KURIOSITY ROBOTICS

FTC 12635

2021-22 ENGINEERING PORTFOLIO

TEAM INTRODUCTION

We believe that FTC is the ideal playground for teenagers to innovate. Kuriosity Robotics is a community team based at Palo Alto, California, made up of 15 members from various high schools. Working in our garage workshop, Kuriosity resembles a startup, **pioneering our visions.**

TEAM PHILOSOPHY & GOALS

Meme posted in our garage

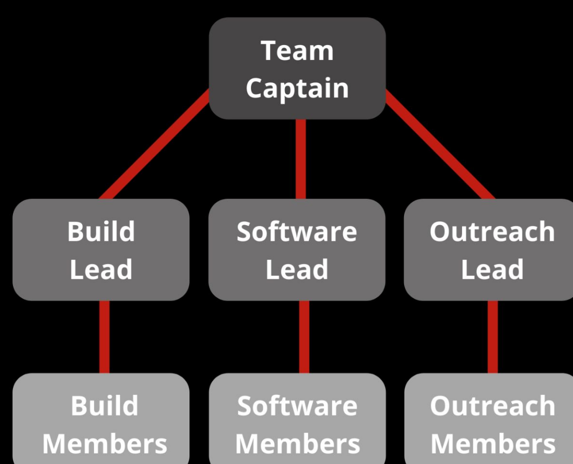
The essence of our philosophy, "**Go Big or Go Home**," is the **ambitious ground-up mentality**. We bring our ambitious hardware, software, and outreach visions to life from the ground up. Ownership of the process gives us a deeper understanding of how it works.

Our team goals for the Freight Frenzy season are to create a **high performing, efficient robot** and build **sustainability** in our team and the community.

TEAM STRUCTURE

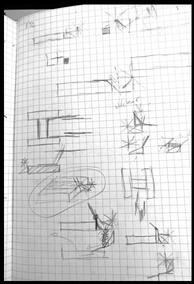
Our team is split into **3 subteams:** Hardware, Software, and Outreach/Business. Each **lead** oversees their subteam's growth. The **team captain** works with leads to guide the team forward. Each member is essential to the overall success of the team.

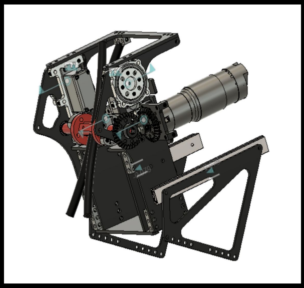
Subteams help other subteams. For example, all members work together to run outreach events. The intertwined nature of the three subteams creates a **unified team**.

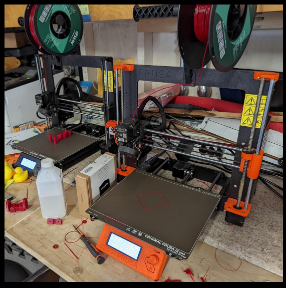


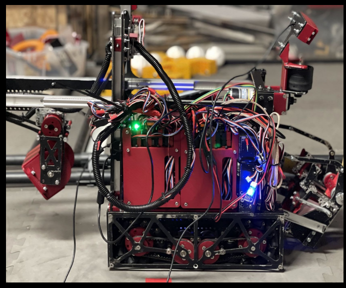
DESIGN PROCESS

By engineering **100%** of our hardware **in house,** we (1) gain end-to-end knowledge on bringing ideas to life and (2) can package complex mechanisms in a small volume.







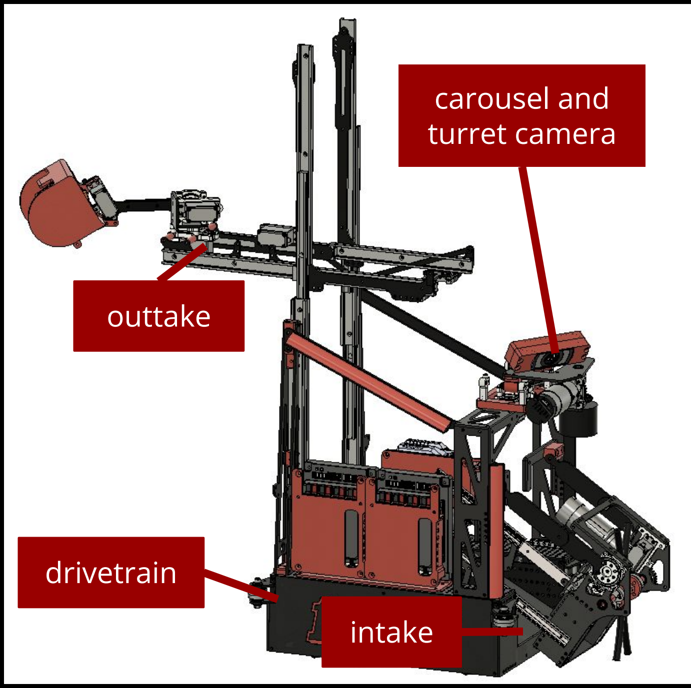


Brainstorm → ***CAD*** → ***Manufacture*** → ***Test***

In brainstorm meetings, we use rough sketches to establish our next ambitious idea. We then **collaboratively** CAD and iterate them in Autodesk Fusion 360. **90%** of our design process is spent on the computer. We **custom manufacture** all our parts in-house using two 3D printers and a CNC router.

GAME STRATEGY

We committed to the game strategy of (1) **quickly cycling** the Level 3 Alliance Hub and (2) **traveling through the warehouse gap** to keep odometry wheels on the ground.



Following our game strategy, we have:

(1) **a tiny drivetrain base**. We package innovative mechanisms in a frame half the volume. **We go big by going small.**

(2) intake and outtake mechanisms on **opposite sides**, so we don't need waste time turning 180 degrees every cycle.

(3) a **long outtake extension**, so we save time by driving less.

