Team Tomato (T017)

ENGINEERING DESIGN

SUMMARY

TECHNICAL UNDERSTANDING
1. DEVELOPMENT OF ROBOT CONCEPT
2. PROCESS CHANGES MADE TO DRIVEBASE, STORAGE, LIFTING MECHANISM AND CLAW GRIP

ENGINEERING CONCEPTS:
1. CHOICE OF WHEELS
2. CENTRE OF GRAVITY
3. LINE SENSOR GEOMETRY
4. CAM MECHANISM
5. SMALL ANGLE APPROXIMATION

MECHANICAL EFFICIENCY:
1. STORAGE AREA CONSIDERATIONS
2. GATE MECHANISM
3. CAM MECHANISM
4. COLOUR SENSOR PLACING
5. HARDWARE LIMITERS

STRUCTURAL STABILITY
1. WHEEL BRACE
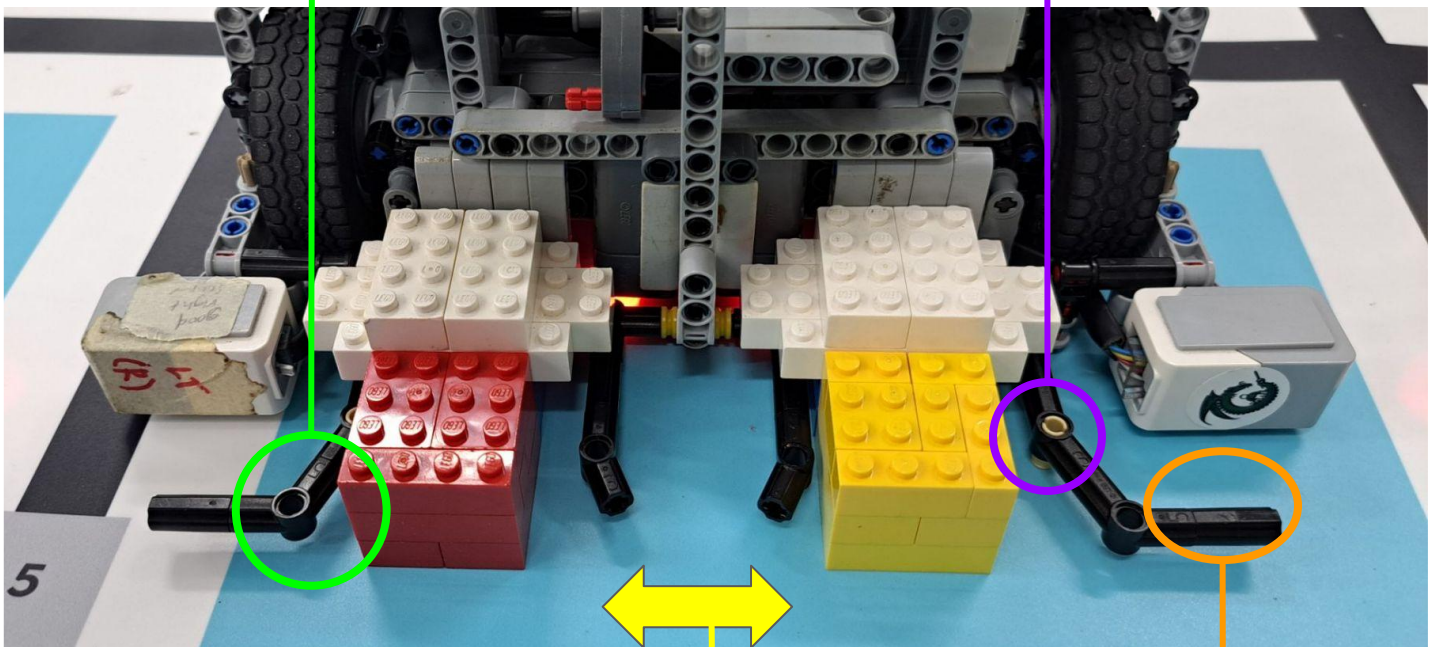2. CLAW ARM AXLE CONNECTORS
3. CHANGES MADE TO CLAW GRIP

AESTHETICS
1. NEUTRAL TONE
2. SYMMETRICAL
3. UNIQUE DESIGN

Storage Area

Funnels for greater tolerance when collecting objects

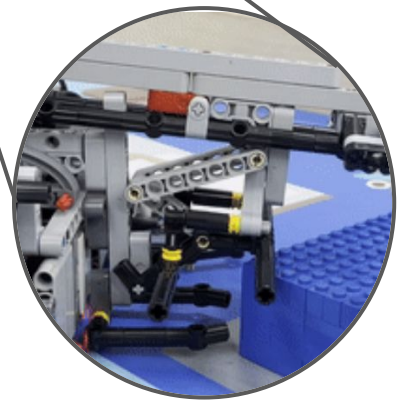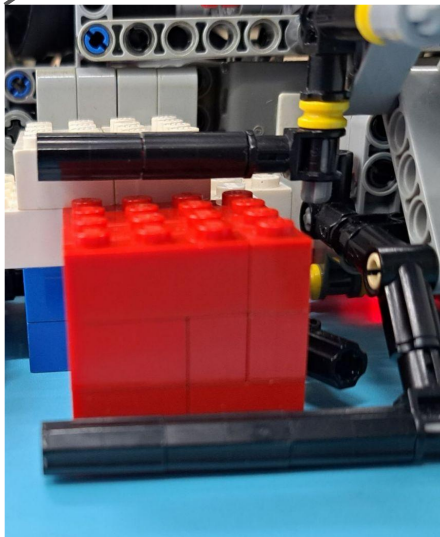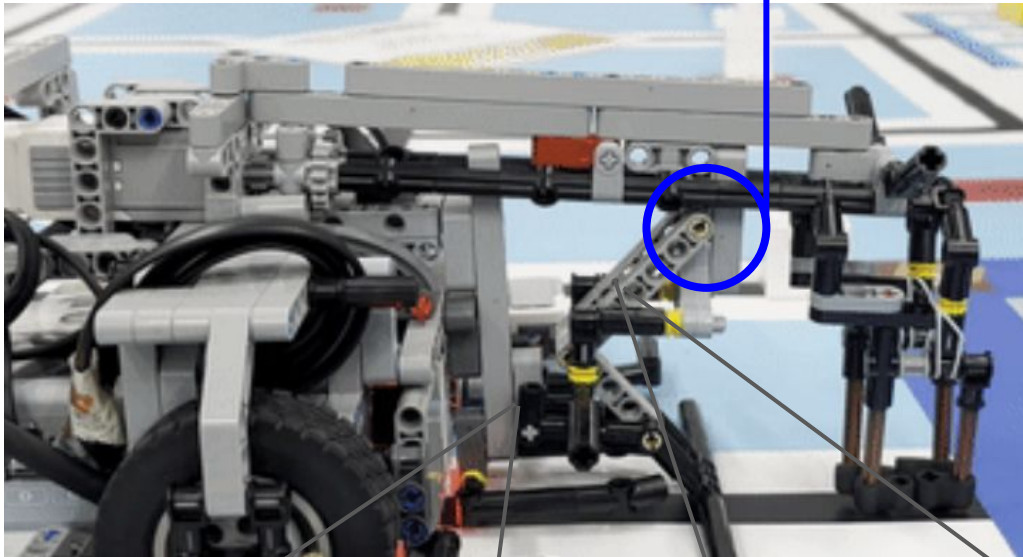Supports to reduce jerking
(using half-pegs)

