Group 5 PDR

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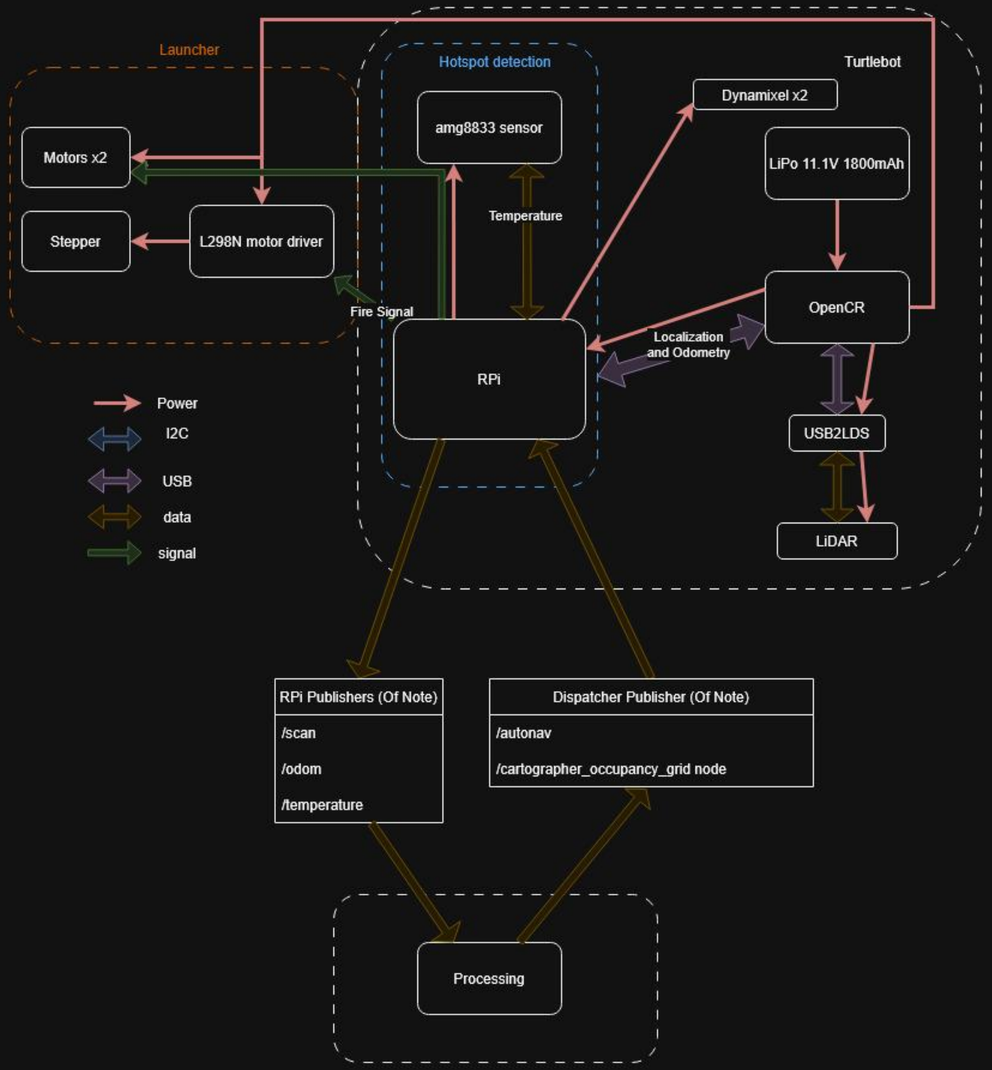
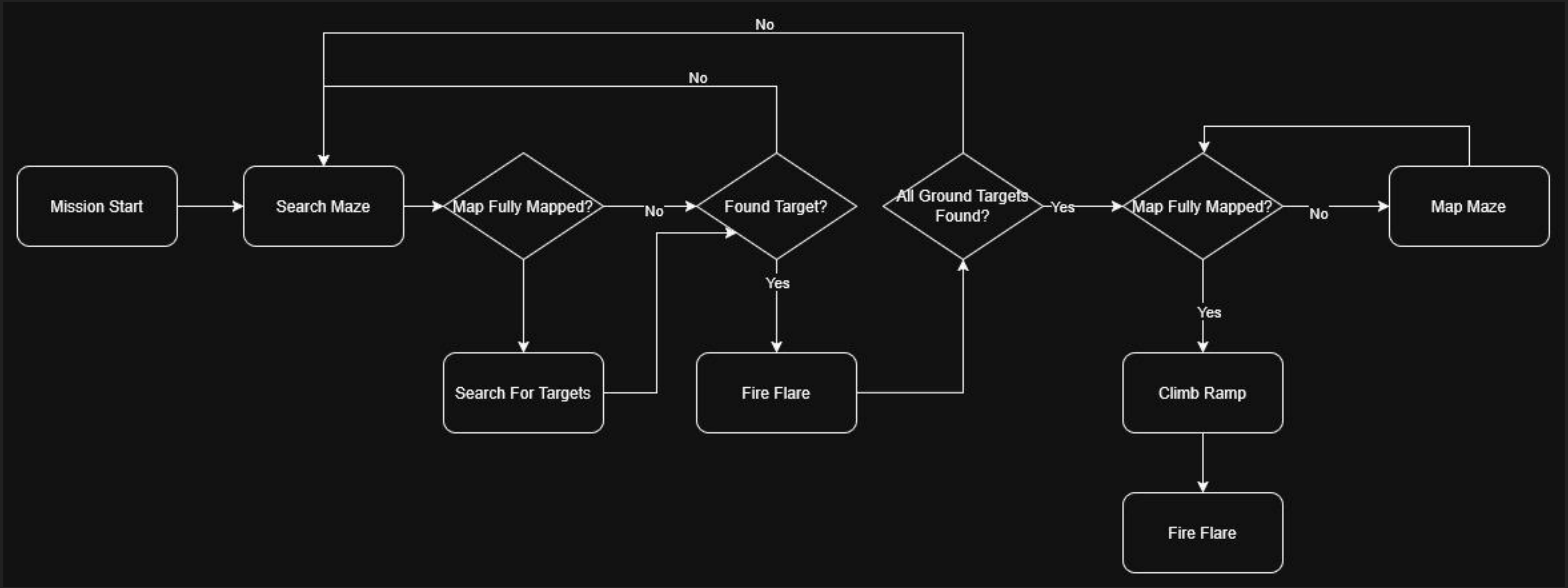
System Overview