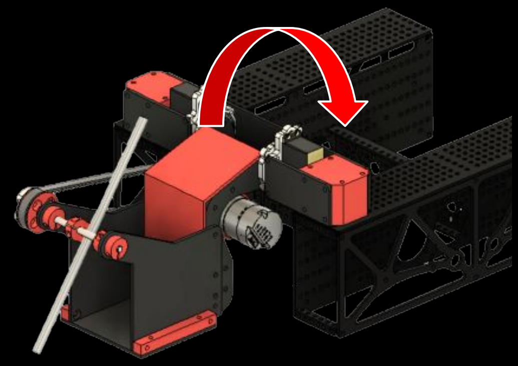
We consistently place **5 autonomous freight** on the alliance hub and **16 tele-op freight.** In the end game, we spin **9 ducks and cap consistently**.

STREAMLINED INTAKE

The two greatest goals for the intake is **intaking one element at a time** and a **streamlined transfer** of freight to the outtake. (8 major iterations)

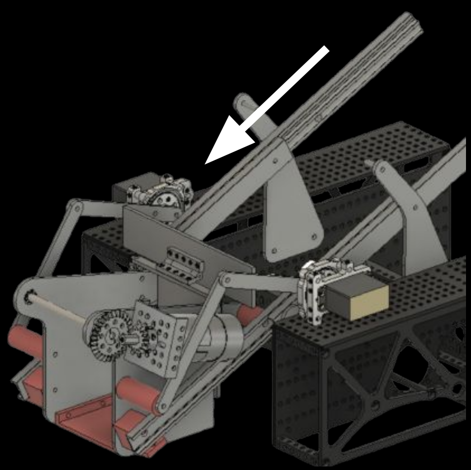
INITIAL SOLUTION

Our first design was a vertically flipping carriage with surgical tubing.



CHALLENGE #1

Flipping the carriage would be **too slow** because of a heavy intake and weak servos.

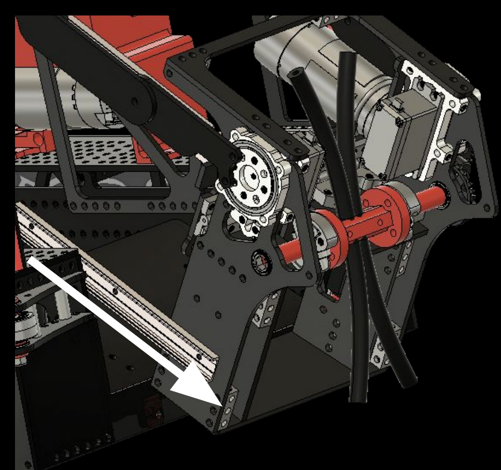


SOLUTION

We designed the carriage on a set of **linear slides** driven by linkages to speed the transfer.

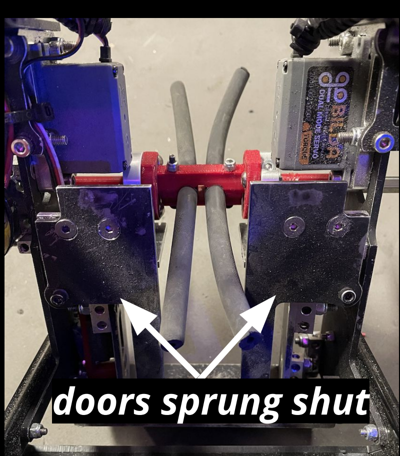
CHALLENGE #2

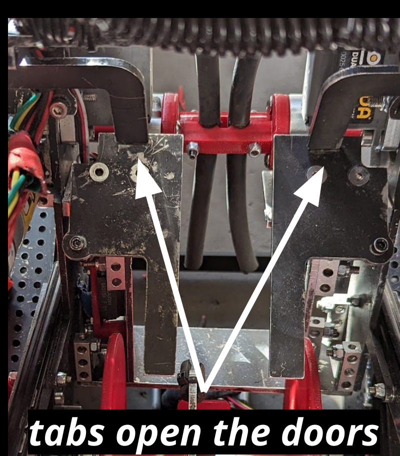
It was **too bulky** to fit in our small robot frame. It's weight also slowed the transfer speeds.



FINAL SOLUTION

We redesigned the carriage to be **50% its original size** to fit in our tiny robot package by optimizing everything, including linkage structure, servo placement, slide type, and door format.





WHAT'S INNOVATIVE?

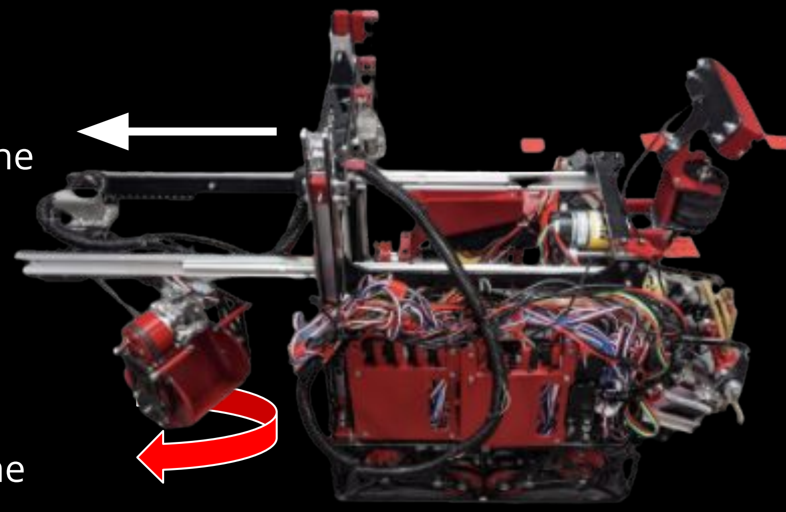
Passive spring loaded doors are sprung shut to keep freight in the intake. When the intake retracts, the doors open when hit by stoppers, allowing a mineral to elegantly transfer to the outtake.
Constant force springs help hold up the intake to accelerate retraction.