Storage areas spaced to collect
both water bottles simultaneously

Flat side arms to allow the robot to align
laundry containers in one motion

Store 4 objects, the maximum number of
objects the robot carries at any time

Gate Mechanism

Attached to arm at this position to amplify gate lifting
1° motor rotation = 4cm gate lift

Small side arms prevent water bottle from rotating within the storage but do not contact the laundry

Slack – Claw can move independently even if gate is jammed on objects
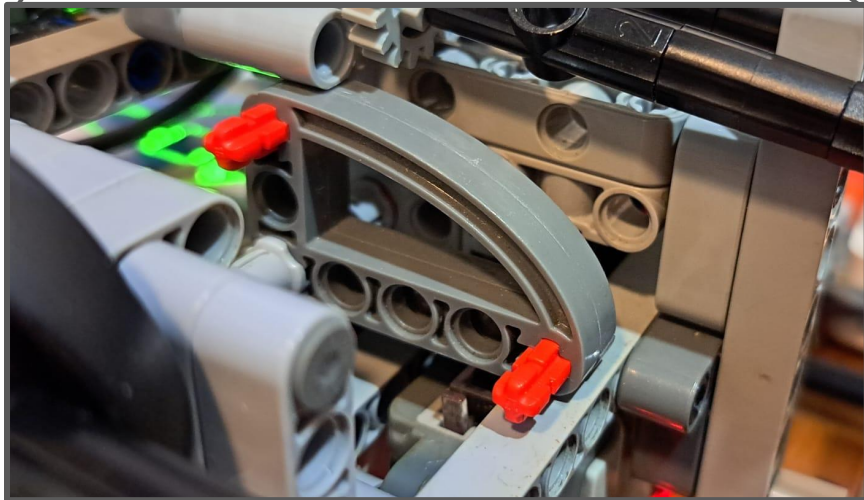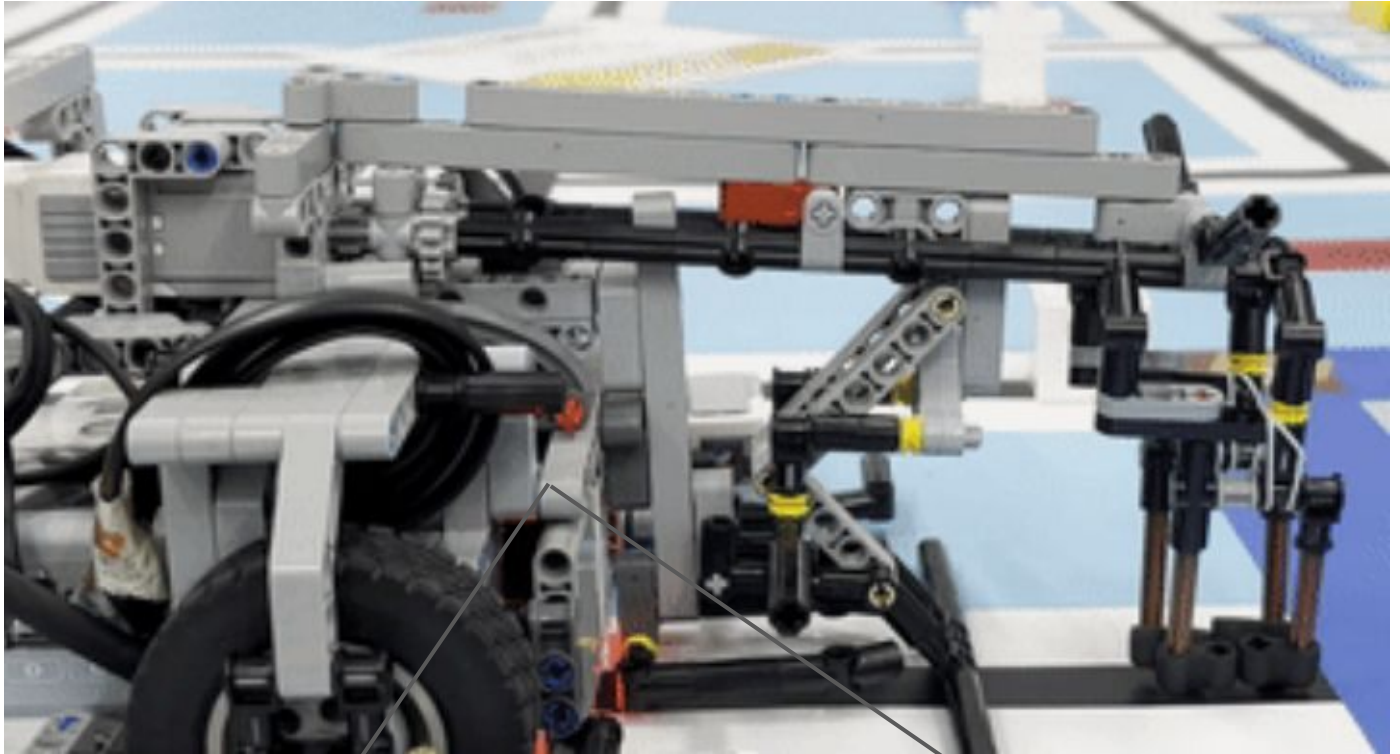
Cam Mechanism

Cam Mechanism:
1. Controlled lift due to less torque needed, 1° motor rotation translates to 0.11° arm lift
2. Less electronic feedback when the arm needs to remain stationary, as the arm rests on the cam and the motor does not need to constantly maintain the angle of the arm
3. Higher power efficiency