Overall System Architecture



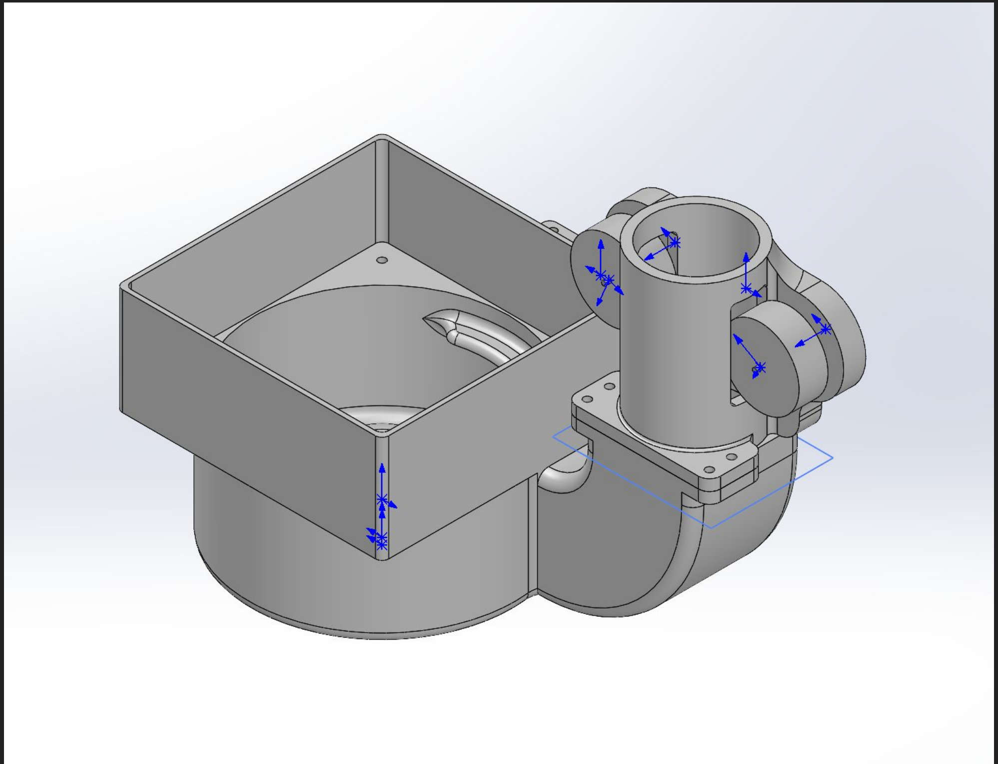
System Description of Solution



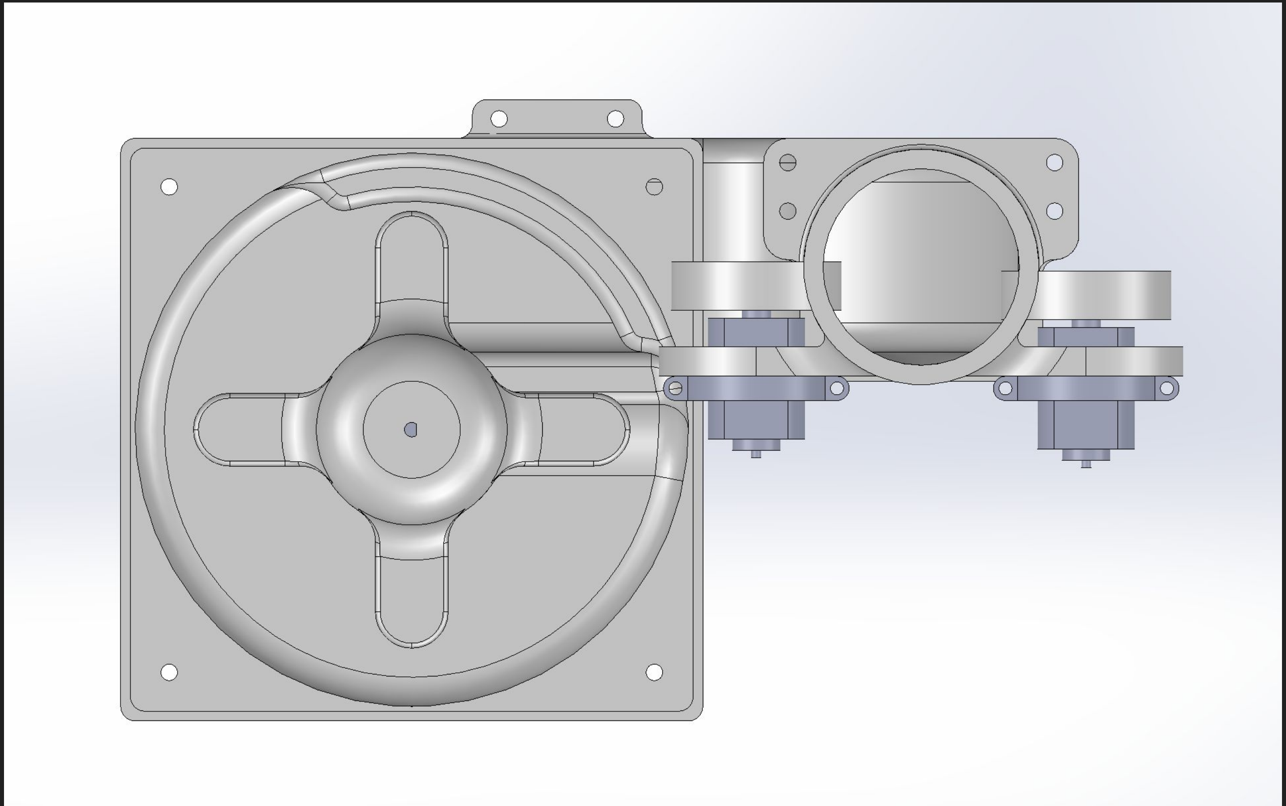
Mechanical

Launching System

Feeder + Flywheel System



Launching System



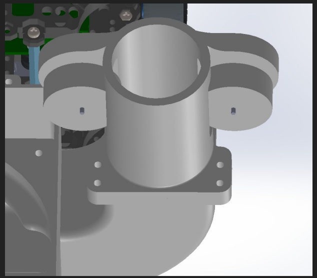
Machine elements

Fasteners (M3 screws and nuts)	25 screws, 18 nuts
DC Motors	2
Stepper Motor	1
Flywheels	2
Rotor	1

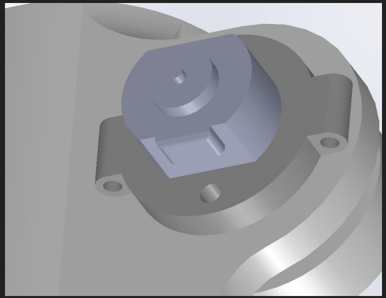
Assembly plan

<u>Screws and Nuts:</u>

Feeder - Barrel

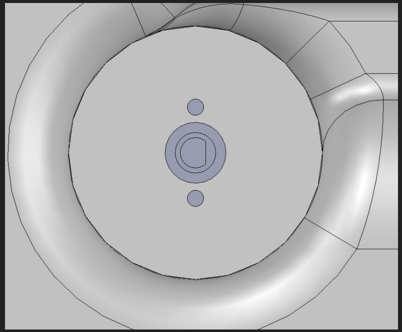


Barrel - Motor



Turtlebot - Launcher

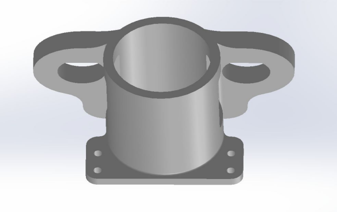
Feeder - Motor



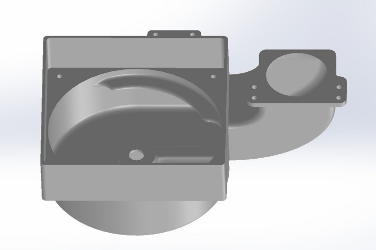
Fabrication plan

3D print (our own printers)

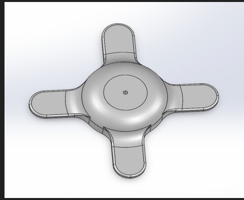
- Barrel



- Feeder



- Rotor



Buy online

- DC Motor (Aliexpress)

https://www.aliexpress.co 37 9190901.html

- Stepper Motor

link

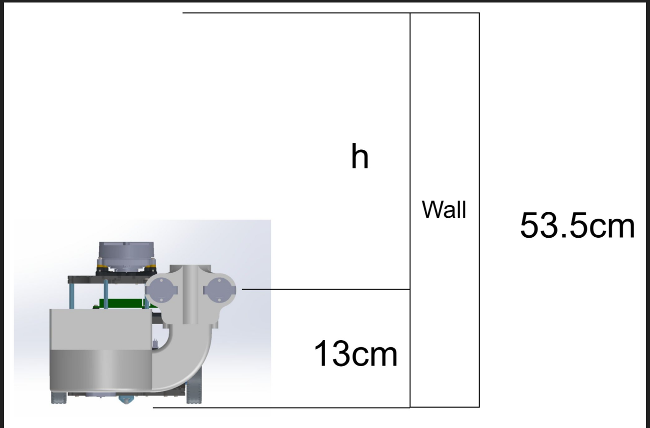
- Flywheels (Shopee)

