SIDEWAYS

2022

Technical Binder

Foreword

The 2022 FRC Season: Rapid React started off with a bang at Team 254, as members and mentors alike were eager to get their hands dirty building a new robot in-person. After extensive analysis of this year's game, we produced a list of robot requirements to pursue. This tech binder details the results of those pursuits, our 2022 FRC robot: SIDEWAYS.

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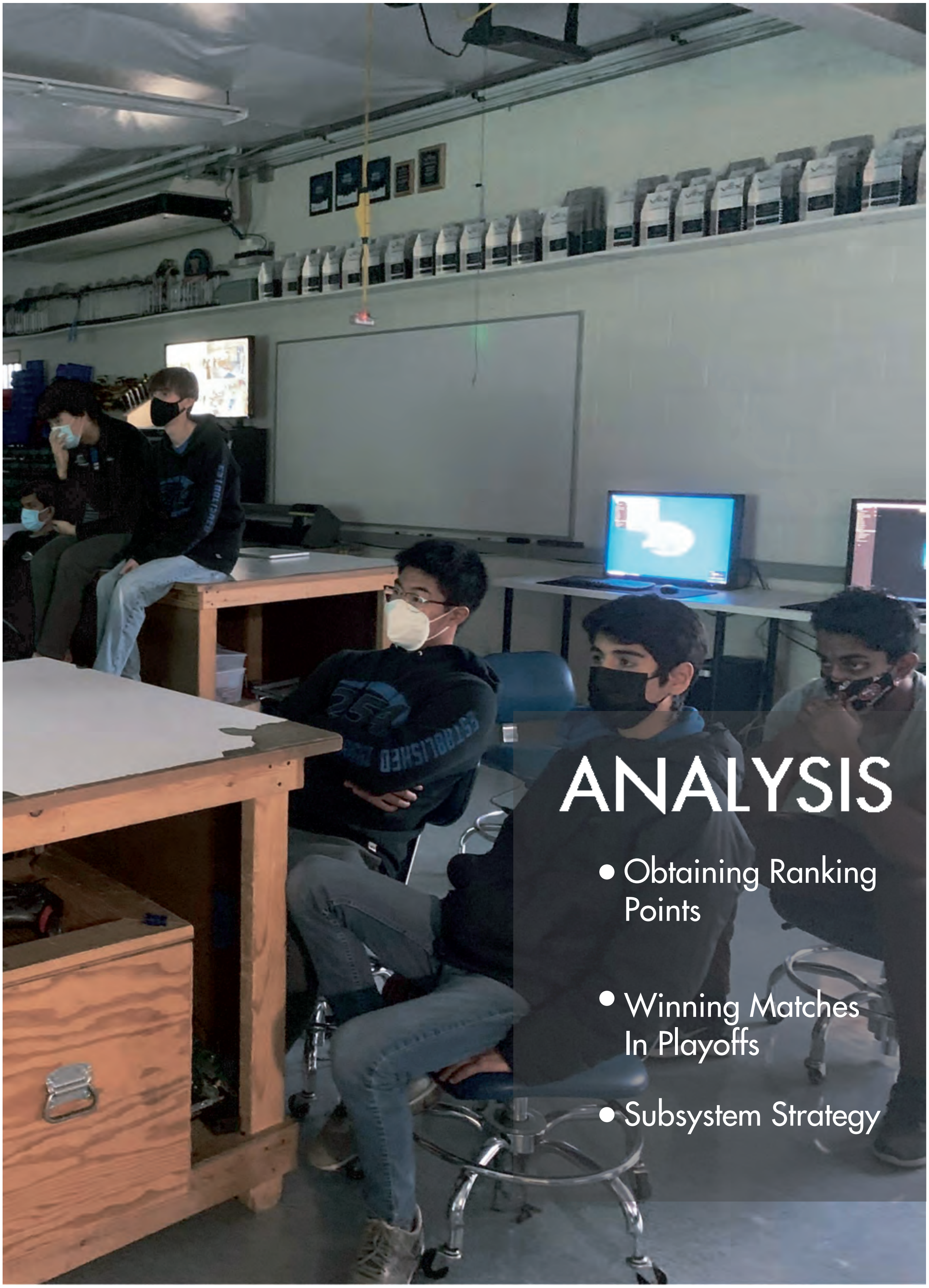


ANALYSIS

- Obtaining Ranking Points
- Winning Matches In Playoffs
- Subsystem Strategy

GAME ANALYSIS

Rapid React focuses on two straightforward, yet complex challenges: scoring cargo and climbing the rungs in the launch pad. To achieve our goal of winning the competitions we enter (especially the FRC Championship), we need to do the following:

Qualifications

- Obtain as many ranking points as possible. Ranking highly allows us the flexibility to form the type of alliance we want for playoffs.

