

ENGG 3961A

Final

Presentation

007是你的福報????

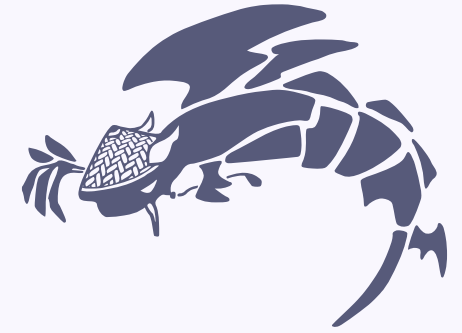




Robocon 2024 Game Rule



HKUST Robocon 2024



Robocon Sub-team had sent 2 teams to compete:

Fiery Dragon



War Dragon



HKUST Robocon 2024



Both teams has won the following prizes:

Fiery Dragon

最佳工程設計獎
BEST ENGINEERING AWARD

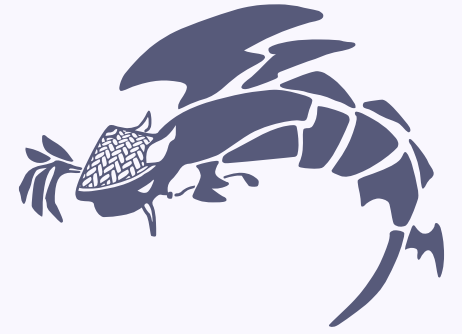
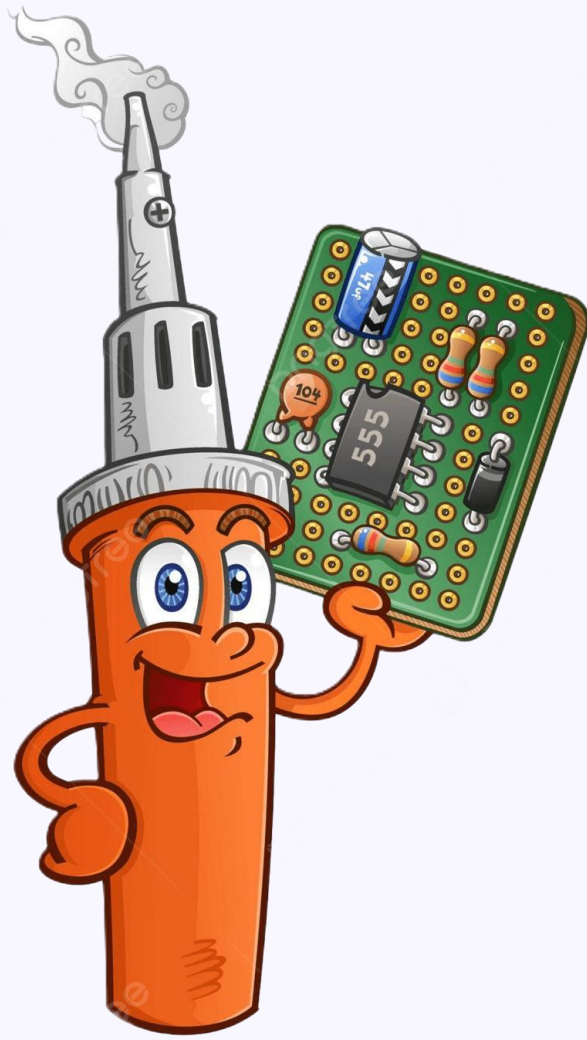
最具院校特色機械人獎
BEST INSTITUTE ENTITY AWARD

傑出戰策獎
INNOVATIVE STRATEGY AWARD

War Dragon

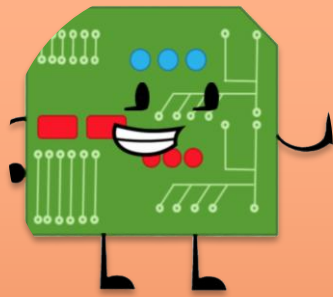
季軍
2ND RUNNER-UP

最佳團隊精神獎
BEST TEAM SPIRIT AWARD



Hardware

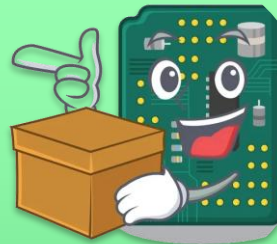
Hardware – Table of contents



Common
PCBs for
R1/R2



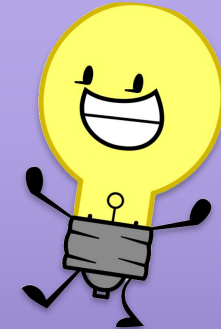
General
routing for
R1



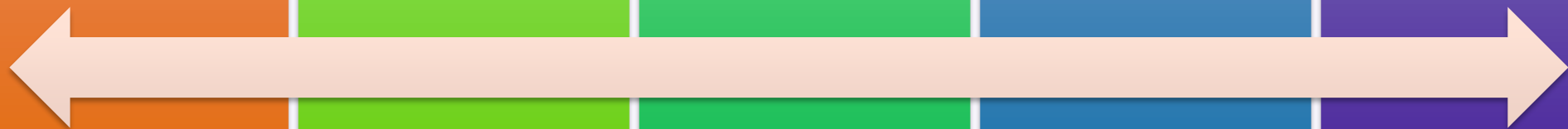
PCBs for
R2



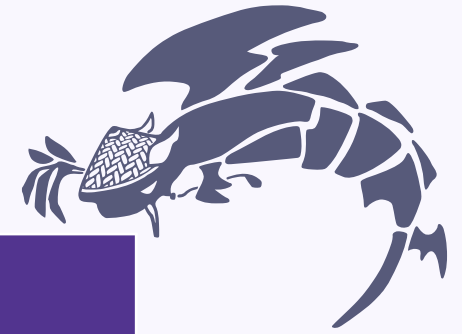
General
routing for
FD/WD
R2



R&D



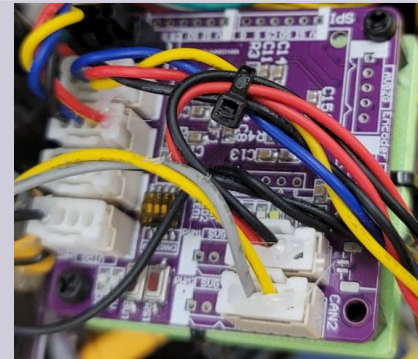
HW – Common PCBs for R1/R2



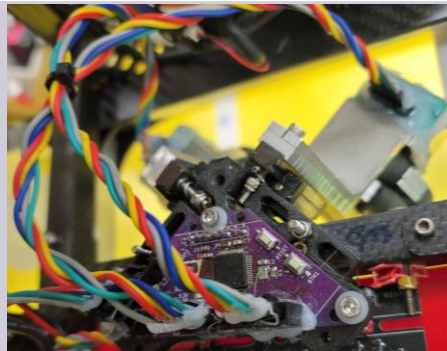
Mainboard



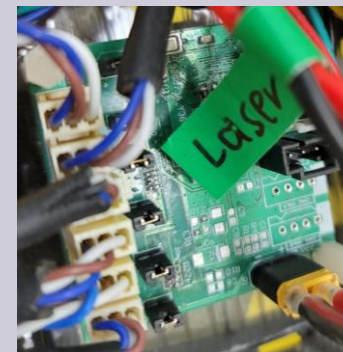
Valkyrie



XY Encoder

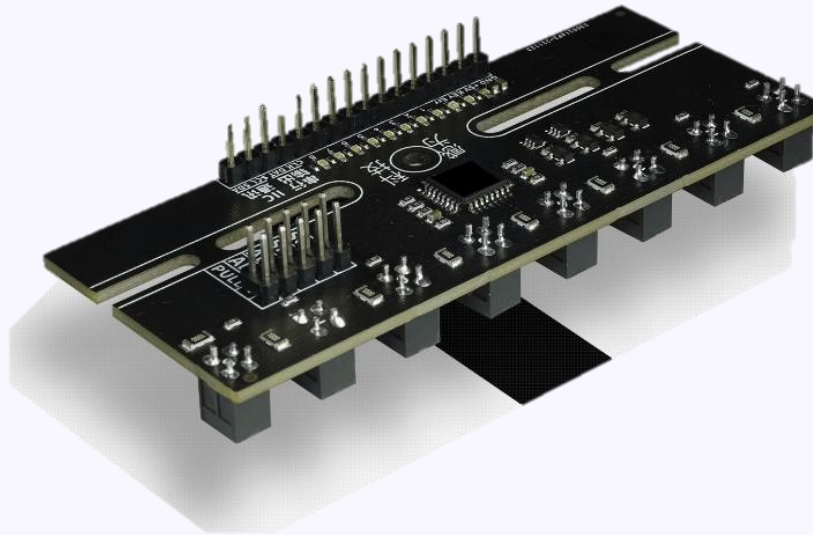


ADC board

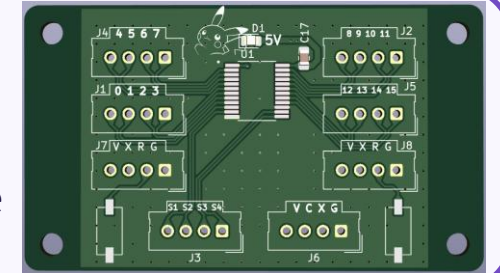


HW – Common PCBs for R1/R2

New for this year theme: **Line sensor board**



- Gen 0 – Gen 1 period:
- Connected to multiplexer
 - Using GPIO to communicate

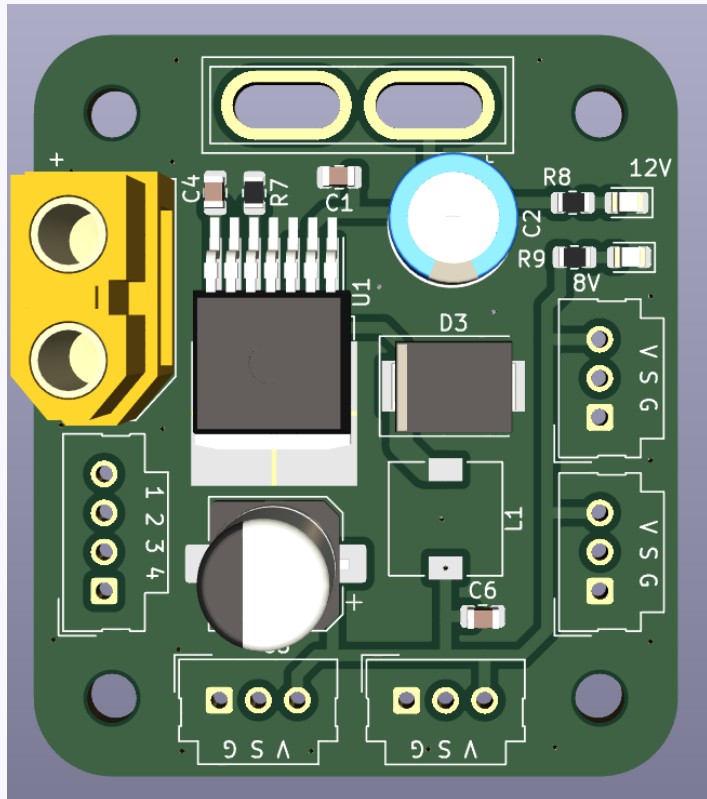


- Gen 1 – Gen 2 period:
- Connected to mainboard directly
 - Using Serial to communicate

HW – Common PCBs for R1/R2



New for this year theme: Servo board



Past year:

- Connected to mainboard directly
- May damage MCU since the power of the servo itself is large



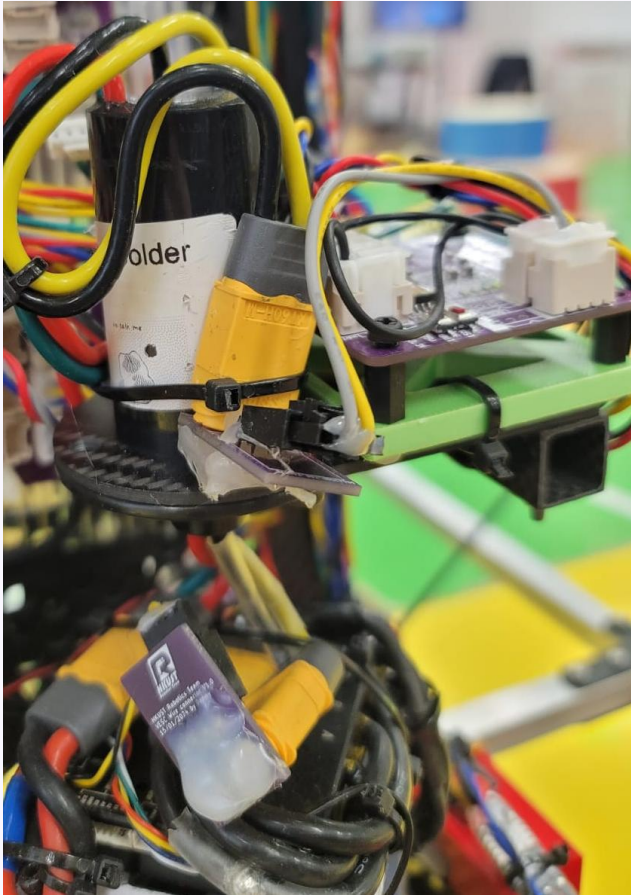
This year:

- Connected to servo board
- Ensure the 5V main power of the control system remains unaffected

HW – Common PCBs for R1/R2



New for this year theme: **Slip ring**



Past year:

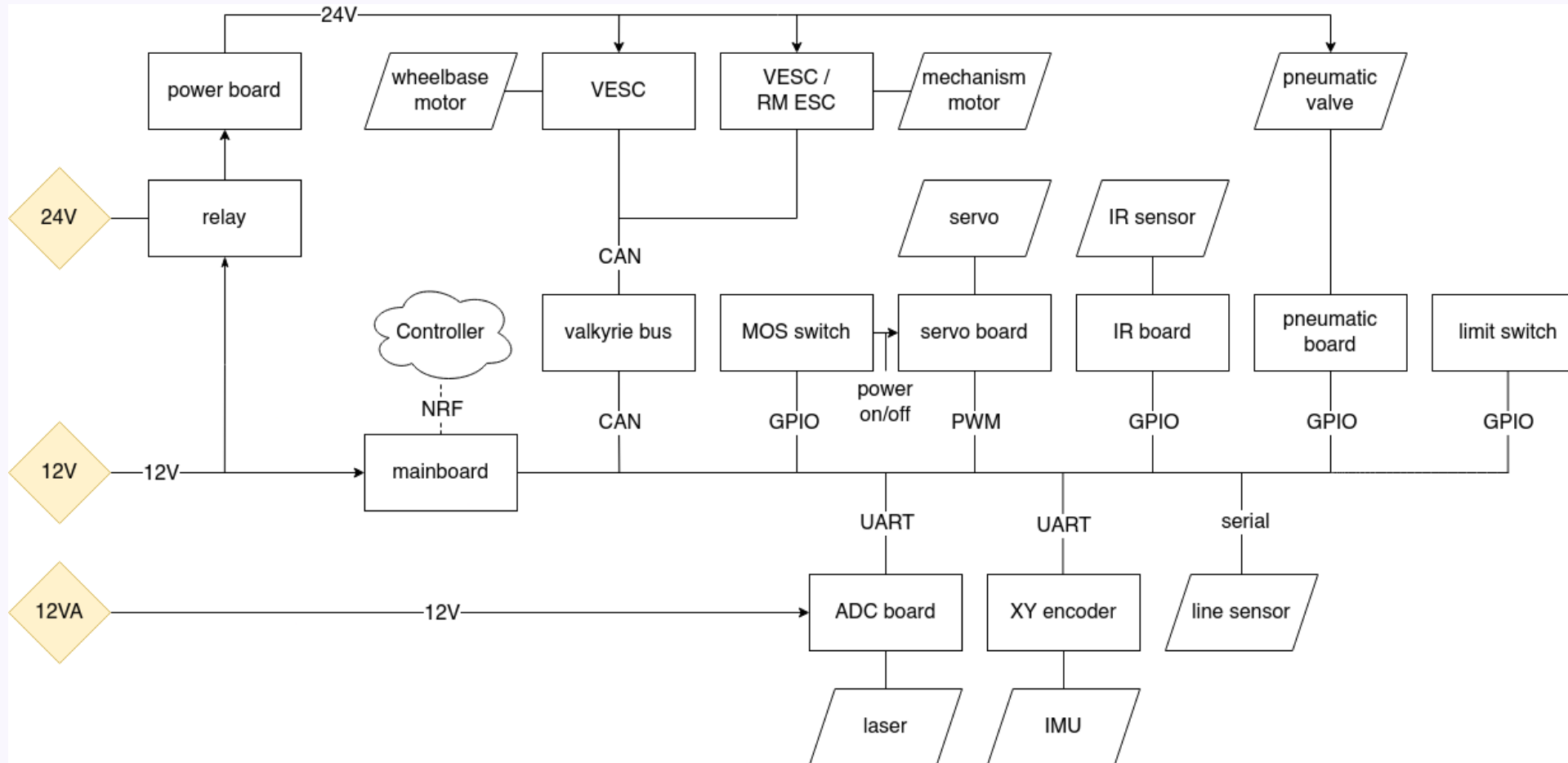
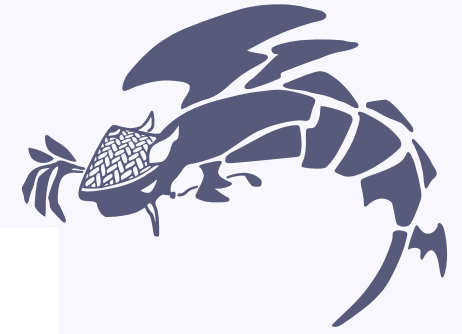
- Connected to wheels' VESC directly
- Relied on SW untwist function
- May damage the wire if the connection isn't well



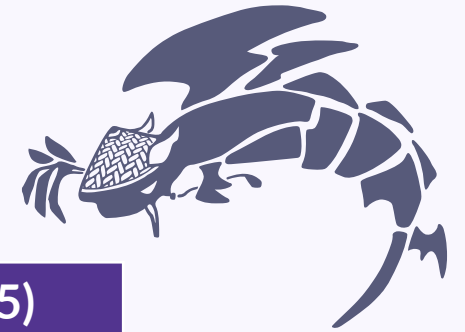
This year:

- Connected to wheels' VESC using slip ring
- Avoid damaging wires and save the untwist time

HW – General routing for R1



HW – PCBs for R2



- Task: to sort out the paddy rice (red/blue ball) in area 3

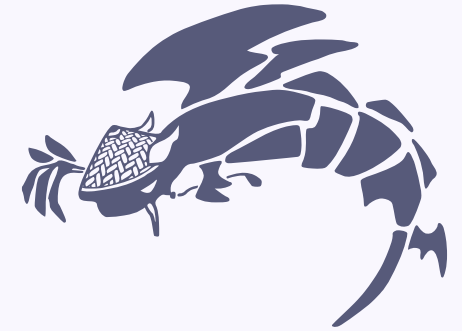
Fiery dragon: color sensor (GY-33)



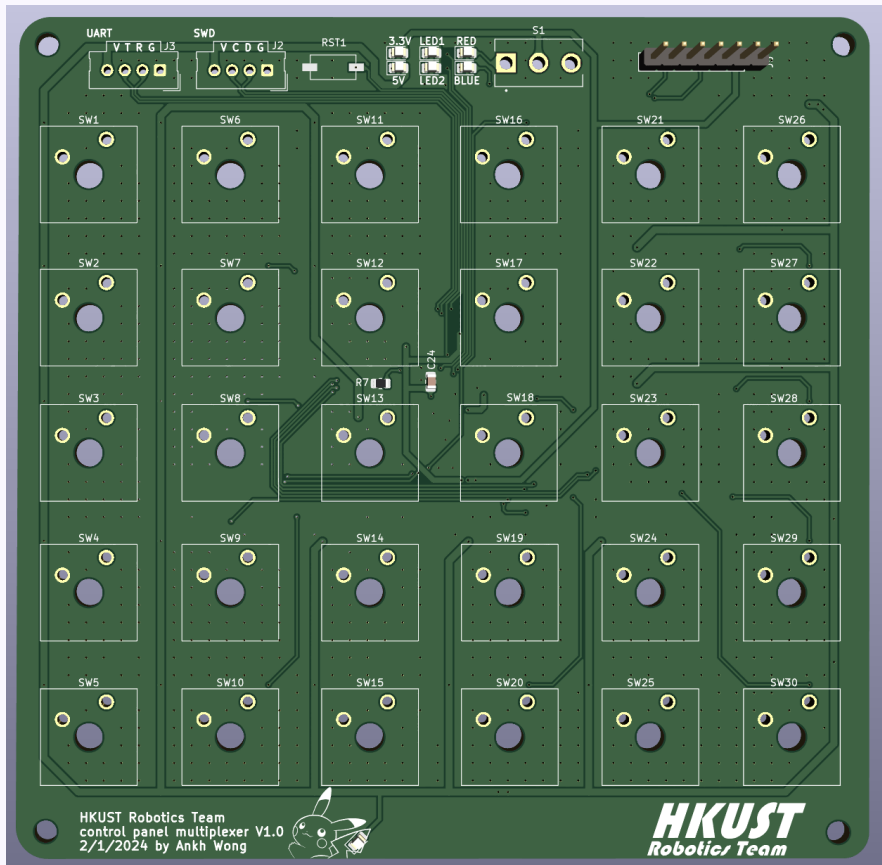
War dragon: embed cam (OV7725)



HW – PCBs for R2



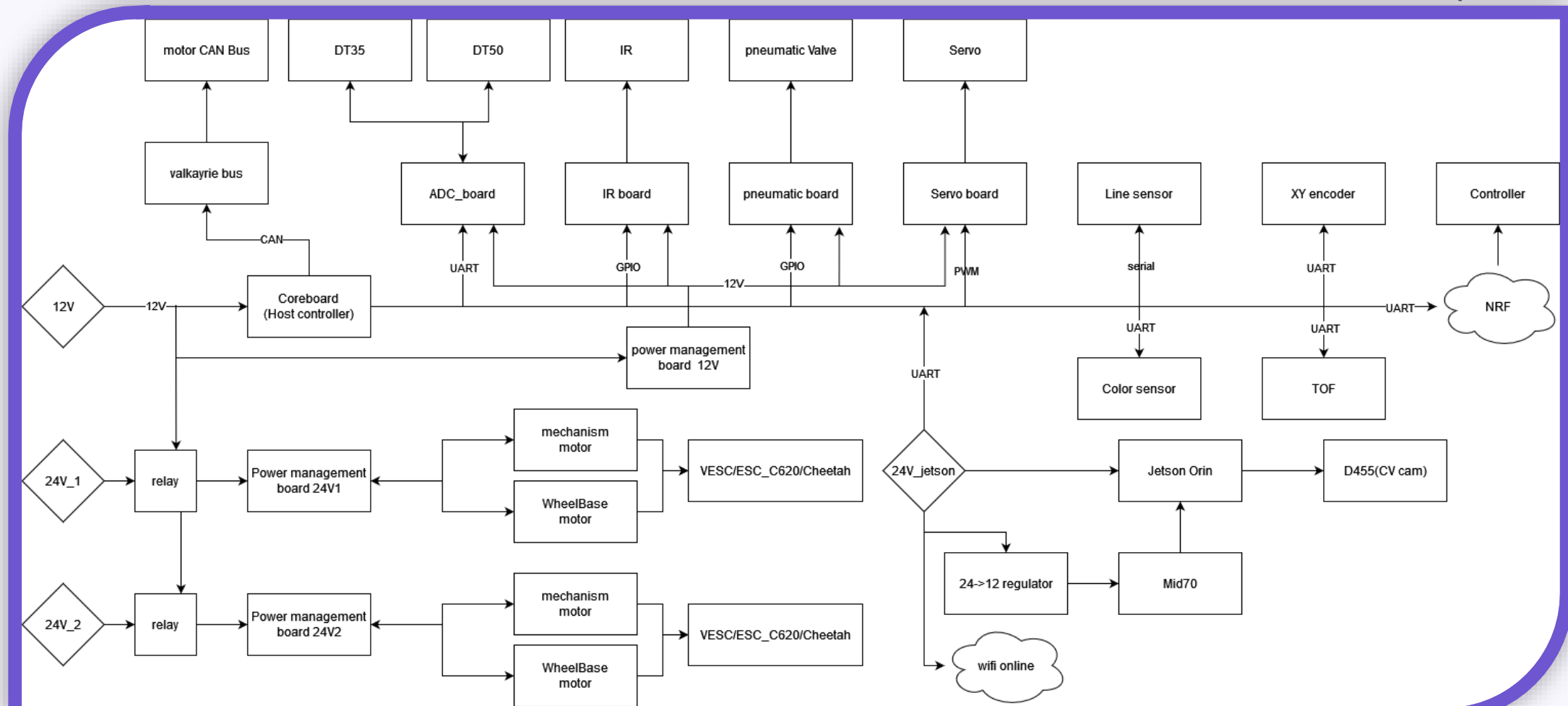
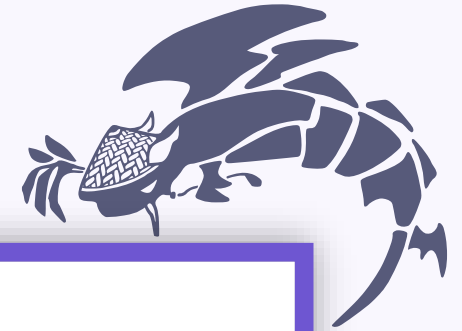
New for this year theme: **Control panel multiplexer**



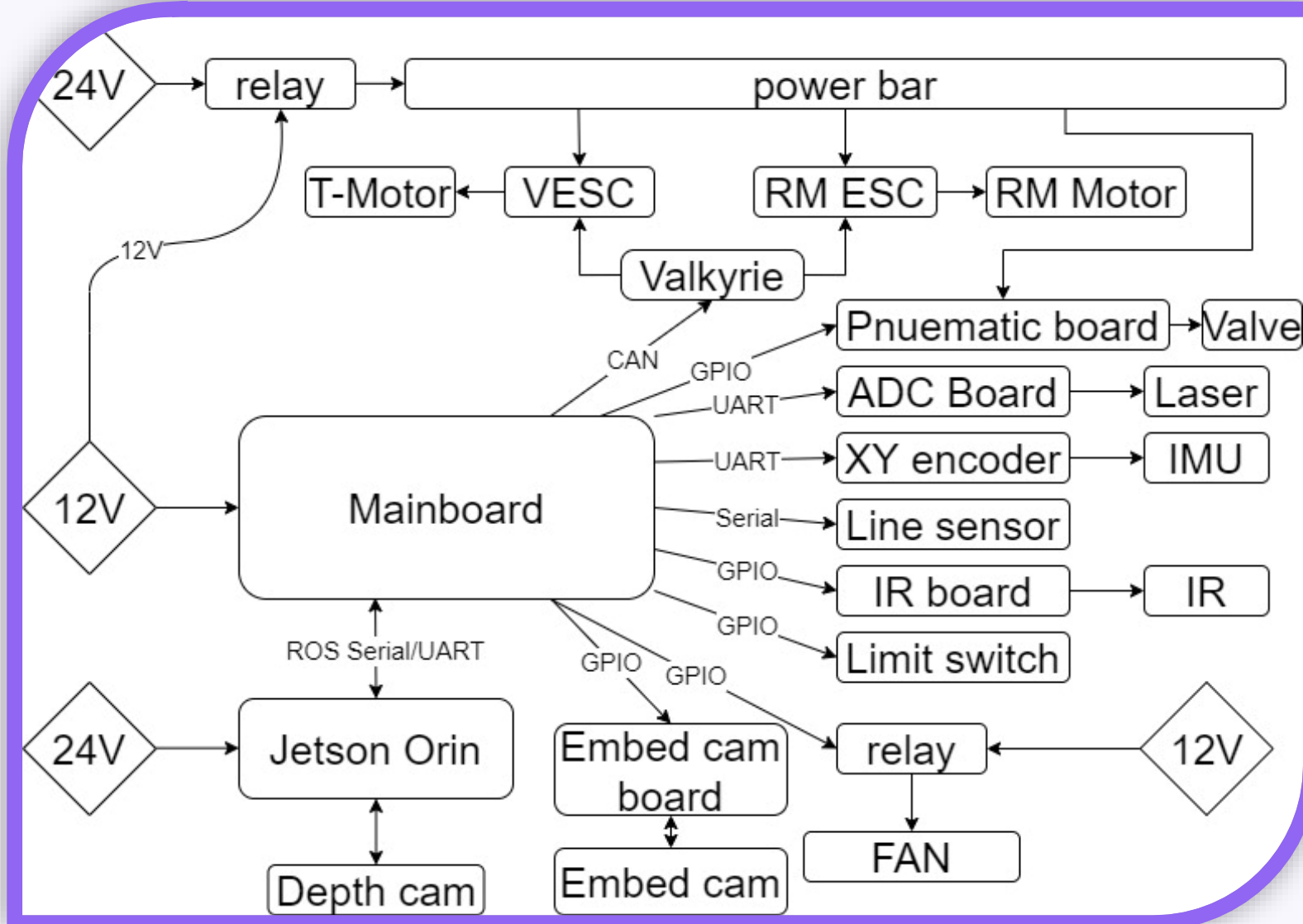
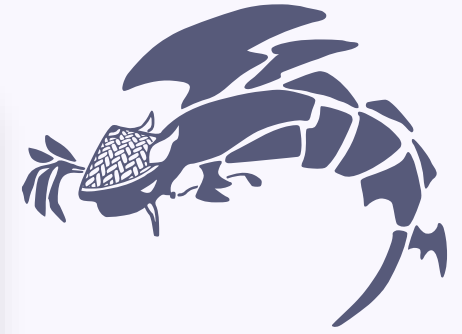
This year:

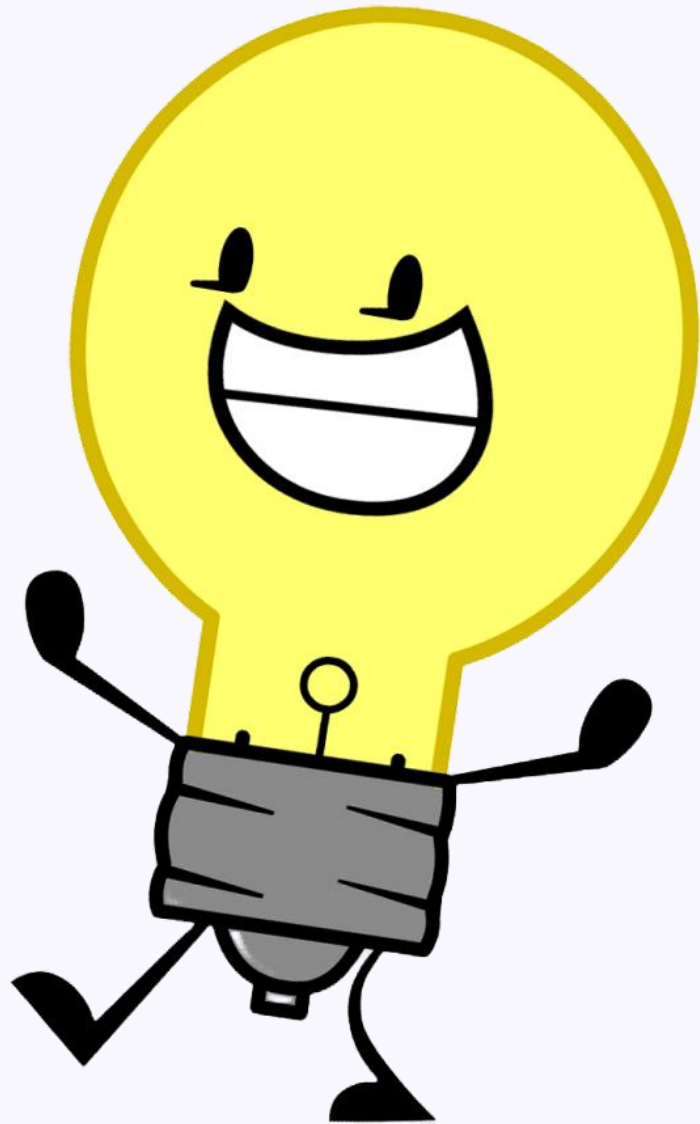
- Allow SW to choose different paths at the beginning of the game
- Using multiplexer to replace button array
- To avoid triggering the wrong buttons

HW – General routing for FD R2



HW – General routing for WD R2

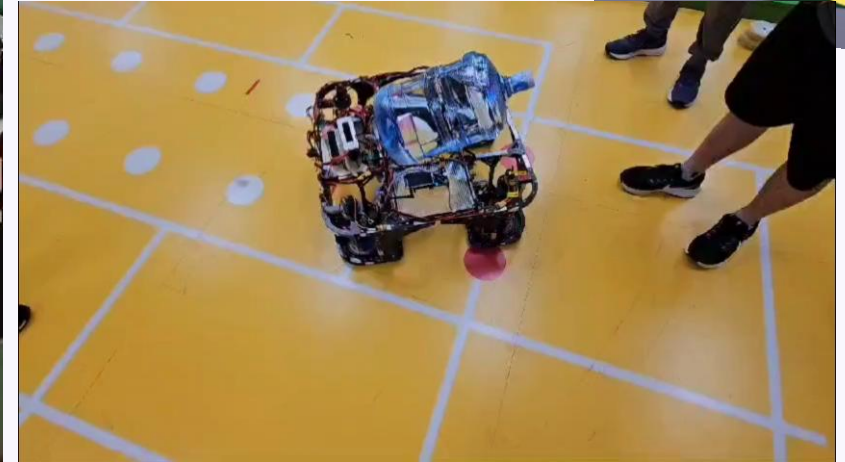
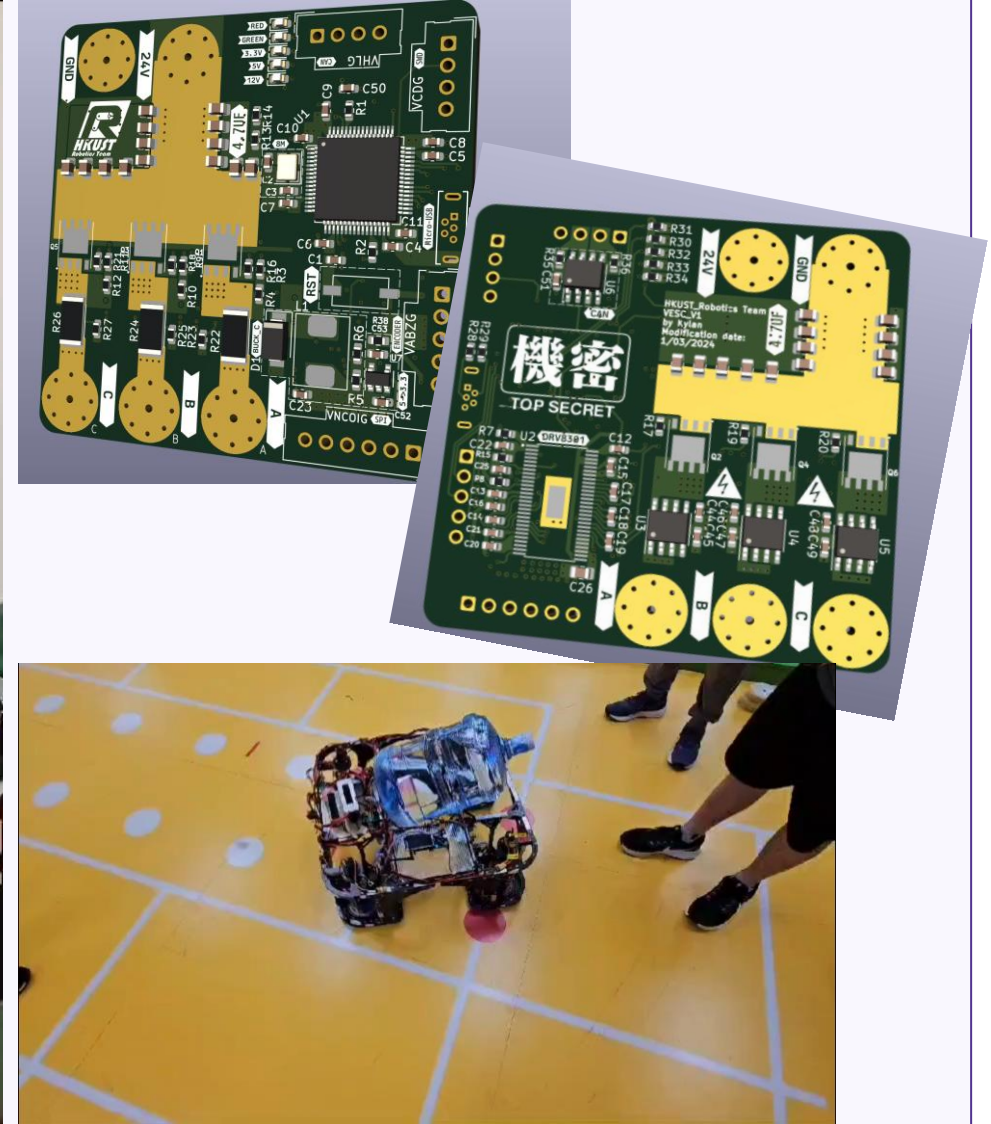




Hardware R&D

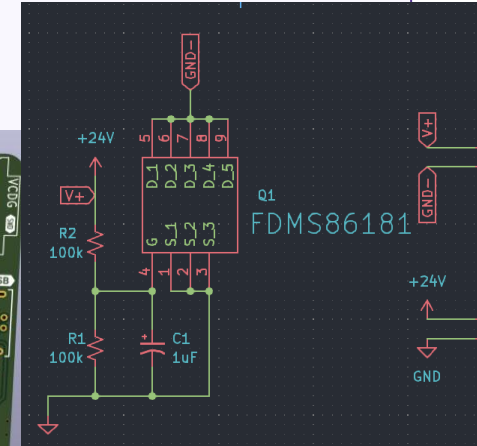
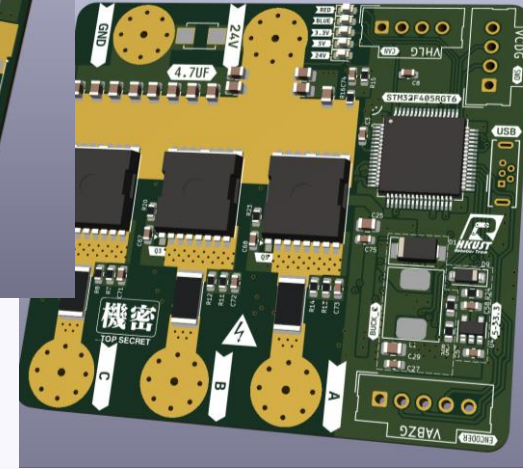
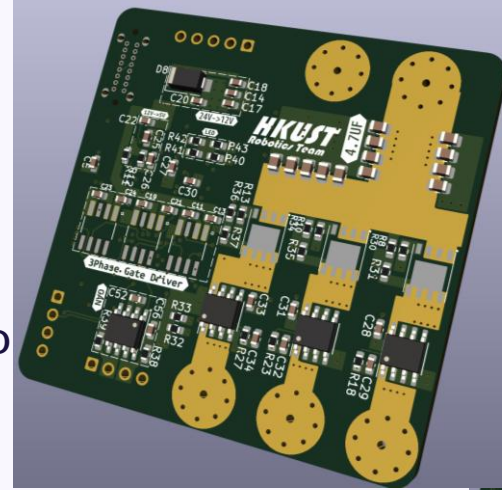
ESC

- Version 1 – ESC 1000 V1
- Aims to develop a high-performance Electronic Speed Controller (ESC) for Brushless DC (BLDC) motors utilizing Field-Oriented Control (FOC)
- Based on VESC open firmware
- 59A current limit



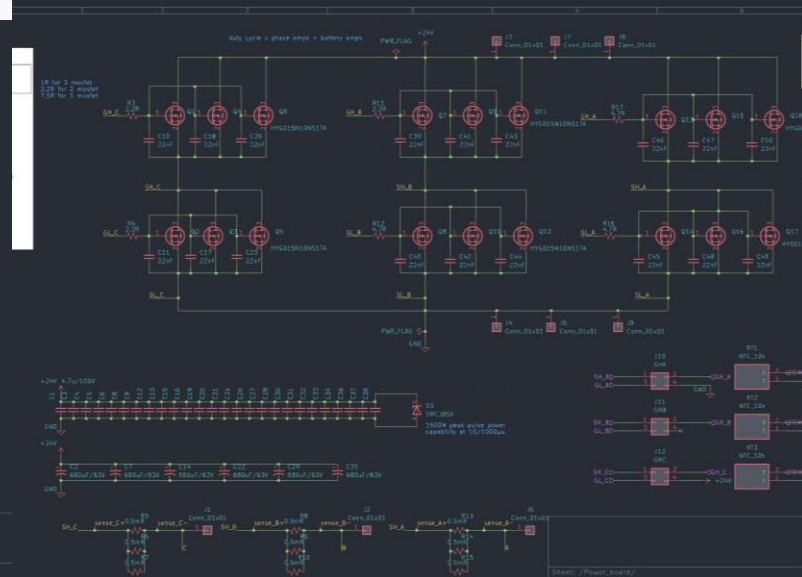
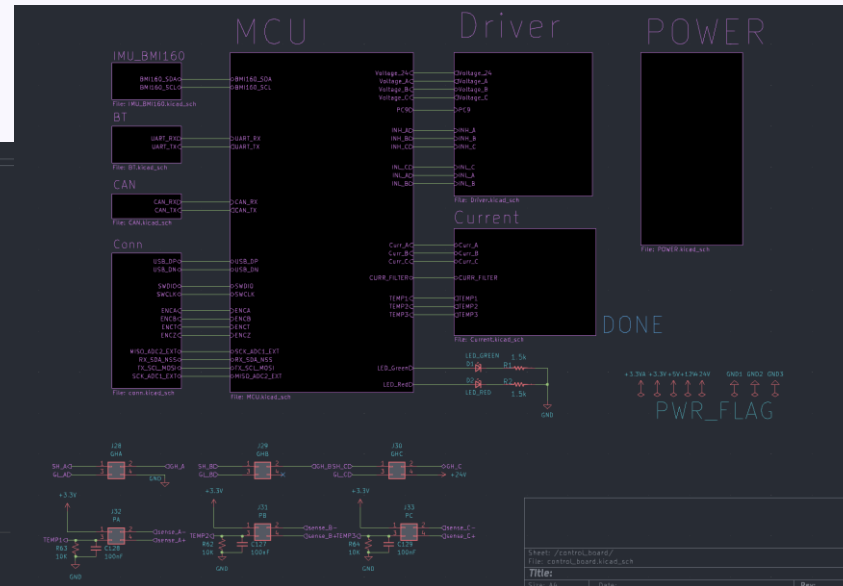
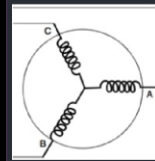
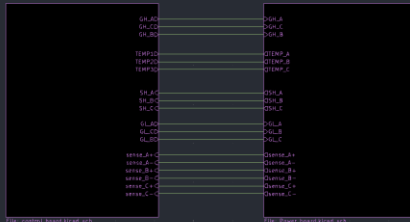
ESC

- Version 2 ESC_2000_V1 and ESC_1000_V2
- Using individual half bridge driver solution to move BLDC motor
- Self-make inrush limiter circuit
- Add TVS diode and ESD diode protection
- Higher power rating mosfet



BLDC motor controller

control_board Power_board

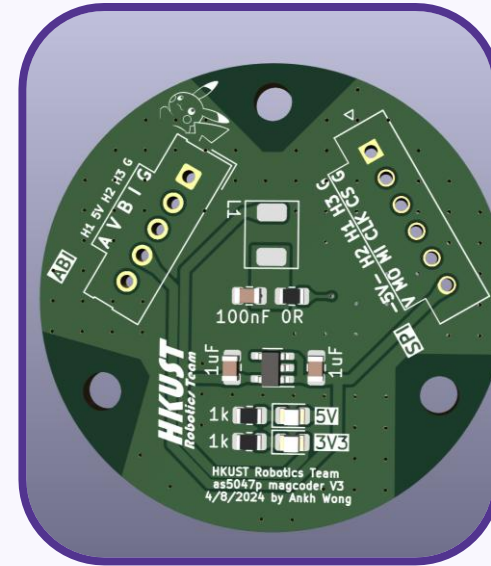


Magnetic encoder

- To accommodate higher RPM reading
- Using ABI output
- Implemented on R3 direct drive wheelbase, linear shooter etc
- **Error:** will suddenly init 0

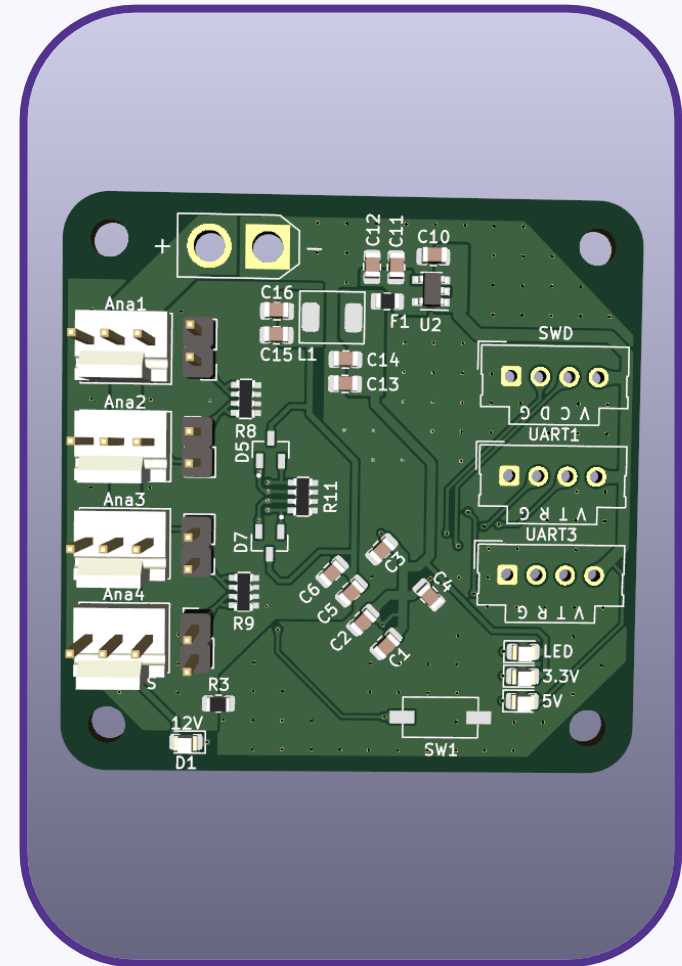
Current
R&D

- Using SPI output
- Provide absolute angle measurements
- Fix the error
- Explore the replacement of the existing incremental encoders
- To enhance synchronization and easier maintenance



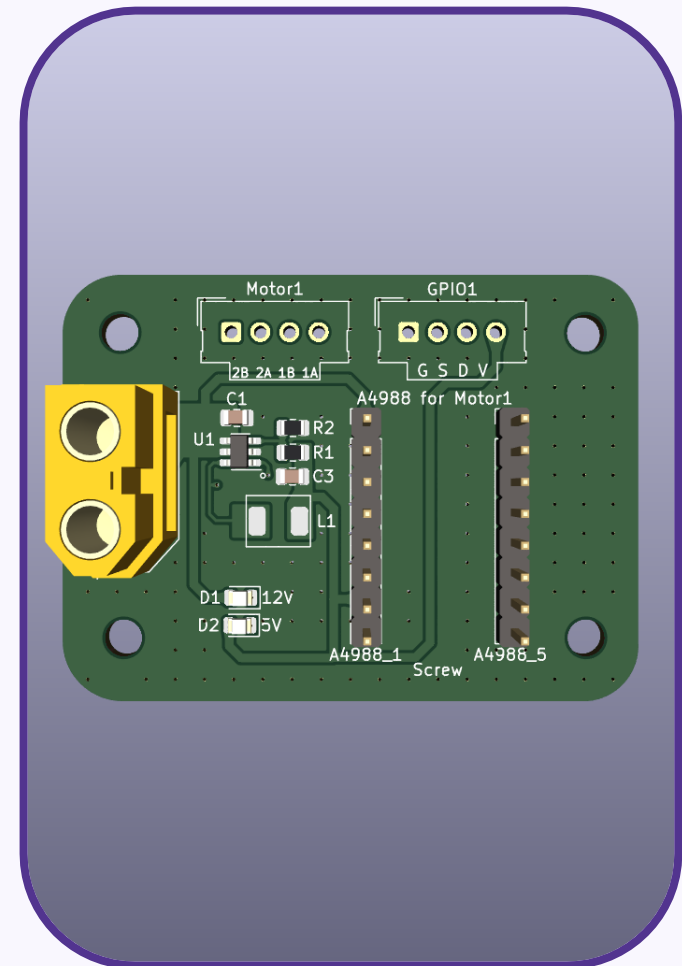
STM32 ADC Refresh

- Awaiting testing after board arrival
- STM32F103CBT6 as ADC chip
- To reduce fluctuation of laser reading
- Continuation of previous STM32 based ADC boards
- Attempt to reduce noise via means of PCB design



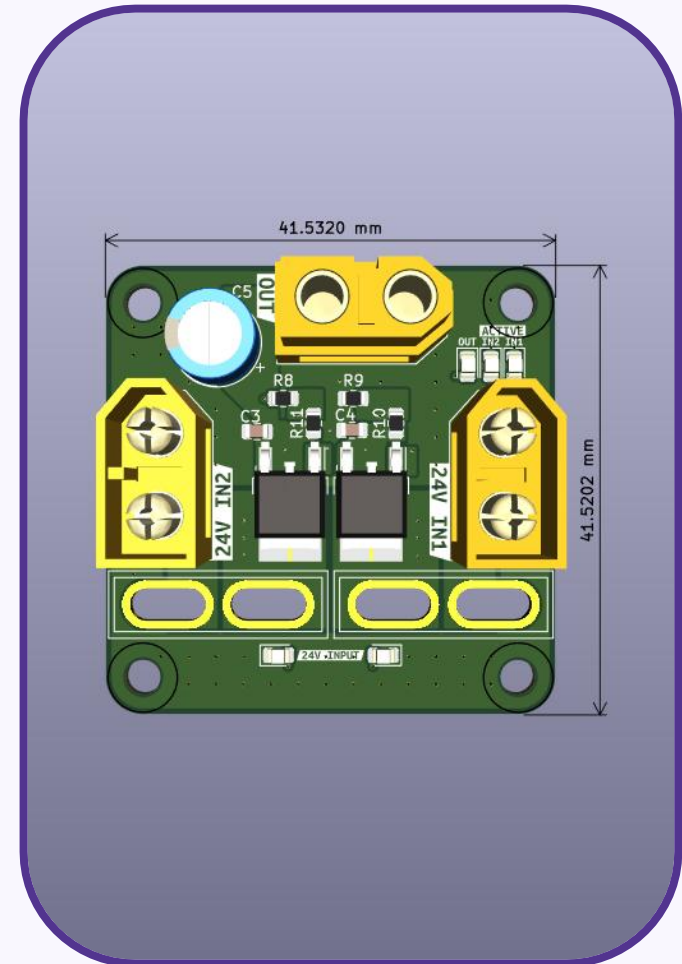
Stepper Motor Board

- Made for Controlling 12V Stepper Motors
- Made use of A4988 Carriers to convert GPIO signal inputs into control signal outputs (step and direction) for the stepper motor
- Include a power system: provide power for both the A4988 carriers and the stepper motor
 - Ensure sufficient power for the motor movement and logical processing of the A4988 carriers



Power Switching

- Prevent ROS computer from shutting down when changing battery
- Power switchover circuit using LTC4412 and external PMOS
 - Auto selects battery with higher voltage
- Supports 12V and 24V input
- LTC4416 version work in progress

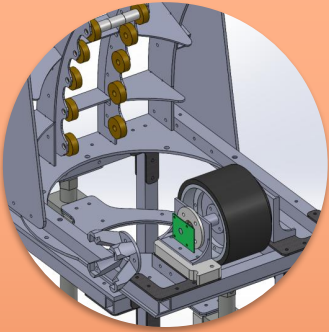


MECHANICAL





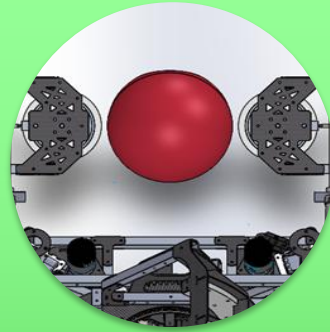
MECH – Table of contents



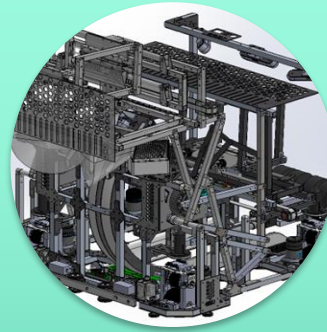
Early
Prototypes



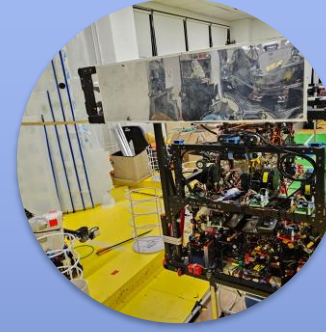
Gen0 Robots



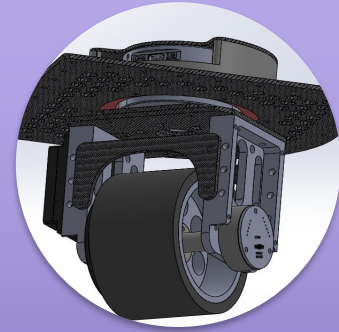
Winter
Training/Winter
Prototypes



Gen1 Robots



Gen2 Robots



R&D





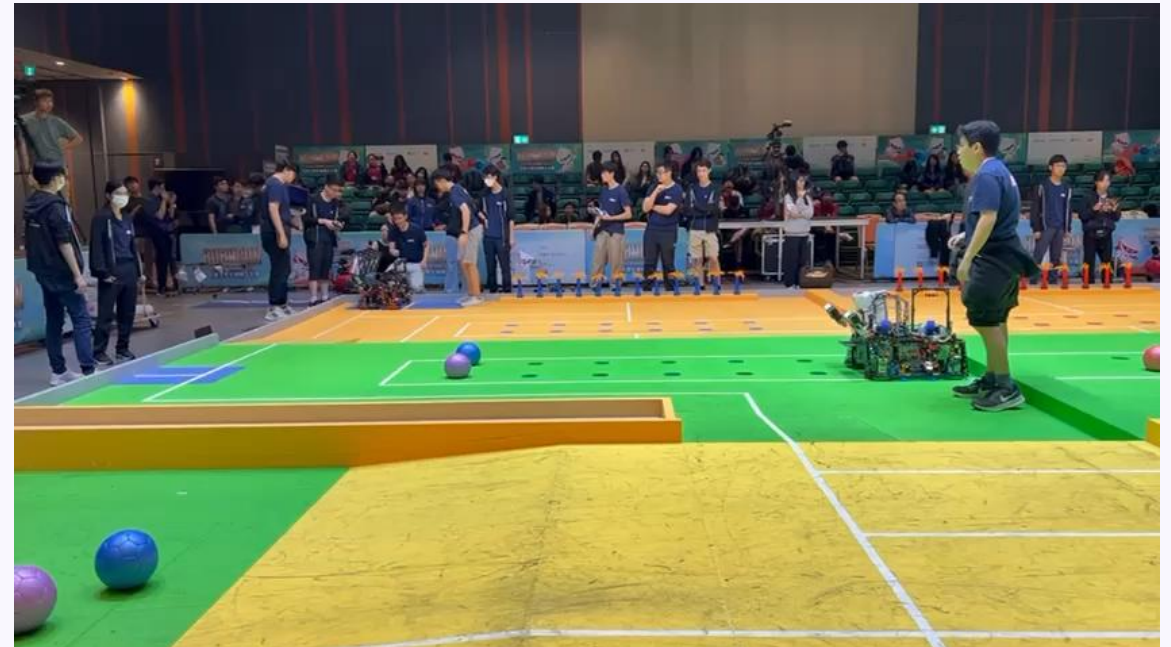
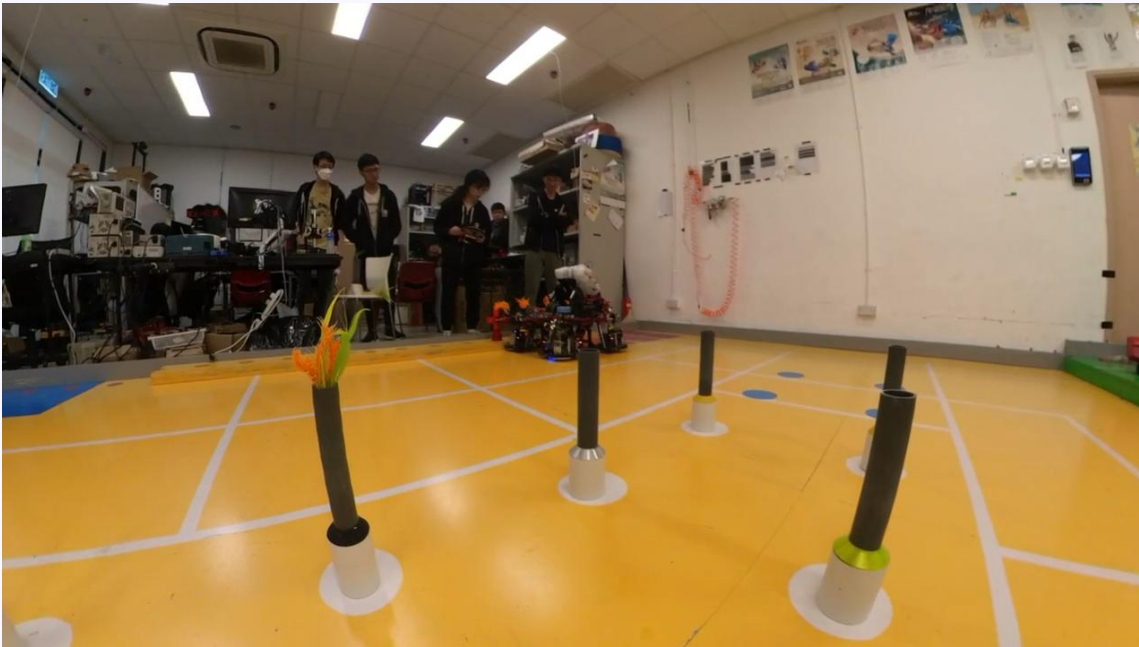
General Features

Mech – Independent Steering System



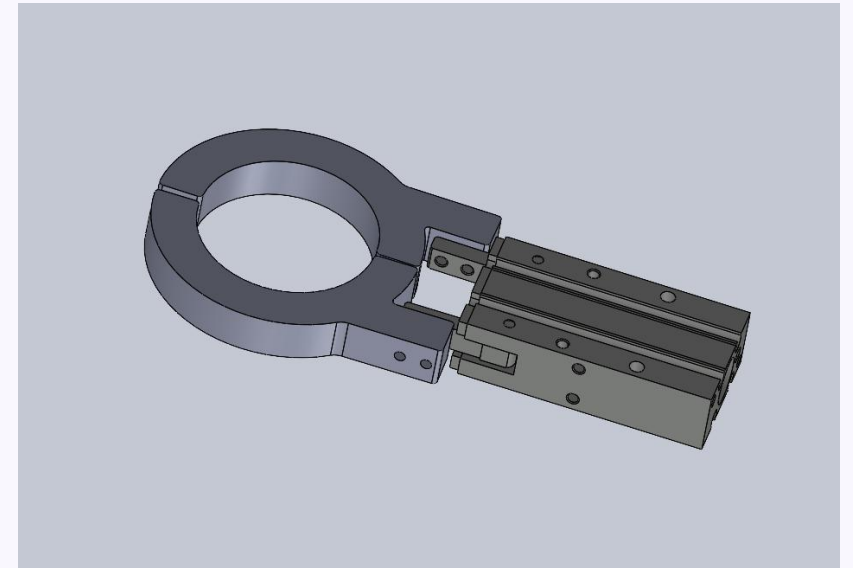
Fast and precise movement

- All 4 robots this season feature 4 independently-moving drive and steering modules each
- Drive motor: T-motor AT4130 KV300 geared 1:3, enclosed within "module"
- Steering motor: RM 3508 (1:71) geared 1:19 – 360-degree rotation provided by cross roller



Mech prototype – A1 Seedling Gripper

- Methodology: 3dp connected with a finger cylinder
- Problem Found:
 1. Finger cylinder is too weak for gripping seedling



Mech prototype – A1 Seedling Gripper



Gripper Part

- Methodology: linkage gripper driving by cylinder
- Problem found:
 1. Difficult to assam
 - Too many small parts
 - Unnecessary thrust bearing
 2. Fail hinge
 - weak torsion spring

Lifting Part

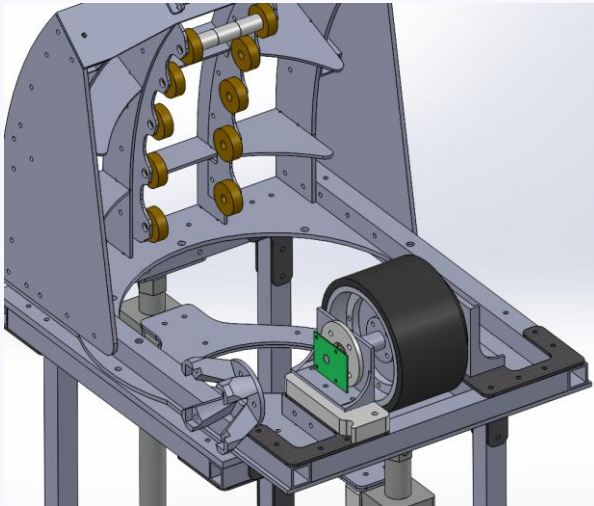
- Methodology: 1 DOF linkage driving by a rodless cylinder
- Problem found:
 1. Layout is hard to fit into the R1
 2. The lifting height is too close to the rack height
 3. Massive

Mech prototype – A2 shooters

Main Purpose -> Shoot A2 paddy rice/empty grain into A3 storage zone

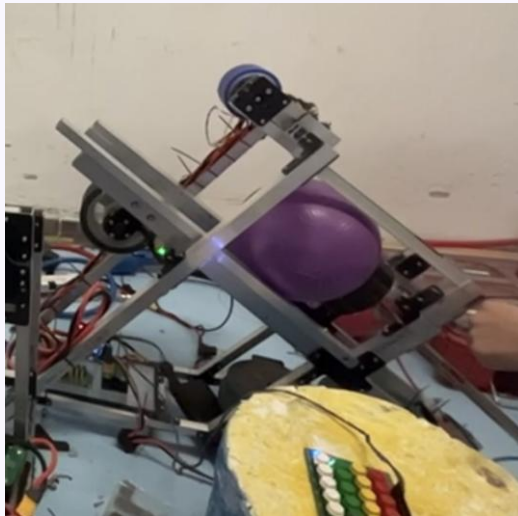
Single flywheel

- One flywheel (1x AT4130 300 KV) which moves ball along a bearing track, which ejects ball out of top
- Ball loads from bottom using set of two rodless cylinders



Double flywheel

- Two flywheels (2x AT4130 300 KV) placed vertically rotating in opposite directions, compressive and rotational force ejects ball
- Ball loads from back using cylinder



Pendulum

- Rotating ball kicker powered by 1 high-torque motor (AK80-9, 100 KV) with 700g counterweight
- Kicker starts from highest position, contacts ball at maximum velocity (bottom), punts ball off ground



Mech prototype – A2 shooter assessment

Single flywheel (used for competition)

Strengths:

- Compact shape and requires just one shooting motor
- Relatively high shooting accuracy

Issues:

- Stability → shooter will shake considerably
- High shooting arc → 30 deg release angle, caused ball to travel further upwards than forwards (range 4-5m)
- Bearing track has uneven compression on ball

Double flywheel

Strengths:

- Greater range → potential to shoot much further distances
- Tunable backspin → can change the rpm of upper flywheel to control degree of backspin

Issues:

- Size → footprint on robot is extremely large
- Resource usage → Heavier than single flywheel and requires double the qty of motors

Pendulum

Strengths:

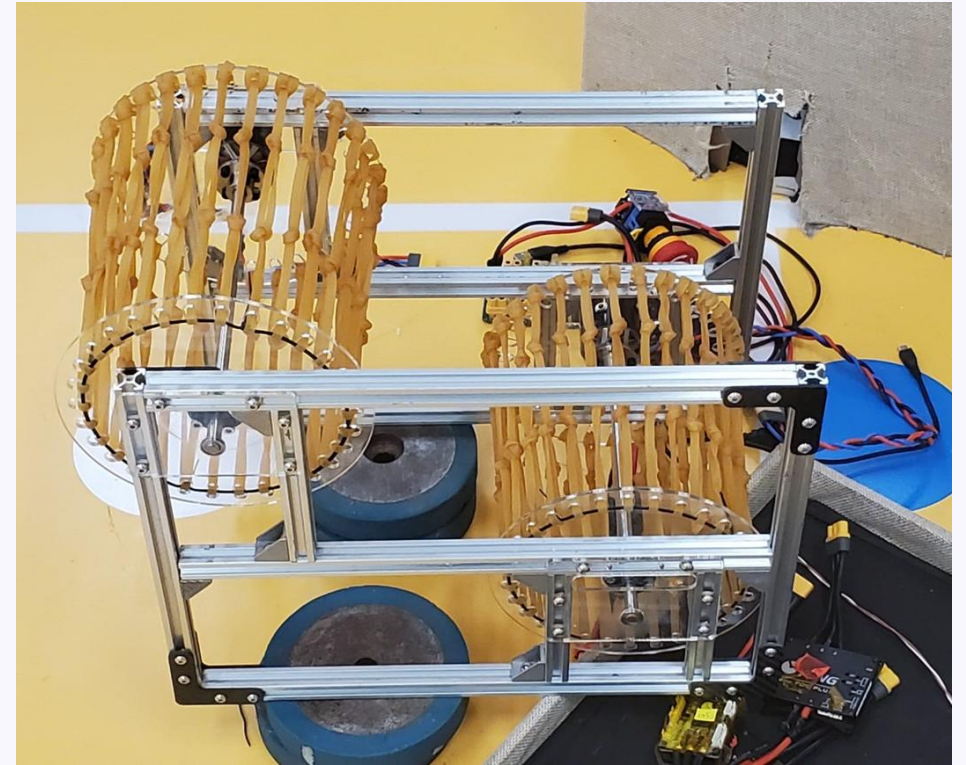
- No loading mechanism → can shoot ball directly out of A2 grid

Issues:

- Stability - centrifugal force from counterweight (added as inertia) creates extreme rocking motion,
- Shooting arc low, cannot cross water zone fence
- Worse shooting range than single flywheel (range 3-4m)
- Weight → counterweight and axle component needs to be heavy

Mech prototype – A3 Roller Loader

- Objective: sorting and transfer the paddy rice from the ground to the silo
- Methodology: Rubberband roller driving by JFRC motor
- Failure:
 1. bad control performance in low spinning speed
 2. Weak tension of the rubber band
 - vibration
 - create heavy wind to brow the ball away



Mech prototype – A3 Robotic arm

- **3 DOF arm made by Nicky**

- Objective: pick up the ball & put it into the silo

- Methodology:

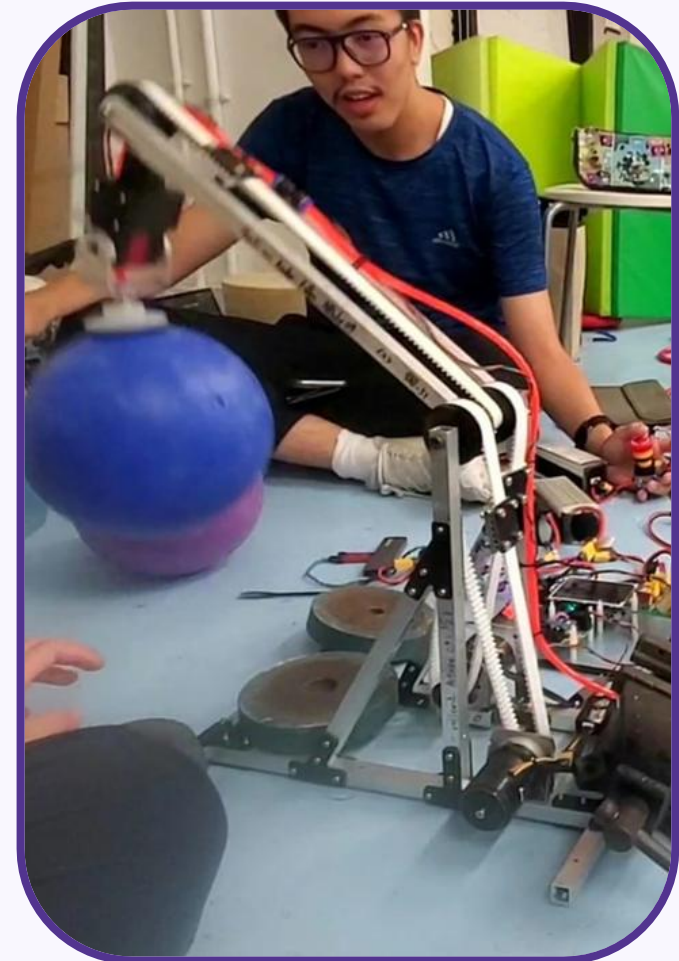
- Arm driving by M3508 with two HTD 3M timing belt

- Tip have a 60kg servo motor.