Link

Get from lab

Screws and nuts

Calculation



Required height = 1.5m
Height to centre of wheels is 13cm

$h = 1.5 - 0.13$
$= 1.37(m)$

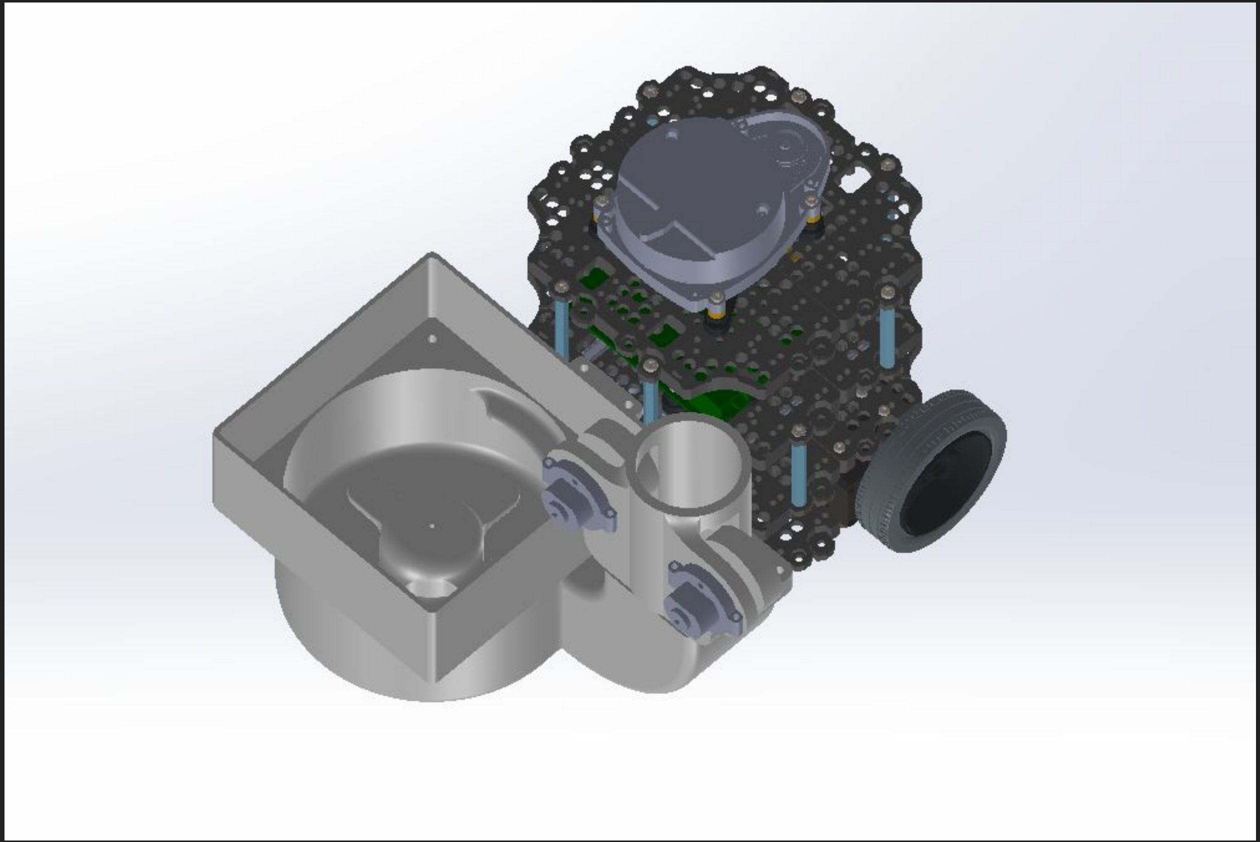
$v = r\omega$; $\omega = RPM \times 2\pi/60$

$\frac{1}{2} mv^2 = mgh$
$\frac{1}{2}(rRPM/60 \times 2\pi)^2 = 9.81 \times 1.37$
$RPM^2 = (2 \times 9.81 \times 1.37 \times 3600)/4\pi^2 r^2$

Our flywheel's radius, r = 17.5mm
$RPM = \sqrt{(8003615)}$
$= 2829$

Motor loaded speed: 4500 ± 1500 rpm
>2829

Overall CAD



Center of Gravity

CG:

20.26222103	**31.30267985**	**62.33789643**
Forward	Vertical	Horizontal
X	**Y**	**Z**