Claw Mechanism
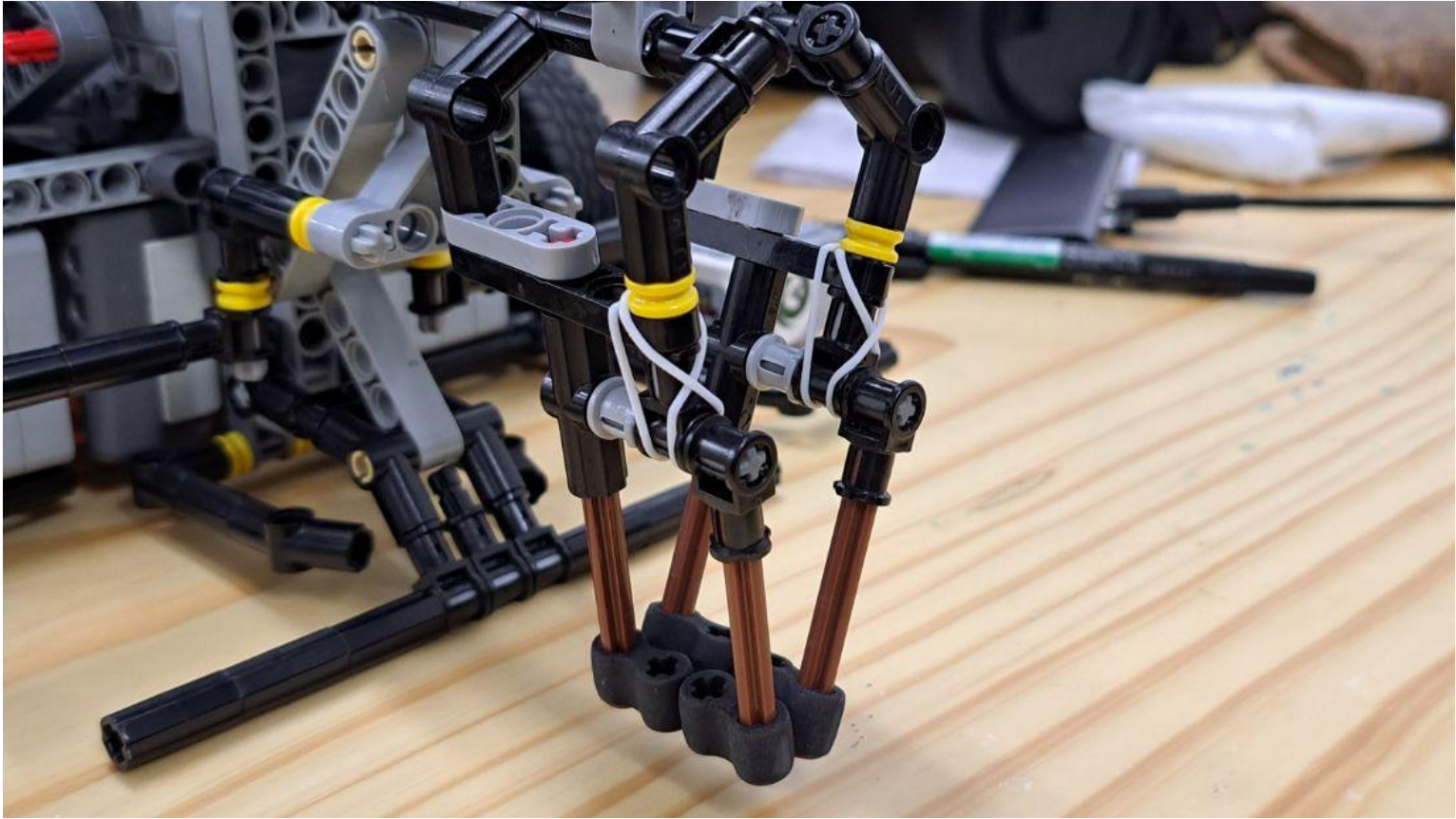
Claw gripping:
1. Rubber grips allows for even contact when gripping items
2. Uses axels to minimise the weight of the claw

Ensuring structural stability:
1. Rubber bands tied to hold claw frame in place
2. Studded axles to ensure rubber grips do not fall off
3. Additional bracing of the claw frame to prevent flexing (remains rigid) → ensures proper contact with laundry blocks

Centre of Gravity
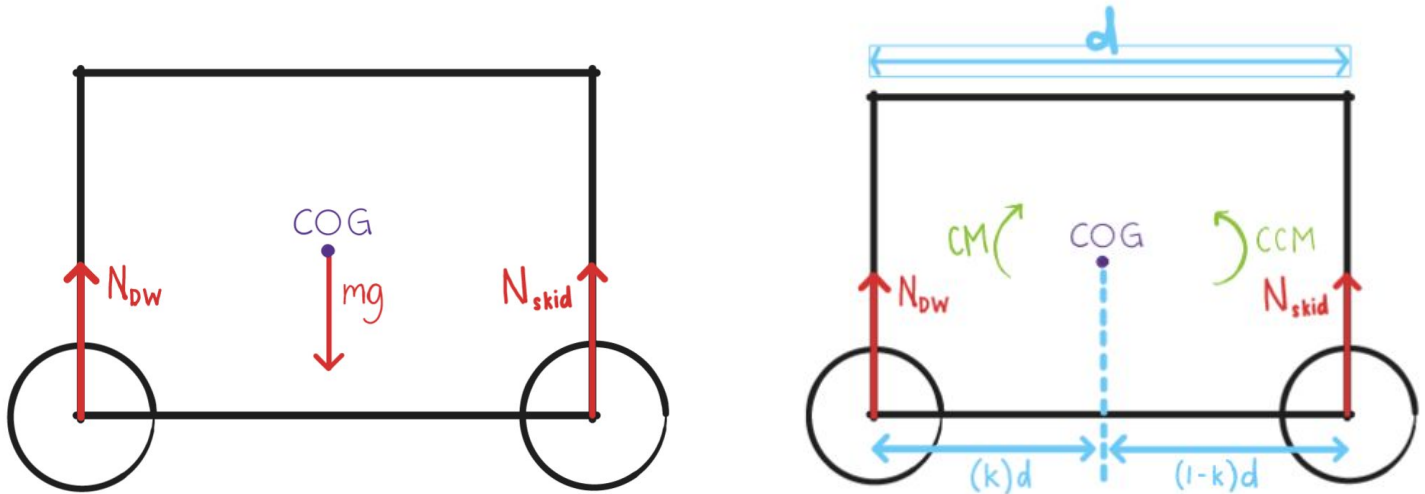## Positioning heavy components lower to lower CG

In Equilibrium

N_{DW} is the normal force acting on the driving wheel.
N_{skid} is the normal force acting on the skid wheel.

To balance forces:

$$N_{DW} + N_{skid} = mg$$

To balance moments:

$$[kd]N_{DW} = [(1-k)d]N_{skid}$$

Deceleration
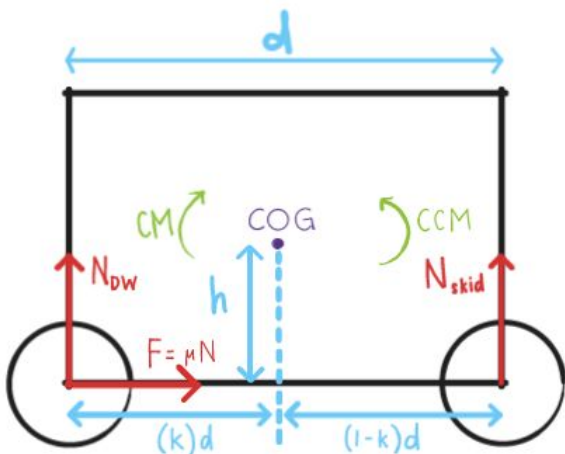
The robot is travelling to the left. When the robot decelerates, there is a maximum decelerating force, $F = \mu N$ where μ is the coefficient of friction and N is the normal force.