- Picking ball with suction cup, and power by a vacuum pump

- Failure:

1. Backlash problem found+
2. Can't keep the pressure to hold the ball



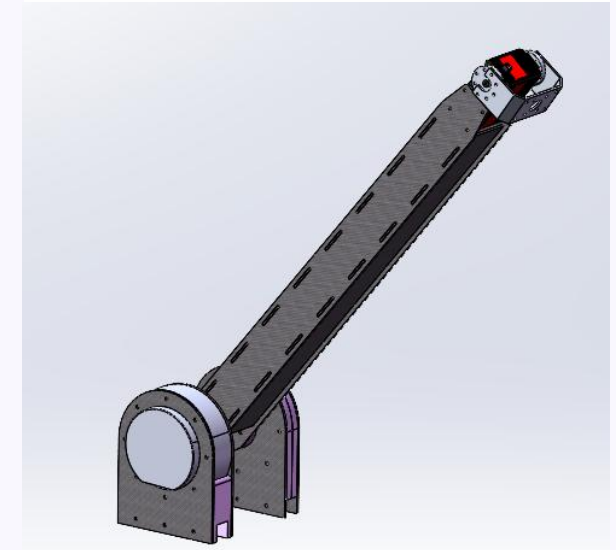
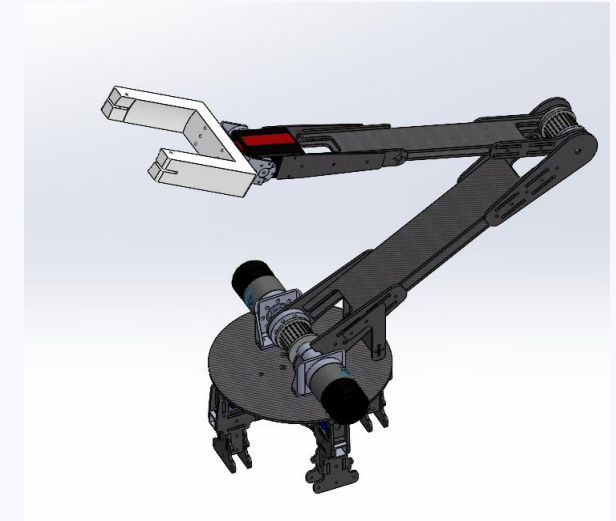
Mech prototype – A3 Robotic arm

4 DOF arm make by Bryce

- First use Vacuum generator to suck the ball, but doesn't work well so change to ducted fan.
- Use timing belt for transmission, but there are back clearance so we add a tensioning wheel.
- Use RM3508

Catapult Arm

- We use catapult arm because compare to the 4 DOF arm, it have smaller back clearance, and we don't need that much DOF
- Use AK80-9



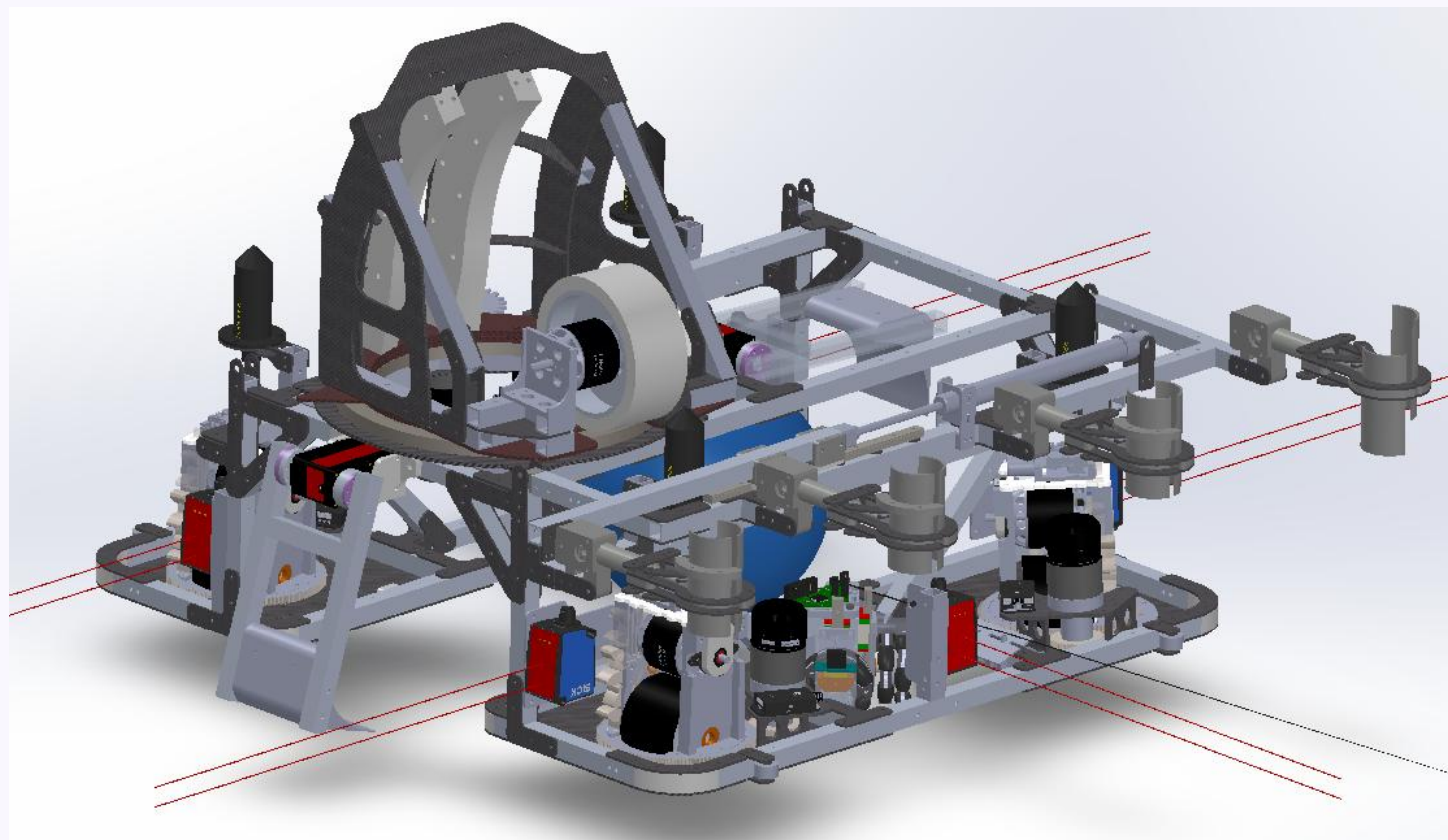


Gen0

robots

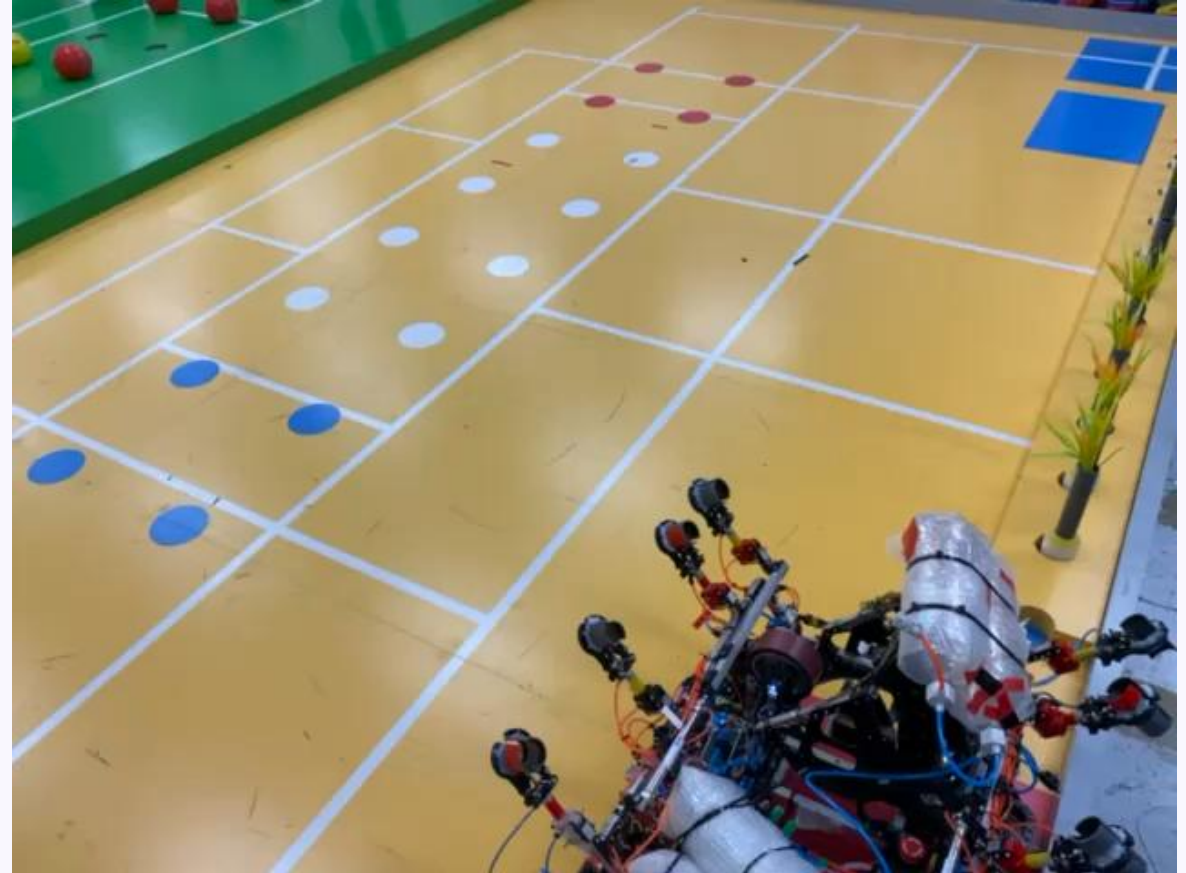
Mech – Gen0 R1

- Purpose – Proof of concept for using tunnel wheelbase to help perform Area 2 task quickly
- Purpose – Test seedling gripper mechanism with context of real game



Mech – Gen0 R1 Seedling Gripper

- Two sets of 4 seedling grippers that grab thin portion of seedling
- Pneumatic extension of fourth gripper (initial position)
- 2 cylinders raise up 4 seedlings out of rack, and places them down in designated planting zone
- R1 can plant 4 seedlings at a time, repeats process 3 times to complete A1 task



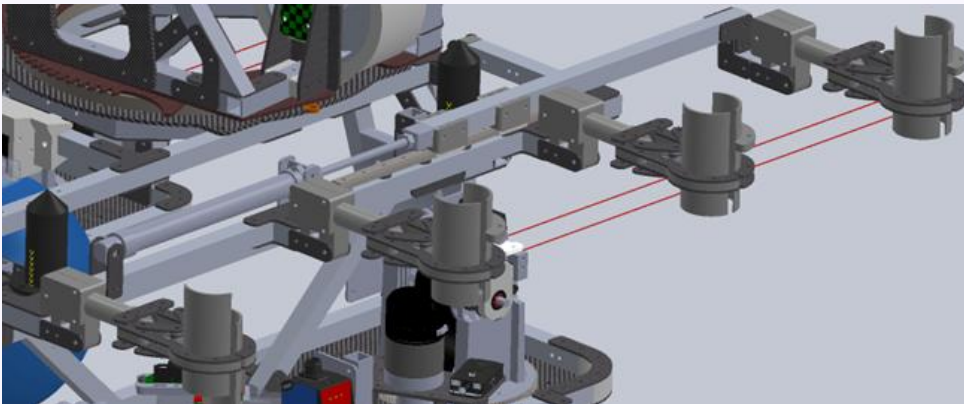
Mech – Gen0 R1 Seedling Gripper

Loader Part

Changes: Driving with two cylinder directly

Failure:

1. Can't lift the seedling when the pressure lower then 5 bar
2. Hard to adjust the cylinder to fit the layout



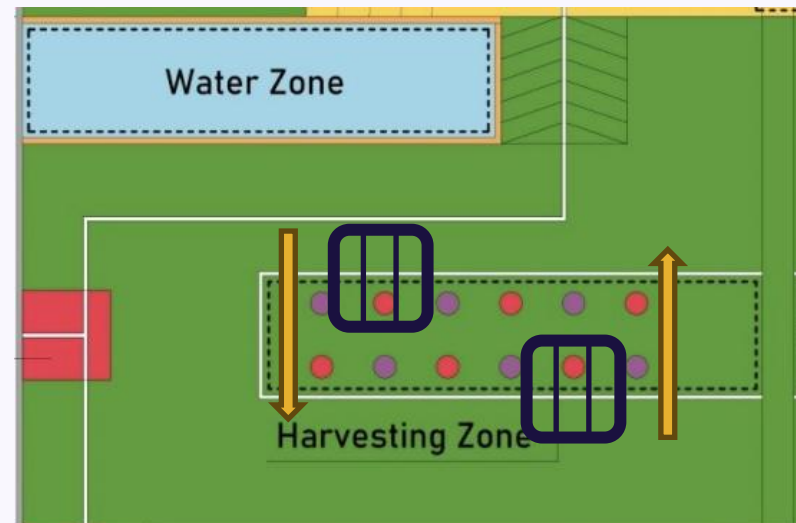
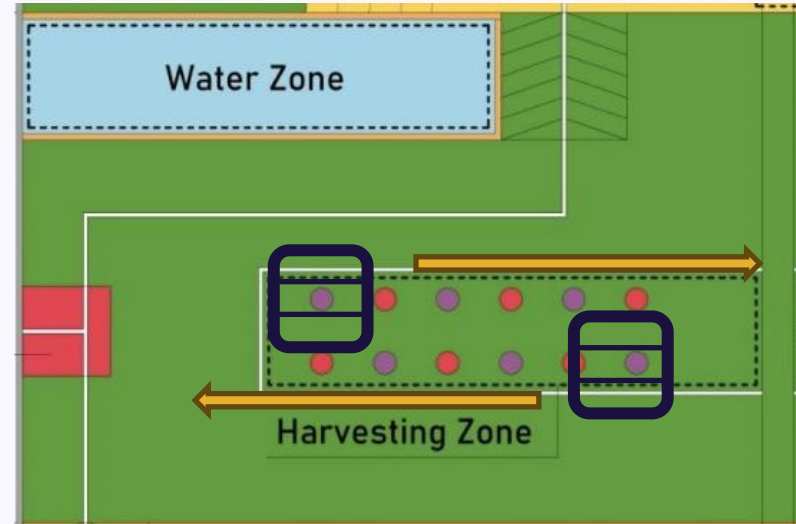
Extend Part

Objective: to allow the fourth gripper retract and extend to fit the extension limit

Mech – Gen0 R1 Single Tunnel Wheelbase

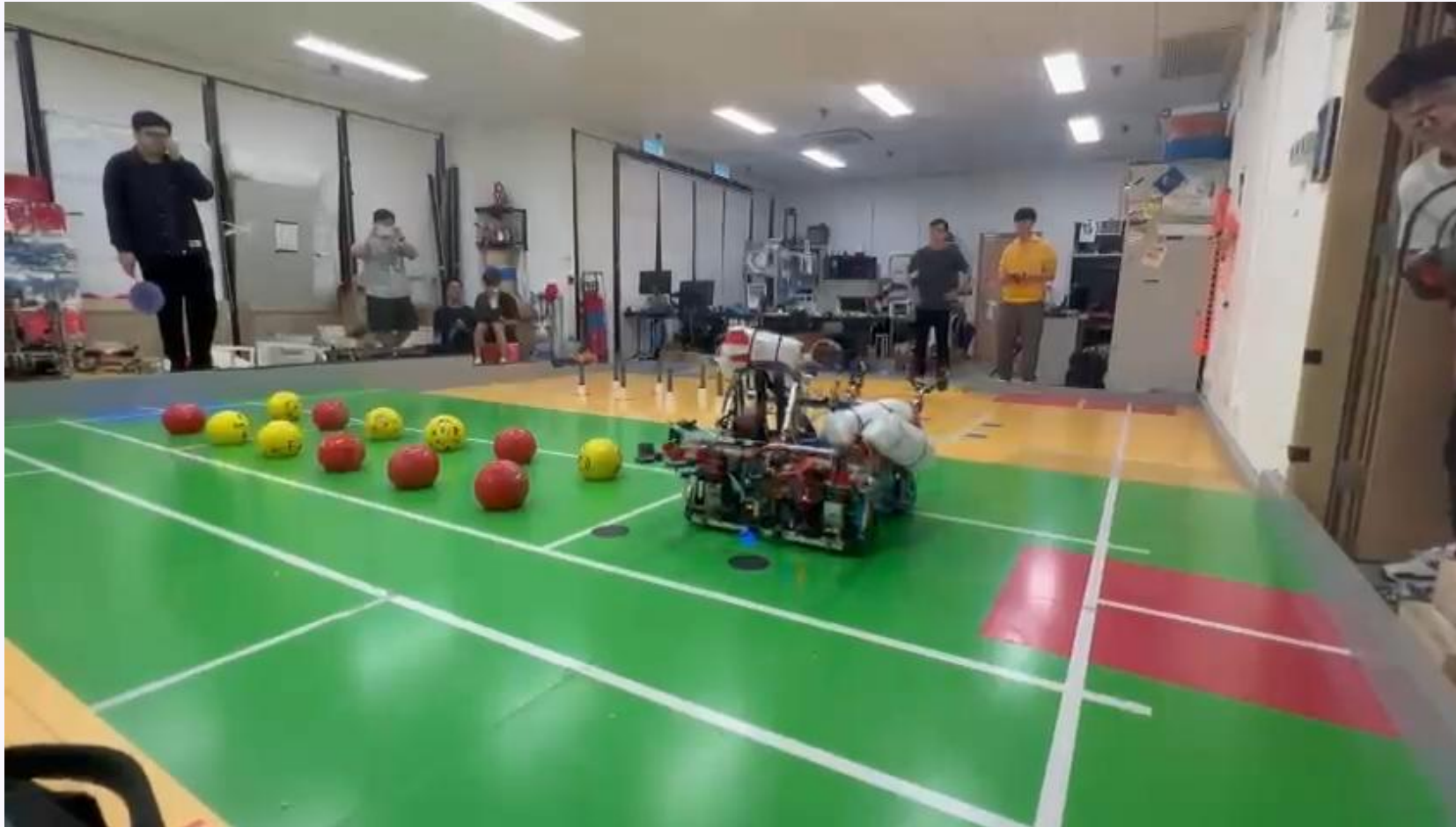
Purpose: Streamlined R1 movement between A2 ball row

- R1 wheelbase split into two rectangular "parts" containing 2 independent steering modules each
- Wheelbase parts connected at top (U-shaped side structure), leaving center region open R1 picks up ball when below tunnel through loader mechanism, feeds directly to single flywheel shooter from bottom
- Accuracy of R1 driving above both A2 first and second rows done using lasers on all 4 sides + line sensor





Mech – Gen0 R1 Tunnel Wheelbase Demonstration

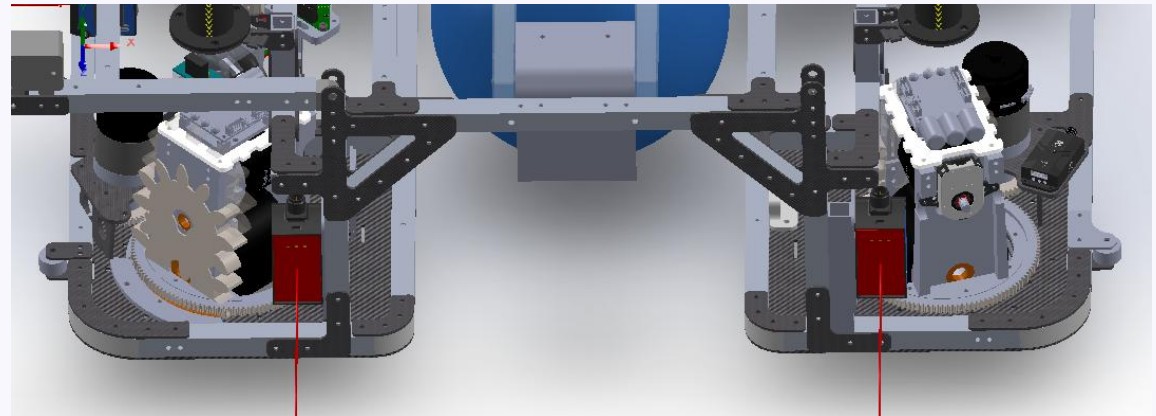
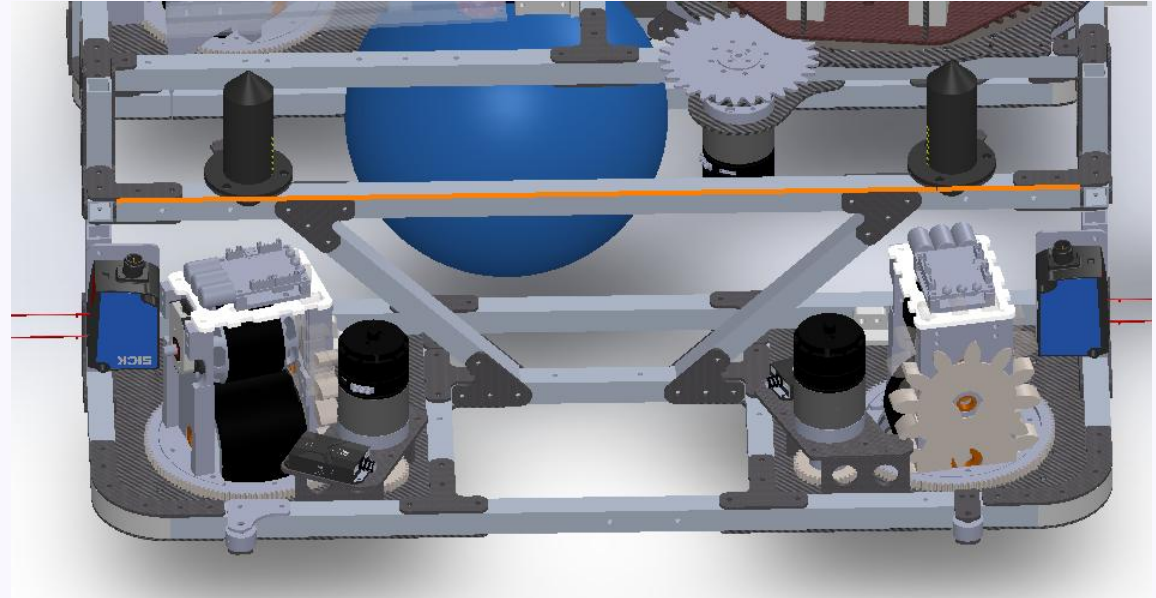


- Quick and efficient movement to load and shoot A2 paddy rice/empty grain

Mech – Gen0 R1 Tunnel wheelbase

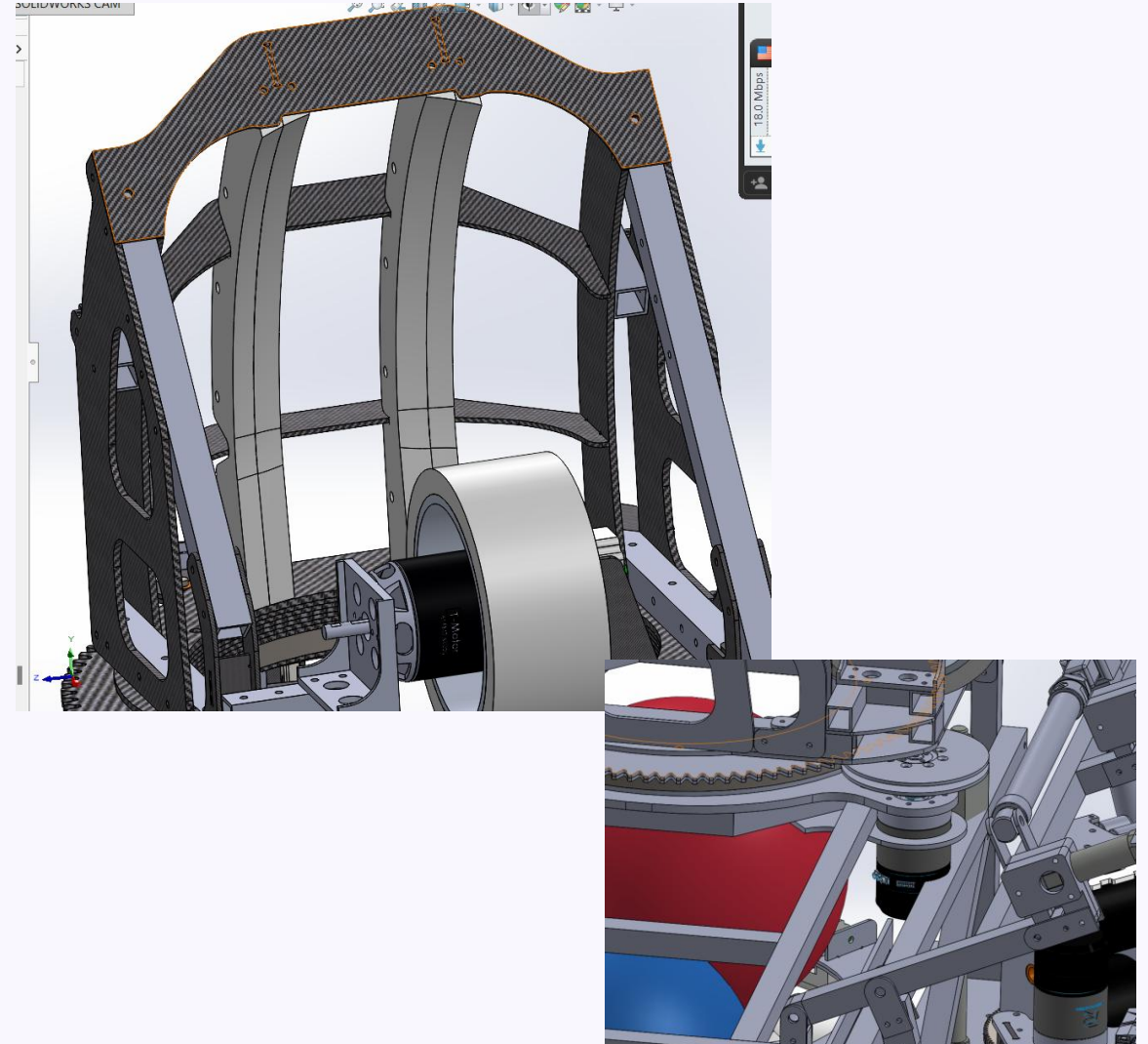
Limitations

- Tunnel structure too low -> loading mechanisms in stowed position will scrape/get stuck on A2 ball
- Tunnel side dimensions too narrow (210mm, 10mm clearance on each side), difficult to drive underneath ball rack without contact
- Lack of direct vertical support holding the tunnel frame -> wheelbase start bending inwards, multiple secondary issues (loading mechanism cannot move, laser position changes etc.)



Mech – Gen0 R1 Flywheel

- 120mm diameter polyurethane flywheel powered by 1 AT4130 (KV 300) brushless motor (regression tuned)
- Yaw movement -> 180 degrees of range (Yaw motor -> RM3508(1:71) with 1:5 spur gear), allows for auto-aiming capability at A3 storage zone from any position in A2
- Yaw movement guided by aluminum cross roller, placed between wheelbase frame and shooter base plate, inner diameter large enough to pass through A2 ball
- 3dp parabolic guide concentric to flywheel -> 150mm compressive distance, ball released at a 45-degree angle to ground



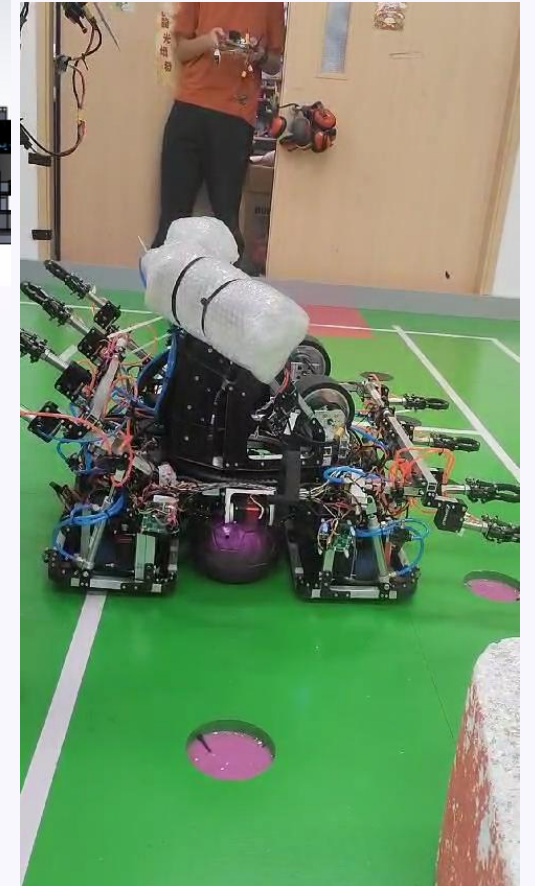
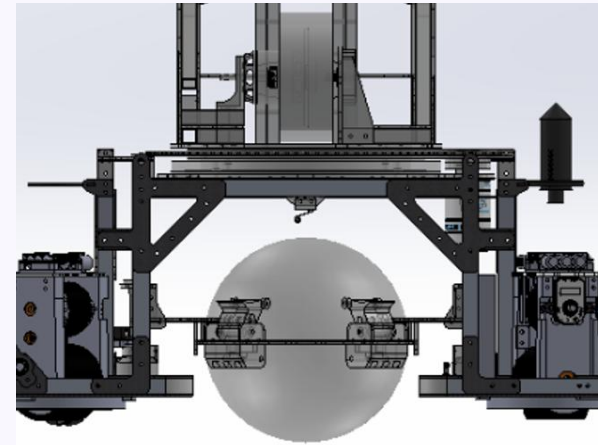
Mech – Gen0 R1 Flywheel Loaders

Elevator loading mechanism

- Hollowed platform with four spring-powered "flaps" lowers to pick up ball in A2, powered by 2x T-motor MN4014 (KV400) motors connected to lead screws
- Platform descends below center of ball, pushing flaps upwards until they retract, next time platform rises flaps will carry ball upwards into shooter

LIMITATIONS (Reasons for design abandonment)

- Bending of wheelbase causes lead screws to point inwards, strain on motor jams platform before ball is transferred to shooter
- Speed of platform movement very slow due to lead screw strain and its "gear ratio" (1:12)
- Minimum position of platform not low enough to position flaps below A2 ball



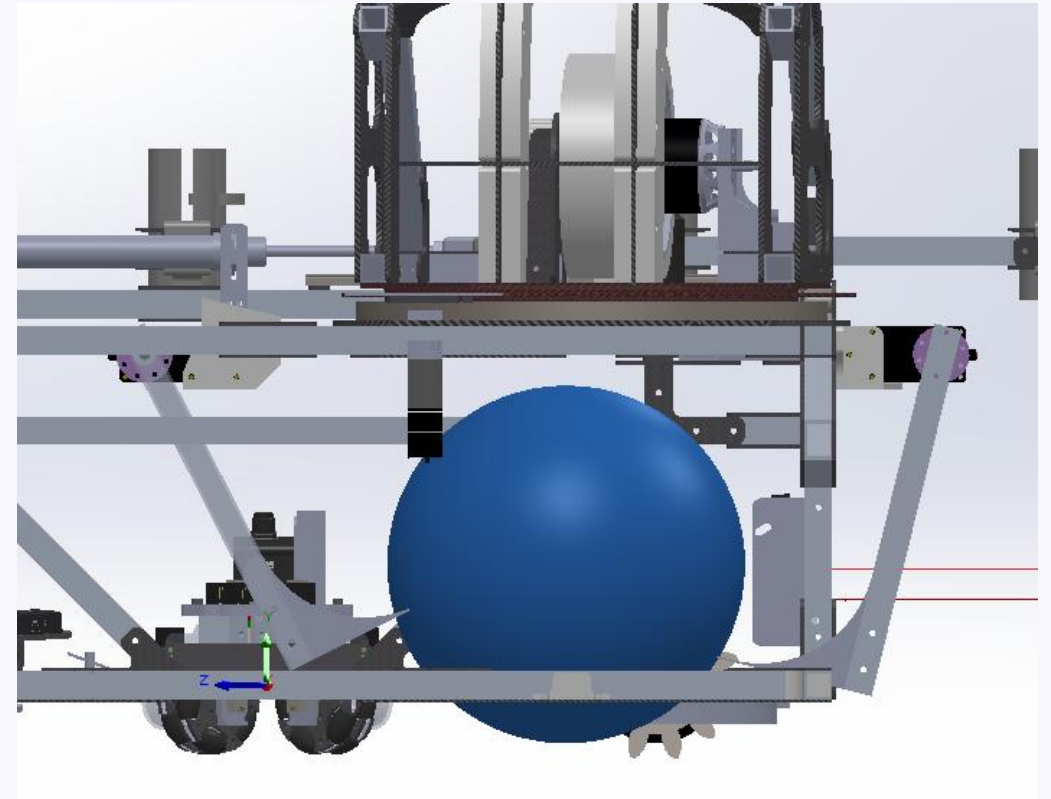
Mech – Gen0 R1 Flywheel Loader -> Replacement

Servo "shovel" mechanism

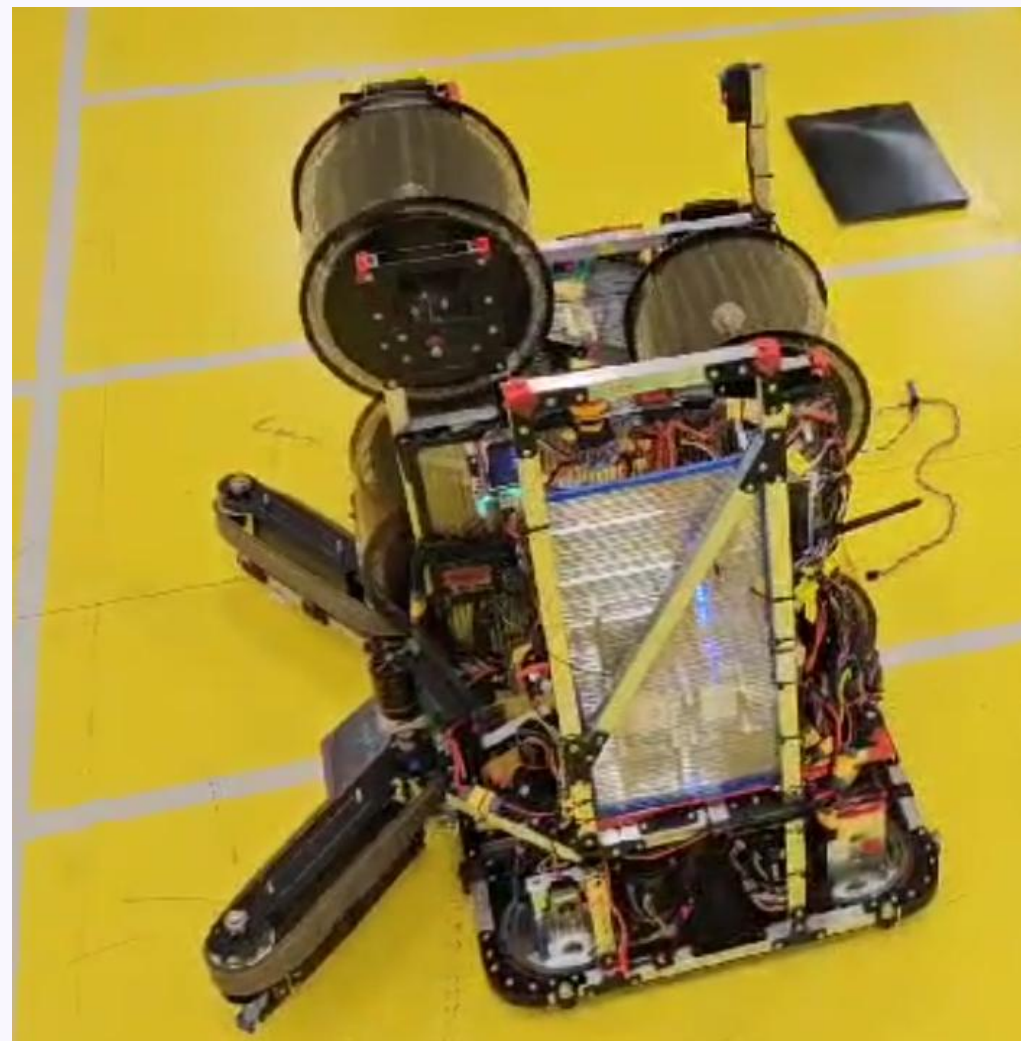
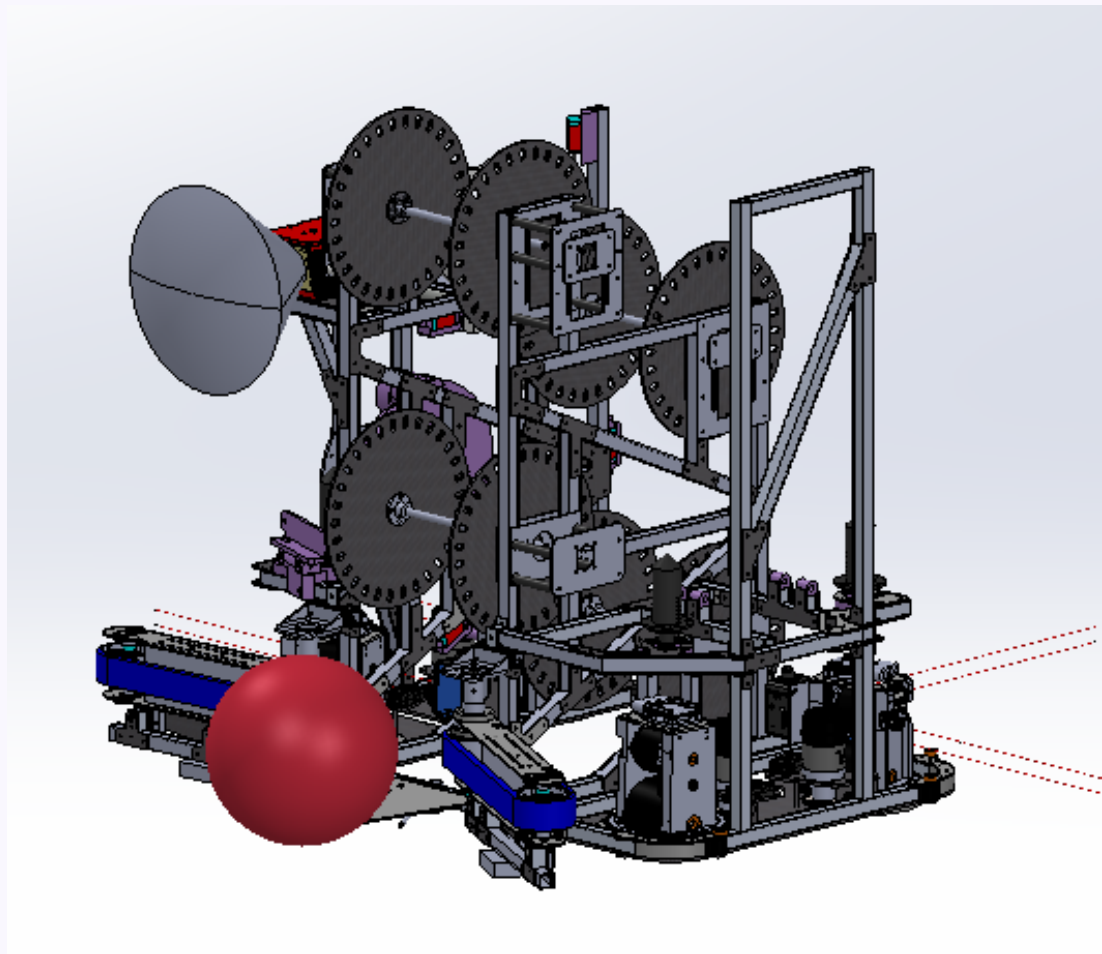
- We decided to transition to "scooping" the A2 ball using two 60kg servo-powered arms
- First arm (shallow slope) -> scoop underneath A2 ball and push ball upwards, Second arm -> serve as upwards guide for A2 ball

ADVANTAGES

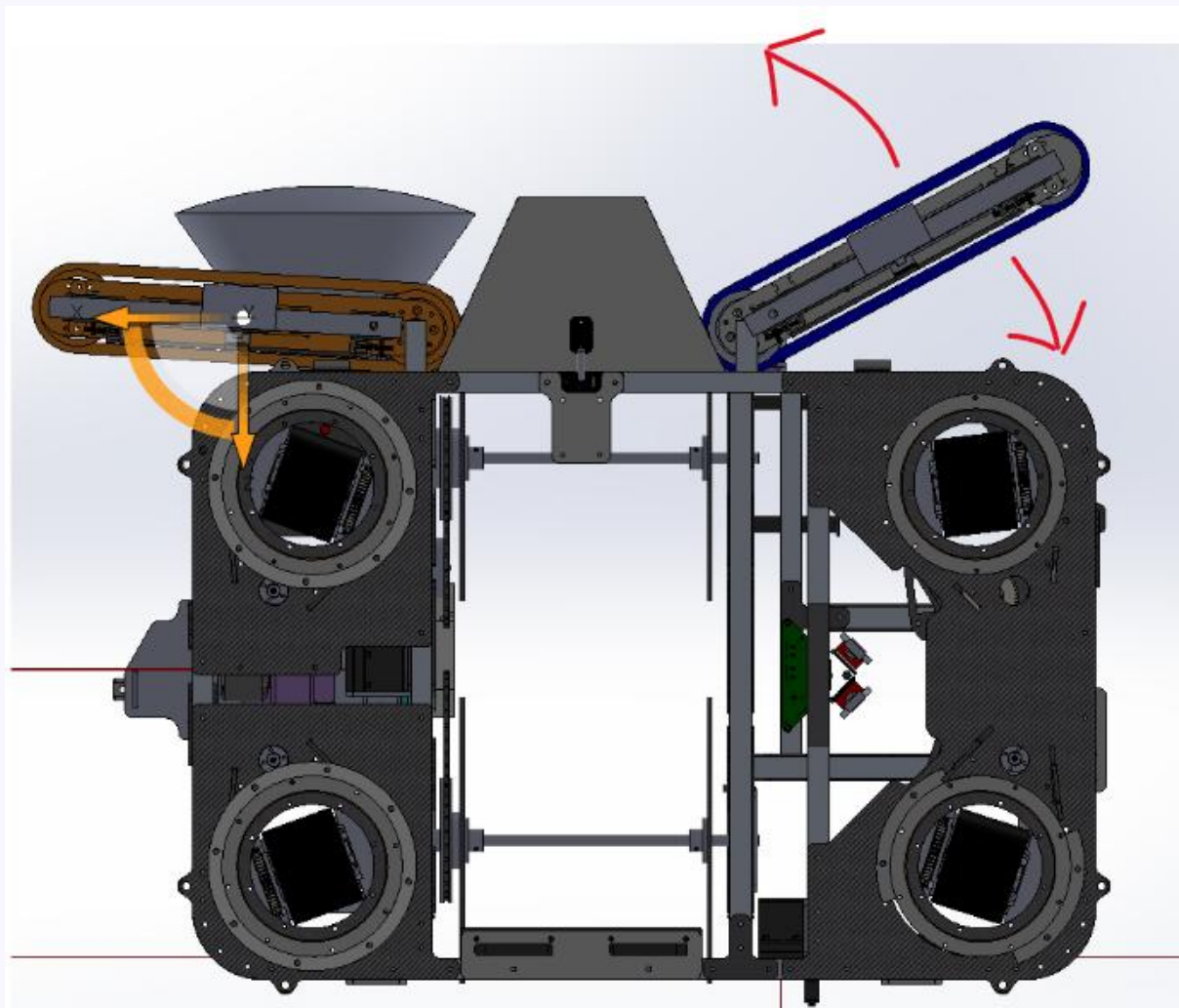
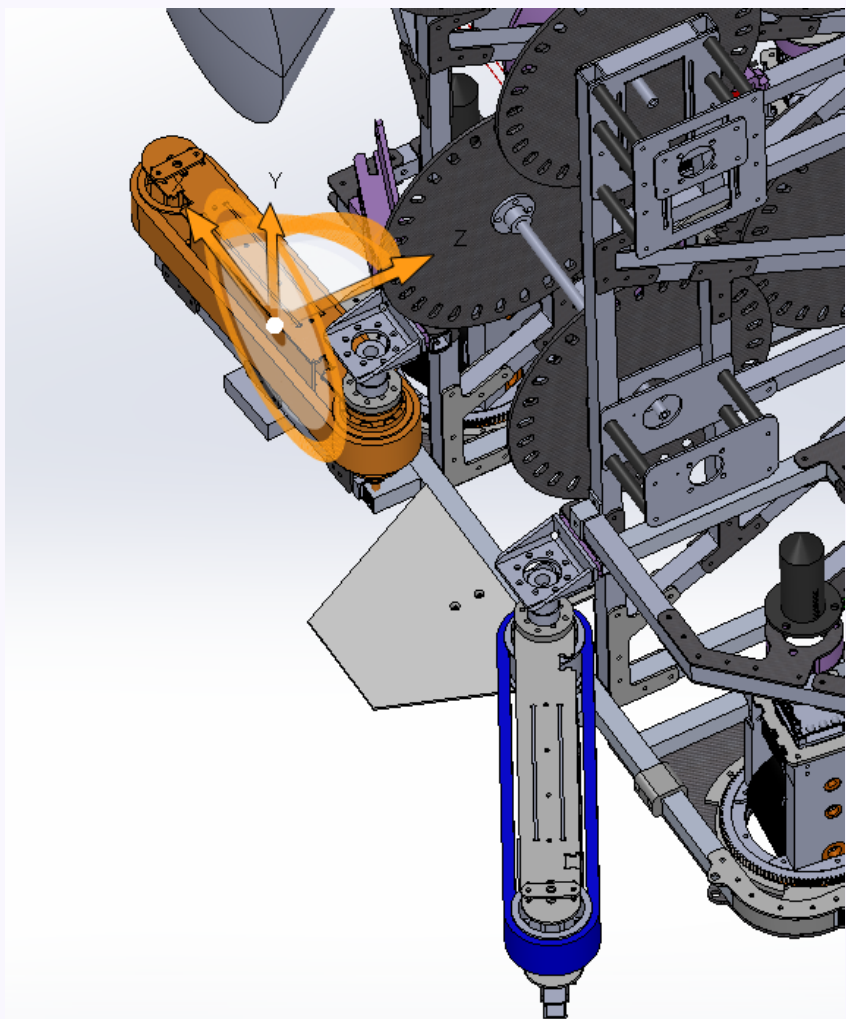
- Not affected by potential bending of tunnel wheelbase -> servo loader mounted on center tunnel connectors instead of independent steering plates
- Servo motion much quicker than lead screw-powered elevator, full loading/shooting sequence reduced to 1-2 seconds



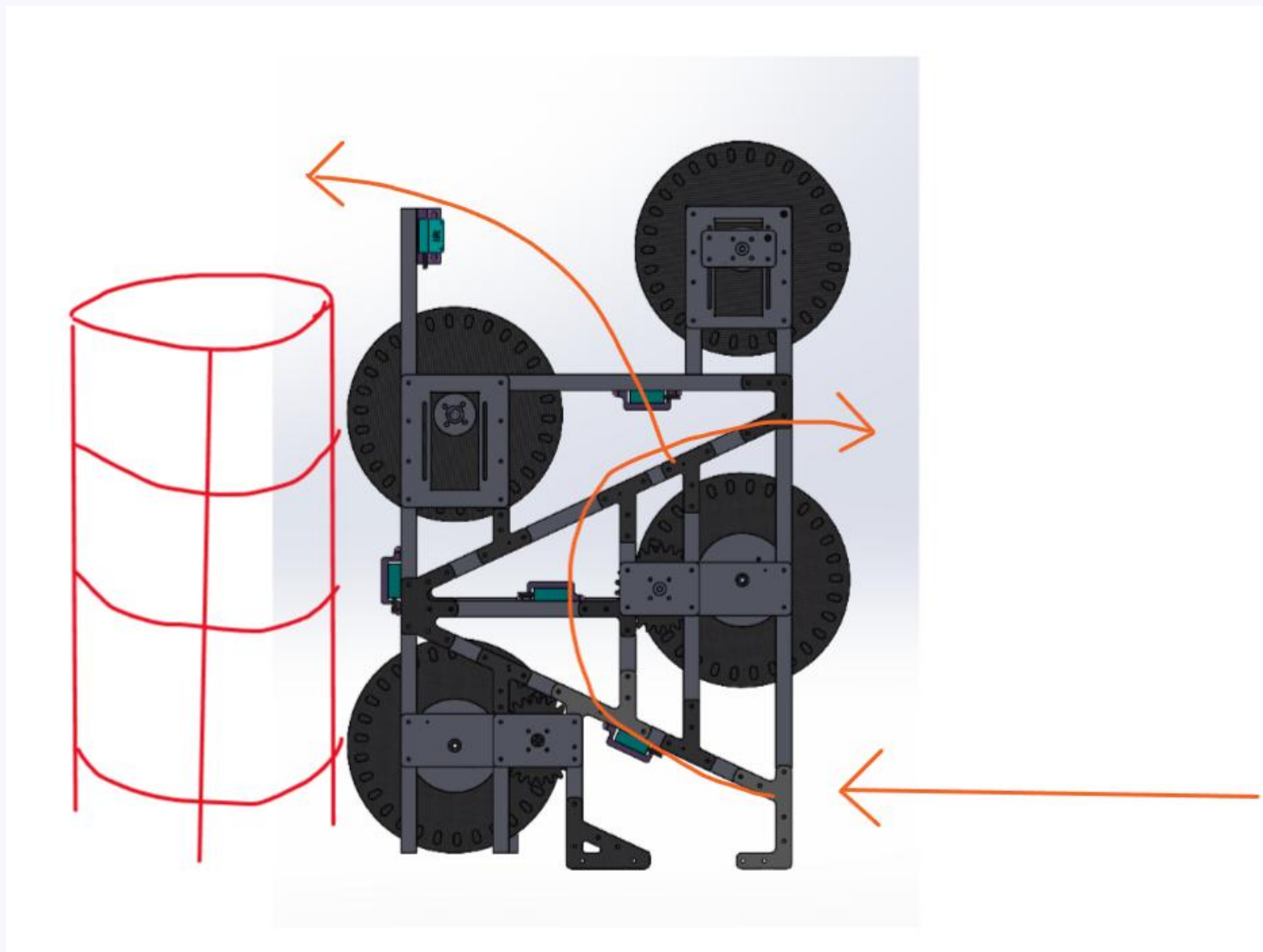
Mechanical – Rubber Band Roller R2



Mechanical – Rubber Band Roller R2

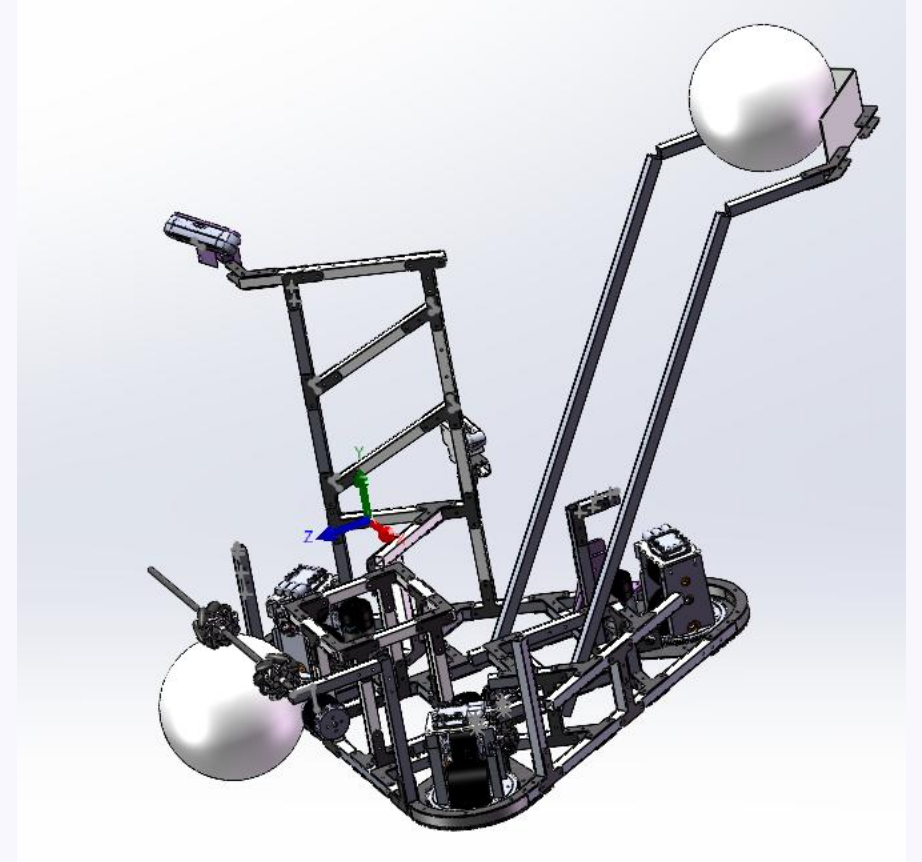


Mechanical – Rubber Band Roller R2



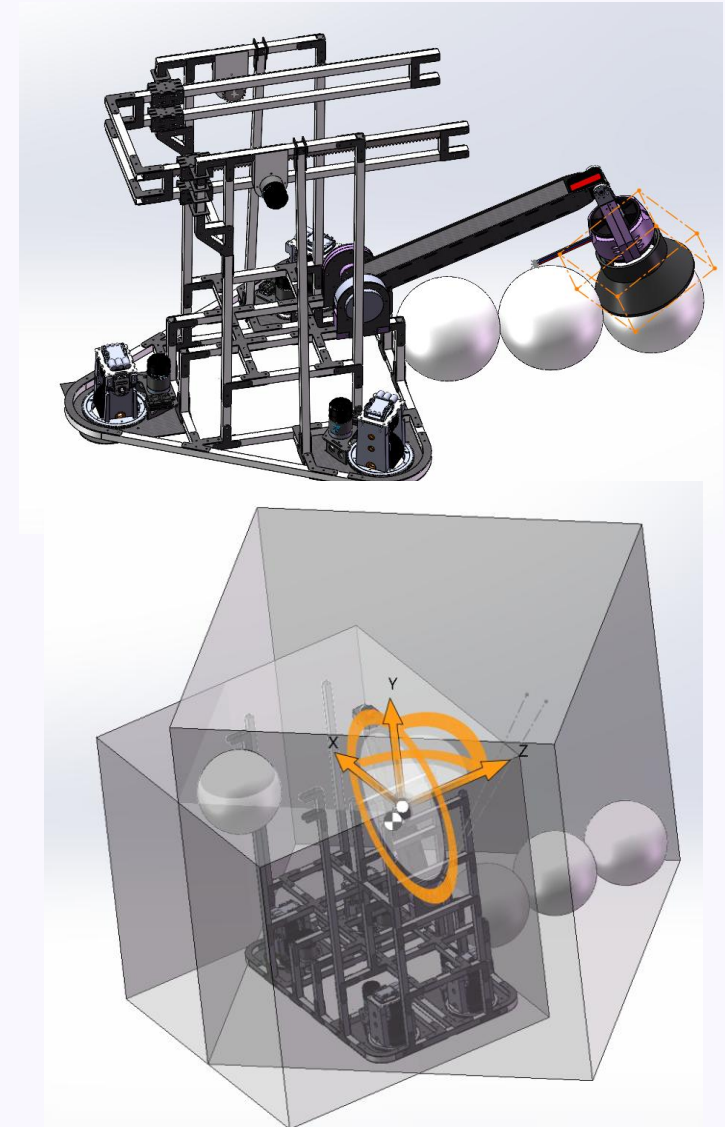
Mech – Robotics arm R2

- Testing platform use to test multiple prototypes
- It was converted from a robot that is built in winter training, it originally use a 4 DOF arm, and change to catapult arm.
- Possible to end game in late April
- Robotics arm able to catch ball which is 400mm away that is 3 balls
- It use a triangular wheel base, there are structure on it to lift the camera
- It was used to test mechanical damper, 3 suction.



Mech – Robotics arm R2 ver 2

- May solve some shaking structure problem on Robotics arm R2
- Add defence
- End because seniors think the camera shaking problem can't be solve





Winter training & winter prototypes

Mech – Electro-ducted fan suction cup

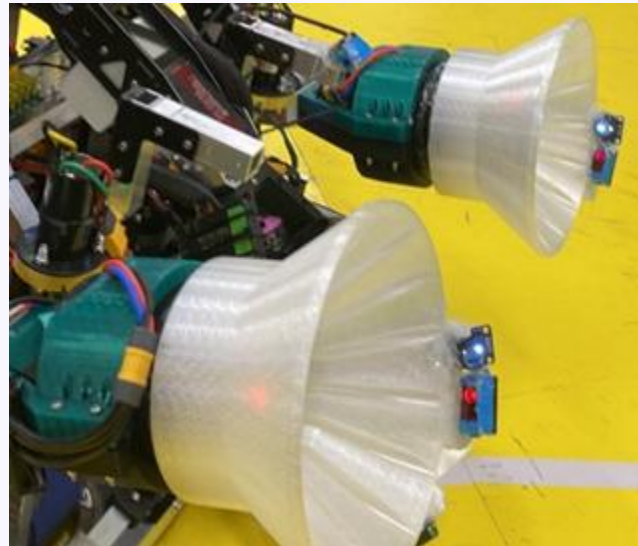
First prototype

- TPU 3d-printed cup
- Trenches to maintain least air flow rate though EDF
- Conical shape to fit the ball



On Gen1 R2

- Mounting for the sensors
- Modified angle of conical surface & volume of negative pressure chamber

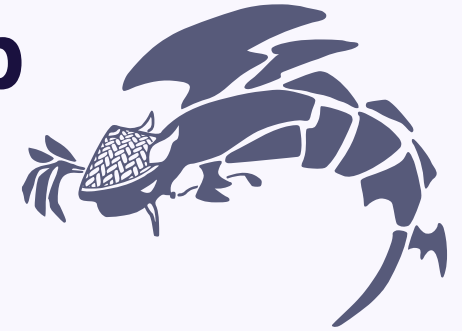


On Gen2 R2

- Fuzzy skin feature
- Modified sensor mount
- Less infill density to allow more deformation



Mech – R2 Electro-ducted fan suction cup



Pros

- Attractive force (non-contact)
 - Reduced robot dimension
 - Increased tolerance
 - Less disruption on the gamefield settings
- Stable loading
 - Balls are hard to fall from the suction cup

Cons

- Attractive force
 - Efficiency of loading affected by friction coefficients
- Noise pollution
- Great current & power requirement

Mech – R1 Belt Shooter

Purpose:

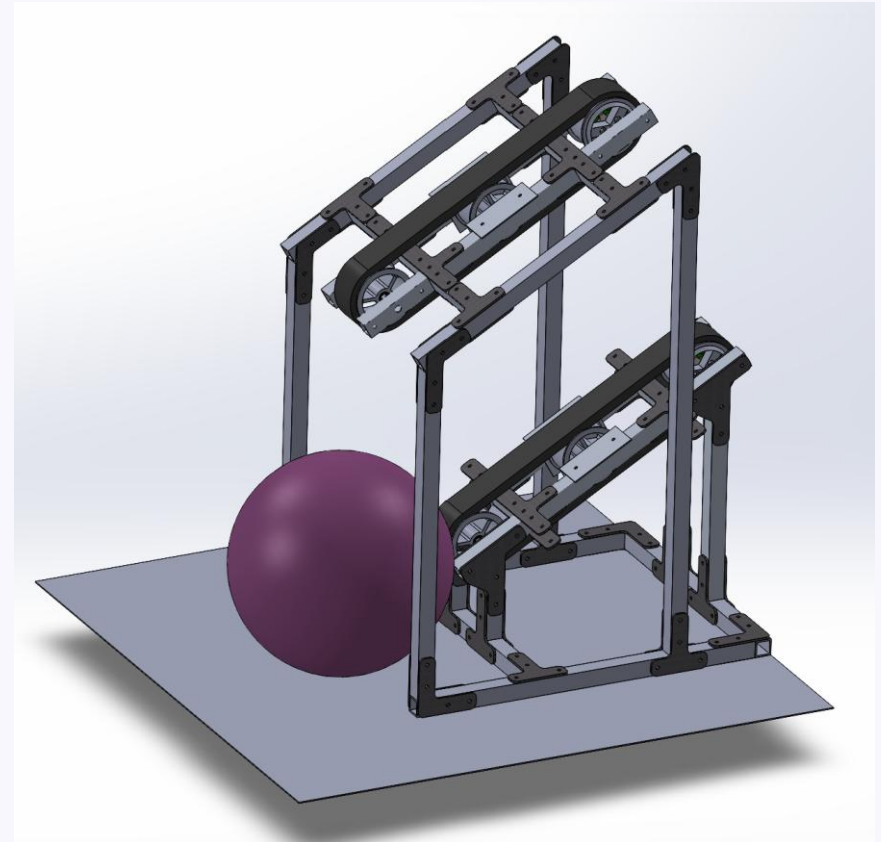
- Shoot the ball from area 2 to area 3 accurately
- Relatively stop the ball at the landing position when it enters area 3

Methodology:

- Adjusting the velocities of the belts to give the ball a backspin
i.e. the upper belt is faster

Results:

- Could shoot the balls accurately and consistently
- Could give the ball backspin and stop it at the landing position



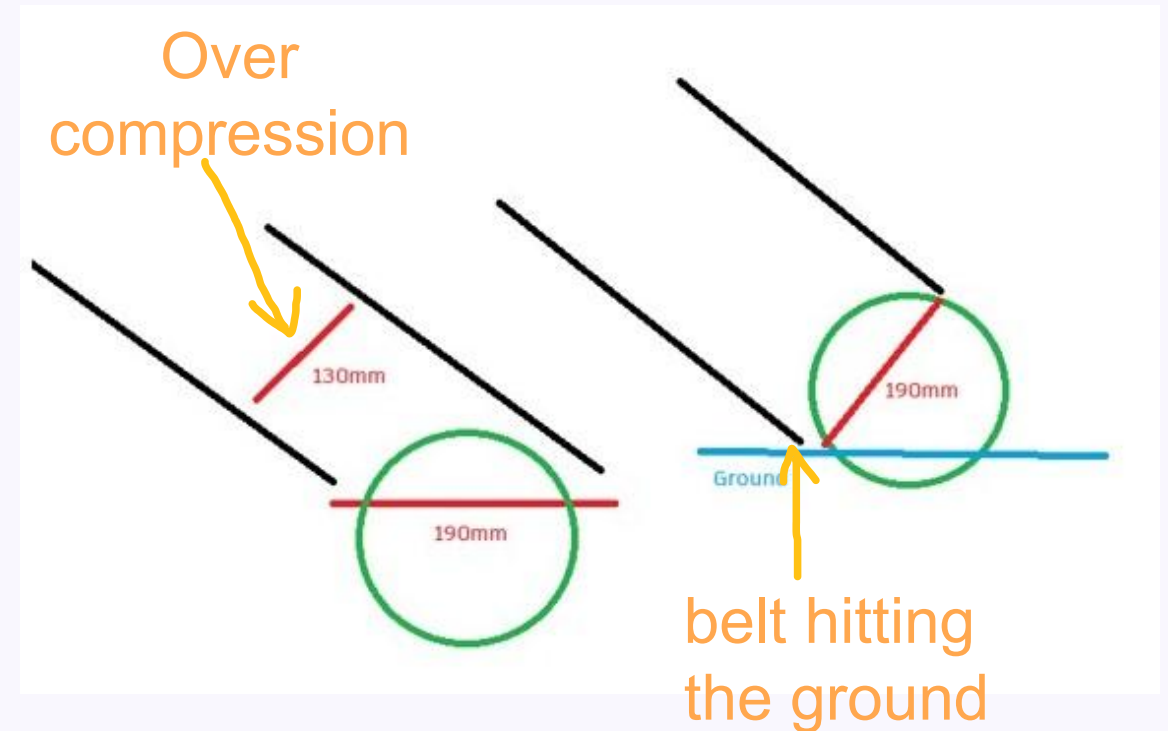
Mech – R1 Belt Shooter

Pros:

- Could shoot the balls accurately and consistently
- Could give the ball backspin and stop it at the landing position

Cons:

- The compression to the ball is difficult to adjust
- The tension of the belts is difficult to tune
- Can't utilize the main function of belt i.e. constant power transmission along its parallel direction



Mech – roller loader

Purpose:

load a ball to the robot quickly

Methodology:

Roller drive by AT4130

Results:

Can load ball in a short time when the roller touches the ball, need to aim the ball by turning and moving the wheelbase

Can load ball in both area 2 and area 3

End because there are macanum loader which is better



Mech – R1 loader

Purpose:

- Grab balls from holes and then hold it vertically and cooperate with kicker to kick balls to area3

Methodology:

Grab balls from hole using a cylinder and hold it vertically with four bearings, lifted by rm motor.

Once the ball was held in place, a kicker behind the loader would kick the ball out.

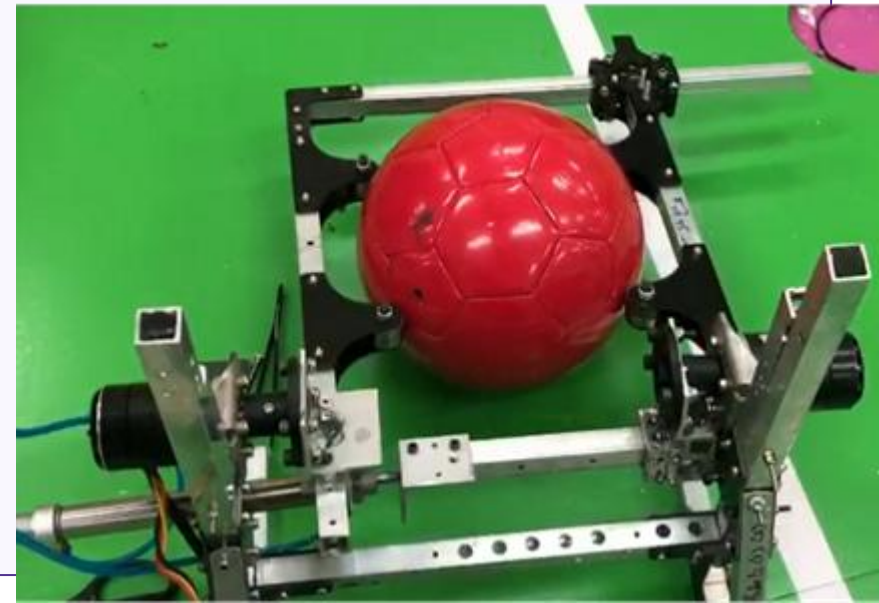
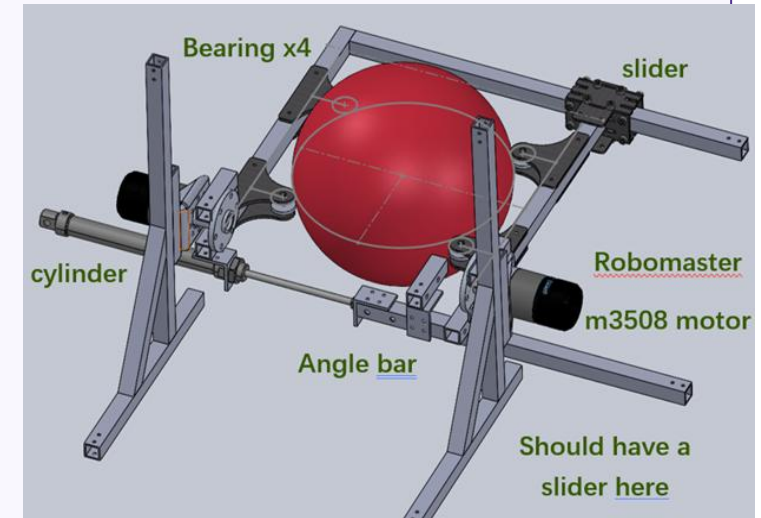
Result:

Overall success

weak point:. The motor and slider were mounted on an angle bar, which became easily bent after lifting the ball several times

But solvable

And need more cooperate with kicker



Mech – R1 Kicker

Purpose:

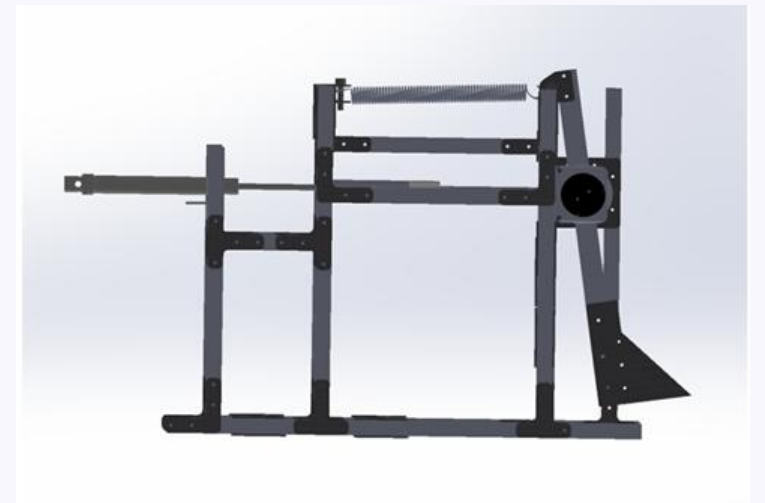
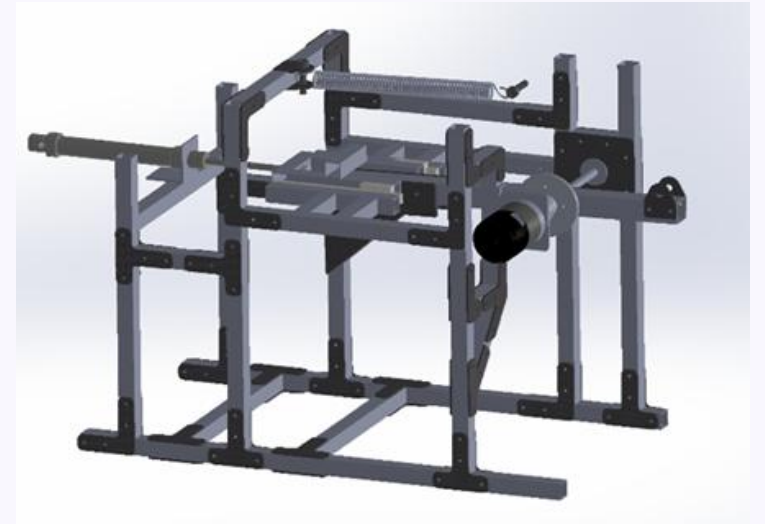
- Efficiently pass ball from A2 to A3

Methodology:

- Driven by RM M3508 Motor and extension spring
- Motor turns, extending the spring, kicker moves inwards
- Kicker is held in fixed position before releasing

Results:

- Discontinued, cannot reach target storage zone
- Stored elastic energy is being absorbed and dissipated by the motor
- Motor will be damaged



Mech – R2 Catapult

Purpose:

- Accurately shoot the balls into the 5 silos
- Enable efficient scoring without the robot moving from storage to silo zone



Methodology:

- Driven by AK80 Cheetah Motor
- Holder maintain ball in fixed position



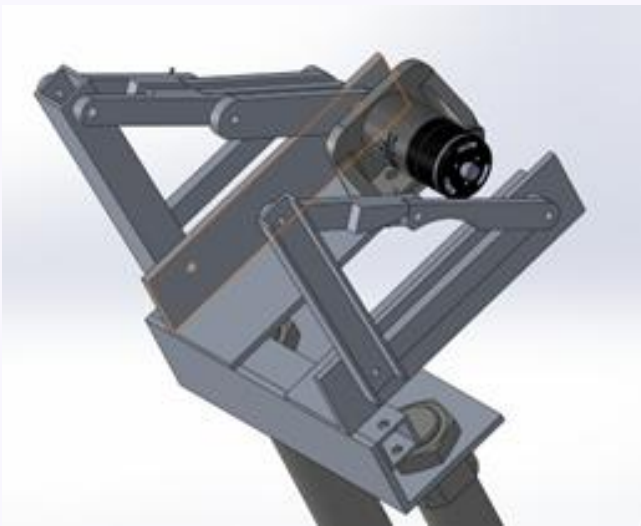
Results:

- Discontinued
- Has < 5% success rate
- Structural instability
- Low clearance between ball and inner diameter of silo
- No way to score the third ball

Mech – R2 Absolute defense shield

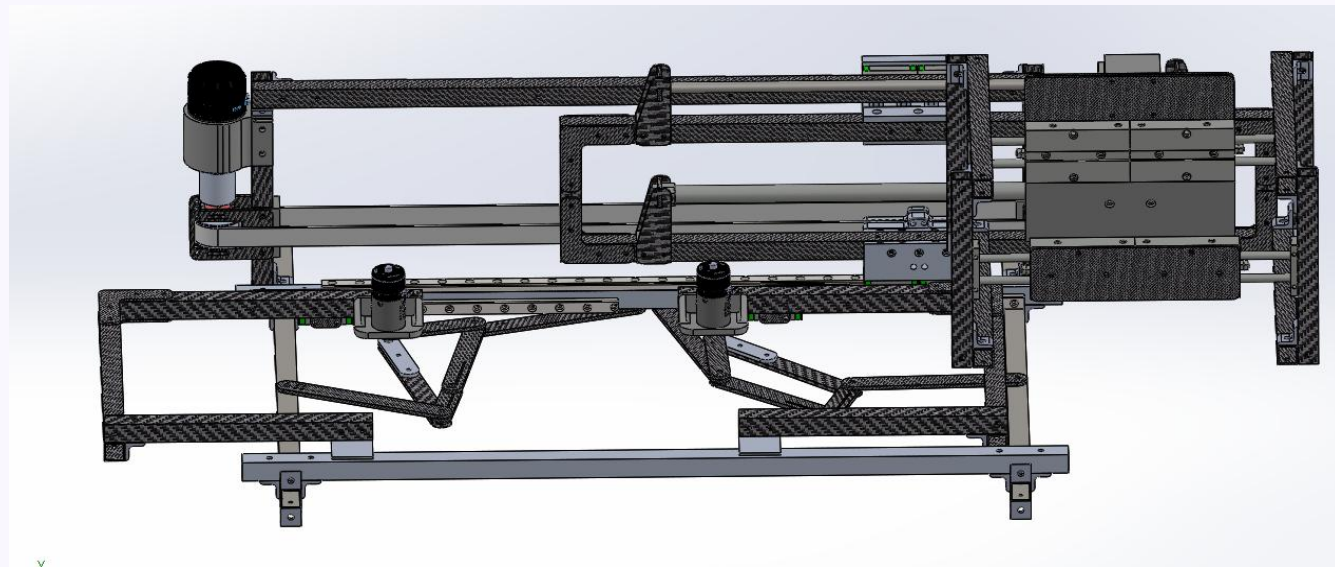
First prototype

- Extendable shield
- Four-bar linkage
- Dead lock



On Gen1 R2

- Six-bar linkage with dead lock
- Reaching two silo at once
- Loading ball at the bottom



Mech – motor damper

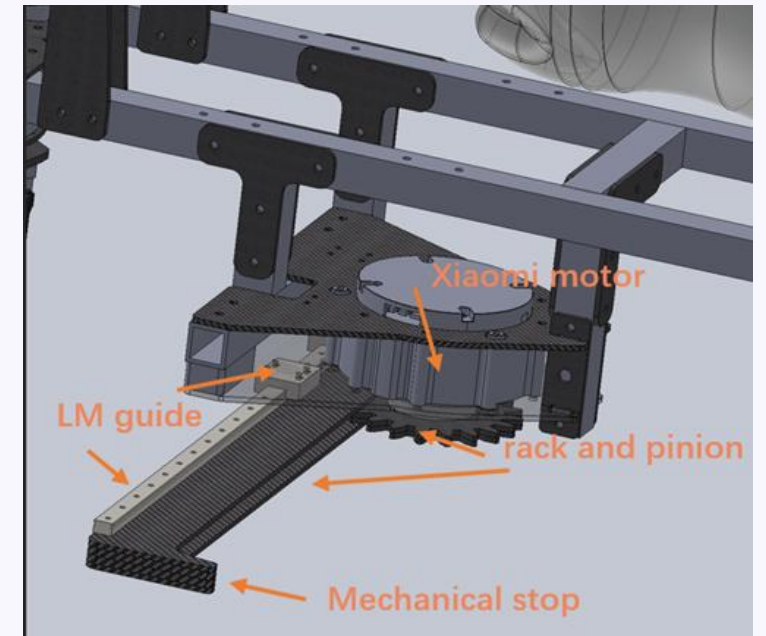
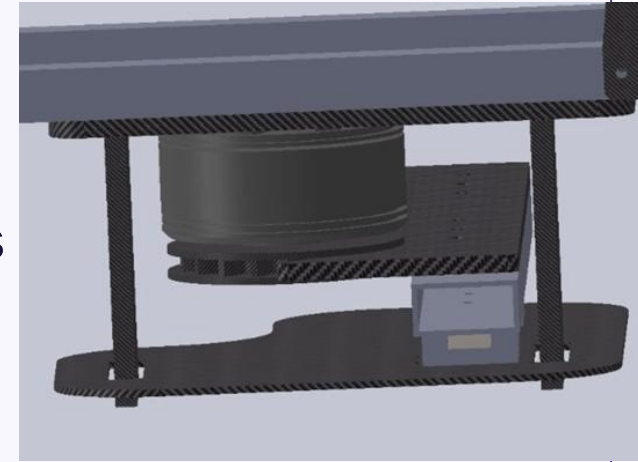
Purpose:

- use motor to reduce the speed of the robot and stop it eventually so as to maximize the deceleration

Result:

Fail:

- Driven by Sunny sky T motor (high RPM and less torque)
- Later use Xiaomi motor test (torque up to 12Nm and built in encoder)



Mech – Motor Damper 2

Purpose:

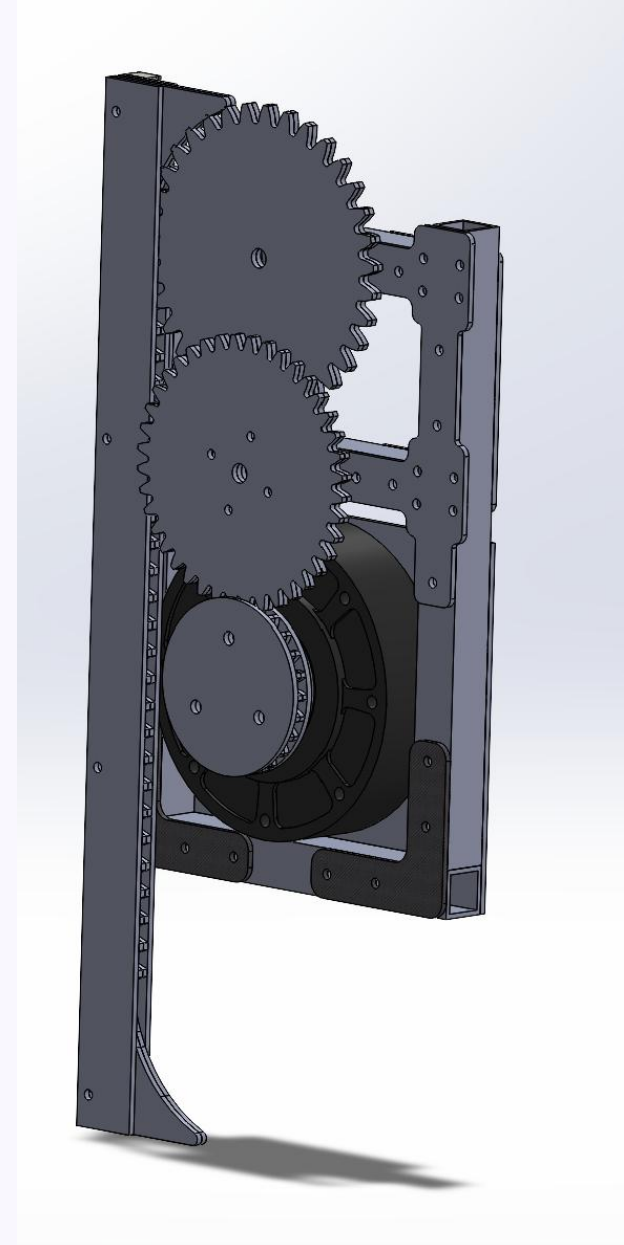
- Stop a 25kg robot when it is moving with 5m/s

Methodology:

- Driven by AK80 Cheetah Motor
- Gear ratio: 1:4
- Actively counter the force reacted and then gradually decrease the force output

Result:

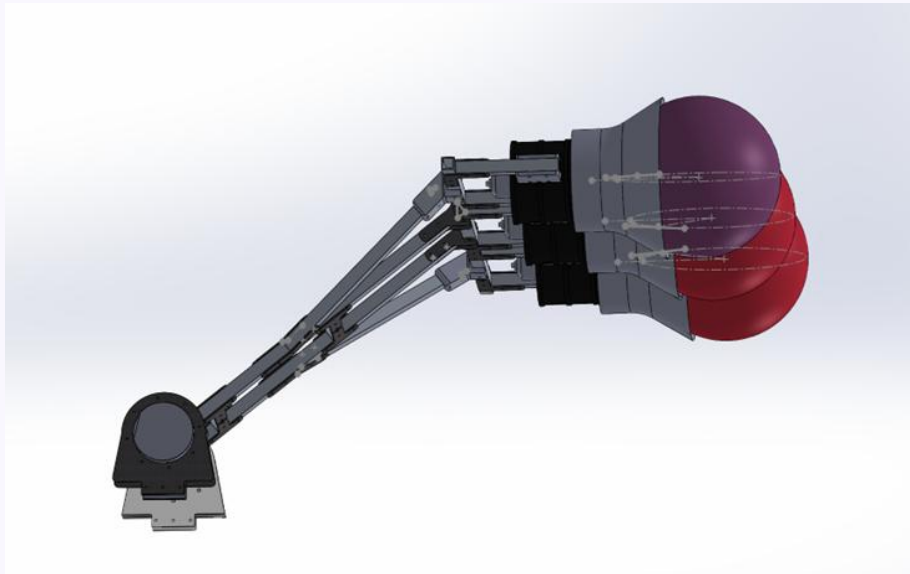
- Banned according to seniors' advices/current technology:
 - The motor may exceed its rotation limit after the ratio change
 - The motor may be damaged



Mech – Three suction arm

Purpose:

- ✓ Try using three suction cup arm instead of one suction cup arm.
- ✓ Able to sort ball using the three suction cups.