Playoffs

- Maximize our score while minimizing our opponent's score to win all matches.

These goals are aligned in that a strategy focused purley on scoring points will also gain ranking points, but there are slight differences between qualifications and playoffs.

Obtaining Ranking Points

Ranking points are awarded as follows: 2 for winning a qual match, 1 for scoring 20+ cargo, and 1 for obtaining 16 alliance hangar points. To maximize ranking points in qualification matches, we must do the following:

- If an alliance scores 5+ cargo in auton, the Cargo RP threshold lowers to 18. If our robot can reliably score 5 cargo in auto, it makes it slightly easier to achieve the Cargo RP.
- Score 18/20+ cargo in a match ourselves, guaranteeing the Cargo RP without relying heavily on randomized alliance partners. (+1 RP)
- Climb to the traversal bar for 15 hangar points so our alliance partners only need to get 1 more hangar point for the Hangar RP. (+1 RP)
- Hang in such a way that partners have sufficient space to climb and achieve more hangar points.

At regional level competitions, following the above bullets will enable our alliance to both win and achieve the two bonus RPs, granting a high likelihood of achieving 4 RP per match.

Winning Matches In Playoffs

We are more likely to play with reliable L4 teams in the playoffs than in a qualification match, so it is important to enable our alliance to have multiple L4 climbs. However, we are also more likely to play against reliable L4 teams in the playoffs, requiring us to differentiate ourselves via cargo points.

To increase cargo points, we need to do the following:

- Maximizing cargo score in auton (points are worth 2x and there is no defense)
- Score cargo in the high school (worth 2 points vs 1 for low)

- Minimize cycle time for scoring cargo
    - Always be on the move to acquire cargo
    - Intake cargo the moment the robot touches it
    - Shoot accurately to avoid misses
- Deal with defense
    - Be fast and maneuverable to avoid defenders. You don't need to fight through a defender who can't catch you.
    - Shoot from a variety of positions on the field as defenders will prevent us from shooting from ideal locations

Subsystem Strategy

General

1. Agile, fast, swerve drive to minimize cycle time
2. Fit under low bar to access hangar and to retrieve balls under truss
3. Low center of gravity to prevent tipping during high acceleration manuevors

Intake

1. Touch it, own it (grab balls regardless of driving speed or angle)
2. 2 over-the-bumper max-width intakes to minimize retrieval time of cycle
3. Intake multiple balls without jamming
4. Automatic rejection of the opposing alliance cargo
5. Passively retract in direct collisions and flex through lateral hits

Serializer

1. Store 2 balls without jamming
2. Feed shooter consistently from both intake sides

Shooter/Turret

1. Reliability (>90% accuracy shooting into upper hub)
2. Aim and shoot quickly (2 balls in <1.5 sec)
3. Shoot from anywhere within 15ft radius
4. Shoot while moving

Climber

1. Climb to traversal bar in <10 seconds
2. Easy for drivers to align
3. Climb in a narrow space so alliance members have room

Robot Design

DRIVETRAIN

The drivebase allows the robot to maneuver around the field quickly and precisely. Unlike the past 20 years of West Coast Drives, this year features Team 254's first-ever swerve drive. The swerve was chosen for its increased maneuverability and ability to avoid defense.

SDS MK4i Modules

- Falcon 500s for drive and steering
- L3 drive reduction (18 ft/sec free speed)
- Customized with additional bearings to support falcon shafts
- 3/8″ spacer plates raise modules above frame, lowering frame-ground clearance

Chassis

- 2 x 1 x 1/16″ aluminum tube
- 1/8″ bellypan, non pocketed to lower CG

Electronics and Pneumatics

- REV Power / Pneumatic / Radio hubs
- Battery in middle of robot to centralize CG
- Single-acting solenoids
- 2 air tanks, onboard compressor

INTAKES

The two intakes pull balls from the ground over the bumper into the Serializer. Robot-width horizontal rollers on a pneumatically actuated four-bar create a robust touch-it-own-it mechanism.