In the worst case scenario where the robot is about to jerk,
$N_{DW} = mg$ and $N_{skid} = 0$

To prevent jerking,

$$\tau_{CCW} < \tau_{CW}$$
$$(h)\mu N < (kd)mg$$

∴ Minimise h, lower centre of gravity

Centre of Gravity
Positioning heavy components lower to lower CG

Acceleration
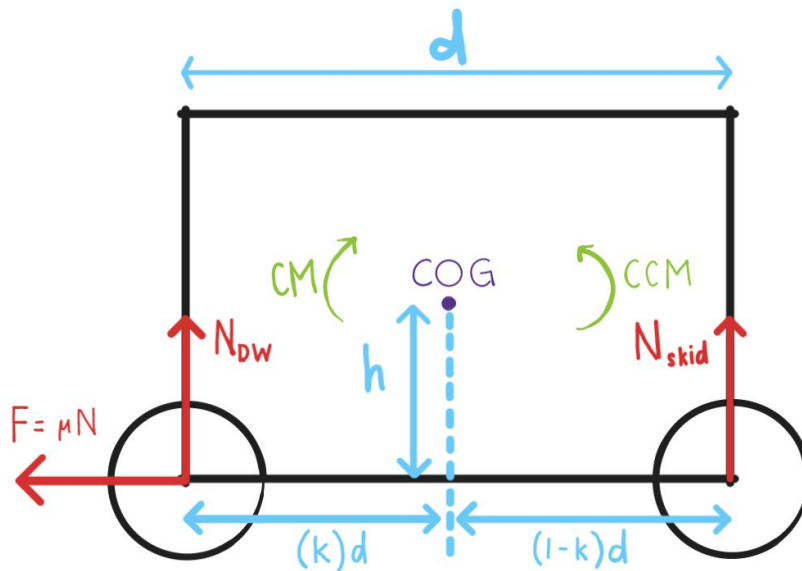
When the robot decelerates, there is a maximum accelerating force, $F = \mu N$ where
μ is the coefficient of friction and N is the normal force.

Taking moments about CG,

$$[kd]N_{DW} + hF = [(1-k)d]N_{skid}$$

To prevent slipping i.e. maximize normal contact force on driving wheels, hF must be at a minimum.

$\therefore$ Minimise h, lower centre of gravity

Line Sensor Geometry
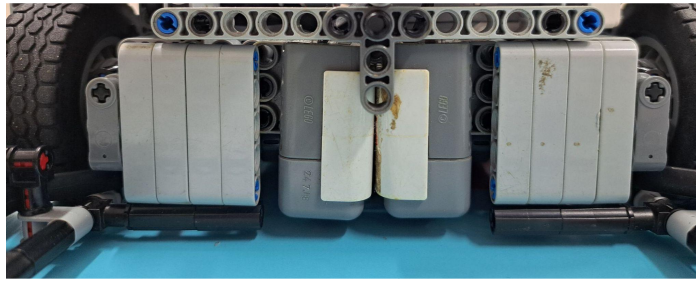
1. Distance between sensors = width of line

Enables robot to centre itself in a single-axis using 2 sensor line tracking

2. Distance from mat

Placed at the optimal height for dynamic range when line tracking

3. Distance from wheels

- Closer to the wheels → greater the turning angle of the robot when line tracking, faster lateral movement, and ensures that the robot will correct translation from the line as quickly as possible
- Higher rotation rate, higher line sensor polling rate needed → use EV3-G over EV3 Micropython for faster loop time (400 loops/s v.s. 30 loops/s)
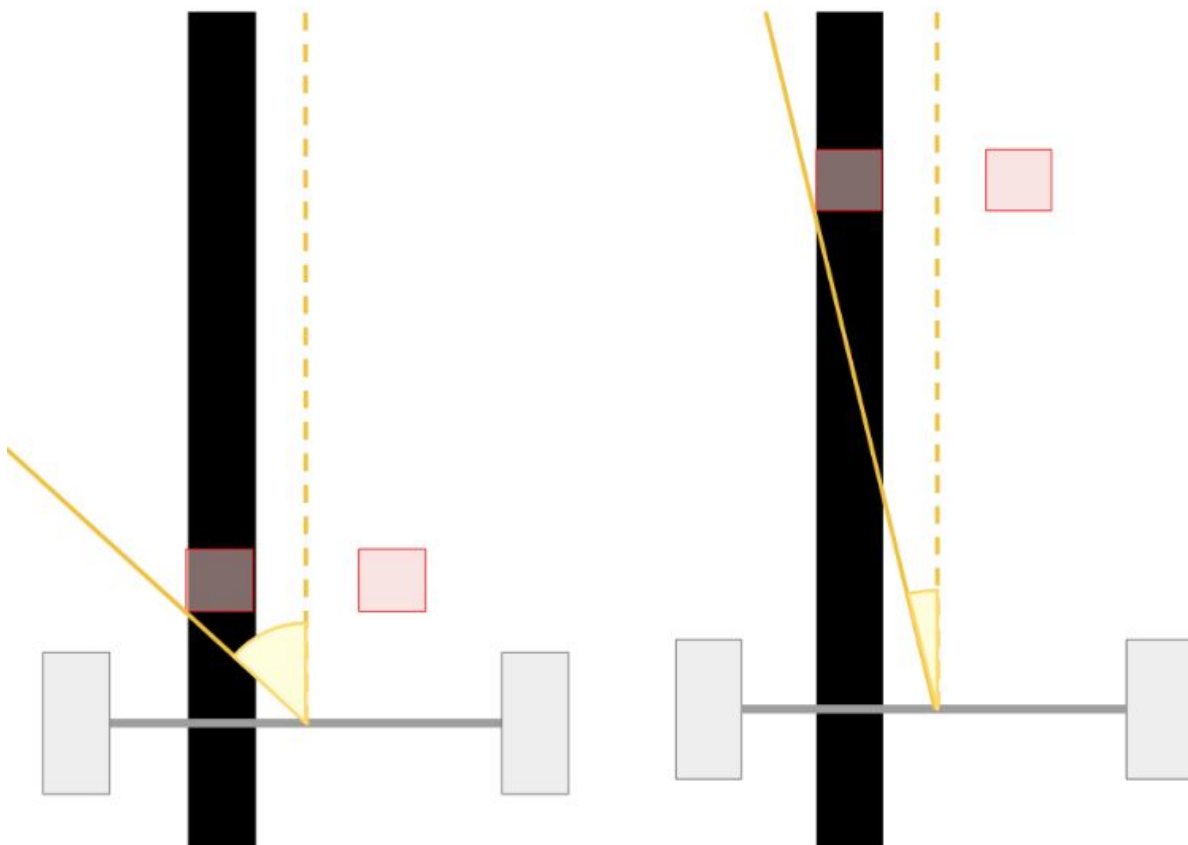
Colour Sensor Placement