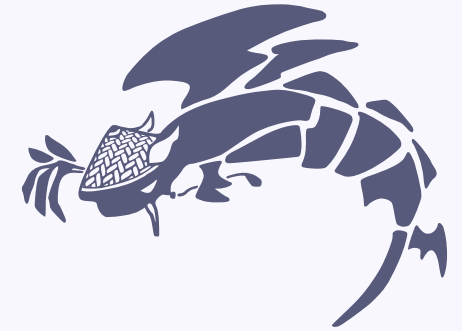
Methodology:

- ✓ Using 3 edf fan and 3 suction cup
- ✓ Lifting by a AK80 motor
- ✓ Load the ball if it is a paddy rice, close the edf and release the ball if it is empty grain

Result:

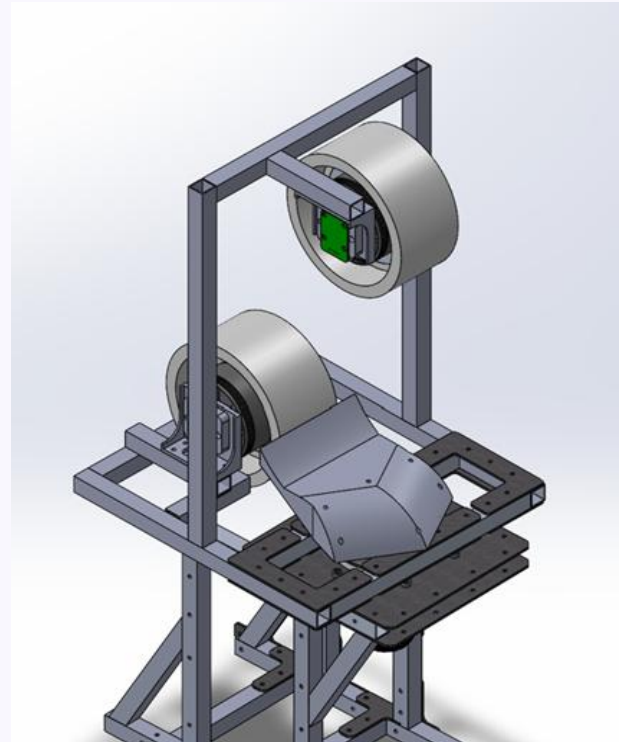
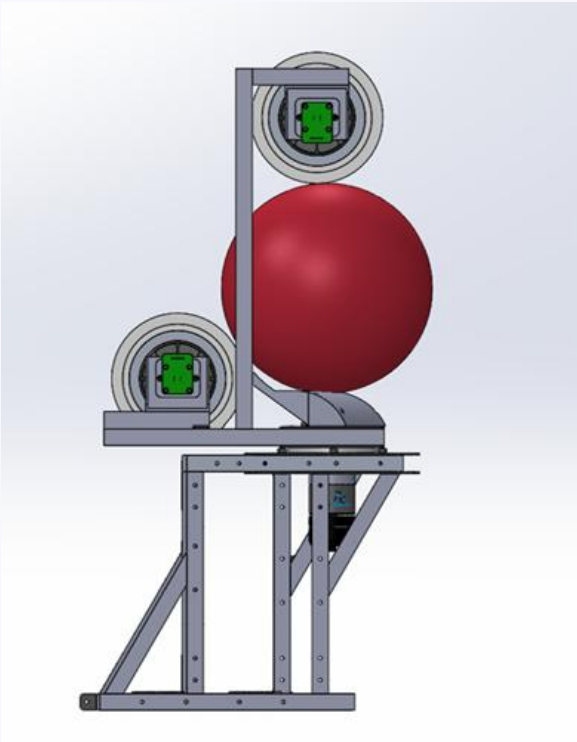
- ✓ not able to lift up by a AK80 because the whole arm is too heavy.
- ✓ Basically success to do the sorting process.

Mech – R1 Suction 2nd Row Flywheel



Purpose:

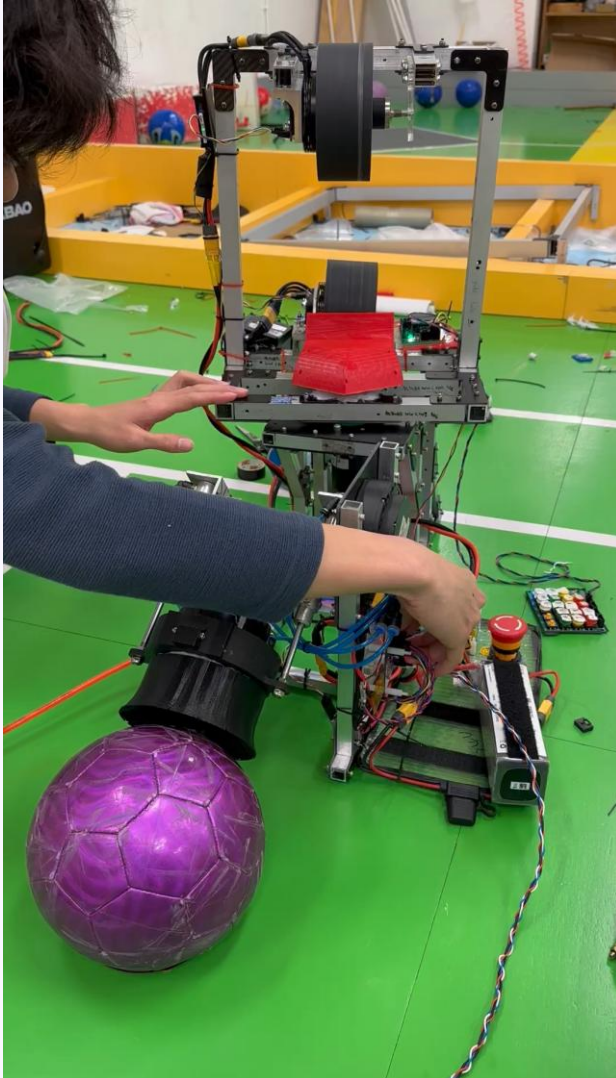
- Transfer the second row of balls from A2 to A3 without interfering the first-row flywheel



First Prototype:

- 2 PU 120mm flywheels (AT4130) placed at 45 degrees with each other
- Guide made of PLA
- Yaw (RM M3508) beneath the flywheels
- Balls load from back by suction cup, compressive and rotational force ejects ball out of shooter

Mech – R1 Suction 2nd Row Flywheel



Pros:

- **Great range** --> Able to shoot to A3
- **Tunable backspin** --> RPM of flywheels can be tuned to control the final position of the ball.
- **Efficient** --> Takes less than 2 sec to load and shoot the ball, does not interfere with the 1st row shooter

Cons:

- Huge power required for EDF
- Contributes to weight
- Yaw interfere with tunnel

Used in FD R1

Mechanical – 2nd Row Foldable Flywheel Shooter

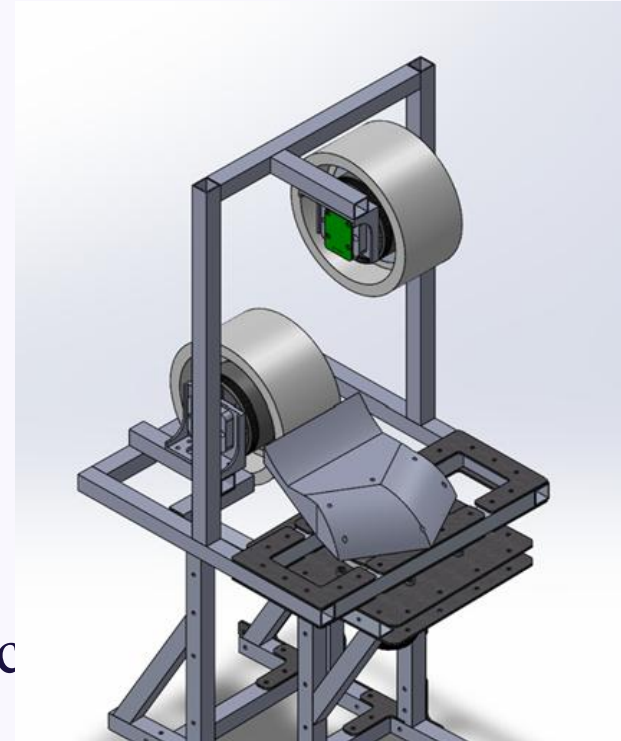
Compact.

Yaw Axis Tunable.

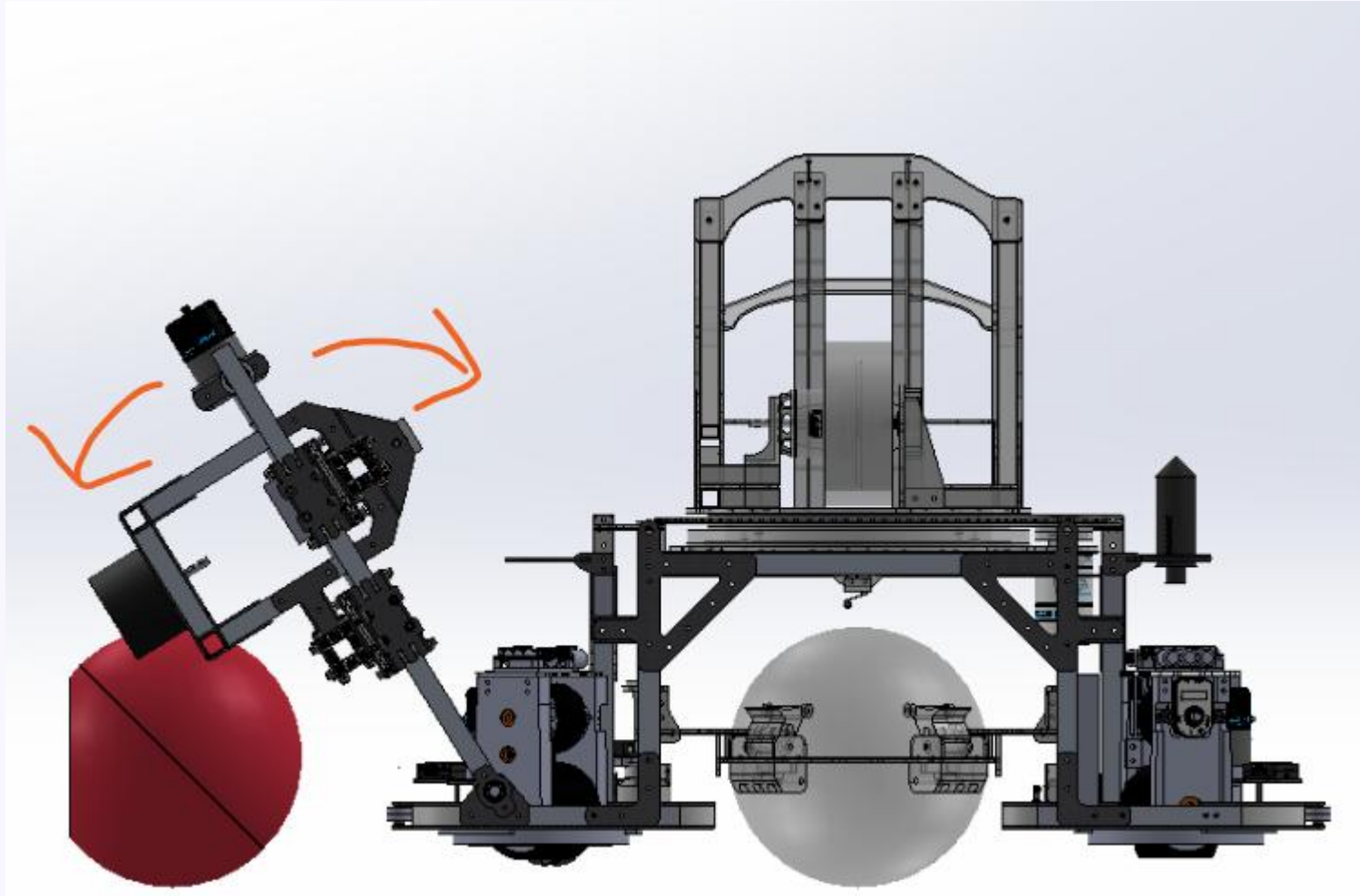
Feasible.

Efficient.

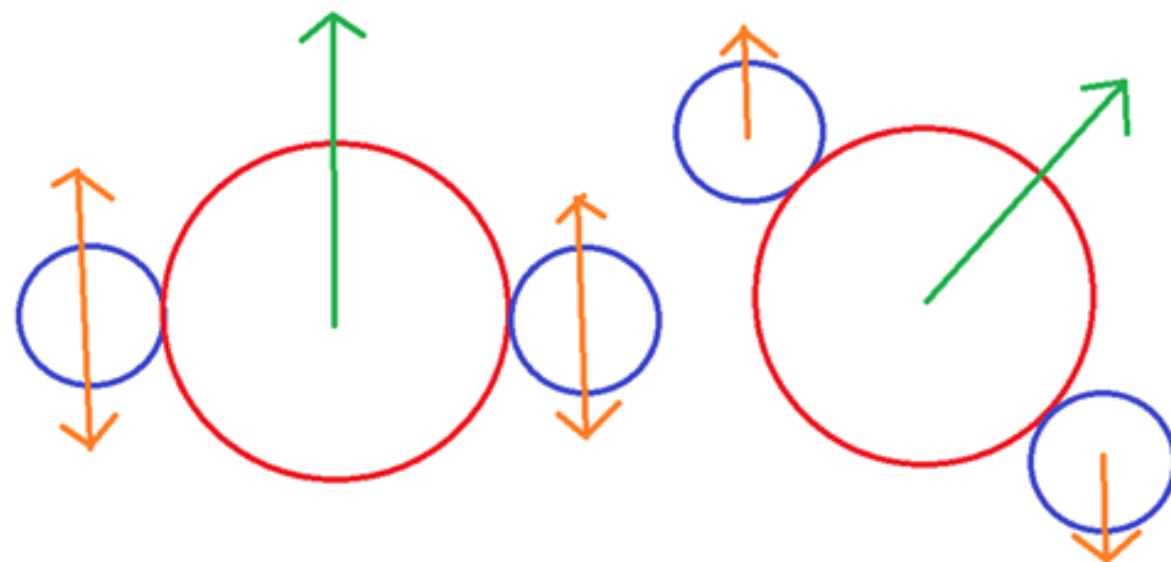
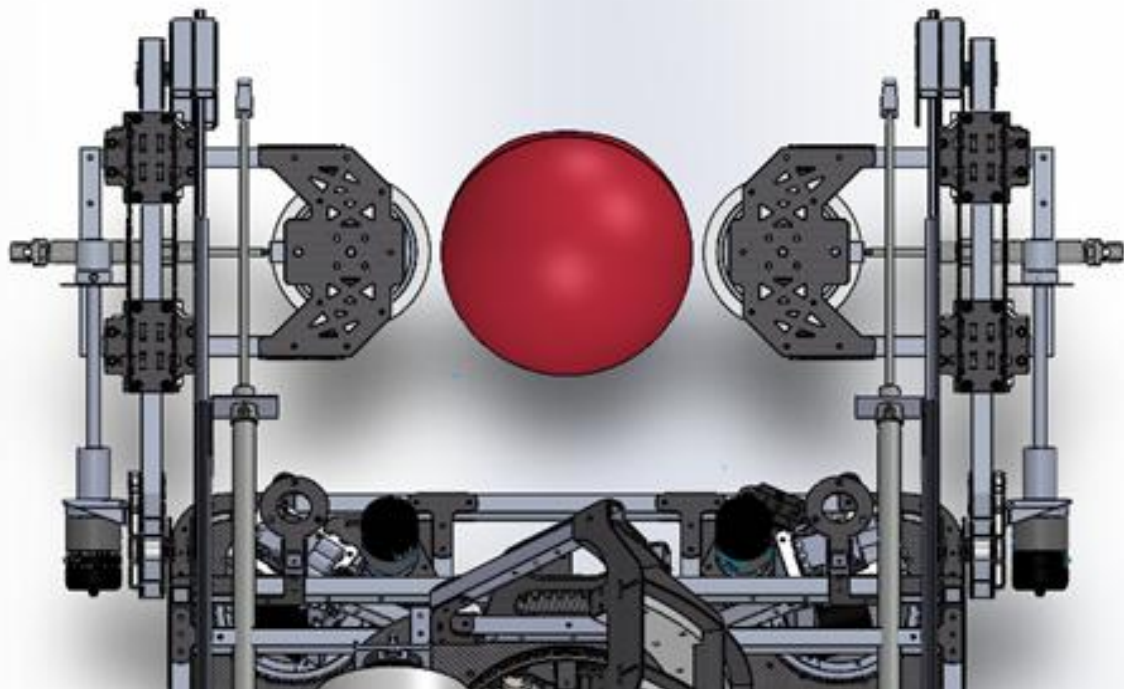
Compact is the main consideration. Weight and ac concerns.



Mechanical – 2nd Row Foldable Flywheel Shooter



Mechanical – 2nd Row Foldable Flywheel Shooter



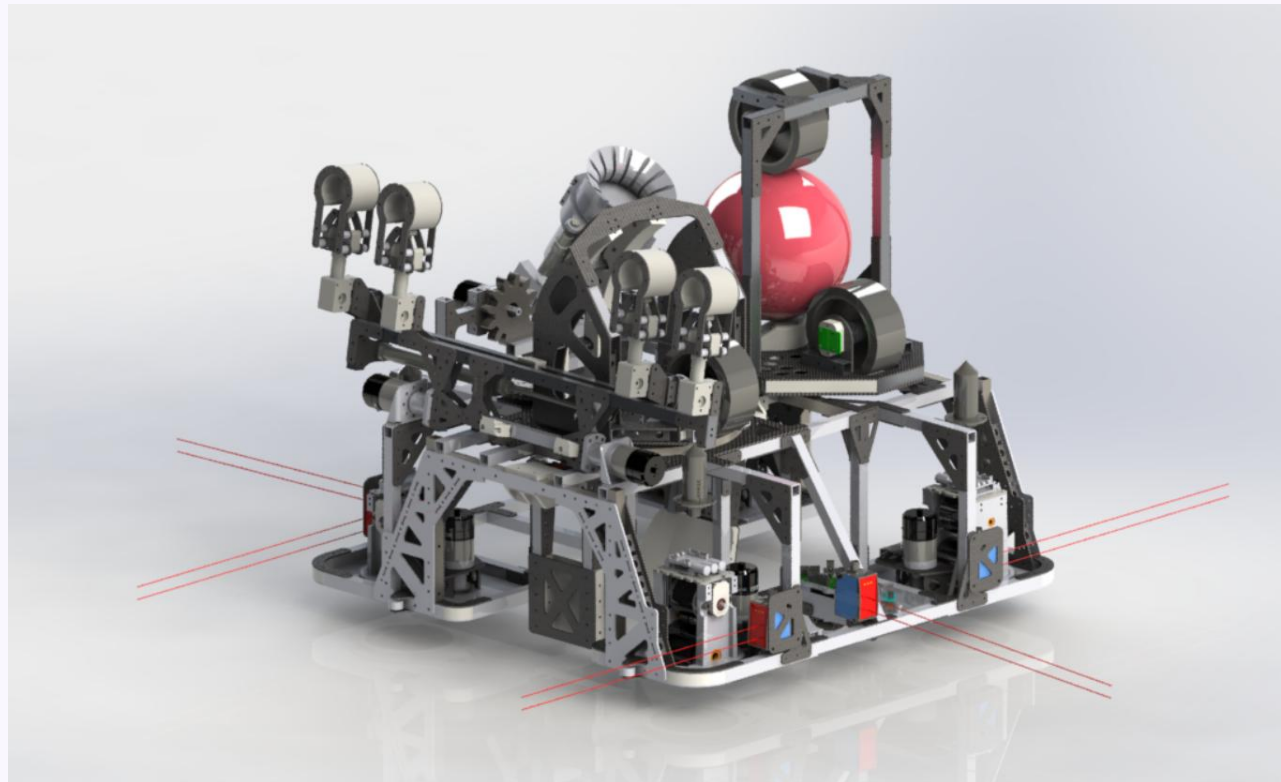
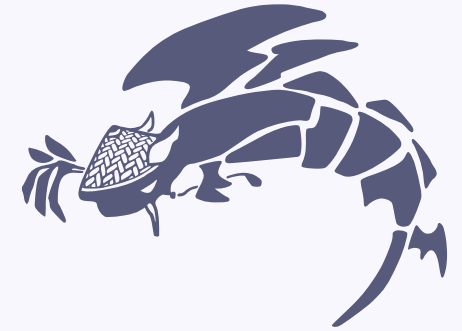


Fiery Dragon

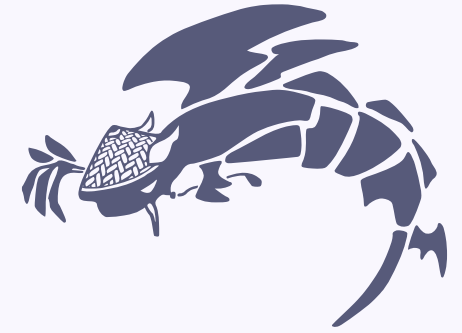
**Gen1
robots**

Mech – FD R1

- Development of R1 with two independently-operated shooters, each shooter dedicated to front or back row of A2 paddy rice/empty grain
- Purpose: R1 can access all 12 balls in A2 and shoot them in any order through only one linear movement



Mech – FD R1 Seedling Gripper



Gripping Part

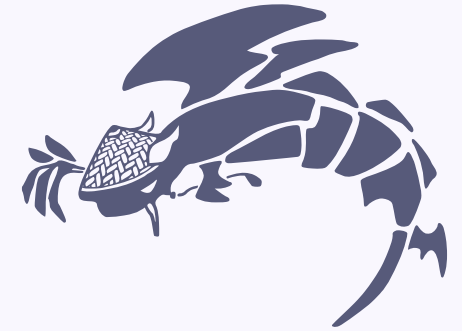
- Objective: Can grip the seedling firmly
- Methodology: Use cylinder to control the gripping motion
- Pros:
 1. Gripping I/O can finish within 0.1 sec
- Cons:
 1. Limited no. of I/O operate

Suspension Hinge Part

- Objective: Allow R1 to drag the seedling out from the rack without fully lift up
- Methodology: Using a 3dp hinge and spring to achieve suspension function
- Pros:
 1. Passive return to the position after drag the seedling out
 2. designed weak point to prevent gripping part damaging

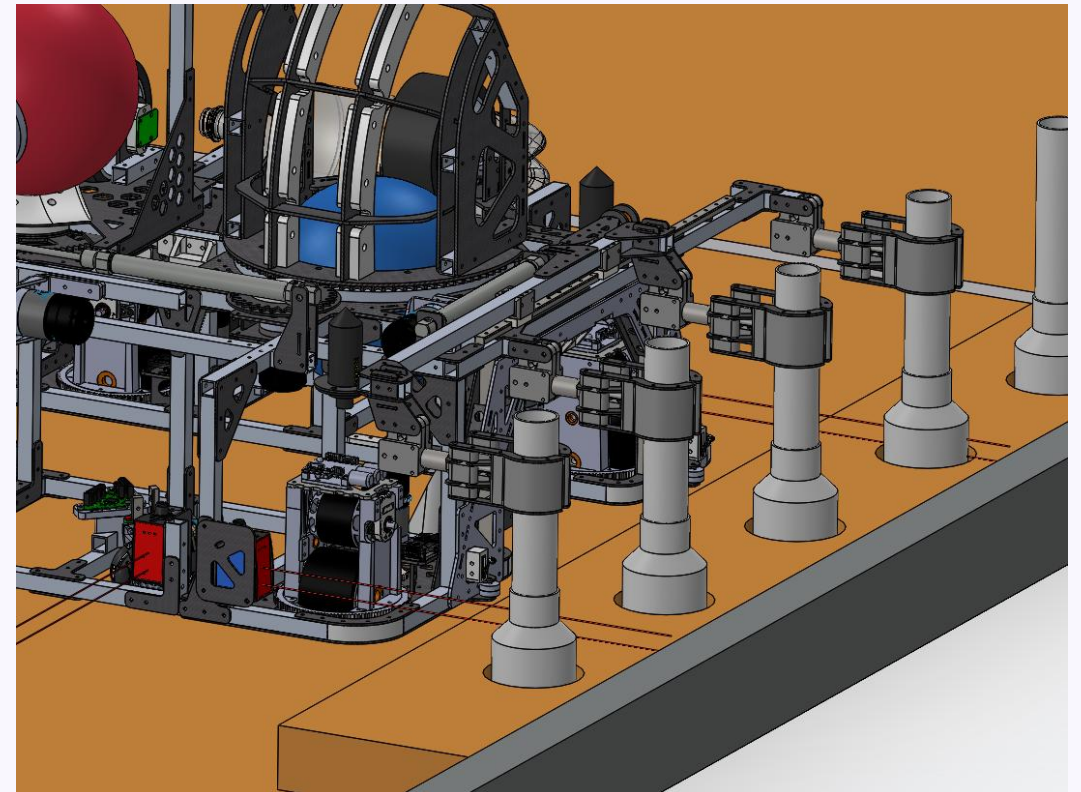


Mech – FD R1 Seedling Gripper

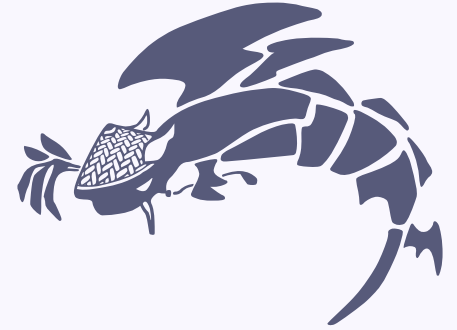


Seedling rack rotational movement and extension

- Uses 1x RM 3508 (1:71) motor to rotate seedling gripper upwards (stowed -> initial starting position)
- Rotational movement connected using bearing/shaft coupler
- R1 releases two seedlings per planting cycle, two sets of grippers 500mm apart are connected to each other
- Second set of grippers are extendable, retracts during starting position/planting seedlings, extends when grabbing seedlings



Mech – R1 Tunnel Wheelbase

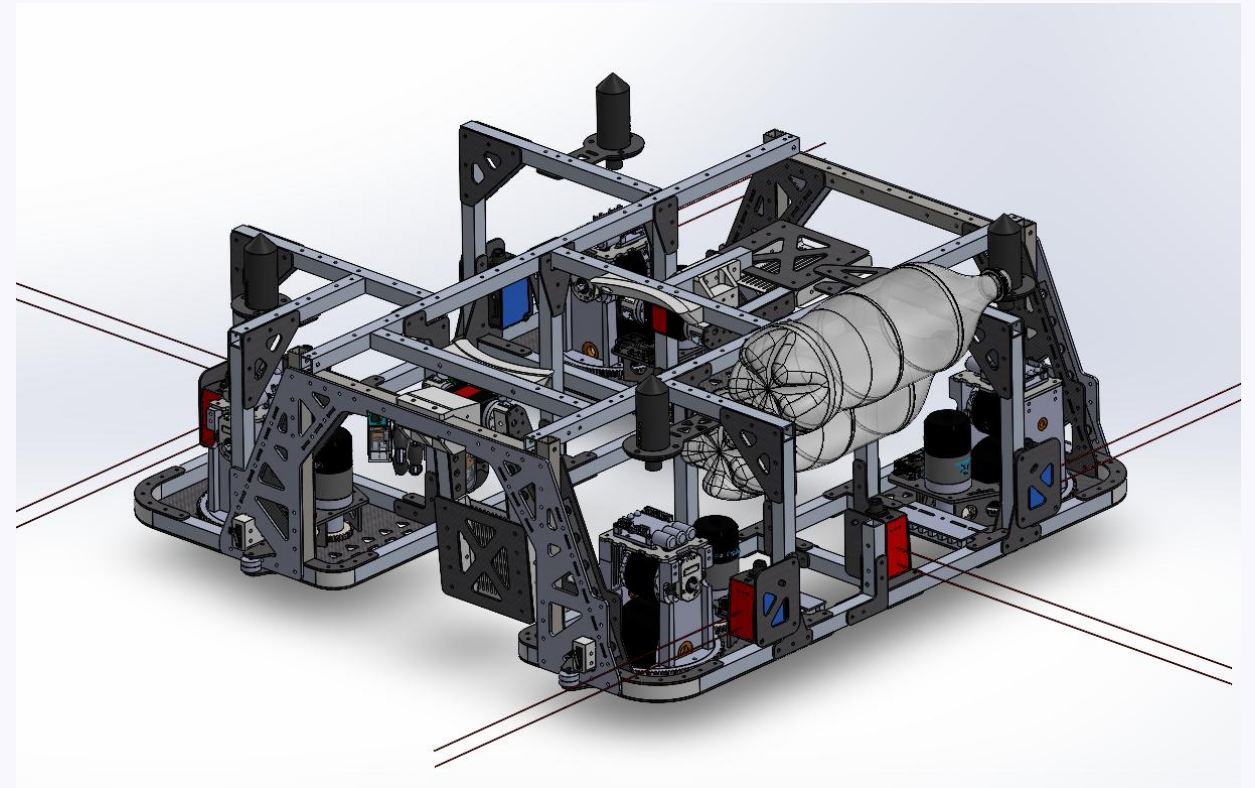


Improvements -> Reinforce + optimize structure

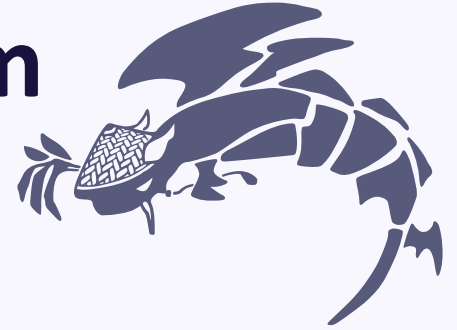
- Added 6 vertical tubes between tunnel and inner wheelbase structure
- Added diagonal “truss” structures at each end of tunnel, direct linkage between horizontal tubes of wheelbase
- Added 4 additional support structures connecting tunnel with outer wheelbase tubes

LIMITATIONS:

- FD Gen1 R1 wheelbase mitigated bending force, but grossly overweight
- R1 still difficult to drive above first row, and suction fan is too close to 2nd row, frequently contacting



Mech – R1 1st row shooting Mechanism

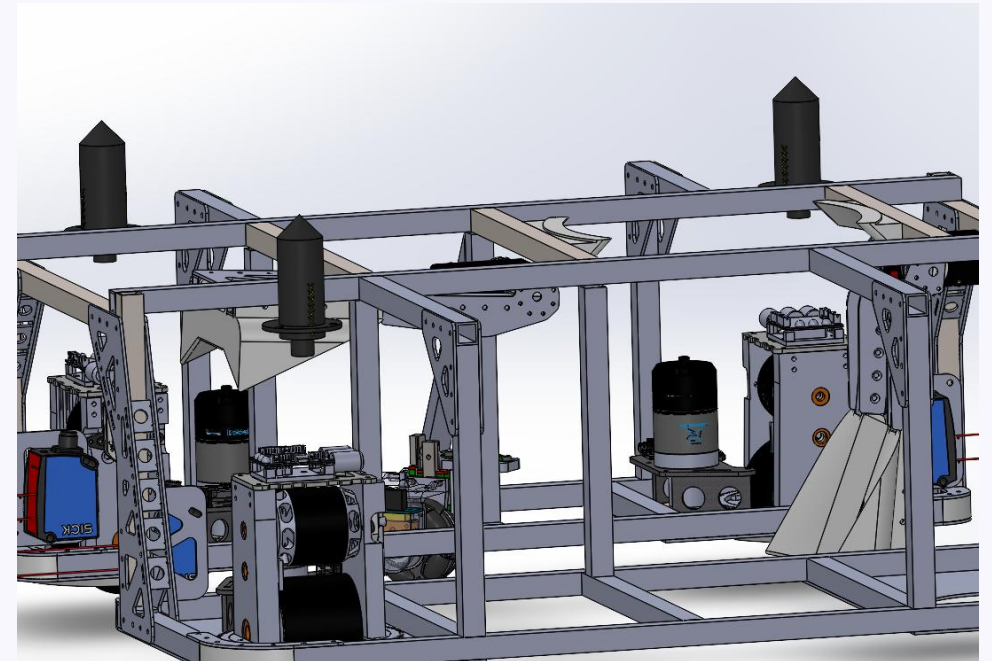


Improvements - Servo Loader

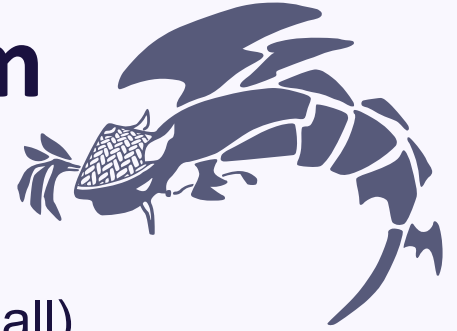
- 2-shovel servo loader -> one shovel functions as guide for other shovel to scoop and push ball upwards
- Flattened servo guides to maximize clearance of tunnel (steeper slope)
- Increased height of tunnel by 15mm, adds clearance for A2 ball when shovel loader in stowed (upwards) position

LIMITATIONS:

- Ball still gets compressed/stuck during loading (distance between shovels too small)
- Thick region at bottom of shovel could still get jammed by ball when driving over A2 grid



Mech – R1 1st row shooting Mechanism

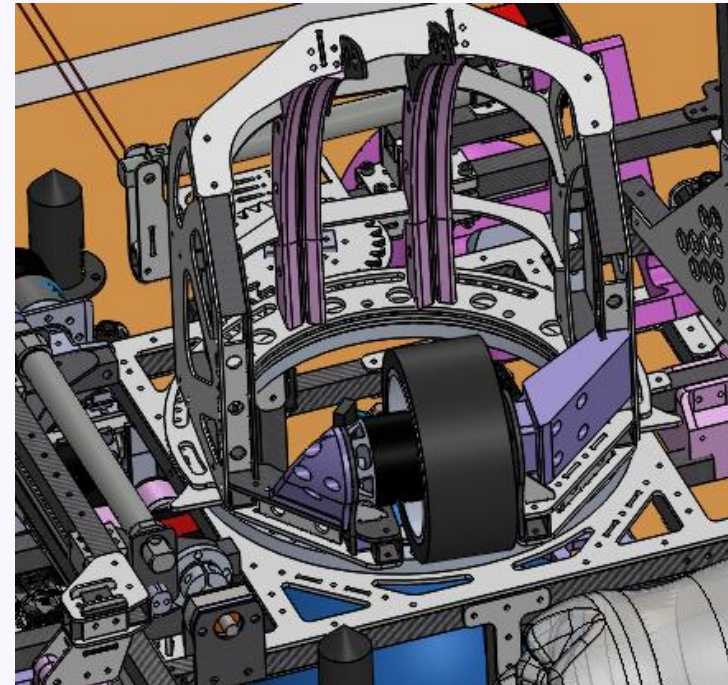


Improvements - Single flywheel w/ hood

- Reduced overall footprint of flywheel -> Smaller flywheel base plate, flywheel frame part size reduced,
- Yaw gear changed to 1:3, faster movement of shooting yaw angle positioning
- Reduced weight -> decreased number of aluminum tubes, slimmed size of ball shooting guide, removed some structural reinforcement of motor mount

Issues

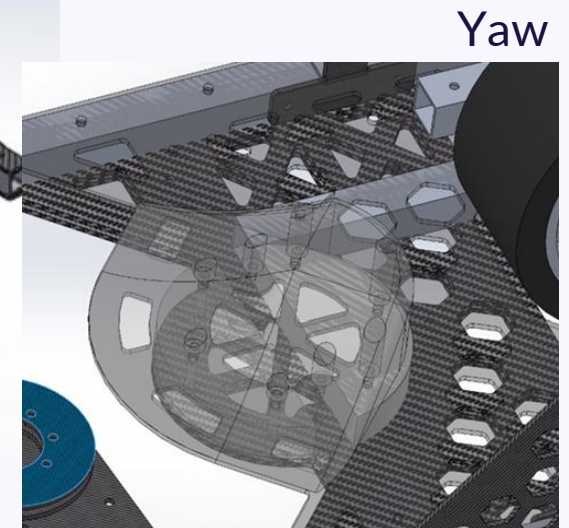
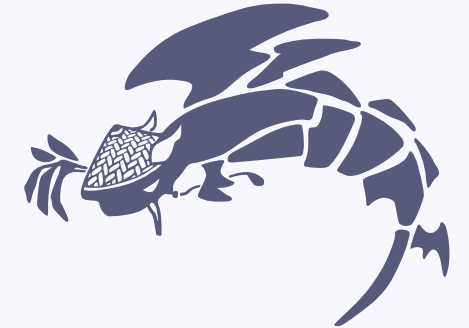
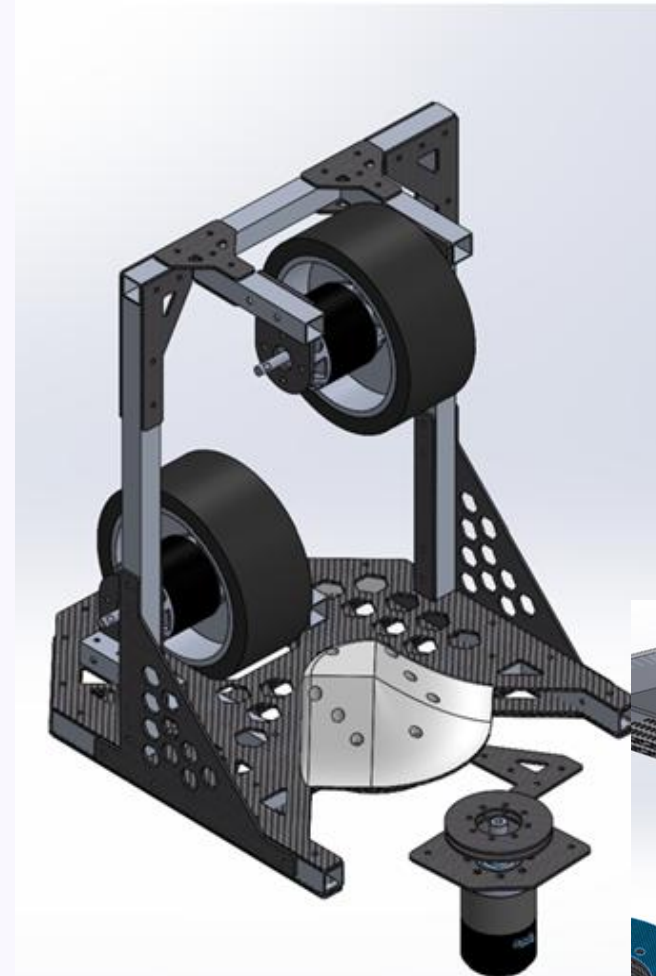
- Change of game prop (ball) hardness overstress and crack motor mount structure



Mech – R1 2nd row shooting Mechanism

Improvements from prototype:

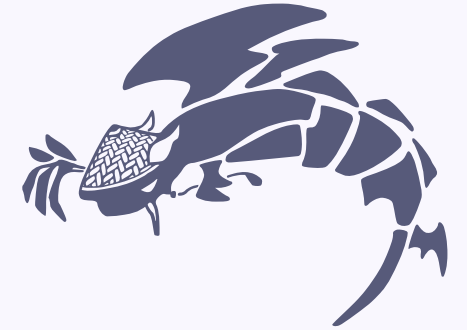
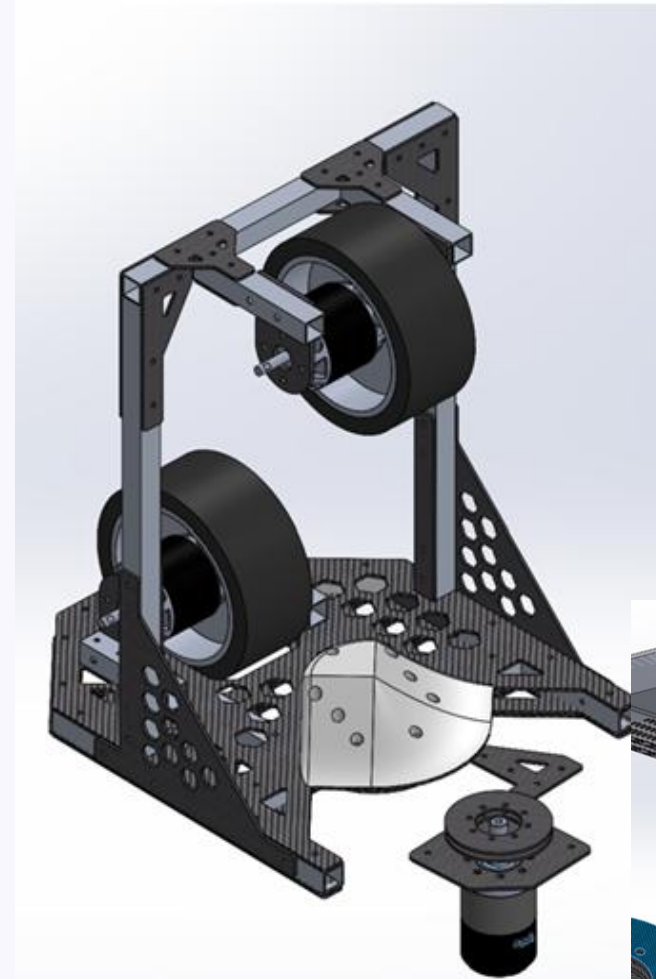
- **Weight Reduction** --> simplified structure
- Better **slope** design
- **Yaw Positioning** --> motor mounted on wheelbase outside of tunnel
- **Yaw** --> cross roller bearing and spur gear
- **Mechanical stop** --> +/-45 degrees of rotation, allowing the balls to reach red and blue field w/o interfering with the first row shooter



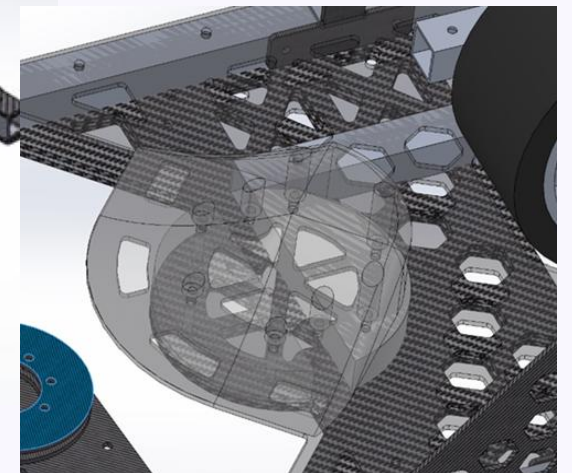
Mech – R1 2nd row shooting Mechanism

Problems found:

- Contributes to a lot of weight
- **Unstable structure** --> tilts left and right
- Hardness of balls changed --> **compression** needs to be retuned
- Complicated installation of yaw



Yaw



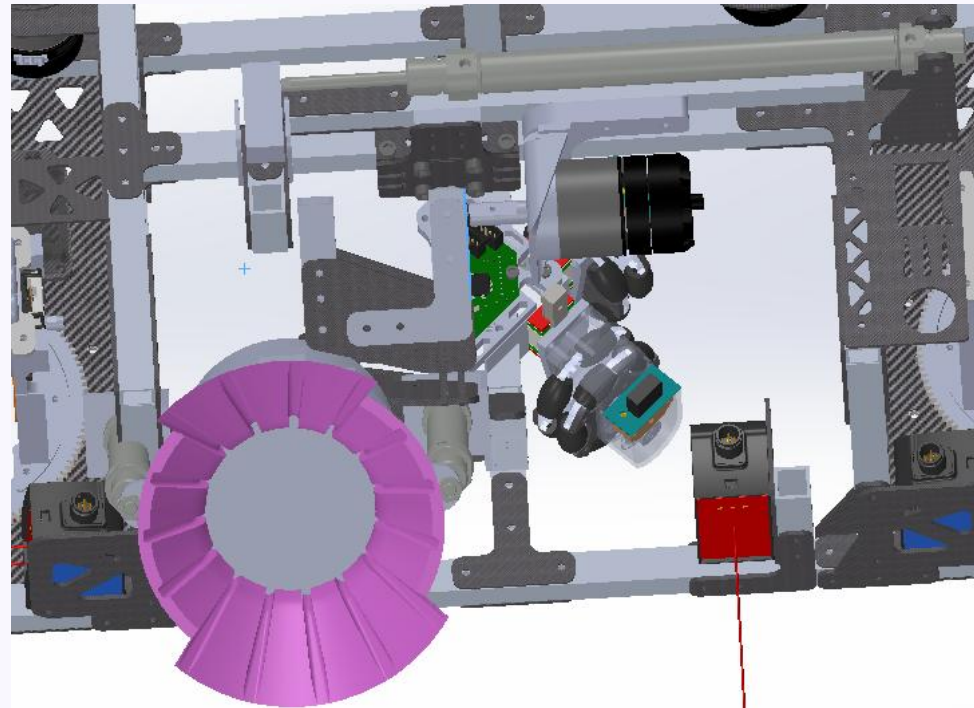
Mech

– R1 2nd row shooting Mechanism



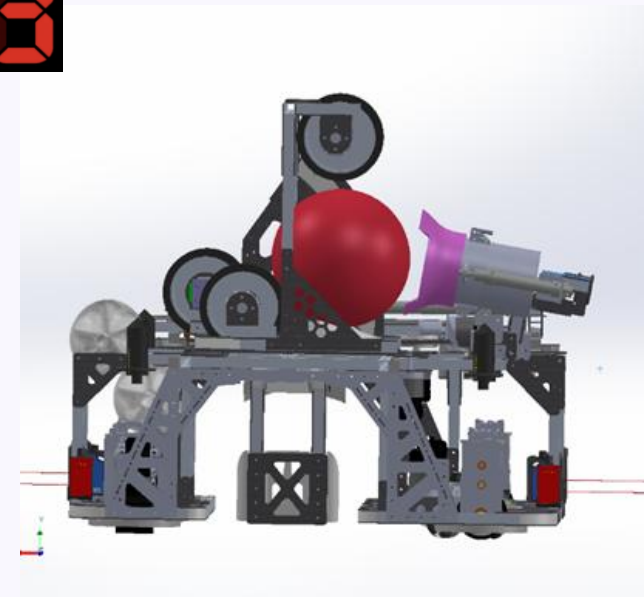
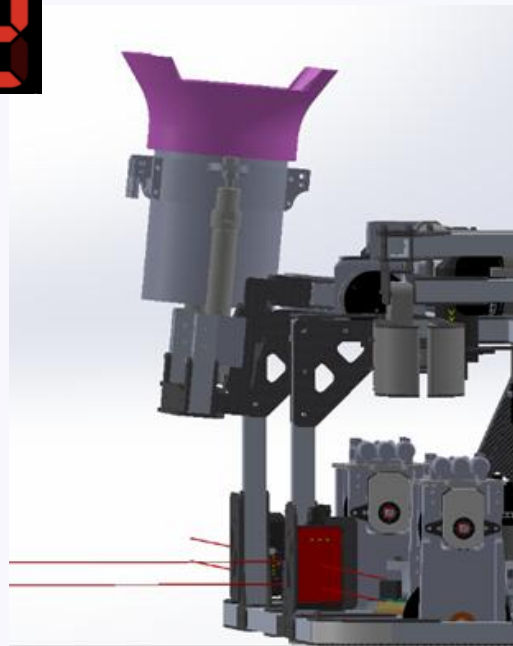
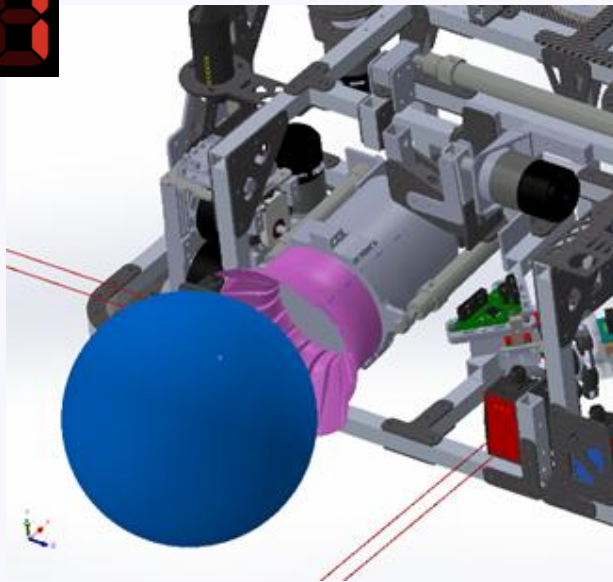
Suction arm

- In gen 1, The suction arm movement is powered by RM and pneumatic cylinders
- Carbon fiber is used for structure of arm. The motion is supported with a slider to guide the suction arm movement



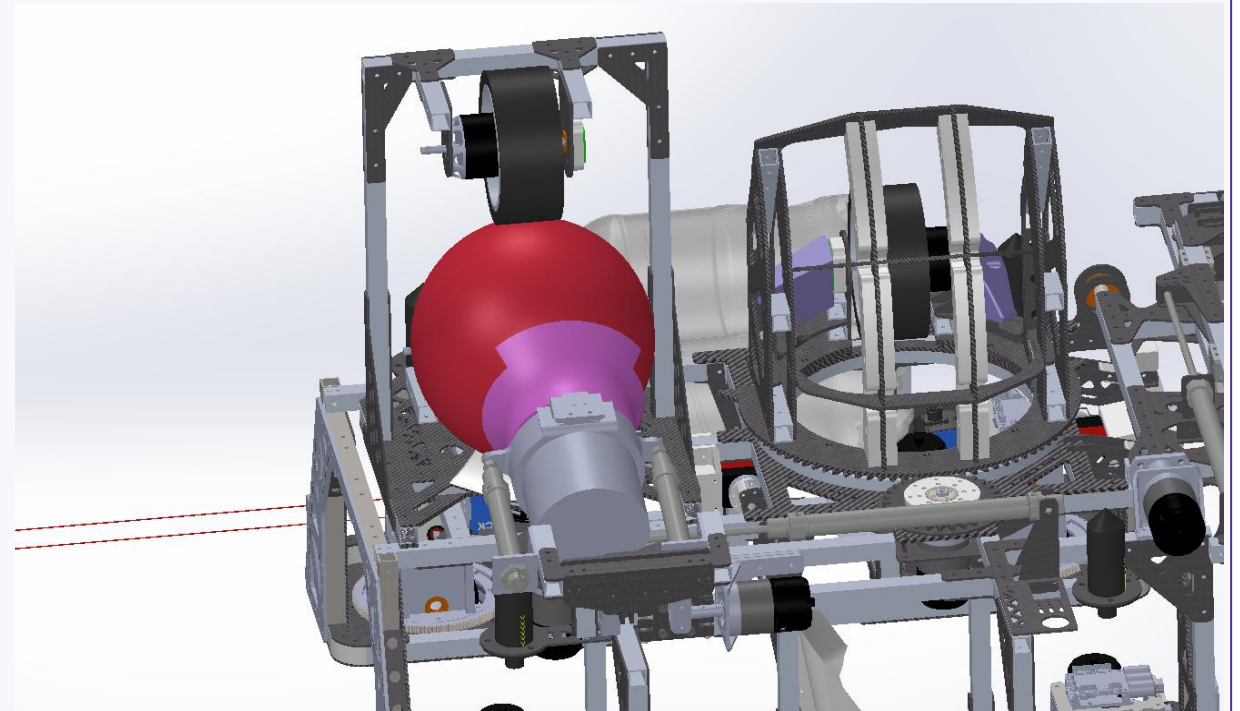
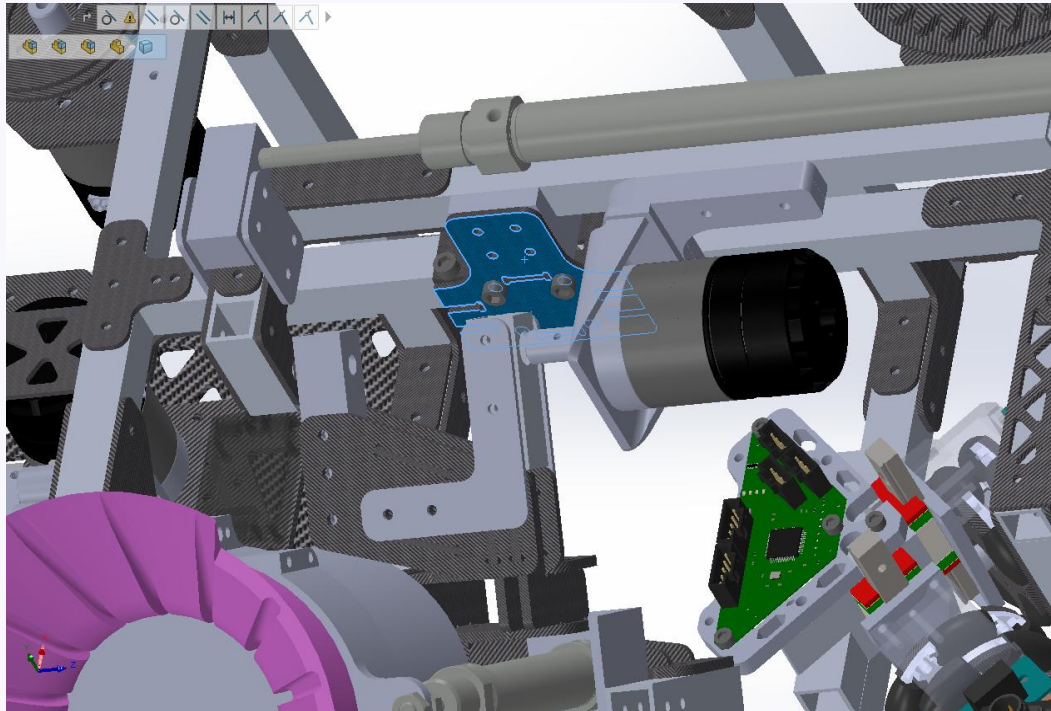
Mech

– R1 2nd row shooting Mechanism



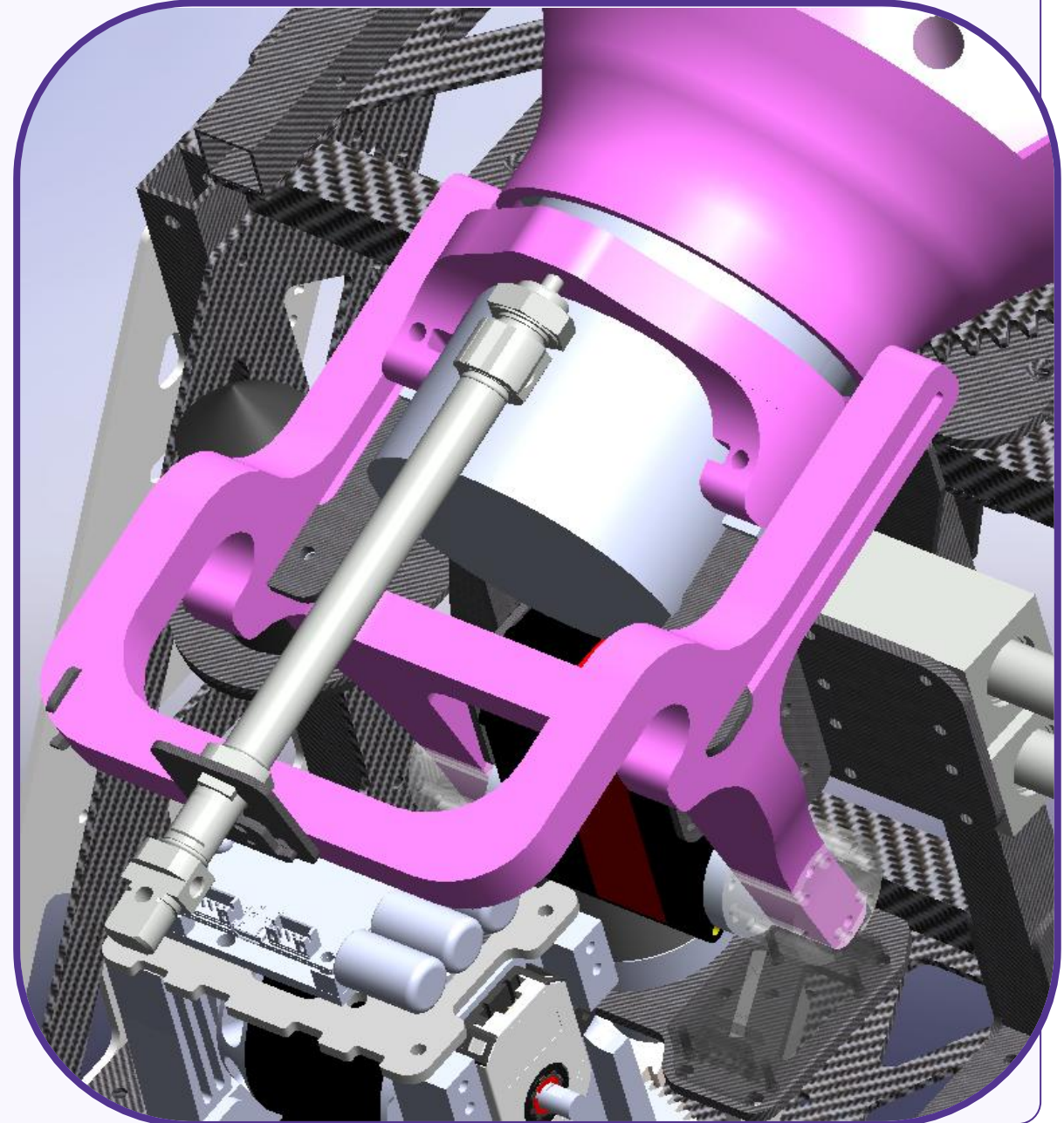
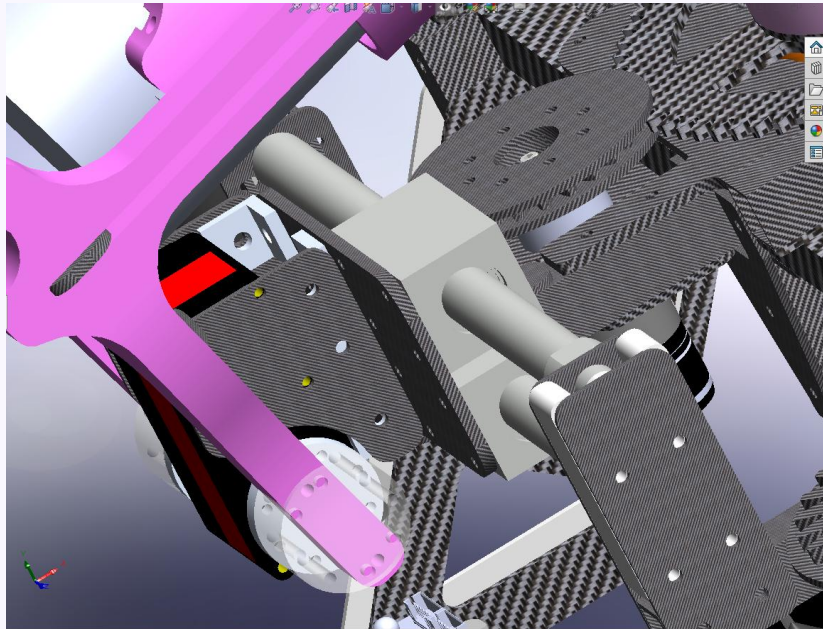
Problems with the loader

- The assembling time for the suction arm is too long owing to many ki structures
- Tolerance of Sliders bearings are too large, causing wobbly movement
- The arm structure is too heavy and bulky and the two cylinders on the suction arm have little tolerance on the weight of the arm , causing shifting to the final position of the arm



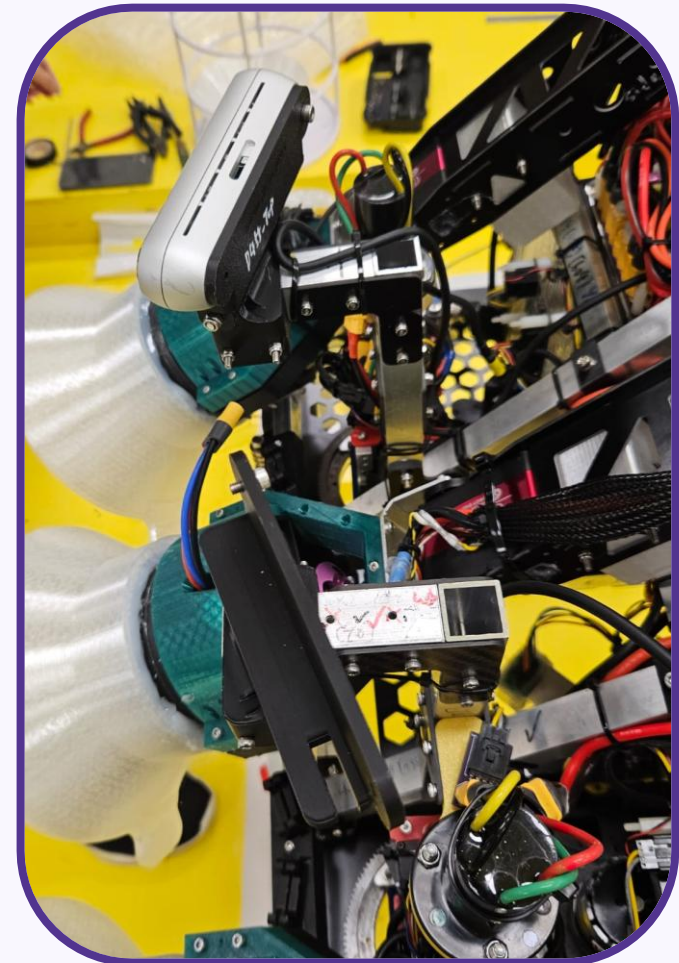
Solution

- A lighter 3dp arm is used to replace carbon fiber arm
- One cylinder is used instead of two to push the ball towards to the loading position
- Rodless cylinders and servo motor are used instead of double acting and RM motors respectively



Mech – Gen1 R2 Three suction cup arm

- Using three catapult like suction arm to sort and load ball
- each catapult arm powered by AK80.
- The suction cup part of each arm is powered by 60kg servo.



Mech – Gen1 R2 defense shield

- A passive shield using the three catapult like arms as actuator
- Using deadlock mechanism to lock the shield
- Act as a guide to guide the paddy rice into silo
- Act as a defense mechanism to affect opponent

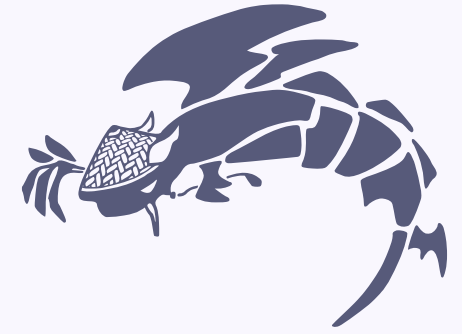




War Dragon

**Gen1
robots**

Mech-R1 Seedling Gripper



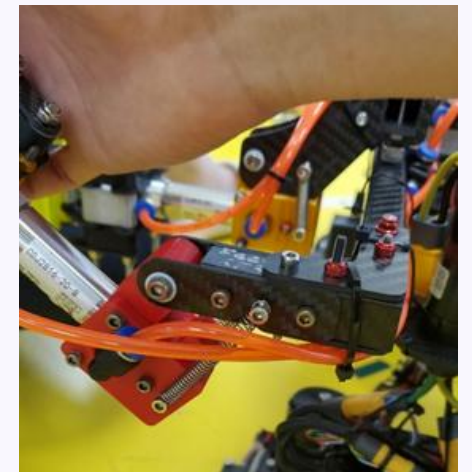
Gripping Part

- Objective: Can grip the seedling firmly
- Methodology: Use cylinder to control the gripping motion
- Pros:
 1. Gripping I/O can finish within 0.1 sec
- Cons:
 1. Limited no. of I/O operate



Suspension Hinge Part

- Objective: Allow R1 to drag the seedling out from the rack without fully lift up
- Methodology: Using a 3dp hinge and spring to achieve suspension function
- Pros:
 1. Passive return to the position after drag the seedling out
 2. designed weak point to prevent gripping part damaging

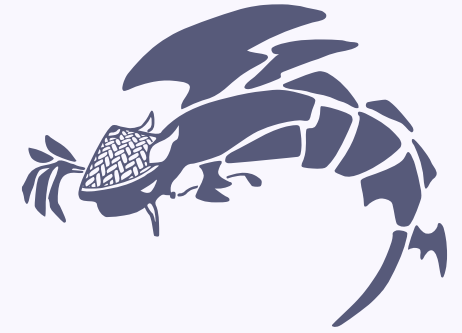


Mech-R1 Seedling Gripper

Lifting Part

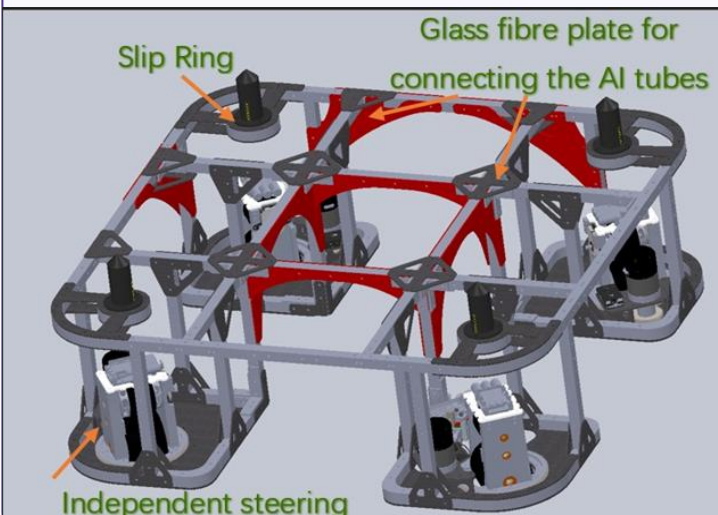
- Objective: Allow to lift the gripper up and down when it carries four seedlings
- Methodology: Lift the gripper with a 1:71 M3508 Motor
- Pros:
 - 1. Can work even in a high loading condition
 - 2. Unlimited using time compared to the cylinder driving
 - 3. Controllable pitch
- Cons:
 - 1. Lower lifting speed compared to the cylinder driving

Mech-R1 Table Wheelbase



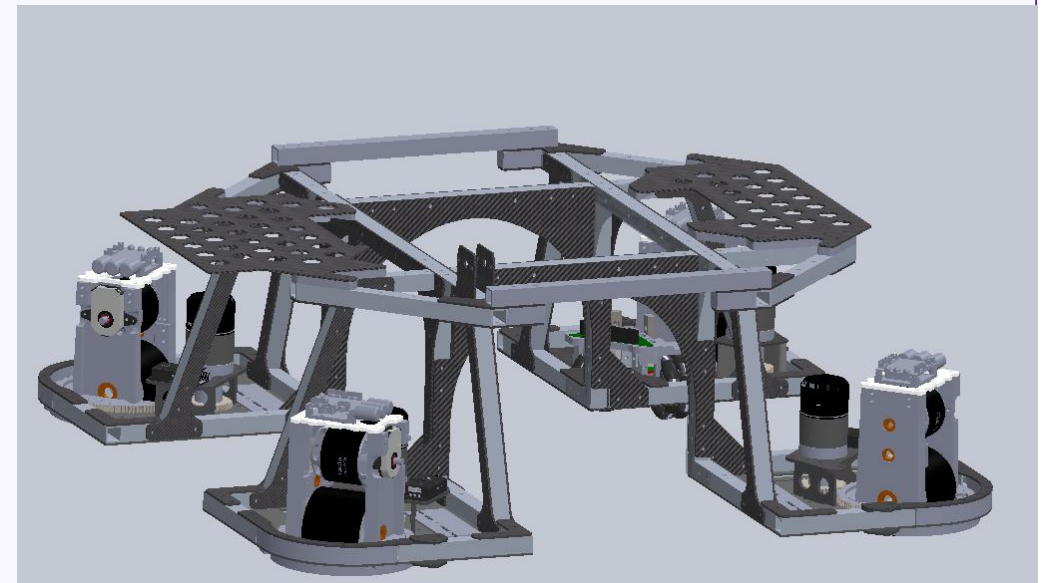
“cross tunnel” structure ->

- target: Allow travelling walk across two rows of balls in Area 2 without touching
- Enable the robot pass through 12 balls as fast as possible
- Accuracy issue solved by multiple lasers and line sensors

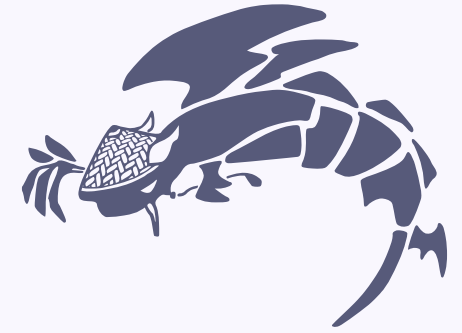


Change from prototype to gen 1

Reduce unnecessary structure

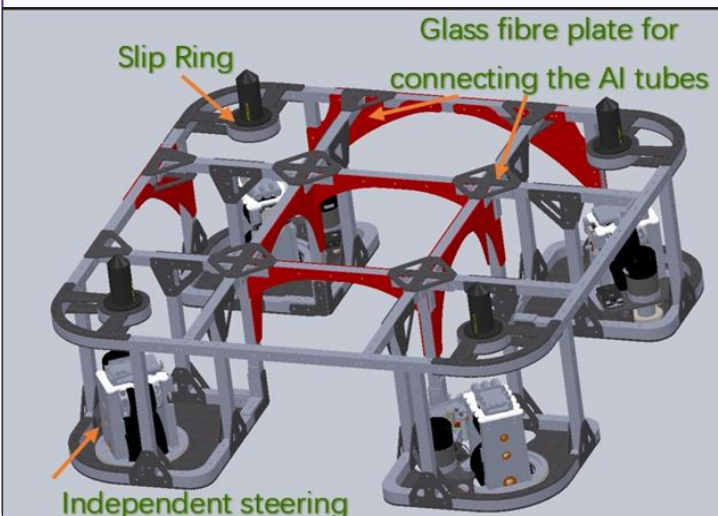


Mech-R1 Table Wheelbase



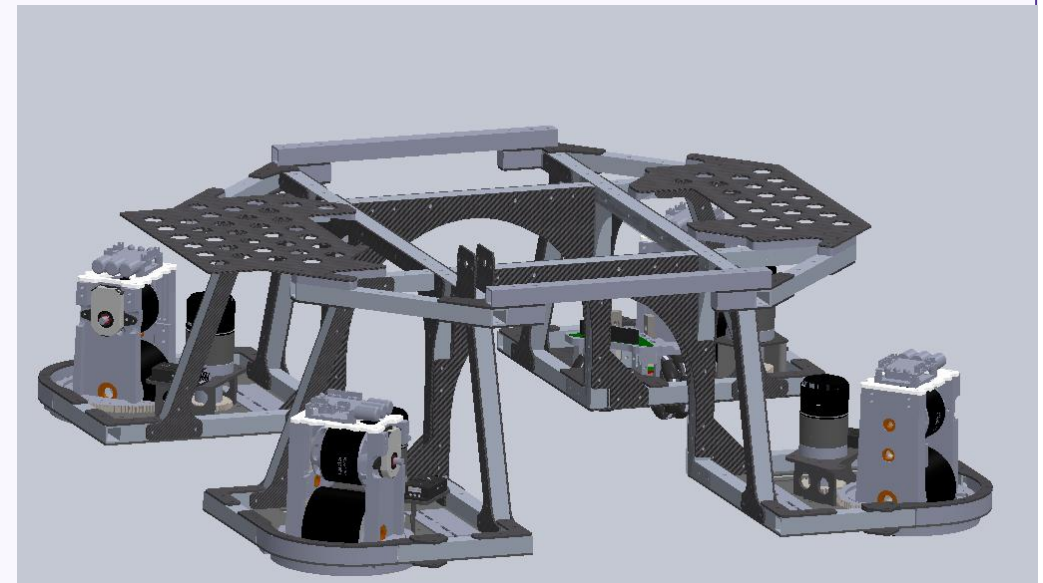
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Change from prototype to gen 1

Reduce unnecessary structure



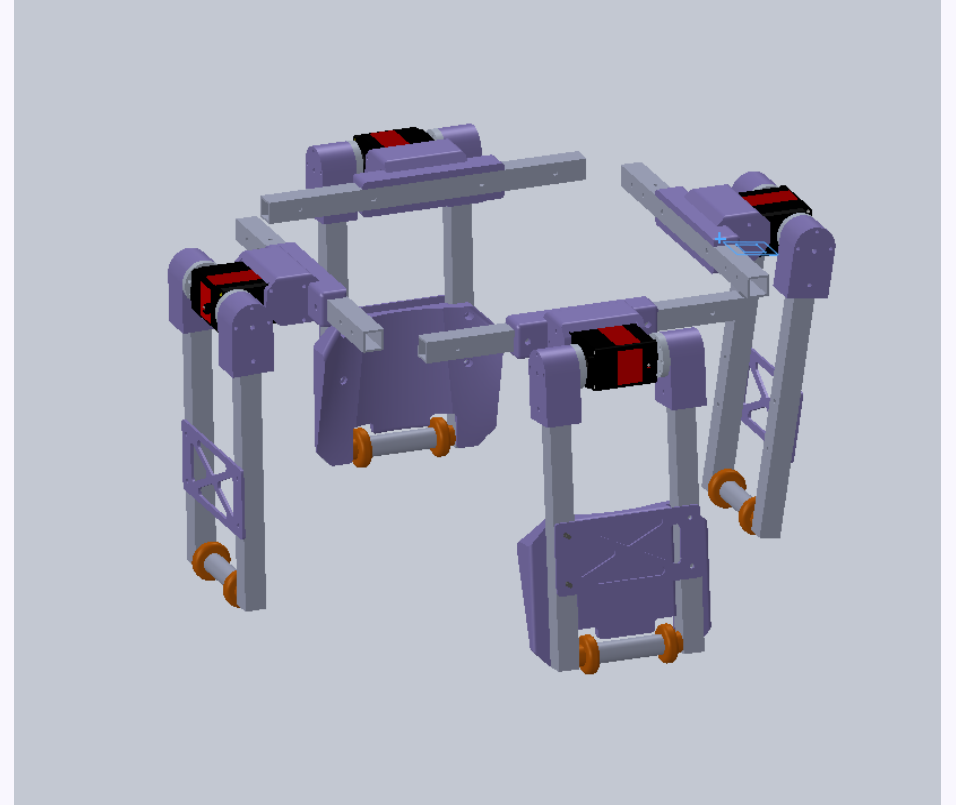
Mech-R1 loader design

Purpose:

- Accompany with the tunnel wheelbase to load the balls in area 2
- Load the balls to the shooter successfully

Methodology:

- Use 4 servo motors to rotate the shovel-like loader
- For every loading, the opposite pairs would move simultaneously
- 2 small 3D printed wheels in each loader
 - To force the ball going upward during loading
- Use 3D printed shovel to hold the ball and preventing it sliding out



Mech-R1 loader design

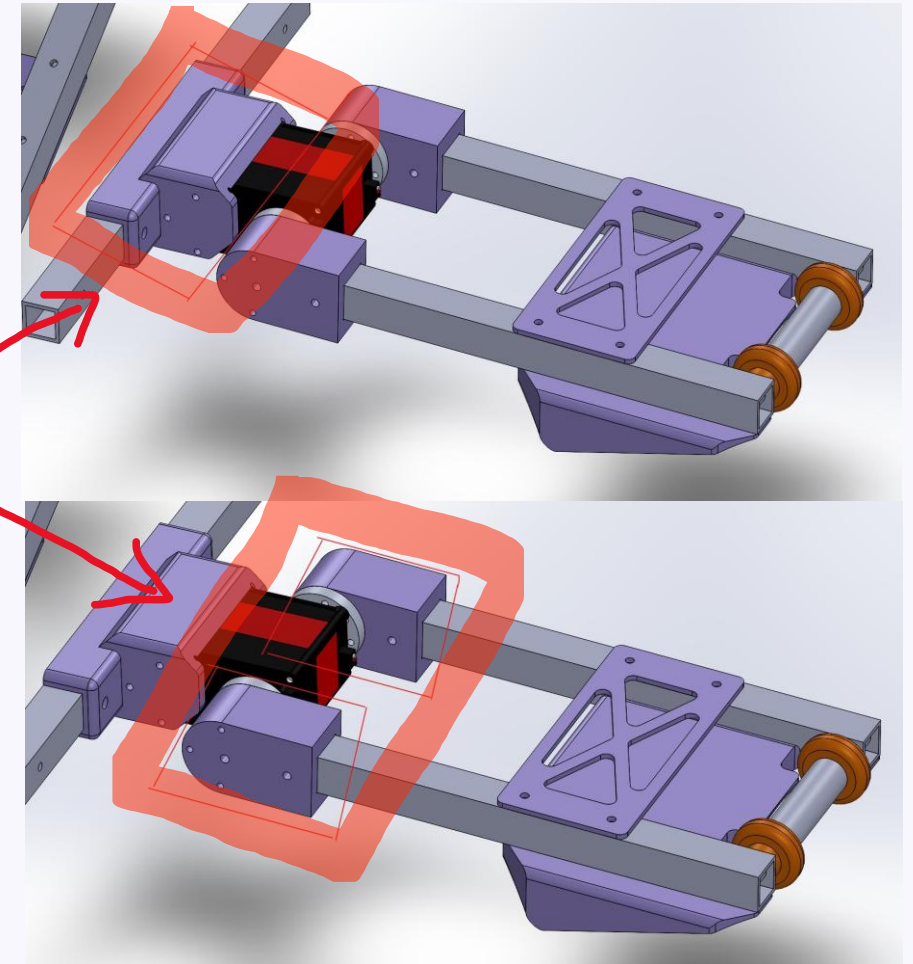
Pros:

- Could load the ball in 2 directions
- Could complete the task with high accuracy and consistency

Cons:

- Have weak points
- A little bit heavy
 - Redundant 3D prints
 - Aluminium connectors

Weak points



Mechanical – Gen1 R2

Problems of Gen 0:

Rubber Bands and Intake too easy to break, too hard to fix.