FAST, VERSATILE OUTTAKE

Our goal for the outtake was **fast extension** to the Level 3 Alliance Hub to optimize cycle times. All season, we have aimed to removed cycle bottlenecks on our outtake.

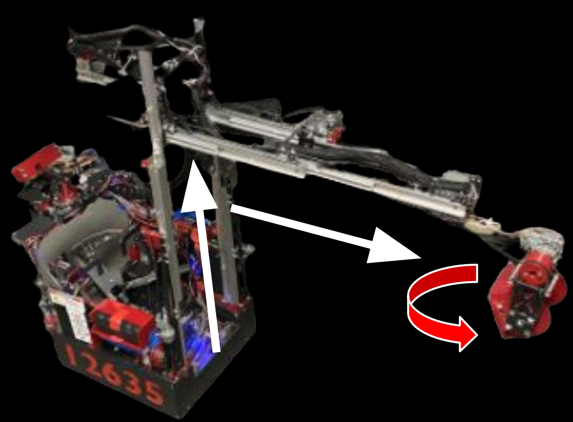
INITIAL SOLUTION

For Q1, our outtake featured a horizontal linkage extension and horizontal pivot, and one set of vertical slides to reach Level 3.



CHALLENGE #1

The two biggest bottlenecks were that our **vertical extension wasn't long enough** to stack freight on Level 3, and our **horizontal extension was too short** and we wasted time driving up to the alliance hub.



SOLUTION

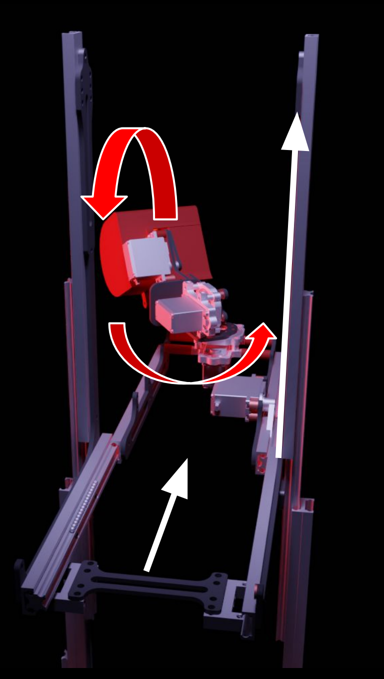
For Q2, we added another set of vertical slides, **doubling our vertical reach**. By cascade rigging an additional horizontal stage, the **lateral reach also doubled** while maintaining the compactness of the linkage extension mechanism.

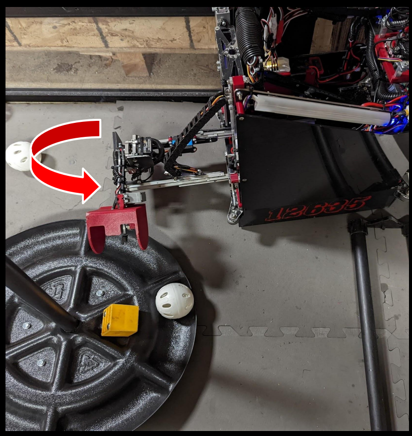
CHALLENGE #2

The bottlenecks were that **the cascade rigging made extension very slow.**

FINAL SOLUTION

Recently, we turned the horizontal pivot extension vertical, allowing us to **parallelize horizontal extension**, removed our cascading rigging system, switched to high speed SAVÖX servos, and supplied extra power through a servo power module. Compared to our second qualifier, our outtake now **extends 300% faster**, in just 300 milliseconds.



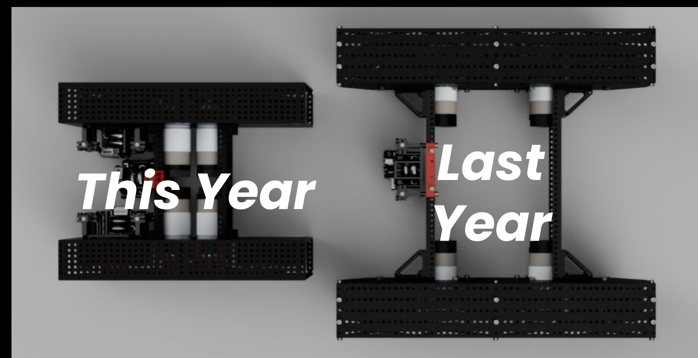


WHAT'S INNOVATIVE?

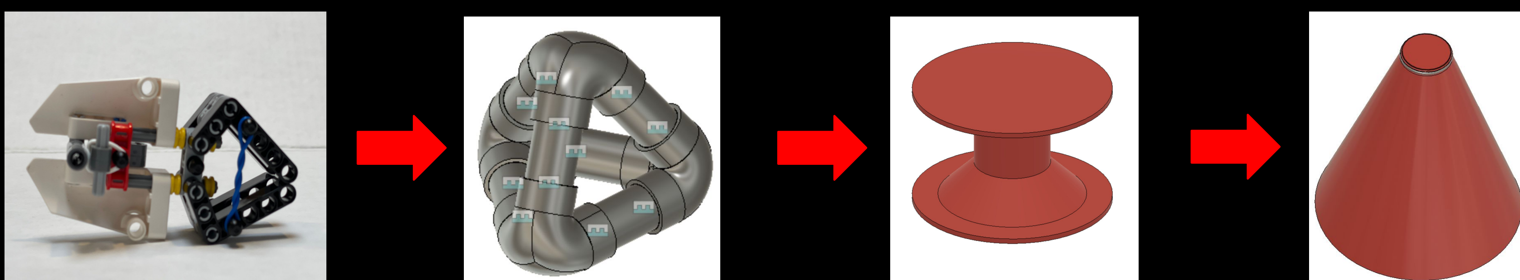
Not only is our outtake fast, but it is also versatile. A horizontal turret allows us to automatically adjust the outtaking position without moving the robot, **reducing alignment times**. The pivot also allows a much faster deposit on the shared hub.

