GOOD MORNING!
早上好!
안녕하세요!

DAY 4

DAY 1

- Welcome
- Project Introduction
- Introduction to Project Development Process
- Business Requirement Development
- System Requirement Development
- System(High Level) Design
- Time Management

DAY 2 (MINI PROJECT)

- Yolo객체 인식 모델 활용과 성능 평가 방법 이해
- Custom Dataset과 Fine Tuning으로 자체 객체 인식 모델 구현 및 평가
- (Optional)경량화 모델 등 개별 요구사항에 적합한 모델 탐색 및 성능 검증

- YOLOv8 기반 데이터 수집/학습/deploy (Detection Alert)
  - 감시용 데이터 수집(bus, truck, tank 등)
  - 감시용 데이터 라벨링
  - YOLOv8 기반 학습
  - YOLOv8 Object Detection
- Porting to ROS
  - Create Detection Alert Node
  - Generate Topics to send image and Obj. Det. results
  - Create Subscriber node and display image and print data from the Topic

DAY 3 (MINI PROJECT)

- AMR(Autonomous Mobile Robot) Turtlebot4 개발 환경 구축
- 로봇 개발 환경에 완성 모델 서빙 및 테스트 / 로봇 H/W, 제반 환경의 한계점 도출
  - Tracking 데이터 수집(bus, truck, tank 등)
  - Tracking 데이터 라벨링
  - YOLOv8 기반 학습
  - YOLOv8 Object Tracking
- Turtlebot4 시뮬레이션 환경 구축
  - SLAM과 Map 생성 및 파라미터 튜닝 (Localization, AMCL)
  - AutoSLAM으로 맵 생성

DAY 4 (MINI PROJECT)

- Turtlebot4 API를 활용한 Initial Pose Navigate_to Pose 구현
- Turtlebot4 API를 활용한 Navigate_Through_pose, Follow Waypoints 구현
- 로봇 개발 환경에 적용 및 테스트 / 로봇 H/W, 제반 환경의 한계점 도출

- AMR기반 카메라 인식 autonomous driving 시스템 with obstacle avoidance 구축 (AMR Controller)
  - Digital Mapping of environment
  - Goal Setting and Obstacle Avoidance using Navigation
  - Object Tracking w/ AMR camera
  - Control logic between navigation/obj. tracking/ obj. following (teleop)
- Porting to ROS
  - Create AMR Controller Node
  - Create and send Obj. Tracking Image and data to Sysmon
- Integrate and test with Detection

DAY 5 (MINI PROJECT)

- Flask 를 이용한 웹 서버 구축 (System Monitor)
  - Flask/HTML Intro
  - Deploy YOLOv8 Obj. Det results to web
  - Log in 기능 구현
  - Sysmon 웹기능 구현
  - 알람 기능 구현
- SQLite3를 이용한 데이터베이스 구축 및 연동 (System Monitor)
  - SQLite3 기본 기능 구현
  - DB 기능 구축
  - 알람이 울리는 경우 DB에 저장하는 기능 구현
  - 저장된 내용 검색하는 기능 구현

DAY 5 (MINI PROJECT)

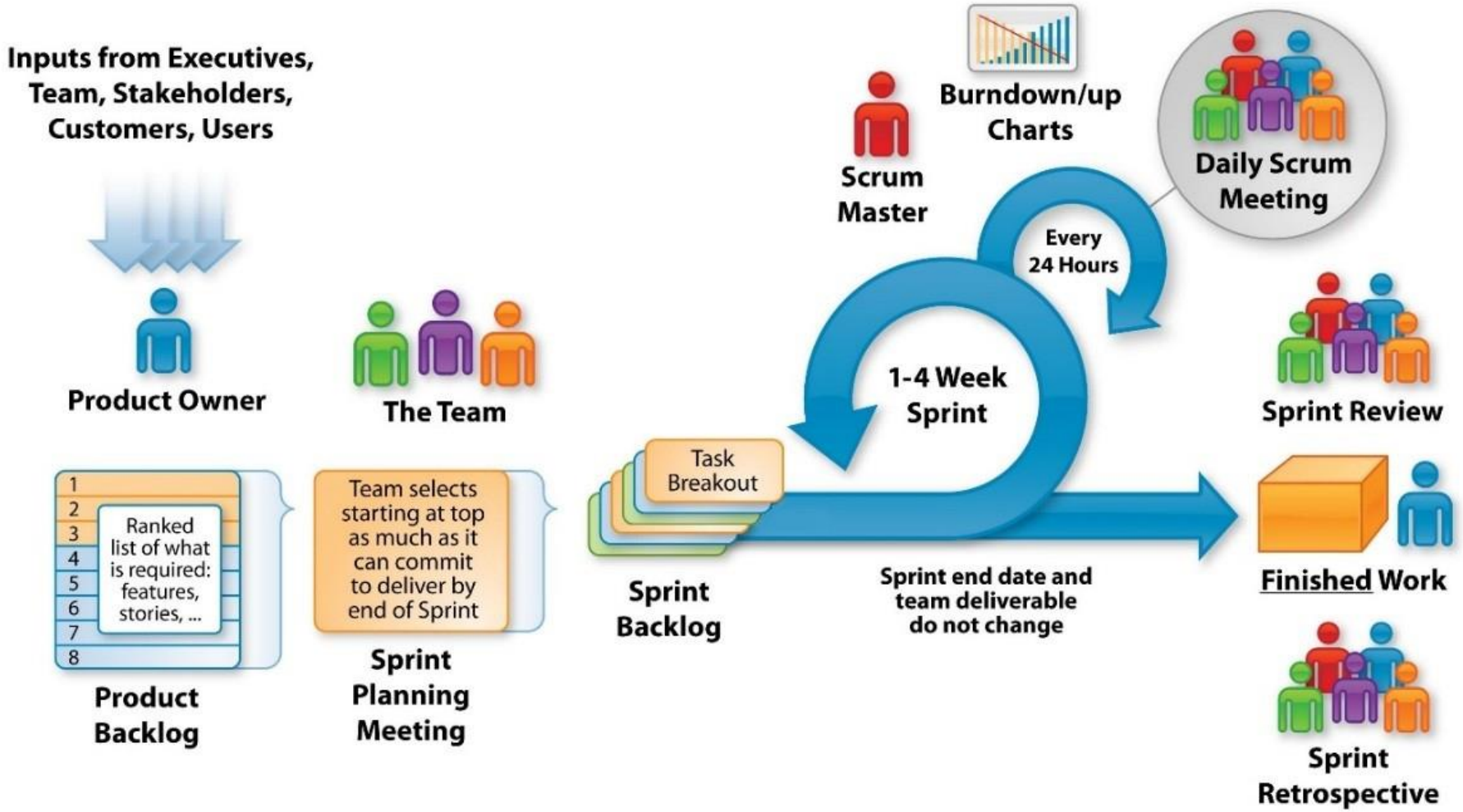
- Porting to ROS
  - Update Sysmon Node code
  - Update the database with received Obj. Det. Data from Detection Alert Node
  - Display the content of DB on System Monitor web page

- And finally, Integration and Test of Detection Alert & System Monitor

프로젝트 RULE NUMBER ONE!!!

Have Fun Fun Fun!

