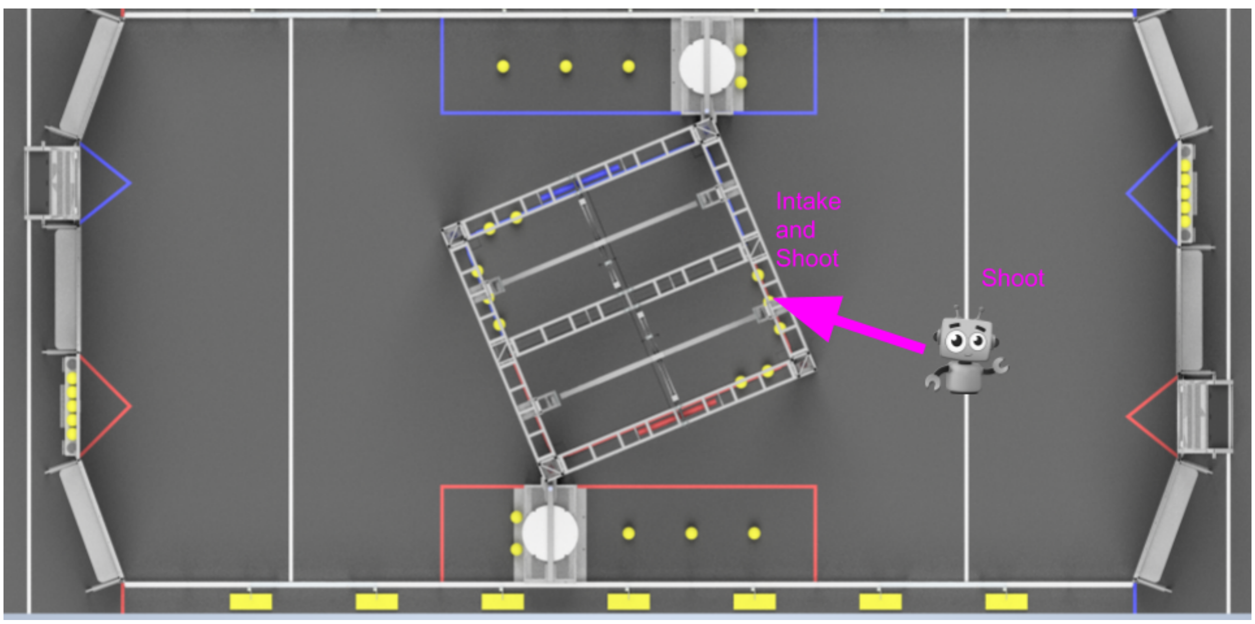
Lifecam HD-3000 camera, connected to our router through an ethernet bridge. We also have a Google Coral Edge TPU plugged in to the Pi, which helps greatly increase processing speed while running the model. Once a Power Cell comes into our camera's field of view, the script running on the Raspberry Pi publishes the horizontal position of the Power Cell to NetworkTables. We then use this data to turn our robot so it is aligned with the Power Cell, allowing us to collect Power Cells with much more accuracy and precision. Although we've run into hardware issues with consistently powering the Pi, we plan to use it to make the 6 ball auto on the control panel side more reliable and implement it in teleoperated period to simplify picking up balls.

Autonomous Routines

This year we created four different autonomous routines for the start of the game. Using the game manual, we found measurements of relevant distances to create accurate routines. Our four different autonomous routines vary in complexity. In our simplest auto, the robot shoots from in front of the Power Cell port into the power port, and then drives off the starting line. We also have routines that align the robot to the outer port using a Limelight computer vision system, and then pick up balls from the shield generator or the control panel, before shooting again. For our most reliable 6 ball auto, the robot's gyro is zeroed perpendicular to the auto line. Then, the drive team aligns the robot so it can shoot into the Power Port. When the game starts, we shoot 3 balls in, and then turn the robot back to 0 degrees. We drive back slightly, then stop, which drops the intake out of the robot. Then, the robot drives to the control panel, while intaking and starting a shooter PID (proportional integral derivative) loop. Once it reaches the control panel, the robot aligns with the power port, then shoots the last 3 balls. For the positions we will be firing from, we tested out the right speed the shooting system needs to use to be accurate. During the autonomous routines, we use a PID controlled feedback loop, to correct errors the robot may be making. We use these to control the drivetrain, vision systems, and shooting subsystems.