Reference Point: Outermost side of the right wheel on the wheel axis of rotation

X: 20.26mm

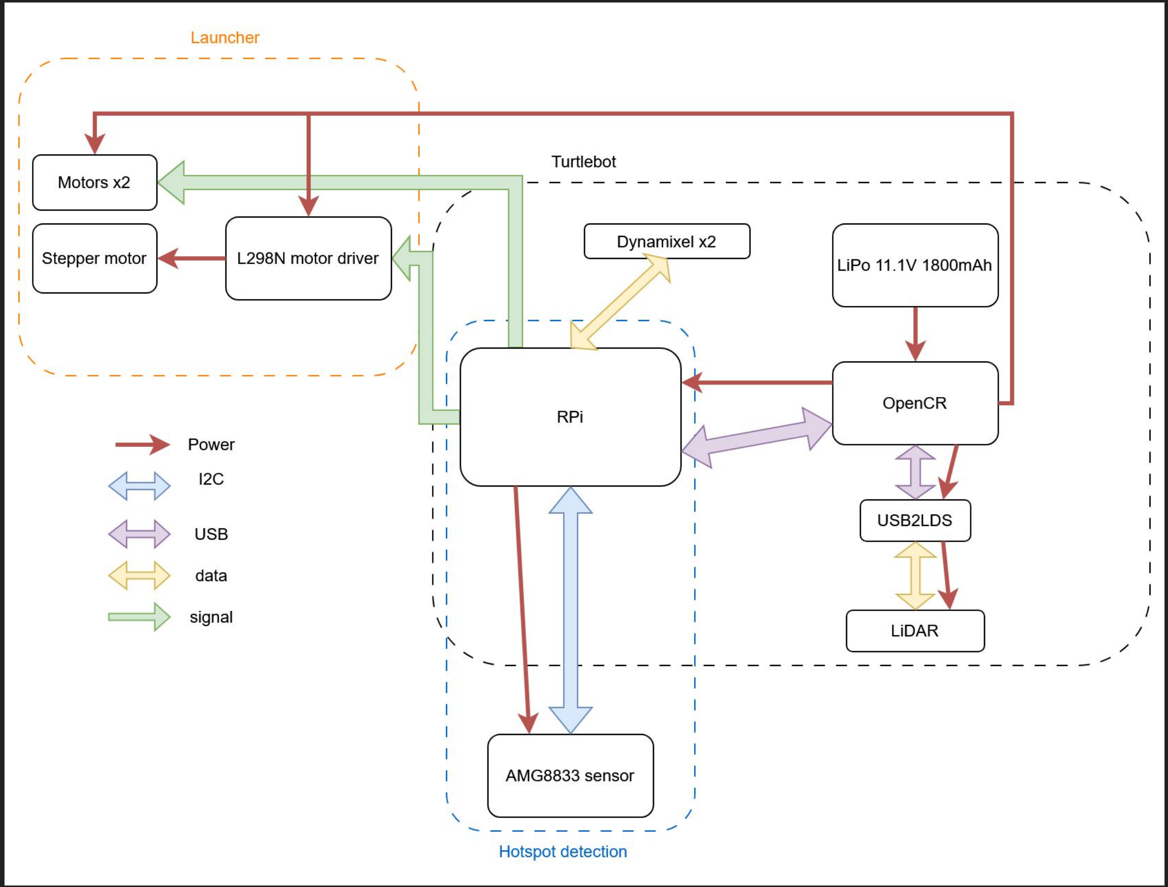
Y: 31.30mm

Z: 62.34

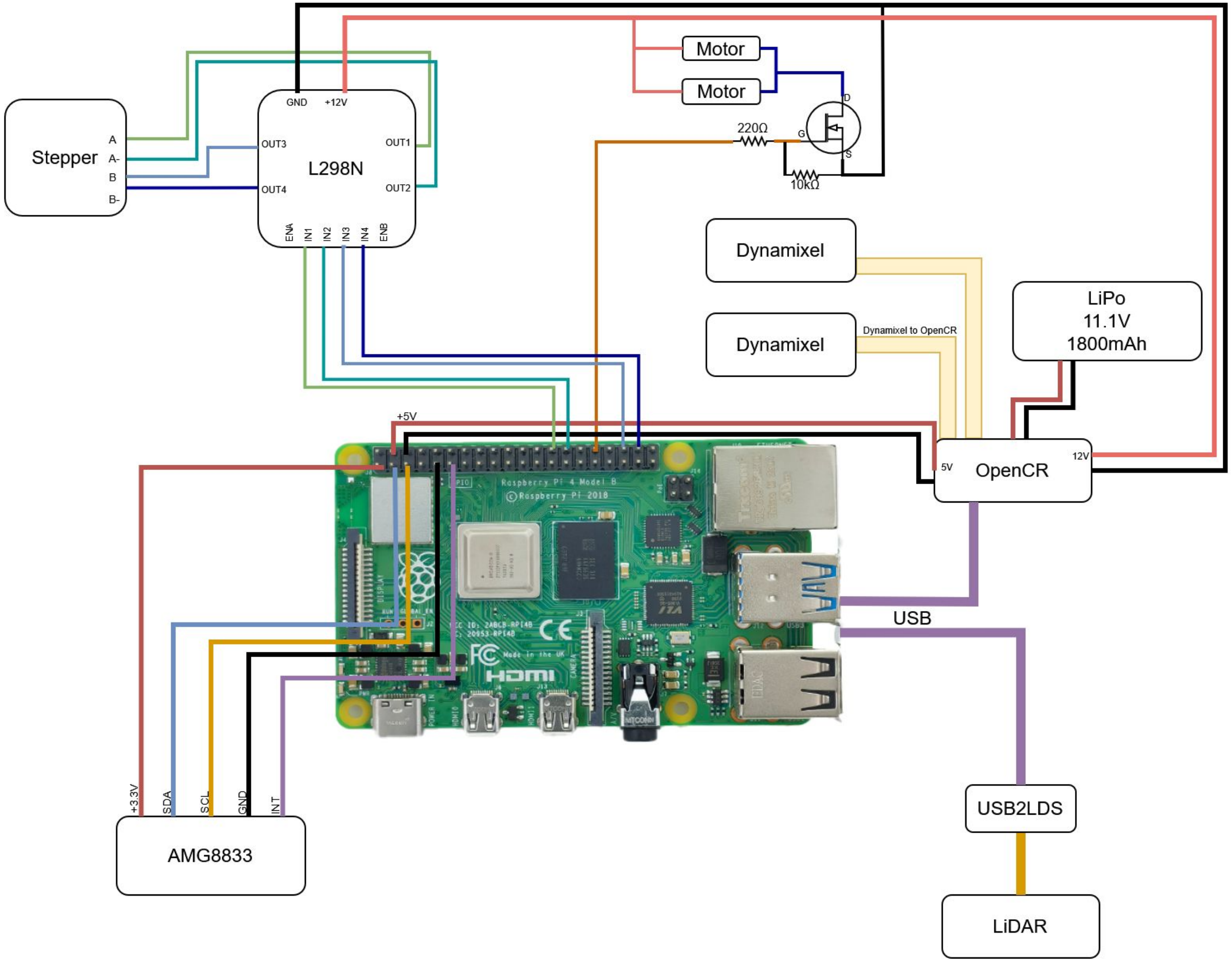
No	Part	Weight (g)	X	Y	Z	CGX	CGY	CGZ
1	1st Layer Waffle Plate	80	32	-17.68	88.15	2560	-1414.4	7052
2	Right Motor	56	11.04	-0.19	34.55	618.24	-10.64	1934.8
3	Right Wheel	27	0	0	9.53	0	0	257.31
4	Left Motor	56	11.04	0.19	141.75	618.24	10.64	7938
5	Left Wheel	27	0.01	0.01	166.77	0.27	0.27	4502.79
6	Battery	137	34.16	-0.5	87.65	4679.92	-68.5	12008.05
7	Ball Bearing	4	81	-26.62	88.15	324	-106.48	352.6
8	Standoff	6	-32	1.25	64.15	-192	7.5	384.9
9	Standoff	6	-32	-1.25	112.15	-192	-7.5	672.9
10	Standoff	6	96	-1.45	64.15	576	-8.7	384.9
11	Standoff	6	96	1.25	112.15	576	7.5	672.9
12	L Bracket	2	84	-10.89	87.42	168	-21.78	174.84
13	L Bracket	2	-16.27	-10.69	79.15	-32.54	-21.38	158.3
14	L Bracket	2	38	-6.18	66.59	76	-12.36	133.18
15	L Bracket	2	-16.27	-10.69	97.15	-32.54	-21.38	194.3
16	L Bracket	2	38	-6.18	109.72	76	-12.36	219.44
17	2nd Layer Waffle Plate	80	32	19.33	88.15	2560	1546.4	7052
18	Standoff	6	56	40.55	152.15	336	243.3	912.9
19	Standoff	6	56	43.05	24.15	336	258.3	144.9
20	Standoff	6	-32	43.25	100.15	-192	259.5	600.9
21	Standoff	6	-32	40.75	76.15	-192	244.5	456.9
22	PCB Support	2	-9.89	25.53	65.33	-19.78	51.06	130.66
23	PCB Support	2	-9.89	25.53	110.97	-19.78	51.06	221.94
24	PCB Support	2	73.89	25.53	110.97	147.78	51.06	221.94
25	PCB Support	2	73.89	25.53	65.33	147.78	51.06	130.66
26	Open CR	64	25.63	35.13	89.38	1640.32	2248.32	5720.32
27	3rd Layer Waffle Plate	80	32	66.62	88.15	2560	5329.6	7052
28	Standoff	6	96	87.85	64.15	576	527.1	384.9
29	Standoff	6	96	90.35	112.15	576	542.1	672.9
30	Standoff	6	8	90.55	152.15	48	543.3	912.9
31	Standoff	6	-32	88.05	112.15	-192	528.3	672.9
32	Standoff	6	-32	90.55	64.15	-192	543.3	384.9
33	Standoff	6	8	88.05	24.15	48	528.3	144.9
34	PCB Support	2	71.78	72.83	116.74	143.56	145.66	233.48
35	PCB Support	2	42.78	72.83	118.36	85.56	145.66	236.72
36	PCB Support	2	71.78	72.83	58.74	143.56	145.66	117.48
37	PCB Support	2	42.78	72.83	60.36	85.56	145.66	120.72
38	RPi	47	53.96	84.88	71.63	2536.12	3989.36	3366.61
39	4th Layer Waffle Plate	80	32	114.12	88.15	2560	9129.6	7052
40	PCB Support	2	57.26	120.53	112.74	114.52	241.06	225.48
41	PCB Support	2	18.49	120.33	104.61	36.98	240.66	209.22
42	PCB Support	2	57.25	120.53	63.57	114.5	241.06	127.14
43	PCB Support	2	18.49	120.33	71.7	36.98	240.66	143.4
44	Lidar	128	32	130	88.15	4096	16640	11283.2
45	Launcher	395.18	146.66	32.17	100.04	57957.0988	12712.9406	39533.8072
		1379.18				**20.26222103**	**31.30267985**	**62.33789643**
						Forward	Vertical	Horizontal

Electrical

Electronics System Architecture (E3 Assignment Requirement)



Wiring diagram



Component selection (E3 Assignment Requirement)

- IR temperature sensor
- Launcher mechanism
  - Motors for flywheel and feeder
  - Motor driver
  - Power source

Temperature sensor

	Option 1: MLX90614	Option 2: AMG8833
Function	Single-point measurement	8x8 array (64 data points)
Communication protocol	I2C	I2C
FOV	90°	60°
Detection distance	2-5cm	Up to 7m
Cost	$17.82 from Cytron	$38.40 from Shopee

- Can use AMG8833 from the lab if we manage to get it

Flywheel motors

- Size 130 DC motors
- Operating range 4.5-9V
- Loaded RPM 4500 ± 1500
- Small size
- Use PWM+MOSFET (IRL3803PbF) to control voltage output to motors

Option 2: high speed DC motors (like what they use for model aircraft/drones)