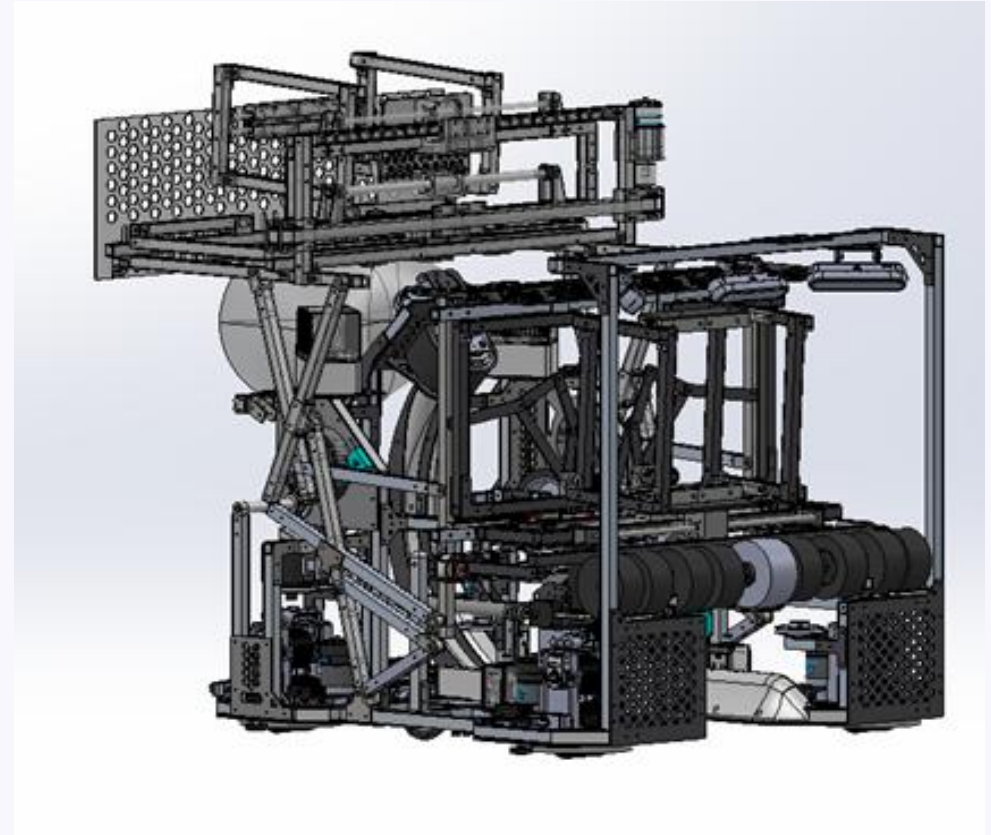
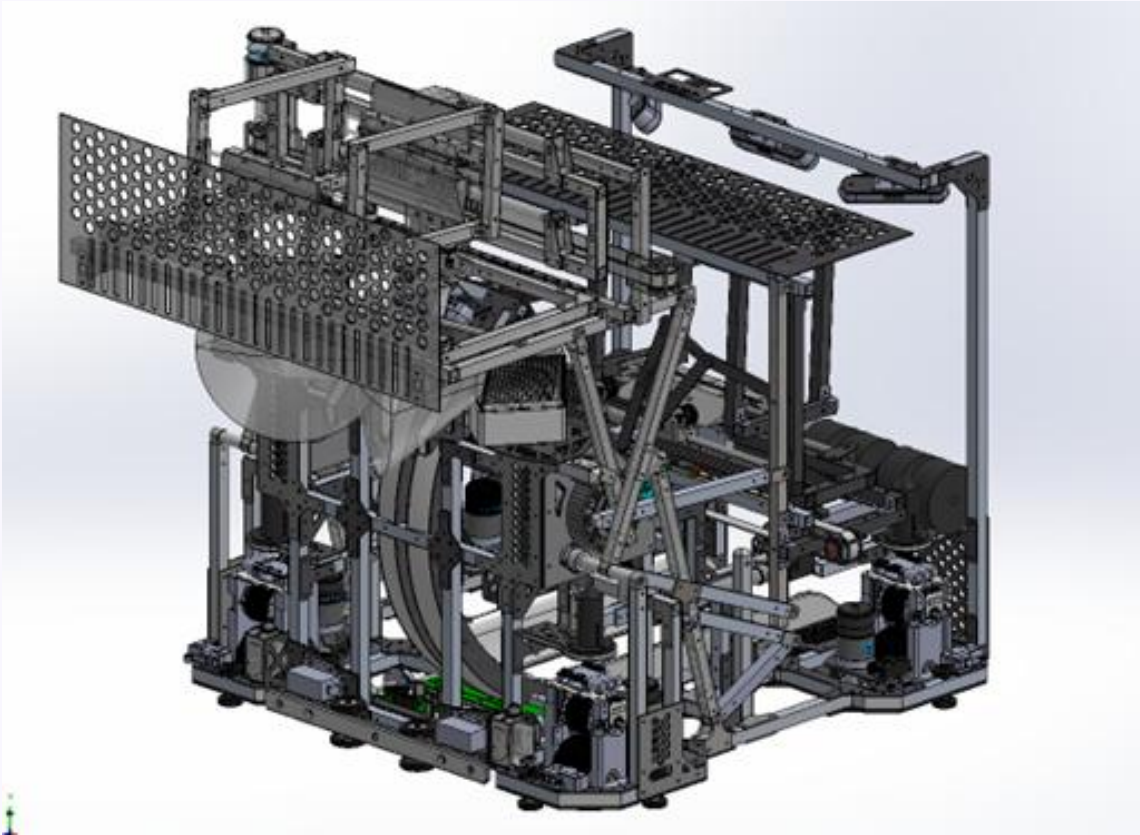
Inconsistent

High Center of Gravity

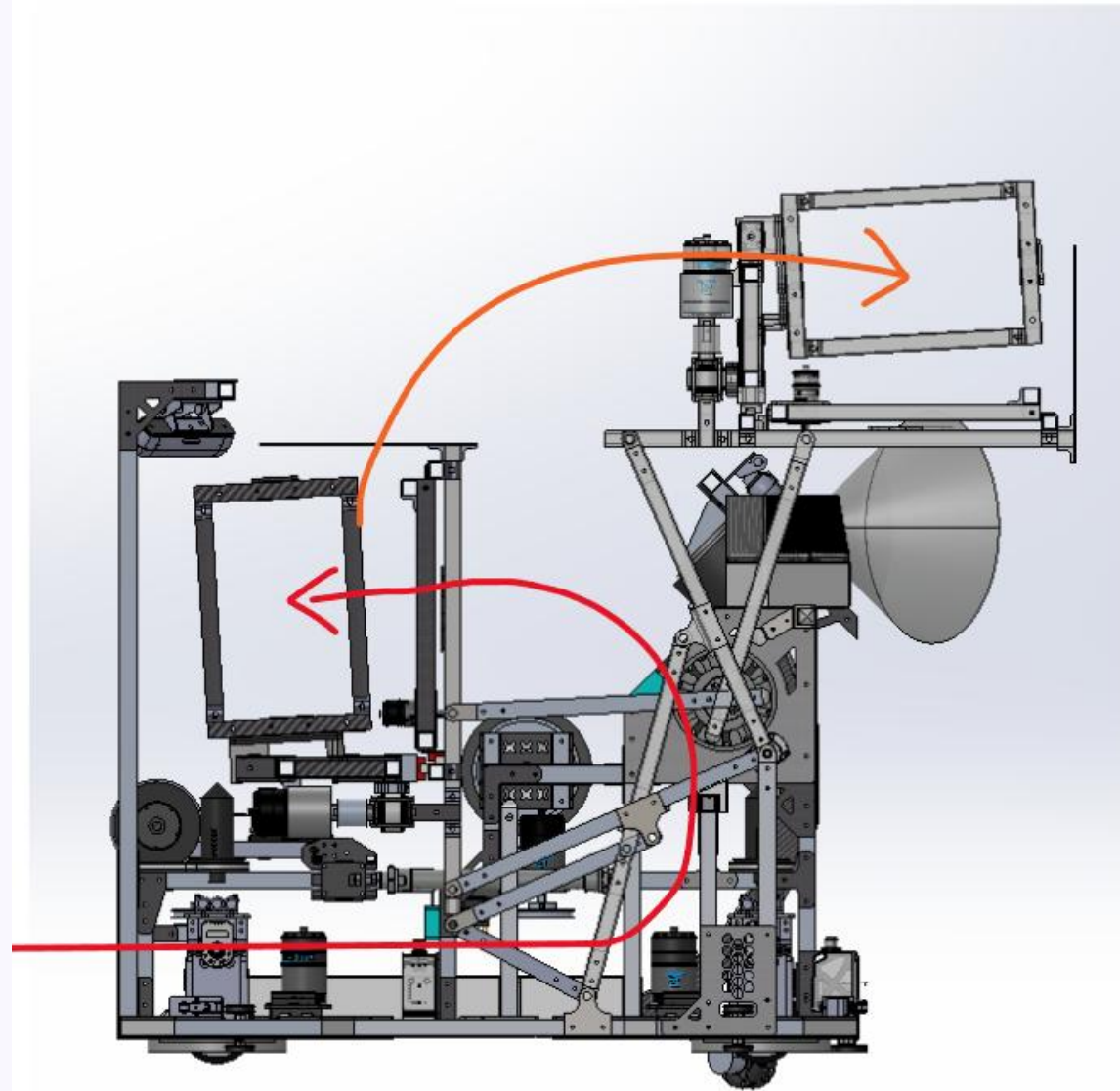
No defense capability

Loading buggy

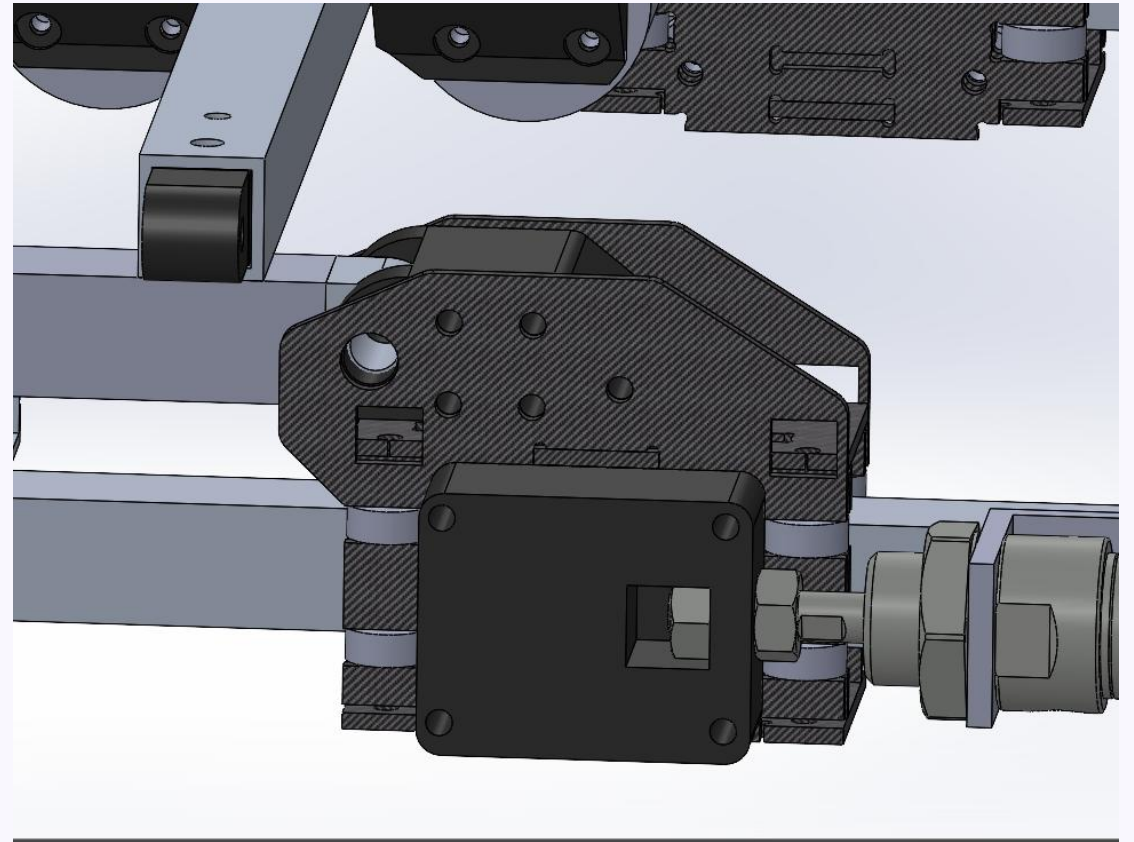
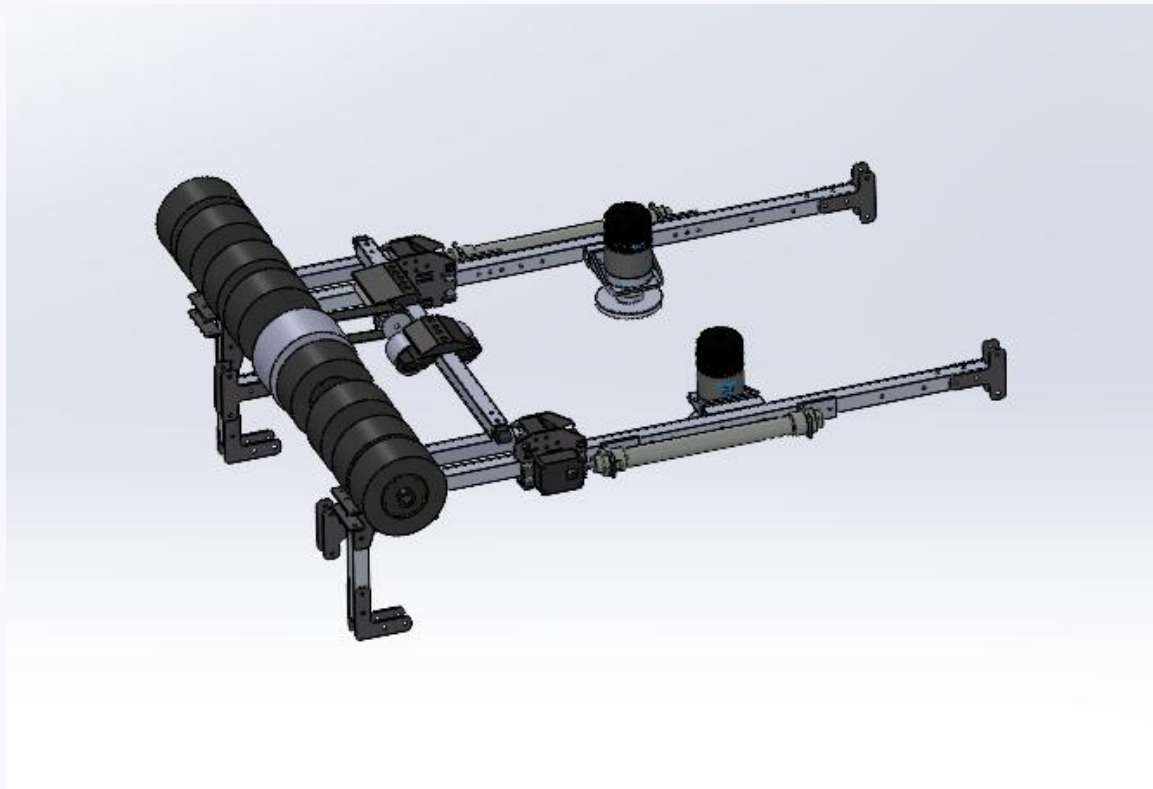
Mechanical – Gen1 R2



Mechanical – Gen1 R2



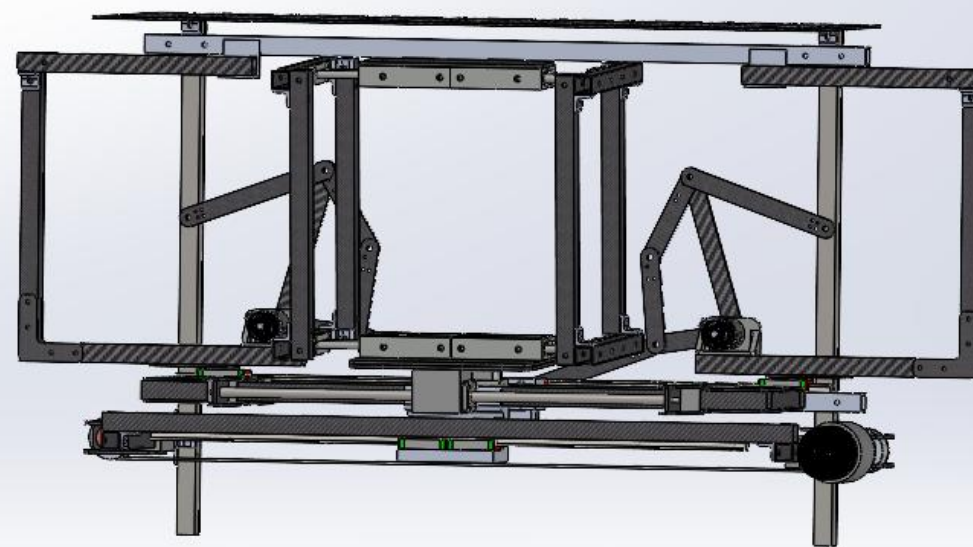
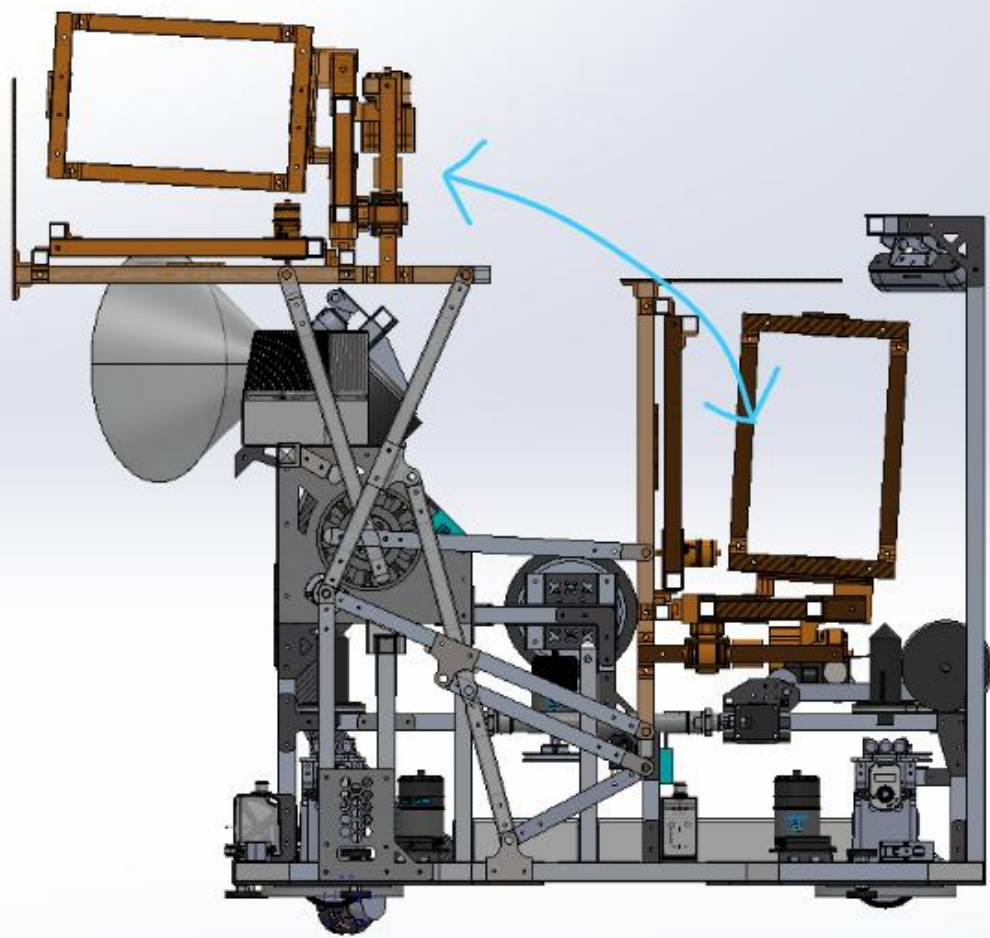
Mechanical – Gen1 R2



Mechanical – Gen1 R2



Mechanical – Gen1 R2



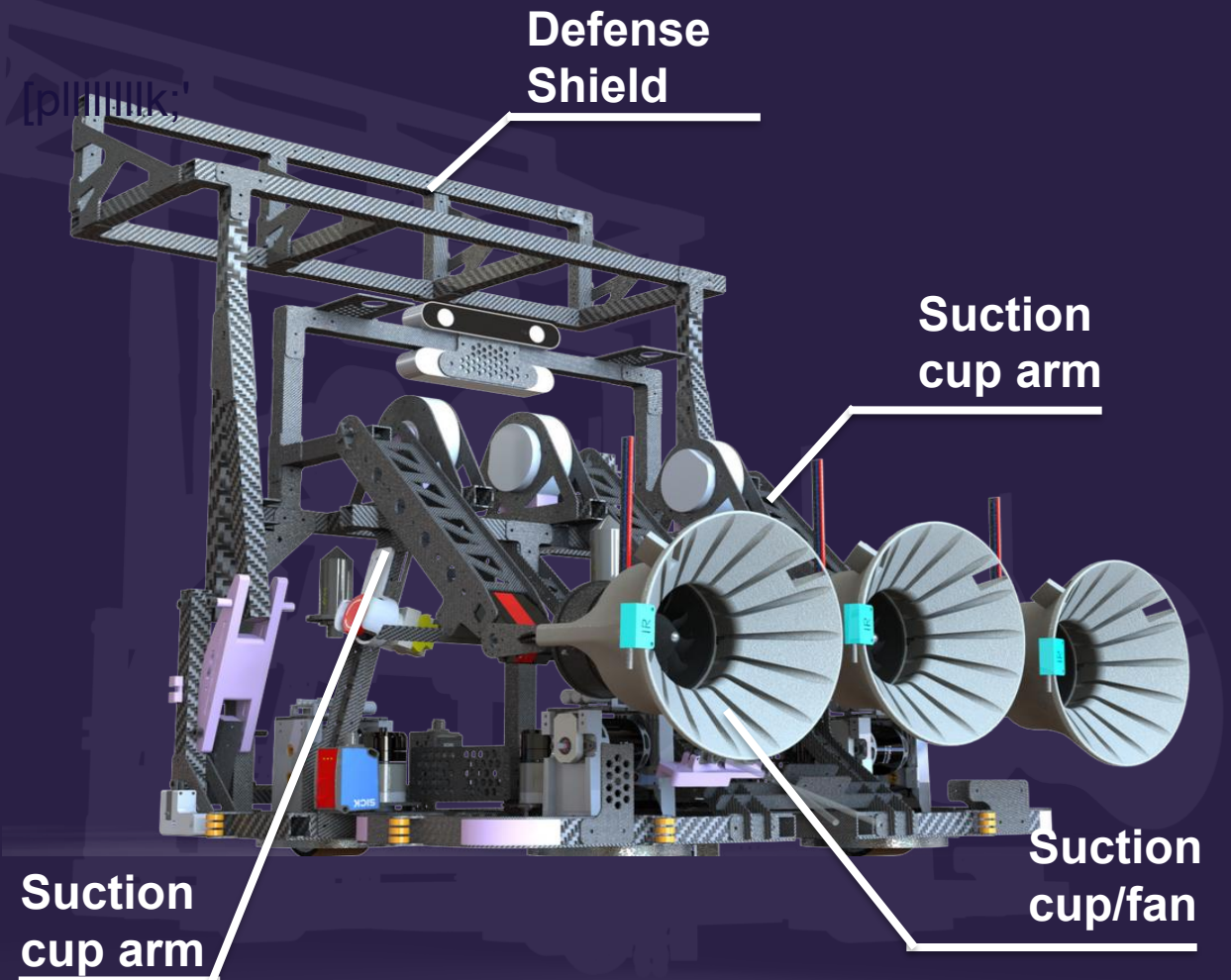


Fiery Dragon

**Gen2
robots**

MECH – FIERY DRAGON

Suction
Loader

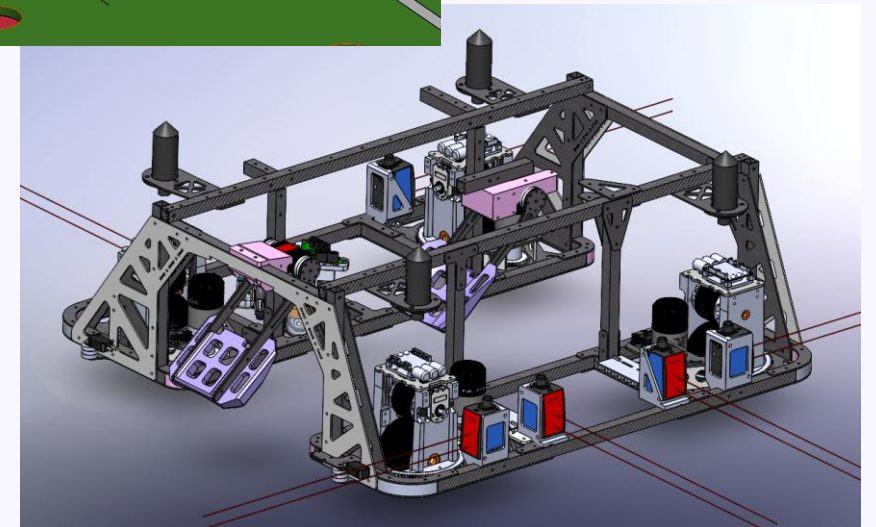
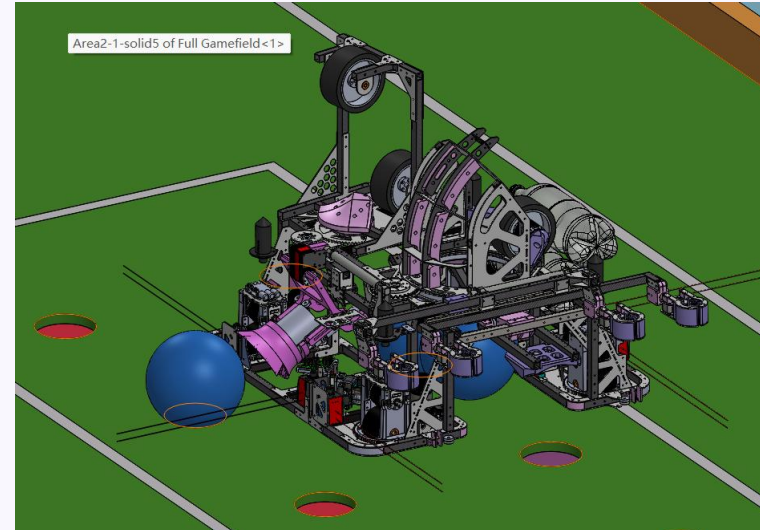


Mech – Gen2 R1 Tunnel Wheelbase

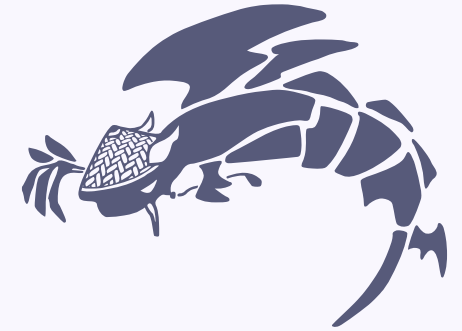


Further improvements for Gen2

- Remove excess tunnel support structures (reduce number of vertical tubes connecting inner wheelbase and tunnel structure to 4)
- Further widening of the tunnel by 15mm, and shorten the wheelbase width by 30mm, eliminate unintentional contact
- Extended diagonal frame support directly to outer wheelbase tubes
- Added custom laser locking mounts to prevent excessive shifting of laser position

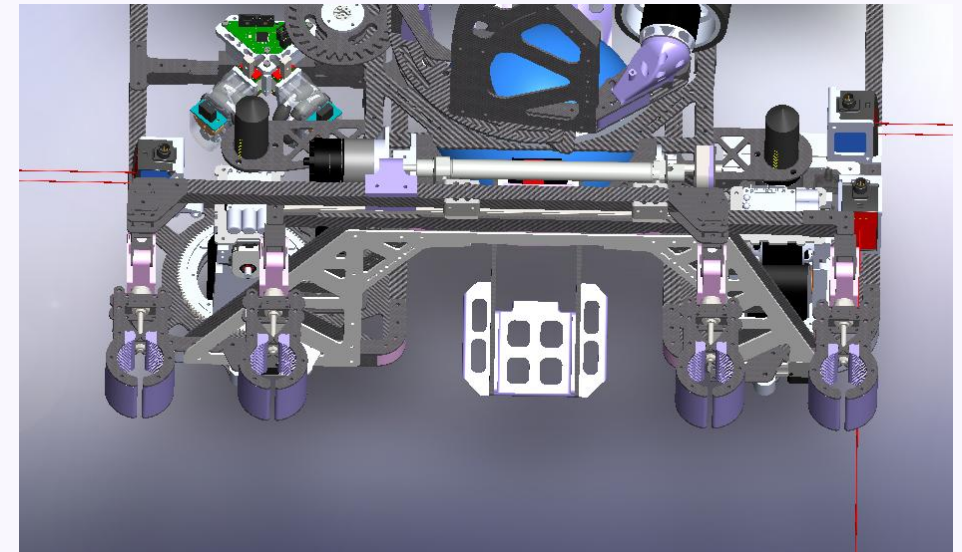


Mech – Gen2 R1 Seedling Gripper



Further improvements for Gen2

- Change to TPU gripper 3dp structure with low infill density and thicker inner portion (deformed structure when gripping provides friction)
- Reduced all unnecessary structural components/features for further weight reduction
- Movement of gripper location to be further recessed into wheelbase, allow for grippers to be concentric to seedlings during contact with A1 rack

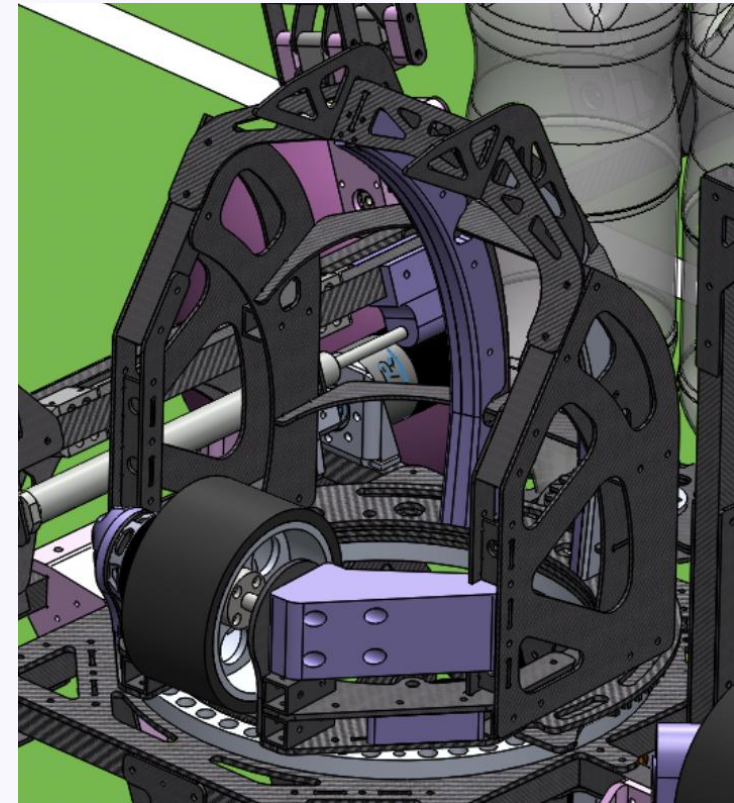


Mech – Gen2 R1 First row Flywheel Shooter



Further improvements for Gen2

- Change of flywheel size from 120mm to 100mm (adjust to new compressive force from 150mm -> 170mm)
- Yaw movement actuator changed to RM2006(36:1) with 1:3 spur gear), allows for auto-aiming capability at A3 storage zone from any position in A2
- Size/weight of 3dp guide reduced further, change to full carbon fiber frame
- Change shooting angle from 40 deg to 30 deg from surface, lower shooting arc allows for lower bouncing height of ball entering A3, greater control

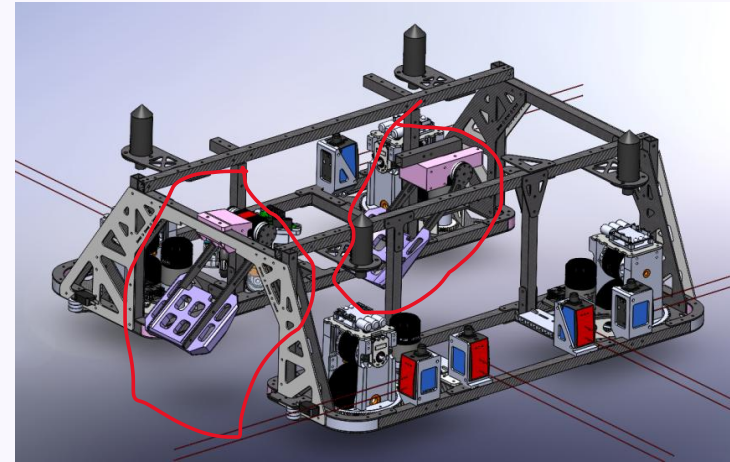


Mech – Gen2 R1 First row Flywheel Loader



Further improvements for Gen2

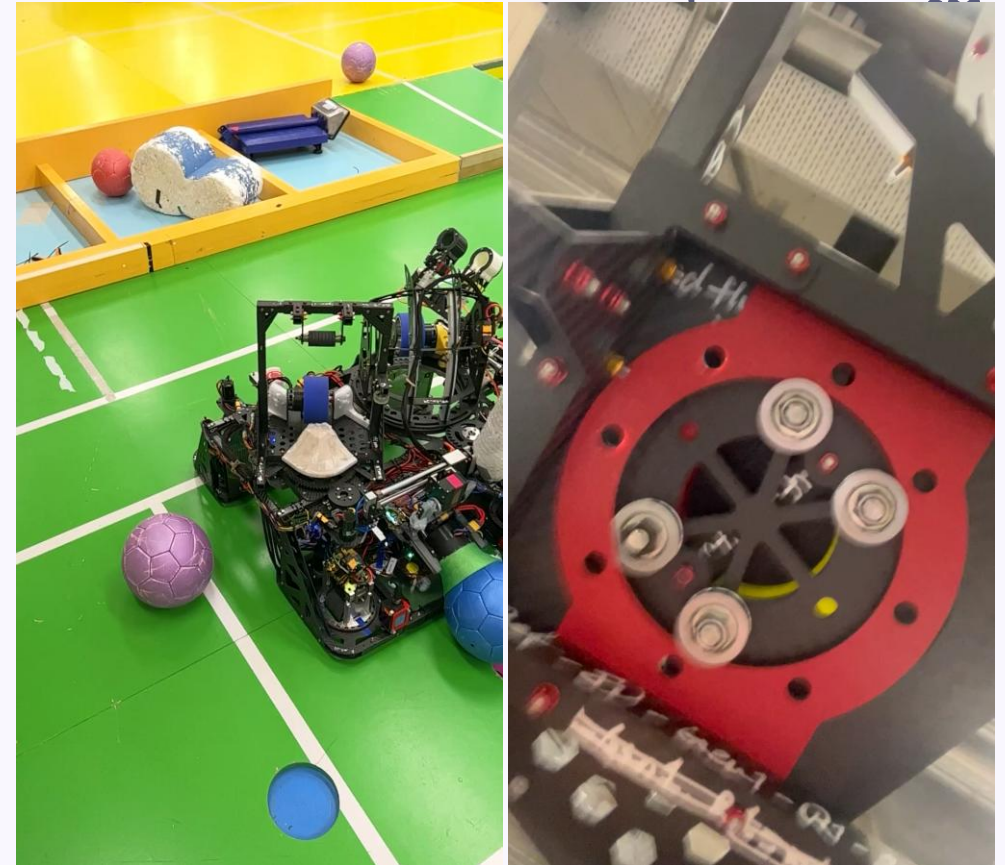
- Eliminate tube layout from shovel loader in replacement with carbon fiber structure arms
- Arm positions moved so arms don't interfere/compress ball to achieve smoother grabbing/loading process, decreasing load time to $<1.5s$
- Integrated approach -> direct loading and shooting of ball from A2 hole in one command



Mech – R1 2nd row shooting Mechanism

Further improvements for Gen2

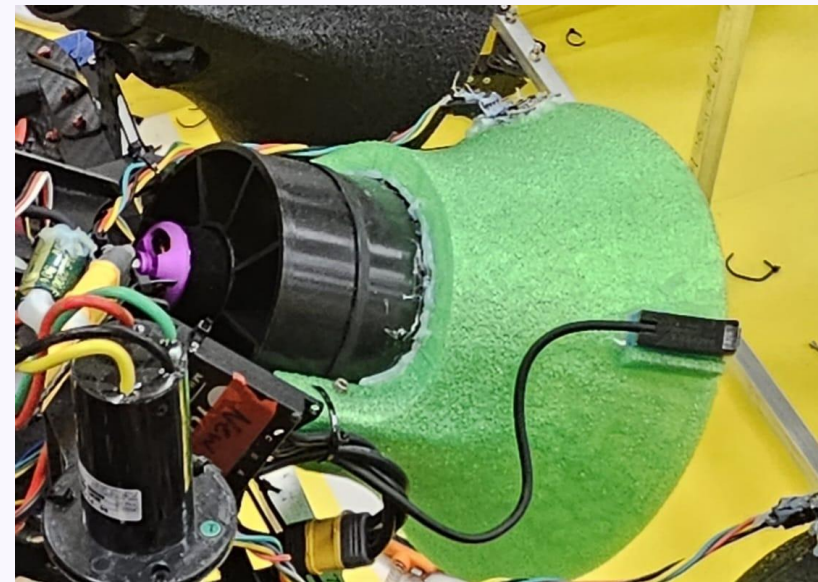
- **Yaw guide** --> from cross roller bearing to H-bearing with a horizontal carbon fiber plate guide
- **Flywheel** --> upper flywheel replaced with set of 3 polyurethane-coated bearings, provide compressive force without actuation
- **Suction cup structure** to 1 3dp structure (polycarbonate)
- Replacement of tube guide & cylinder to 2x rodless cylinders



Mech – Gen2 R2 Three suction cup arm

Improvement:

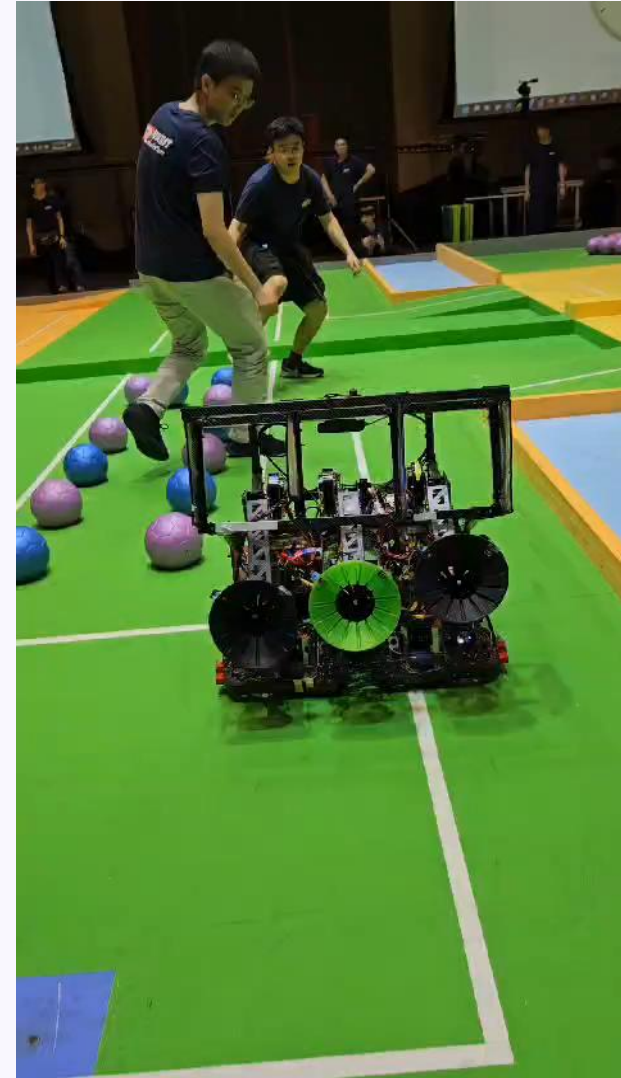
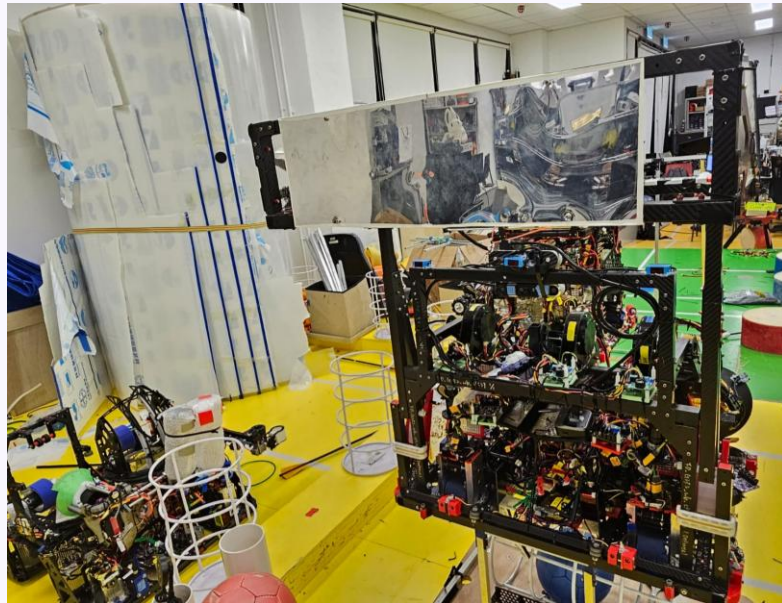
- To prevent the suction cup from frequently detaching from the EDF fan, screws have been added to the suction cup, rather than relying solely on hot glue.
- Weight of the arms are reduced comparing to Gen1



Mech – Gen2 R2 defense shield

Improvements:

- To limit the impact of the heavy shield on the center of gravity of the entire robot, the weight of the shield is reduced compared to the Gen1 design
- Added a mirror to reflect light, try to affect opponent's camera

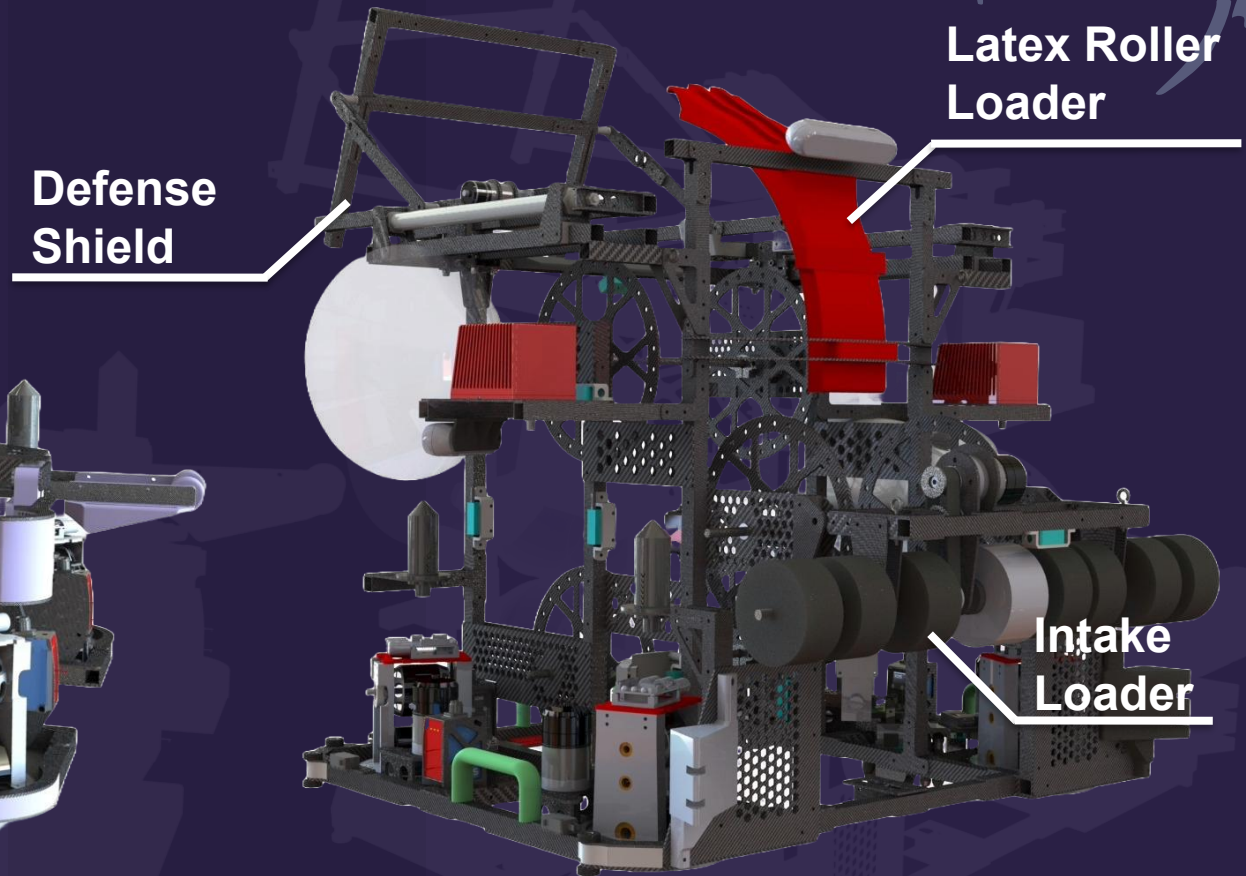
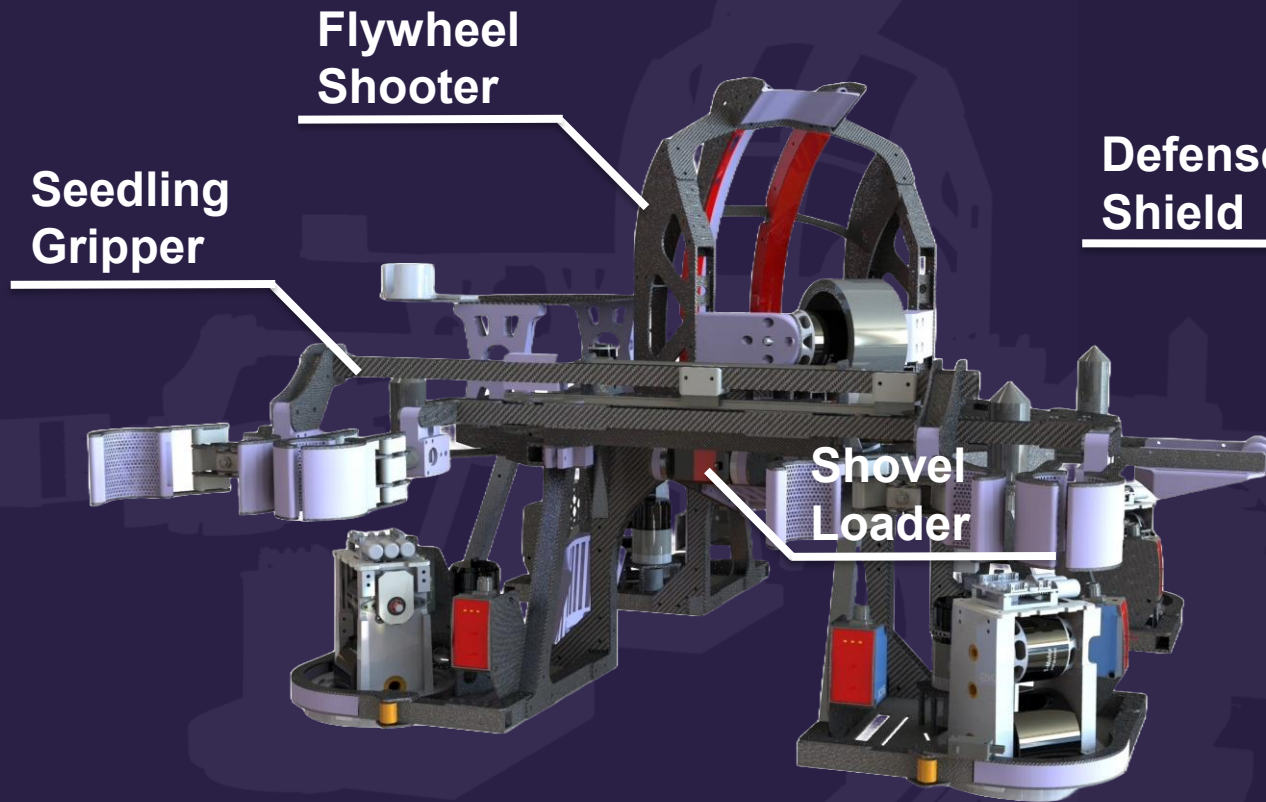




War Dragon

**Gen2
robots**

MECH – WAR DRAGON

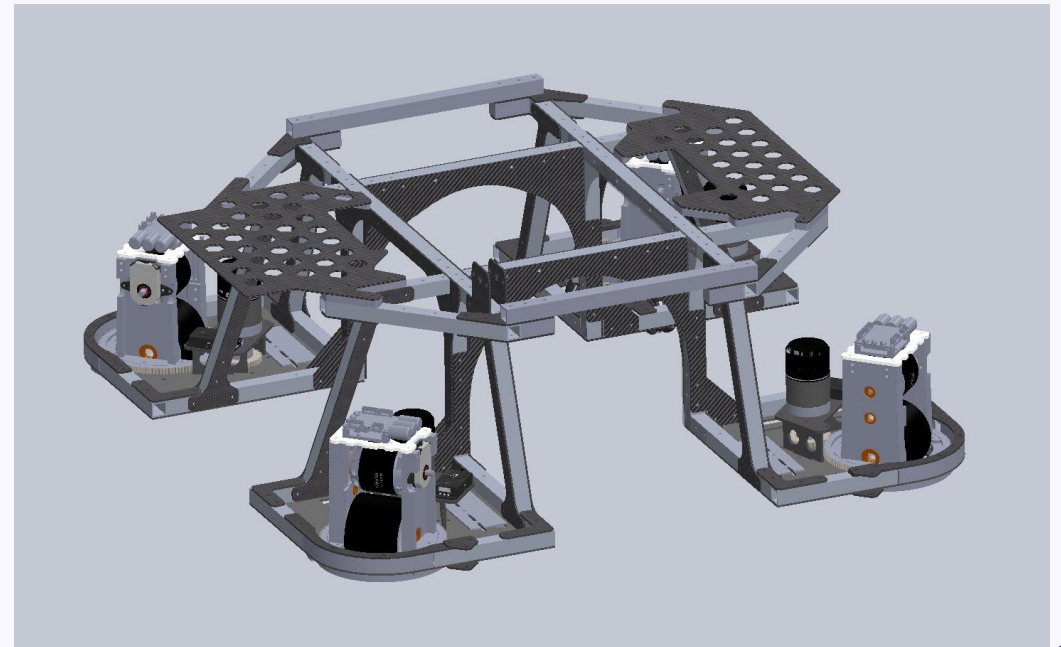


Mech – R1 table cross tunnel wheelbase

Improvement after gen 1:

- Higher the tunnel by 2cm
- Change the connecting fiber plan
- so loader and move up to 180 degree
- And able to pick up balls on floor

Didn't change too much from gen 1 coz gen 1 that one already so stable except the bending problem



Mech – R1 loader

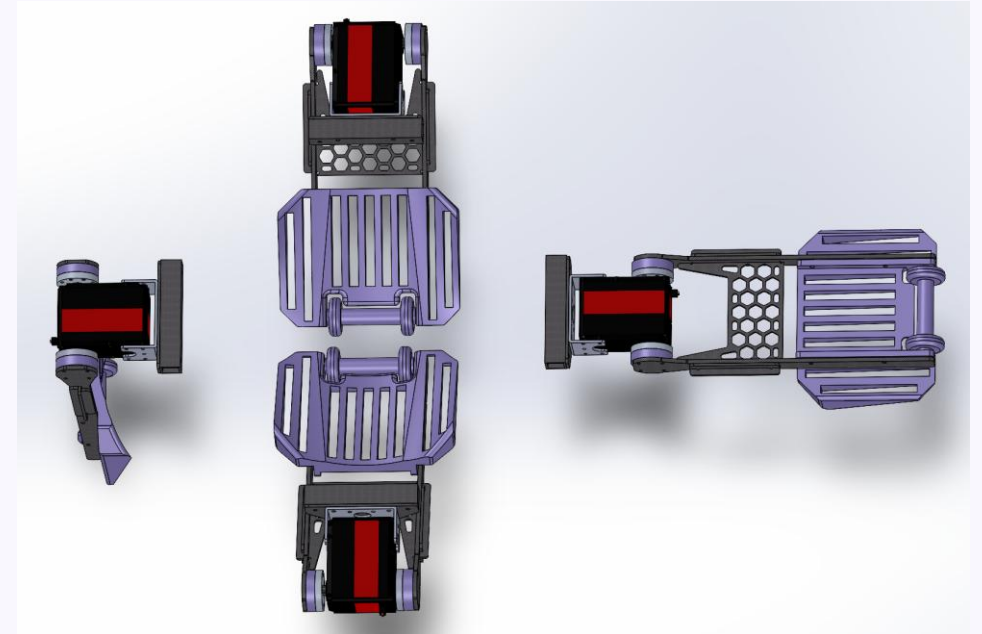
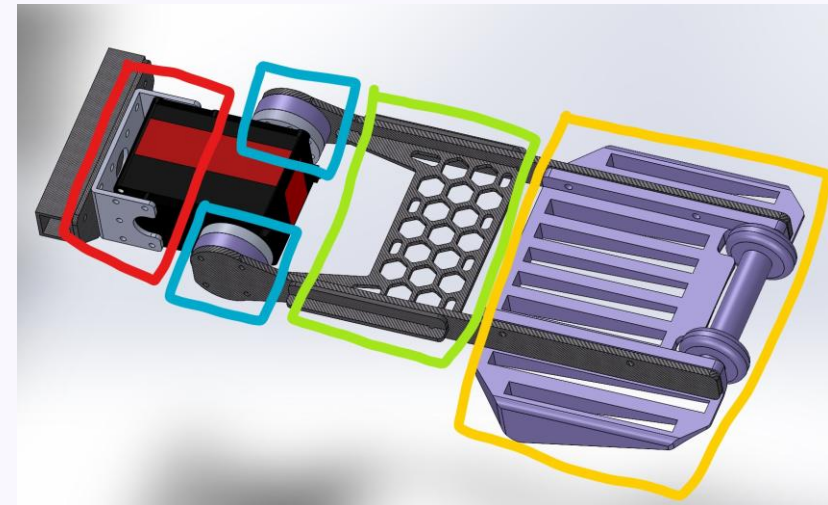
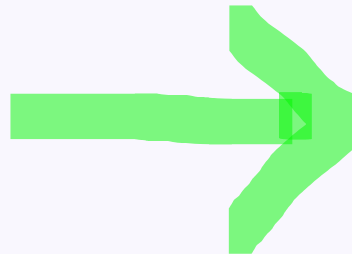
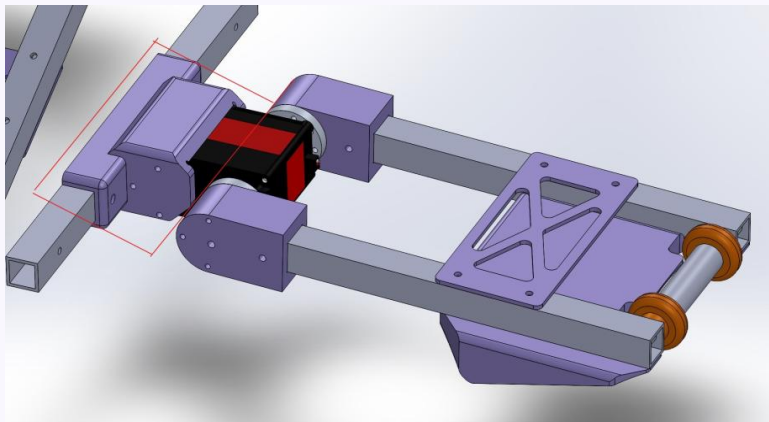
Improvements:

1. Lighter

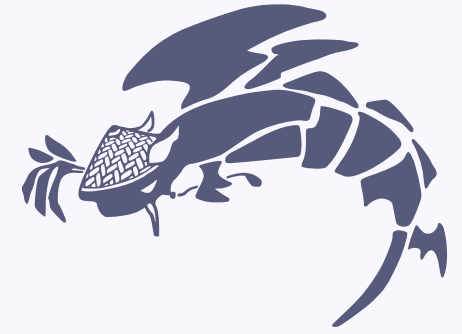
- All aluminium parts are changed to carbon fibre
- Reduced the weight of 3D prints

2. More rigid

- All weak points in the previous design are strengthened



Mech – R2 Defense Shield

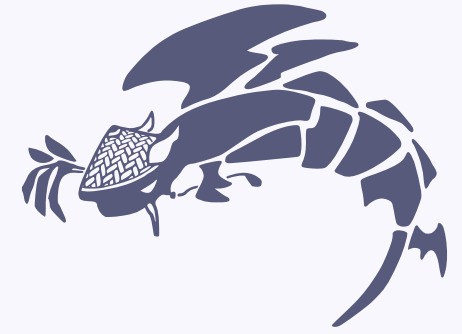


Init state

- Shield retracted and locked by the 3DPrint ball guide

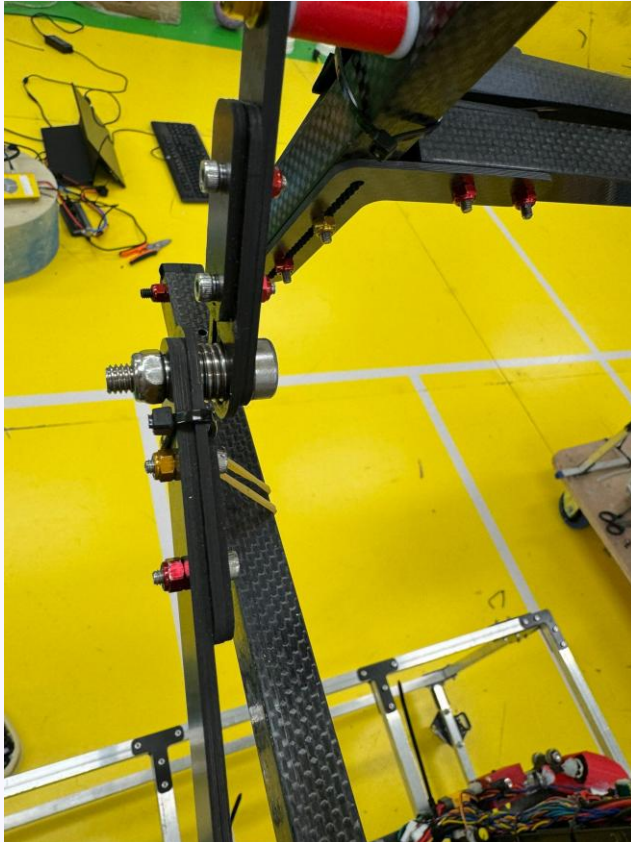


Mech – R2 Defense Shield

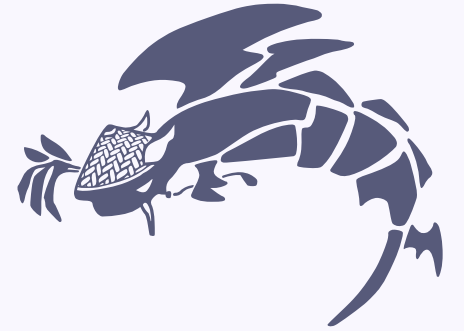


During extend

- Spring on the two arms automatically push up the shield to its blocking state.

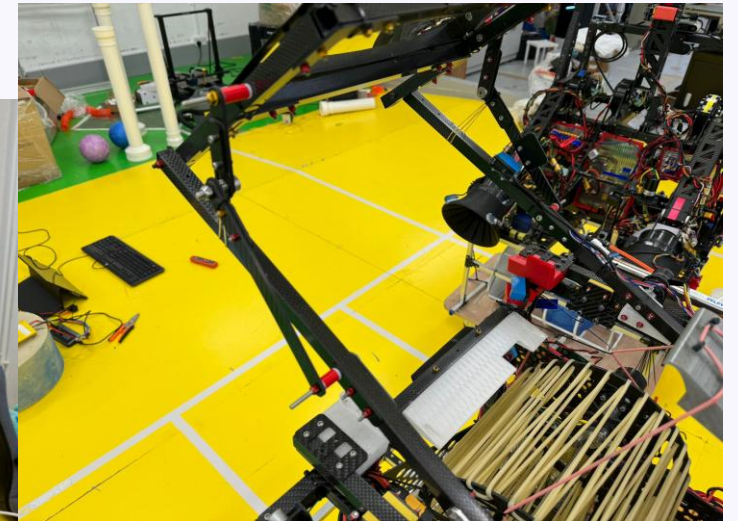
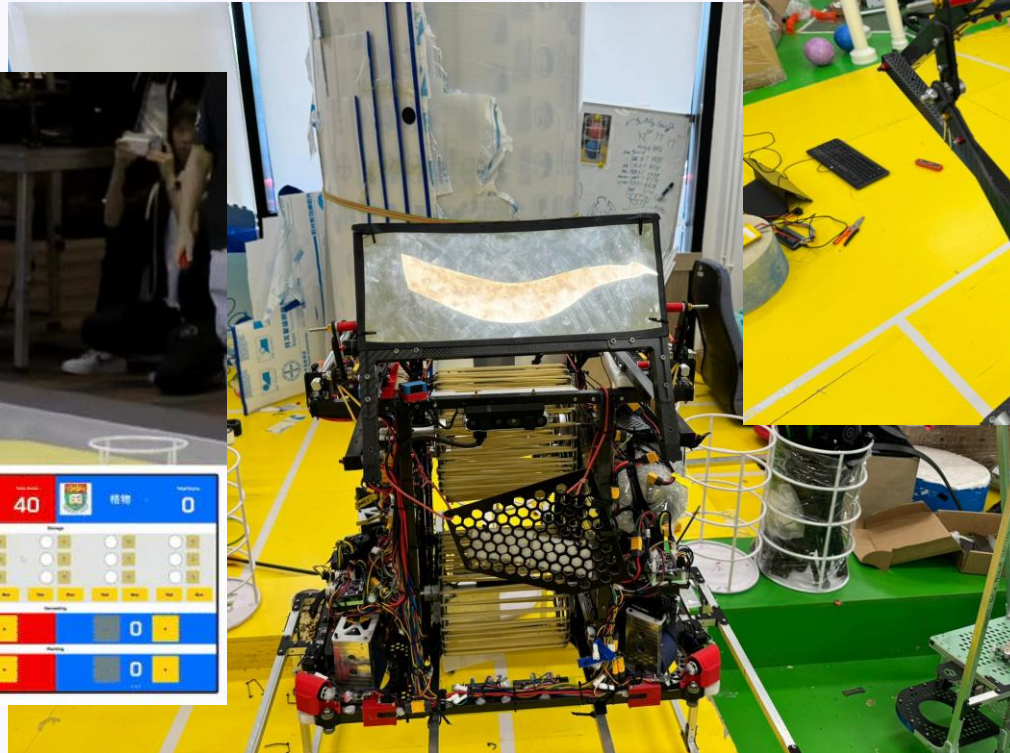
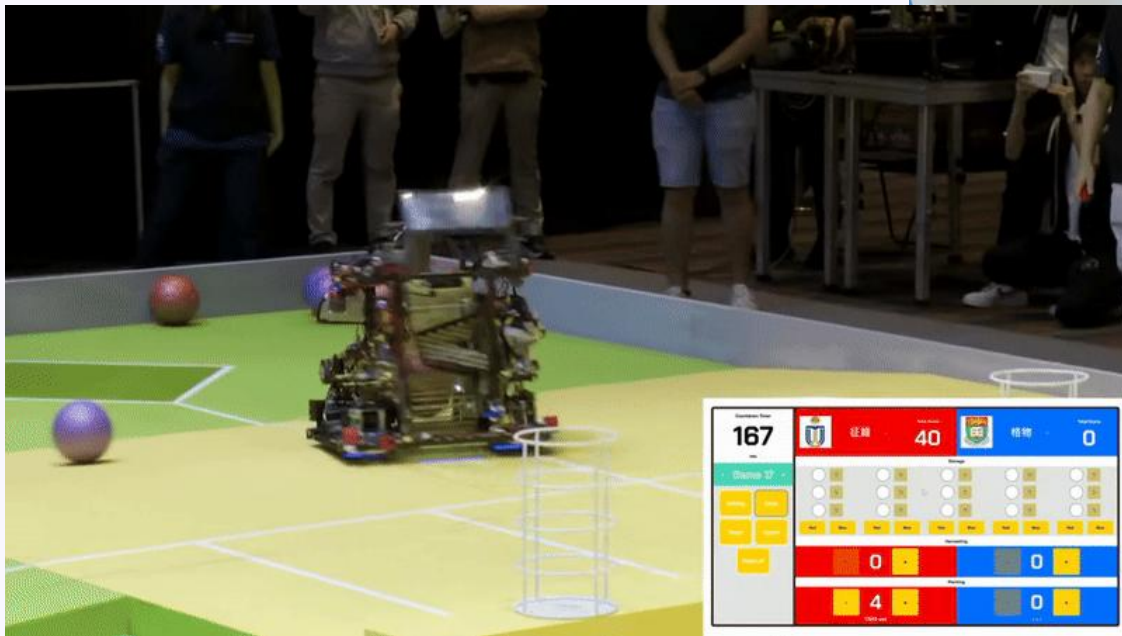


Mech – R2 Defense Shield



Putting balls into silo

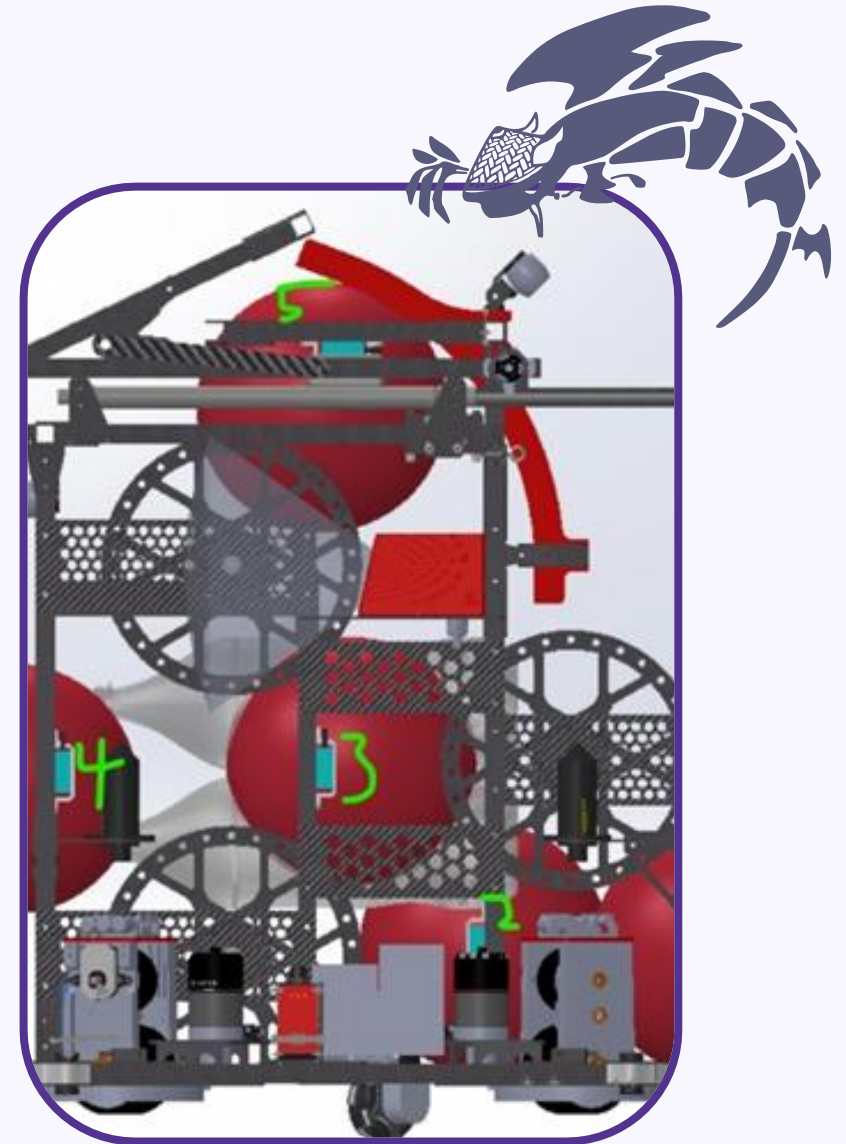
- The shield rebound the ball into silo
- A mirror at the front of the shield to disturb opponent's sensors
- Shield can be lifted to avoid collide with third ball in the silo



Mech-R2 Roller loader

After transferring the ball from the intake loader to the roller loader

- Position 2: lift the ball up
- Position 3: to hold the ball
- Position 4: sort the ball out
- Position 5: Put ball to the silo



Mech-R2 Roller loader

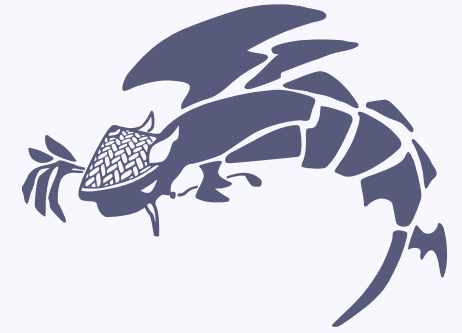


Latex String Roller

- Objective: A flexible roller of transfer and sorting the ball
- Methodology: Roller route with latex string, and driving with 1:19 M3508 Motor
- Pros:
 1. Can work with a high compress rate
 2. Can stop and lock roller position from fast spin
- Cons:
 1. Latex string easy to break
 - Reduced stress by under tensioning
 - Affect ball transfer due to friction drop
 2. Need 3 motor to transfer the ball to the silo

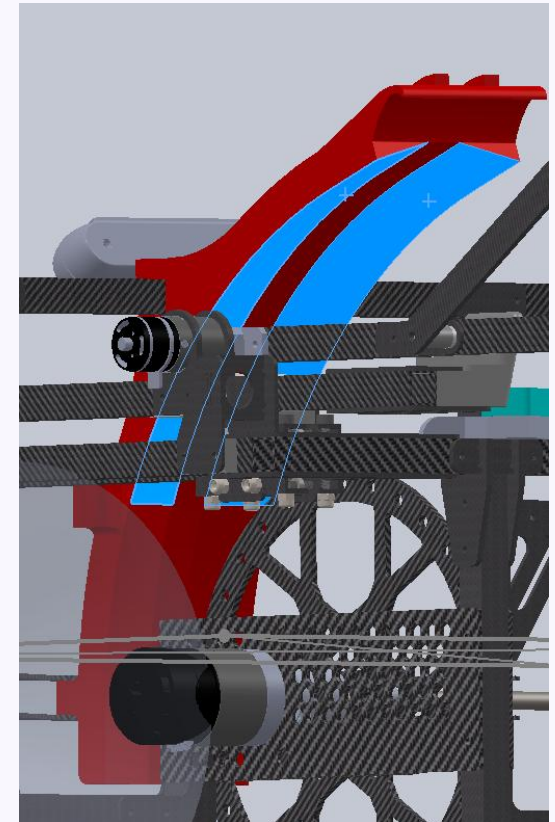


Mech-R2 Roller loader

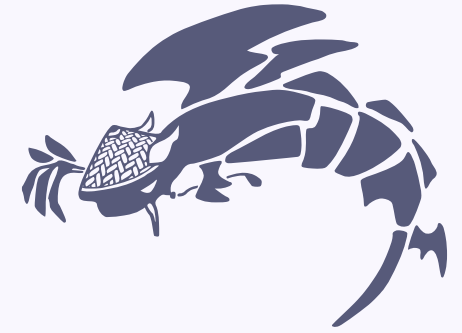


3dp Guide

- Objective: Guiding the ball into silo & hold the defense shield before game start
- Pros:
 1. Reduce one roller
 2. Can guide the off-center ball back to center
- Cons:
 1. Fragile 3dp
 2. Takes a long time to print (8+ hr)

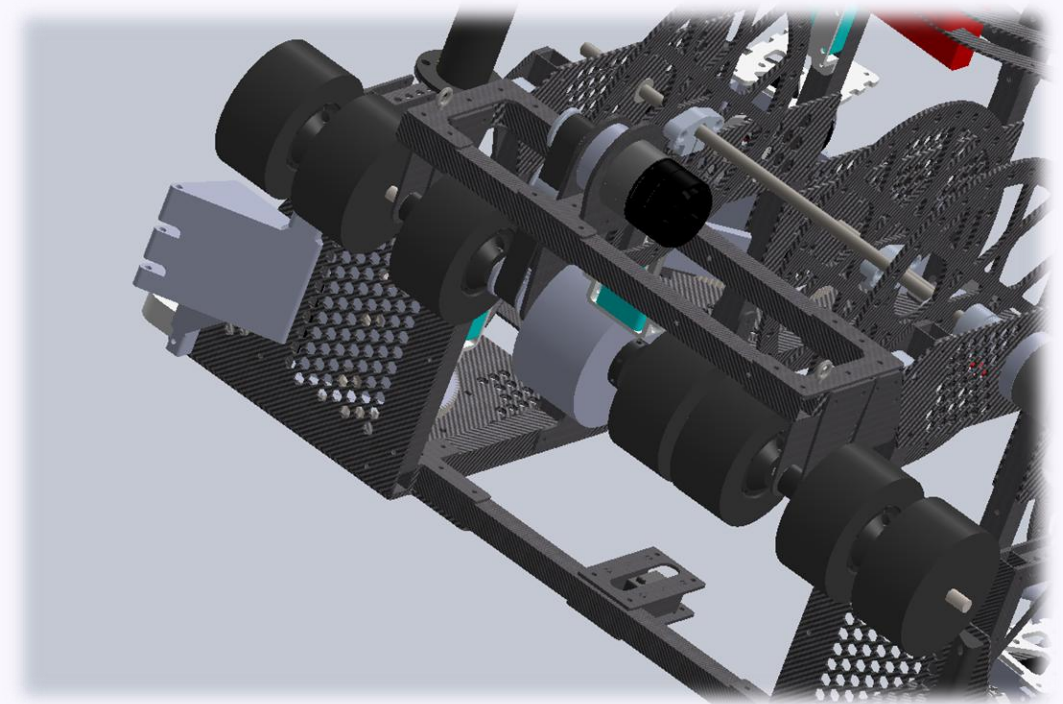


Mech-R2 Intake loader

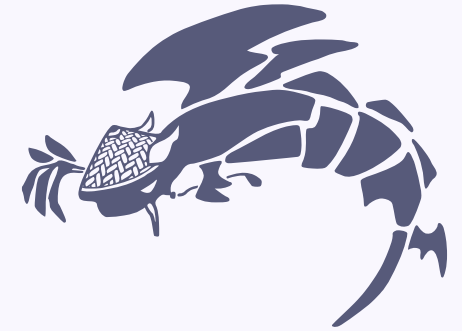


Mecanum and Omni wheels

- Array of omni wheels and mecanum wheels
- Vectored force pushing the ball to center
- Pros:
 - Enable ball intake for all angle
 - No accurate positioning required
- Cons:
 - Low efficiency intaking many balls
 - Solved with agile wheelbase pathing