TINY DRIVETRAIN

We designed our own 4-wheel-mecanum drivetrain in the offseason, but for it to fit in the warehouse gap, we redesigned it to have an **11" x 13" frame**. We can fit between the warehouse gap in both dimensions and clear the gap with 2.5" of tolerance. This tiny drivetrain has been **the largest change** compared to previous years.



TEAM SHIPPING ELEMENT



Our first design was a complex passive gripper, but slowly simplified into a final **thin hollow cone with a steel ring** that attracted **magnets** on our outtake. This design allowed double capping, where we stack two team elements on the shipping hub.

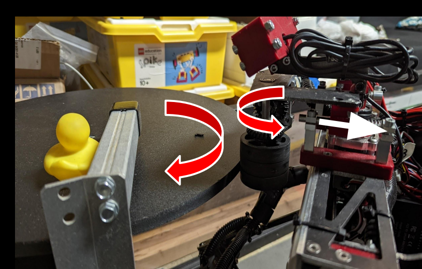
SPRING-LOADED CAROUSEL

CHALLENGE

It's **hard to align** the carousel mechanism to the carousel consistently with a fixed wheel.

FINAL SOLUTION

Spring loading the carousel mechanism allows **easy alignment**. Since qualifiers, we've doubled the spring cushion length to make it even easier.



DESIGN LESSONS LEARNED

SIMPLE DESIGNS

Our mechanisms all became simpler over time. Especially in building small robots, simpler designs are more effective and reliable.

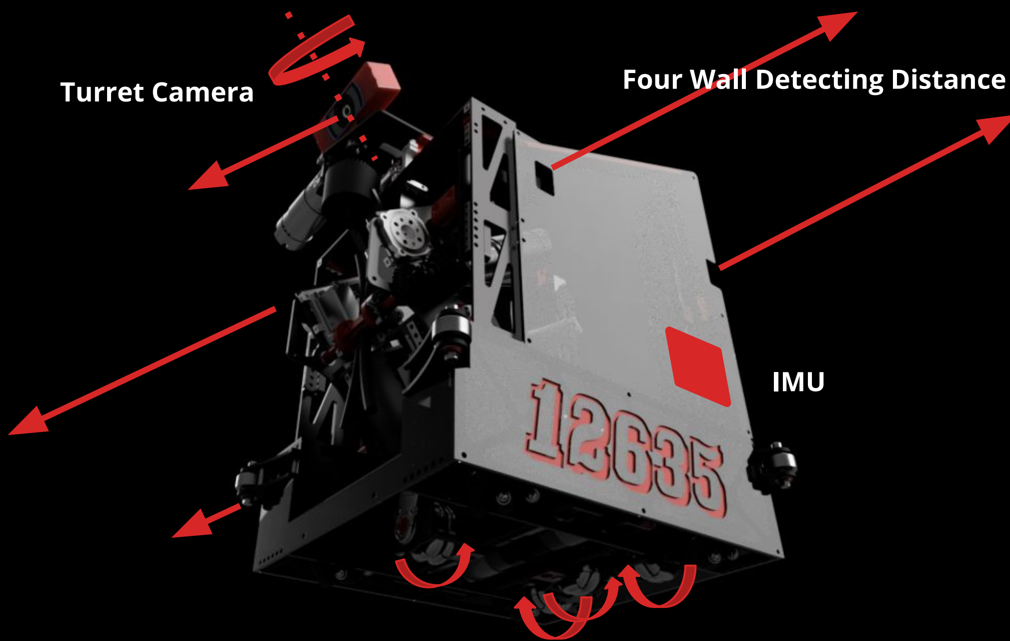
COLLABORATION

CAD helps us collaborate. Our intake and outtake were iterated on in parallel by different teammates and CAD allowed them to function together seamlessly.

CUSTOM SOFTWARE STACK

We develop control algorithms to know where we are (localization), find a way to get somewhere (pathfollwing), and perform mechanism actions (action executor).

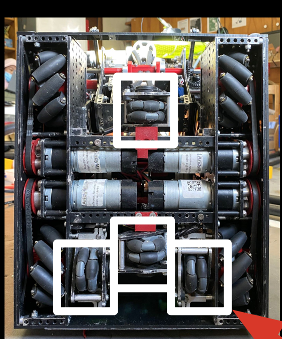
MULTI-SENSOR LOCALIZATION

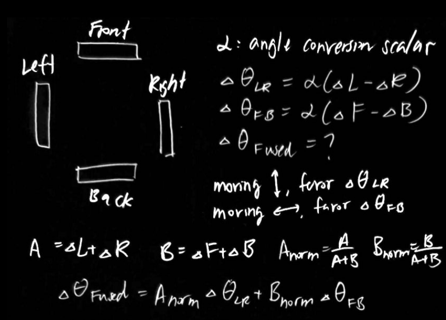


All of our Localization Sensors are fused with a custom modular Kalman Filter to achieve localization to within an inch all match @ 60 Hz

FOUR WHEEL ODOMETRY

Odometry uses encoder wheels sprung to the ground to calculate the robot's position with high frequency. Typically, FTC teams use 3 odometry wheels.





REV Through Bore Encoder (x4)

CHALLENGE

Our sensors had **significant noise** and accumulated error over time, especially in the heading calculation. If the heading is off, error will quickly accumulate.

SOLUTION

We added a fourth odometry wheel to gather redundant data. Using our own **custom adaptive weighted average filtering algorithm**, we dynamically fuse the data to get a more precise calculation. Now, our odometry is **3 times more accurate**.

TRACKING IMAGES WITH CV

INITIAL SOLUTION

We switch between **two cameras** facing different directions to track field images (VuMarks).