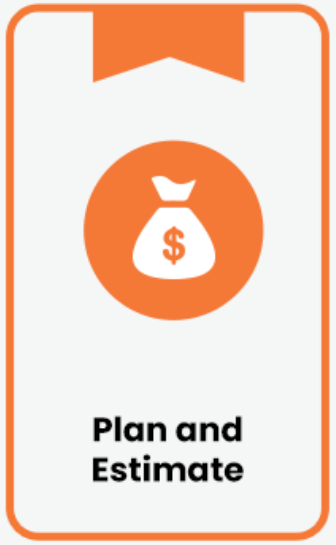
The Agile - Scrum Framework



5 Stages of Scrum Sprint

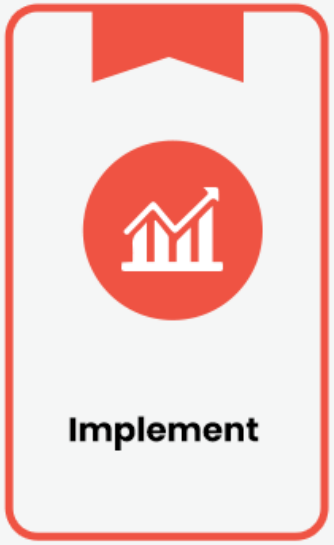
Initiate

This phase includes the processes related to the commencement of a project, such as a scope and objectives, creating and distributing its charter, and taking other steps to guarantee success.



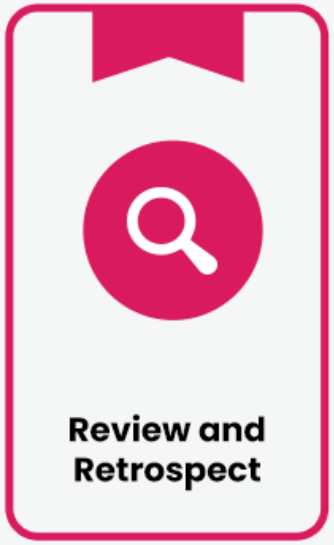
Plan and Estimate

This phase involves planning and estimating processes, including creating user stories, approving, assessing, committing user stories, creating tasks, evaluating tasks, and creating a Sprint backlog.



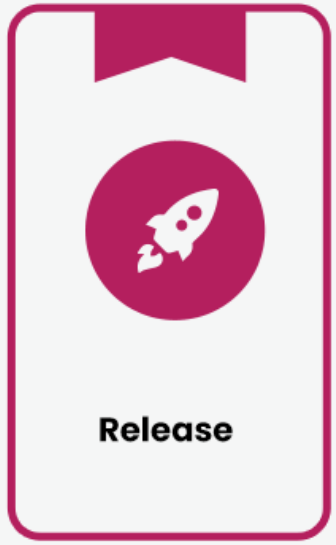
Implement

This phase is about executing the tasks and activities to create a product. These activities include building the various outputs, conducting daily standup meetings, and grooming the product backlog.



Review and Retrospect

This stage of the project lifecycle is concerned with evaluating what has been accomplished so far, whether the team has worked to plan, and how it can do things better in the future.



Release

This stage highlights delivering the accepted deliverables to the customer and determining, documenting, and absorbing the lessons learned during the project.

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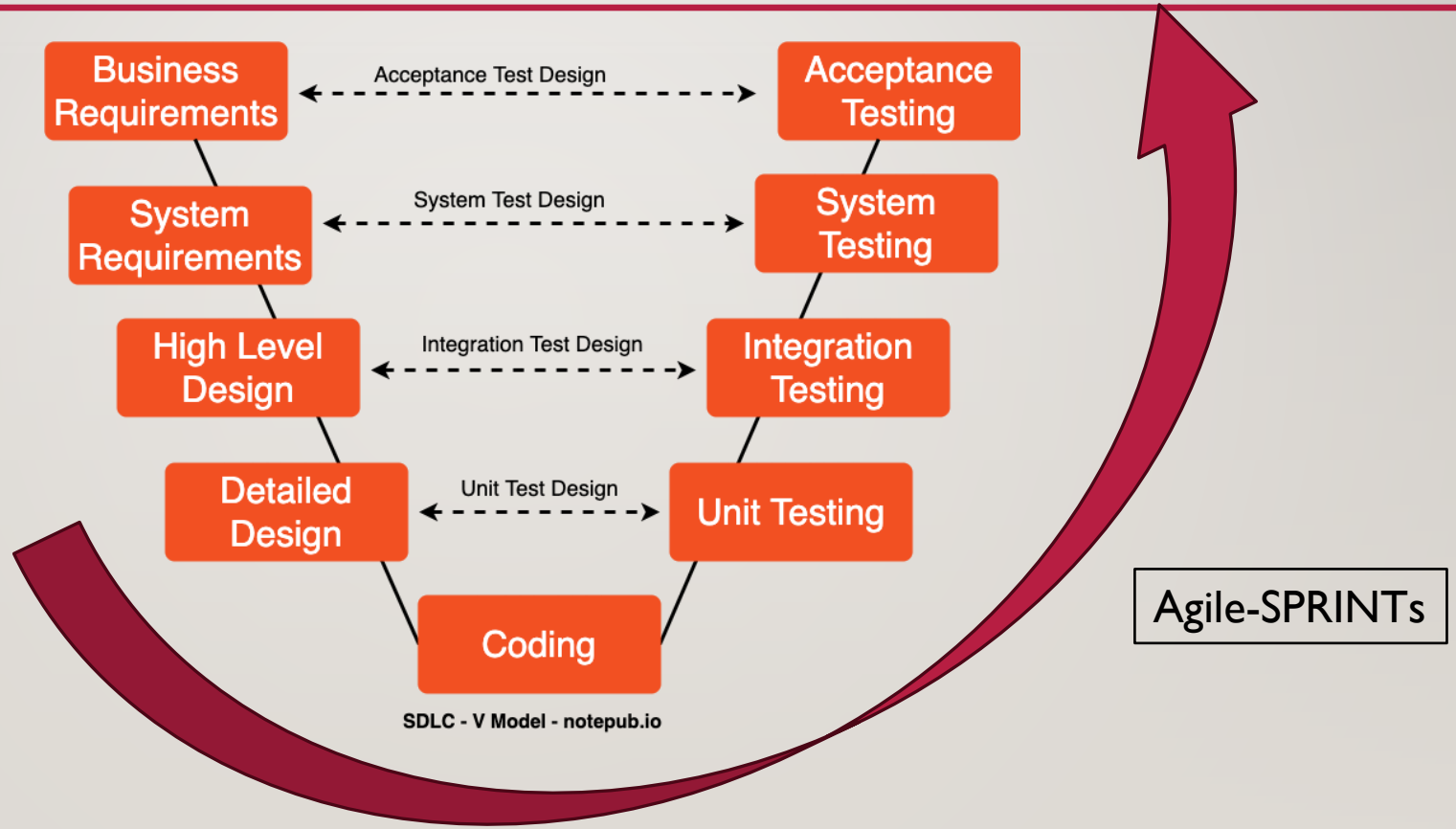
SW DEVELOPMENT PROCESS



Agile-SPRINTs

PROJECT SPRINTS

- Detection Alert
  - Camera Capture
  - Object Detection
  - Send messages to other subsystems

- AMR Controller
  - Receive messages and act accordingly
  - Move using (SLAM) with Obstruction avoidance
  - Target Acquisition (Obj. Det.) and Tracking
  - Follow target using camera and motor control

- System Monitor
  - Receive and Display Detection Camera and info
  - Receive and Display AMR Camera and info
  - Store, display, and report Information and Alerts

OBJECT TRACKING WITH AMR CAMERA

UNDOCK/DOCK AMR

UNDOCK

$ ros2 topic list

Check the list

$ ros2 action send_goal /robot<n>/undock irobot_create_msgs/action/Undock "{}"

DOCK

$ ros2 topic list

Check the list

$ ros2 action send_goal /robot<n>/dock irobot_create_msgs/action/Dock "{}"

WHICH IMAGE TOPIC TO USE?