Shoot


Intake
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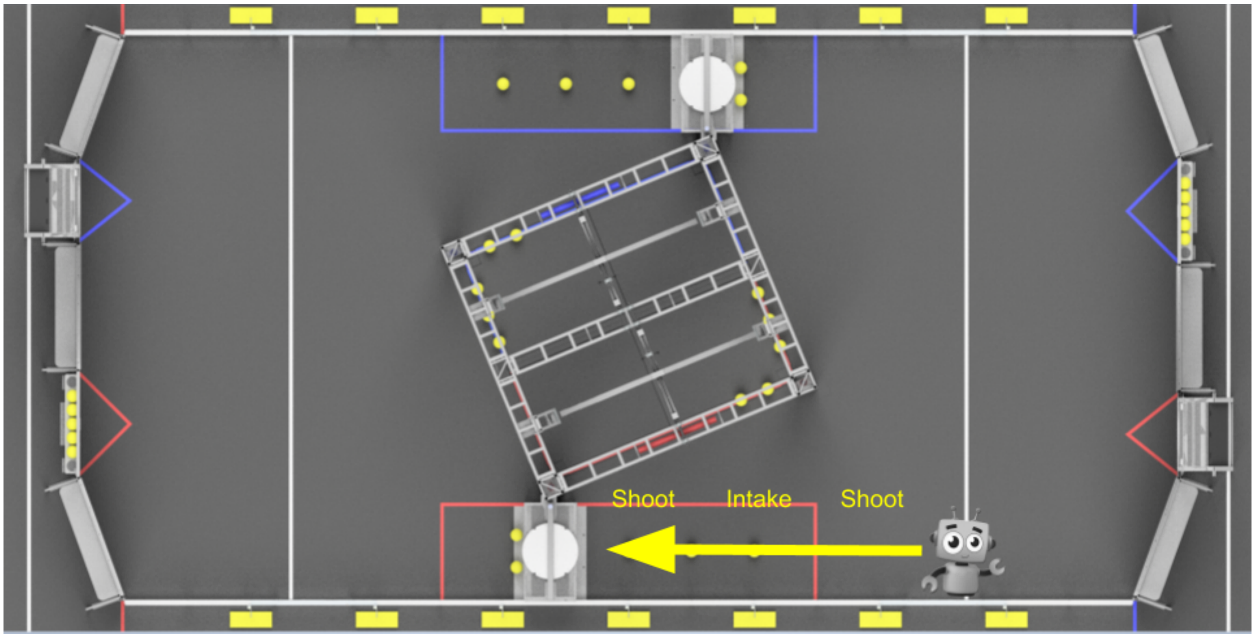
Shoot



Identifying and Aligning with the Power Port

We are using the limelight 2+ on our robot to face the target automatically in both the Tele-Operated and Autonomous periods. To make the limelight recognize the power port, we created a model of the power port, complete with reflective tape. Then we set the limelight to find objects of the same hue, saturation, and value as the tape around our model. We also made it recognize the specific half-hexagon shape of the tape, to ensure that it wouldn't falsely identify lights or other objects as the power port. As a result, the limelight can see and identify the target from across the field, and then we use a PID control loop to face the target quickly and efficiently. This makes shooting much easier on the drivers, because they just have to face the robot in the general direction of the target and press a button, leaving the aligning and actual shooting to the program. We also use the limelight to find our distance to the power port. The distance then lets us calculate the speed we need to shoot at to hit the target. This lets us shoot from a wide variety of distances, allowing us to have more versatility on the field.

Mentor Support

This year, we gained a new mentor, Elliot Capek. He's a recent college grad, who was a programming member of an FRC team in Washington State during high school, which meant he brought specific understanding of the type of problems we need to solve as the software division of an FRC team. Mr. Capek helped us a lot when we needed to deviate from WPILIB's guide for training the model because of an issue in the process, providing intuition for how the ML model works, as well as help figuring out how to train the model. He also provided valuable advice for our members about approaching college and working life from the perspective of someone who was recently in our position.