Sensors far apart for maximum efficient dynamic range

Maximising space

25cm

25cm

35.4cm

35.4cm
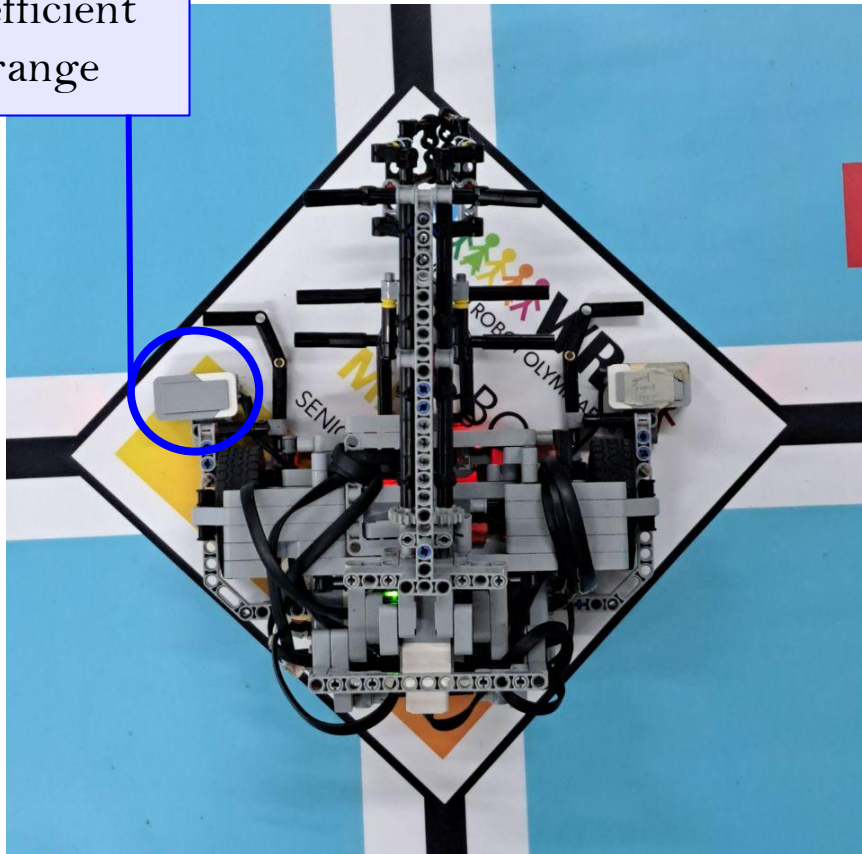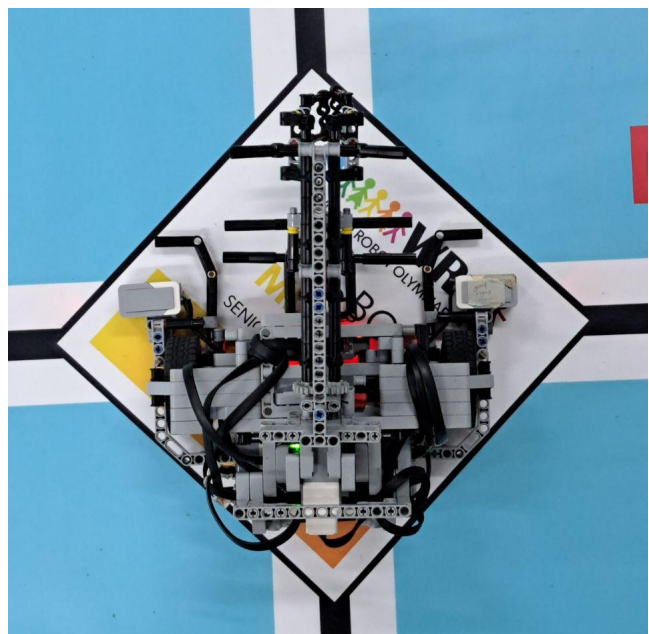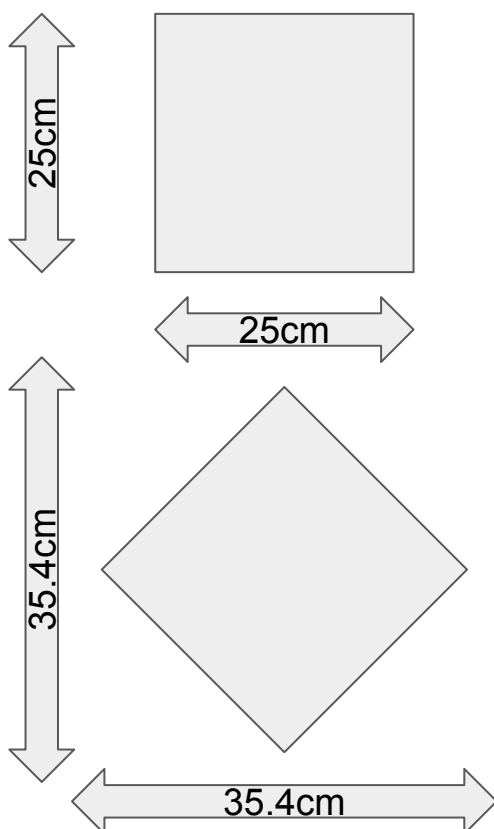
Positional Considerations
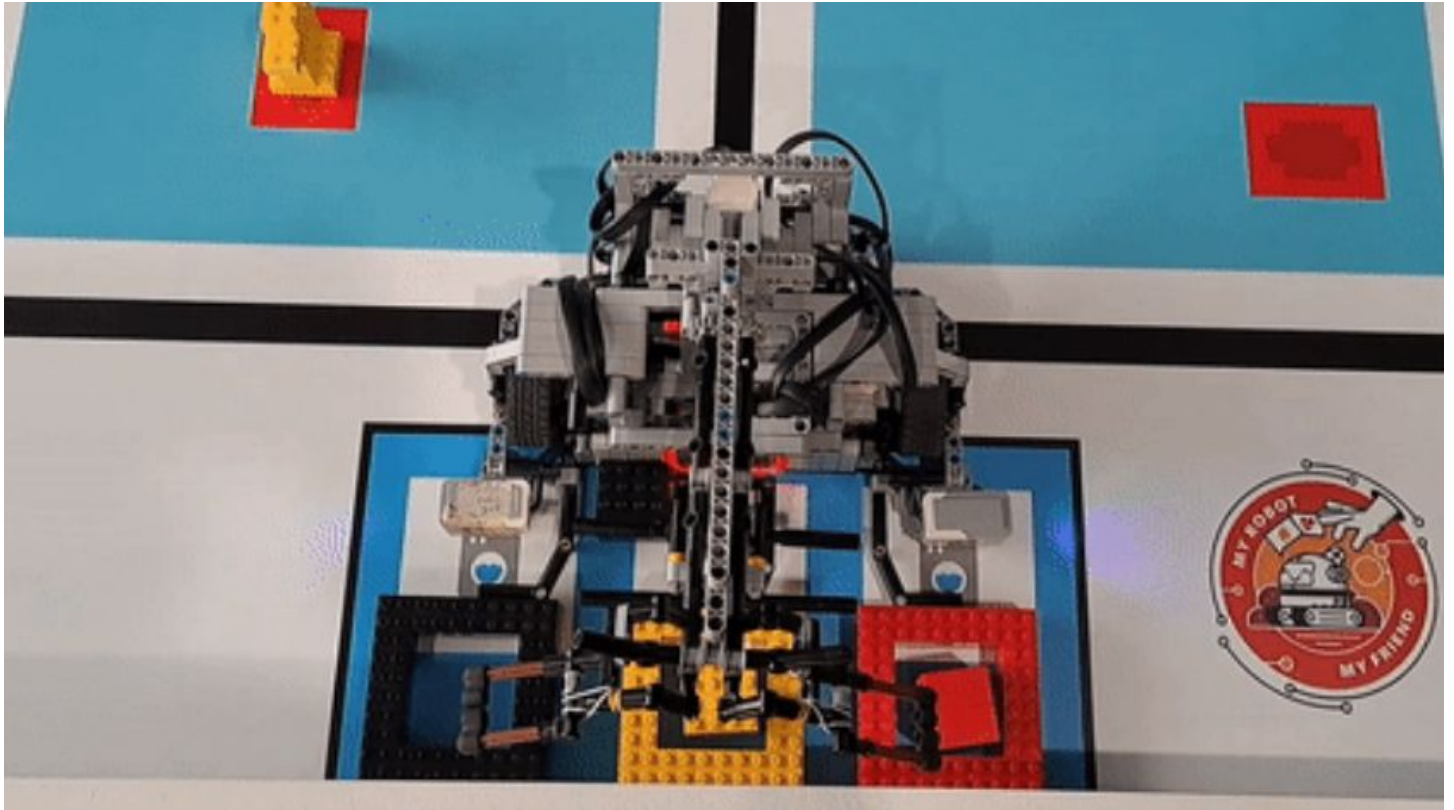
For physical alignment, we realign the robot against the wall before each laundry deposit to 'reset' the errors accumulated in heading and position, increasing reliability.