- /oakd/rgb/preview/image_raw
- /oakd/rgb/image_raw
- /oakd/rgb/image_raw/compressed
- /oakd/stereo/image_raw
- …

- EXERCISE
  - Create a script to display and compare

HOW TO MOVE FILE FROM PC MOVE MAP TO AMR

PC TERMINAL

Connect to turtlebot via ssh first

$ scp <dir_path>/<file_name> ubuntu@<rokey IP>:/home/ubuntu

$ EX: scp oakd_pro.yaml ubuntu@172.30.1.1:/home/ubuntu/

AMR TERMINAL

$ cd ~ #go to home

$ ls oakd_pro.yaml #check if the file transferred correctly

$ sudo mv oakd_pro.yaml /opt/ros/humble/share/turtlebot4_bringup/config/

$ ls /opt/ros/humble/share/turtlebot4_bringup/config/

UPDATING THE OAKD CONFIG (ROBOT)

ON TURTLEBOT4:

$ cd /opt/ros/humble/share/turtlebot4_bringup/config

$ sudo cp oakd_pro.yaml oakd_pro_orig.yaml

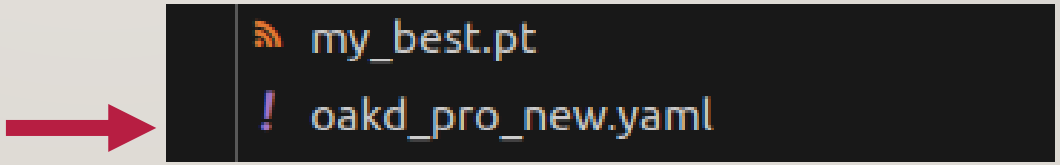
$ sudo cp oakd_pro_new.yaml oakd_pro.yaml

$ sudo reboot

$ sudo systemctl status turtlebot4.service

$ sudo systemctl restart turtlebot4.service

$ ros2 topic list



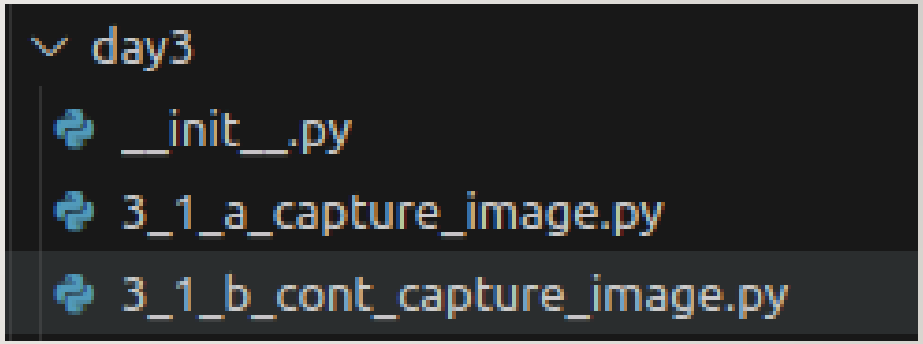
DIMENSIONS AND RESOLUTION

Supported `i_resolution` values (RGB):

Resolution Keyword	Width × Height	Notes
`1080P`	1920 × 1080	Default, high-res
`720P`	1280 × 720	Medium-res
`800P`	1280 × 800	Slightly taller
`480P`	640 × 480	✅ Ideal for alignment with stereo
`400P`	640 × 400	Wide, cropped top/bottom
`320P`	640 × 360	Lower-res
`240P`	320 × 240	Very low-res, fast

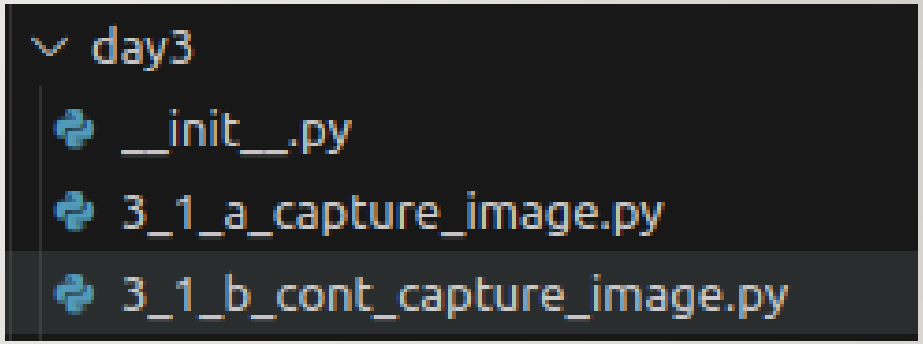
CODING HINTS

- Image Capture



CODING HINTS

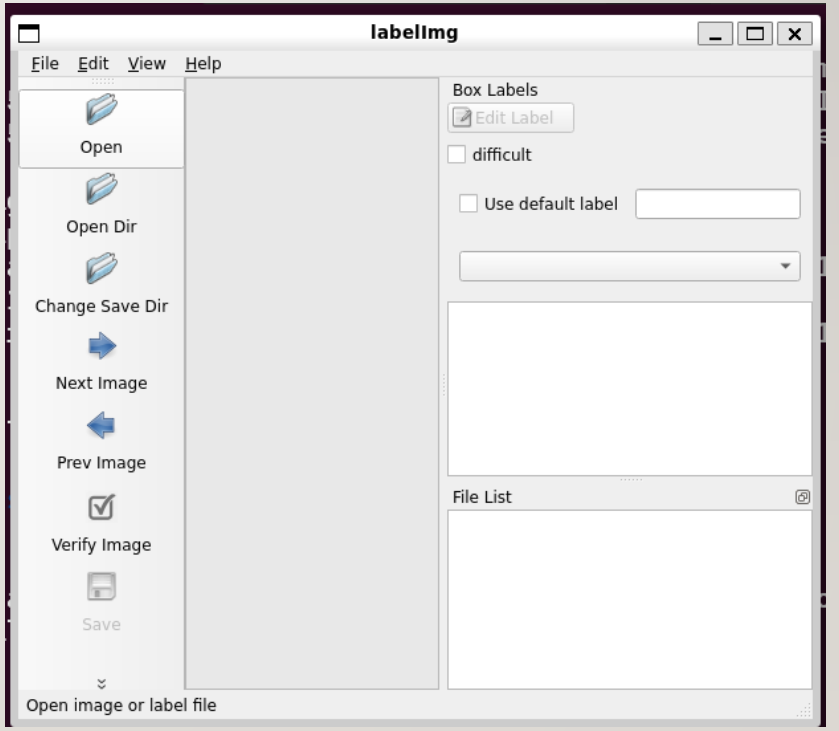
- Image Capture



- Data Labelling
  - labelImg

CODING HINTS

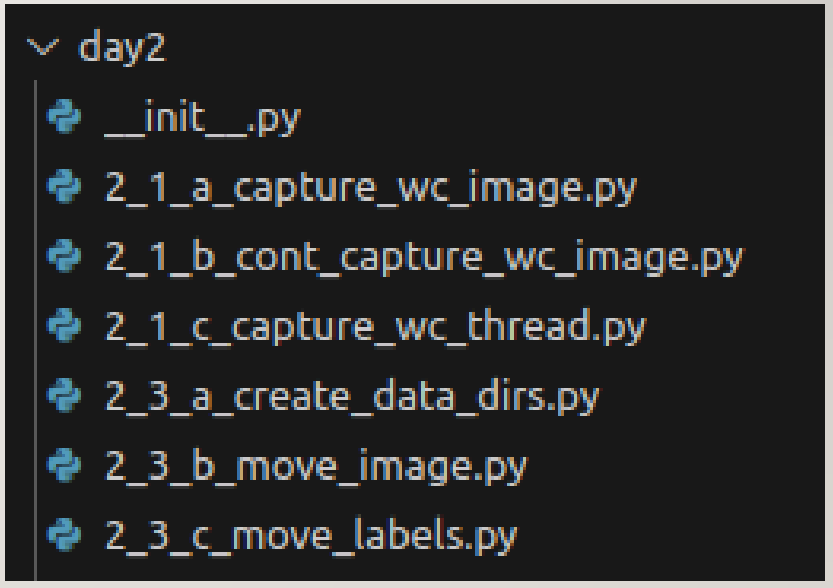
- Data Labelling : use previously installed LabelImg