Plates

- ¼″ polycarbonate is robust and compliant to impacts

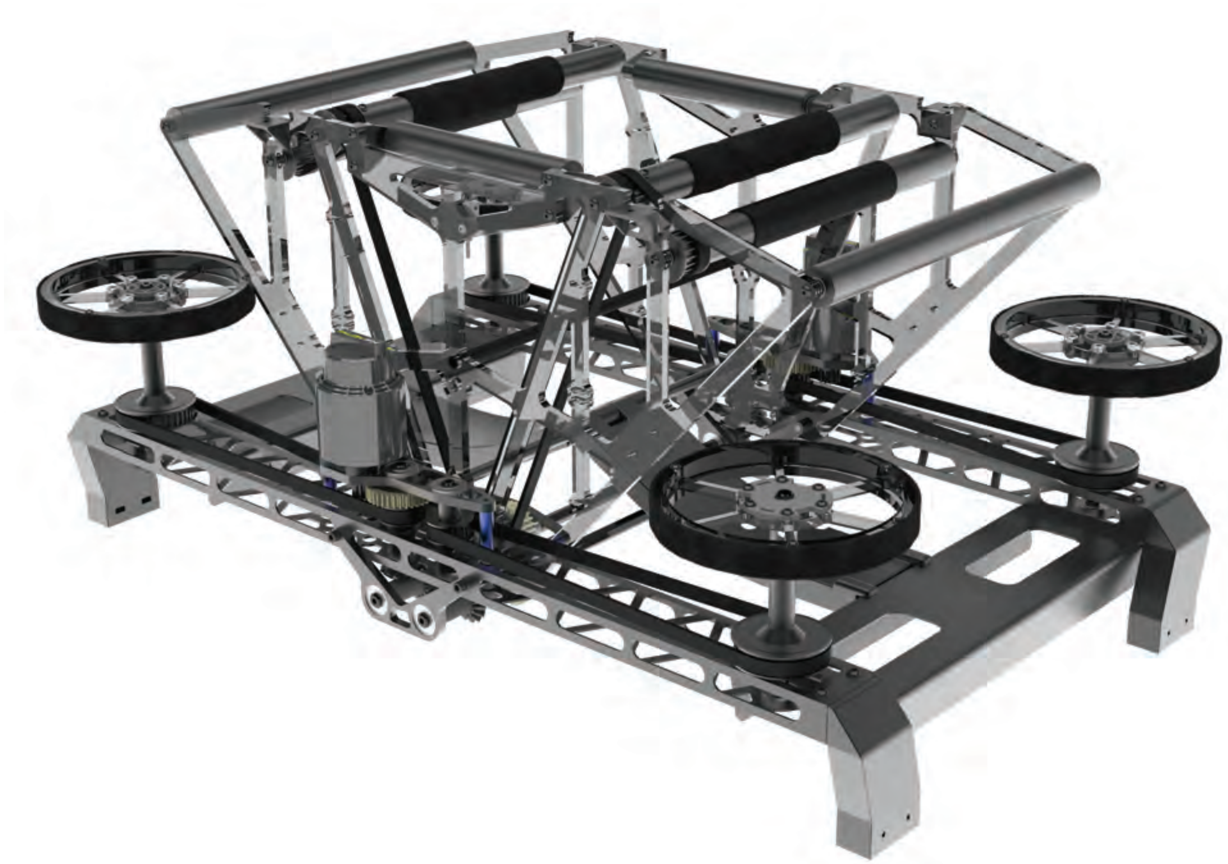
Stow/Deploy Linkage

- ¾″ Bore 2″ Stroke cylinders
- 4-bar stows roller above Serializer wheels

Rollers

- 2 belt-driven rollers powered by 1 Falcon 500
- Polycarbonate tube (3″ OD, 1/16″ wall, 2.4:1 reduction) with anti-slip tape grabs the ball
- Aluminum tube (1″ OD, 0.3″ wall, 1.6:1 reduction) with heat shrink pushes ball into Serializer wheels

SERIALIZER



The Serializer funnels balls from the dual 30″ wide intakes into a single stream to feed into the Shooter. Color sensing enables the Serializer to store our balls while ejecting opponents'.