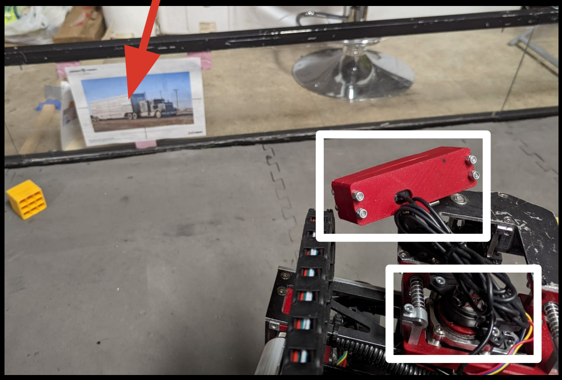
CHALLENGE

Switching cameras was **too complex** and faced compatibility issues with OpenCV and the FTC SDK.

FINAL SOLUTION

Our rotating camera allows our robot to see all around its surroundings and is the **first ever in FTC**.

VuMarks on walls



Logitech C920 Webcam(x1) & REV Through Bore Encoder(x1)

ABSOLUTE HEADING WITH IMU

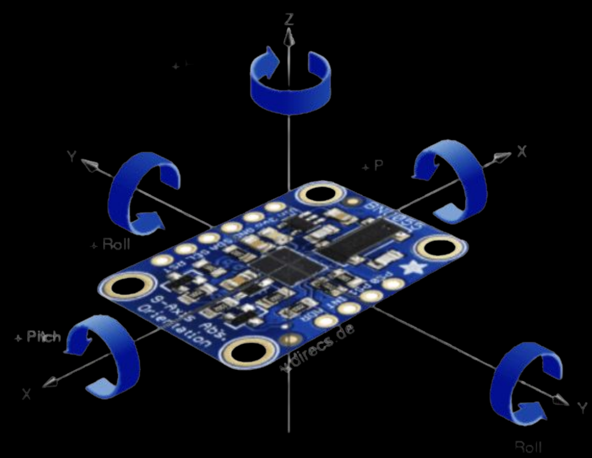
CHALLENGE

Heading is the most important part of localization. We need absolute heading consistently for **agility** and **robustness**.

SOLUTION

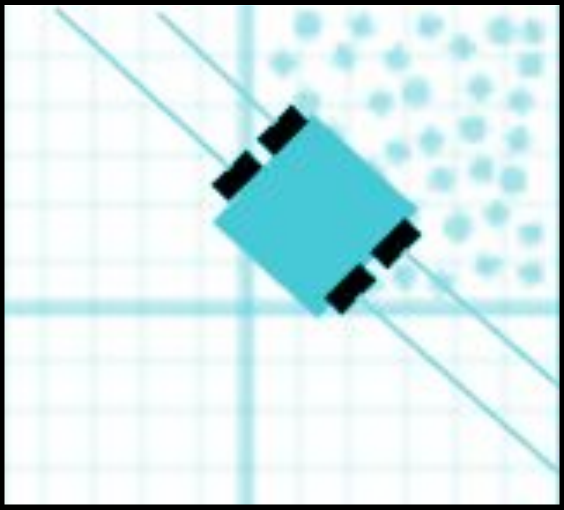
We use the internal Control Hub **IMU** to calculate absolute heading. In addition, the updates are **asynchronous**, so it doesn't slow down other processes.

Adafruit BNO055 9-axis Absolute Orientation Sensor



DISTANCE SENSOR WALL LOCALIZATION

Taidacent 2-15cm Short Range Analog Infrared Range Sensor (x4)



CHALLENGE

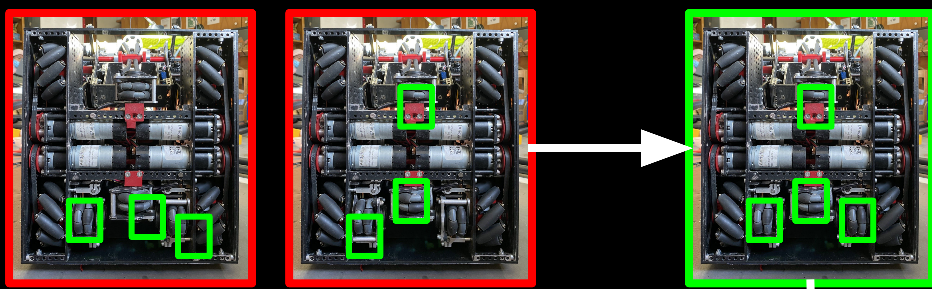
Even with our three methods of localization(, we don't have enough accuracy to exit the warehouse at high speeds.

SOLUTION

4 **analog infrared distance sensors**, 2 each on the left and right, allows for absolute localization by measuring distance from adjacent walls. We use trigonometry to not only predict which wall the sensors see, but also to localize when we get readings.

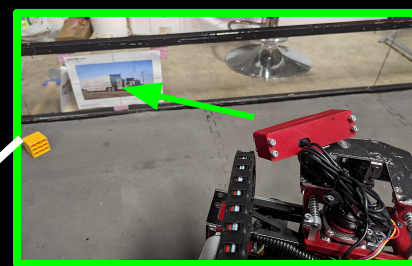
KALMAN FILTER **FUSION**

Imagine walking down a street, with your eyes closed. You will soon lose sense of direction, but the second you open your eyes, your vision puts you into place. In the past, our localization used only odometry estimates, like a human with their eyes closed. This season, our robt **fuses odometry, computer vision, distance sensors, and IMU** data together.