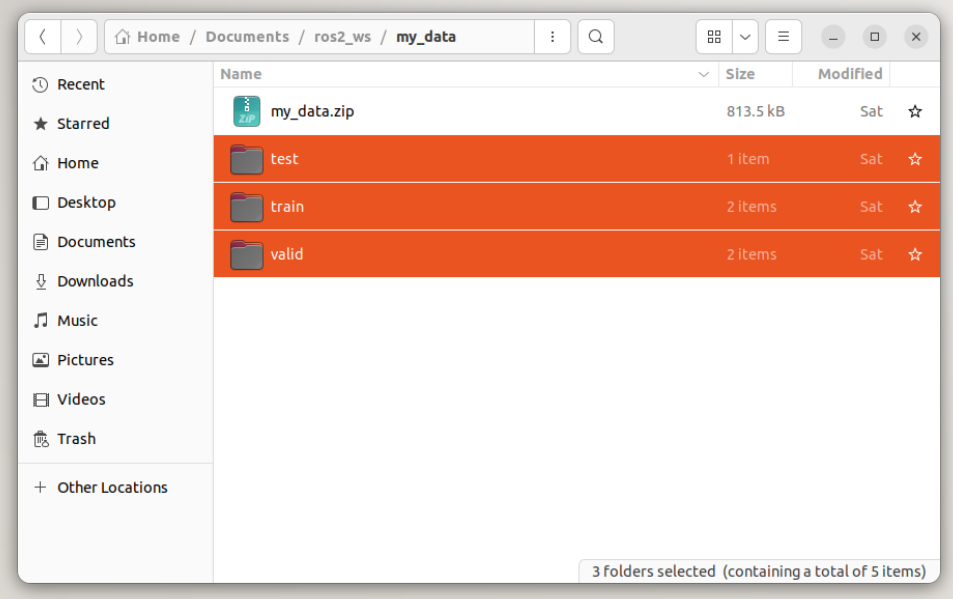
CODING HINTS

- Image Capture
- Data Labelling

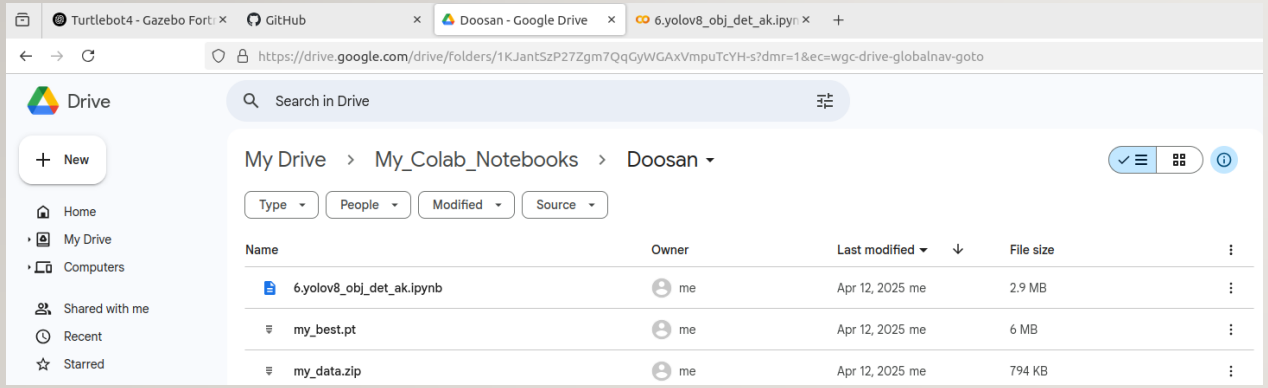
- Data Preprocessing (from previous day)