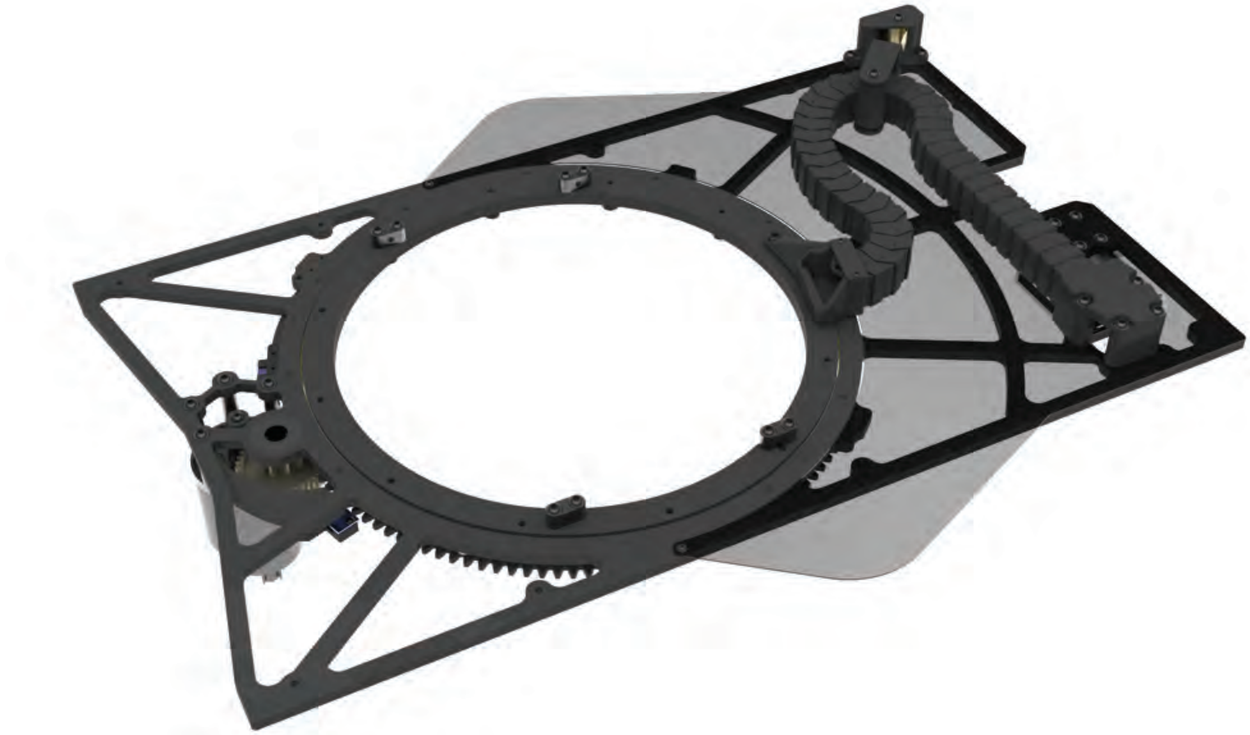
Rollers/Wheels (per side)

- Two 6″ PC wheels (6:1 reduction) wrapped in grip tape center balls from intake
- Two 1″ rollers (3:1 reduction) move ball to center
- Two passive 1″ rollers keeps the ball centered while feeding into shooter
- Bevel gears allow one Falcon 500 to power each side's wheels and rollers

Color Differentiation

- Three Banner beam break sensors identify ball locations within the Serializer and count ball entrances/exits
- Two REV Color Sensors detect red vs blue balls to drive storage vs ejecting logic
- Balls of the incorrect color are immediately ejected through the shooter
- The first correct color ball is stored on the opposite side of the Serializer from the active intake

TURRET



To enable accurate shooting while moving, a turret with a large range of motion was deemed necessary. Our familiarity with turrets in previous year made this a relatively easy addition.