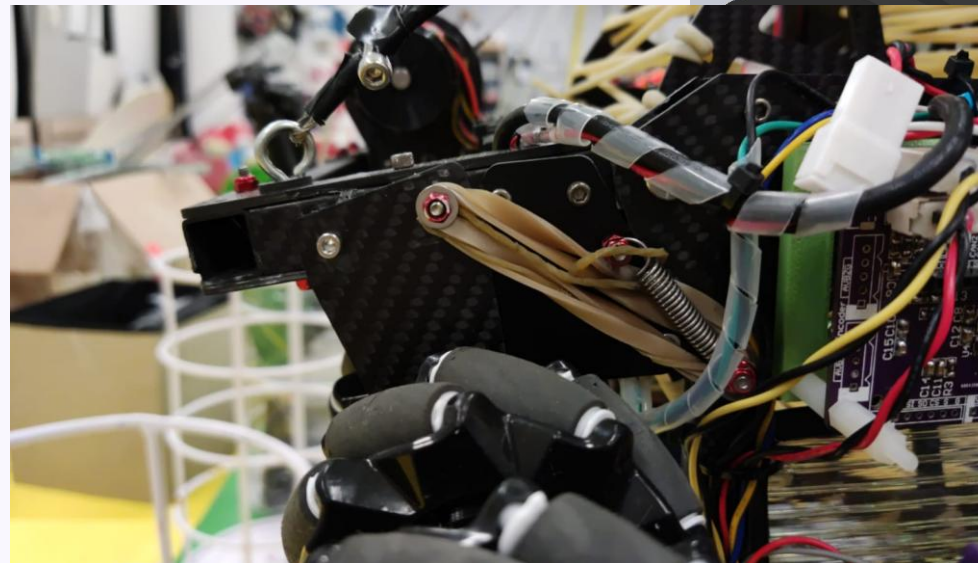
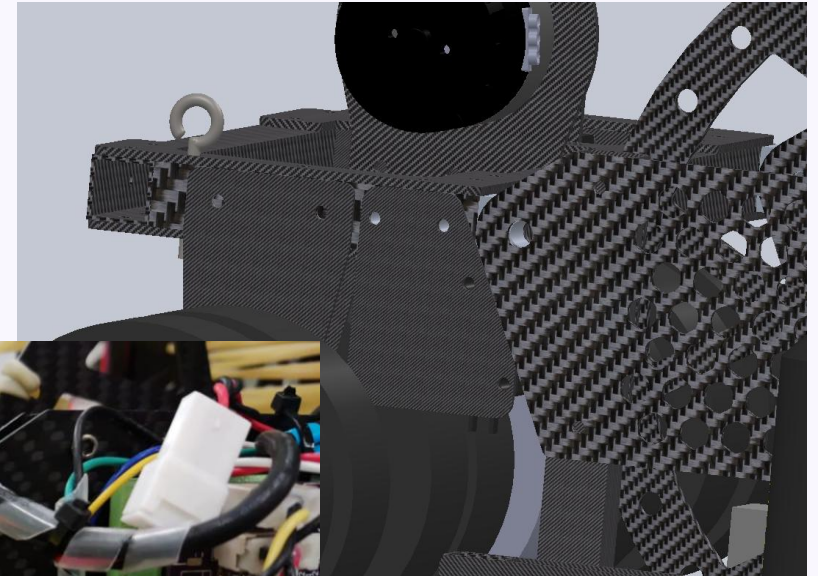


Mech-R2 Intake loader



Automatic tensioning system

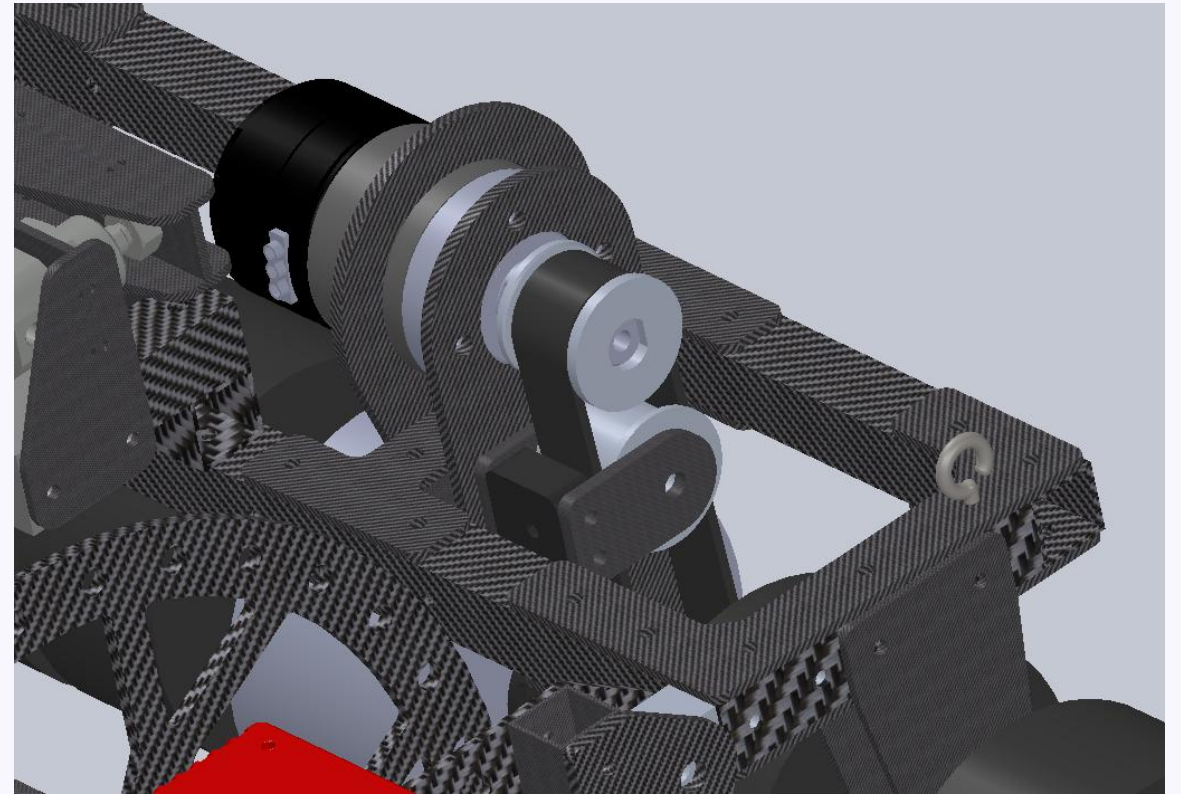
- Spring+rubberband tensioned intake
- Providing sufficient downforce for intaking balls
- Once and for all adjustment

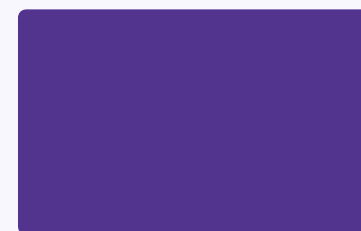


Mech-R2 Intake loader

Timing Belt drive shaft

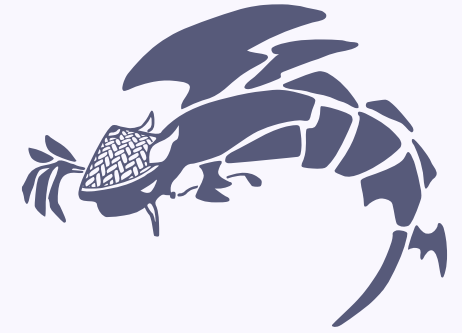
- Belt transmitting force stably
- High torque by playing with pulley ratio
- Compact design by stacking motor above





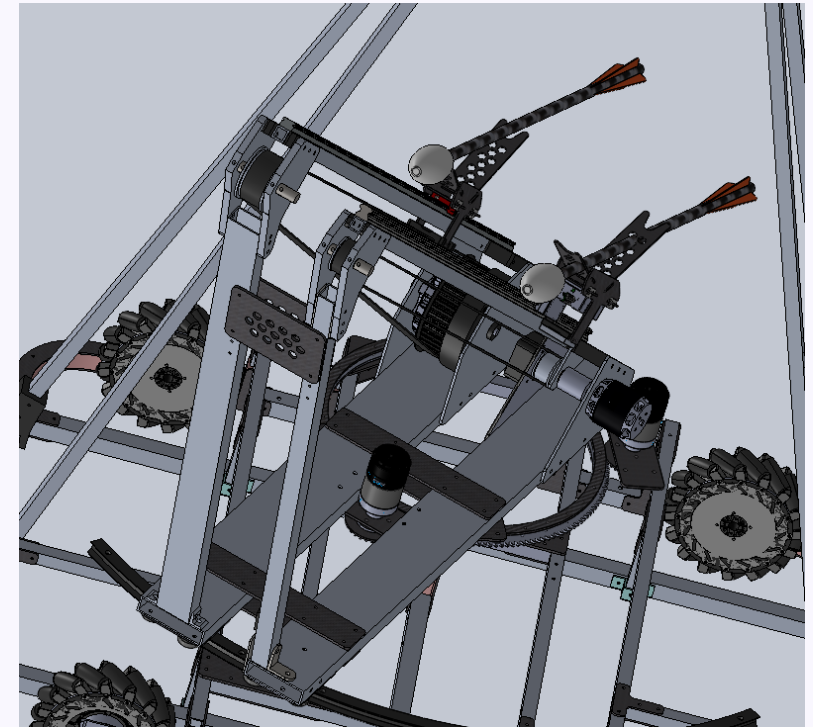
R&D

Mech-Linear shooter

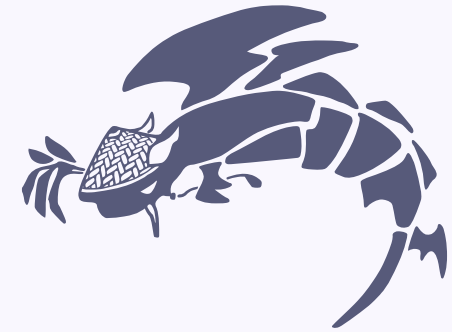


Linear shooter using AT8030 AT4130

- Shooting Robocon 2021 game props with belt drive linear shooter
- Versatile design for different projectile
- Attained satisfactory shooting range and accuracy
- Integrate with LIDAR to track target



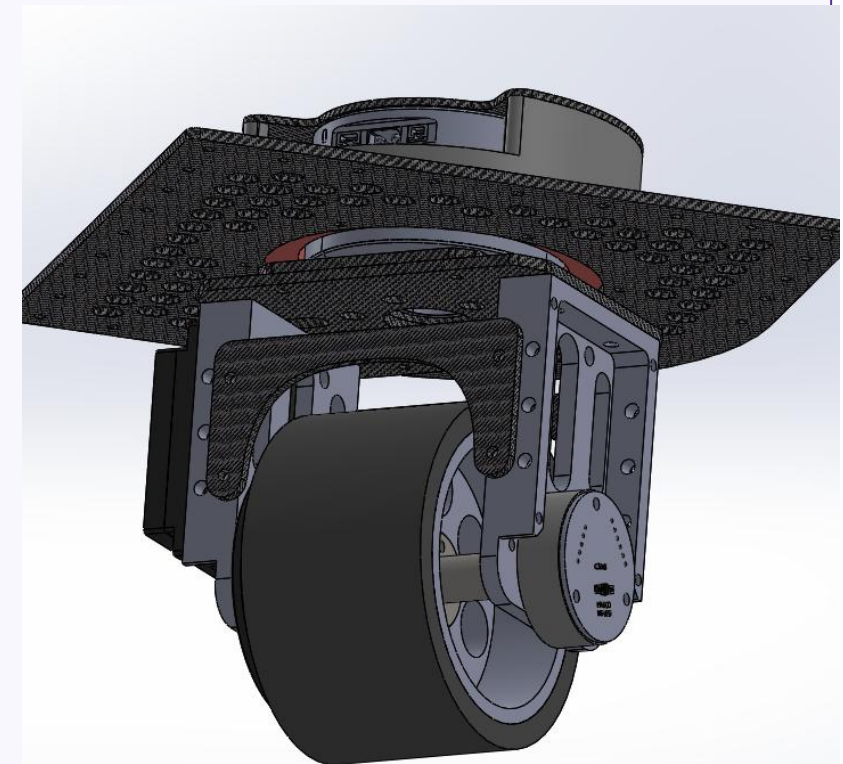
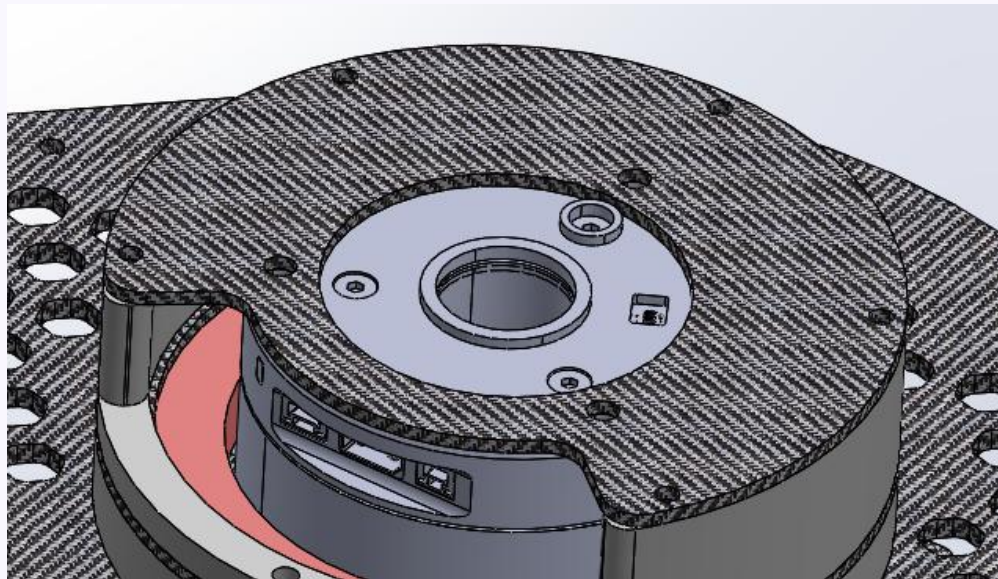
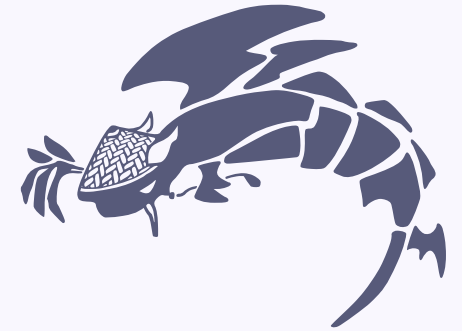
Mech-Linear shooter



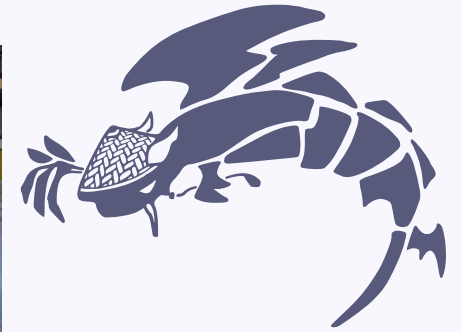
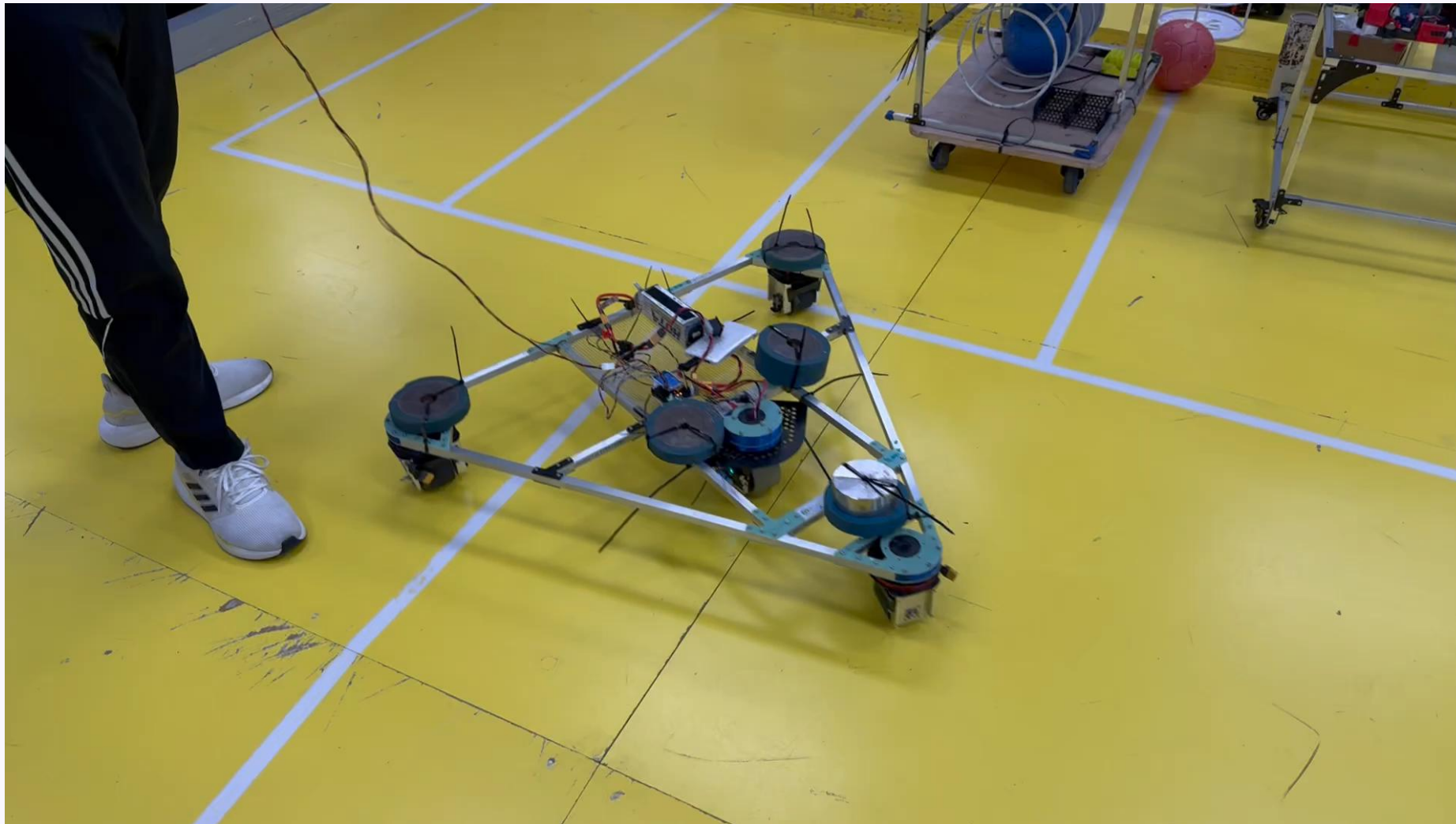
Mech-GM6020-V605 Direct Drive Independent Steering

Improvement of maintainability

- The steering part and driving parts can easily be separated into two parts
- Whole set of wheels can be removed from the wheelbase by removing three M4 screws.

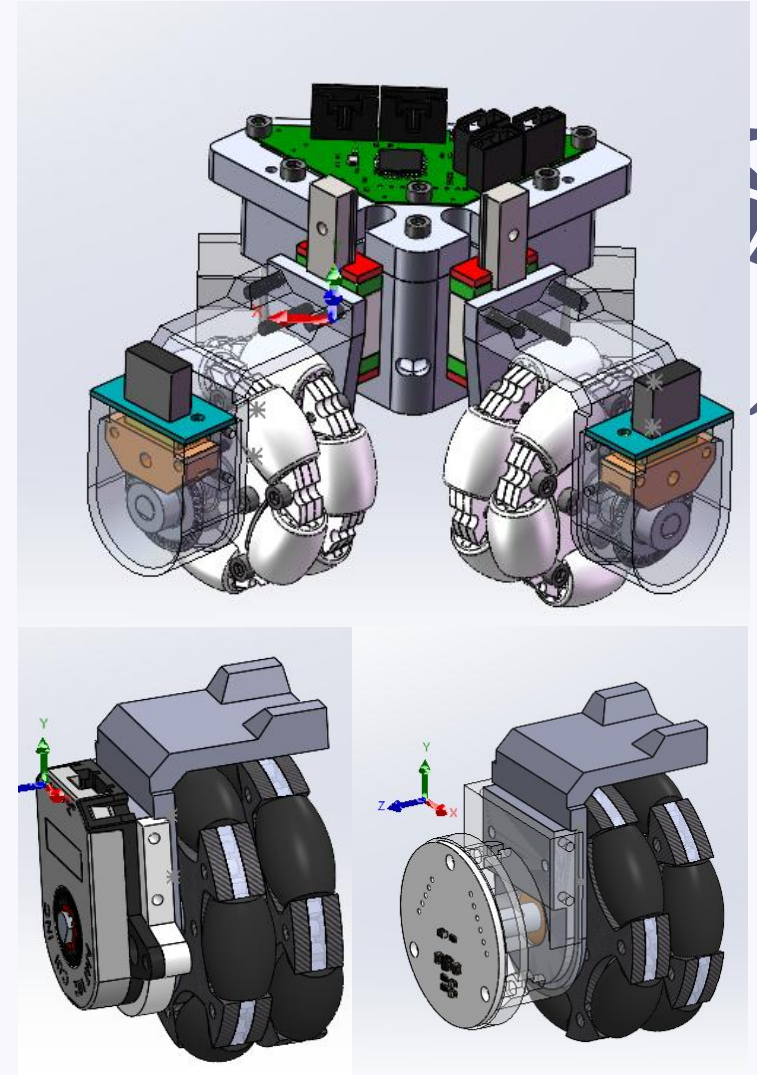


Mech-GM6020-V605 Direct Drive Independent Steering



Mech-XY encoder

- NEW MOUNT
- NEW WHEELS
- MAGNETIC ENCODER
- AMT102

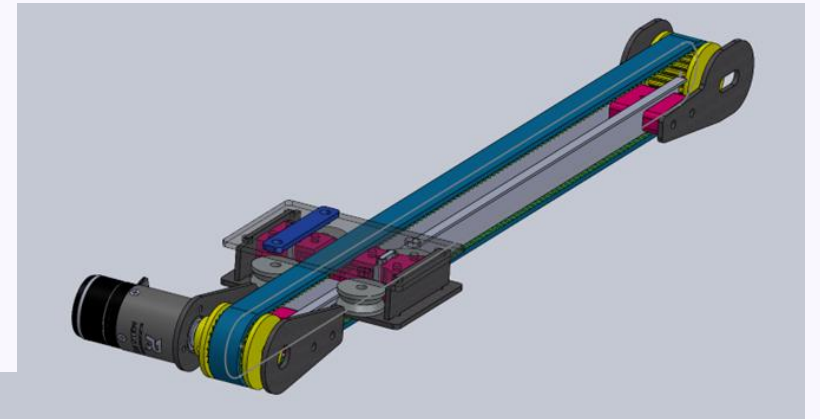
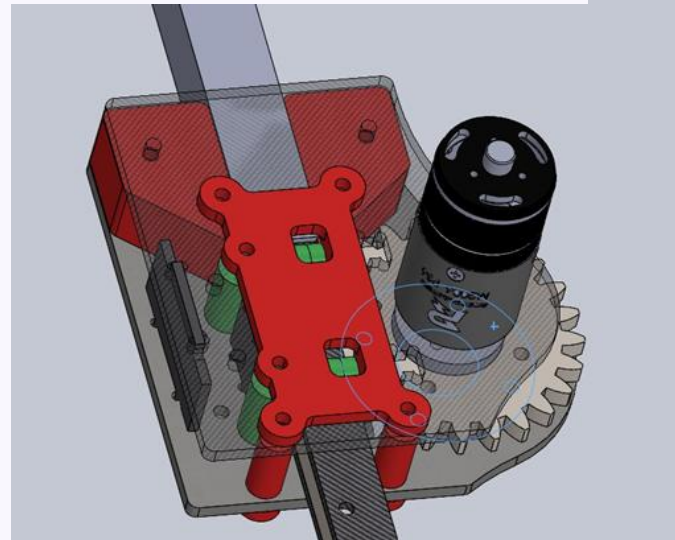
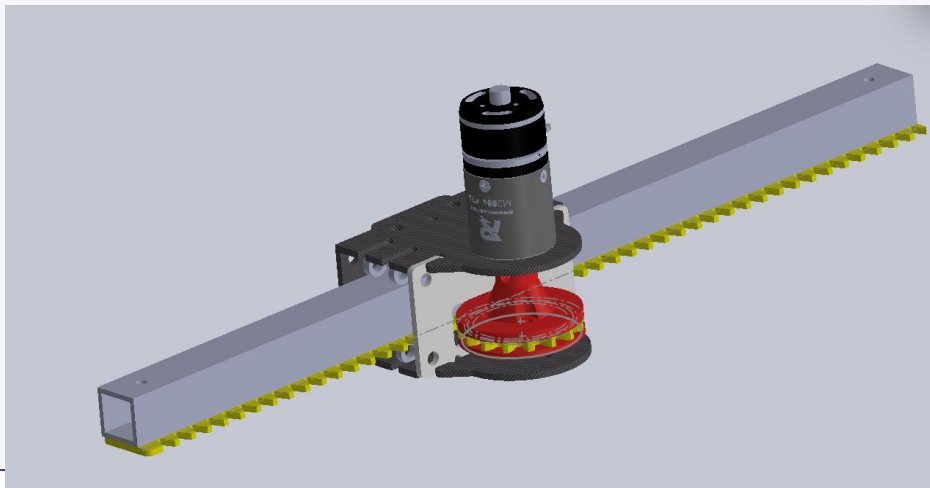


MECH-RND_LINEAR GUIDE

- **target:** A simple, easy replaceable mechanism which give a linear motion like cylinder but lighter and smaller.

TEASTING 3 ASPECT:

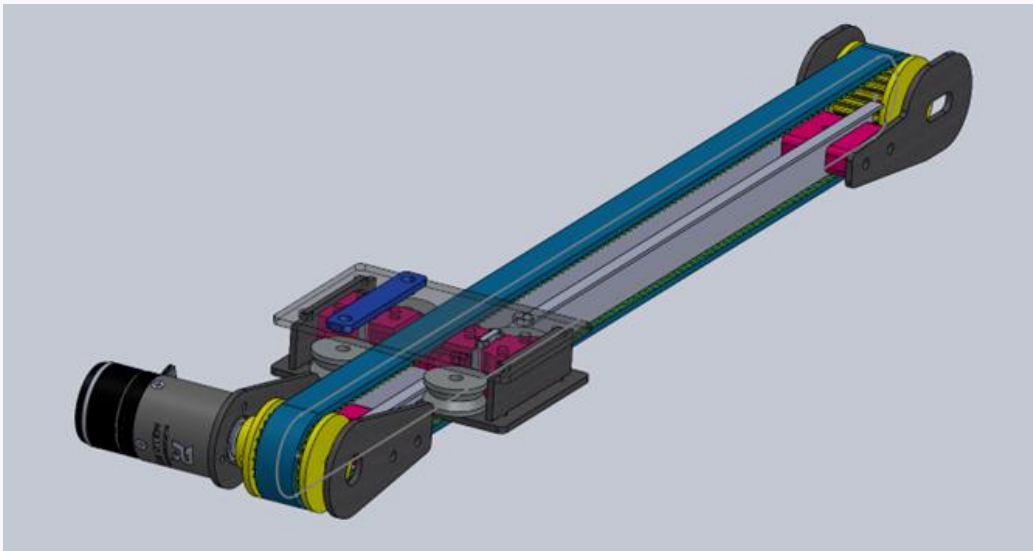
- Belt
- Electrical Cylinder
- Active sider



MECH-RND_LINEAR GUIDE

BELT LINEAR GUIDE

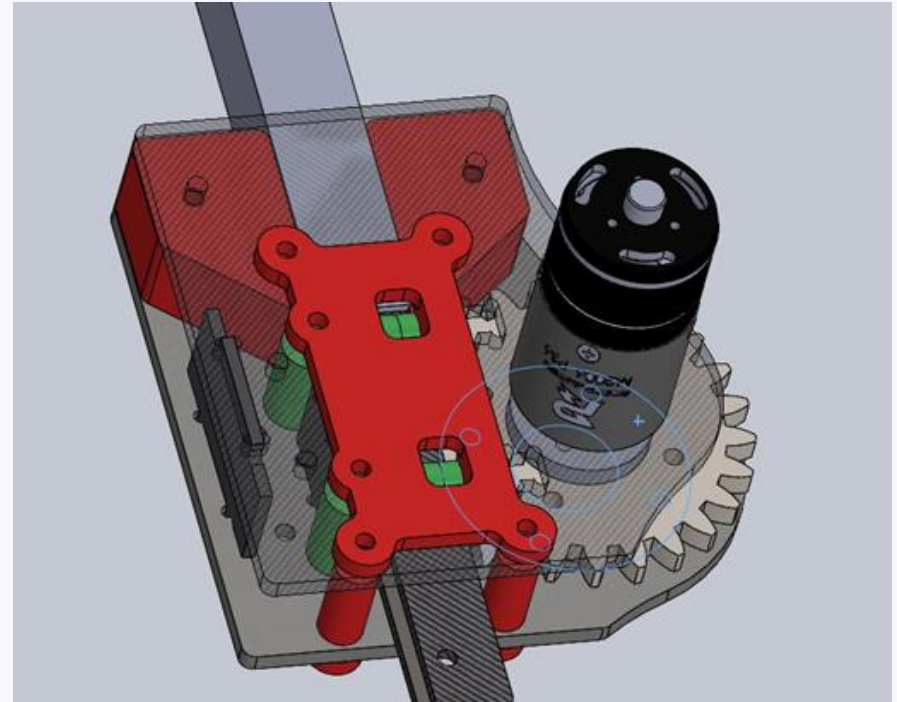
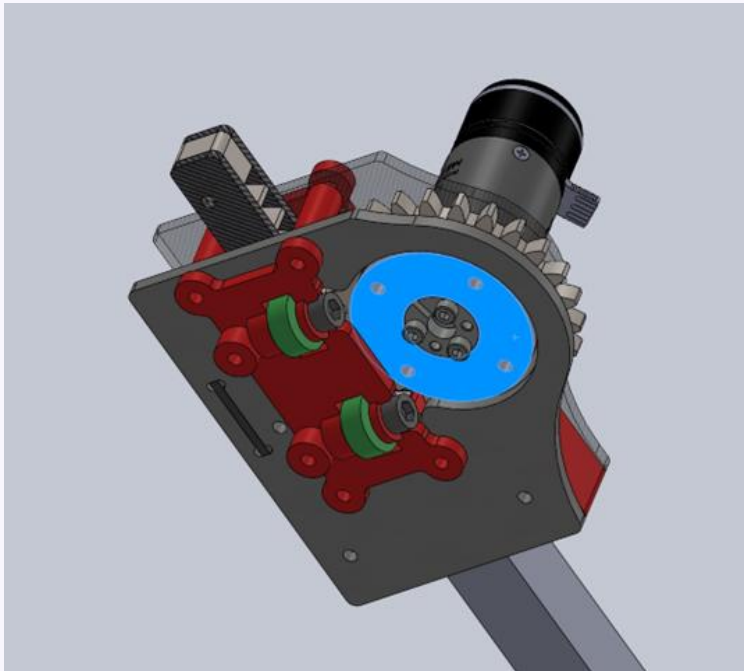
- Driven by small rm motor(rm2006)
- Use 3m belt and bearing allow linear movement
- Small and convenient to use (to replace 1m guide)



MECH-RND_LINEAR GUIDE

ELECTRICAL CYLINDER

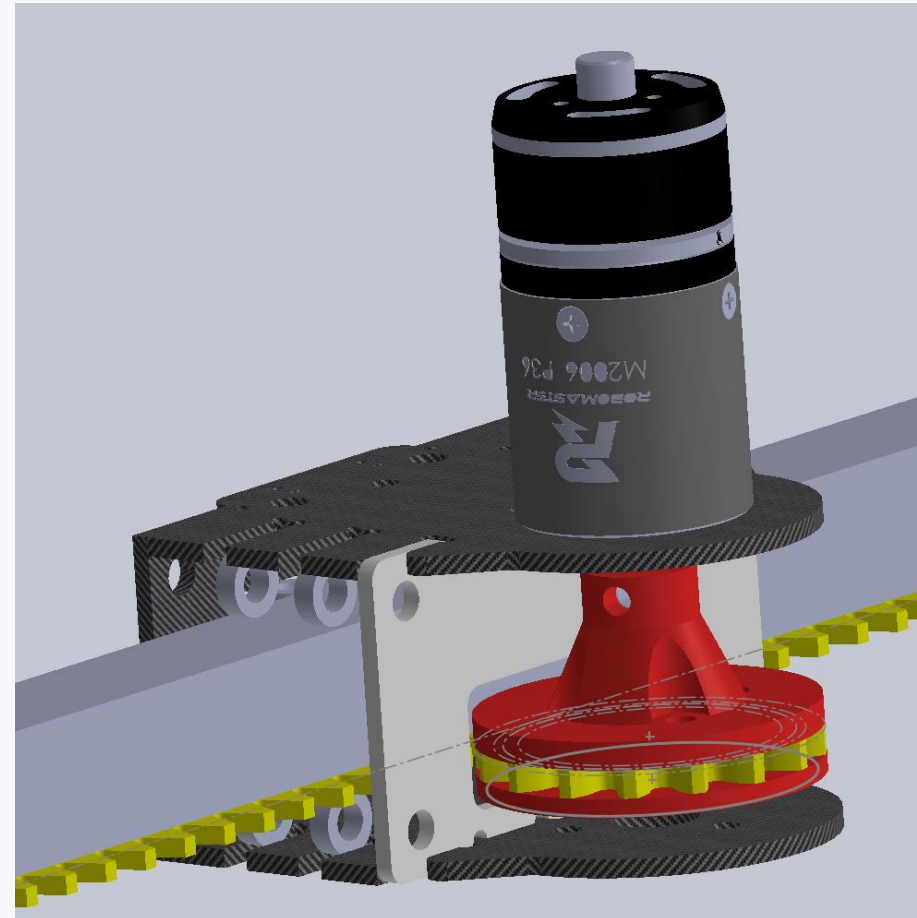
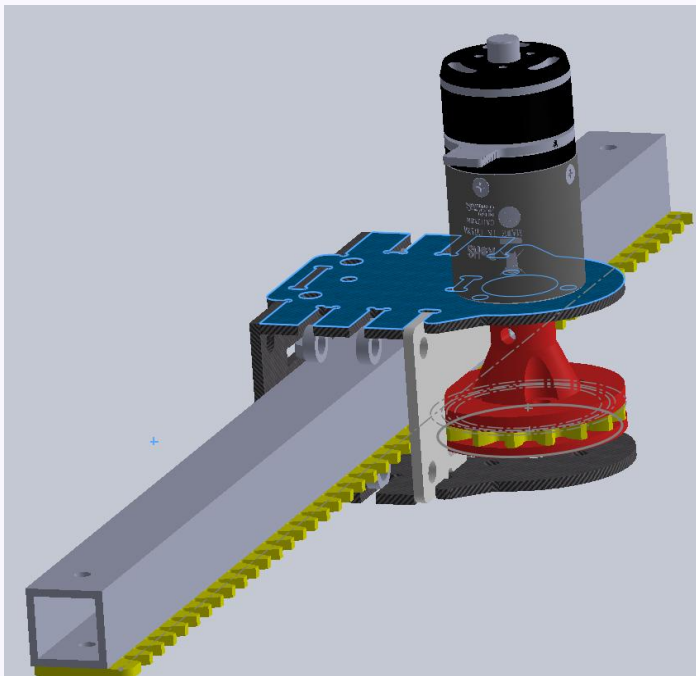
- Act like a cylinder which can contract and extend.
- The whole system can easily install on a random 1515 tube without drilling a single hole on it.



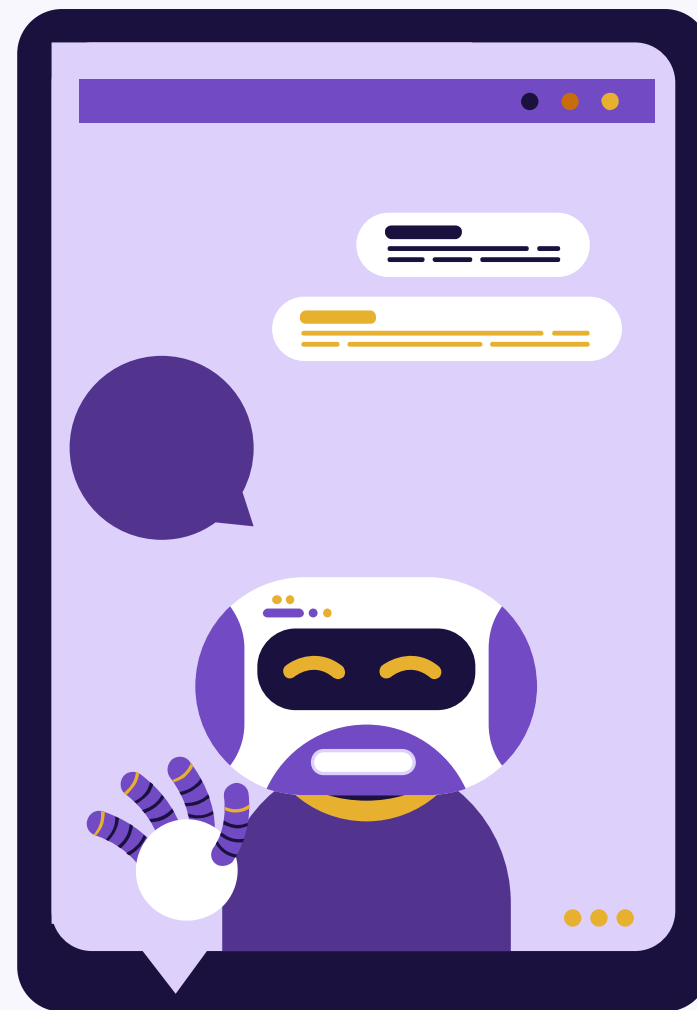
MECH-RND_LINEAR GUIDE

ACTIVE SIDER

- Sider driven by small rm2006 motor
- Allow active linear motion
- And easy install on tubes(only two holes)



Software





Software - Table of contents

01

R1 SW

03

Lidar

05

ROS

02

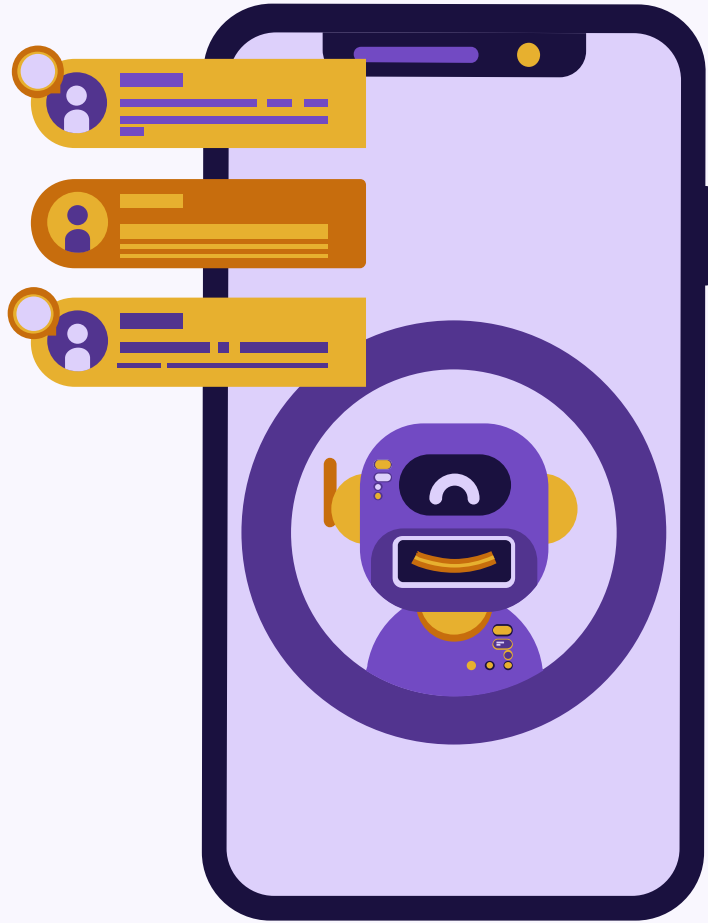
R2 SW

04

CV

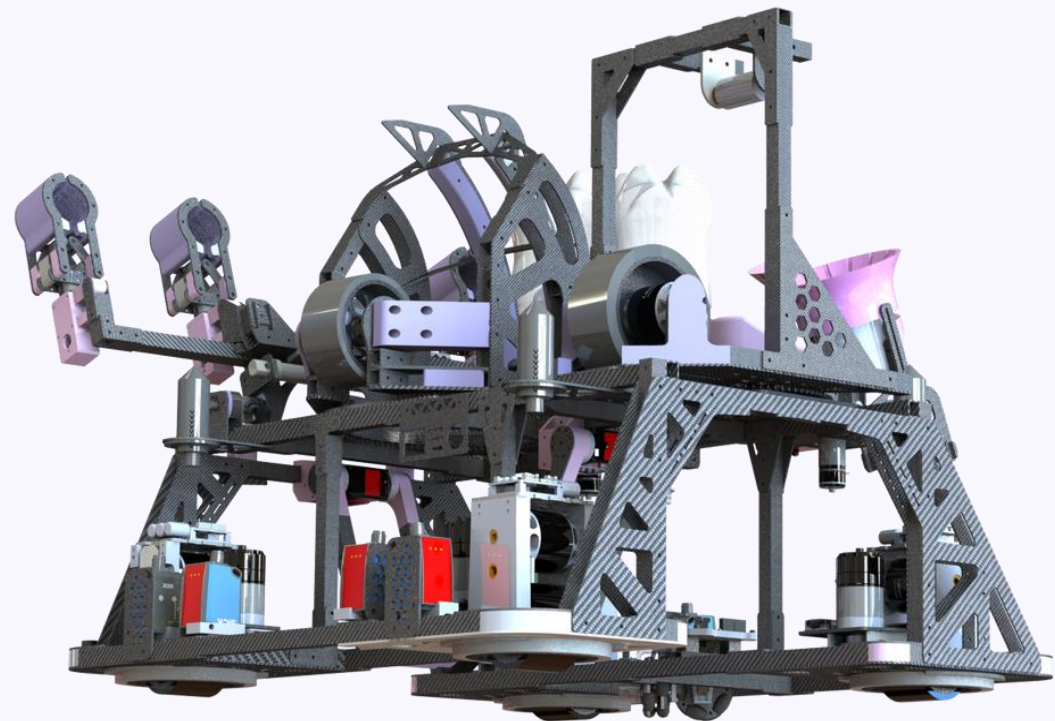
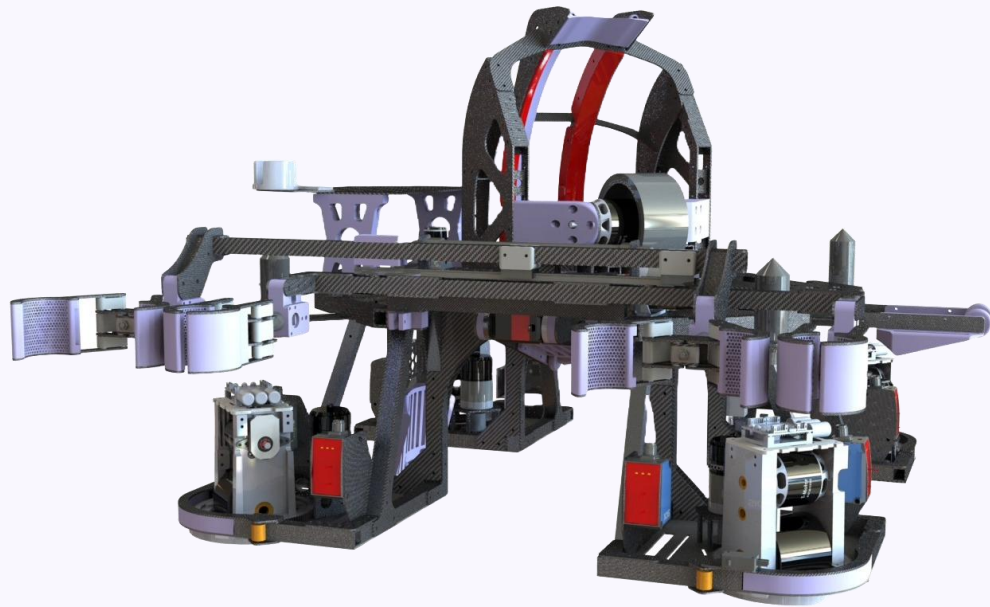
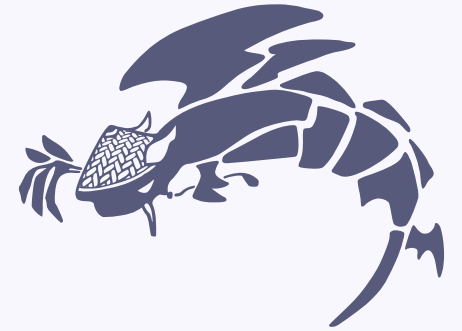
06

Q&A





Software – R1



Software – R1 General Things



Area 1
Pathing



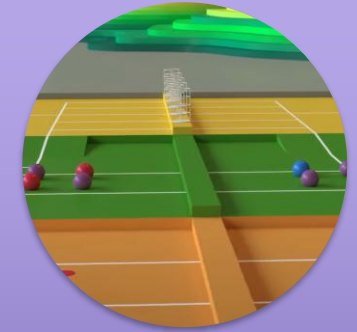
Area 2
Pathing



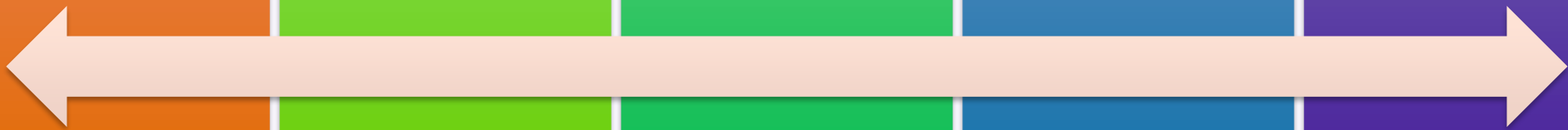
Shooter
Regression



Laser /Line
sensor



Red-Blue
field
flipping



R1 Area 1 pathing

During our tuning, we've done the following things:



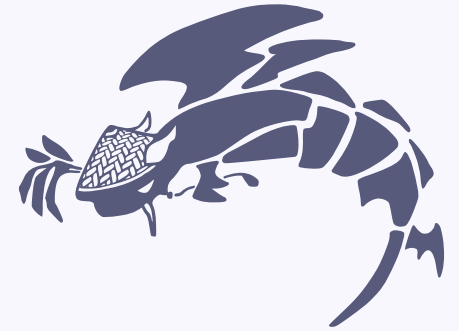
Used Trapezoidal & Bezier pathing



Tried and test more path



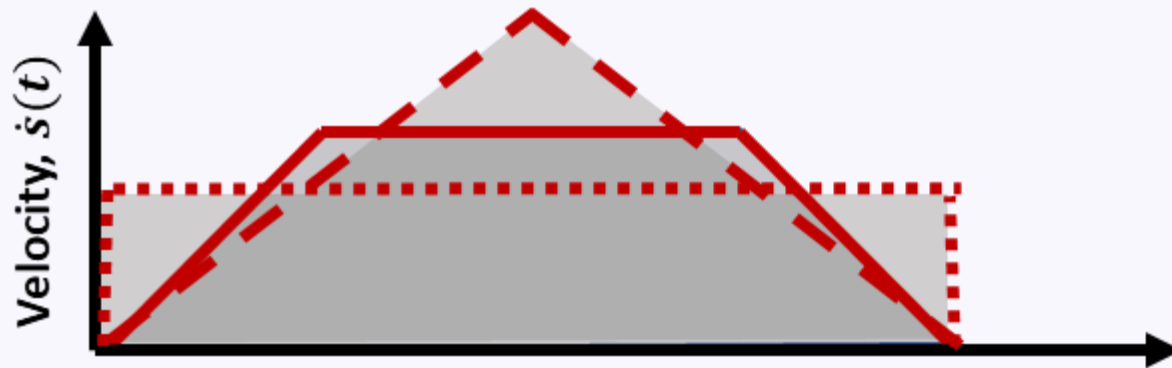
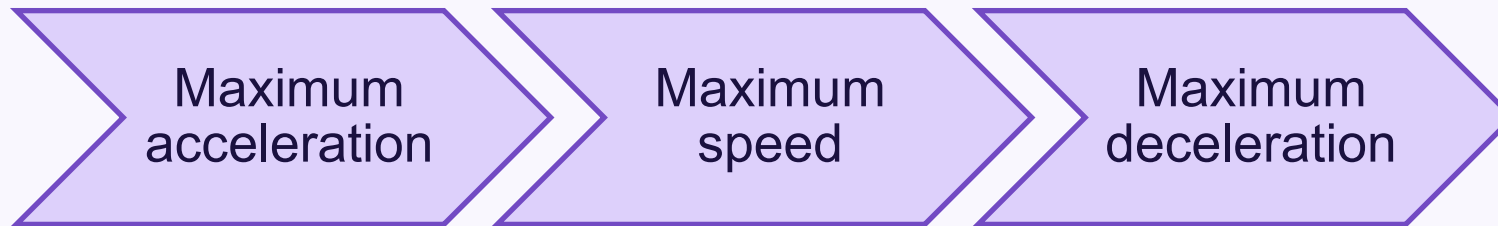
Retracted Clamp for Shorter path



Trapezoidal Pathing



This is a **pathing technique** for straight line that requires the following params:

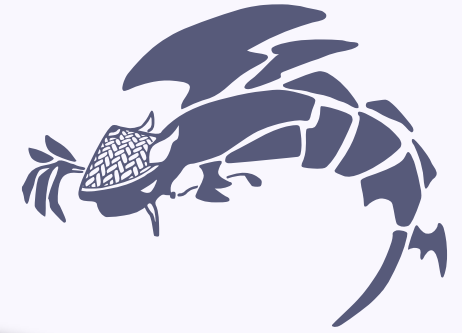


They represent different property of the path, which are calculated based on time elapsed / current position.

Pre-steering are also involved to avoid collision and unwanted behaviors.

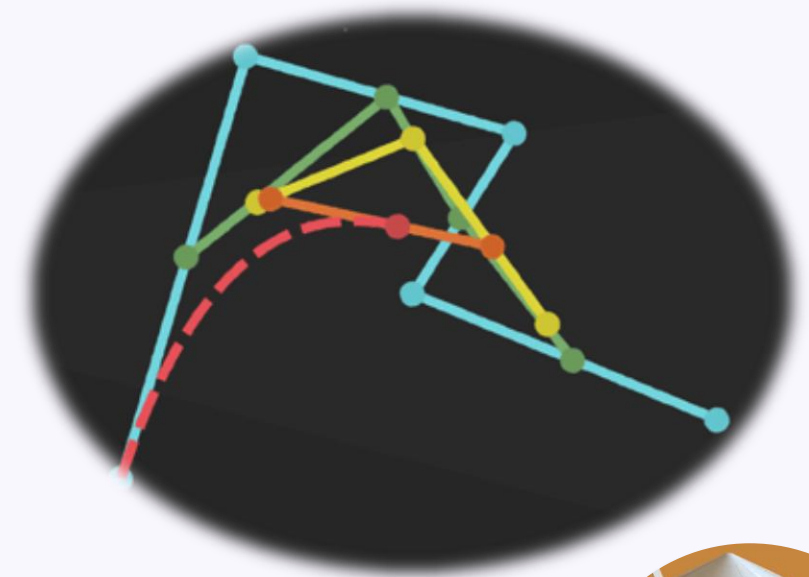
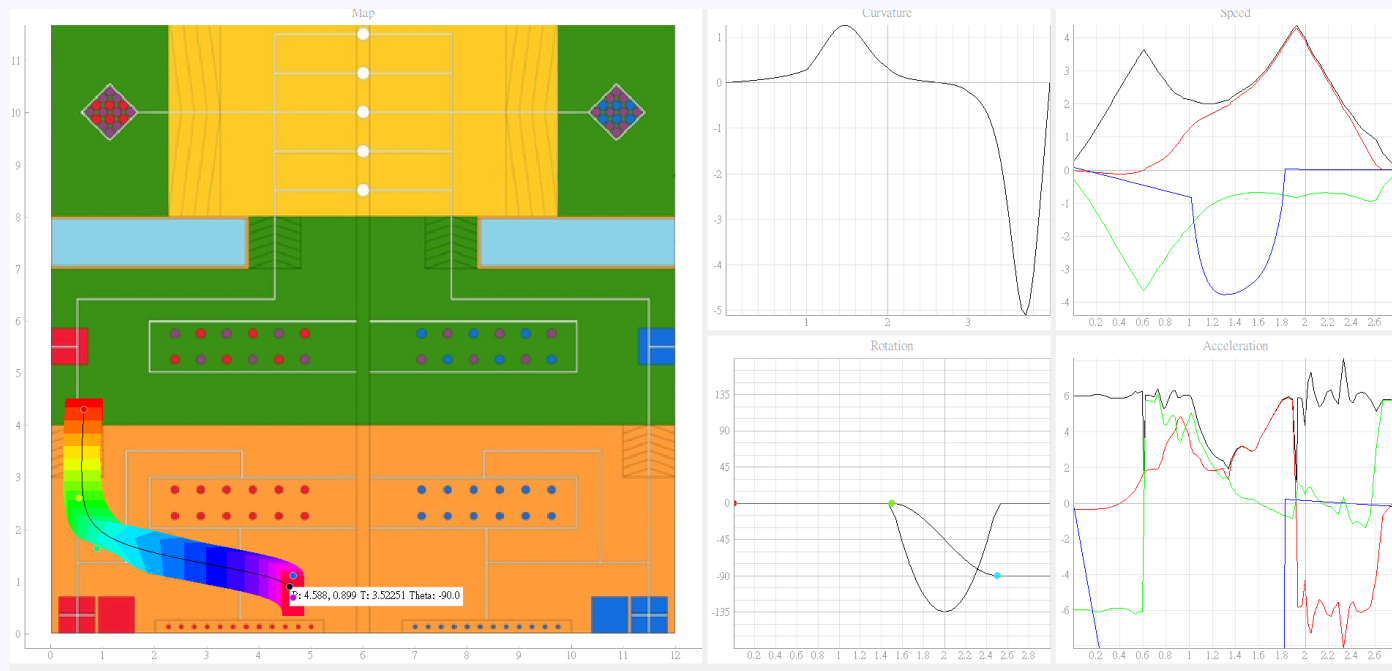


Bezier Pathing

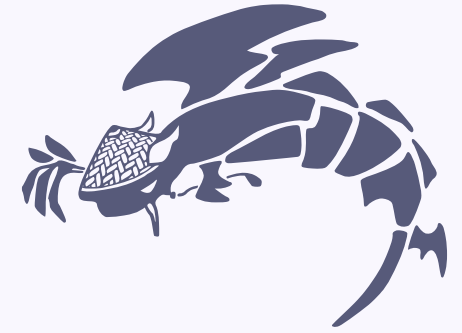


This is a **pathing technique** for complex pathing

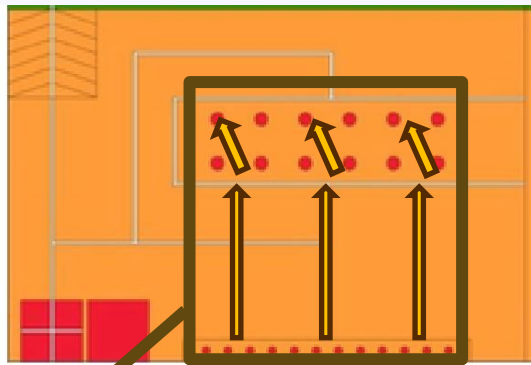
The concept is to make use of Bezier curve,
And calculate the optimal speed the finish the pathing.



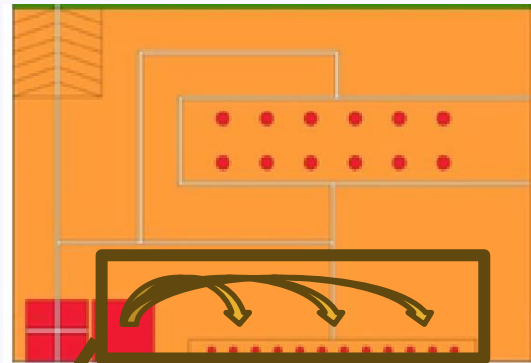
Pathing Distribution



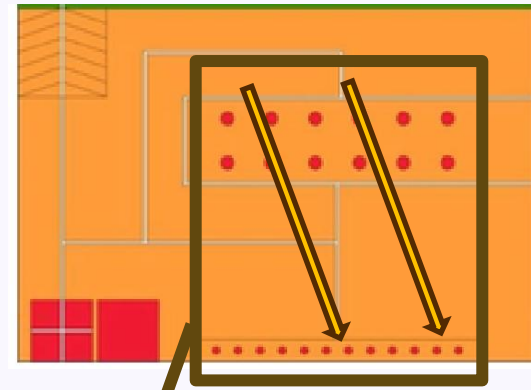
Base on the property of different paths, we've distribute them into different area.



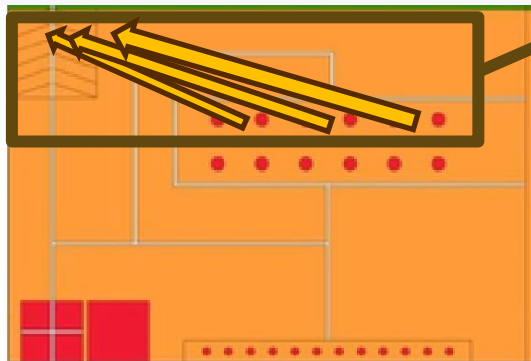
Rack -> Plant
Trapezoidal



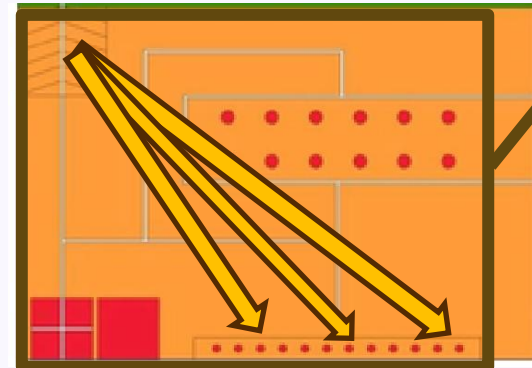
SZ -> Rack
Bezier



Plant -> Rack
Bezier

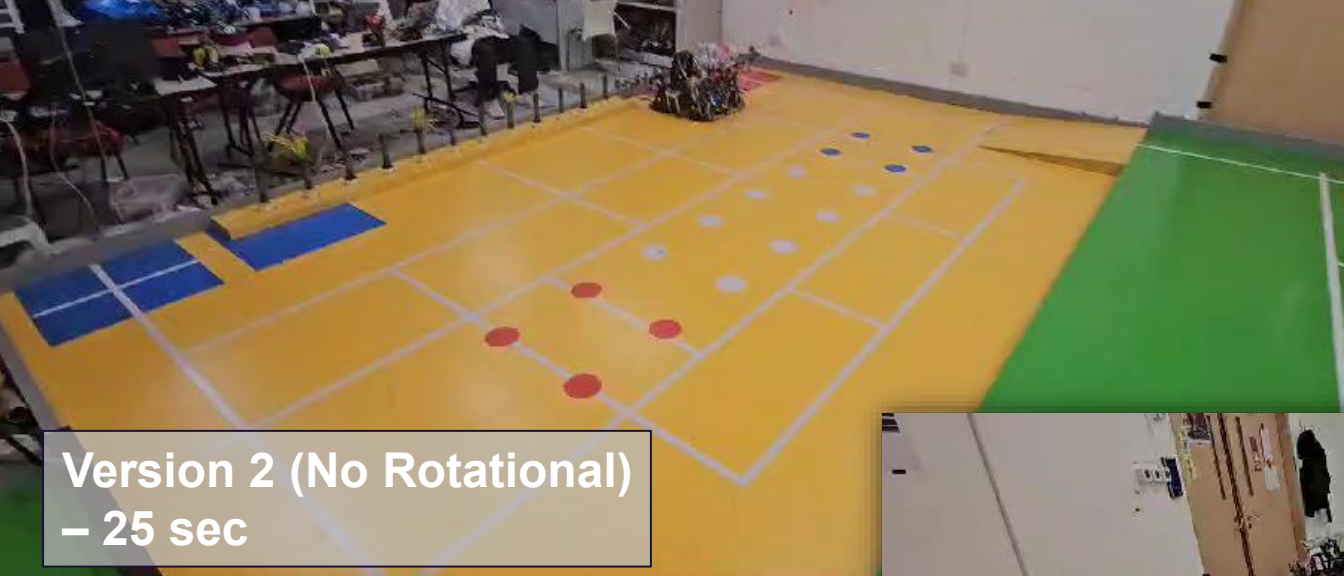


Plant -> Area 2
Bezier



Area 2 -> Rack
Bezier

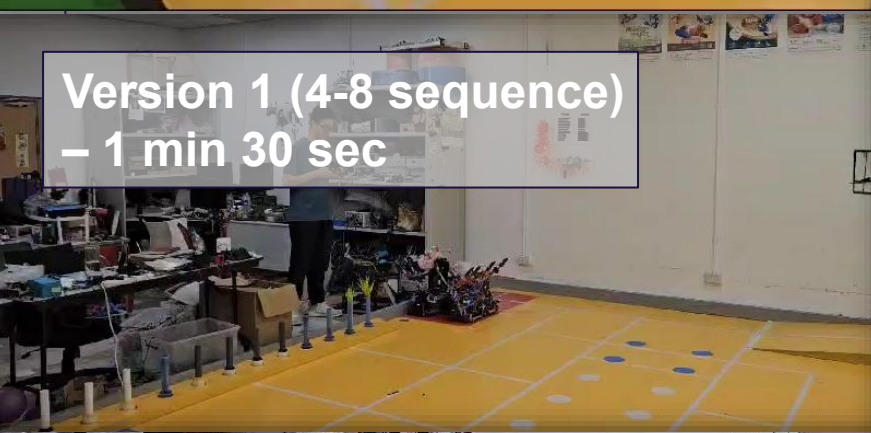




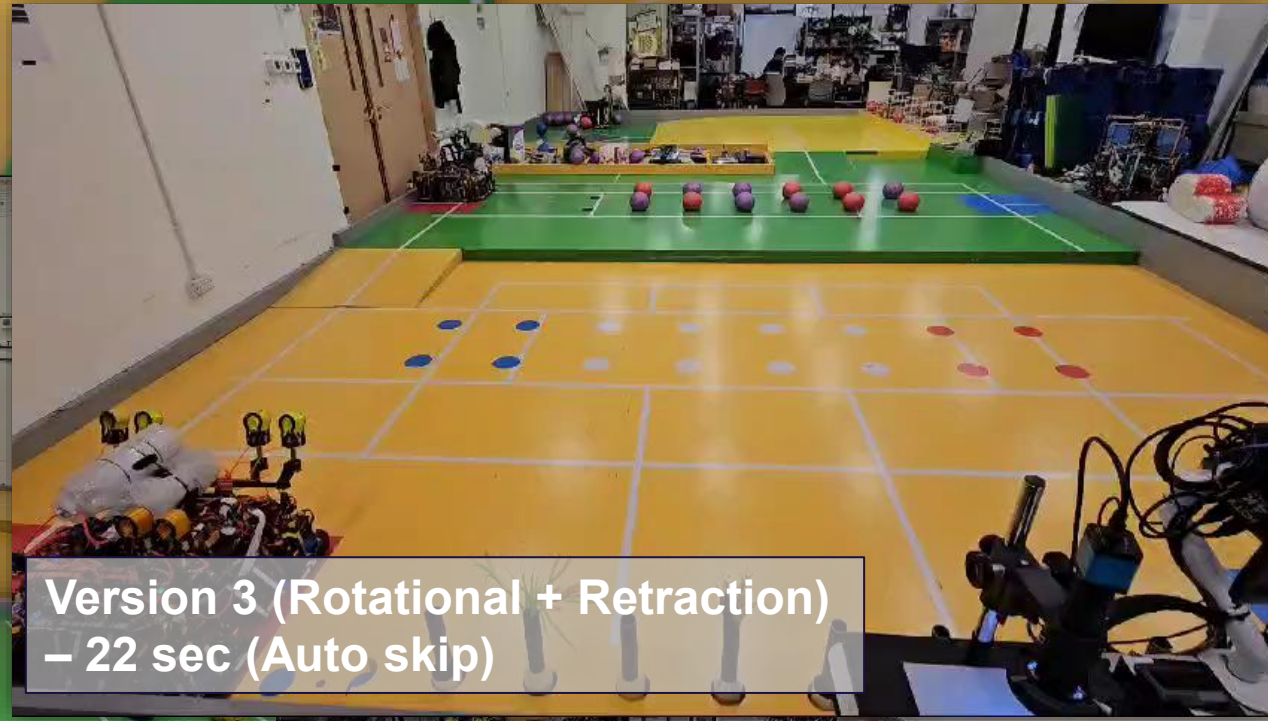
Version 2 (No Rotational)
– 25 sec



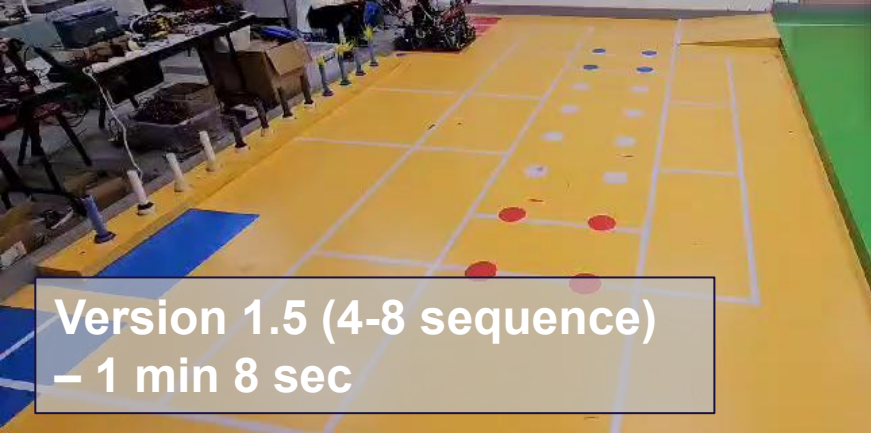
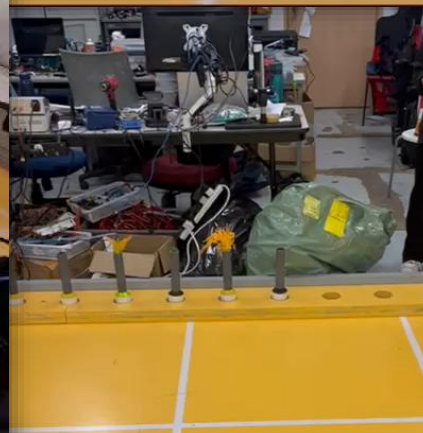
Version 3 (Rotational + Retraction)
– 25 sec (Manual Confirm)



Version 1 (4-8 sequence)
– 1 min 30 sec



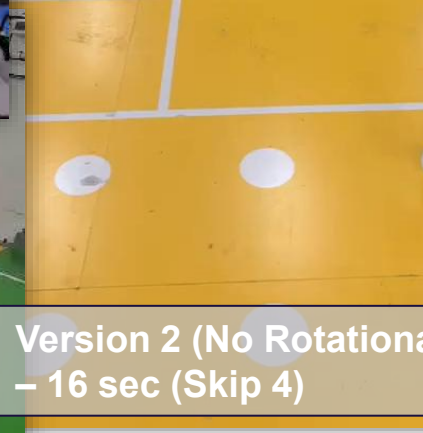
Version 3 (Rotational + Retraction)
– 22 sec (Auto skip)



Version 1.5 (4-8 sequence)
– 1 min 8 sec

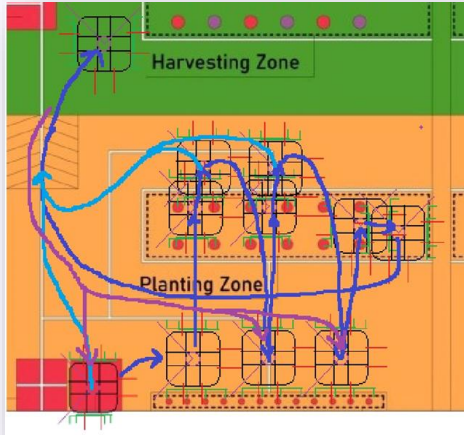


Version 1.9 (Manual No Rotational)
– 49 sec

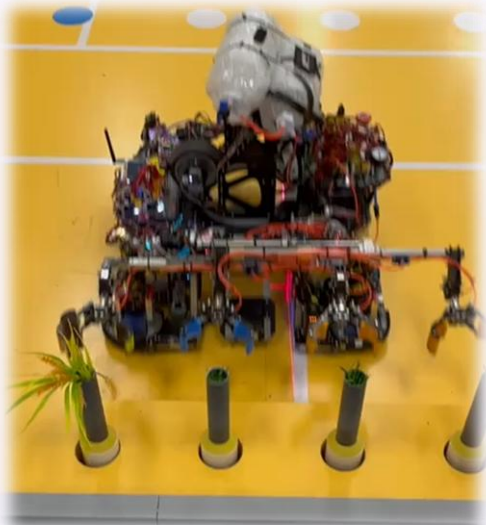


Version 2 (No Rotational)
– 16 sec (Skip 4)

- Path Decisions -

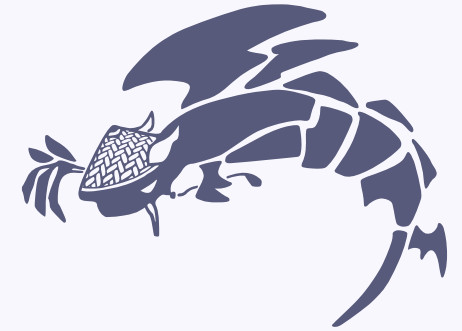


- Path Retries -



Final pathing decision

- Result -



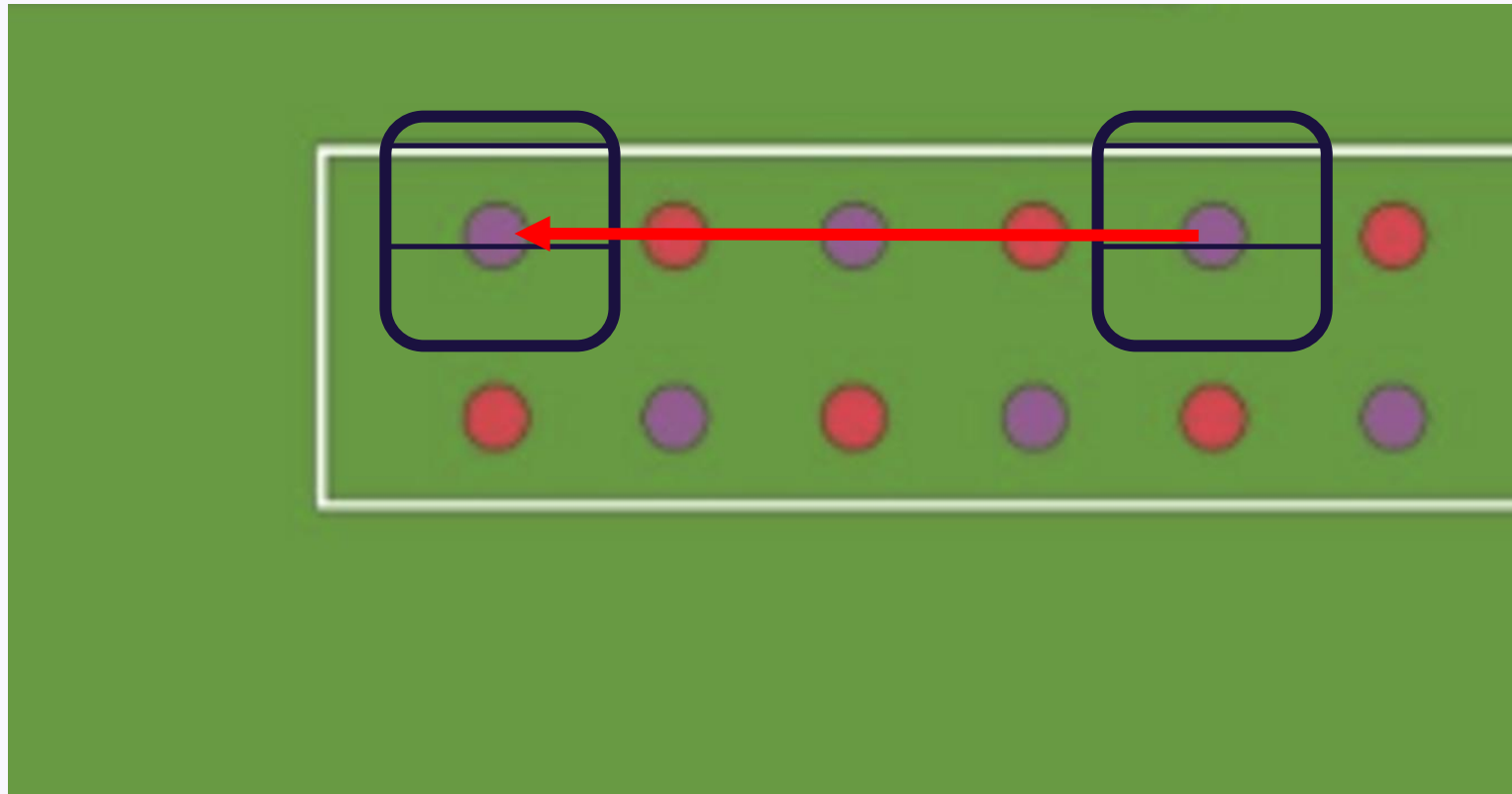
Final Version (No rotational + Retraction)
- 20 sec (Manual confirm)



FD R1 Area 2 pathing

Ideal case: Both shooter working

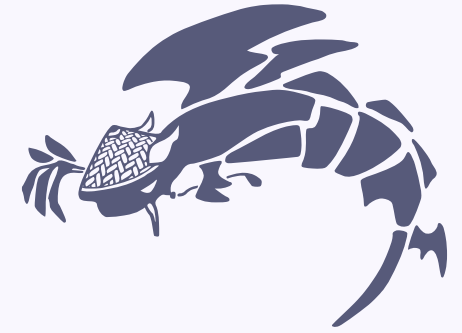
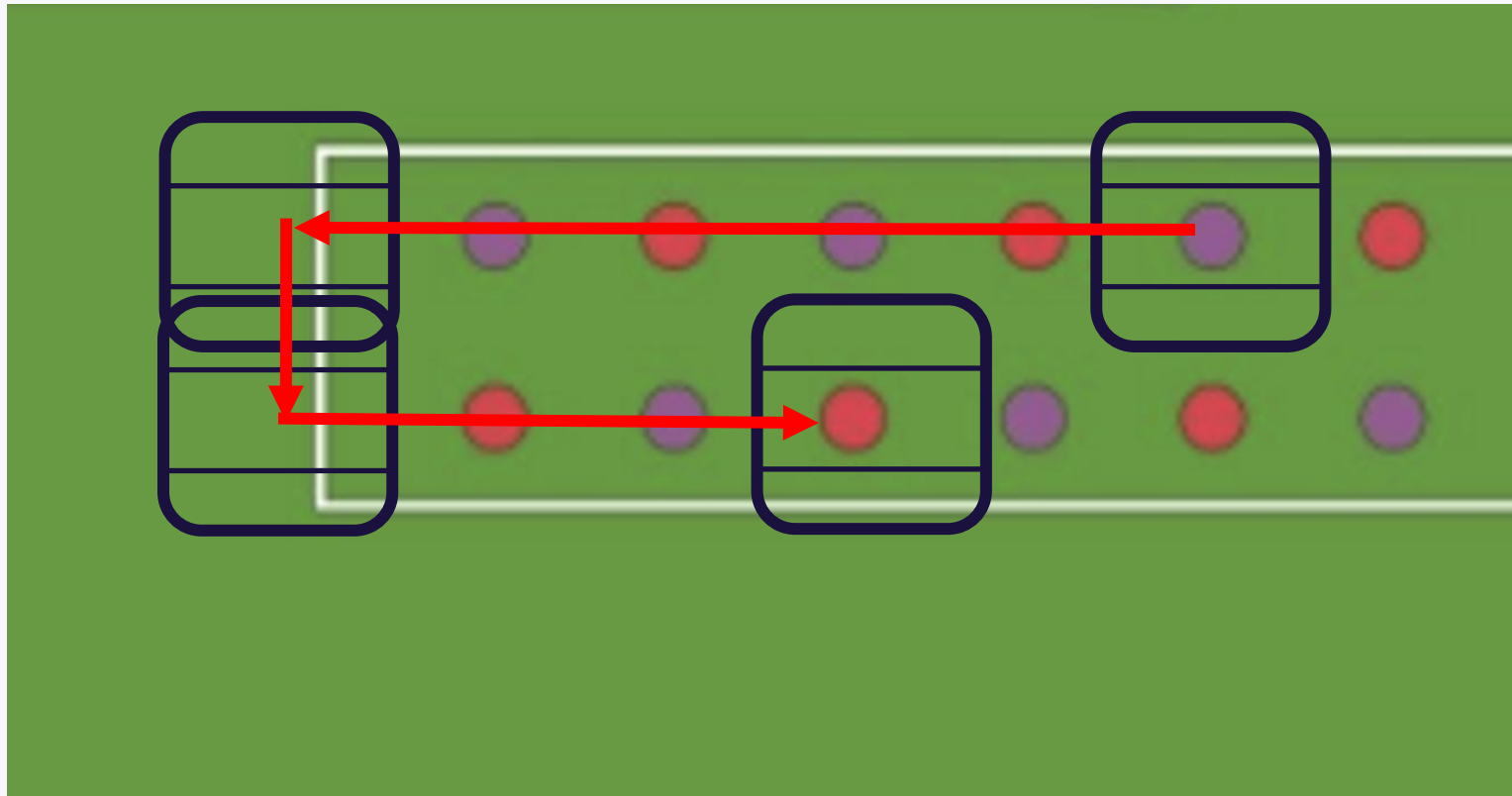
Ideology: Use single Trapezoidal pathing to perform intra-row movement



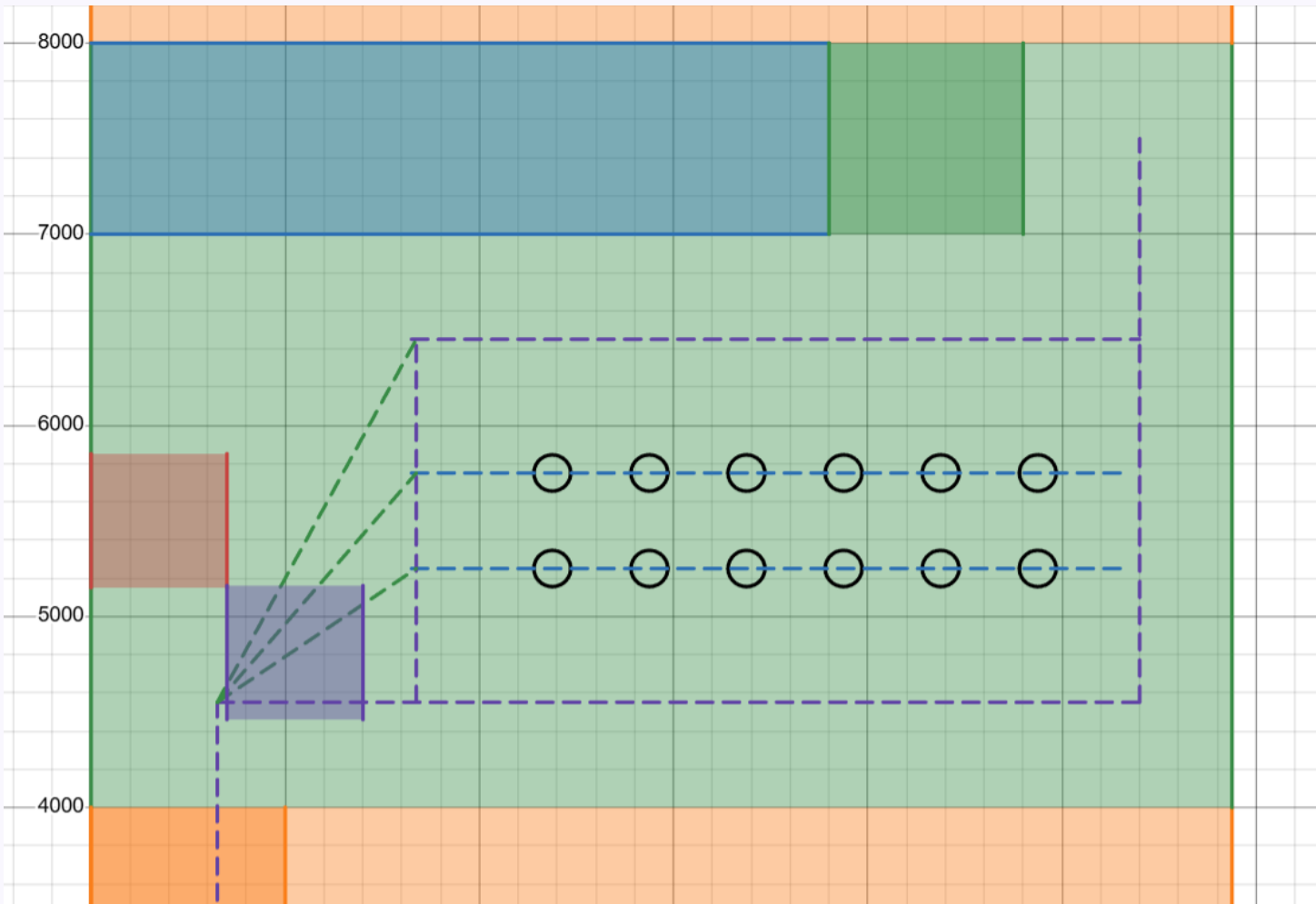
FD R1 Area 2 pathing

Q: What if one shooter malfunctioned?