- More expensive
- Tend to need more voltage (7.4-12V)
- Faster (eg. no-load RPM of 10000)

adafruit

DC Toy / Hobby Motor - 130 Size

PRODUCT ID: 711

SG$0.78

Wholesale 10+ pieces, extra 5% off

Tax excluded, add at checkout if applicable

Mabuchi FC-130SA-20120 Micro 130 DC Motor DC 3V 3.7V 5V 6V 17000RPM High Speed Carbon Brush Strong Magnetic DIY RC Toy Car Boat

by Motor Star Store (4.8 | 10,000+ sold)

- Rated Load: 10 g*cm
- No-load Current: 70 mA max
- No-load Speed: 9100 ±1800 rpm
- Loaded Current: 250 mA max
- Loaded Speed: 4500 ±1500 rpm
- Starting Torque: 20 g*cm
- Starting Voltage: 2.0
- Stall Current: 500mA max
- Body Size: 27.5mm x 20mm x 15mm
- Shaft Size: 8mm x 2mm diameter
- Weight: 17.5 grams

Stepper

- FIT0503
- Weight: 14g
- 5-12V
- 30Ω coil resistance
- Max current = 12/30 ≅ 0.5A

- Option 2: Servo (SG90)

Motor driver: L298N

- Max current output: 2A per channel
- 4 channels → can be used to control stepper motor
- In lab

- Option 2: L293D
  - 600mA max output
  - Not in lab

Power source

- 12V from OpenCR
    - Max 55W total supplied from both the 5V and 12V outputs

Power budget

Component	Voltage/V	Current/A	Power/W	Remarks
Turtlebot during operation	12.00	0.66	7.92	From E2 assignment
AMG8833	3.3	0.045	0.1485	3.3V from RPi
Motors x2	6	0.5*2 = 1	6.0	Loaded current is 0.25A per motor Stall current is 0.5A per motor
Stepper + L298N	12	0.5 + 0.36 = 0.86	10.32	L298N consumes up to 36mA Stepper is rated for max 0.5A
Total			**24.4 < 55**	

Battery life (Turtlebot)

Turtlebot3 LiPo battery: Lithium polymer 11.1V 1800mAh / 19.98Wh 5C
Given Data:

- Battery: 11.1V, 1,800mAh
- Battery energy: 11.1V x 1.8Ah = 19.98Wh.

Assume 15W average power use, since motors are only used when firing flares
Estimated battery life = 19.98Wh/15W = 1.3h

Software

Key concepts

Nodes

Topics

Services

Parameters

Actions

Key concepts

Move by publishing to **/Cmd_Vel**

Subscribe to **/Odom** for robot orientation

Subscribe to **/Scan** for Lidar information

Subscribe to /**Map** to get SLAM information

Algorithms

Mapping Algorithm

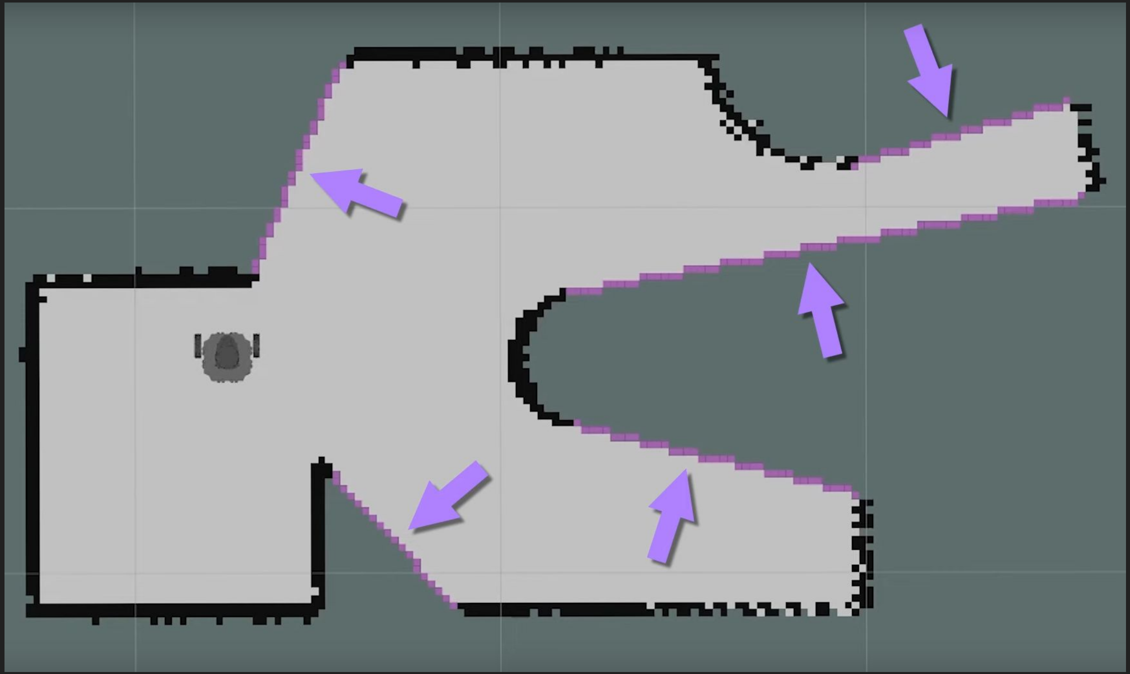
Pathfinding Algorithm

Overall Navigation Algorithm

Mapping Algorithm

Frontier Exploration

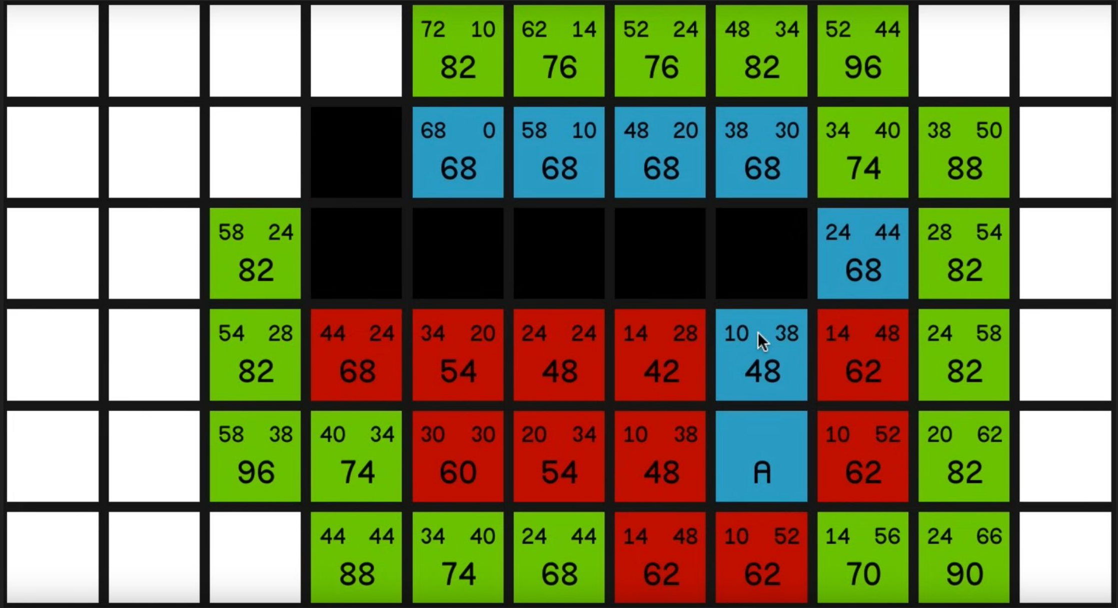
- Prioritise frontiers based on distance and size of frontier