Structure

- 12″ ID kaydon bearing held by clamp rings creates stiff, smooth rotation
- 130T 10 DP gear machineable by in-house router
- ±120° rotation range of motion
- 3 hall effect sensors trigger and center and soft-stops position

Powertrain

- 45:1 reduction from 1 Falcon 500
- Custom hex shaft minimizes backlash between gears and standard shaft

Shooter Wiring

- Bidirectional energy chain with constant-force-spring tensioner guides wires

Stinger Release

- Underside of main plate mounts pancake cylinder and gas spring to release and deploys Stinger

SHOOTER

The high accuracy and large shooting range requirements drove the need for a flywheel shooter with a lot of grip, wrap (acceleration time), and an adjustable hood.

Wheels and Rollers

- 9″ diameter, billet aluminum, 14:72T reduction
- 5 1.75″ diameter 3D printed back rollers, 1:1 reduction
- Both powered by 2 Falcon 500s and covered in grip tape
- Diameters and reductions chosen to operate a motor peak-power-point and surface match to shoot ball with no backspin to minimize bounce-outs

Adjustable Hood

- 35° stroke, powered by a single Falcon 500
- 16:52 belt, 14:42 gear, and 14:510 3D-printed sector gear reductions

Limelight Mount

- Carbon fiber tubes and 3D printed clamps are lightweight but stiff

ELEVATOR CLIMBER & REACTION ARM

The Elevator and Reaction Arm are the first components of the inventive and fast climber. The Elevator grabs the second bar and pulls down until the Reaction Arm hits the underside of the truss and tilts the robot to level, allowing the Stinger that is just within the extension limits to reach the traversal bar. The exceptional forces (500+ lbs) generated during this maneuver made for a challenging design!

Elevator

- Powered by 1 Falcon 500, 41:1 reduction, 11 in/s linear speed
- Single stage moved by #25 chain with inline turnbuckle tensioner
- 2 x 1 x 1/16″ aluminum tube uprights and carriage
- Short enough to fit under lower rung

Hooks

- Hooks pivot out, pulled by surgical tubing
- Upper plate (1/8″ PC) hits truss to serve as alignment guide for drivers

Reaction Arm

- Reacts against the truss while climbing to maintain optimal angle
- Held in by folded-down hooks, pulled out by surgical-tubing
- Tensile-member strap takes load

STINGER

The Stinger extends and hooks onto the traversal rung, completing the climb sequence. Passively extending and not needing to retract enables it to be lightweight and simple.

Telescoping tubes

- 1/16" wall tubes (2", 1.5", and 1")
- 4 4lb Constant force springs (2 per tube) extend tubes
- Since no retraction-under-load, 3D printed end plugs serve as bearings

Hooks

- Main hook pivots to stow within frame perimeter and not block shooter
- Additional sprung-loaded plate serve as latches to prevent robot from falling off rung

Deployment

- Aluminum tube (2" OD, 0.049" wall) tube serves as robust pivot deadaxle
- 30lb gas spring pushes Stinger angle out
- 0.75 stroke, 1.125" bore pancake cylinder pulls pin to release
- Tensile-member strap takes load and keeps Stinger within height and horizontal extension limits

PROGRAMMING

Autonomous

The robot smoothly follows precalculated trajectories autonomously through the use of both feedforward control based on precomputed robot velocities and feedback control on positional error.

Path Generation

- Generated using parametric Quintic Hermite splines and a web-based visualizer
- Optimized to minimize the change in curvature over multiple splines to limit large torques that could result in wheel slip and inaccuracy
- Results in smoother paths that allow for more reliable tracking