Line intersections are used before each room and the laundry area, aligning the robot in 3 axes.

Logbook

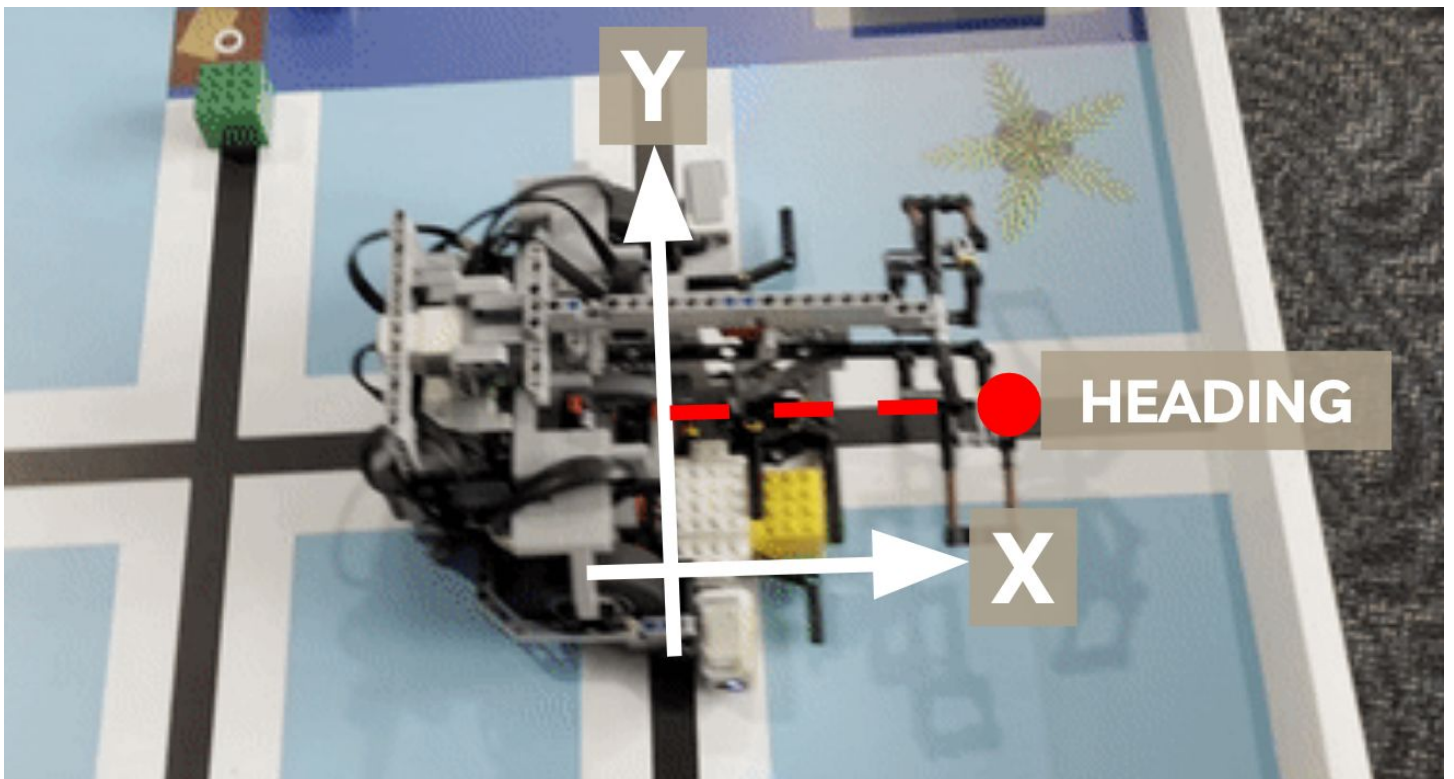|	
08/06	-built drivebase?? + sensors -attempt at claw 1 but was too heavy and messed up cg of bot so jerk when stopping -moved med motor to the back n plonked on top of the large motor
10/06	-changed storage area (x2) so can store 4 things yay also moved it down by half so wldnt hit the water bottle wingsss -added a claw made out of beams w a cage like thing so the bol and other stuff wont fall out -tried to line track (stole bloccs) n the claw was too chonk and caused the bot to oscillate on the line so made it out of axles -braced the claw to the centre axles so it wldnt bend backwards and also make the grabby part more rigid by bracing btn the two sides, also added rubberband so it wld grip onto the laundry block properly (oh hopefully it can still line track we didn't try after) -for codes things did line track + line count + line turns + one/two wheel turns (gave up on the meth for the arc turn will do another time after logic things are done) -calibrate sensors function -move distance function
15/06	-changed claw to straight claw so it can pick up stuffs and wrapped the whole things in rubber bands yay can pick things up -added gate curtain thing so the stuff stays inside the storage -in the beginning line track was shady if offset too much but as long as the bot ends up mostly centered on line sld b fines -completed the scanning for the white/green blocs -did single line track stuffs, added speed and -did claw pickup for one position (back rigjt) -did claw deposit on table -got it to deposit bottle on table -turn_deg still dying
16/06	-changed some of the axles cmg down to axel connectors so it stops coming misaligned -added another gate on top of the first one so the wbottle won't rotate and end up vertical -changed the angle of the claw (smoller angle) so it contacts the bottle more vertically? ish and then made it longer cos it was too short -changed limiter for open close claw cos it was hitting the top of the bottle -oooooo also tried to use the old nrc field walls but the bottom was warped so exercised and unscrewed it and now we have walls