A: Use multiple Trapezoidal pathing to move from 1 row to another



FD R1 SW – Area 2 pathing



How the robot handle path conversion?

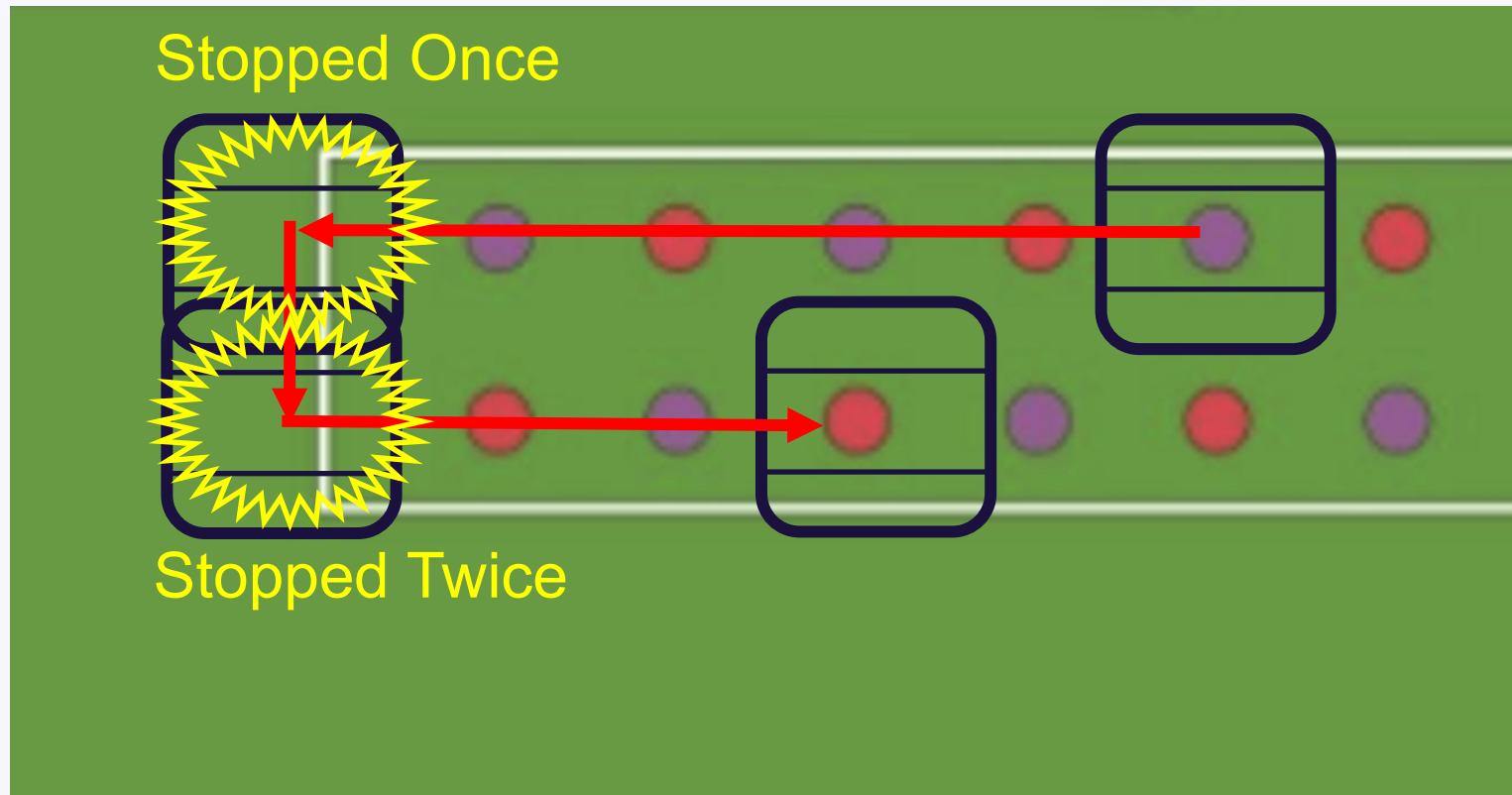
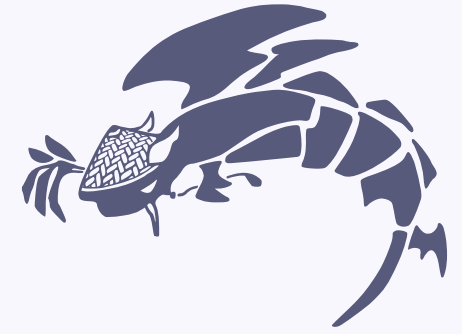
- Direct conversion:
- Directly go to the closet conjunction
- Indirectly conversion:
(including more than one conversion between the start and the end)
- Hard-coded direction till the last conversion



WD R1 Area 2 pathing

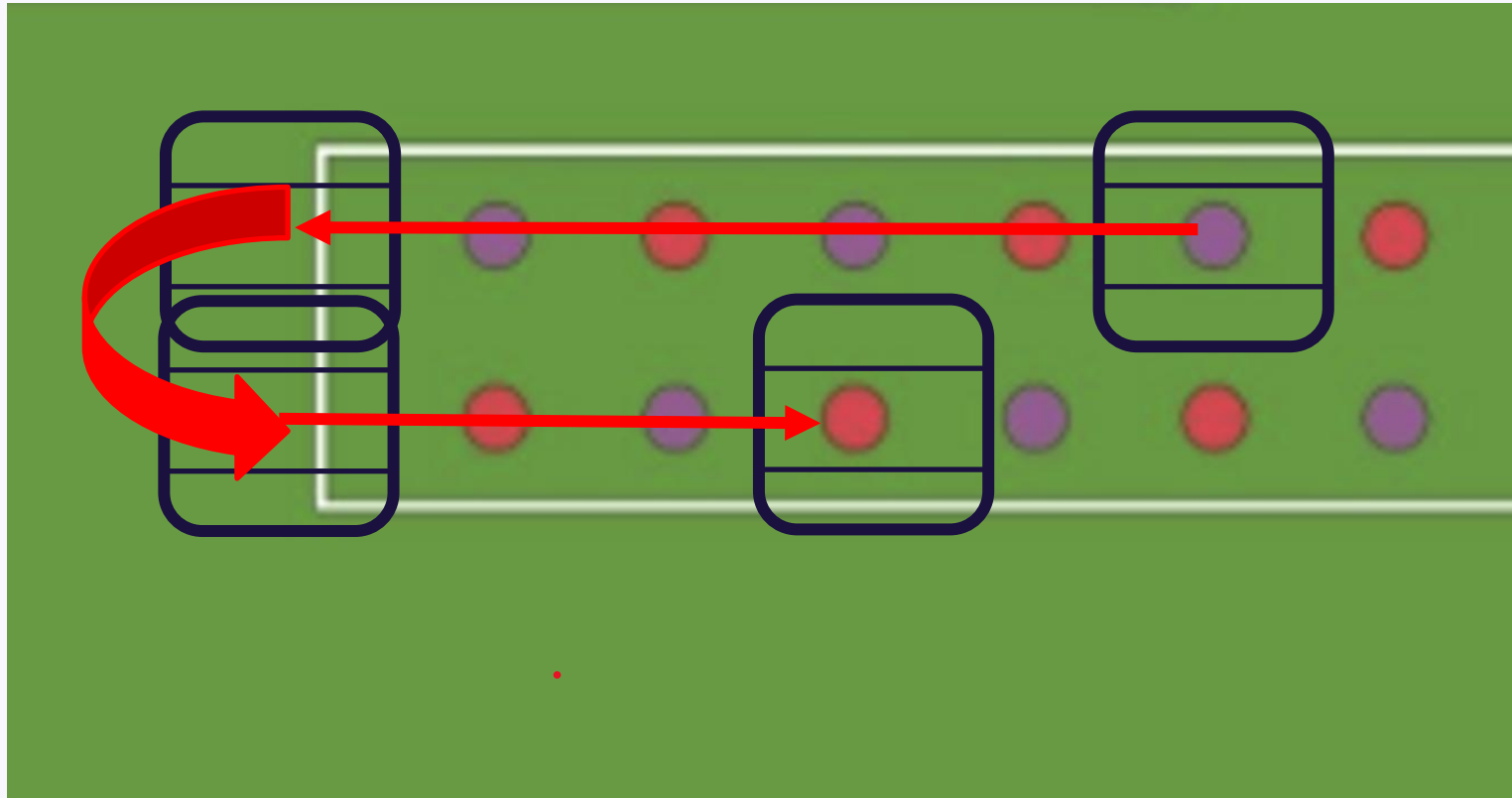
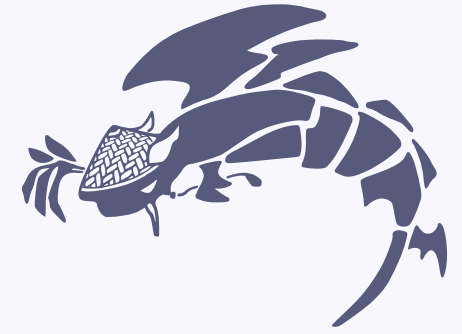
Q: Why WD didn't use this?

A: because i think trap pathing is slow as it stops twice



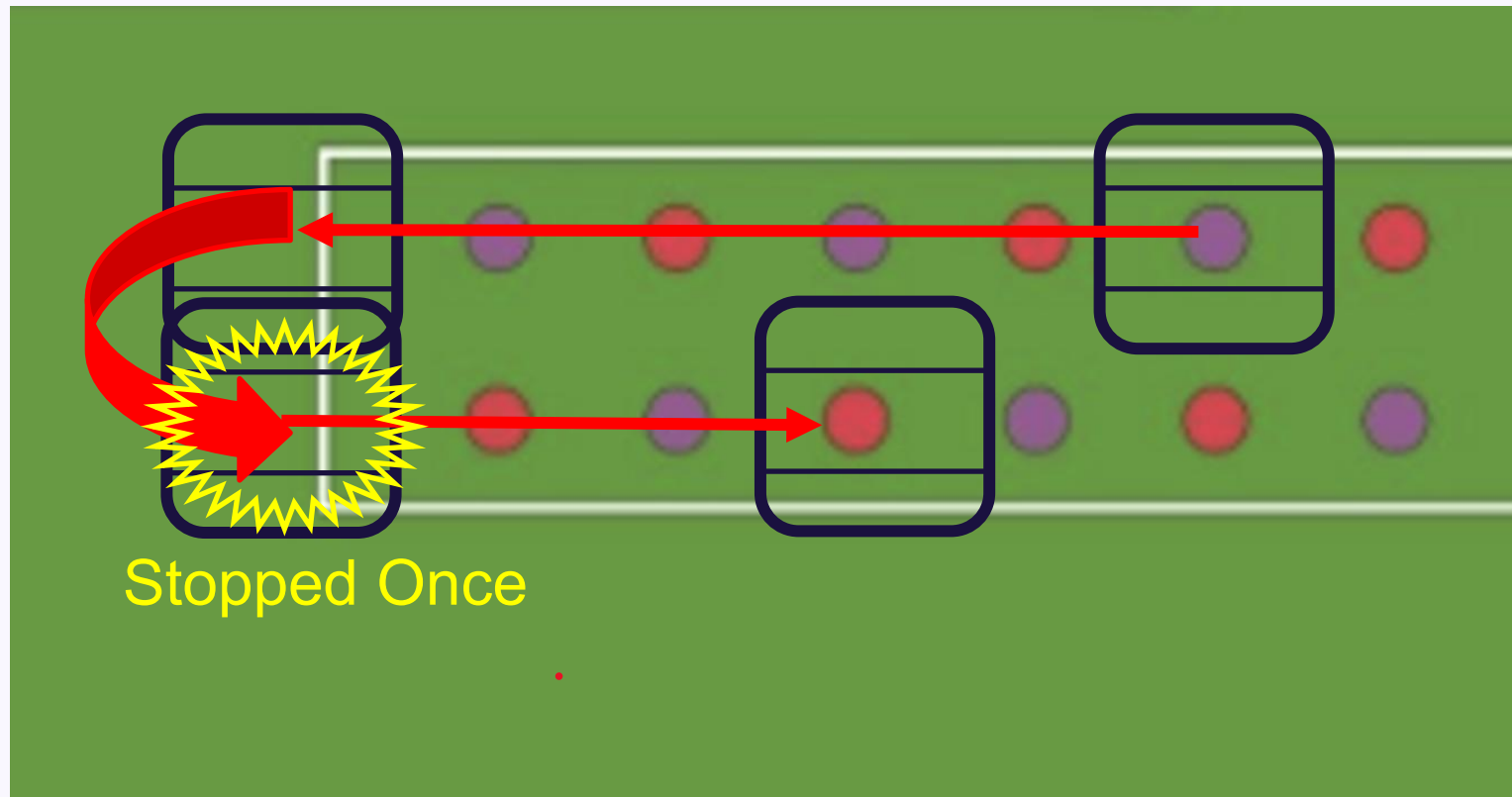
WD R1 SW – Area 2 pathing

That is why I made the circular arc :
I can maintain the previous speed and move non-stop



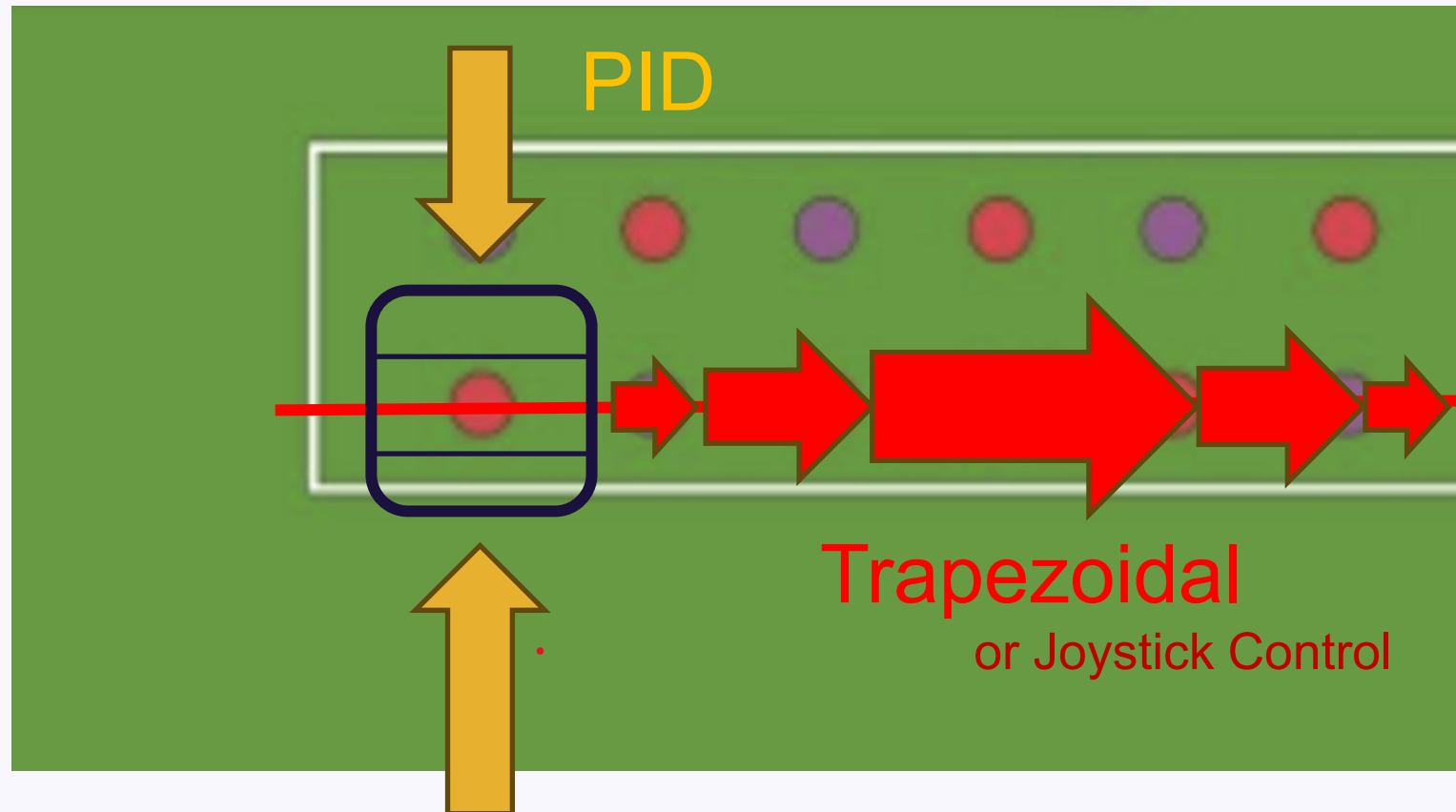
WD R1 SW – Area 2 pathing

However in reality, I have to stop once after the arc for pre-steering for accuracy. So, not really faster. :(



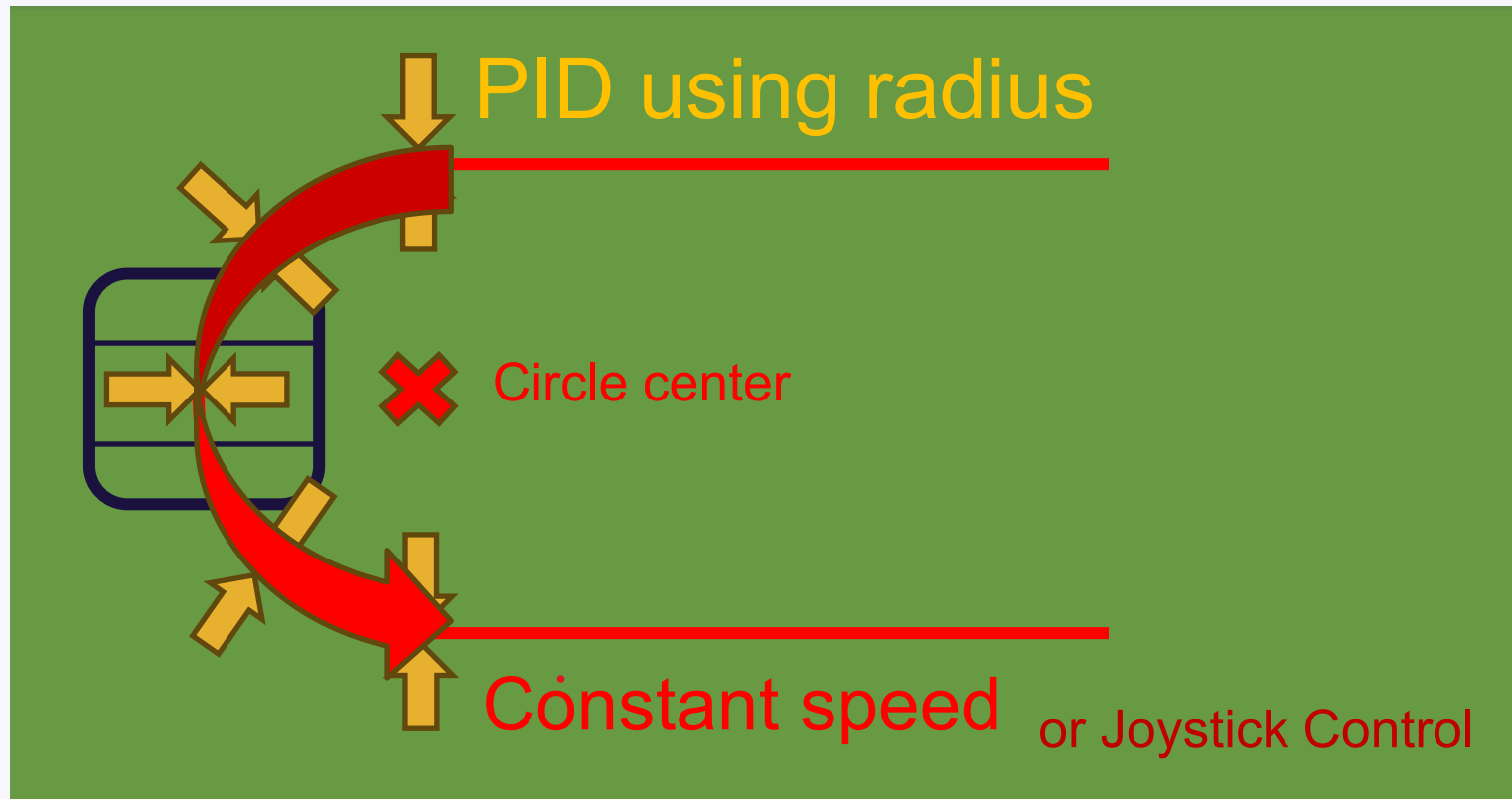
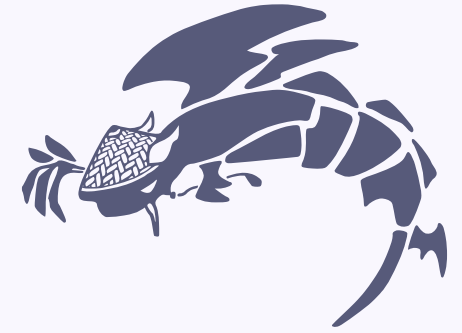
WD R1 SW – Area 2 pathing

How it works: Straight line

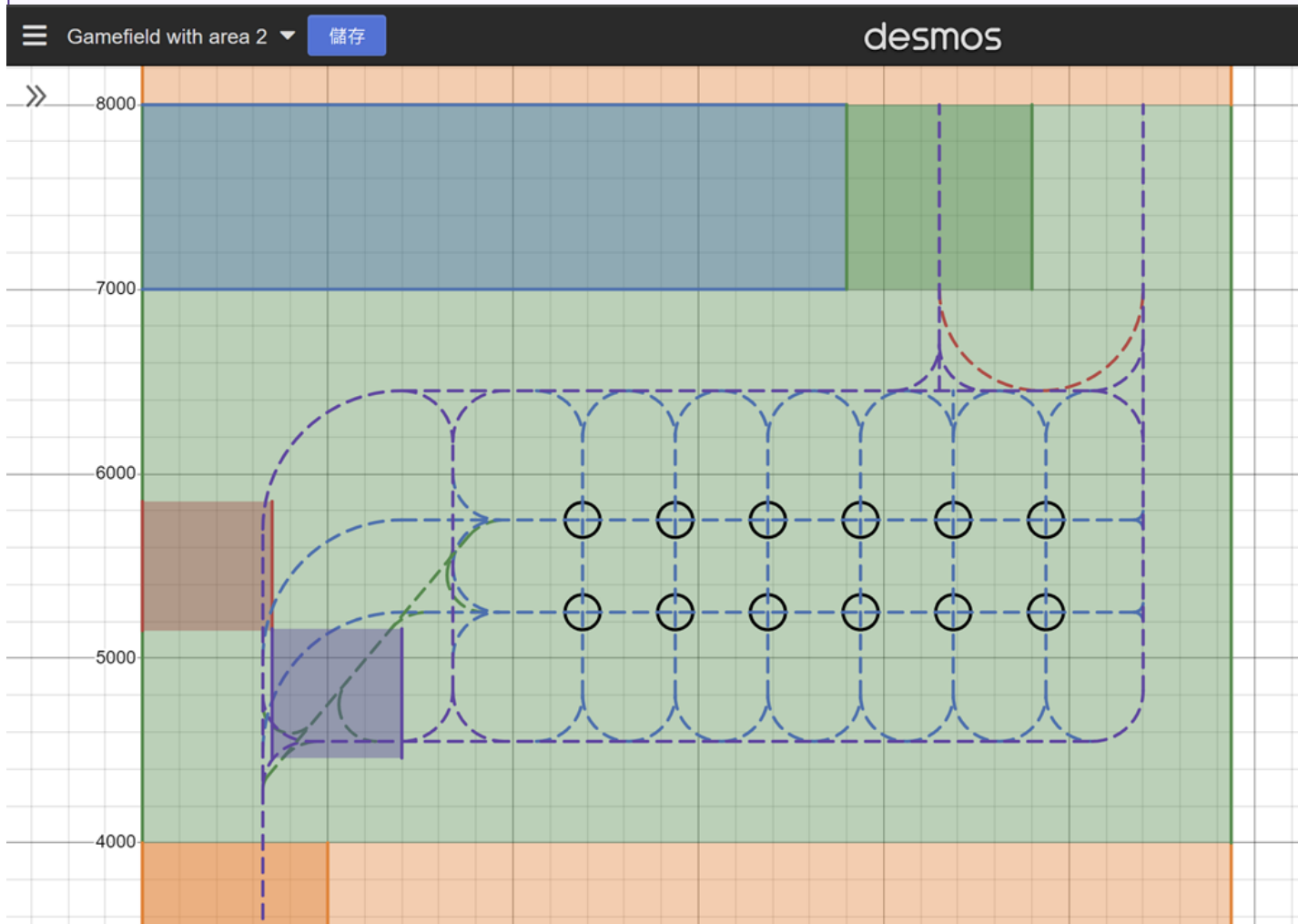
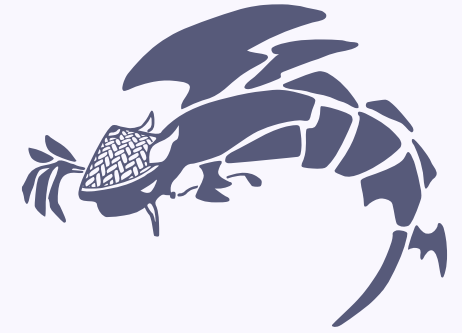


WD R1 SW – Area 2 pathing

How it works: Circular arcs



WD R1 SW – Area 2 pathing

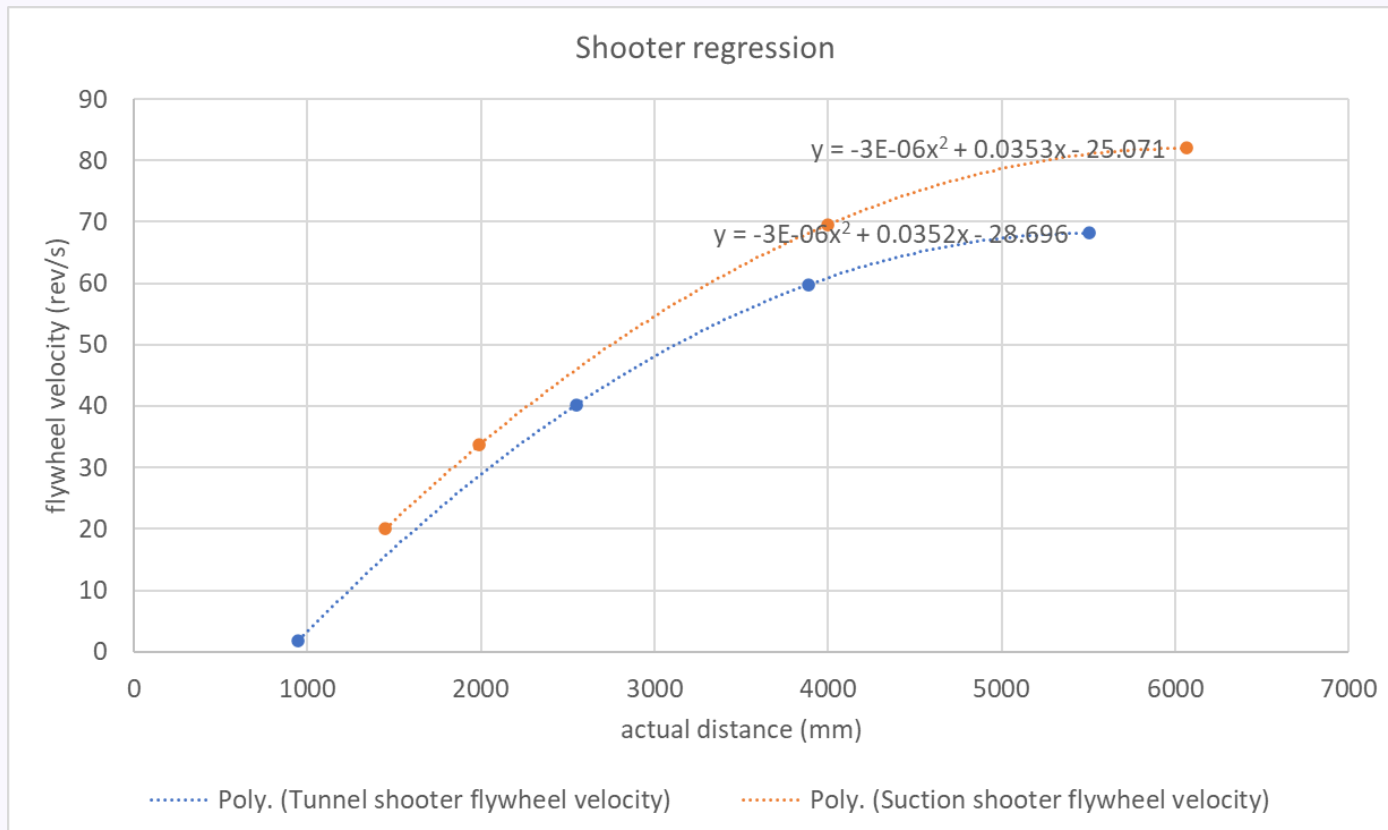


I drew lots of straight lines and circular arcs for our robot to follow.



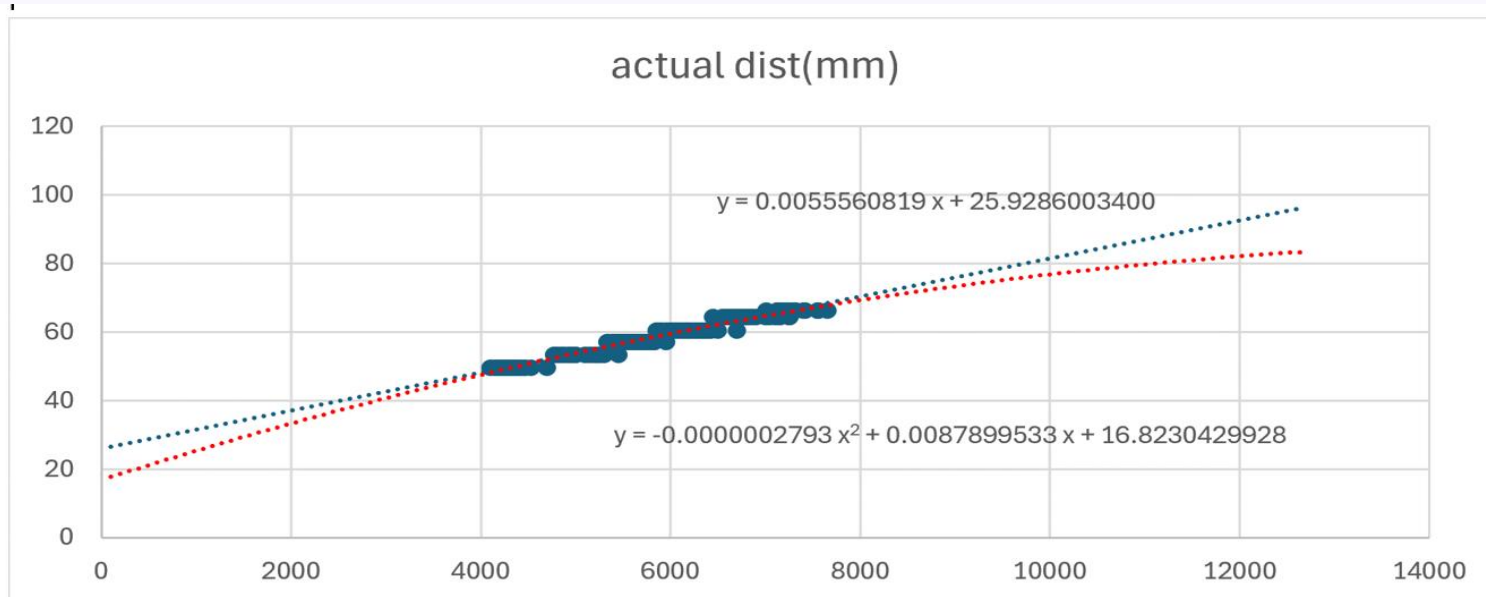
FD R1 SW – Shooter regression

FD R1 has 2 different shooters. So, we have 2 different shooter regression



WD R1 SW – Shooter regression

WD R1 Shooter is mostly same with FD so let's not repeat



x-axis: ball flying distance(mm)

y-axis: shooter flywheel velocity(rev/s)

blue line: linear regression best fit line

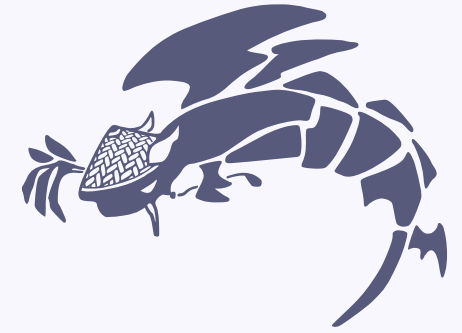
red line: quadratic regression best fit line





GENERAL R1 SW

– Laser Line sensor positioning



On our robot, we use laser & line sensor to recal our position **after several ticks.**

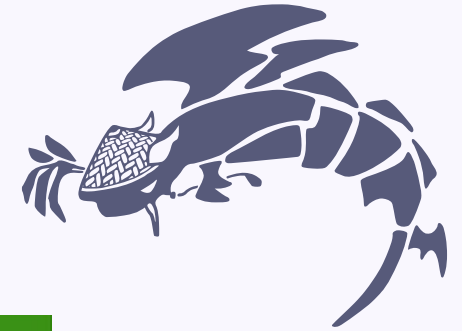
In **short time purposes**, we rely on XY-encoder!

```
Front IR: No (19.994)
Back IR: No (19.988)
Right IR: No (19.988)
Left IR: No (19.994)
L off off R off off
0000000 0010000 1100001
0000000 0001000 0000000
```



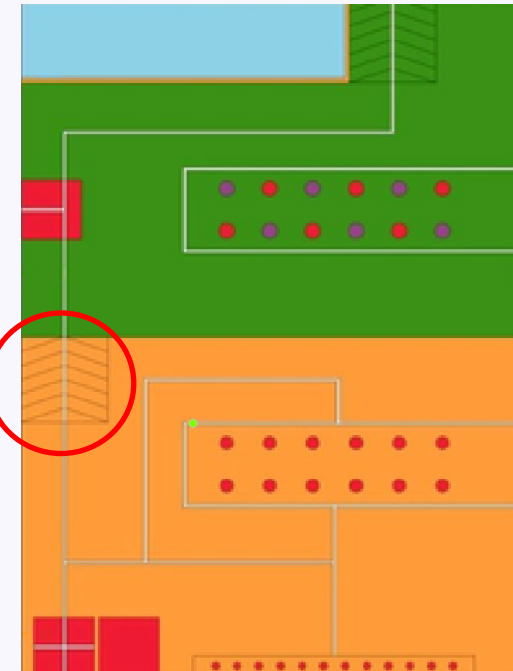
FD R1 SW

– Laser Line sensor positioning



Challenges:

- Picking up seedlings and tunneling in area 2 require high-accuracy on positioning
- 3D game field and slope lead to shifting in the XY-encoder reading
- Error reading due to game props (seedlings and balls), R2 and game field members



FD R1 SW

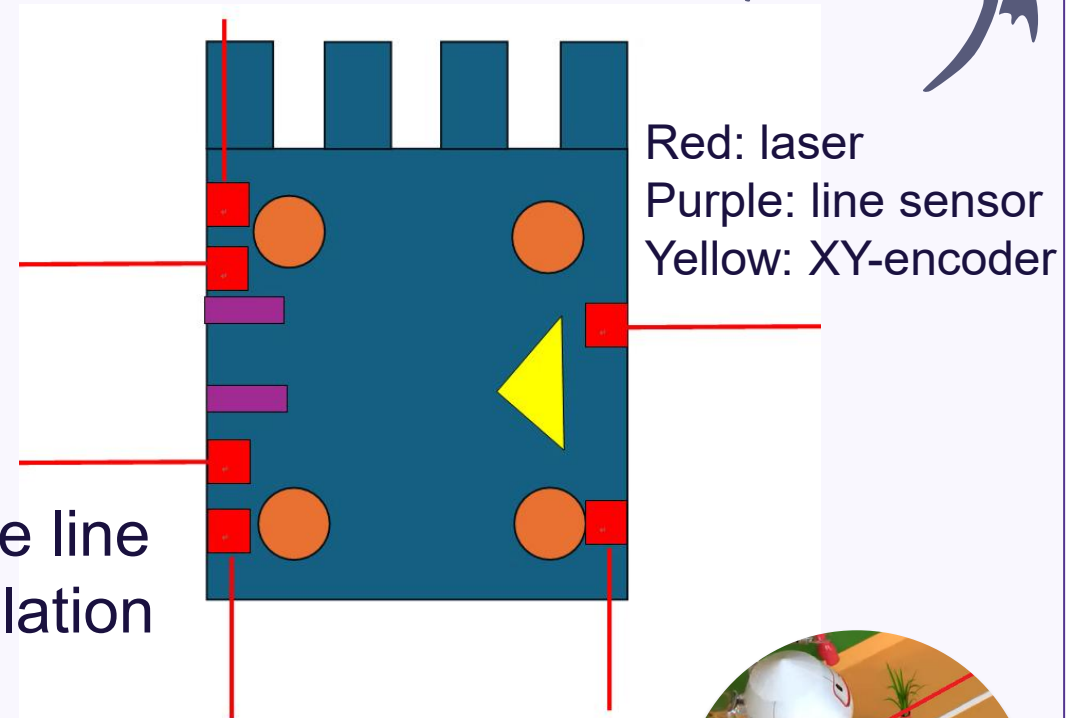
– Laser Line sensor positioning

Area 1

- Laser in both x and y direction

Area 2

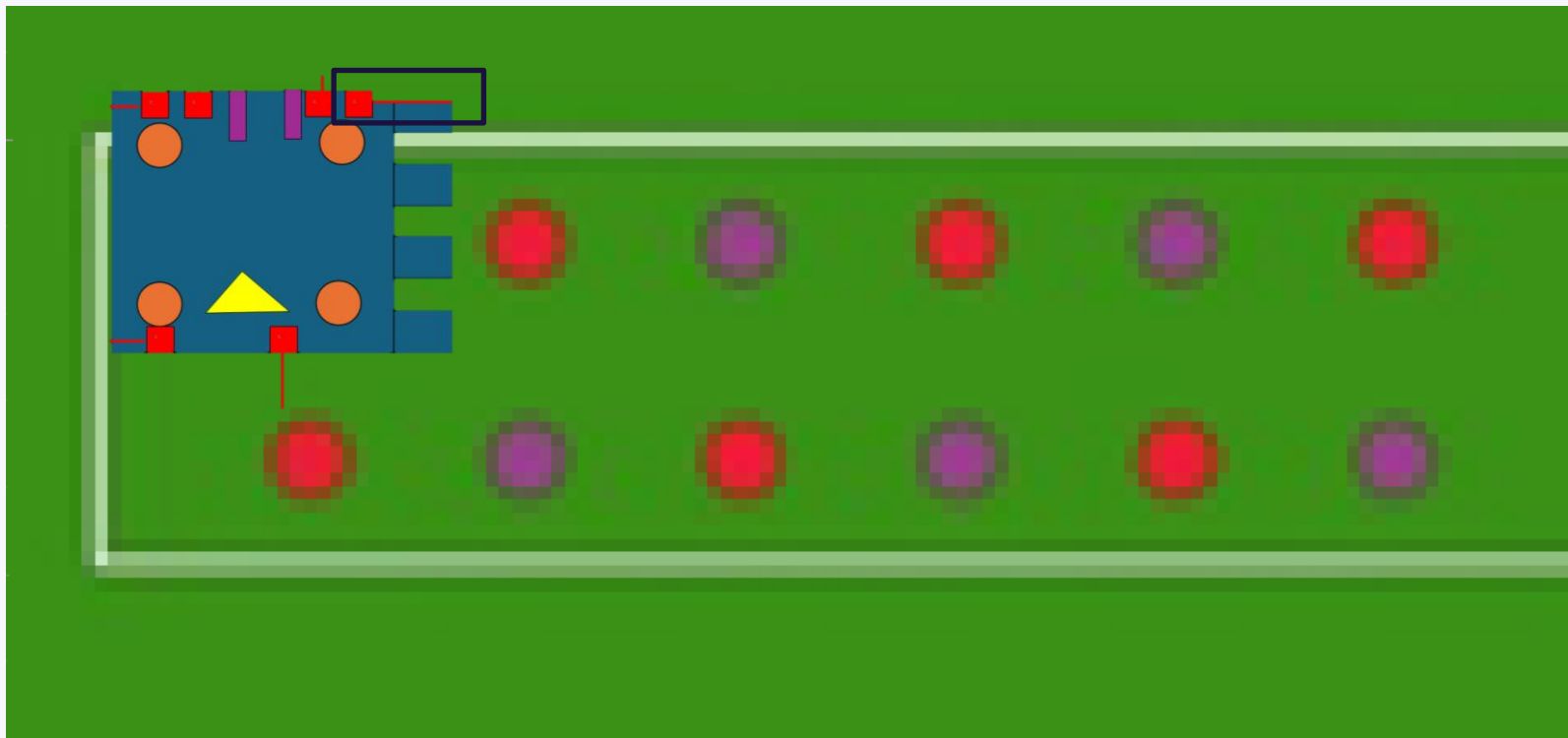
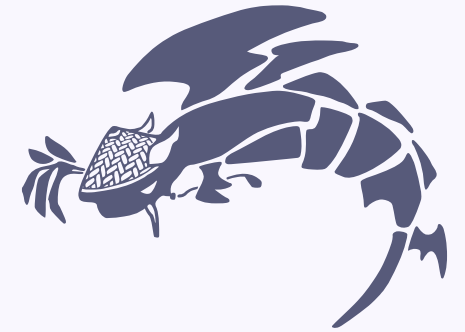
- XY-encoder: reference for positioning calculation
- 2 line sensors: follow the horizontal white line
- 6 lasers: real-time XY-coordinates calculation



FD R1 SW

– Laser Line sensor positioning

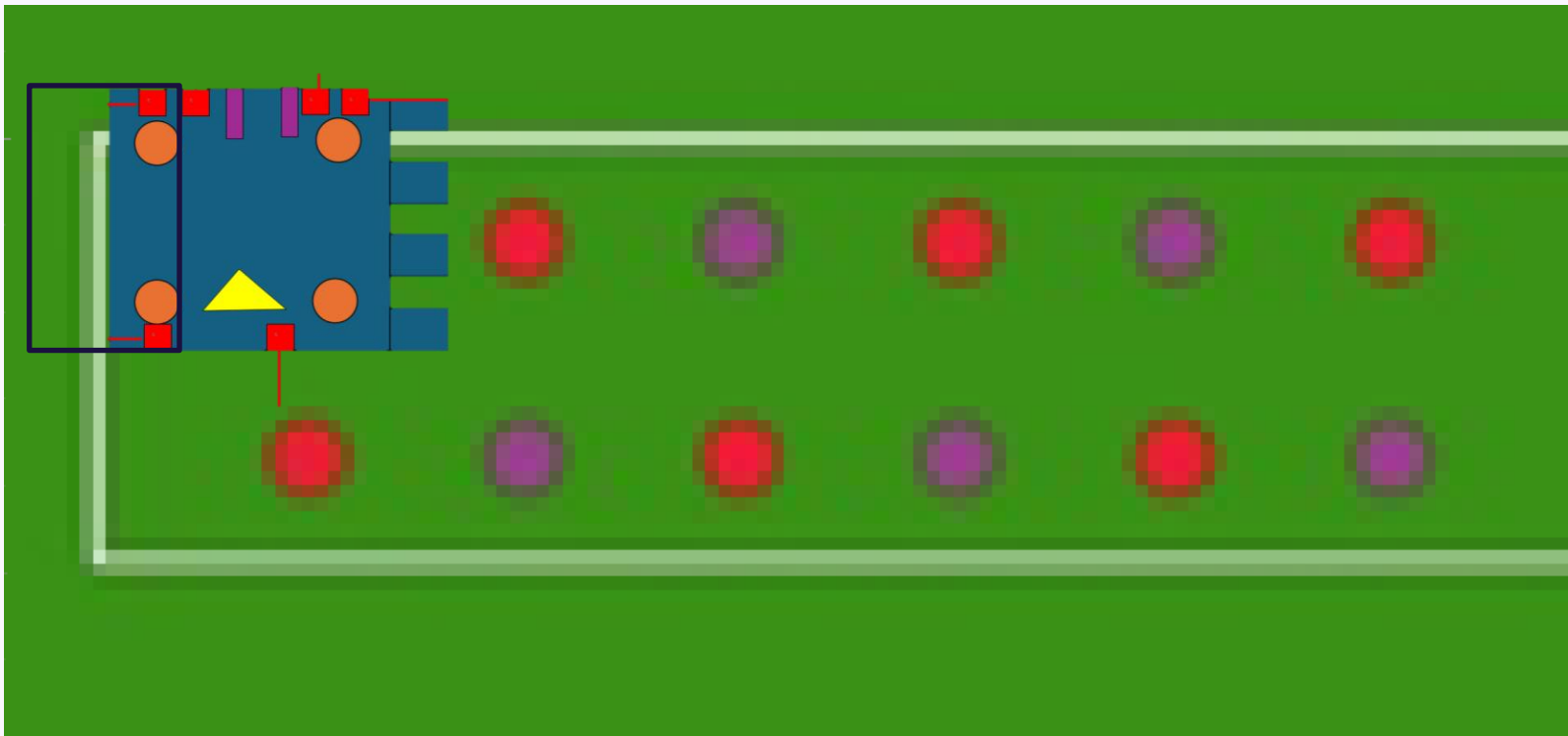
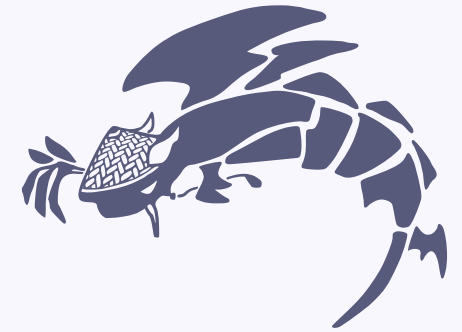
Laser at the front: calculate the x coordinate



FD R1 SW

– Laser Line sensor positioning

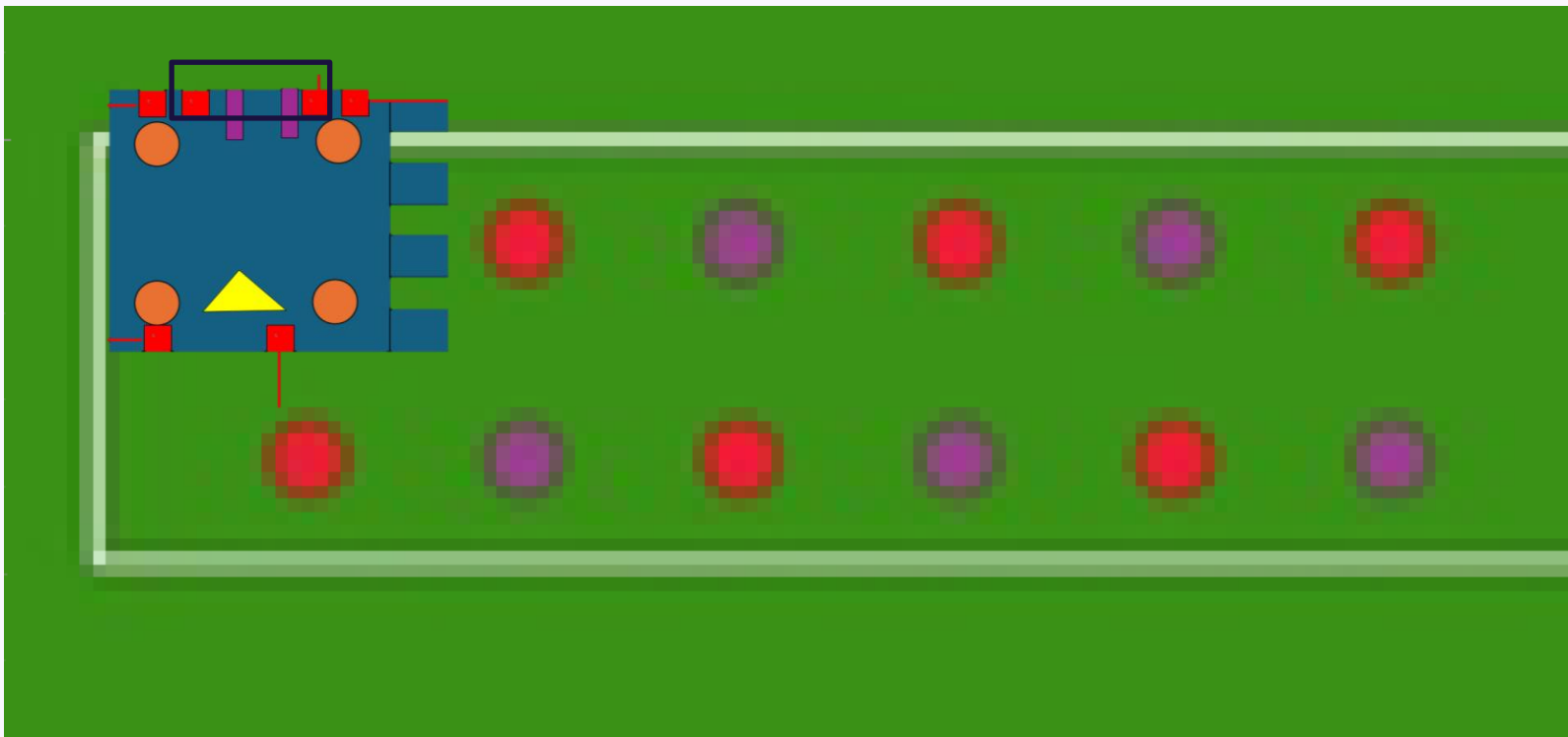
Lasers at the back: double-check with the calculation of the front laser



FD R1 SW

– Laser Line sensor positioning

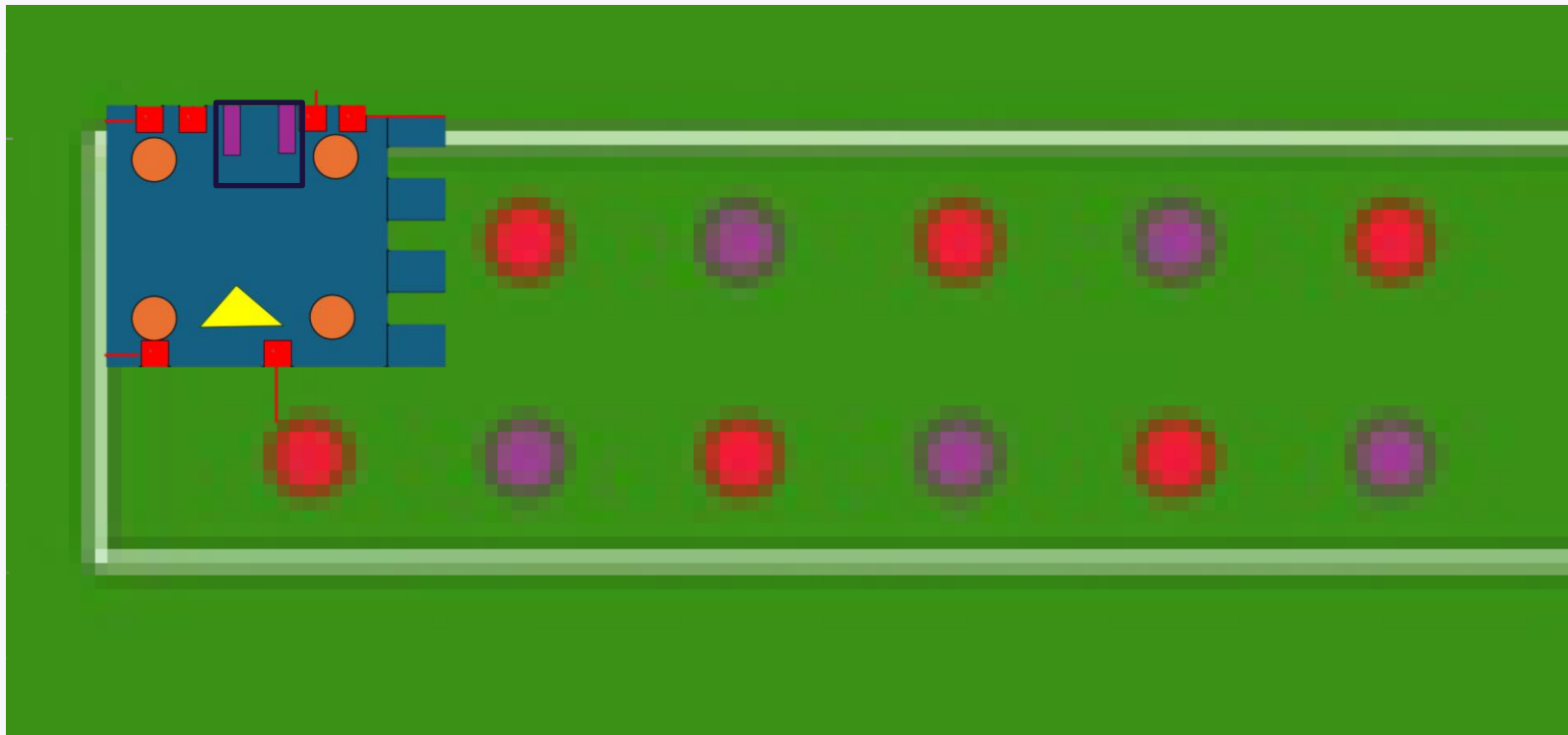
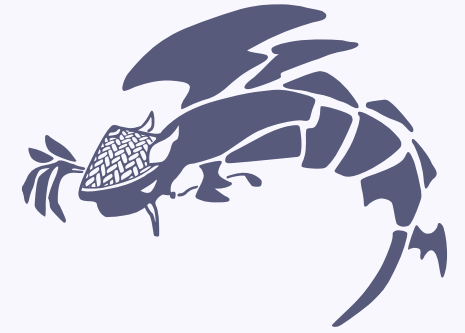
Lasers at the center: calculate the y coordinate



FD R1 SW

– Laser Line sensor positioning

Line sensors: tracking the line above the first row to recalculate the y-coordinate



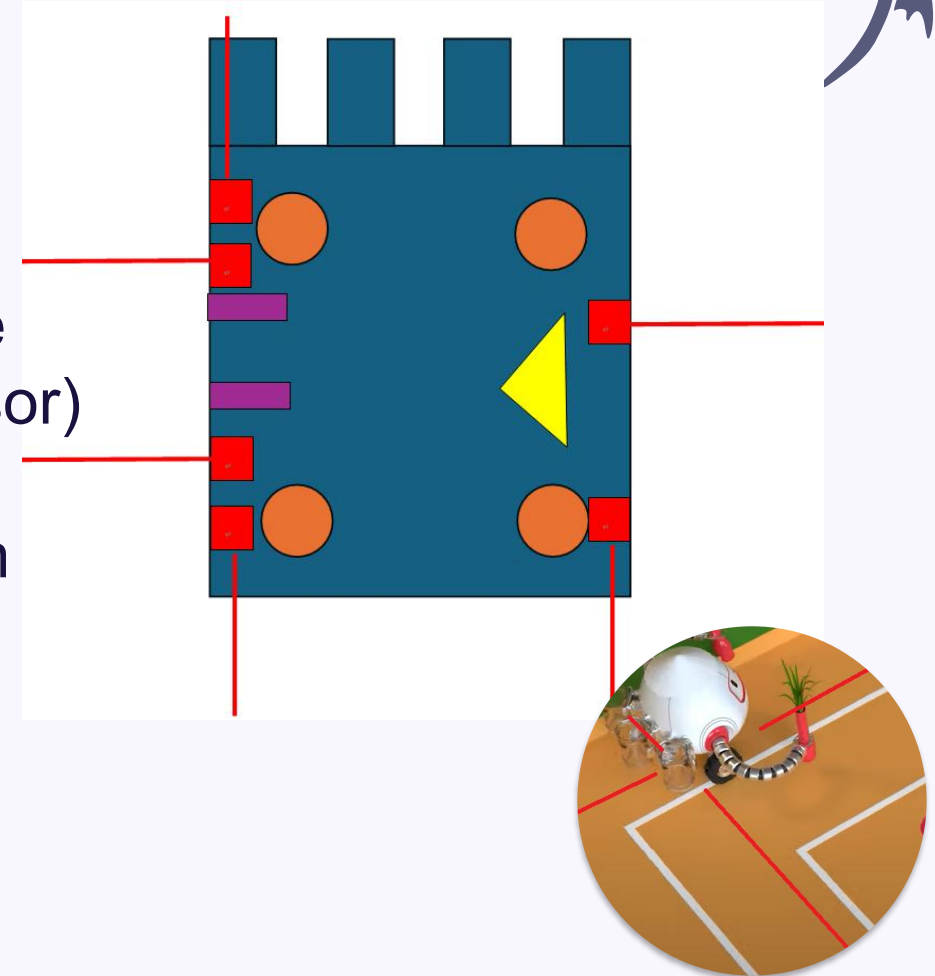
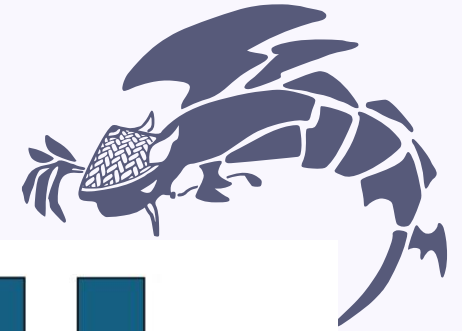
FD R1 SW

– Laser Line sensor positioning

Hierarchy of positioning re-calculation:
XY-encoder > line sensor > laser

If the laser's reading is much different from the XY-encoder's, ignore it. (same for the line sensor)

If the center laser's reading differs greatly from the line sensors', ignore the laser's reading. (since the laser may point to the slope)



WD R1 SW

– Laser Line sensor positioning

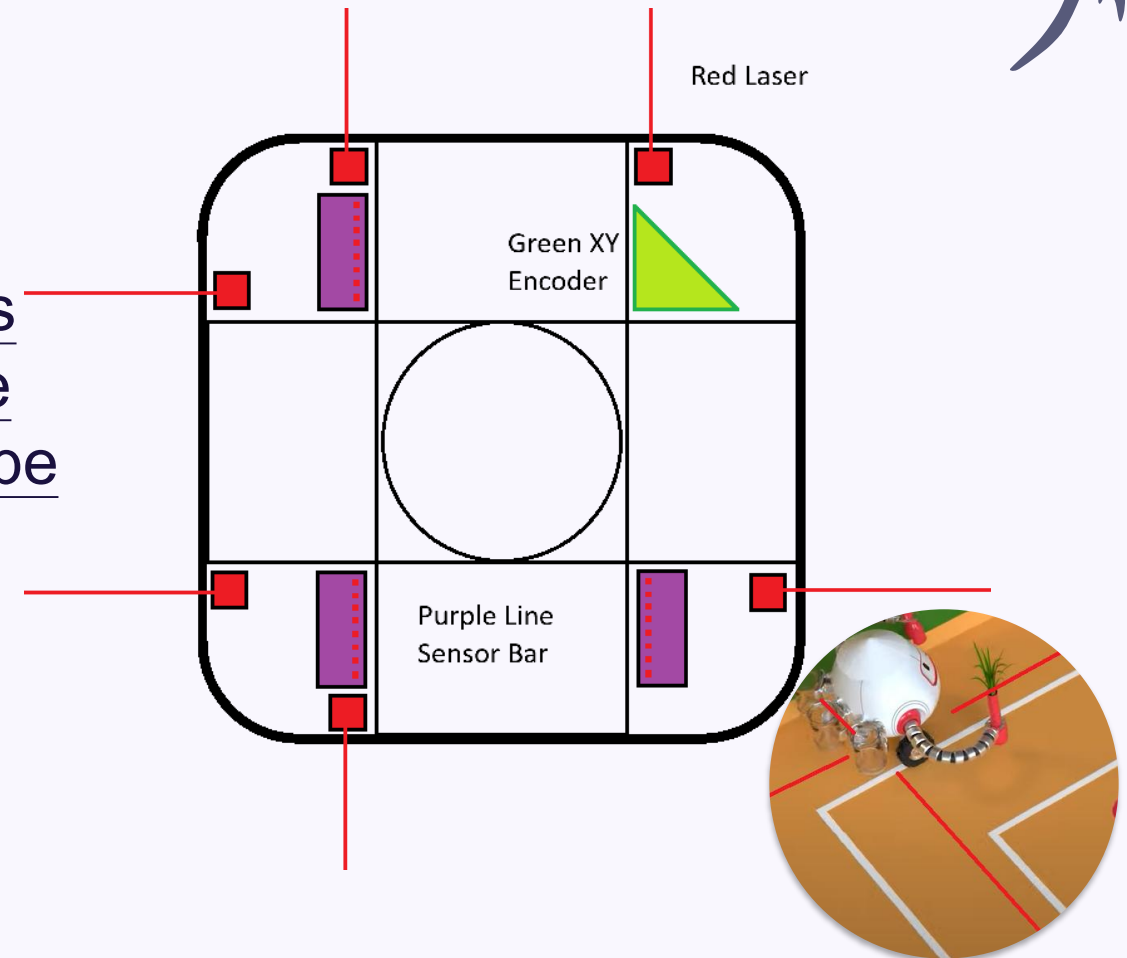


Purpose

- To increase the accuracy of our positioning
- To avoid the false readings when lasers are blocked by R2/seedlings/balls/slope
- To overcome inaccuracy due to the slope

We merge/fused the sensor readings of

- XY-Encoder X, Y, and Theta reading
- Laser Distance reading * 6
- Line Sensor Bar reading * 3



WD R1 SW

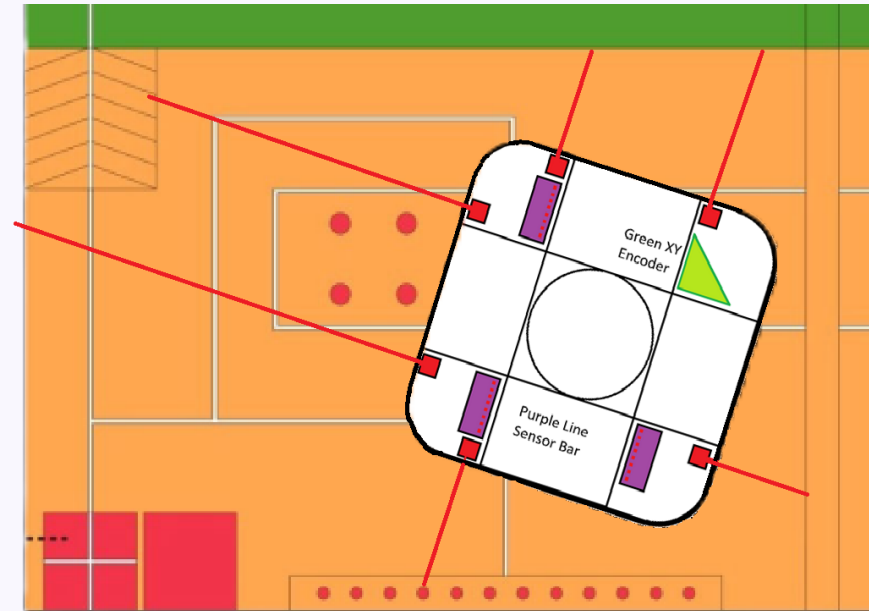
– Laser Line sensor positioning



XY Encoder gives us a rough position and its facing angle

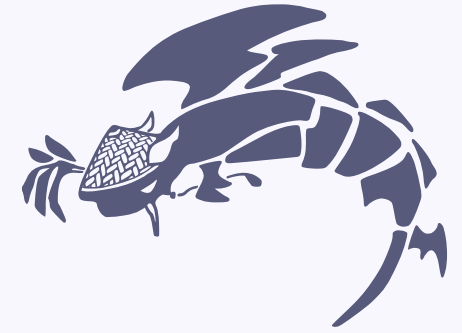
We can use it to determine

- which laser is facing which fence
- which line sensor bar is reading which white line



WD R1 SW

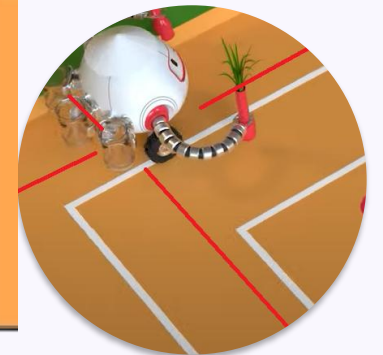
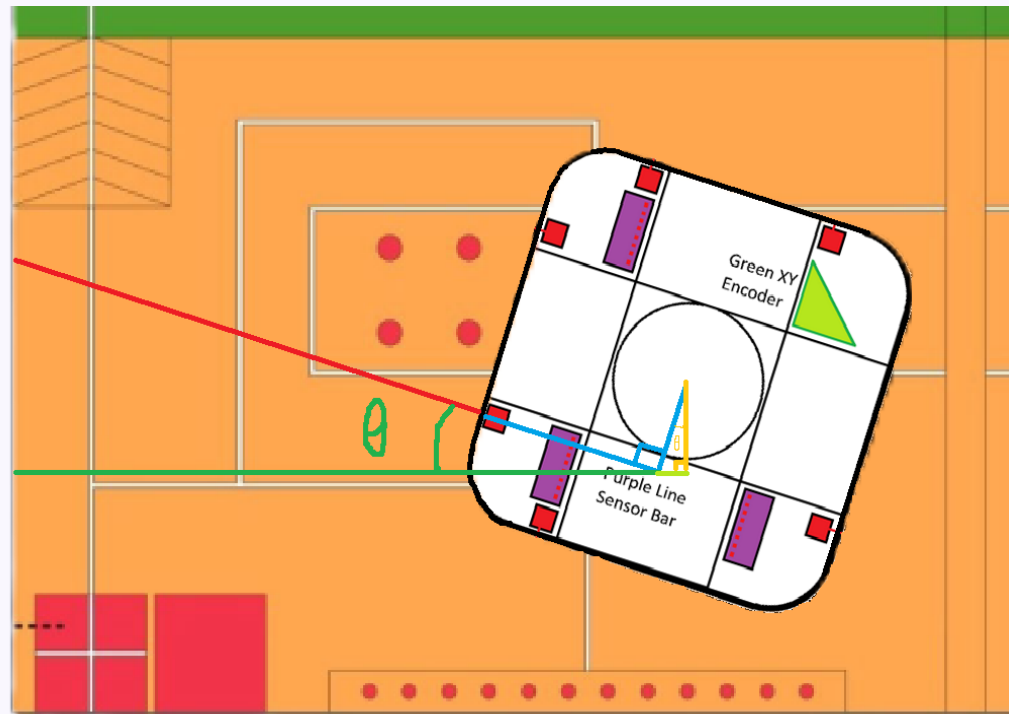
– Laser Line sensor positioning



For each laser,
after we determine which vertical/horizontal fence it is facing

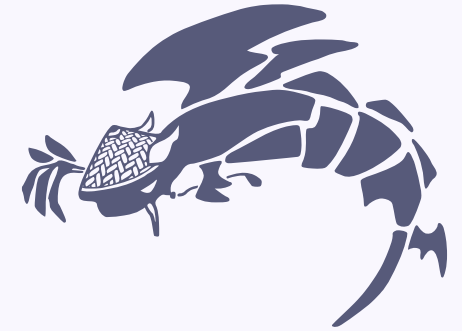
We can then compute
either the horizontal x
coordinate
or the vertical y coordinate
of our robot

So, we have multiple x and y
coordinates for the 6 lasers.



WD R1 SW

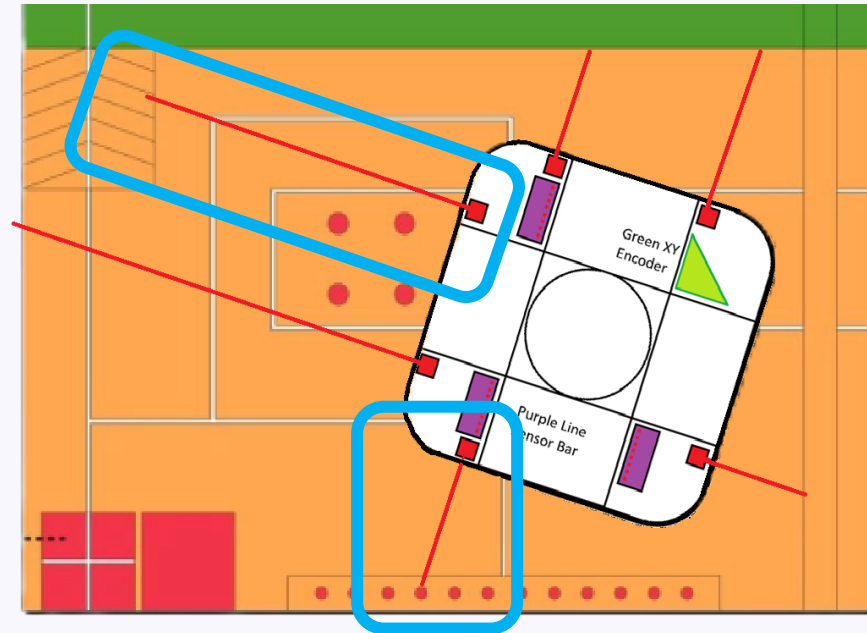
– Laser Line sensor positioning



With the multiple x and y coordinates, we can then compare it with XY-Encoder coordinates

If some readings differs from other readings a lot, they must be blocked by slope/seedling/ball so we ignore them

Else we recal with all other readings.