Driving Controller

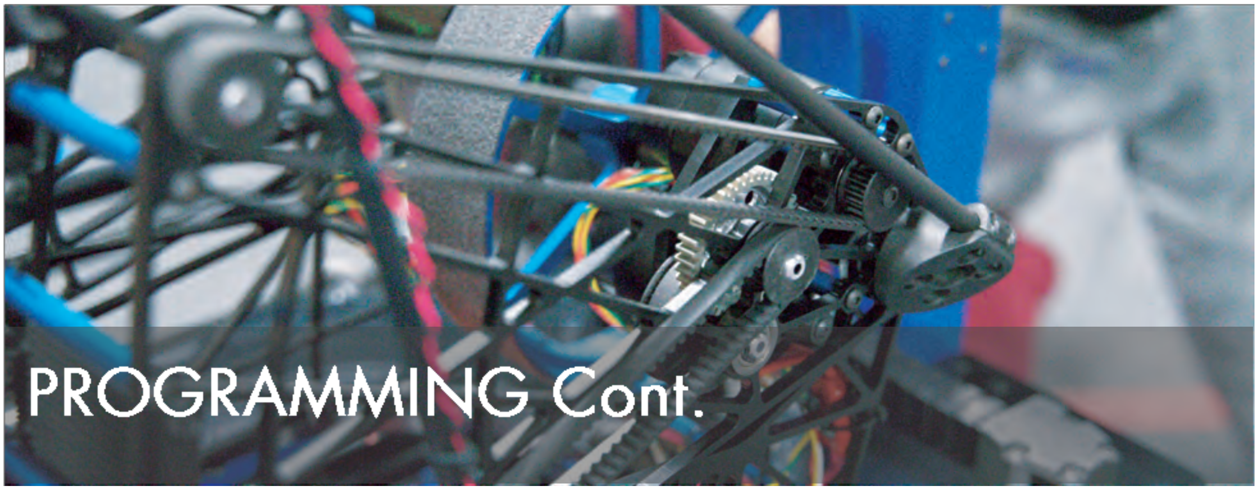
- Uses feedforward control baed on on precomputed velocities from generated trajectories
- Uses P controllers for translational position error and time-parameterized heading error along paths
- Generates setpoints for individual swerve modules based on physical module constraints: preventing modules fighting each other and improving odometry

Tele-op

The various subsystems are controlled through state machines to prevent undesired actions, with interlinked superstructure and serializer state machines to control overall robot actions

Wrong Ball Rejection

- Utilizes 2 REV Color Sensors near the middle of the serializer to recognize cargo color after intaking
- If a wrong ball is detected, the robot will eject the ball to an undesirable location for the opponent (changing the shooter rpm and turret angle) determined by proximity to the goal and current robot pose



PROGRAMMING Cont.

Tele-op cont.

Wrong Ball Rejection cont.

- Correct balls will be stored in the serializer or shot depending on the driver command

Shooting on the fly

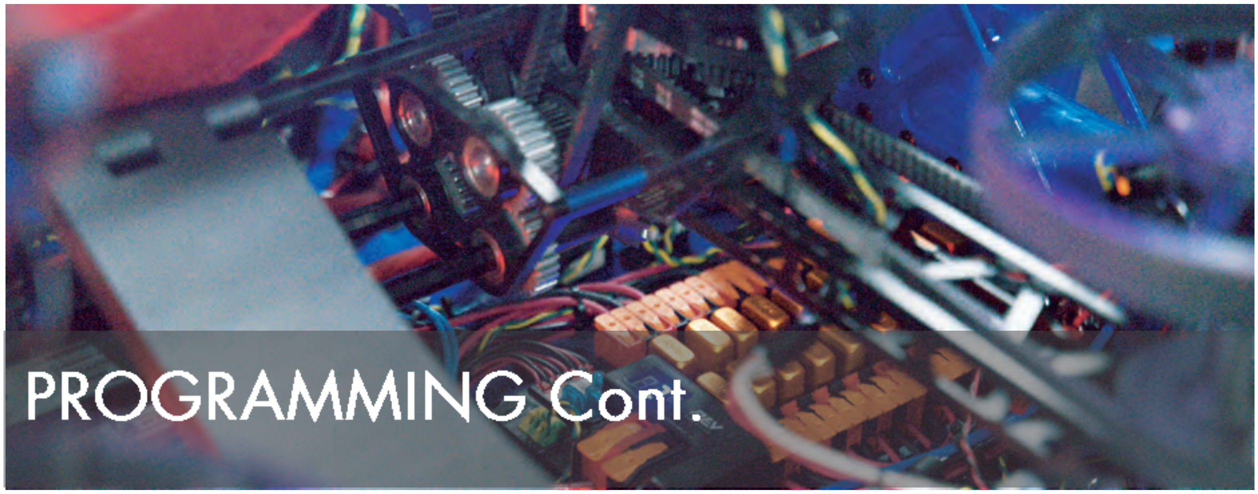
- Compute turret feedforward based on robot rotation rate and angular velocity relative to the goal, so the turret is always lined up for an ideal shot
- Calculate optimal shooter rpm and hood angle from a linear regression on the ball's vertical and horizontal velocity vectors