Pathfinding Algorithms

A* Navigation

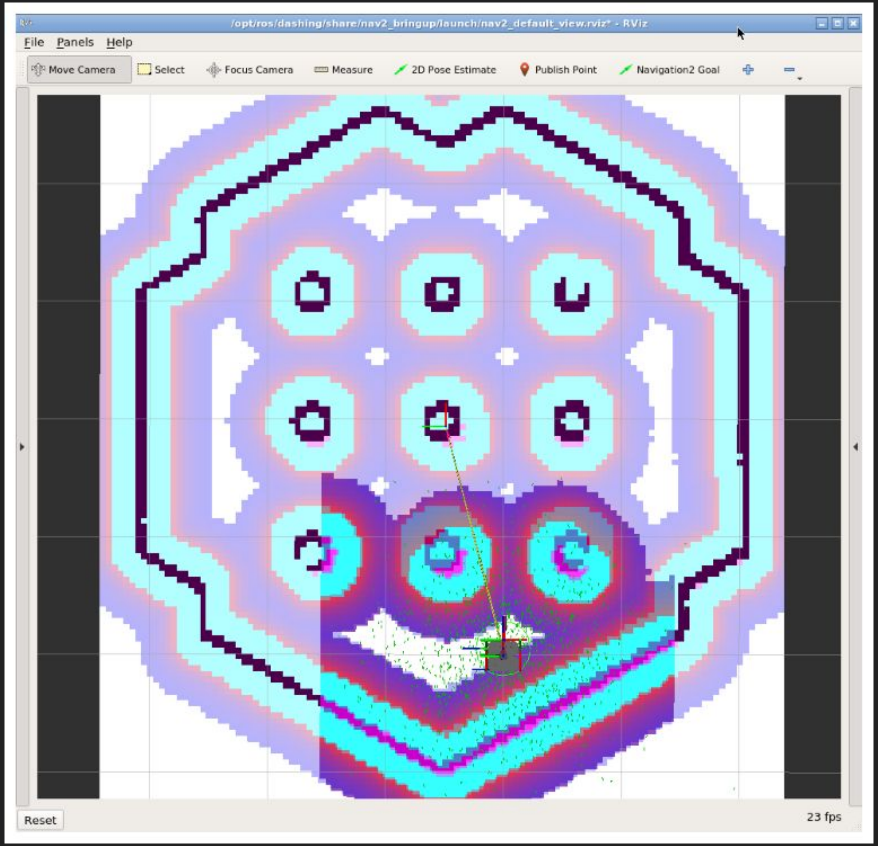
- Gives cells values based on G cost and H cost
- Shortest path is very close to walls



Pathfinding Algorithm

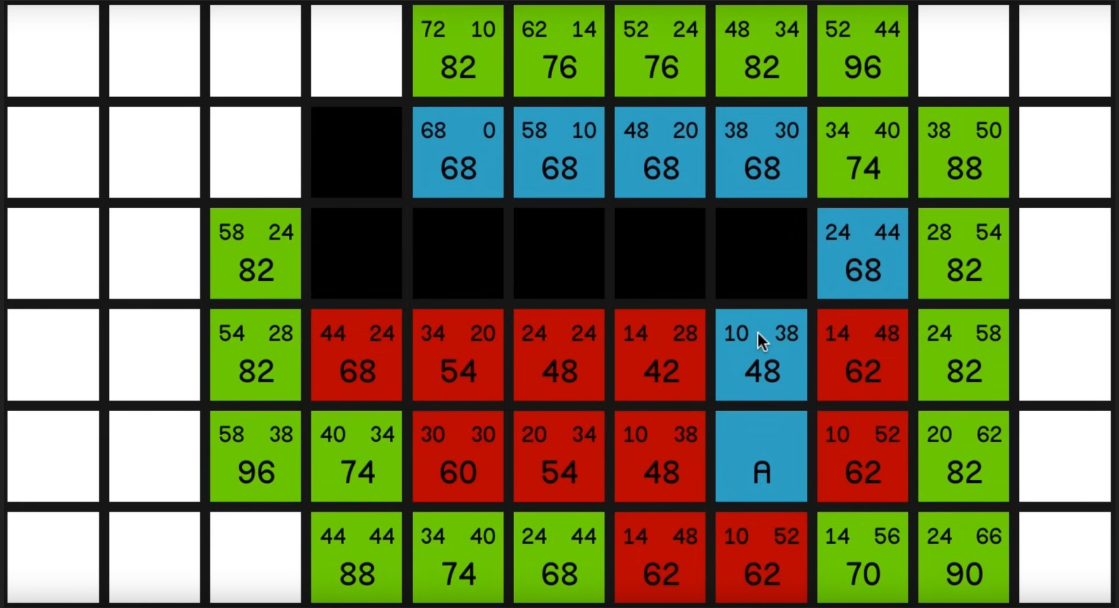
Collision Costmap

- Grids near walls = high cost
- Grids away from walls = low cost
- Prioritise using low cost grids to build path



Pathfinding Algorithm

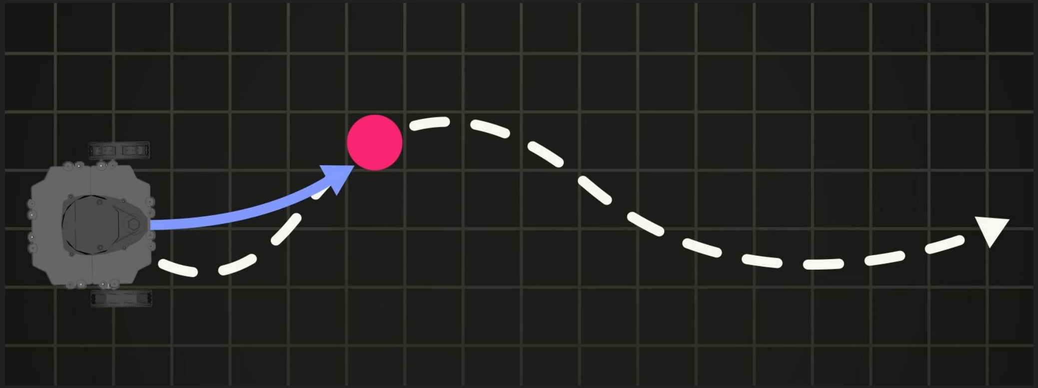
A* Navigation + Collision Costmap



Pathfinding Algorithm

Pure Pursuit

- Pick a point on the path which is a set distance ahead of the robot
- Make the robot move directly towards that path
- Distance too small > Robot will overcorrect
- Distance too large > Robot may move very close to walls



Overall Navigation Algorithm

Mapping Phase: Focus on mapping

Searching Phase: Mapping complete, focus on searching

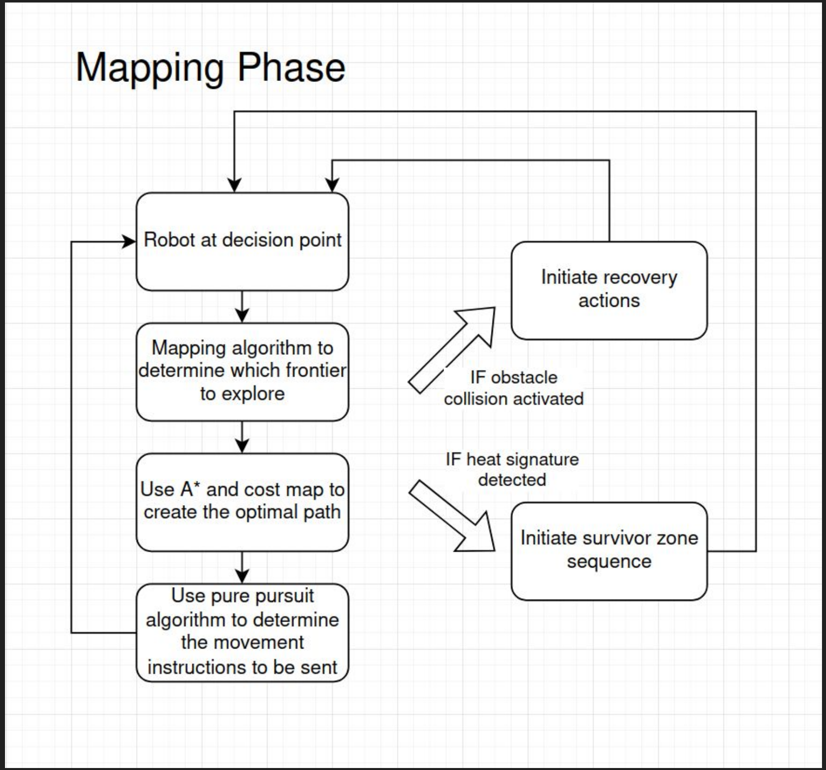
Scenario 1:

- Robot finds both targets before it completes mapping
- Robot completes mapping

Scenario 2:

- Robot completes mapping before finding both targets
- Robot focuses on searching for remaining targets

Overall Navigation Algorithm

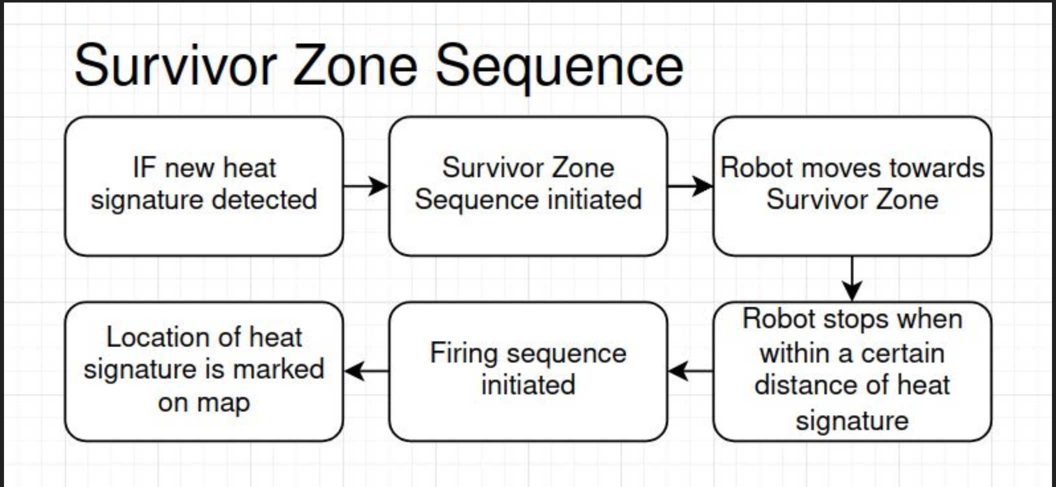


Overall Algorithm Structure

Searching Phase:

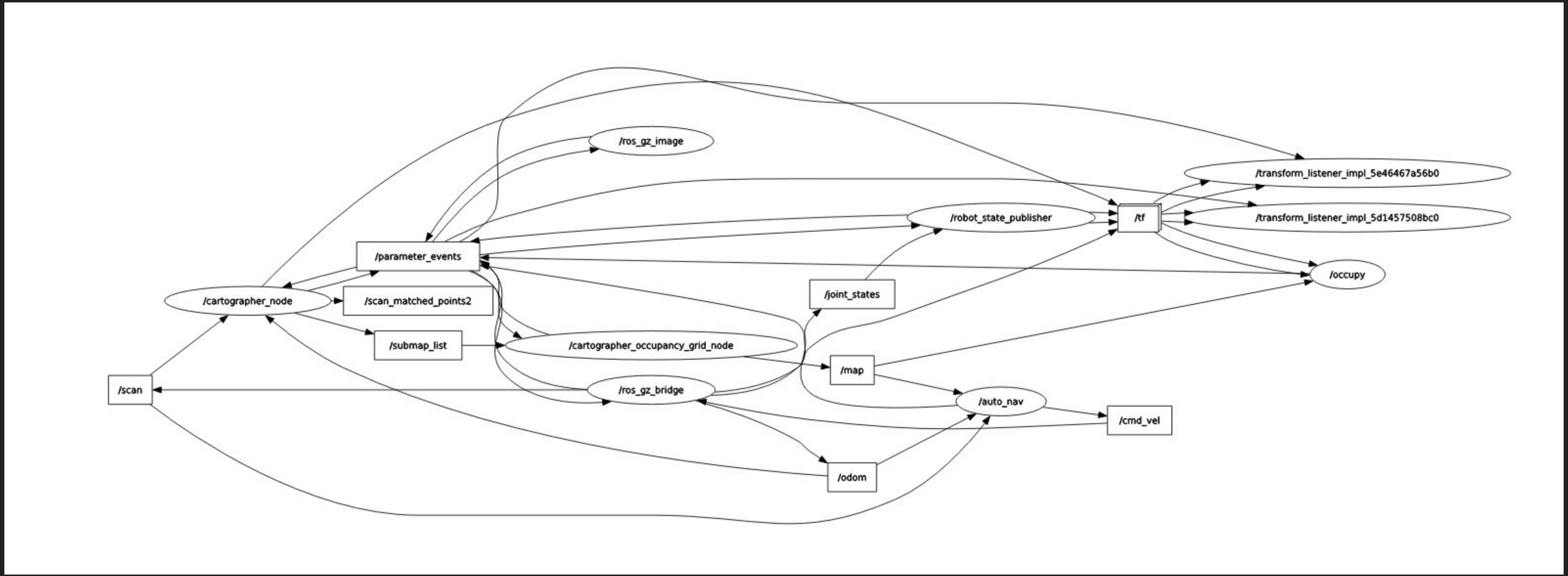
- Search Area Footprint (Rotate 360 once in a while)
- Cost Map of areas thermally searched
- Cost Map of areas rotated
- BFS if desperate