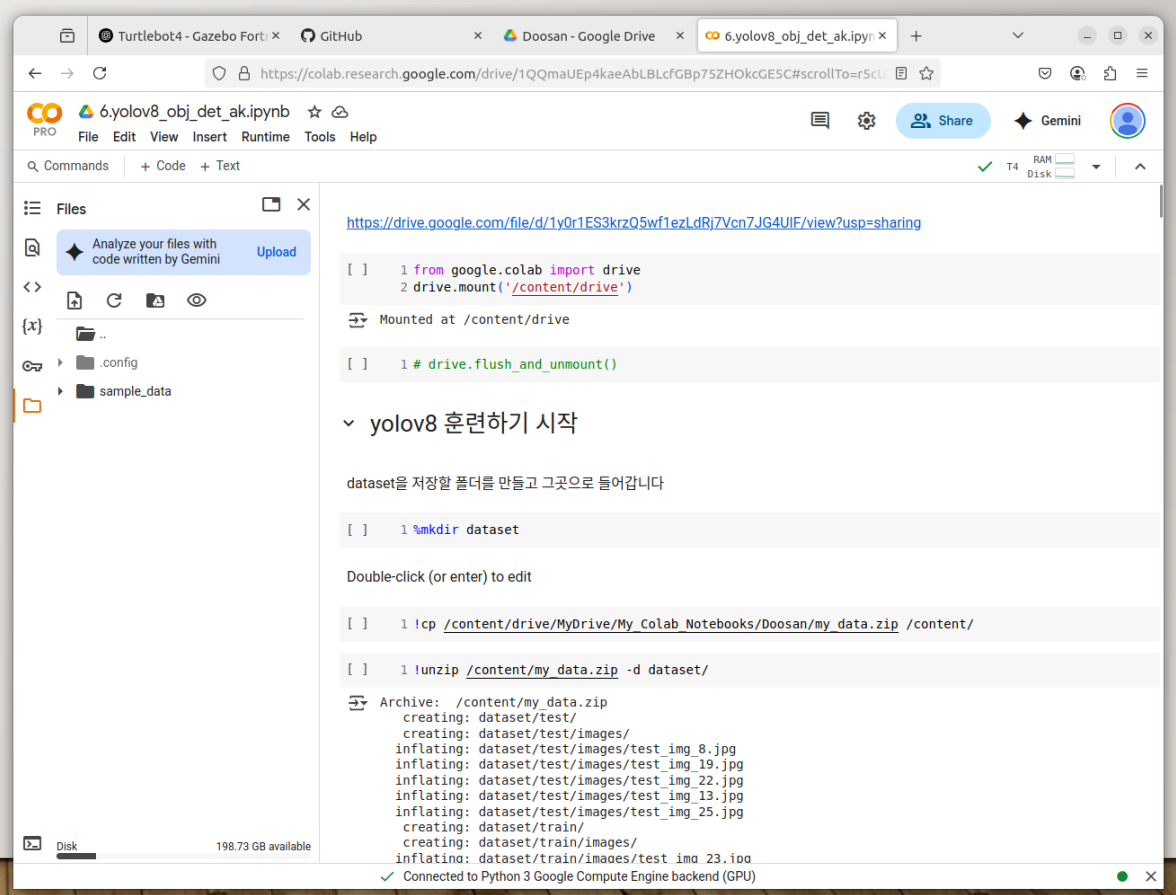


ZIP TRAIN DATA SET



USING GOOGLE COLLAB.TO CREATE CUSTOM MODEL

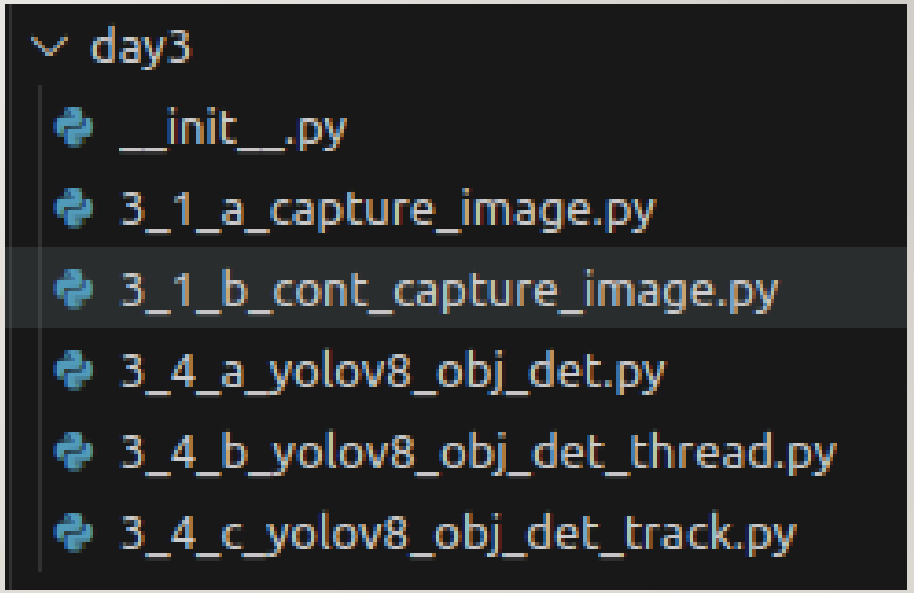




PERFORM YOLO TRAINING & INFERENCE FOR AMR CONTROLLER

CODING HINTS

- Image Capture
- Data Labelling
- Preprocessing
- Yolo8 Object Det



RUNNING IN SIMULATION

SETUP BASH

- Make sure bashrc has:
  - ROS_DOMAIN_ID = 0
- Make sure discovery setup.bash is not sourced! Comment it out.

- source ~/.bashrc

OPERATING A ROBOT(SIM)

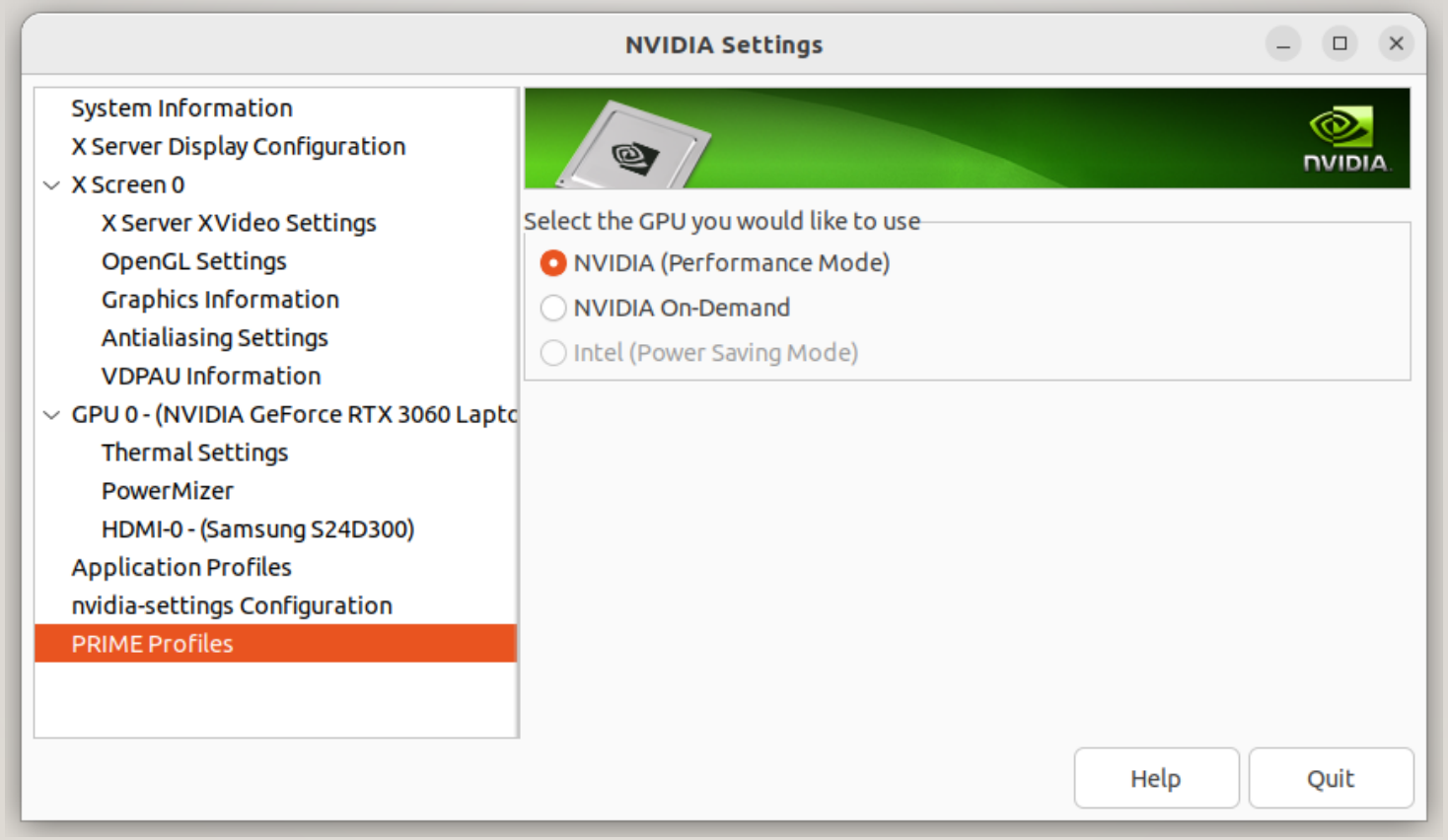
TERM1

- ros2 launch turtlebot4_ignition_bringup turtlebot4_ignition.launch.py rviz:=true

TERM2

- ros2 topic list
- ros2 topic echo <topic> --once
  - /oakd/rgb/preview/image_raw
  - /oakd/rgb/preview/depth
  - ….

SETUP NVIDIA GPU FOR SLAM



DIGITAL MAPPING USING SLAM (SIM)

TERM1

- ros2 launch turtlebot4_ignition_bringup turtlebot4_ignition.launch.py nav2:=true slam:=true rviz:=true

TERM2 (SAVE MAP AFTER MAPPING FINISHES)

- ros2 service call /slam_toolbox/save_map slam_toolbox/srv/SaveMap "name: data: 'map_name'"

Ex:: ros2 service call /slam_toolbox/save_map slam_toolbox/srv/SaveMap "name: data: 'my_map'"

DIGITAL MAPPING WITH AUTO – SLAM (SIM)

TERM1

- ros2 launch turtlebot4_ignition_bringup turtlebot4_ignition.launch.py nav2:=true slam:=true rviz:=true
- Undock the robot