Color Sensing

- Uses REV color sensors wired to a Teensy 4.1 microcontroller
- Teensy boards periodically read RGB inputs from the sensors, then output a single PWM signal containing the ratio between the red value detected by the sensor and the blue value detected
- Robot code utilizes a synchronous interrupt to read the duty cycle of the PWM signal, then depending on red:blue ratio will categorize the reading as RED, BLUE, or NONE

Driving

- Field-Centric Drive - Standard field-centric control of a swerve drive base that uses odometry (encoders and gyro) to determine position
- Velocity and acceleration constraints on the drivebase for more controlled movements, improving shooting on the fly



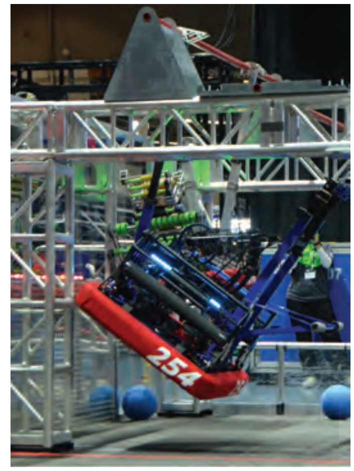
PROGRAMMING Cont.

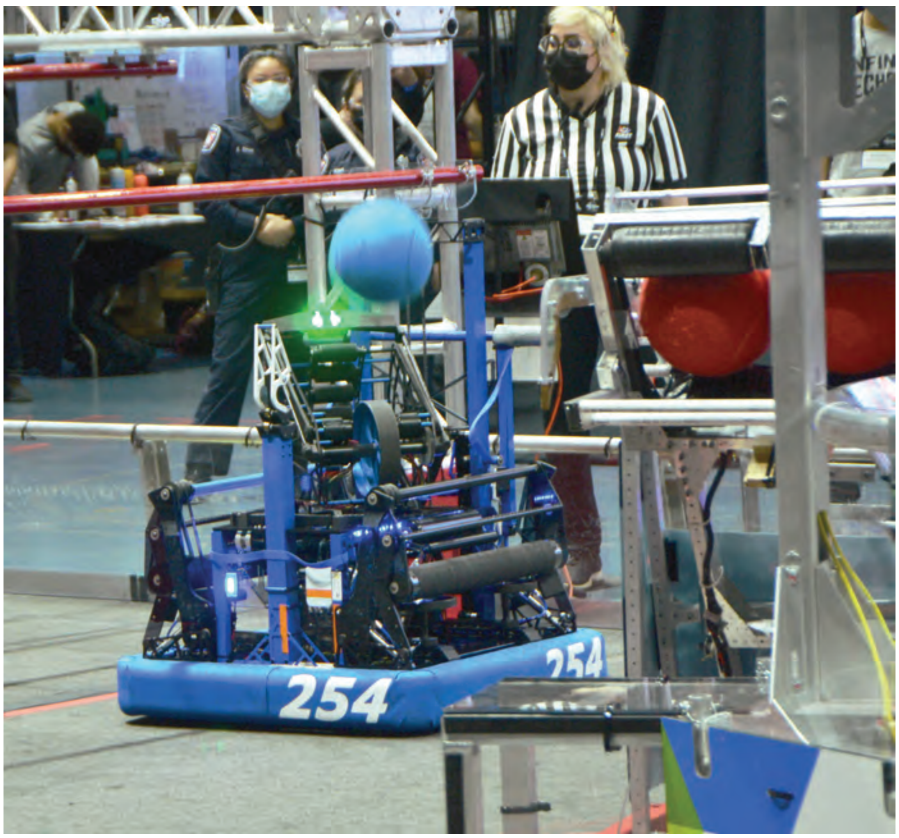
Vision

A Limelight 2+ camera provides information from vision targets to track the goal's position.

Target Tracking

- Uses known height of targets along with corner data sent by the Limelight to calculate the goal's position relative to the robot's starting location using Pinhole Camera Model.
- Goal trackers allow the robot to remember the position of the goal throughout the entire match, even when it can't be seen, and smooth this position with each vision update to account for noise





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