Overall Navigation Algorithm

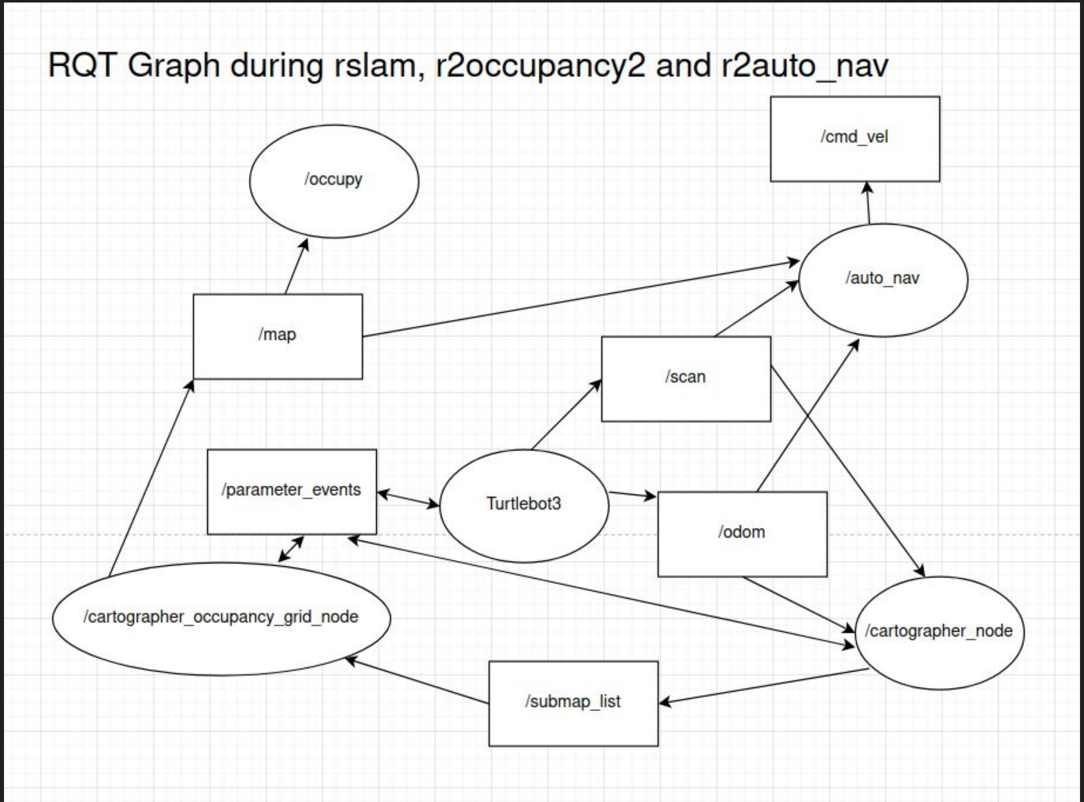


ROS2 Implementation

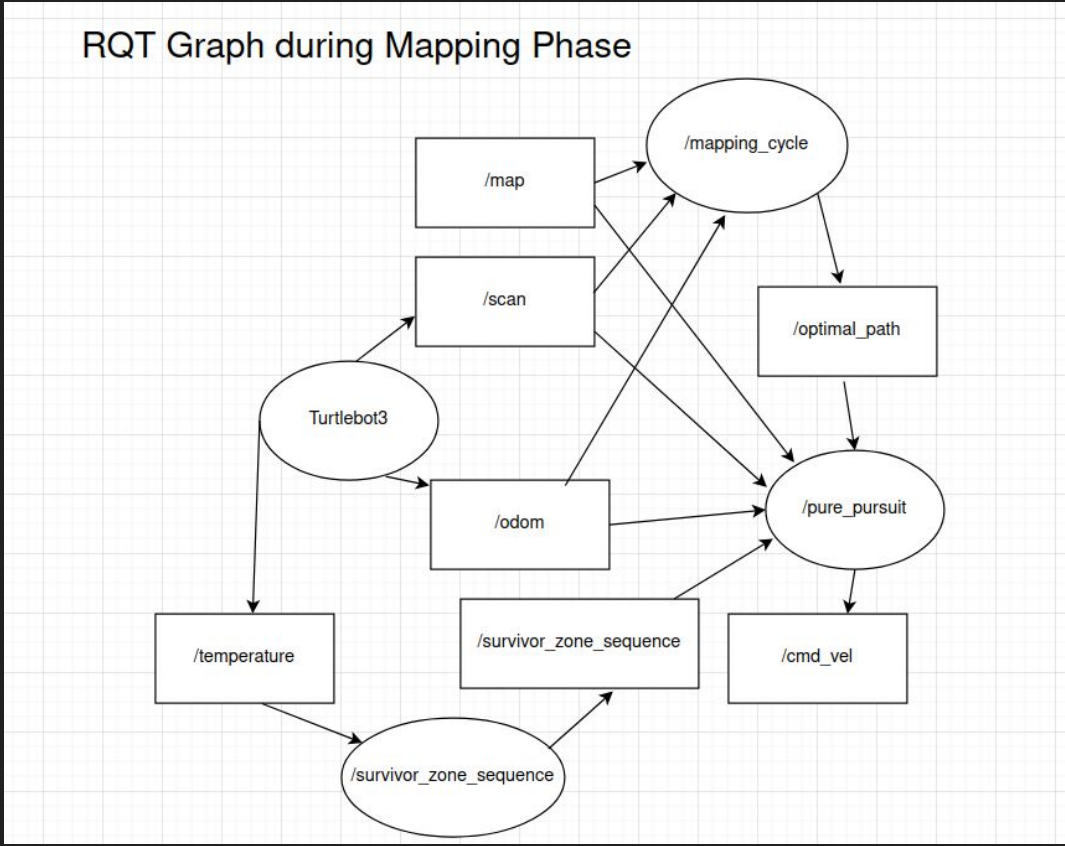
RQT Graph during rslam, r2auto_nav, r2occupancy2



ROS2 Implementation



ROS2 Implementation



Embedded firmware

AMG8833

```python
    def pixels(self) -> List[List[float]]:
        """Temperature of each pixel across the sensor in Celsius.

        Temperatures are stored in a two dimensional list where the first index is the row and
        the second is the column. The first row is on the side closest to the writing on the
        sensor."""
```

- I2C
  - Default address 0x69
  - SDA to GPIO 2, SCL to GPIO 3 (corresponding I2C pins on RPi)
- Adafruit AMG88xx python** library (https://github.com/adafruit/Adafruit_CircuitPython_AMG88xx)
- Read data: 8x8 array of values
  - Heatmap (for visualisation/debugging)
    https://makersportal.com/blog/2018/1/25/heat-mapping-with-a-64-pixel-infrared-sensor-and-raspberry-pi

**Actually a circuitpython library but possible to run it without circuitpython:
https://learn.adafruit.com/circuitpython-on-raspberrypi-linux/running-circuitpython-code-without-circuitpython

Embedded firmware

AMG8833: finding heat signature

- Basic idea: If any pixel is above a threshold temperature (which we would set based on tests with the heat source), initiate survivor zone sequence
- Option 1: Search through the array; check if any entry is above our threshold temperature
- Option 2: INT pin on AMG8833
  - Connect interrupt pin to GPIO pin (may have to add 10k ohm pull-up resistor)
  - Read value of interrupt pin
  - INT pin outputs low/raises interrupt flag whenever any pixel reaches above/below threshold temperature

BOM

Component	**Part no.**	**Cost per unit**	**No. of units**	**Total cost**	**Link**
IR temperature sensor	AMG8833	$27.61	1	$27.61	https://shopee.sg/AMG8833-IR-8*8-MLX90640-32*24-Camera-Module-Thermal-Imager-Array-Temperature-Sensor-8x8-32x24-Infrared-MLX90640BAA-MLX90640BAB-i.240782317.23649387689?sp_atk=43ffb058-cc48-46c0-82d7-65f1fd7e1ff2&xptdk=43ffb058-cc48-46c0-82d7-65f1fd7e1ff2 (or from electronics lab)
Motor	FC-130SA-20120 DC Motor	$1.94	4 (2 spare)	$7.76	https://shopee.sg/130-Micro-Mini-Motor-DC-3-To-9.6V-19200RPM-High-Speed-FC-130A-13220-Carbon-Brush-for-Four-wheel-Motor-Small-for-DIY-Motor-i.925606537.23913893584?xptdk=f5d8c1d1-56e8-4134-8f07-f91c2d7625ce
Stepper	28BYJ-48	$1.96	1	$1.96	https://shopee.sg/1set-28BYJ-48-5V-4-phase-Stepper-Motor-Driver-Board-ULN2003-for-Arduino-1-x-Stepper-motor-1x-ULN2003-Driver-board-i.161750523.7234856914?sp_atk=457a612f-dcb8-465b-b9f0-970304bd023c&xptdk=457a612f-dcb8-465b-b9f0-970304bd023c
Flywheel	PU60835-18	$5.71	2	$11.42	https://shopee.sg/product/362240629/24425940748?d_id=68a20&uls_trackid=524r0an901r2&utm_content=3WQ2YUUU9WQgTr8zPZ6cKL66Er9M
Filament roll (1kg)		$17	1	$17	
Total				$65.75	

Testing plan

The plan

- Buy parts
- Begin working on navigation
- Begin printing launcher and testing
- Once parts arrive: sensor stuff + launcher
- Integrating subsystems

Plan B

Hardware failure: Use spares

Launcher design flaw: Redesign in 1 day, print in 1 day -> Total 2 days

Backup launcher mechanism: 9x spring loaded firing mechanisms

Parts don’t arrive on time: find alternative sources

If LIDAR cannot see the guy on the floor: borrow basic IR distance sensor and put it near the bottom of the turtlebot

TPM/MOE

Mapping	Measures of Performance: The robot must be able to map the maze. Technical Performance Measures: The robot must be able to accurately store and retrieve a map of the maze representing a 5 meter by 5 meter space.
Navigation and Localization	Measures of Performance: The robot must navigate the maze to two heat sources (incandescent light bulbs) that are within the maze behind acrylic walls without bumping into the walls. Technical Performance Measures: Robot must be able to return to the starting position with deviation of under 5 cm after 25 minutes of movement. The robot must be able to stop and recalibrate its path if it were to move within 5 cm of the wall.
Identification of heat sources	Measures of Performance: The robot must identify heat signals, detecting their distance from the robot and identifying their position relative to the maze. Technical Performance Measures: The robot must identify an incandescent bulb (a local maximum temperature) within 20 cm and approach the heat signal.
Firing mechanism	Measures of Performance: The robot must store up to 9 ping pong balls and launch 3 ping pong balls at a set time interval Technical Performance Measures: The robot should be able to launch 3 ping pong balls 1.5m vertically with a time interval of 2-4-2s
Scaling a ramp	Measures of Performance: The robot should be able to identify and scale a ramp Technical Performance Measures: The robot should be able to scale a 10° ramp without slipping.