Logbook

16/06	-added accel decel + synch for two wheel turn (not yet for the one wheel turns) -tried to do pick front item but don't need so only half complete (not tuned) -increased lt speed from 50 to 60 (65/70 dies) -for wbottle case realised the bot wld hit the table out of pos depending on which way it turned so shifted the pickup to before entering the room -added ball case -added pickup laundry for both ball and bottle cases -did scan laundry block (much pain, stored the item pos in array w colour as the index AND IT WORKS) - **possible thing we might need to figure out ltrs on is when we deposit the laundry if we check the pos of block and it ends up being the block in front we can't pick it up? -added transition to second room -added cases for second room but problems 1. the claw was picking up the bottle weirdly so had to align it against the gate before picking up again 2. bc the claw isn't symmetric the depositing of the bottle wasn't the same so the angle it needs to turn to dep isn't the same (need to make sure the offset is the same when we reassemble) 3. when we tried to scan the colour of the room block once it sensed white as green and did the ball case, another time it sensed white as green but then it still did the bottle case (cldve js been our prints)
01/07	-tuning was shady bc of the batt? everyth died -fixed the accel for turn (doing take 1/5 of the dist) so everyth didnt work -managed to fixe clawpick -version6 fracaccel js has the changes to the accel, and added brakes for some of the movement/linetrack functions, and added function to countline, linetrack then move straight wo breaking --> also i added some logic stuffs for laundry basket in it under deposit_laundry (and added a scan the basket thing but prolly need to tune thresh)
06/07	-rebuilt with medium motor hidden lower inside bot and used D things to make lift more controlled ++ new wheels -still looked like it was gna tip over and die so flipped the orientation of the brain so it's pancake against the ground -turned line track sensors 90deg to save one beam space and changed claw mechanism -extended claw a bit (might extend more if have spaces) -moved colour sensors to the front so bot can fit in diamond (might angle?)

Logbook

07/07	-originally the move distance with acceleration + synch wasn't working (inaccurate) so tried to do manually (constant accel and decel no matter the distance, find the minimum speed between accel decel and max speed graphs to limit the speed the bot can move so it won't jerk) and it kind of worked except the completion for the movement wasn't fulfilling all the time -after adding the half pegs the jerking wasn't that bad ++ the move steer was very accurate and motors were synched so used that instead -line track was dying originally but was js the calibration max/min values so bot can line track now - start with high gain (2.8/5.6) at 50ish speed so bot can correct very quickly back onto the line then once it's aligned low gain at max speed to zoom IT CAN LINE TRACK NICELY NOW

08/07	(made new file bc the old code was mess)
	-added all the basic stuff (move, linettack dist, countline, single line tracks, two wheel turn, one wheel turn)
	    -but the turns are only accurate at very low speed (like 10?) n distances r also not accurate at like 50ish speed
	-added bracing from the side wheel brace to the front of the bot (forgot to take pic)
	-clawr
	    -when i was testing the lifting motion of the claw sometimes it wldnt lift all the way? then the bottle wldnt make it over the table but but turns out it was the loose medium motor axle thing so even when the motor is braking the D piece can shift arnd n the weight of the claw pushes it downwards (i think)
	    -so swapped the lift/claw motors then realised there were spare new motors so now bot has 4 new motors yay
	    -rn the lowest point of the bottle clears table by one bean space but if need can still extend the claw (didnt bc i tjink it can do the game net w the gate coming down so it doesn't lose the objects but kiv?)
	    -managed to tune pickup function works consistently? the times that i tested it did (vid attached brr) but slow rn
	-did laundry scan n tuned thresh (works yay)
	-was in the middle of changing the green/white block scan bc cs are in front now so after the turn then linetrack dist (15?cm) then sum all the values
	    -when it's stationary the cs vals w the white block are high (4-12?) n green 0 but but when i ran it with white it gave 0 almost all the time (i tjink it gave a legit value once only) and it looked like it didn't sense any reflection value? throughout the scanning but didn't have time to properly check it so will continue next tuess

Logbook

12/07	-extended claw so can deposit in table and net wo leaving collected items somewhere else -extended storage so can turn with claw lifted up -finished the bloc scan (wasn't working bc scanning too early) so now scanning from start of turn -finished bottle logic - picking up from side with fewer number of items so can pick laundry block before doing bol -half done w bol logic - pick laundry then collect ball, tried to do one wheel turn to drop ball but need reverse first (two turn will hit table) -added handle for bot wee
13/07	-switched claw to rubber to improve grip because the laundry blocks were rotating when being picked up -finished water bottle case and ball case -duplicated and tuned second room bottle case and ball case -finished first room to second room transition -shortened the gate but extended the side funnels to form a flat side for ramming the laundry baskets against wall -pick up laundry from outside of room instead of inside cuz no space to manoeuvre for bottle case, cuz kept bumping into table -laundry basket scanning block created without movements -reversed the laundry checking (storing the position value of the laundry as in front if its behind the "nothing" laundry) because laundry pickups would be aligned in front against the gate instead of behind (reversing instead of driving forward) -tried room 2 to 3 transition (navigate thru middle) but couldn't manage to get back onto line so abandoned it -finished laundry pickup from front two positions n tuned back movements for laundry pickups cuz diff from bottles -finished transition to the laundry (lt double black lt straight turn straight) -started laundry movements
14/07	-moved the sides of the storage forward so that the laundry baskets don't get tilted bc if there's 2 laundry blocks the edge of the blocks will knock the basket out of position -did the movement from end of last room to the first pickup but can't figure how/which basket to get it to deposit at cos it keeps hitting either the baskets/human or losing the objects -tried to scan before hitting and aligning the baskets but wastes some time? -will cont trying tmr (mb change the gate so that the claw can lift up halfway wo the objects falling out)

Logbook

15/07	-changed gate so it can be lifted to deposit laundry wo the barrier lifting too high (so can recollect blocks) -did the sequence for laundry deposit and works consistently? only time it dies is when the line track after the turn ends up w the bot being tilted then it rams the laundry baskets tilted and can't scan but pickup is consistent/deposit is too -did transition btn the second and third rooms -replicated the seq for the third and fourth rooms -we tried to do a full run ~2.15 iirc but many problems (altho batt was dying so some of distances were off) problems during full run: -water bottle deposit sometimes gets hit by claw -when the bot is collecting the laundry block at an angle during the ball sequence sometimes it can't recollect the bloc and loses the block (make angle less steep when collecting probs) -when it's moving twds the second and third room sometimes the marker block ends up in front of the colour sensor and travels w the bot as it tried to cross, so it hit the human once -transition btn second and third room (turn arc turn) failed once iirc it sensed the border black again -when sensing the right task for the forth room the bot sensed green as white (alr reset the values after the first round of sensing, maybe threshholding but will see how next wk) -bot barely fits inside the diamond might have to move the smol wheels so there's tolerNce for when it ends the run -when depositing middle laundry when the claw closes sometimes it drags against the so fix that
19/07	-swapped out colour sensors n changed the task scanning to do max -for transition from last room to laundry ran the line track at 100 speed n worked? -retuned the laundry colours (reversed more to scan second basket so won't have overlapping case for red n ylw) -realised we were dumb n the logic for one part of the laundry picking up was wrong (forgot to update the storages) WAIT now that i think abt it we hv a block called update storage i forgot what's in it will check tmrrr