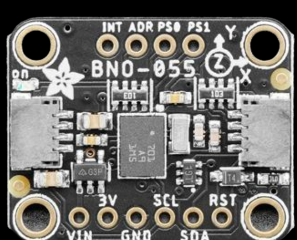
Redundant Odometry Data (x2 position prediction)

Computer Vision Image Tracking



Position on Field

IMU Heading



Accurate to <0.25" through entire match

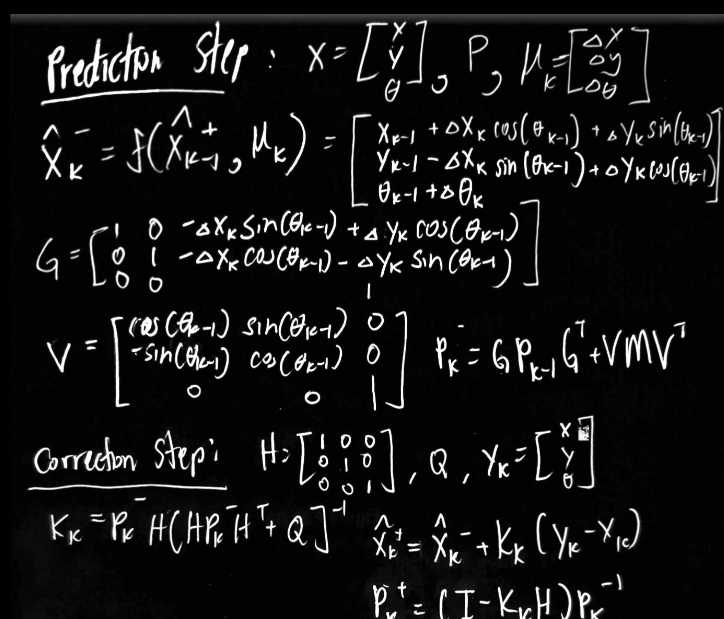
Distance Sensor Wall Detection

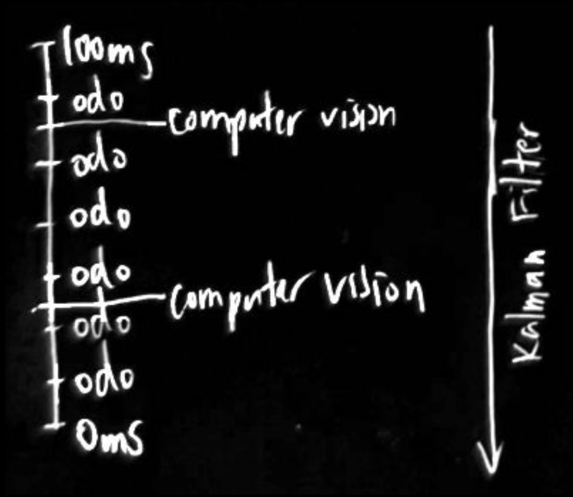
CHALLENGE #1

Odometry updates frequently but **accumulates error**. Computer vision gives absolute positions but works **only when an image is in sight.**

SOLUTION

We developed a Extended Kalman Filter (EKF) to fuse odometry and computer vision. EKFs are an **industry standard** and use statistics, linear algebra and multivariable calculus to minimize mean-squared error. Our robot localizes to **<1.25"** when the robot is not moving.





CHALLENGE #2

Computer vision data is **delayed**, throwing off the algorithm when the robot is moving.

SOLUTION

We added timestamps to all our data and developed a **Moving Window EKF (MWEKF)**, the **self driving car industry standard** for localization sensor fusion. The MWEKF retains sensor data from the past 100 milliseconds and fuses them with their timestamps in mind.

CHALLENGE #3

Dependence on CV slowed our autonomous because **our robot had to stop** for a few seconds to detect the field images.

SOLUTION

We implemented IMU and Distance Sensor data into our Kalman Filter correction steps. These sensors are not dependent on computer vision and are high frequency.

CHALLENGE #4

Our Kalman Filter fused odometry, computer vision, IMU, and distance sensor data. The implementation, with all these sensors, became very messy.

SOLUTION

We restructured our Kalman Filter to be **modular**. It is easy to add and remove sensor sources, and calling one method will fuse new data. We hope to bring this implementation of the Kalman Filter to the public for other FTC teams to discover.

CHALLENGE #5

Adding more sensors had the consequence of slowing down frequencies of other sensors. This meant that **adding a sensor changed the behavior of the other sensors**.

FINAL SOLUTION

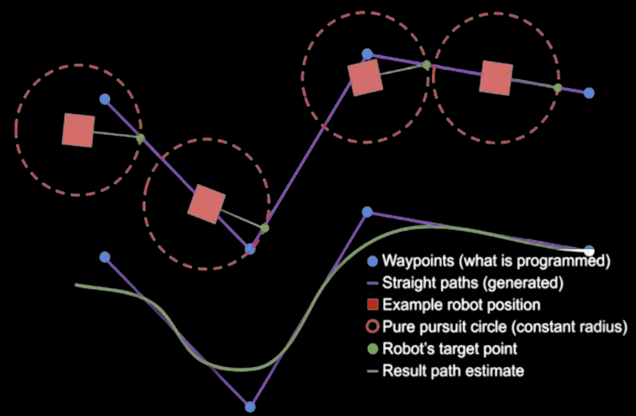
We developed a **custom frequency controller** that forces sensors to be read at a specified frequency. This is more deterministic and scientific than reading sensor data as fast as possible.

DYNAMIC PATH FOLLOWING

Efficiently following a **curved path**

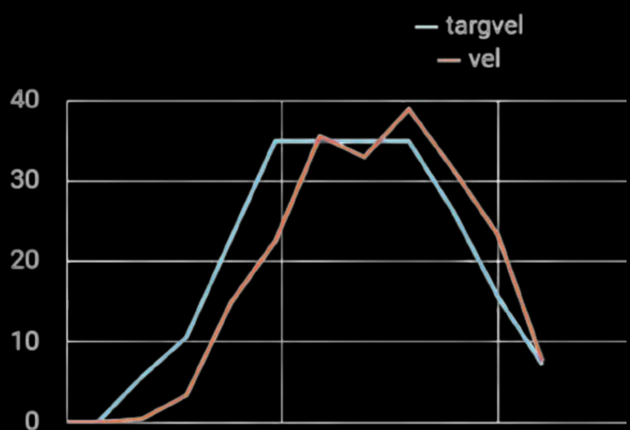
INITIAL SOLUTION

Pure Pursuit is our homemade path following algorithm which works by constantly pursuing a moving point down a pre-programmed path that is within a fixed distance from the robot.