WD R1 SW

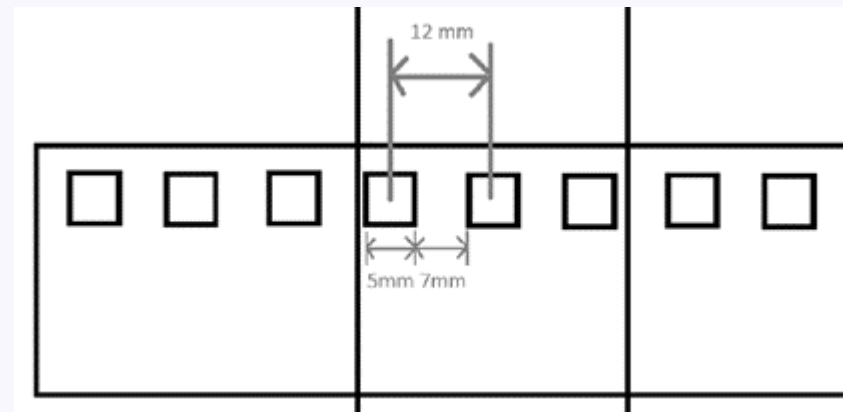
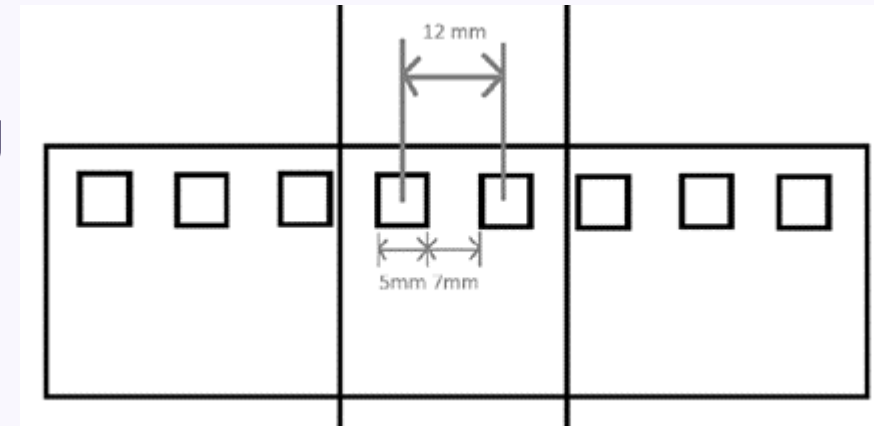
– Laser Line sensor positioning



For each line sensor,
after we determine which white line it is facing

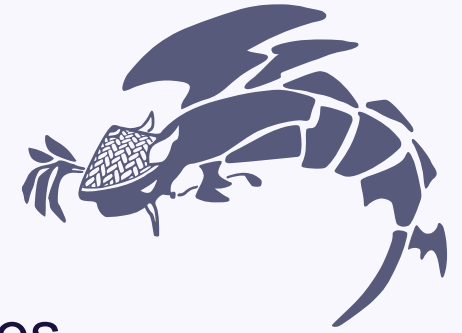
We can then compute the
vertical y coordinate of our robot

Although the line sensors are 12 mm
apart, we can get 6 mm
accuracy reading from the line
sensor bar.

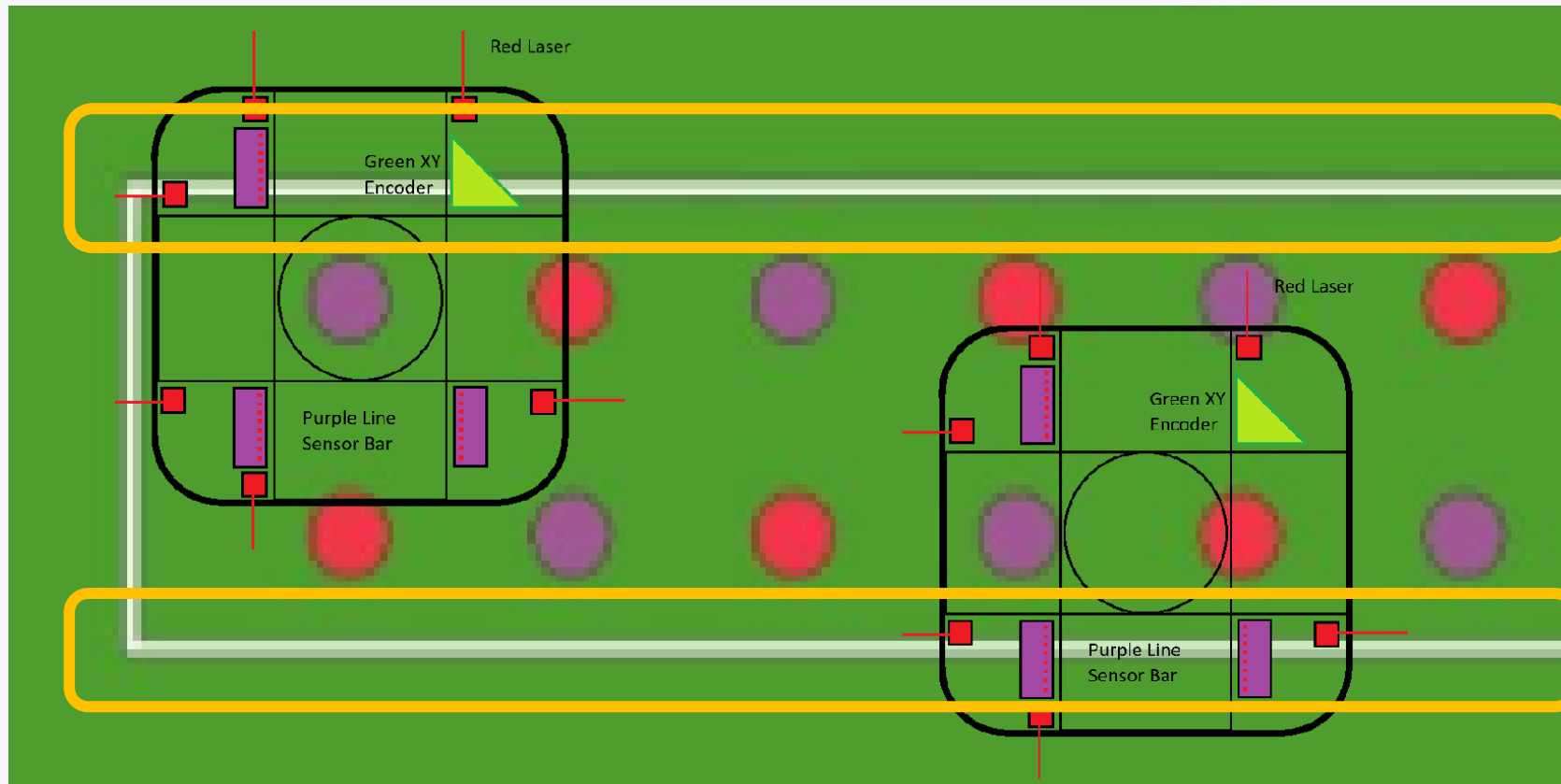


WD R1 SW

– Laser Line sensor positioning



We use line sensors in Area 2 to follow these horizontal white lines



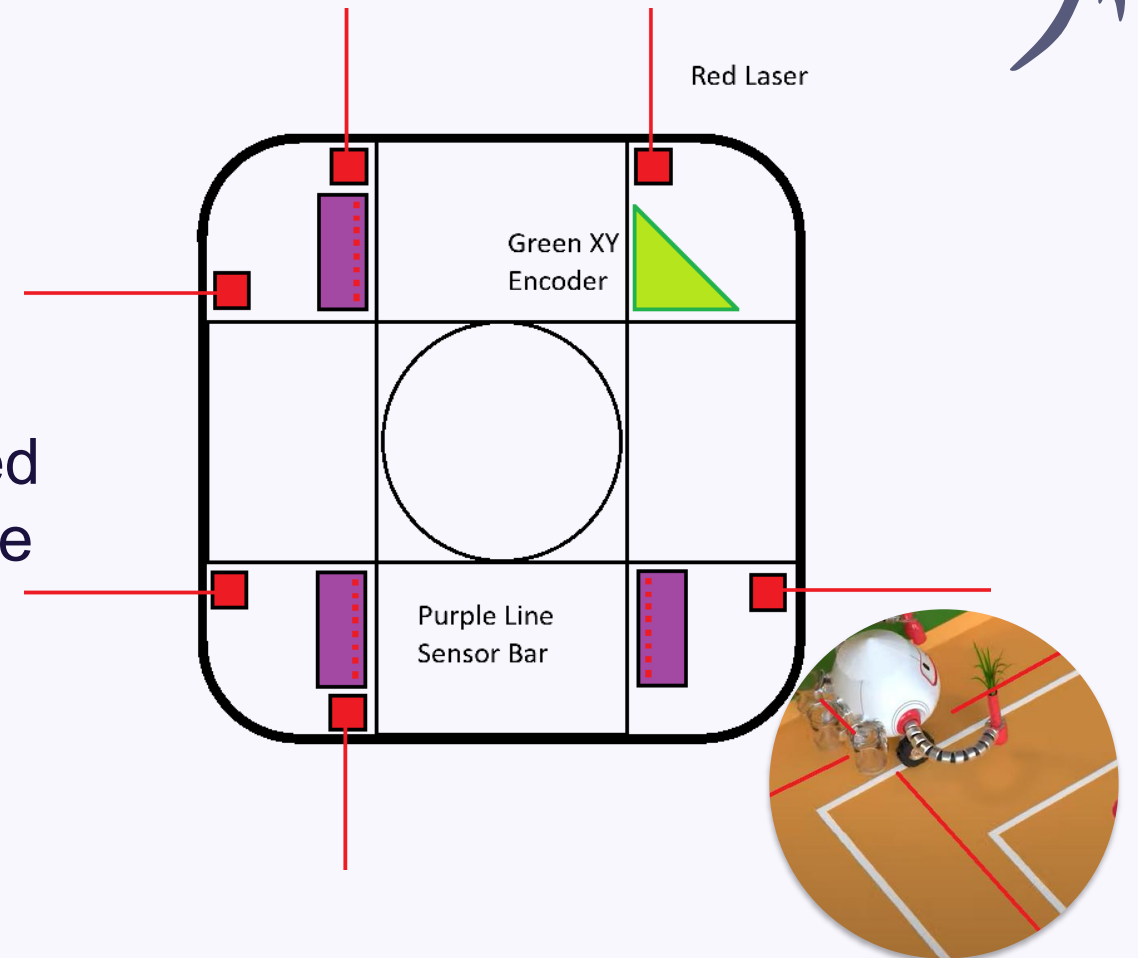
WD R1 SW

– Laser Line sensor positioning

We merge/fused the sensor readings of

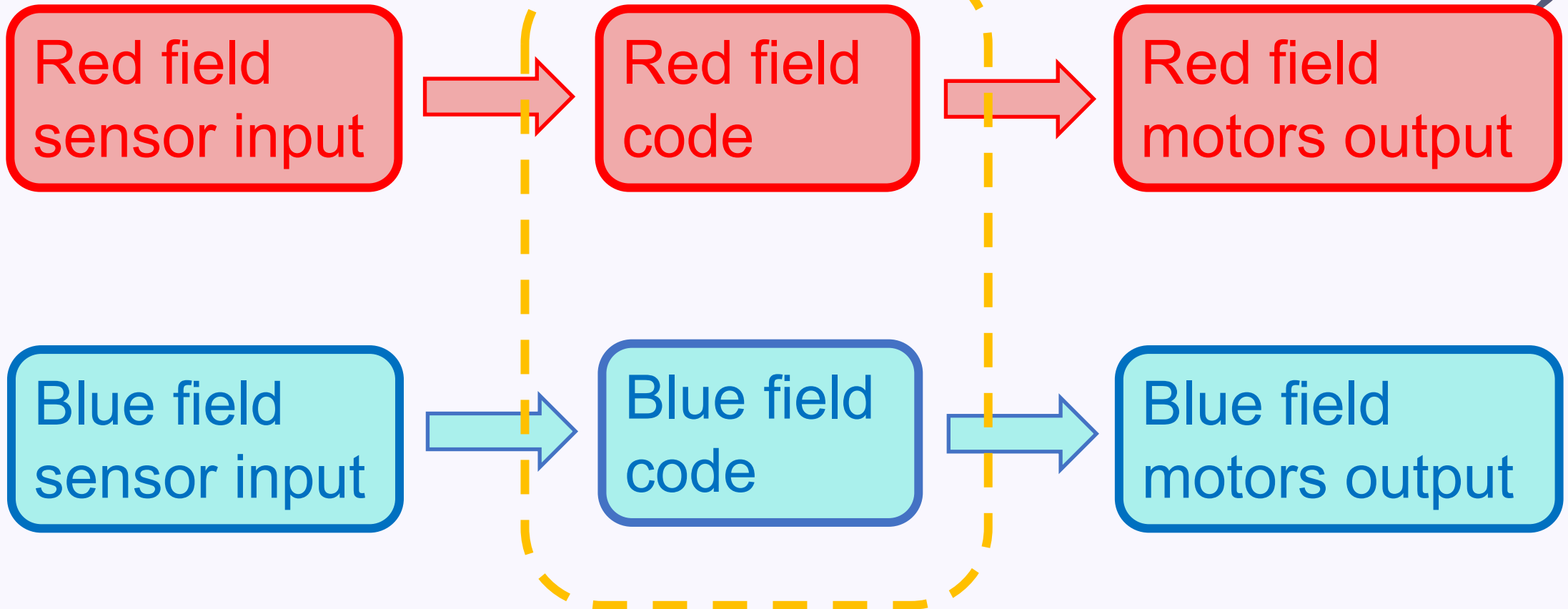
- XY-Encoder X, Y, and Theta reading
- Laser Distance reading * 6
- Line Sensor Bar reading * 3

After each sensor independently computed its x y coordinates, we would recal with the most accurate one.



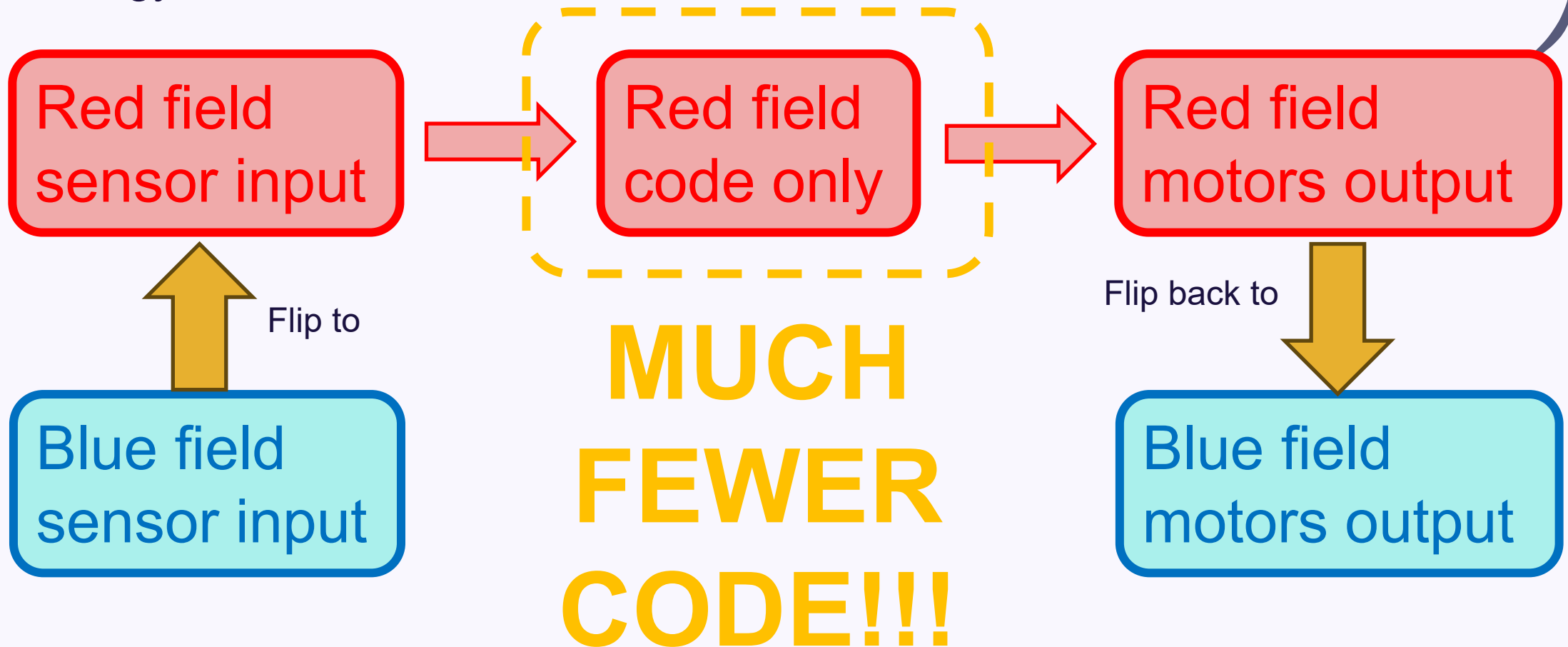
WD R1 SW – Red Blue Field Flip

Original structure:



WD R1 SW – Red Blue Field Flip

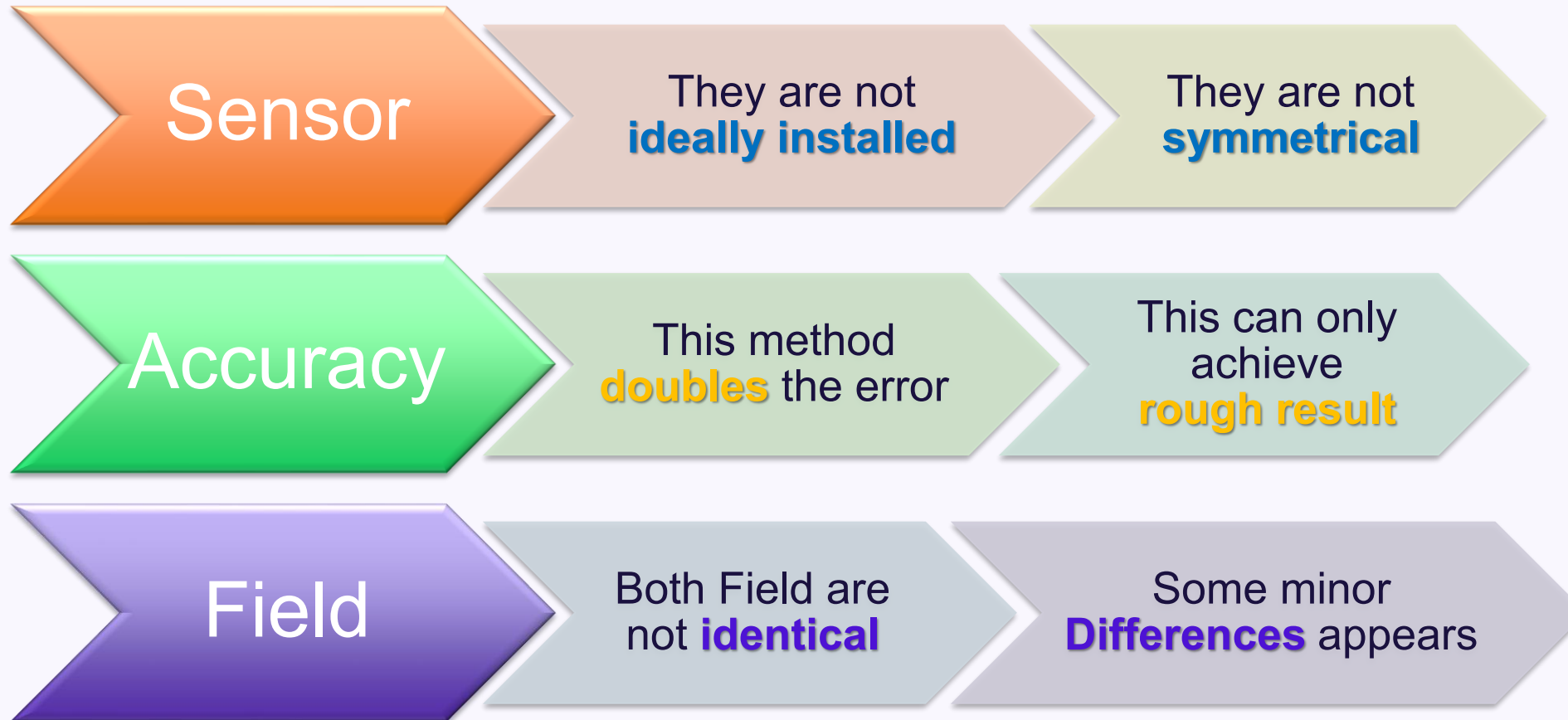
Ideology:



WD R1 SW – Red Blue Field Flip



Although the concept is ideally working, some **challenges** has been found.



WD R1 SW – Red Blue Field Flip



To overcome the issue, we use the following **techniques**:

General Coordinates

- Instead of **hardcoding** a path, we **draws paths** base on general coordinates
- Only a minor offset is needed

Different offset

- The flipping only provides a general shapes
- **Offset are applied to both field** to allow minor tuning

Field Dependency

- Allow some path to have path dependency, some path can **skip the flip and be tuned directly**

FD R1 SW – Red Blue Field Flip

Situation:

- non-symmetrical mechanism and sensor location

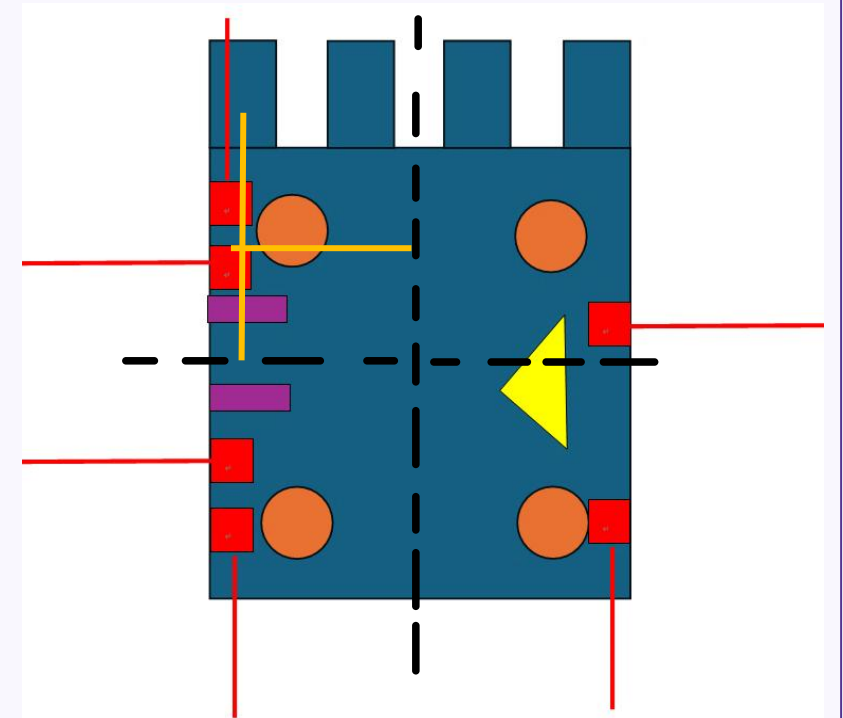


- We can't just simply flip the coordinate to handle field flipping

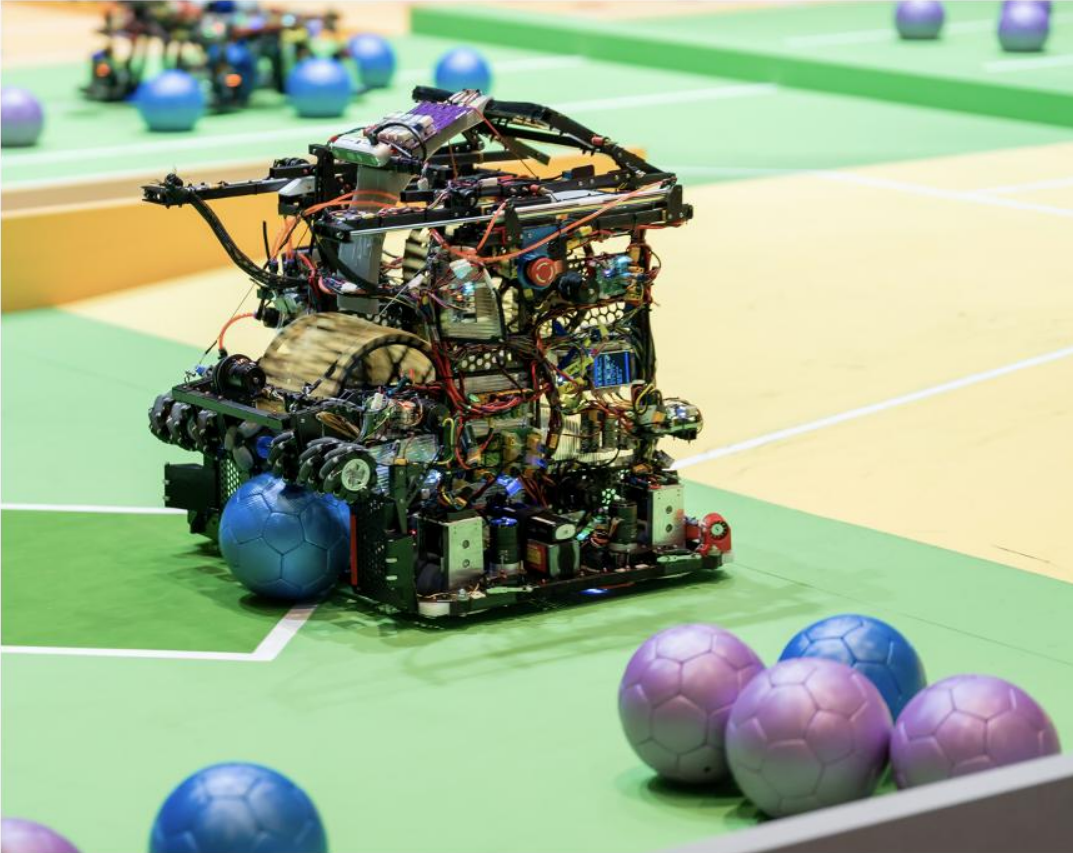
FD R1 SW – Red Blue Field Flip

Solution:

- Path planning:
 - No hard-coded path
 - Using x and y coordinate to build up the network in area2
 - For area 1 and the coordination of the target ball in area 2 we need
- Field dependent offset
 - Record down the offset of the laser sensor and mechanism relative to the center of the wheelbase
 - Using them to find out the target coordinate



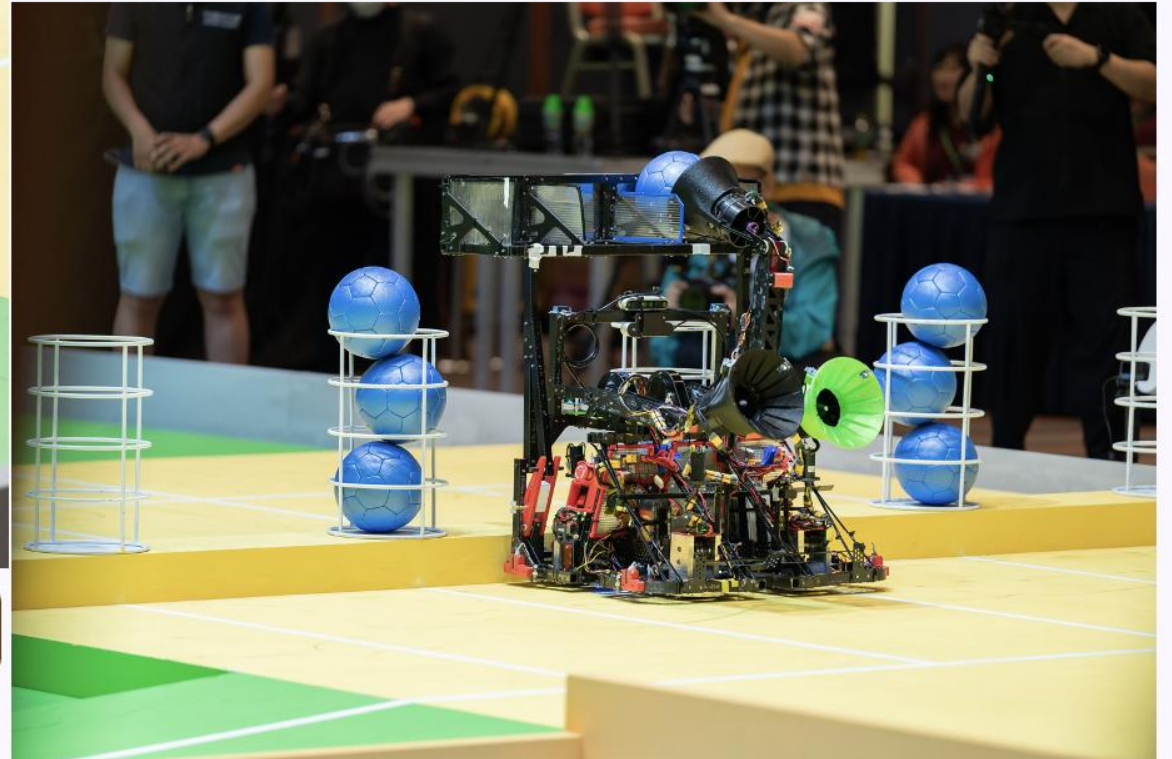
Software – R2



War Dragon R2

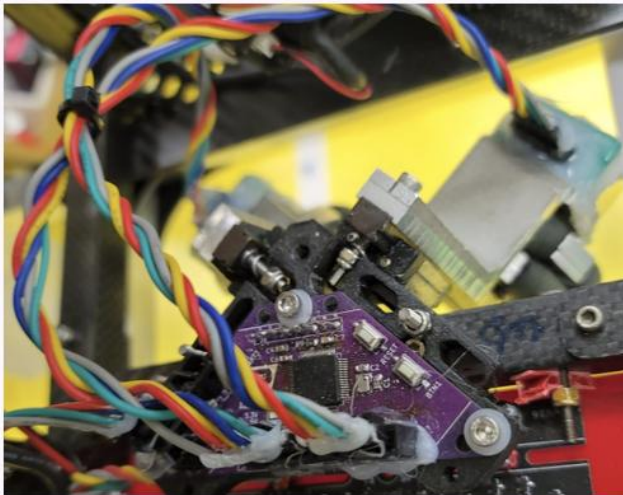


Fiery Dragon R2



R2 Localization Methods with XY-Encoder Reading (Laser, Line sensor, Limit Switch)

R2 Recalibration Helpers!!!



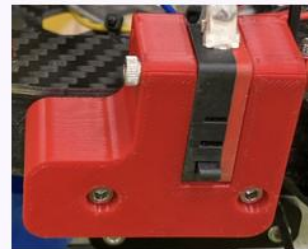
XY-encoder

- Two passive wheels with encoder
- Inertial Measurement Unit (IMU)

Our major localization tool can directly provide the XY coordinates relatively to starting points.



Laser



Limit Switch



Line sensor

XY-Encoder + Laser Recalibration

Key Features:

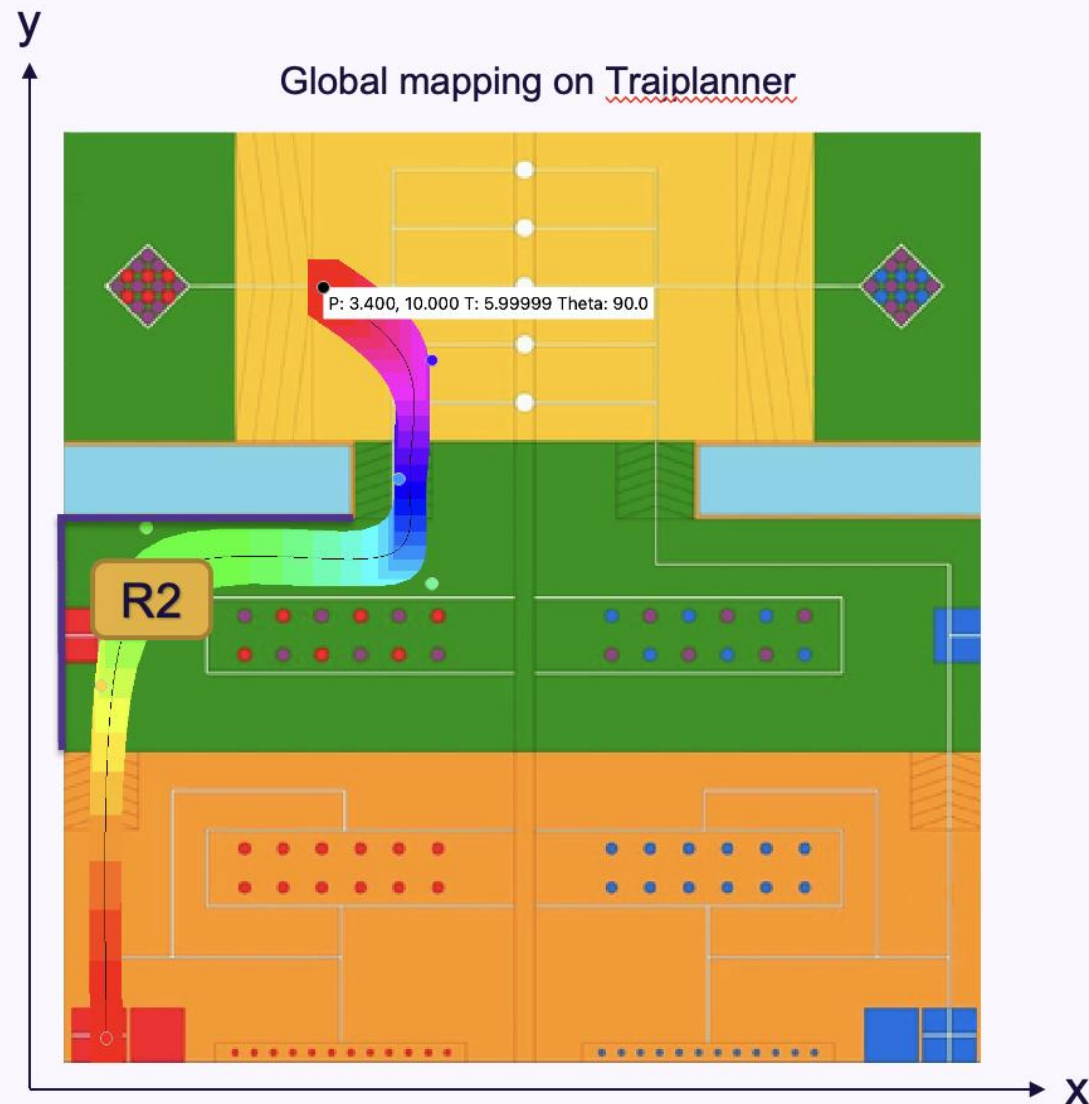
1-D distance high-accuracy measurement

For known paths without obstacles, we may measure the distance between the wall and the robot for XY coordinates calculation.

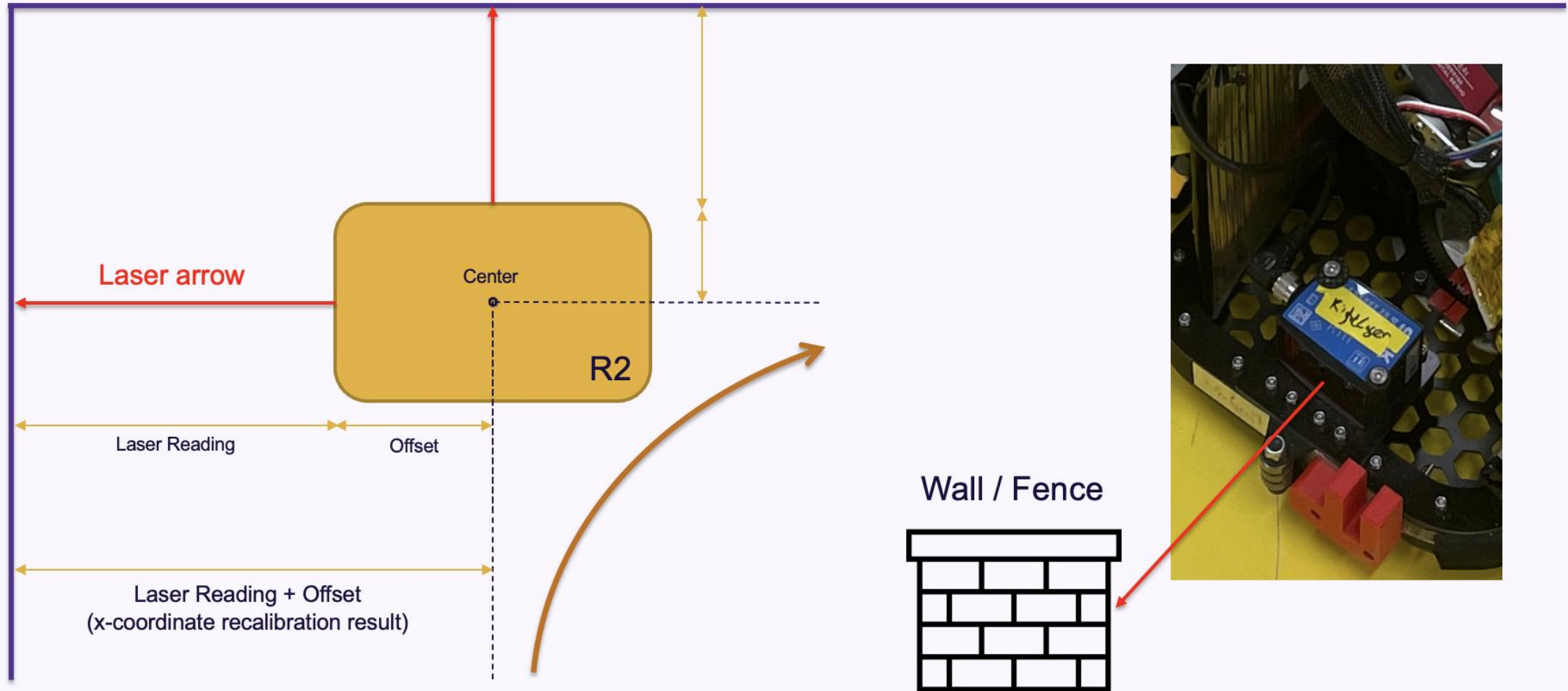


Use Cases for **AUTO** Pathing:

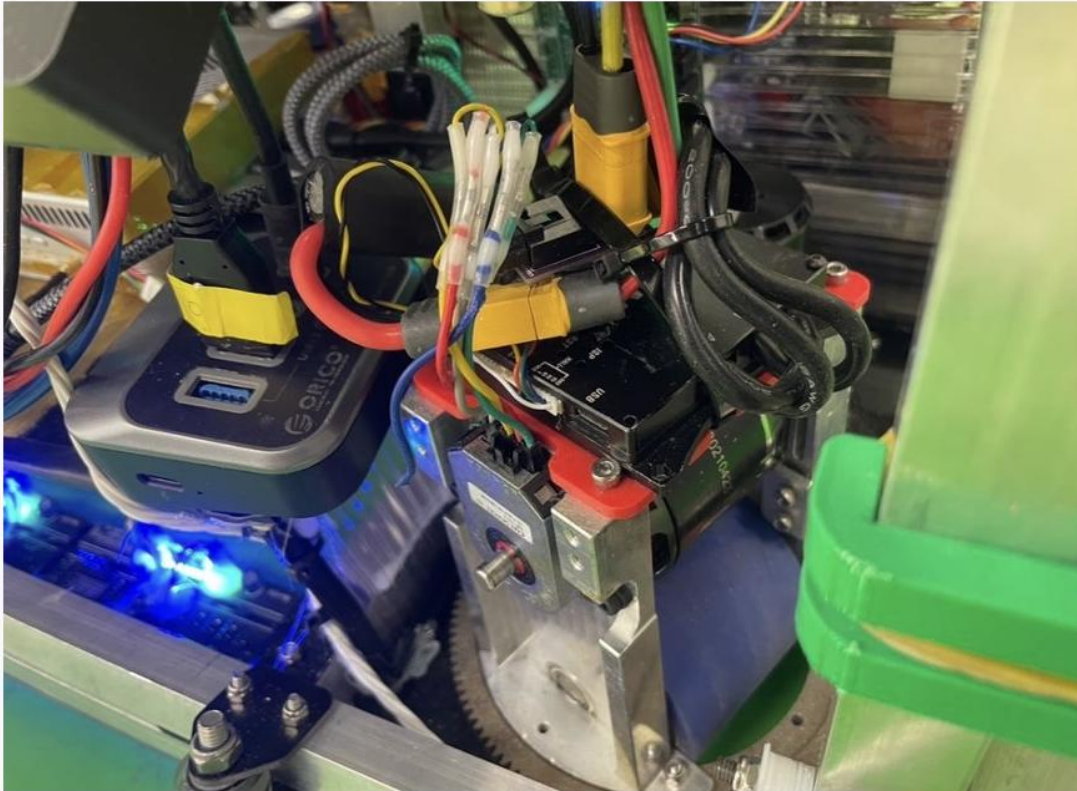
1. Start Zone to Area 3
2. Retry Zone to Area 3



Easy-To-Understand Laser Recalibration Methodology



Recalibration with Line Sensor + IMU Reading



Line Sensor

Identify the location of line under the robot if white line is detected.

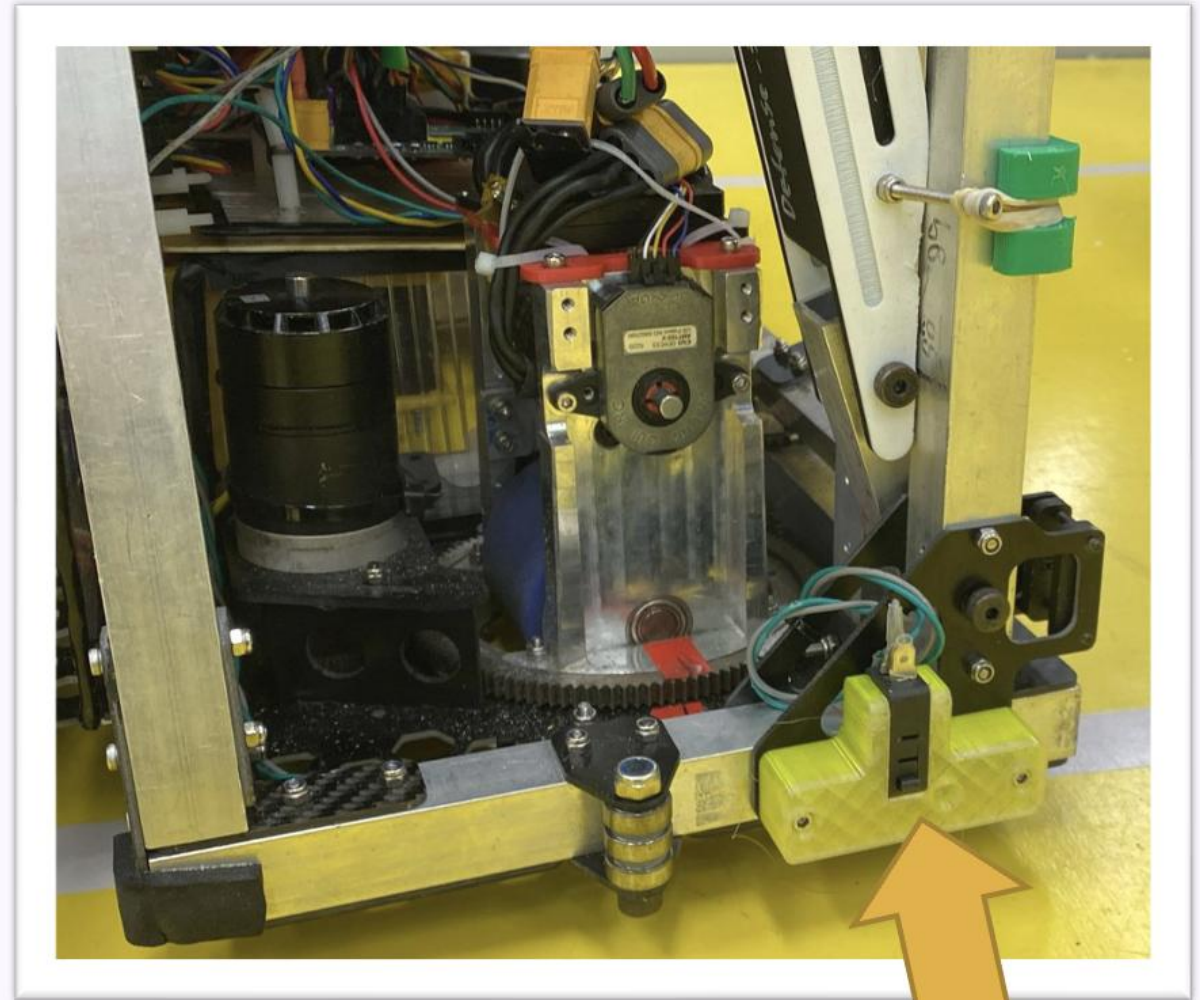
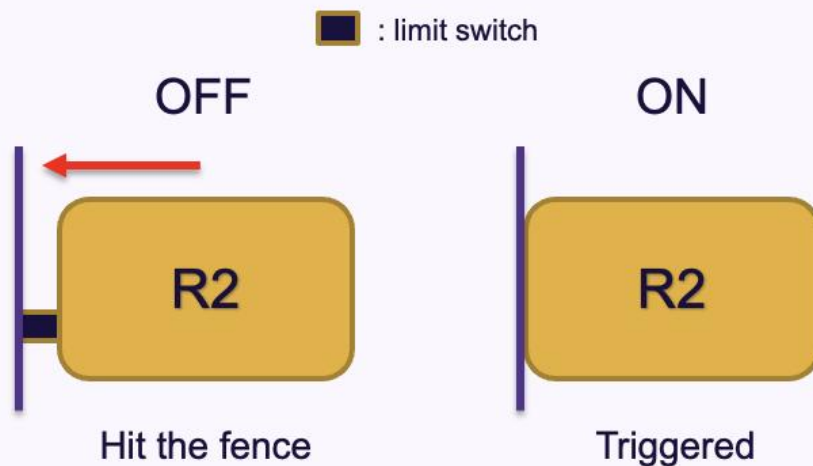
Based on the position from XY-encoder, we can calculate the coordinates based on the offset with lines.

Robust way for localization when there is a lot of obstacles.

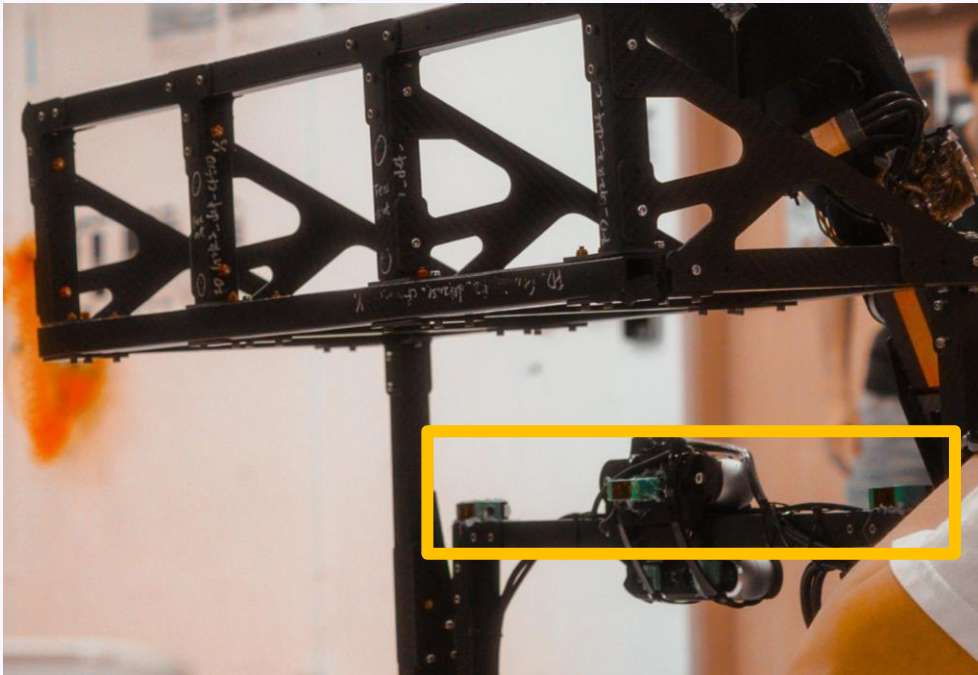
Recalibration with Limit Switch

Identify the location of the robot when limit switch is triggered to ON by hitting the fence.

With low latency, we approximate a positioning data for our robot, automatically comparing with our IMU Reading for technical reference.



Silo Full detection with IR sensors



We install IR sensor at the height a little bit above the silo to detection if the silo is full or not, this can prevent our robot from putting the ball into a full silo

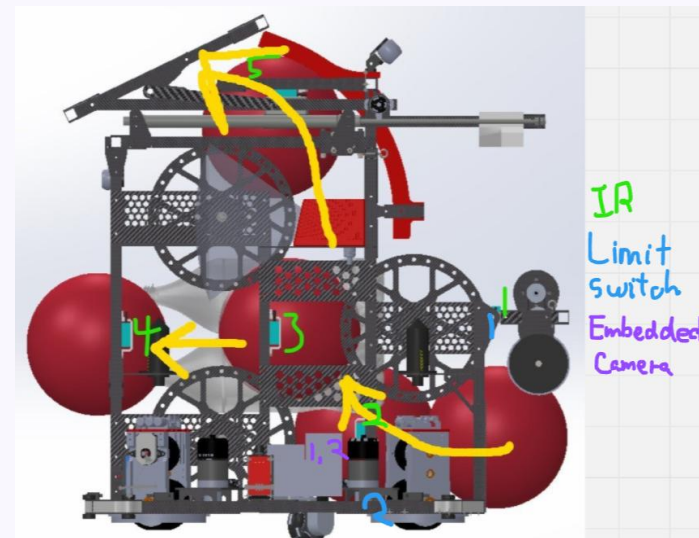
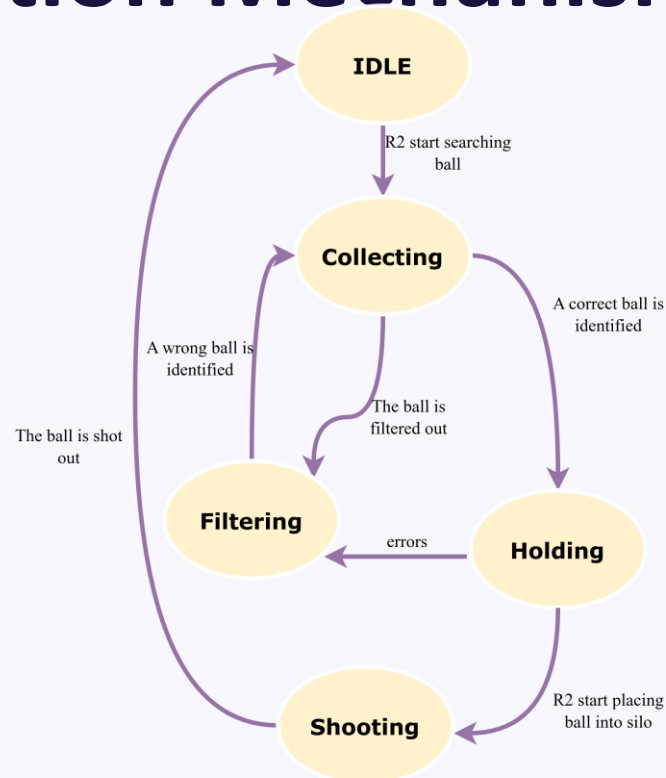
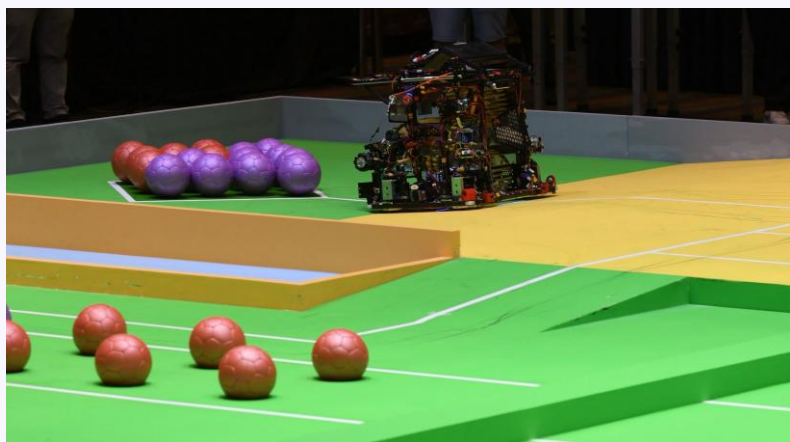
Software

– WD R2 Ball Collection Mechanism



Fast and responsive fully automatic ball collection will color filtering

- Motors cooperate with sensors:
 - IR: collected ball position tracking
 - Limit switch: trigger by incoming balls for quick response
 - Embedded camera: quickly identify color

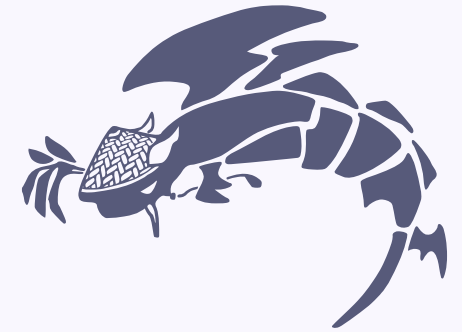


Simplified and abstracted workflow

WD R2 inner sort/collection

Software

– WD R2 Ball Color Detection



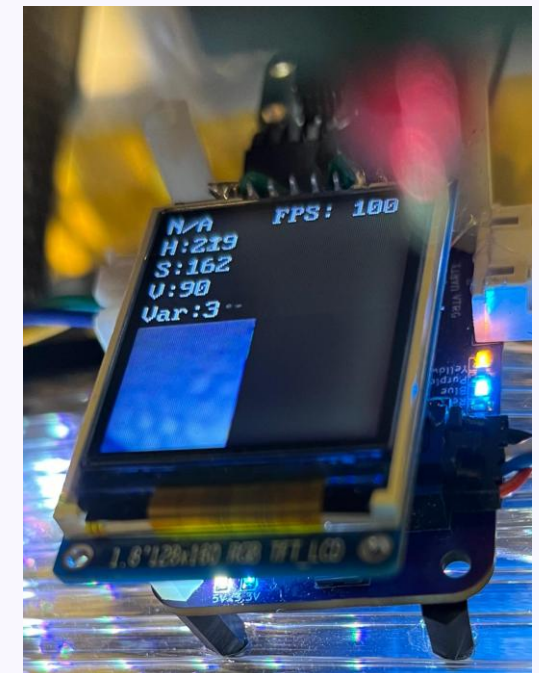
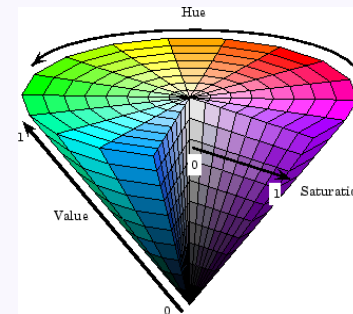
Embedded cameras are used in WD R2 for ball sorting.

To detect camera obstruction by empty grain or paddy rice, the captured RGB565 image is first converted to HSV color space. This conversion aids in distinguishing the image color.

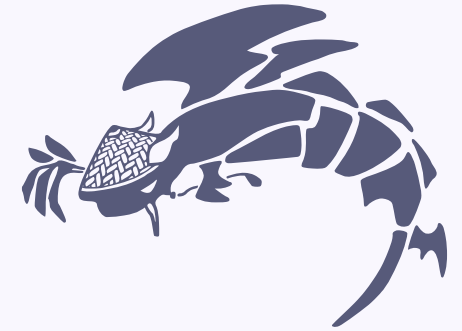
The mean values of the HSV components (hue, saturation, and value) are then calculated to represent the dominant colors in the image.

Additionally, the variance of the image is computed, indicating the color homogeneity. Low variance suggests a uniform color distribution, likely indicating an obstructed view by the ball.

By analyzing these statistical measures, the algorithm effectively determines if the camera is obstructed by the empty grain or paddy rice.



Software – WD R2 Pathing



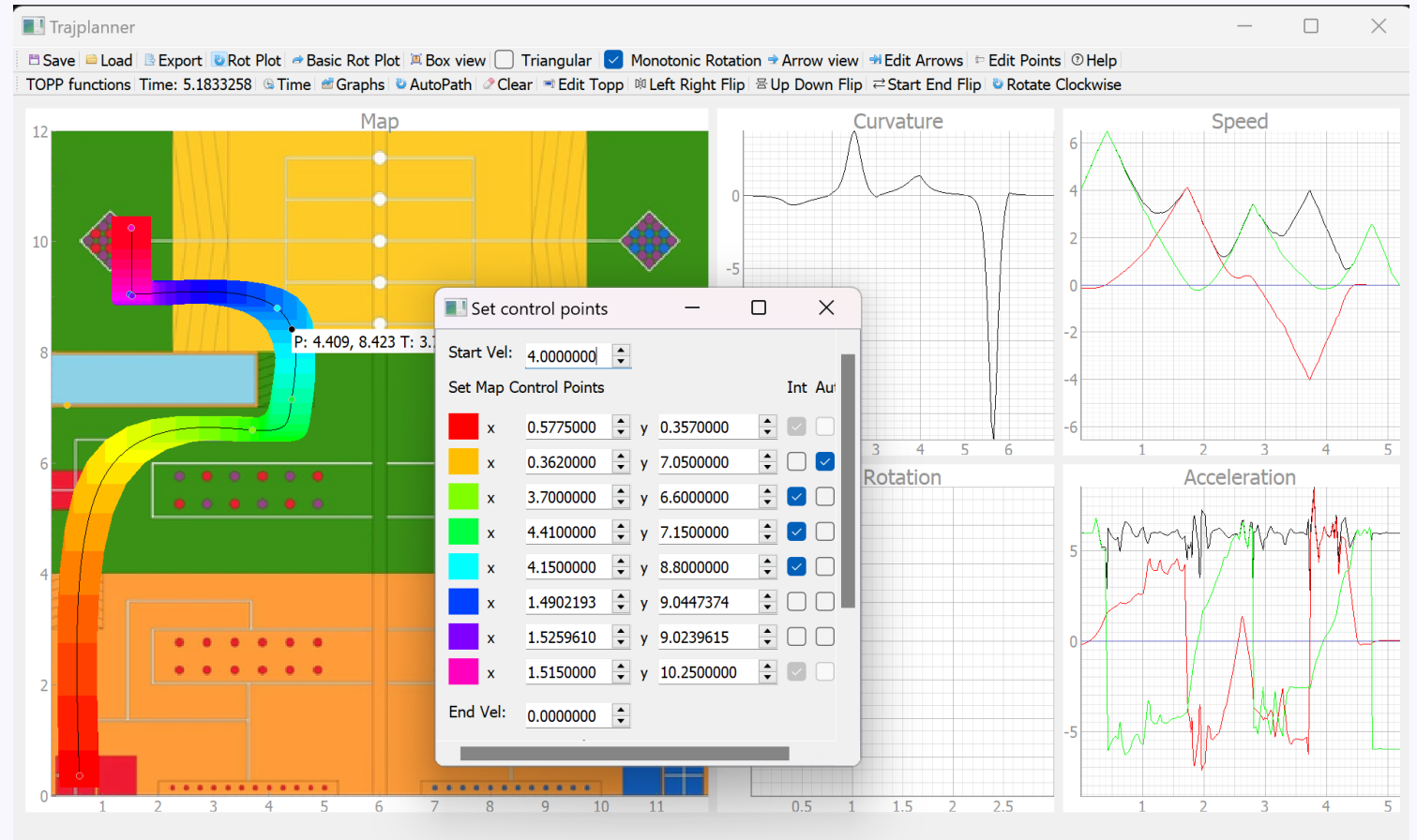
Static Path

- Start from start zone
- Retry

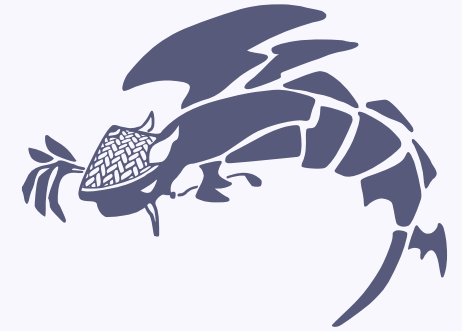
Fixed path for every game

Calculate (optimal) Bezier curve and follow the trapezoidal trajectory for fast and smooth reaching storage zone.

Start Velocity = 4 m/s to jump start to max speed in the beginning



Software – WD R2 Pathing



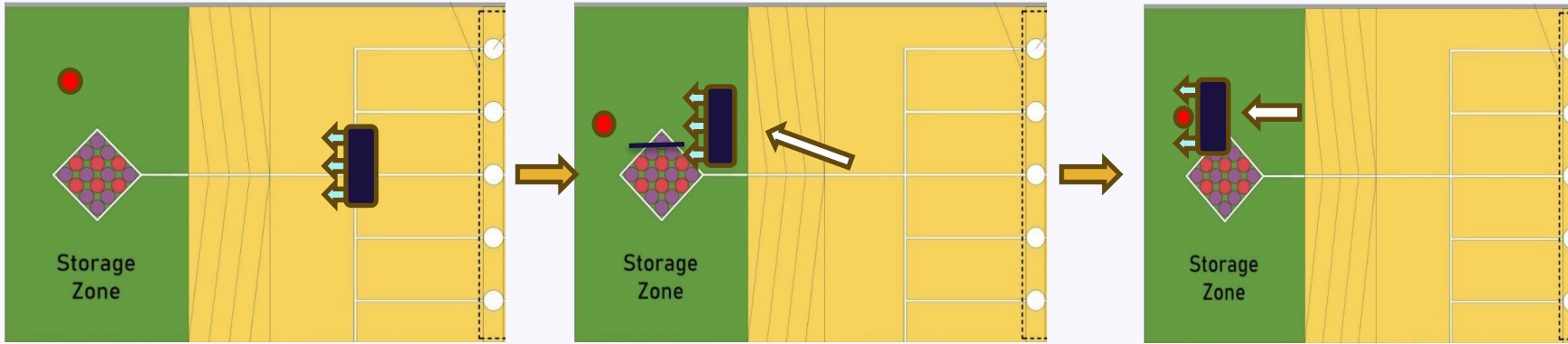
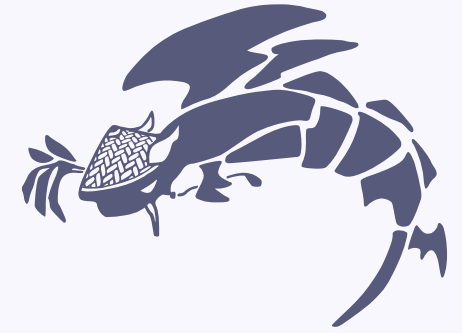
Dynamic Path for Area 3

- Area3 to storage zone's balls
- Storage zone to optimal silo

The start point and end point are dynamic base on conditions and strategy, as the area 3 is full of obstacles.

Paths are formed by combinations of straight lines with calculated trapezoidal trajectory base on conditions: position, velocity, camera reading of balls in storage zone and silos.




Software – WD R2 Pathing

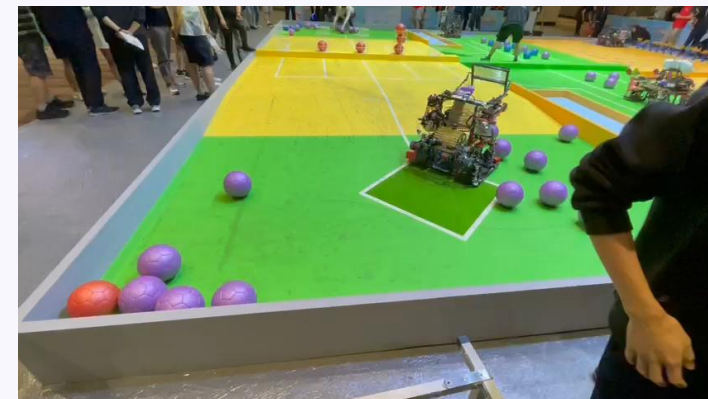


Locate the target within Area3

Continuously drive the R2 towards the target with a certain safety distance where it can perform intake perfectly

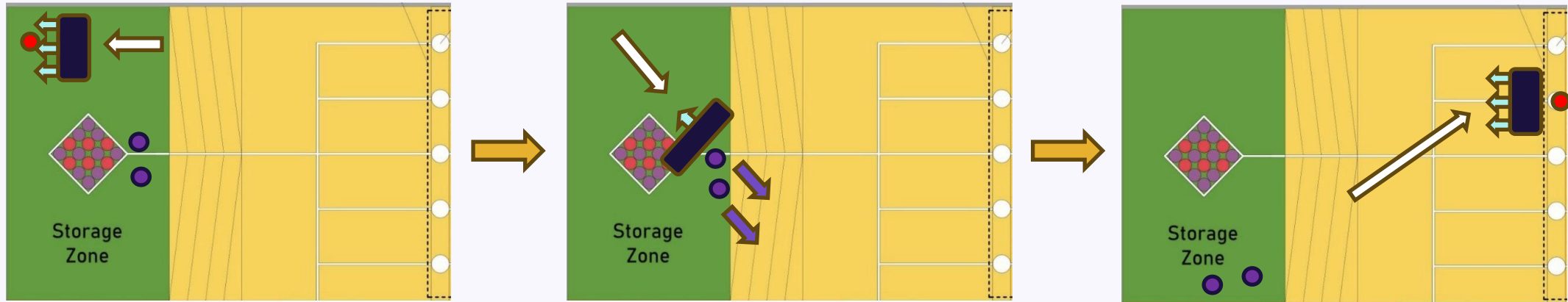
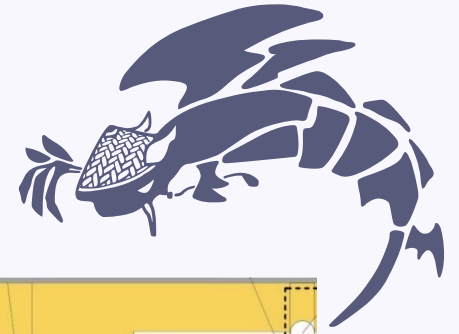
Perform intake (with angle if the robot is close to the wall, as this can improve the performance of the mecanum intake design)

 : R2
 : Paddy Rice
 : R2 movement



Software – WD R2 Pathing

- : Empty Grain
- ➔ : Empty Grain movement



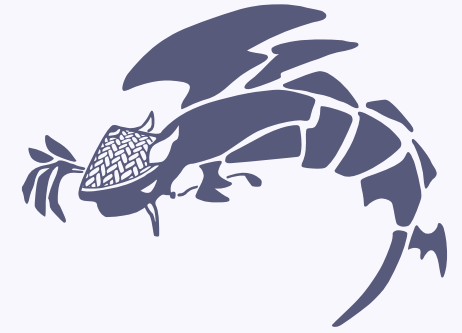
The R2 will rotate and move according to its current position and angle to push the empty grain to the walls and slope

Due to the inclination of the slope, the empty grains will roll back to the storage zone

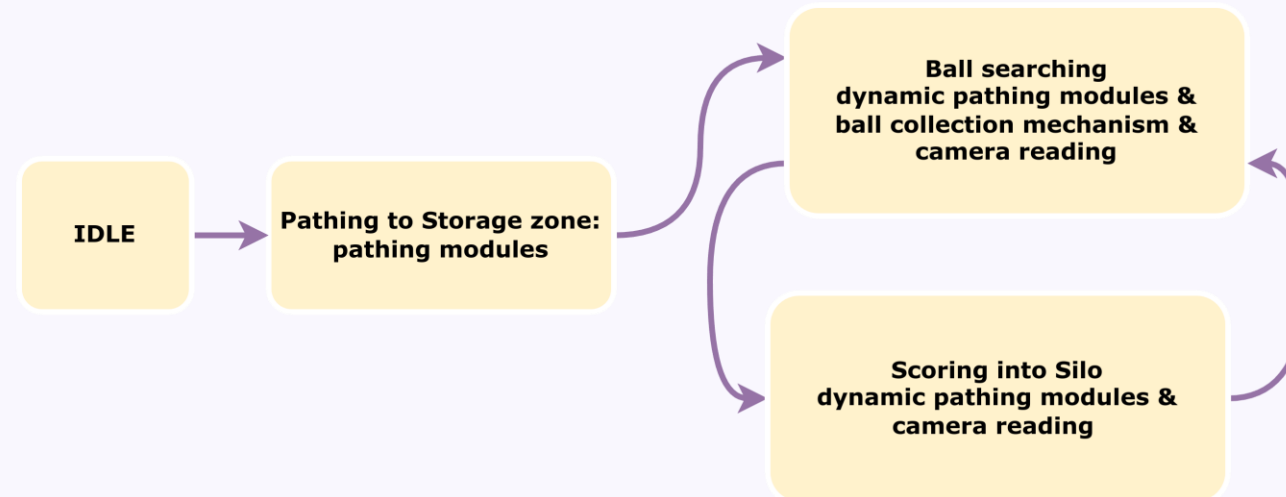


WD R2 SW – Logic flow

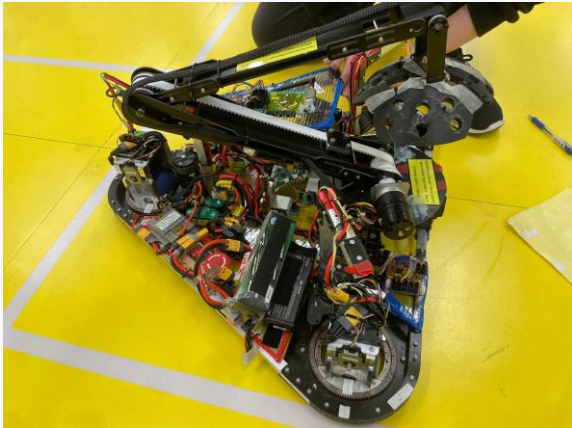
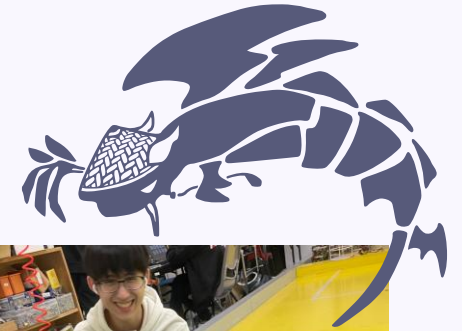
- Intergration of each independents modules: sensors, pathing, mechanisms
- Implementation of our game strategy to provide input for each modules
- Error handling mechanism (timeout, retry, etc.)