Logbook

20/07	-tried to fix rigjt room ball case n single lt for both sensors r diff so the starting position entering room is diff, made centre point for the right room lt 80 -100 speed line track works, but i think when it goes from the 100 linettack to countljne it starts oscillating lots (i think now the countline is overshooting prolly bc of this?) -figured out arc func, using move tank to try and cut time (only added for btn the left n right rooms) -added decel for one wheel n two wheel turns (max 100, min 5/10) to save time -i think now on avg two rooms r 25-30s? based on counting -claw extended thing made of axle connectors was warping so changed to use the 3 long piece n half braced it to the beam running down the claw -drive motor wires were blocking the D from resting flat so rerouted them (but j think it still nvr ends up completely flat rn)
21/07	-rooms work consistently yay (added arc for transition for water bottle case, adjusted the angles of deposit so more on table) -changed the one wheel turns in the laundry pickup -tuned basket vals bc they were dying, ended up switching colour sensors cos vals didn't overlap yay - redid task and laundry scanning -added arc for movement to baskets (unreliable if the lt before is oscillating, so decreased speed) -bottle pickup not consistent n turns were dying -laundry pickup doesn't work if picking up from the front on the side w only one cube (for basket 0 pickup) tried to tune turns but ends up hitting the blocks away and can't recollect aft
22/07	scan forward laundry
26/07	tune laundry movements tune water bottle movements changed inside compartment to bent so water bottles can collect (they were getting stuck) fixed ball right case laundry getting stuck n lost by turning with claw up made guide for starting point?? but flimsy water bottle line track before collecting (not reliable, might switch back) -lt to middle laundry basket was illegit so changed the pickup to before it does the turn turn to get onto the line

Logbook

|	
27/07	-braced the motor more so it stops flexing out n the turns r legit now -moved the inner storage in by half so bottles r legitly collected now (removed line track for water bottle collect) -ball case reliably collects (only lower claw once it has turned to pick up the ball) -changed the high gain lt gain from ofdls ones -added run until stalled for the lifting of the motor -slowed down turns for laundry -changed the arc for laundry -changed arc for align against wall for ball case so it doesn't miss the line anymore -changed the line track gain for before it bangs the laundry baskets but too high rn -mixed up the laundry scanning logic but fixed that
28/07	-fixed bol case for left room bc claw was hitting wall -tried to change wbottle to align at front but kept failing to pick up -scanning for laundry was dying (random 0?) but removed concurrent scanning n all the unnecessary concurrent stuffs + deleted everyth off brain n redoebloafrd n worked -brain does not have usb port aaa -linettack was shady so made it run at 30 instead n it finished in like basically the same time as our fast run shdhfhhf
29/07	-swapped brain -changed water bottle to align before picking up (worked consistently?) -changed ball case a bit since picking up n depositing was a bit off -didn't film but ball + bottle takes arnd 35?s -changed arcs n wall aligns -changed arc btn the second n third rooms (increased speed of slower motor slightly n worked?) -tested laundry n movements were off n pick ups were also shady -managed to test the pickup of laundry n changed pickup from front bc kept hitting the block behind it n dying (sld work but check again next time for sanity)

Logbook

30/07	-fixed ball case for left room bc ball was depositing at the very edge of net -fixed between rooms overrunning -swapped some distances that somehow became negative in 29/07 version -tuned bottle pickup (but this is vv dependent on battery n my positioning which isnt very good :") -finely tuned all positions of laundry pickup for basket 0 -measured 1min46s at 3 bar battery bad: -accidentally collected marking block for right room bottle case with the laundry (but only once, and never again??) + sometimes pushes marking block from second set all the way to laundry area -when picking up water bottle from storage, it sometimes hits the other water bottle's ears for right room -water bottle still topples inside storage -picking up from wrong place...? but the robot movements have been jerky all day so it might be the sensors scanning wrongly
31/07	-fixed the problems above, tested a few times and worked?
02/09	-consistent runs, only minor changes made to optimize

Shortest Time Considerations

Passing through man's space

1. Scans for the presence of the man in the middle of the mat after picking up the water bottles (position marked out in green on the mat) using light intensity values
2. When coming through the diamond from right to left, if the man is not there, the robot does not attempt to avoid it
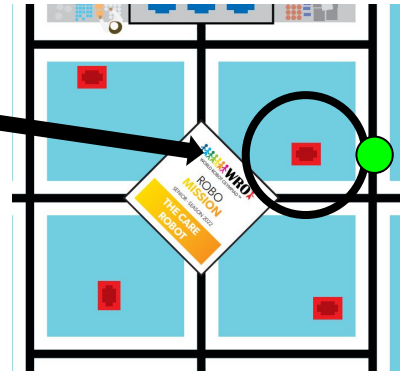
Arc

Motion of a straight and a turn is combined into an arc as it is faster

Page 4 = storage area

Ziegler–Nichols method

Main article: PID controller

The **Ziegler–Nichols tuning method** is a heuristic method of tuning a PID controller. It was developed by John G. Ziegler and Nathaniel B. Nichols. It is performed by setting the *I* (integral) and *D* (derivative) gains to zero. The "P" (proportional) gain, K_p, is then increased (from zero) until it reaches the **ultimate gain** K_u, at which the output of the control loop has stable and consistent oscillations. K_u and the oscillation period T_u are then used to set the P, I, and D gains depending on the type of controller used and behaviour desired:

Ziegler–Nichols method[1]

Control Type	K_p	T_i	T_d	K_i	K_d
P	$0.5K_u$	–	–	–	–
PI	$0.45K_u$	$0.80T_u$	–	$0.54K_u/T_u$	–
PD	$0.8K_u$	–	$0.125T_u$	–	$0.10K_uT_u$
classic PID[2]	$0.6K_u$	$0.5T_u$	$0.125T_u$	$1.2K_u/T_u$	$0.075K_uT_u$
Pessen Integral Rule[2]	$0.7K_u$	$0.4T_u$	$0.15T_u$	$1.75K_u/T_u$	$0.105K_uT_u$
some overshoot[2]	$0.33K_u$	$0.50T_u$	$0.33T_u$	$0.66K_u/T_u$	$0.1\bar{1}K_uT_u$
no overshoot[2]	$0.20K_u$	$0.50T_u$	$0.33T_u$	$0.40K_u/T_u$	$0.06\bar{6}K_uT_u$

The ultimate gain (K_u) is defined as 1/M, where M = the amplitude ratio, $K_i = K_p/T_i$ and $K_d = K_pT_d$.

These 3 parameters are used to establish the correction $u(t)$ from the error $e(t)$ via the equation:

$$u(t) = K_p \left(e(t) + \frac{1}{T_i} \int_0^t e(\tau)\, d\tau + T_d \frac{de(t)}{dt} \right)$$

which has the following transfer function relationship between error and controller output:

$$u(s) = K_p \left(1 + \frac{1}{T_i s} + T_d s \right) e(s) = K_p \left(\frac{T_d T_i s^2 + T_i s + 1}{T_i s} \right) e(s)$$

Evaluation [edit]

The Ziegler–Nichols tuning (represented by the 'Classic PID' equations in the table above) creates a "quarter wave decay". This is an acceptable result for some purposes, but not optimal for all applications.

This tuning rule is meant to give PID loops best disturbance rejection.[2]

It yields an aggressive gain and overshoot[2] – some applications wish to instead minimize or eliminate overshoot, and for these this method is inappropriate. In this case, the equations from the row labelled 'no overshoot' can be used to compute appropriate controller gains.