TERM2

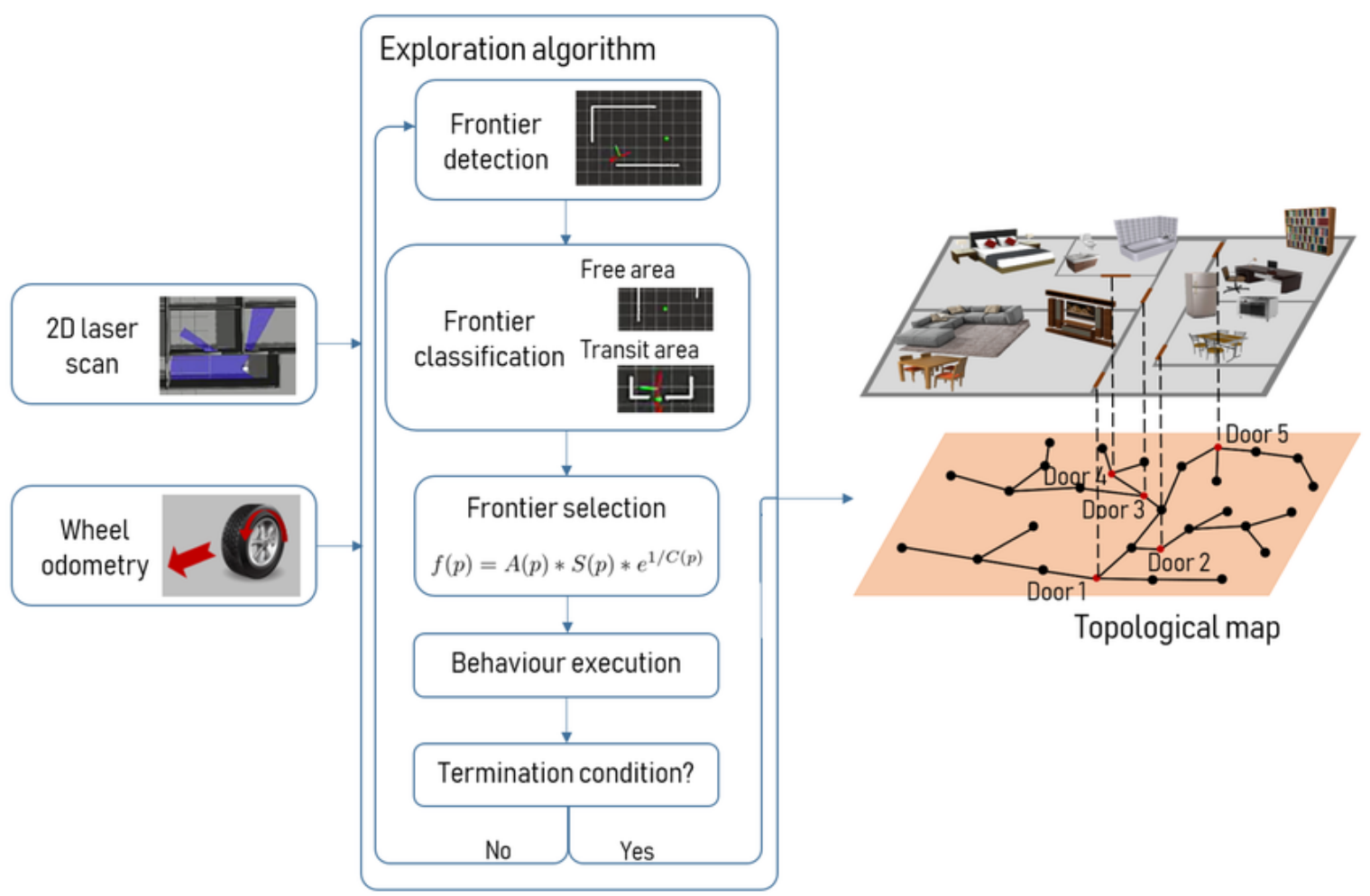
- ros2 launch explore_lite explore.launch.py

TERM3 (SAVE MAP AFTER MAPPING FINISHES)

- ros2 service call /slam_toolbox/save_map slam_toolbox/srv/SaveMap "name: data: 'map_name'"

  Ex:: ros2 service call /slam_toolbox/save_map slam_toolbox/srv/SaveMap "name: data: 'my_map'"

AUTO SLAM CONCEPT/ALGORITHM



ALGORITHM DETAIL

- Map Subscription

explore_lite subscribes to the SLAM-generated occupancy grid (/map topic) and identifies:

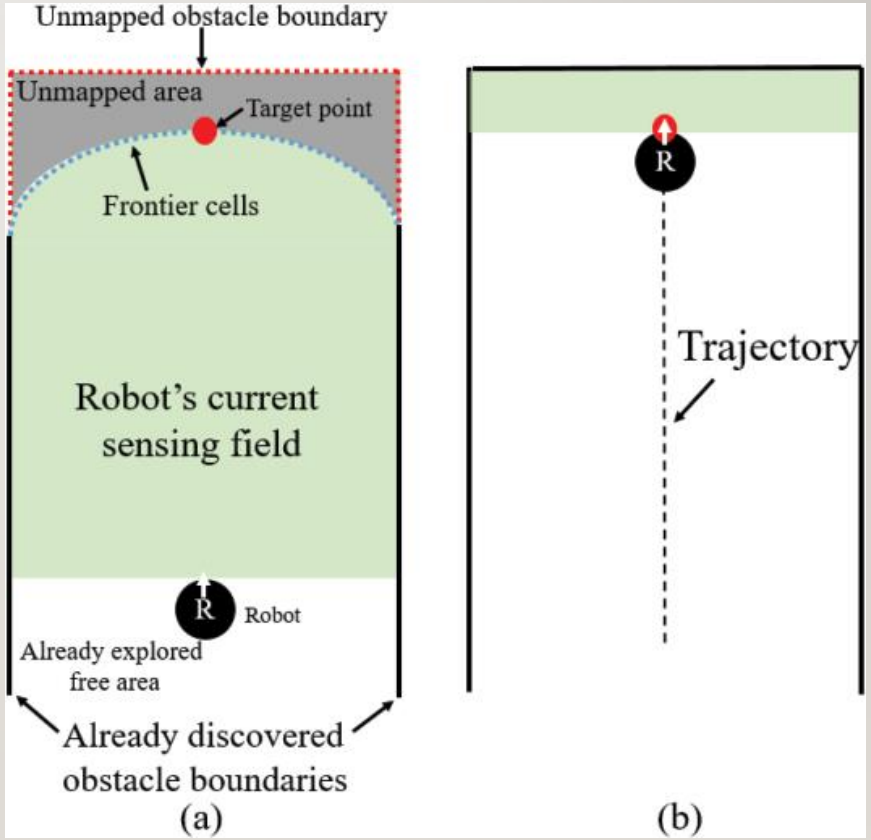
  - Free space: known, unoccupied areas
  - Occupied space: obstacles
  - Unknown space: unexplored

- Frontier Detection

The map is scanned for cells that:

  - Are free, and
  - Are adjacent to at least one unknown cell.

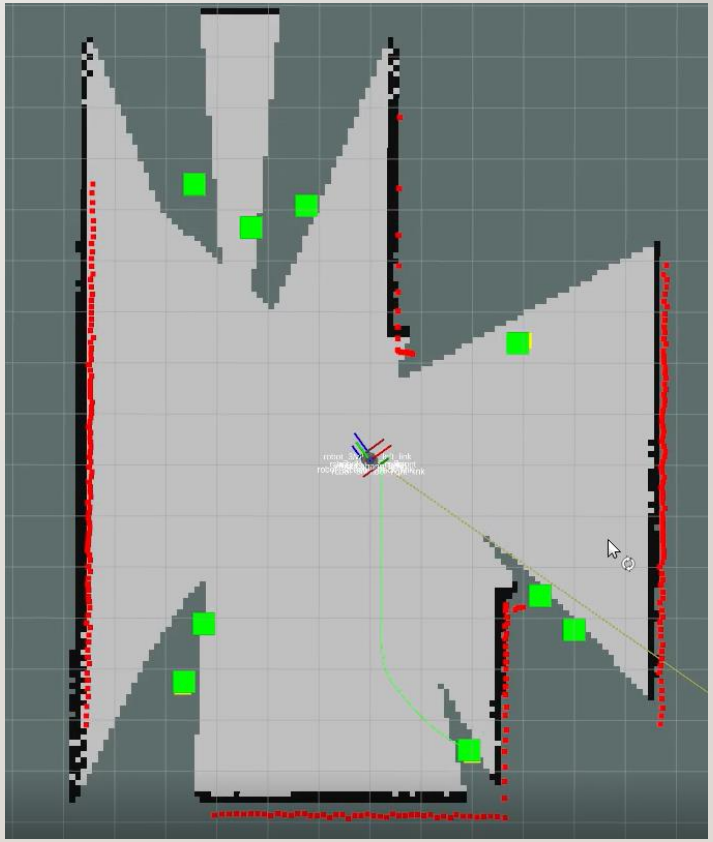
These are marked as frontier cells.