To make sure the logic flow got no error is one of the key for fully automatic R2

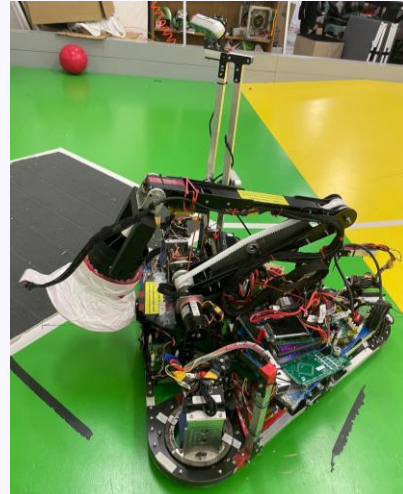


FD R2 Gen 0 – Robotic Arm



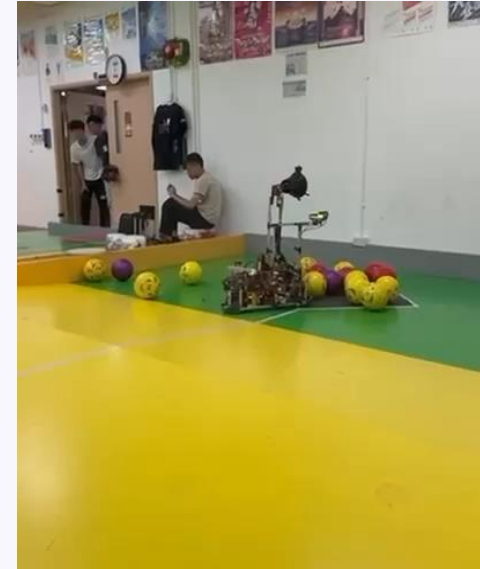
Level 1:

- A wheelbase with 4 degree of freedom nano-type grab
- Used for tuning path
- Used for tuning the
- Able to grab the ball in the last row



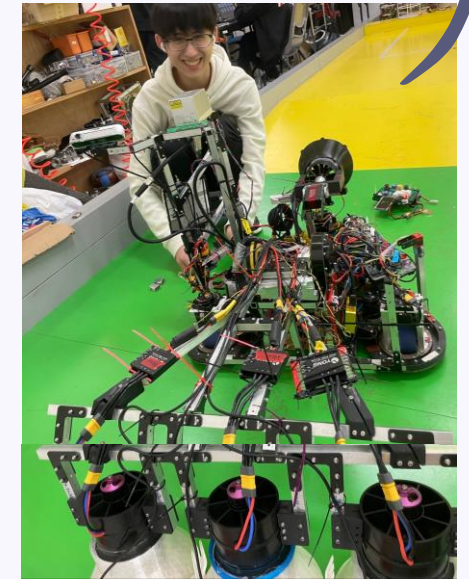
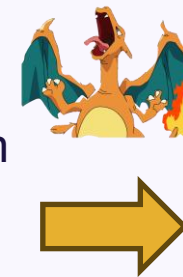
Level 2:

- Prototype of suction arm
- Used for tuning grab and release mechanism



Level 3:

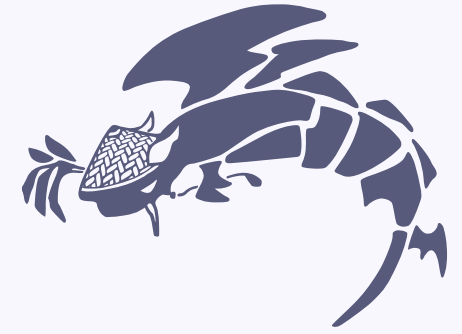
- Prototype of 2 degree of freedom suction arm
- Increased speed and accuracy of grabbing balls
- Archived 1st Great Victory



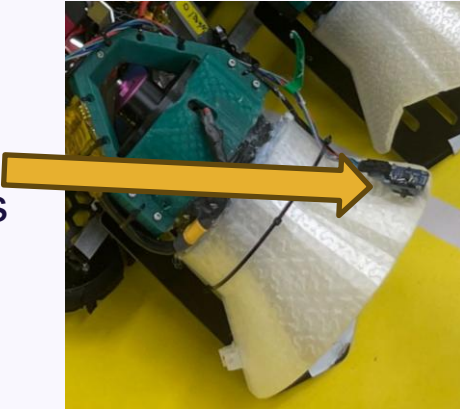
Level 4:

- Prototype of 3 arm
- Tuning sort and release ball mechanism
- Foundation of modern generation

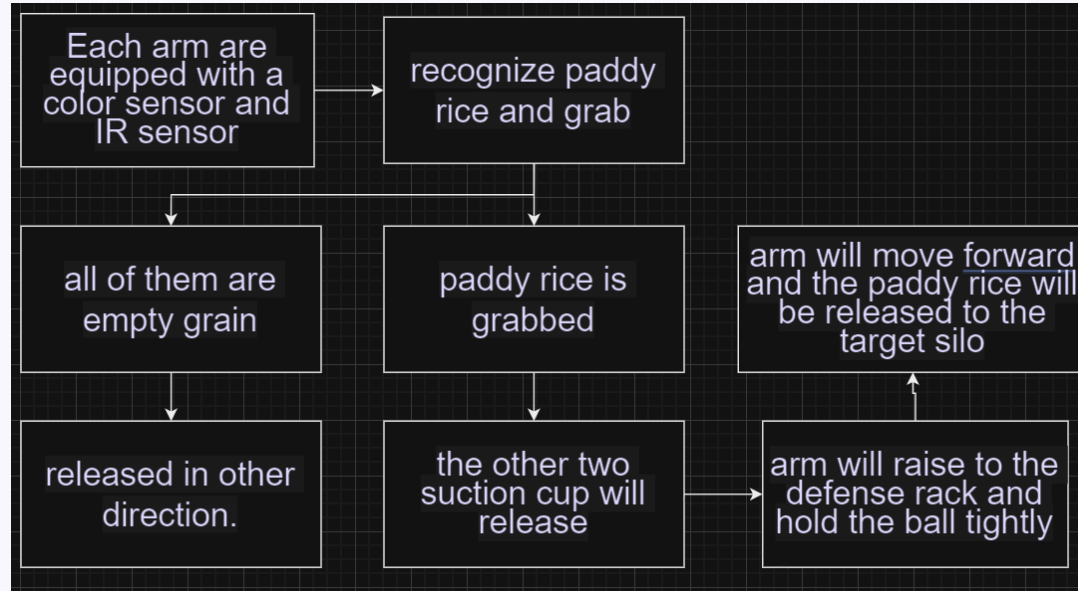
FD R2 SW – Ball Collection mechanism



Color Sensors



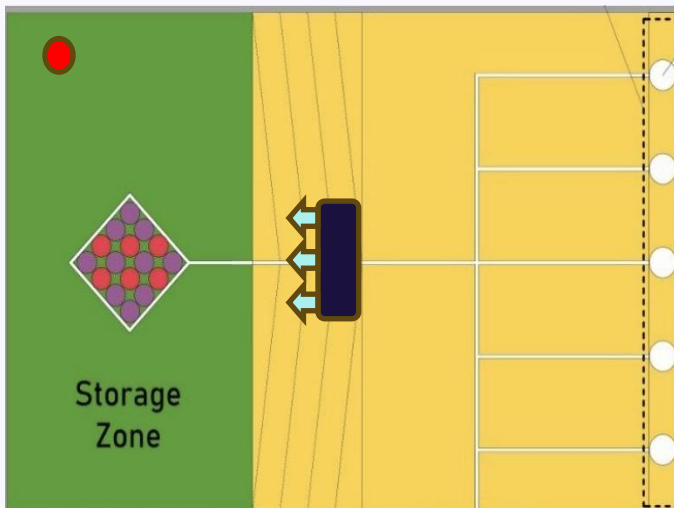
Release



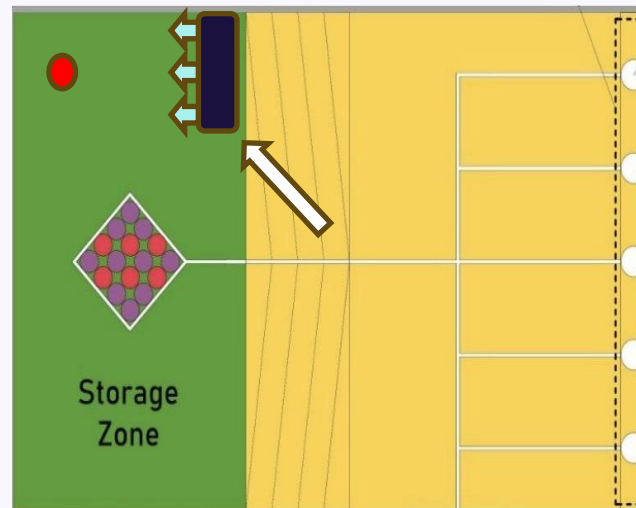
Grab



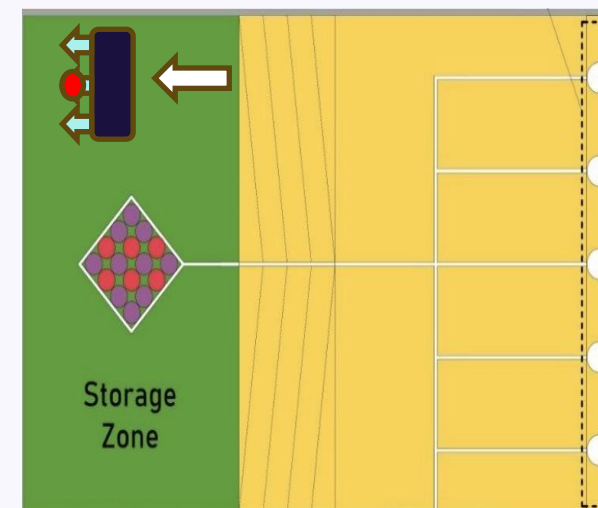
FD R2 SW – Pathing (Grabbing)





Searching position



Continuous chase in y- direction



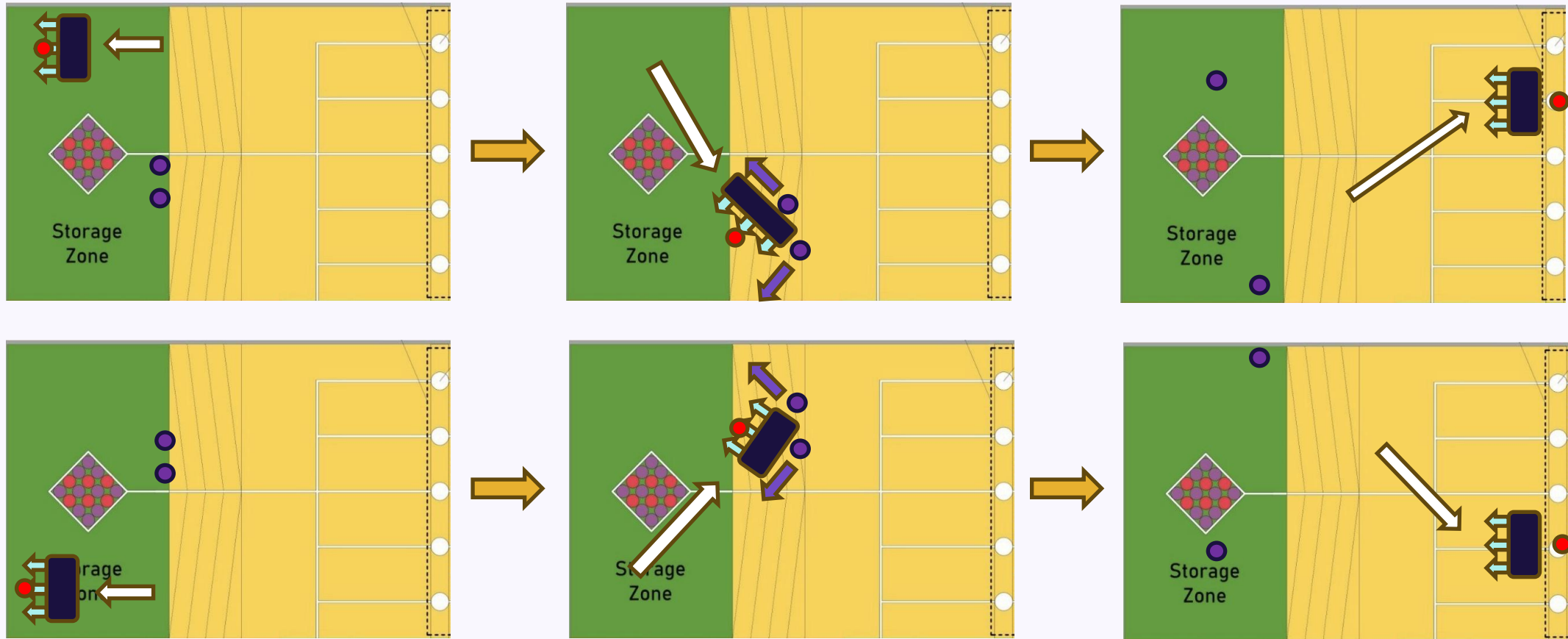
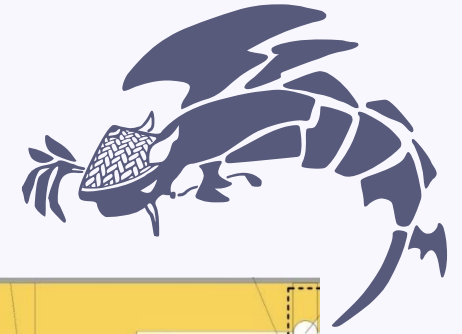
Continuous chase in x- direction

 : Arm R2
 : Paddy Rice
 : R2 movement

FD R2 SW

- Pathing (Area3)

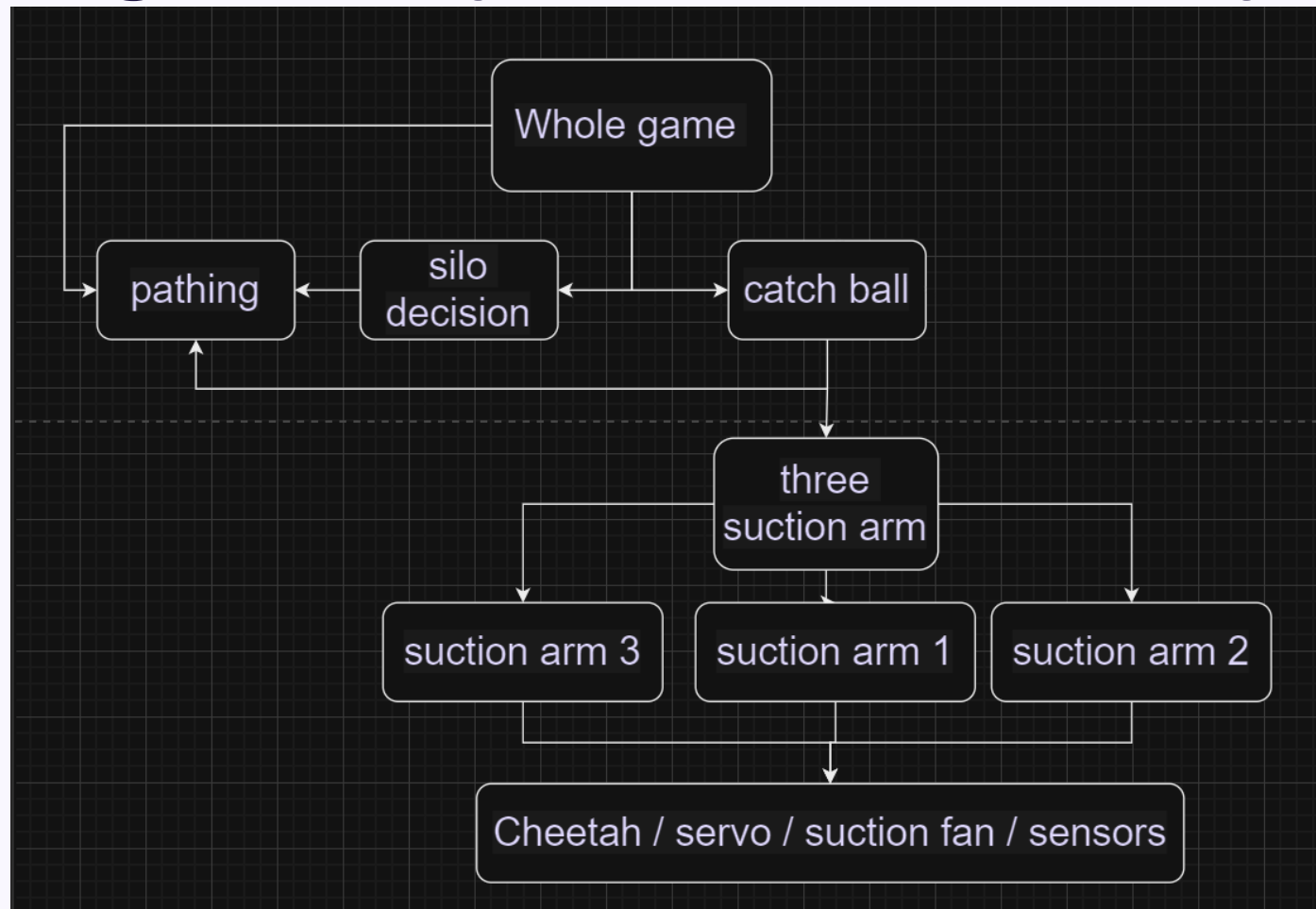
● : Empty Grain
➔ : Empty Grain movement



(Avoid pushing balls to the silo zone)

FD R2 SW

– Logic flow (Whole Game FSM)



Finite State Machine(FSM)

Whole game FSM:
Control the overall game flow decisions and control lower level FSM

- Start / retry path
- Search paddy rice
- Put ball
- Back storage zone

Note:
FSM in higher level can override the FSM in lower level

FD R2 SW – Logic flow (Decision and Motor FSM)



Silo decision

- Using camera and Orin to decide the target silo
- Control arm movement for releasing paddy rice
- Check the color and presence of paddy rice Continuously

Catch ball

- Search balls
- Force rotate search if no paddy rice was found)
- Grab ball paths (x and y movement)
- Grab and release ball mechanism

Three suction arm

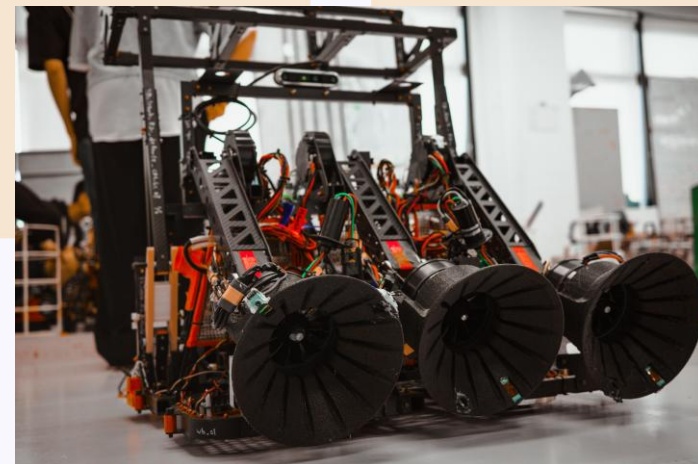
- Control the movement of all suction arms
- Lift the defend rack

Suction arm

- Control each arm individually
- Grab balls
- Detect ball color
- Release balls

Note:

Some FSM have a state which indicate finishes of tasks and allow other FSM to jump states



Software – Lidar



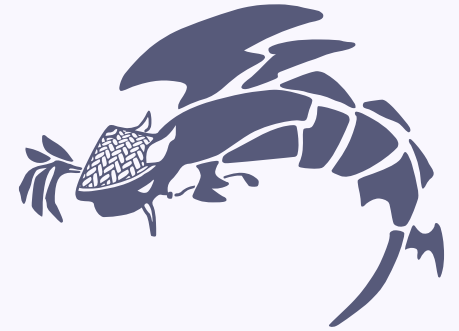
Livox MID-70



Livox Horizon

SW Lidar - Introduction

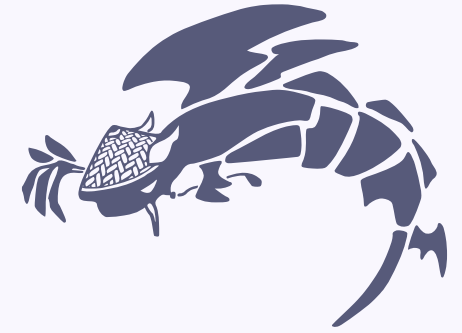
- Livox:
 - Low-cost solid-state 3D Lidar manufacturer
- 3D Lidar:
 - Produce dense 3D point clouds in realtime
 - Able to observe detailed features of the environment
- We use them for:
 - Object detection and tracking
 - 3D odometry and localization



SW Lidar – vs 2D Lidars

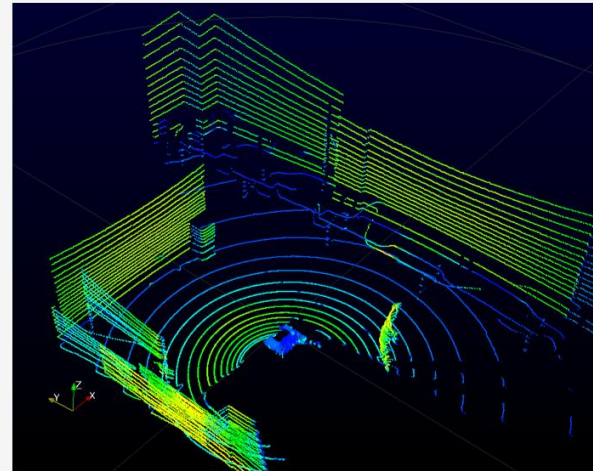
In the past, 2D spinning lidars were used:

- Limited to points in a 2D plane
- Limited object-tracking and feature extraction capability



* Source: siminics.com

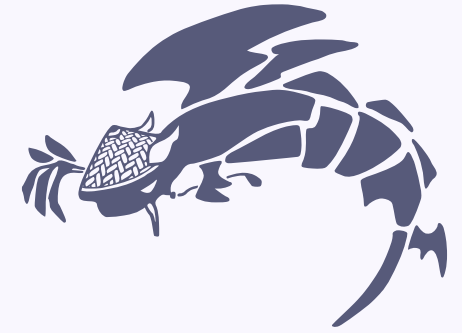
2D LiDAR Point Cloud



*Source: RoboSense

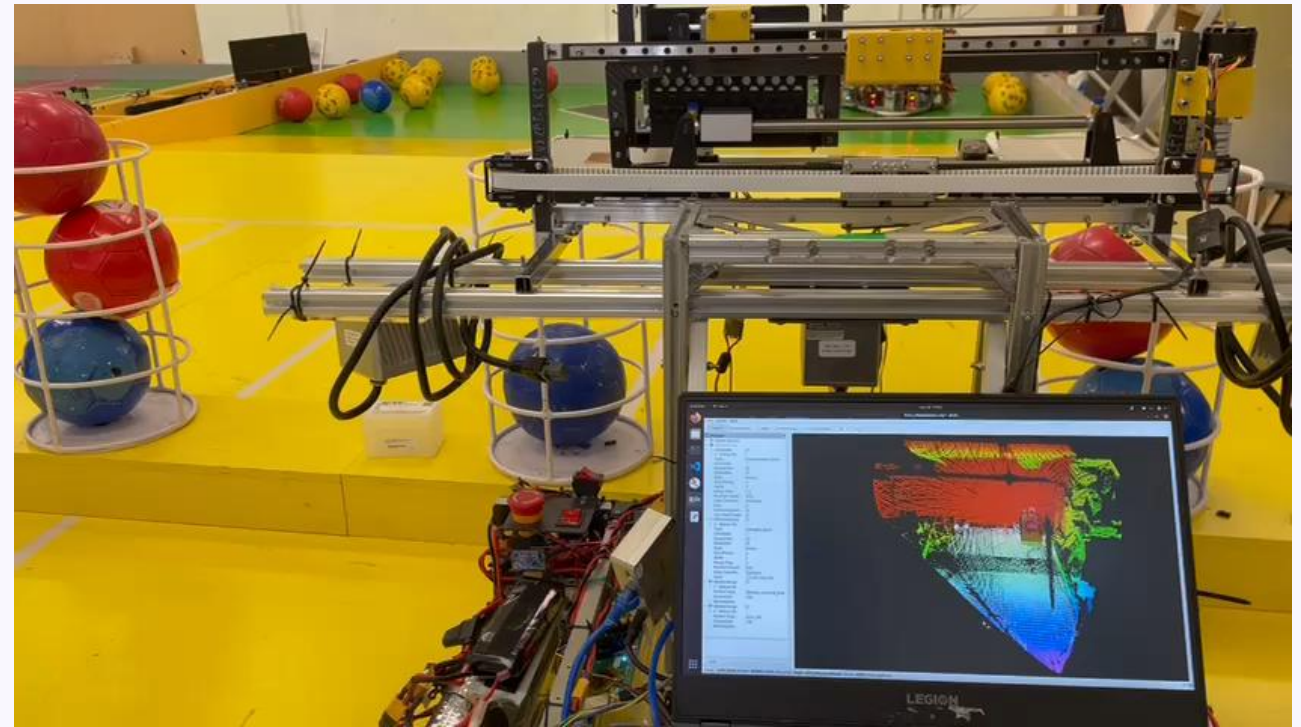
3D LiDAR Point Cloud

SW Lidar - Livox object tracking



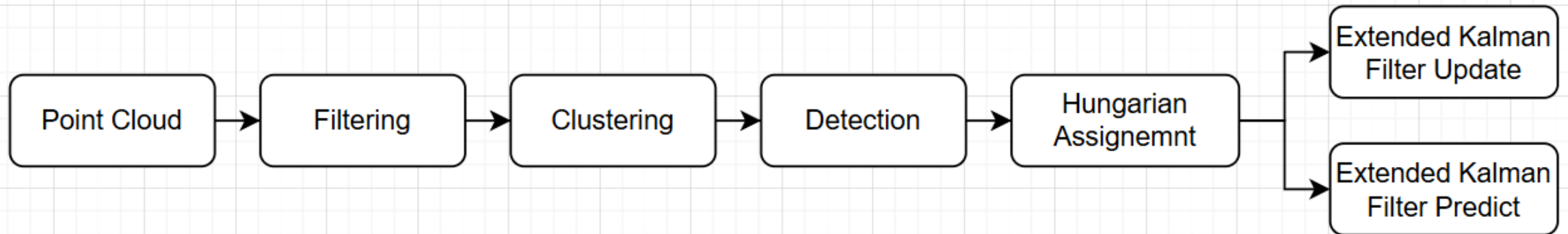
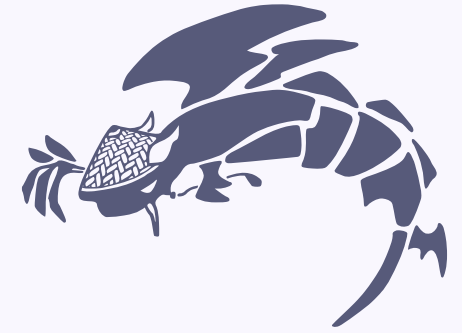
Objective

- Real-time tracking with fast response capabilities to dynamic environments
- Long-distance tracking to monitor opponent robots
- Adaptive detection to detect different robots from various universities



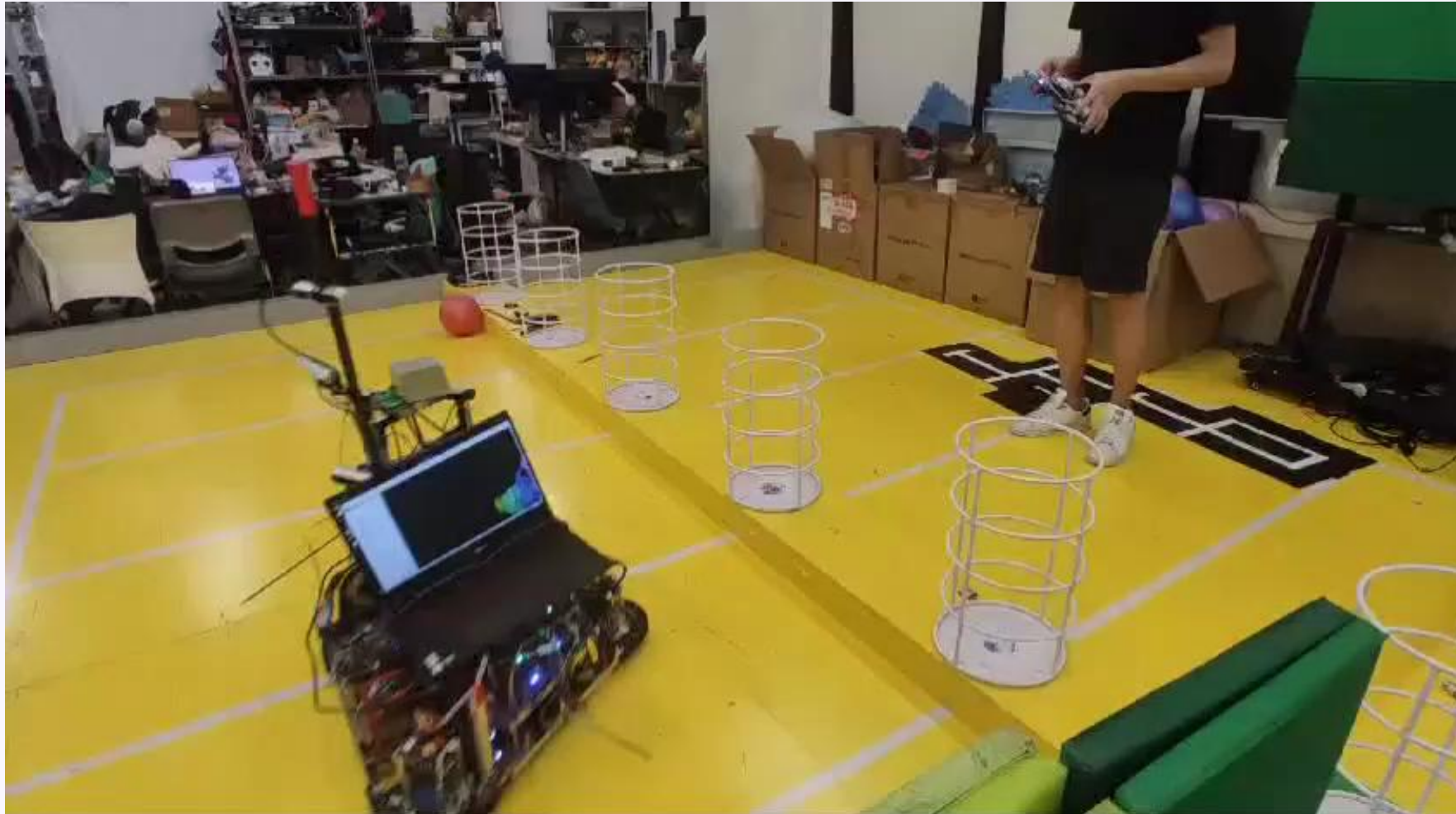
SW Lidar - Livox object tracking

Implementation



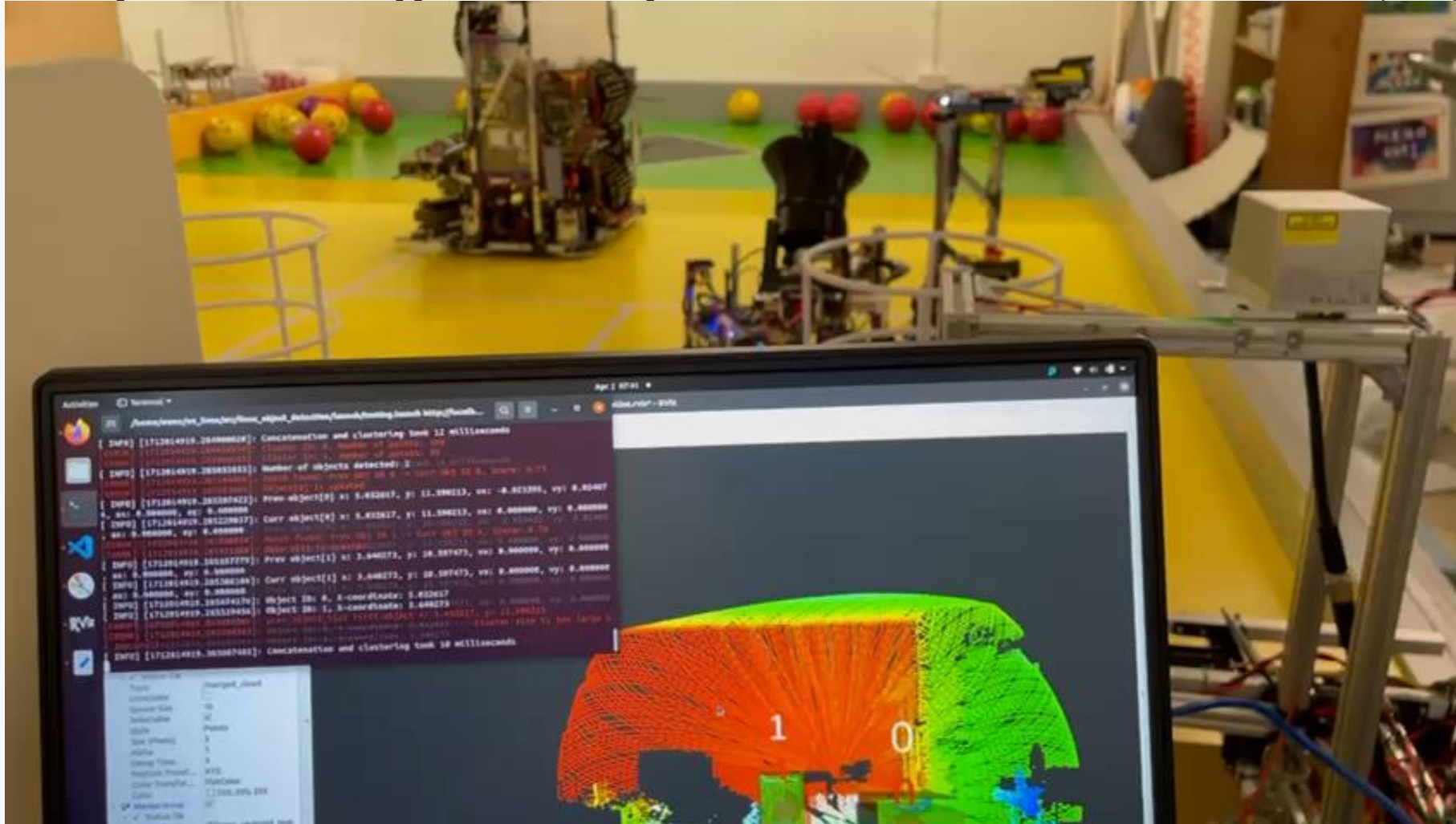
SW Lidar - Livox object tracking

Real-time Tracking and Fast Response



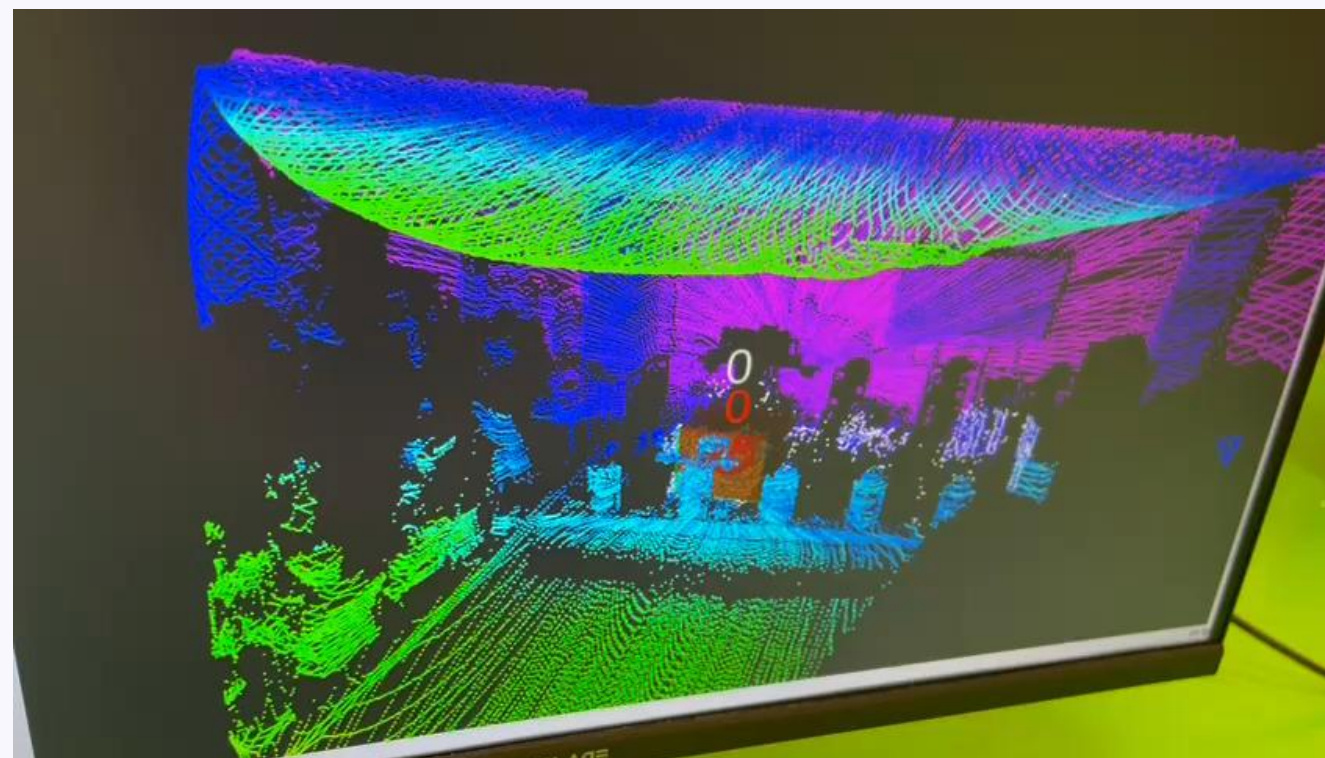
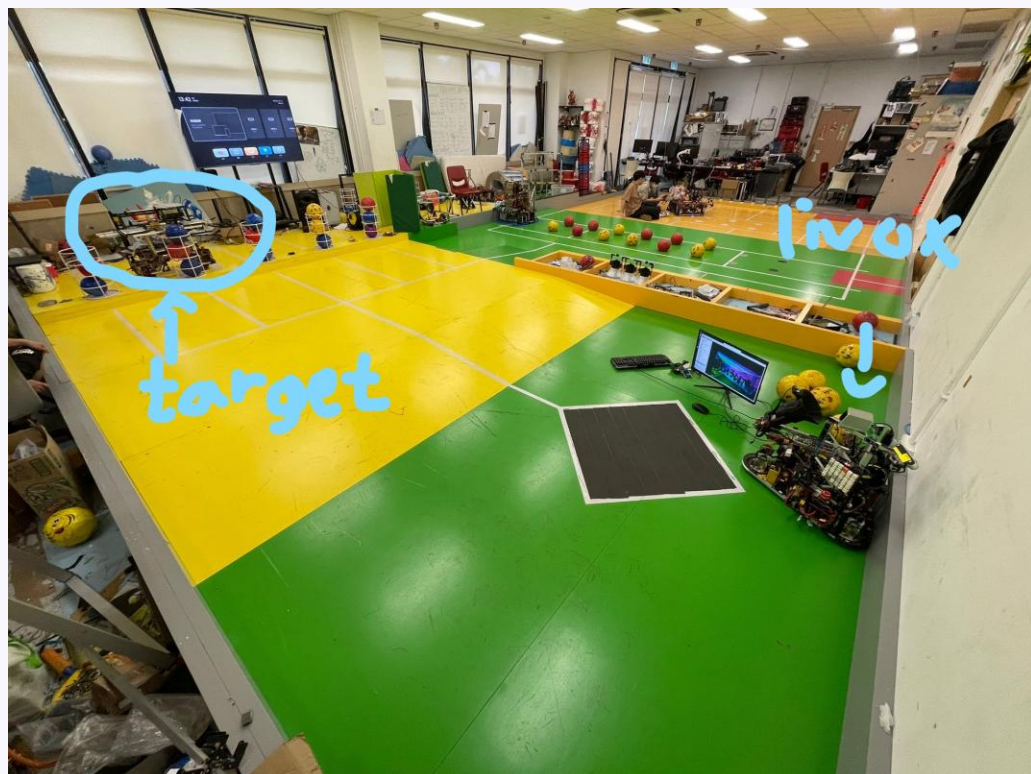
SW Lidar - Livox object tracking

Multi-Object Tracking and Adaptive Detection



SW Lidar - Livox object tracking

Long-Distance Tracking

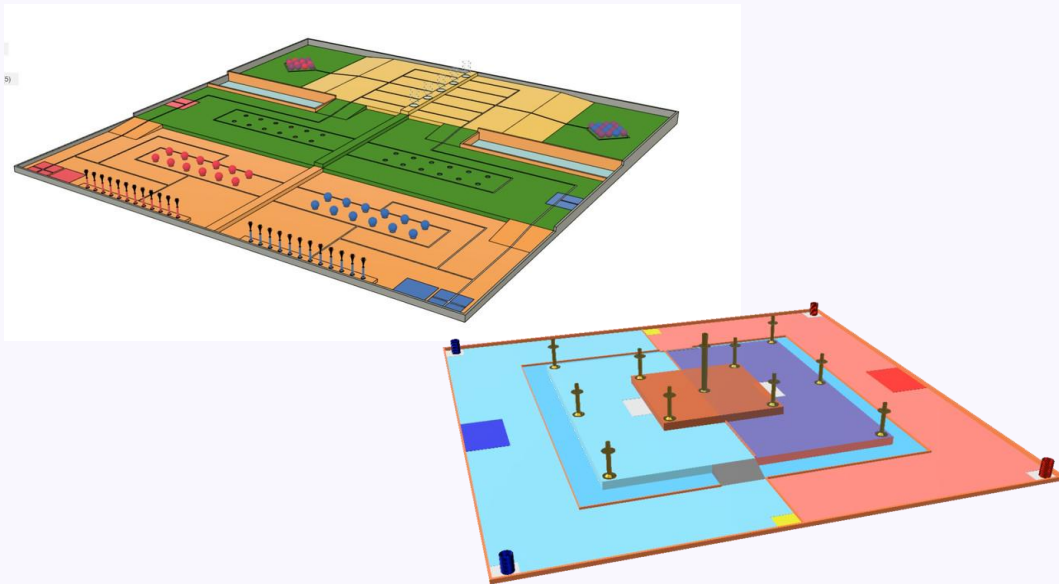
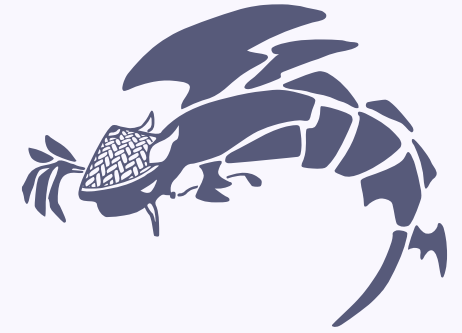


Able to track opponent robots from our storage zone to their storage zone
(I forgot to take video 😊)

SW Lidar - Lidar Localization

Motivation

Our existing global localization methods cannot cope with:



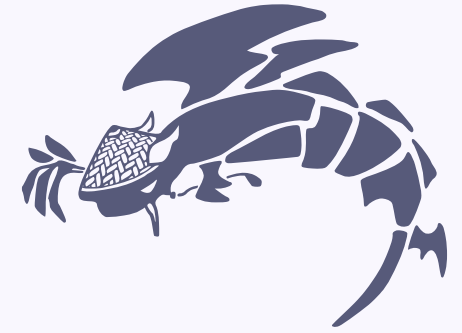
3D Environments



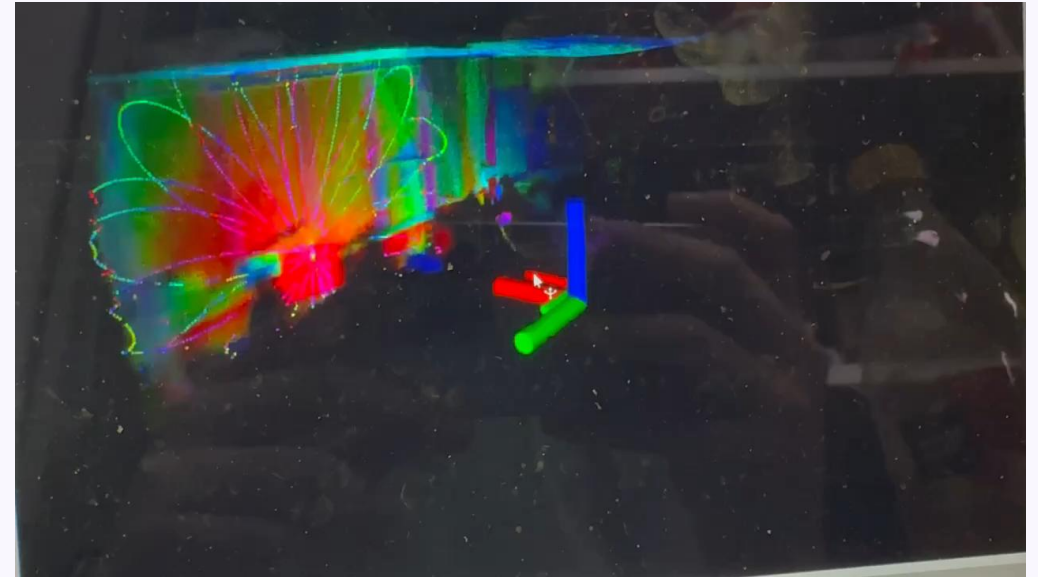
Dynamic Obstacles

SW Lidar - Lidar Localization

Potential Solution - 3D LiDAR Localization



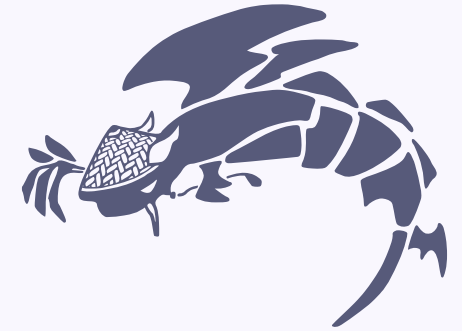
- Can be used regardless of the specifics of the game field
- Accurate position estimation without drift over time
- Works with the presence of dynamic objects
- An existing environment map could be used to improve reliability and stability



Results of LiDAR SLAM in Hall 8

SW Lidar - Lidar Localization

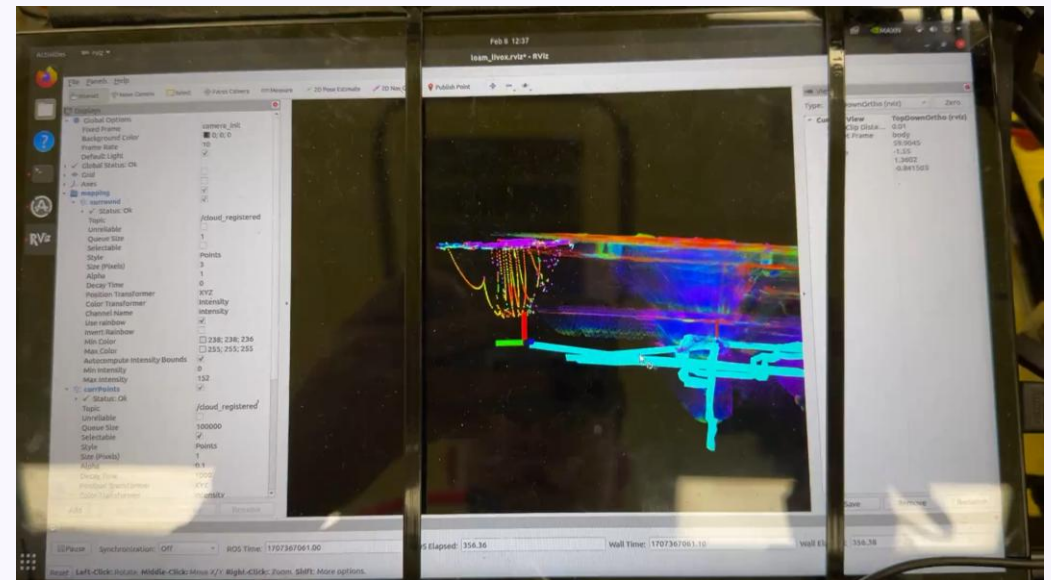
Issue - Degeneration



- Localization using only Lidars easily degenerates in an indoors environment
- Causing significant drift

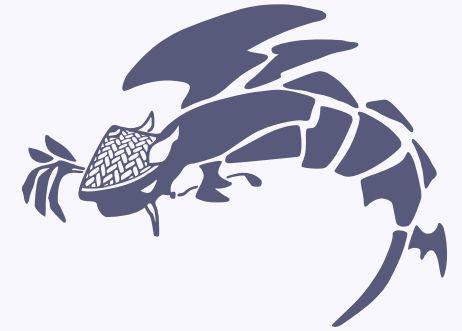
Due to

- lack of feature points (flat walls)
- Repetitive structures

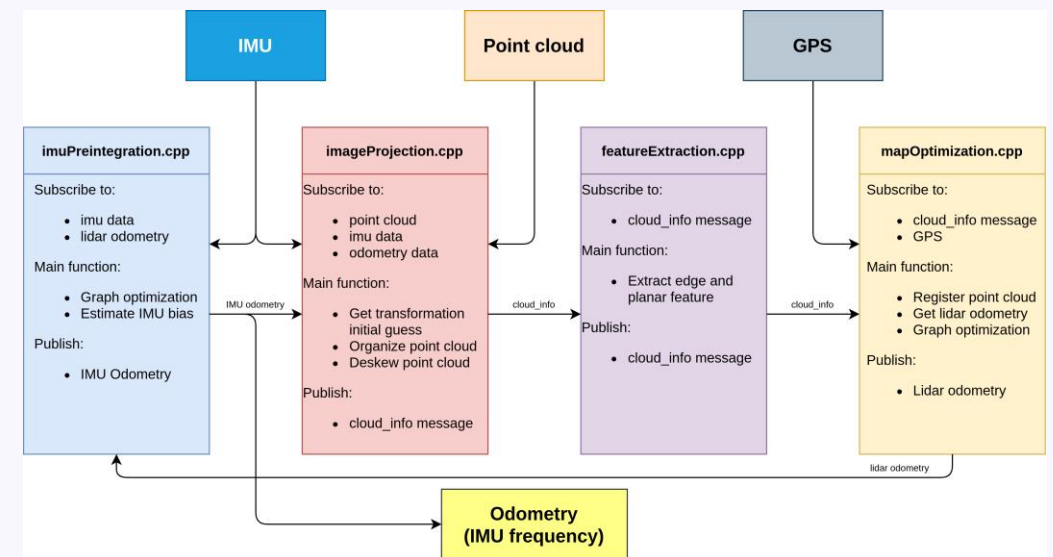


Example of degeneration

SW Lidar - LiDAR Inertial Odometry

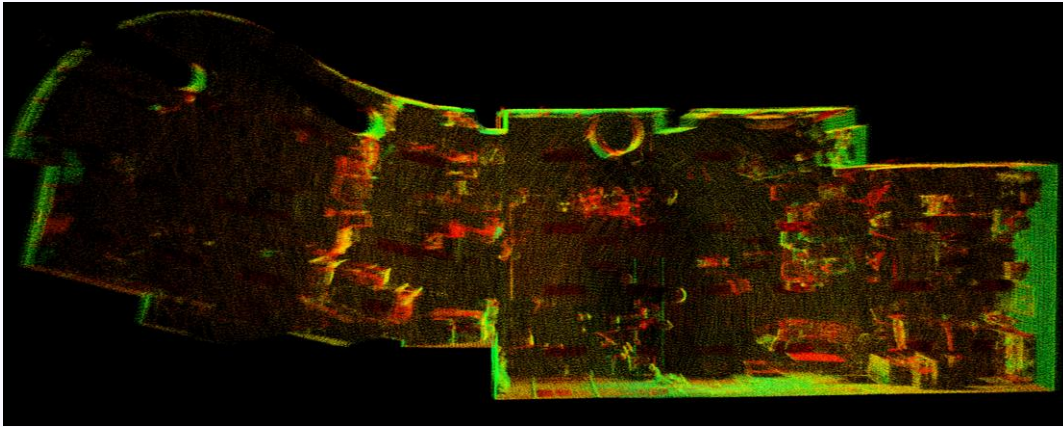


- One way to handle degeneration:
 - Use an IMU odometry source
 - Fuse both Lidar and IMU odometry
- Numerous packages implement this:
 - FAST_LIO2
 - Point_LIO
 - Liorf,
 - LIO-SAM, etc.



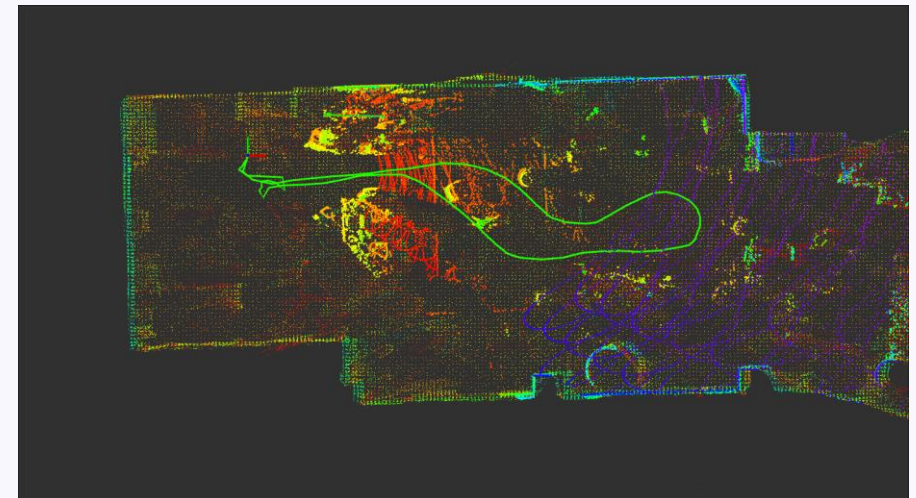
System overview of LIO-SAM

SW Lidar - LiDAR Inertial Odometry



Scanned map of Hall 8 using liorf

Liorf localization using map



SW Lidar - LiDAR Inertial Odometry

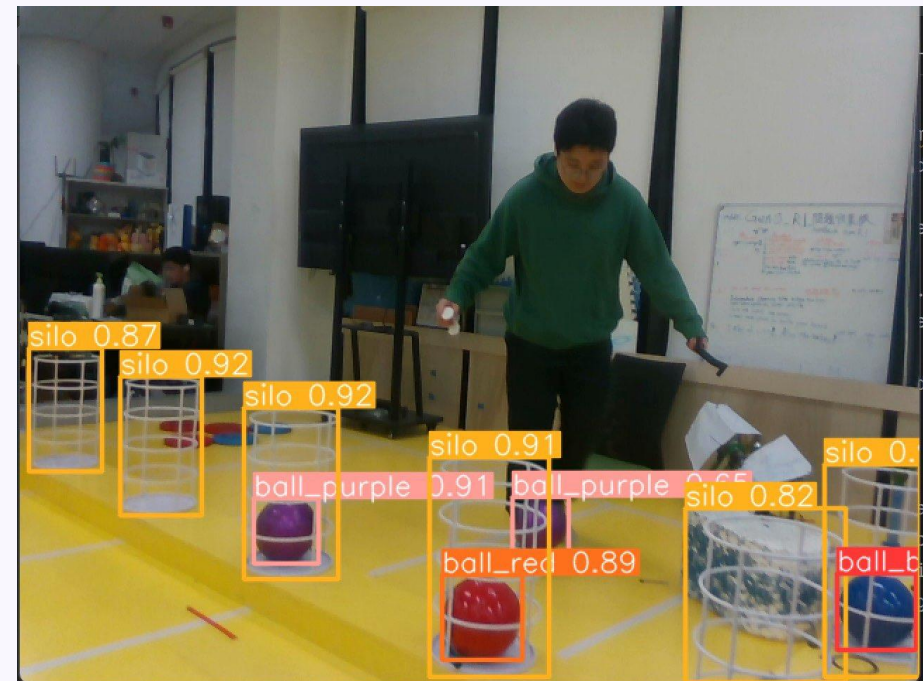


- Points of caution
 - LIO is typically low-frequency (~10 Hz)
 - LIO incurs increased computation requirements
 - LIO latency is higher
- Future applications
 - Global position recalibration
 - Transform LiDAR data to map coordinates for simpler processing

Software – CV

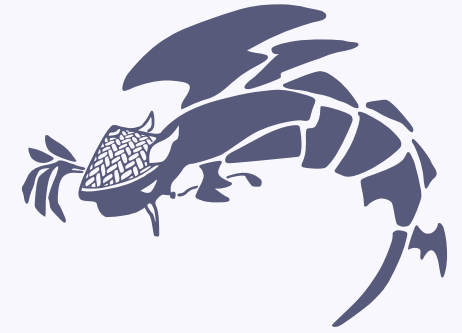


Intel RealSense Depth Camera D455

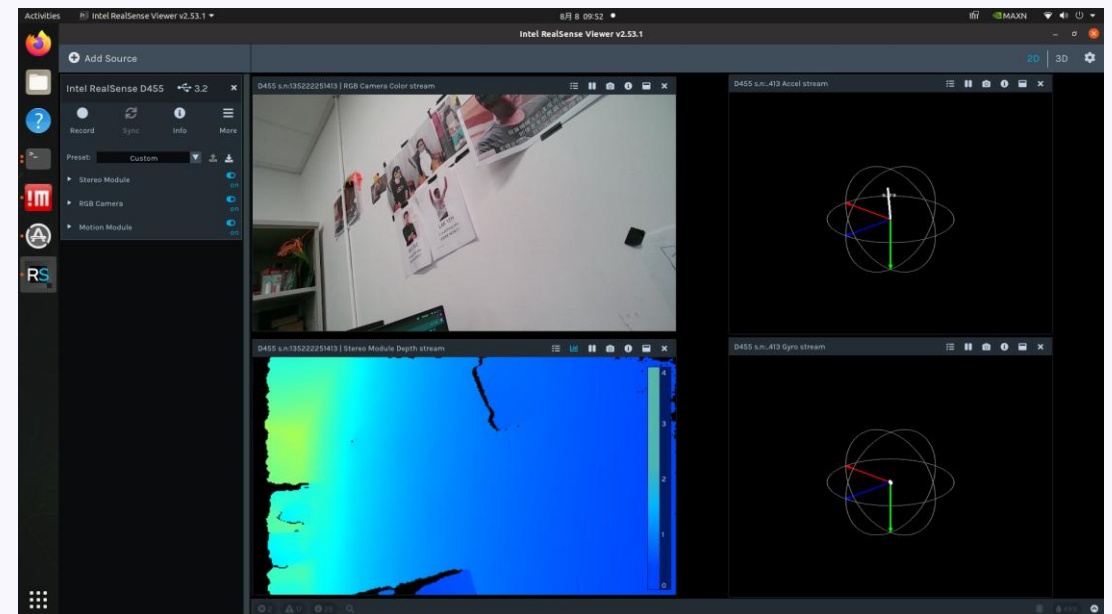


YOLOv8 model

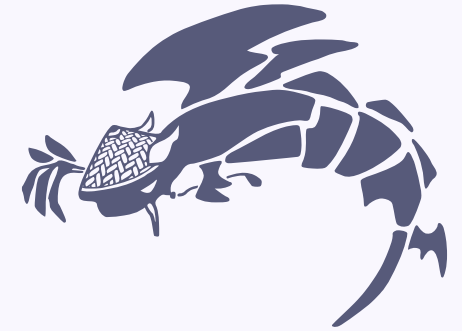
SW CV - Camera tasks introduction



- Depth Camera:
 - Uses stereo vision
 - Measures the distance between the camera and objects in a scene
- We use them for:
 - Real-time object detection and tracking
 - Silo detection + decision making
 - Ball tracking



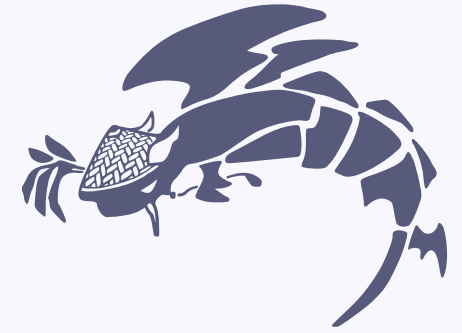
SW CV - AI silo detection



- Silo detection:
 - Uses a D455 depth camera that faces towards the silo
 - Use YOLOv8 model to detect balls and silos
 - Localize each silo from frame position to global coordinates
 - Compares area of balls with silos
 - Calculate which balls are in which silo
 - Only update silos that are currently in frame
 - Publish a silo matrix (contains data of all 5 silos)



SW CV - AI silo detection



- Silo decision making:
 - For R2 to decide which silo it should go
 - Using data from the silo matrix to perform decision making
 - Has multiple modes for different situations
 - Normal mode
 - End game mode (Prioritizes occupying silos)
 - Defend mode (Prioritizes defending)
 - Makes a list of silos based on their priority
 - Sends the data back to mainboard

SW CV - AI ball tracking

Why not just send the nearest ball coordinate to mainboard?

We found it has following problems:

1. Target ball coordinate may swing between two or more similar distances balls

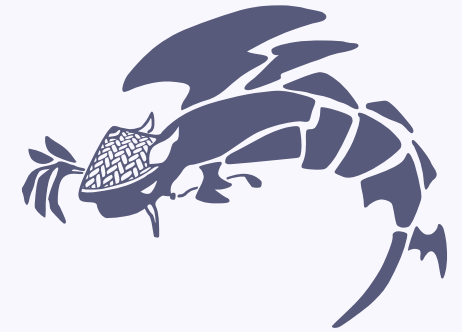


Three balls with similar distance

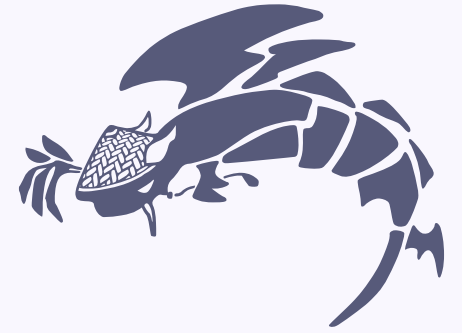
2. Some cases other balls are easier and faster to collect than the nearest ball



Ball at right side is easier to reach than the middle one



SW CV - AI ball tracking



We discovered:

- Target ball may swing between 2 or more similar distances balls

How we solve it?

- Use ball tracking
- Tracked ball ID is saved
- Only sends the tracked ball's coordinate until:
 1. the ball is grabbed or
 2. outside the camera image or
 3. too far away than the nearest ball

SW CV - AI ball tracking



We also discovered:

- Some cases other balls are easier and faster to collect than nearest ball
- Balls are more difficult to be collected when:
 1. Moving
 2. Behind purple balls
 3. Near fence

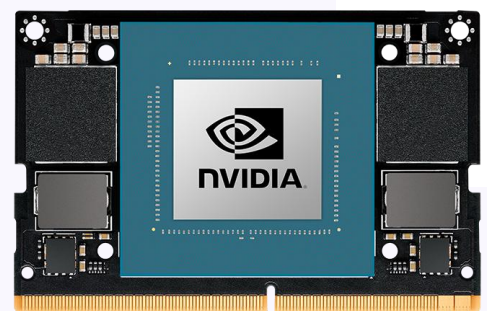
How we solve it?

- Not just sort the ball by distance
- Use several criteria to evaluate the easiest and fastest ball to reach:
 1. Distance from wheelbase
 2. Velocity
 3. Number of ball in front of itself
 4. Is it near the fence



Balls difficult to collect

Software – ROS

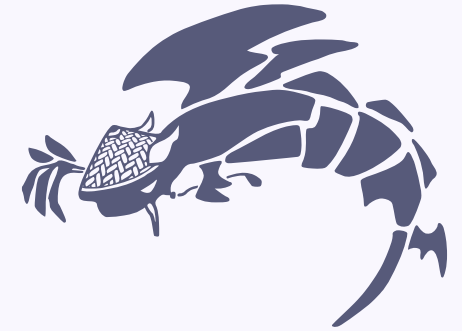


AmovLab AllSpark2 – Nvidia Orin NX



 ROS

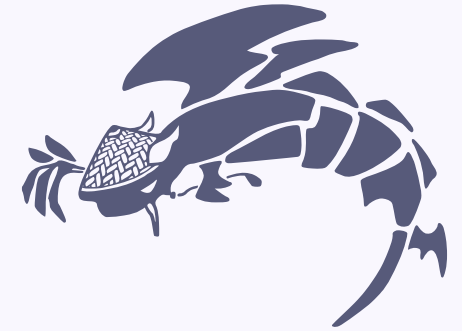
SW ROS - Introduction



We want to migrate more of our control logic to ROS2:

- Increased processing power from Orin
 - Dynamic pathing, etc.
- More advanced control algorithms
 - Existing open-source packages
- Take advantage of the ROS ecosystem
 - Existing open-source packages

SW ROS - Introduction



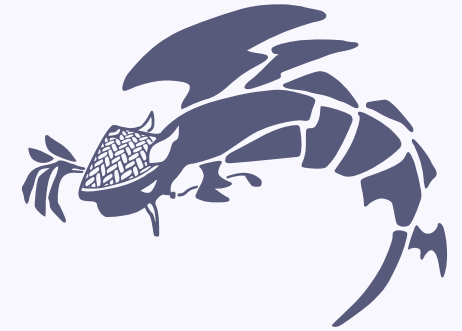
To start this migration, we are:

- Moving from ROS Noetic (reaching EOL) to ROS2 Humble
- Standardizing ROS2 development and deployment using Docker

Initial ROS2 projects include:

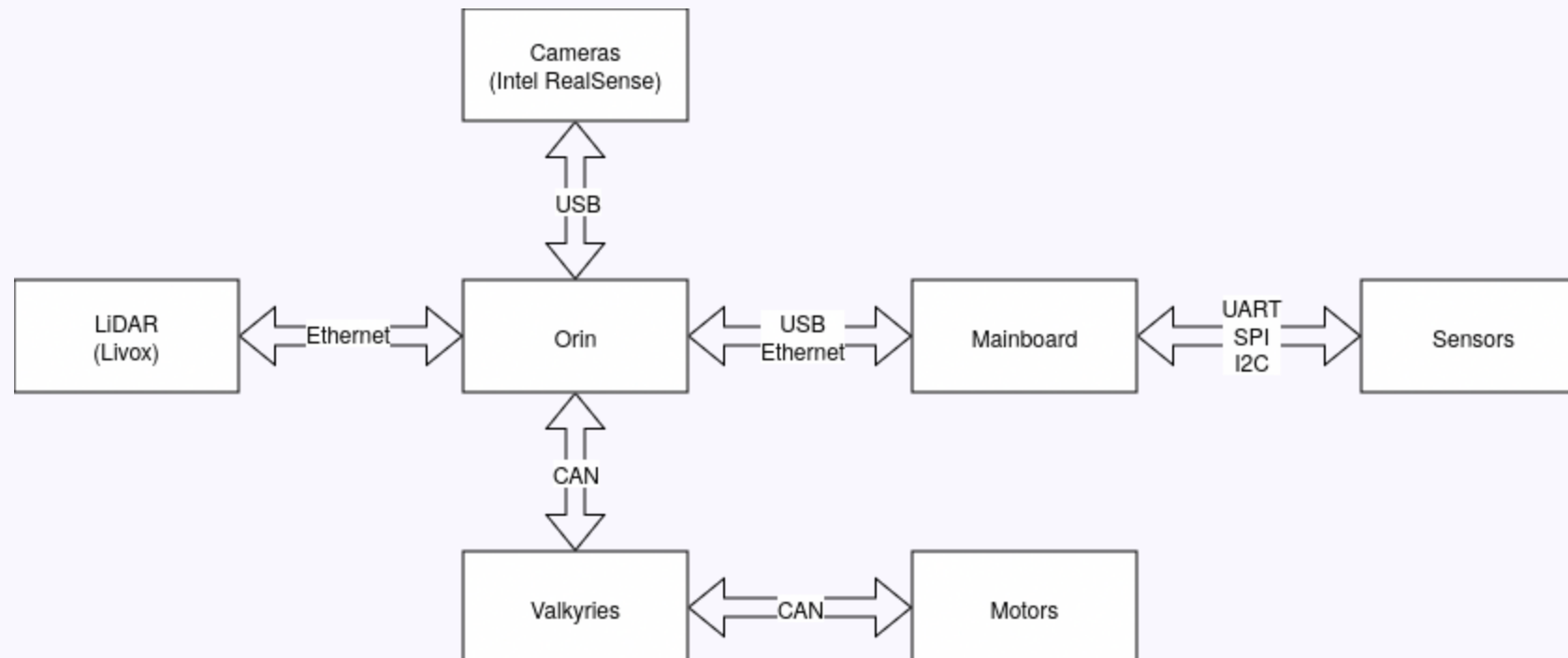
- ROS wheelbase navigation
- Direct motor control over CAN
- Gazebo simulations
- Lidar Object Tracking
- Lidar Localization

SW RND - ROS Robot Control

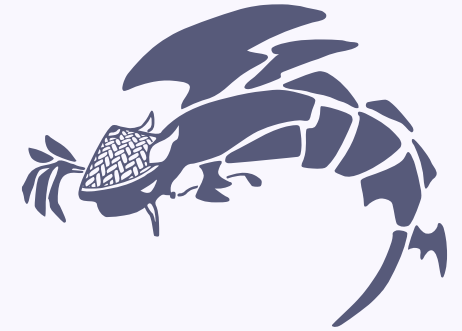


In the long term, the robot would be centered around the computer:

- Most high-level control logic lives in ROS
- The STM32 Mainboard is only responsible for interfacing with sensors and low-level protocols



SW RND – Micro-ROS



Moving from roserial to micro-ROS:

- Support ROS2
- Enable usage of alternative transports
 - USB
 - UDP / Ethernet
- Native support for FreeRTOS and STM32

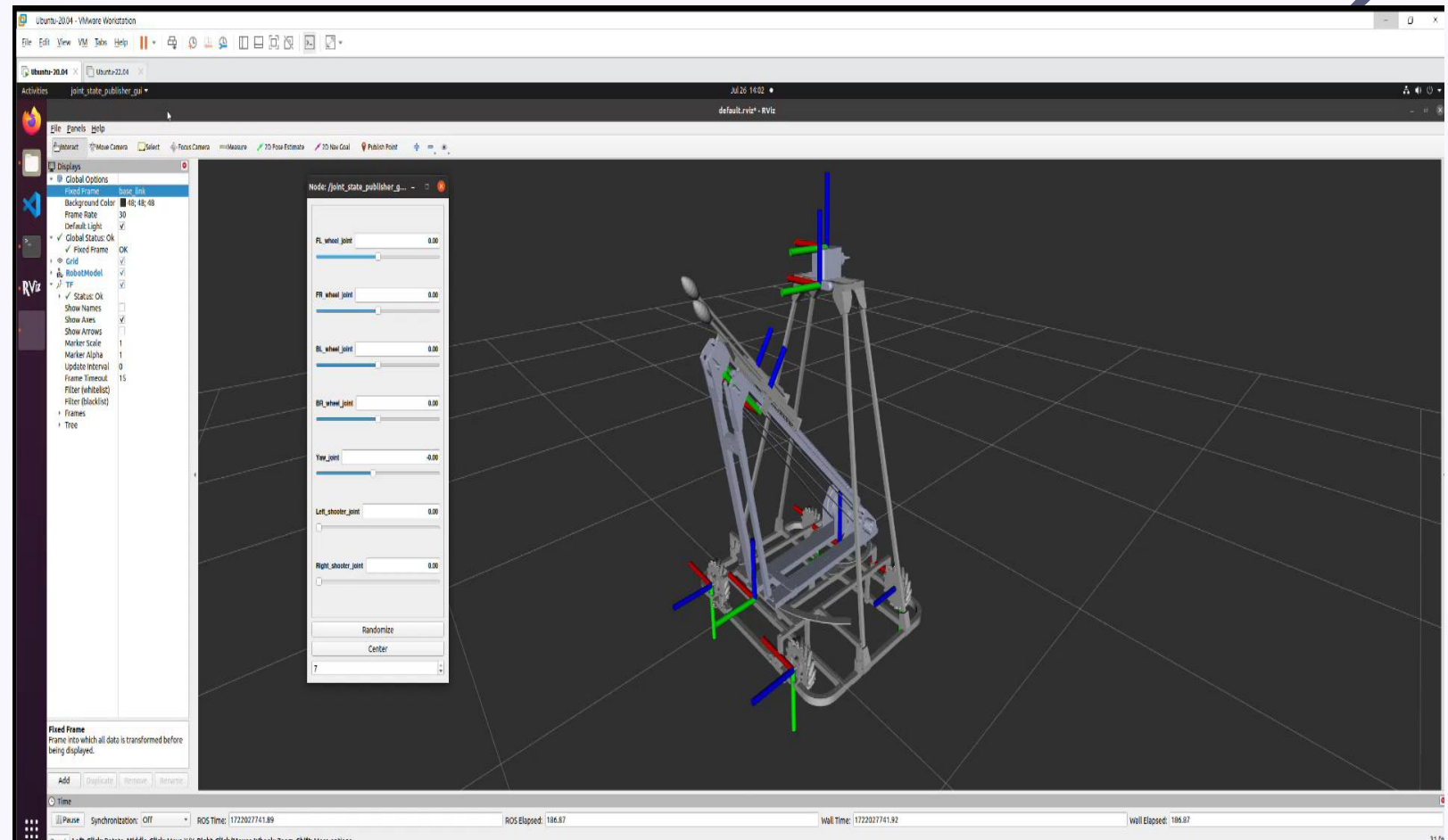


SW RND – Gazebo Simulation

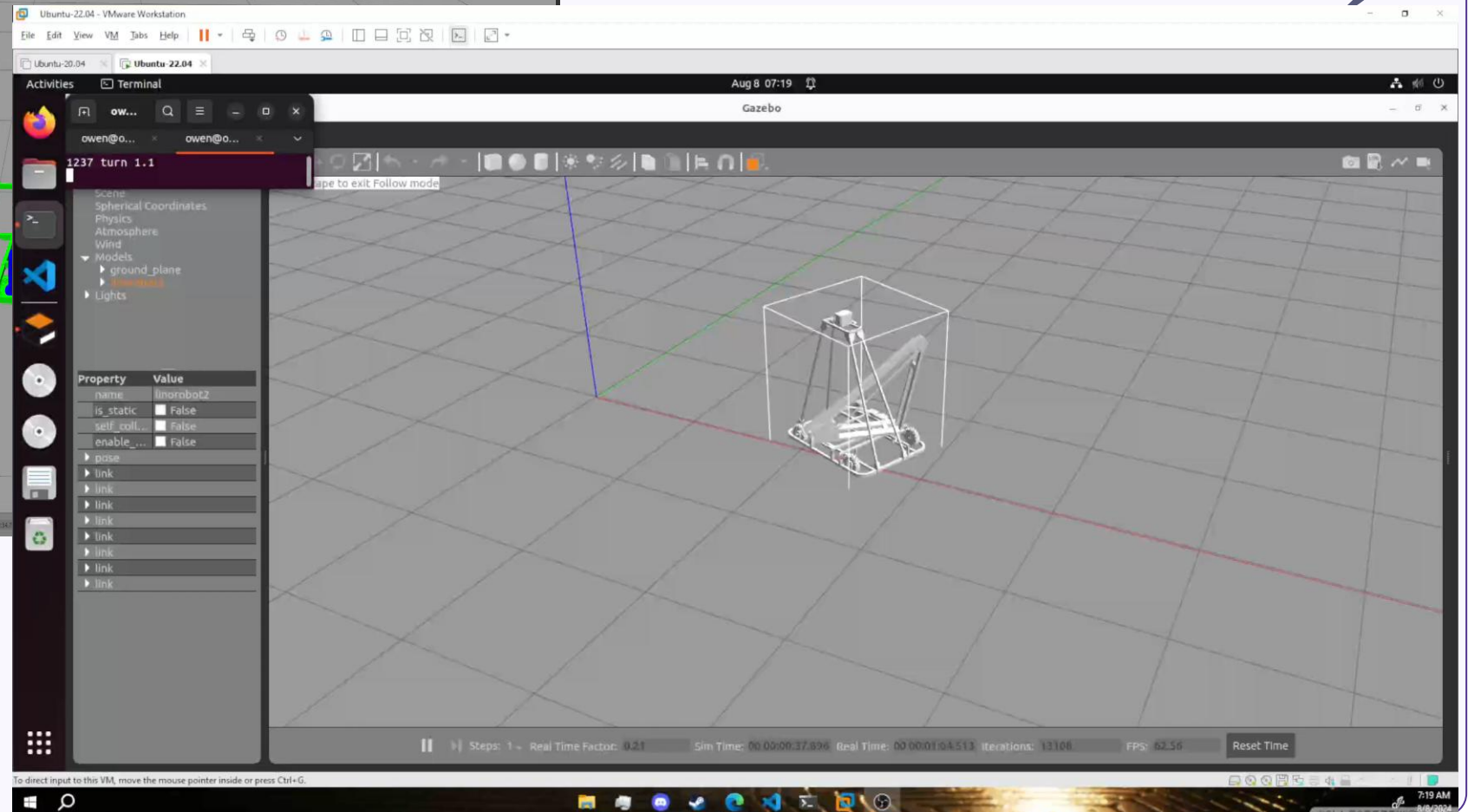
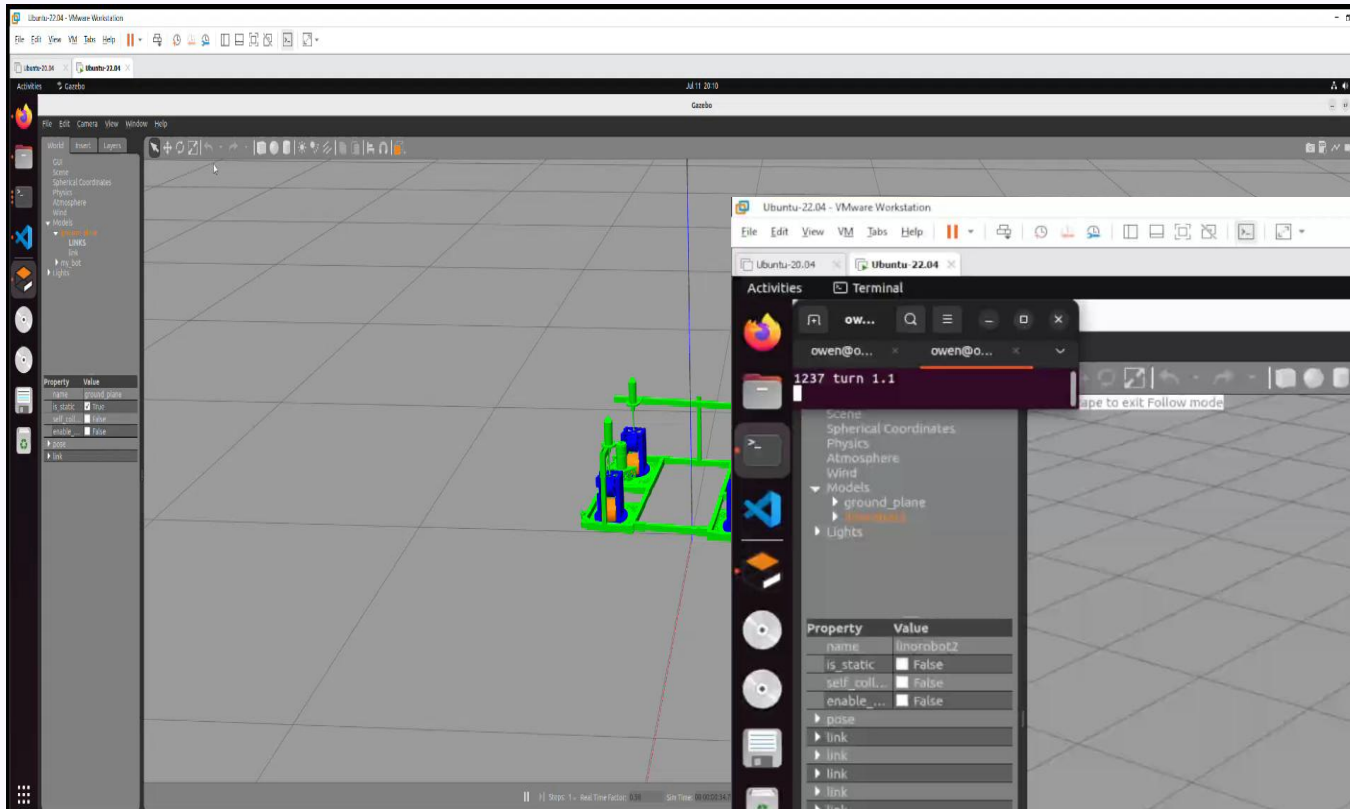
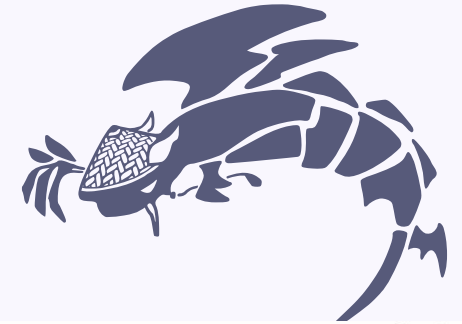


By simulating our robot:

- Validate the design and functionality of the robot before physical construction.
- Test and refine the robot's finite state machine and other control algorithms.
- Provide a cost-effective method for prototype testing



SW RND – Gazebo Simulation



To direct input to this VM, move the mouse pointer inside or press Ctrl+G.

ENGG 3961A
Final Presentation
Q&A