CHALLENGE

Pure Pursuit updates real-time, so it **can't plan path-ending logic**, which means our robot doesn't brake consistently.



FINAL SOLUTION

Our **custom motion profiling algorithm** uses the robot's maximum velocity and acceleration to pre-plan the robot's optimal position, velocity, and acceleration at every point on our path. Our robot uses our custom **Pure Pursuit** algorithm to follow the profile for better path-ending and movement control.

MECHANISM ACTION EXECUTOR

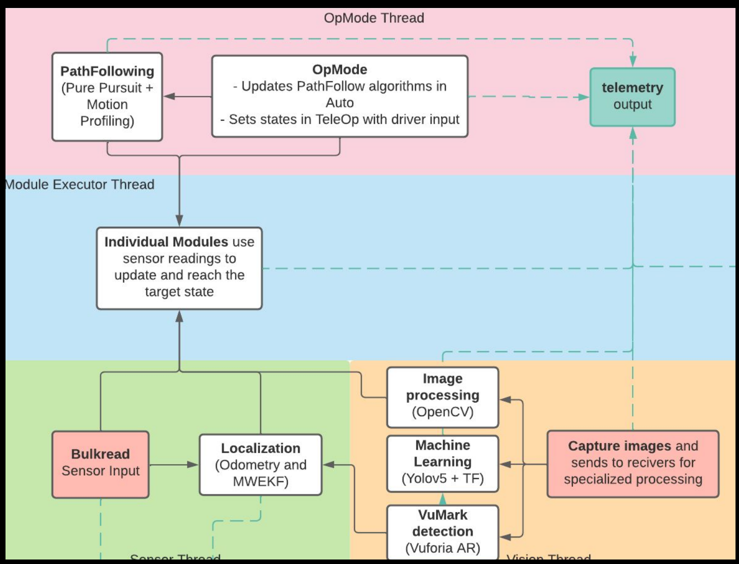
Asynchronous functionality through **multithreading**

CHALLENGE

To make our autonomous more efficient, we execute actions while our robot is moving.

SOLUTION

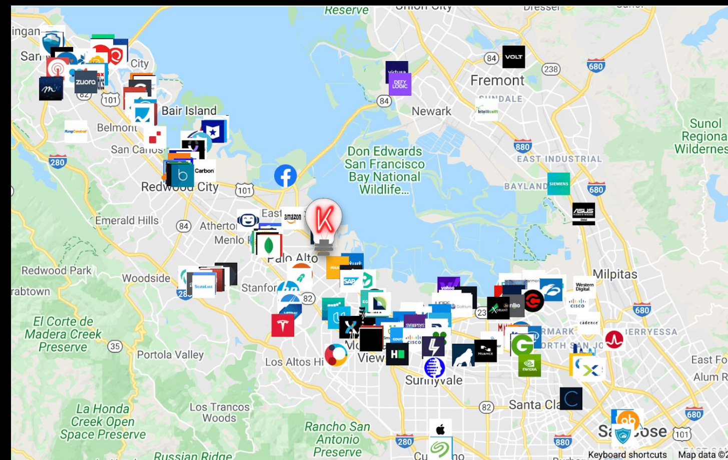
We run our robot's functionality between four threads **(sensor, vision, module, and debug)**, and creates additional threads for asynchronous execution when needed. This ensures our autonomous is efficient and our TeleOp is always responsive, regardless of the computations we have.



OUTREACH & BUSINESS PLAN

Student: I'm an aspiring entrepreneur. What is some advice for my future?
Follow your passion! Passion takes people a long way.

Student: I'm lost. I don't know what my passion is. What should I do?
If you don't know your passion, follow your ***curiosity***.



Our workshop is located in Palo Alto, the heart and soul of Silicon Valley. Surrounding us are curious innovators, from children to elderly. This is the fundamental core of our outreach philosophy. We don't need to collaborate with groups to impact our community, we can impact our community directly through ground up initiatives.

WHAT'S UNIQUE?

We **open our workshop to the community** by keeping our garage open for visitors while we work (which is all weekend), and **using our garage as a venue for outreach events** to deeply impact our community.

WHY

At first, we opened our garage door and worked outside for ventilation during the pandemic. But we kept it open because we learned the value of community. It's Mark Zuckerberg jogging around the block, to the questions we get from neighbors walking their dogs, to the curious little kids who view our garage as a Disneyland of robotics, and so much more, that keep our garage opened to our community of curious innovators.

IMPACT ON OUR **DRIVEWAY**

Though initially out of desperation, running outreach initiatives in our driveway **promoted community closeness** and allowed students to receive **direct in-person exposure** to our team's operations. Showing our students our robot as we work on it helps **inspire** them to pursue robotics.

INTRODUCING **GIRLS** TO ROBOTICS

WHY

Only 5% of our applicants are girls even though our recruitment ads are sent to girls and boys equally. We aim to make robotics more accessible to girls.

WHAT

We **partnered with SmartGurlz**, a Shark Tank appearing company, to use their programmable robot dolls, Siggys, to teach our driveway classes.

IMPACT

Through two classes, we taught **22 girls to code Siggys** to sing, dance, and move using our custom, self-developed curriculum.

INTRODUCING **KIDS** TO FLL

WHY

New FLL teams have declined partly because of the **lack of exposure**. We aim to fix this by exposing kids to FLL.