ALGORITHM DETAIL

- Frontier Grouping
  - Frontier cells are clustered into connected regions.
  - Each group represents a potential exploration target.

- Goal Selection
  - For each frontier group, a representative point (typically the centroid or closest point) is selected.
  - The robot scores each group based on:
    - Distance from the robot
    - Information gain (how much new area might be revealed)
  - The best-scoring frontier is chosen as the next goal.



ALGORITHM DETAIL

- Termination

  While (frontiers exist and reachable)

    Select best frontier

    Send as goal

    If goal fails → blacklist

  If (no frontiers or all blacklisted)

    Terminate exploration

CHECKING DIGITAL MAP (SIM)

CHECK IF CORRECT

$ xdg-open <map-path>/map.pgm

Or,

$ eog <map-path>/map.pgm

NAVIGATION W/ DIGITAL MAP (SIM)

TERM 1

- ros2 launch turtlebot4_ignition_bringup turtlebot4_ignition.launch.py nav2:=true slam:=false localization:=true rviz:=true

TUTORIAL(SIM)

- TurtleBot 4 Navigator · User Manual

  https://turtlebot.github.io/turtlebot4-user-manual/tutorials/turtlebot4_navigator.html

- Terminal 1

$ ros2 launch turtlebot4_ignition_bringup turtlebot4_ignition.launch.py nav2:=true slam:=false localization:=true rviz:=true

- Terminal 2

$ ros2 run turtlebot4_python_tutorials nav_to_pose

$ ros2 run turtlebot4_python_tutorials nav_through_poses

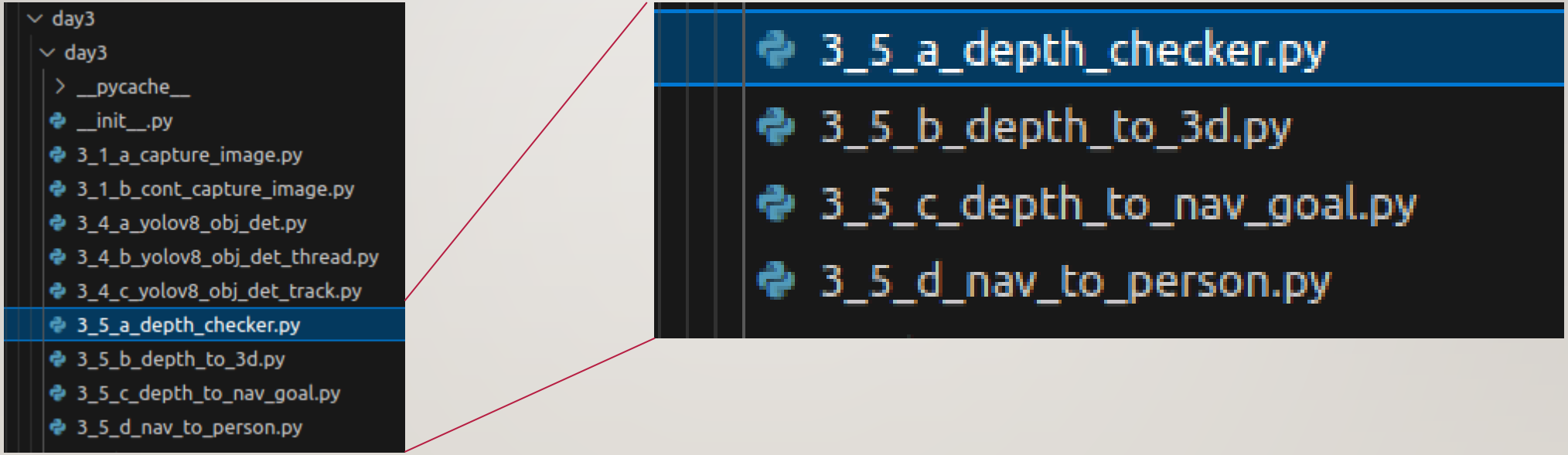
$ ros2 run turtlebot4_python_tutorials follow_waypoints

$ ros2 run turtlebot4_python_tutorials create_path

$ ros2 run turtlebot4_python_tutorials mail_delivery

$ ros2 run turtlebot4_python_tutorials patrol_loop

USING DEPTH (SIM)



TEAM EXERCISE 5

Perform coding and testing of Detection Alert Module

RESULTS & CODE REVIEW BY EACH TEAM

Show actual results against the expected results and explain the code written

PROJECT SPRINTS

- Detection Alert
  - Camera Capture
  - Object Detection
  - Send messages to other subsystems

- AMR Controller
  - Receive messages and act accordingly
  - Move using (SLAM) with Obstruction avoidance
  - Target Acquisition (Obj. Det.) and Tracking
  - Follow target using camera and motor control

- System Monitor
  - Receive and Display Detection Camera and info
  - Receive and Display AMR Camera and info
  - Store, display, and report Information and Alerts

RUNNING IN SIMULATION

SIMULATION SUMMARY

- Topics
- Sensors
- Teleops
- SLAM
- Navigation

CONTROLLING ACTUAL ROBOT

AMR INTRODUCTION

- User Manual ·Turtlebot4 User Manual
- https://turtlebot.github.io/turtlebot4-user-manual/

OBJECT TRACKING WITH AMR CAMERA

- Summary
  - Data Collection
  - PreProcessing
  - Training
  - Inferences
  - ROSify

CONTROLLING THE AMR MOVEMENT

- Teleop with keyboard
- Navigation with SLAM

UNDOCKING AND DOCKING THE ROBOT

UNDOCKING

$ ros2 action send_goal /robot<n>/undock irobot_create_msgs/action/Undock "{}"

DOCKING

$ ros2 action send_goal /robot<n>/dock irobot_create_msgs/action/Dock "{}"

DRIVING YOUR ROBOT

- Driving your TurtleBot 4 · User Manual
- https://turtlebot.github.io/turtlebot4-user-manual/tutorials/driving.html

- Undock your robot

$ ros2 run teleop_twist_keyboard teleop_twist_keyboard --ros-args -r /cmd_vel:=/robot<n>/cmd_vel

DIGITAL MAPPING (SLAM)

- Generating a map · User Manual
  https://turtlebot.github.io/turtlebot4-user-manual/tutorials/generate_map.html

DIGITAL MAPPING (SLAM)

- Undock your robot
- Terminal 1

$ ros2 launch turtlebot4_navigation slam.launch.py namespace:=/robot <n>

- Terminal 2

$ ros2 launch turtlebot4_viz view_robot.launch.py namespace:=/robot <n>

- Terminal 3

$ ros2 run teleop_twist_keyboard teleop_twist_keyboard --ros-args -r /cmd_vel:=/robot<n>/cmd_vel

- Terminal4

$ cd <map_directory>

$ ros2 run nav2_map_server map_saver_cli -f "<map_name>" --ros-args -p map_subscribe_transient_local:=true -r __ns:=/robot <n>