WHAT

We received funding from Janyaa to buy ten LEGO SPIKE Sets. Currently, we run free LEGO SPIKE classes monthly.

IMPACT

21 kids ages 7-14 attended our two self-run LEGO SPIKE classes, coding a **dancing robot** using our self-developed curriculum.

SUMMER ON OUR DRIVEWAY

WHY

As a past FLL team who experienced the lack of Java and CAD knowledge for FTC, we aim to help FLL teams tackle this barrier.

WHAT

We created and ran a Java and CAD summer camp business for 2 weeks, advertising on all **social media platforms**.. Our curriculum had **creative, fun projects** to stretch our student's abilities and imagination.

IMPACT

We became **long-term friends and mentors** with 8 middle schoolers, helping them gain full understanding of Java and CAD.

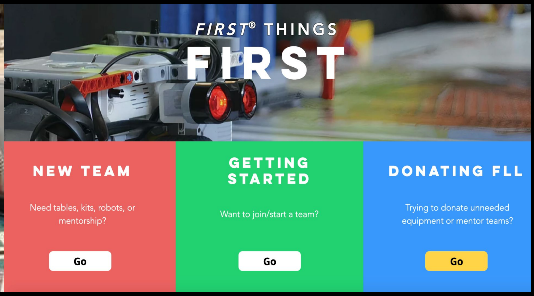
Our class

Student's Work

Generating $1000 in 2020 and $4000 in 2021, summer camps are our **first growing, sustainable revenue stream**. We hope to grow using our free classes to market.

FIRST® THINGS FIRST

A huge hurdle to starting FLL teams is acquiring a **game table.** Starting FLL teams are lost on where to find or how to build game tables. Moreover, tables can't be used elsewhere, so for many graduating FLL teams, **old tables waste space** collecting dust.



OUR SOLUTION

We built a free platform on our website to **connect** graduating teams with rookie teams and act as a **middleman in transferring tables**. Teams can submit donations and requests through our forms and we'll pair teams based on location and exchange times.

10 TEAMS ASSISTED

5 TABLES DONATED

82 TOTAL HOURS

FUTURE GOALS

We aim to help more teams by distributing more tables and **sharing experiences**. We currently have **too many requests and too few donations,** so we plan on using FLL/FTC competitions and qualifiers to connect with teams.

FOSTERING SUSTAINABILITY

We aim to recruit 6 underclassmen to compensate for our 6 graduating seniors, and recruit 4 more girls to have an even number of boys and girls. To achieve this, we recruited from 2 high school Girls in STEM clubs and created a **three-part development plan**:

THREE-TIER RECRUITMENT

We successfully brought in **four** new members to offset the number of graduating members on our team.

SUB-TEAM BOOTKAMPS

New recruits are put through our self-developed **training curriculums** to learn subteam specific knowledge.

SHADOW PROGRAM

We have one member in our new **shadow program** for qualified applicants that we couldn't recruit due to the team size restriction.

FINANCES

$23,000 team budget was raised from 8 companies. Our goal is to break even and participate in FTC without incurring financial costs. We raise money through various sponsorships, grant matchings, and direct donations. Our summer camps raised an additional **$4000.**

CAPTURING MOMENTS

As a two time NorCal Winning Alliance Captain, we have a strong brand within our local community and the FTC community. Being a role model team, we aim to capture genuine, behind the scene moments and share them.

We have accumulated terabytes of GoPro vlog footage, including various meetings, hangouts, competitions, and outreach events. We aim to create a YouTube Kuriosity Documentary. We have also posted countless behind the scenes Instagram Stories of the fun and random things we do.

CONNECTING WITH...

We connect with and find mentors from robotics industries through personal connections and research, to build our knowledge and reach through meetings, collaborations, and showcases.

INDUSTRY PROFESSIONALS

WHO: Maria Bualat from NASA
LEARNED: Industry Standards for Computer Vision

WHO: David Liu, CEO of Plus
LEARNED: How our localization challenges are alike those in self driving cars

SCHOOLS & COLLEGES

WHO: Kids & CS teacher at Unity High
WHAT: Demoed robot
LEARNED: AI-based investing techniques

WHO: Professor Park Lee from Foothill College
WHAT: Workshop tour, demoed Kalman Filter
LEARNED: What we do in garage can be brought into real-life applications

NON-PROFIT ORGANIZATIONS

WHO: Boys and Girls Club of the Peninsula
WHAT: FIRST Things First partnership and plan to create FLL teams

WHO: Janyaa, based in India
WHAT: Plan to bring free LEGO SPIKE education to those in underserved areas

WHO: former founder of Sparkiverse
WHAT: will be receiving donation of various block-coding based robotics sets

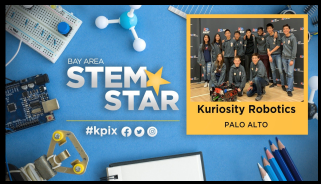
WHO: TeenTechSF
WHAT: Participated in Global Youth Summit

OTHER FIRST TEAMS

WHO: FLL teams
WHAT: Opportunity to demo robot at virtual FLL qualifier hosted by Apple

WHO: Texas FTC 8565 Technicbots
WHAT: virtual FTC workshop, where we taught about 3D printing for FTC and discussed game strategy and FTC life.

MEDIA PLATFORMS



INSTAGRAM
565 followers, **37,523** total reached
Team updates & new outreach events

KURIOSITYROBOTICS.COM
4,700 total unique visitors
Recruitment & initiatives & info

FACEBOOK
177,904 total reached
Advertisements & Initiatives

CBS NEWS
Honored as **STEM STAR** by KPIX,
Bay Area CBS News

YOUTUBE
5,700 total hours watched, **207,400** total views
Videos of our FIRST robots and outreach

KURIOSITY.ORG
1000+ total sessions, **15+** lessons
Free online EV3 curriculum