DIGITAL MAPPING (AUTO – SLAM)

- Undock your robot
- Terminal 1

$ ros2 launch turtlebot4_navigation slam.launch.py namespace:=/robot <n>

- Terminal 2

$ ros2 launch turtlebot4_viz view_robot.launch.py namespace:=/robot <n>

- Terminal 3

$ ros2 launch turtlebot4_navigation nav2.launch.py namespace:=robot <n>

- Terminal 4

$ ros2 launch explore_lite explore.launch.py namespace:=/robot <n>

DIGITAL MAPPING (AUTO – SLAM)

- Terminal 5

```
$ cd <map_directory>

$ ros2 run nav2_map_server
  map_saver_cli -f "<map_name>" --ros-
  args -p
  map_subscribe_transient_local:=true -r
  __ns:=/robot <n>
```

DIGITAL MAPPING

CHECK IF CORRECT

$ xdg-open <map-path>/map.pgm

Or,

$ eog <map-path>/map.pgm

NAVIGATION W/ MAP

- Navigation · User Manual
- https://turtlebot.github.io/turtlebot4-user-manual/tutorials/navigation.html

- 2D_Pose_Estimate
- Nav2_Goal

- Terminal 1
  - $ ros2 launch turtlebot4_navigation localization.launch.py namespace:=robot<n> map:=$HOME/Documents/room/room_map.yaml
- Terminal 2
  - $ ros2 launch turtlebot4_navigation nav2.launch.py namespace:=/robot <n>
- Terminal 3
  - $ ros2 launch turtlebot4_viz view_robot.launch.py namespace:=/robot <n>

TUTORIAL EXERCISE

Make copy and Update the tutorial code to successfully execute in the project environment

TUTORIAL

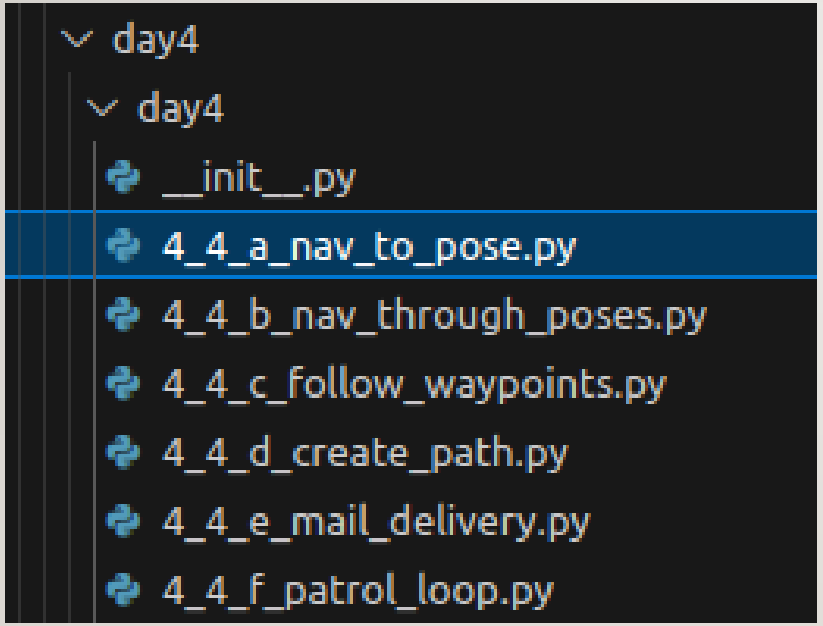
- Terminal 1
  - $ ros2 launch turtlebot4_navigation localization.launch.py namespace:=/robot<n> map:=$HOME/Documents/room/room_map.yaml
- Terminal 2
  - $ ros2 launch turtlebot4_navigation nav2.launch.py namespace:=/robot <n>
- Terminal 3
  - $ ros2 launch turtlebot4_viz view_robot.launch.py namespace:=/robot <n>

SIMPLE NAV2 PARAM ADJUSTMENT

- cd ~/turtlebot4_ws/src/turtlebot4/turtlebot4_navigation/config

- Change/adjust “inflation_radius” to fit your environment

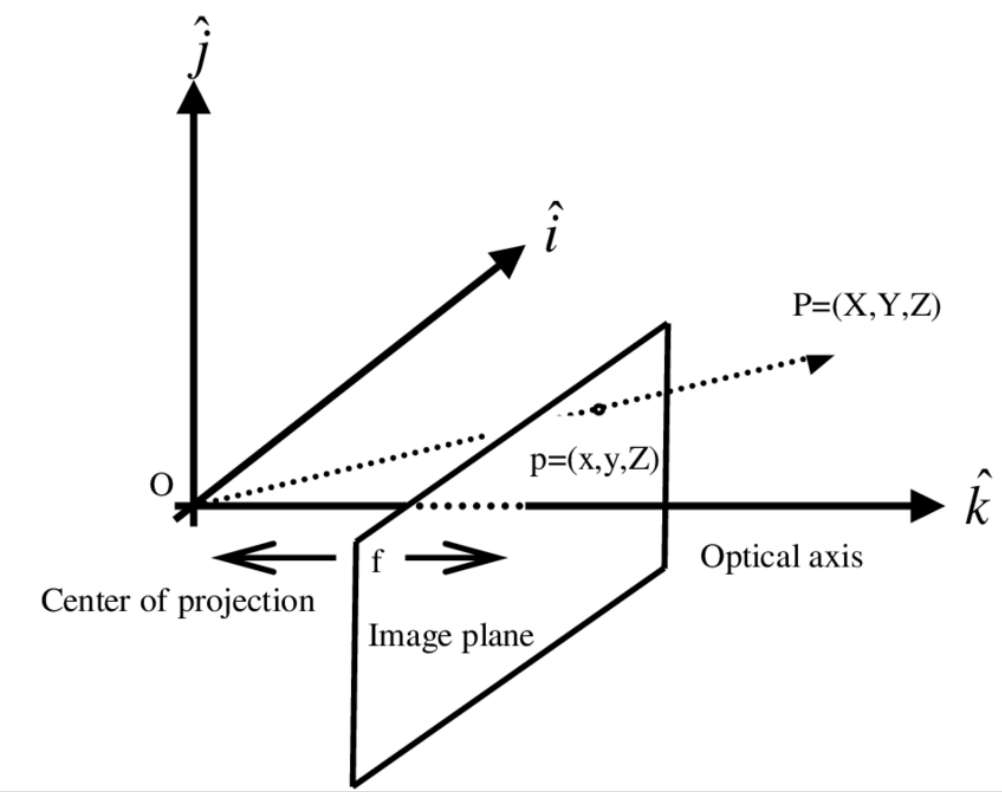
TUTORIAL



- Terminal 4
  - $ ros2 run day4 create_path --ros-args -r __ns:=/robot<n>
  - $ ros2 run day4 nav_to_poses --ros-args -r __ns:=/robot<n>
  - $ ros2 run day4 follow_waypoints --ros-args -r __ns:=/robot<n>
  - $ ros2 run day4 nav_through_poses --ros-args -r __ns:=/robot<n>
  - $ ros2 run day4 mail_delivery --ros-args -r __ns:=/robot<n>
  - $ ros2 run day4 patrol_loop --ros-args -r __ns:=/robot<n>

USING DEPTH

CAMERA INTRINSIC AND REPROJECTION



$$X = \frac{(u - c_x) \cdot Z}{f_x}, \quad Y = \frac{(v - c_y) \cdot Z}{f_y}, \quad Z = Z$$

USING DEPTH (ROBOT)

ON TURTLEBOT4:

$ cd /opt/ros/humble/share/turtlebot4_bringup/config

$ sudo cp oakd_pro.yaml oakd_pro_orig.yaml

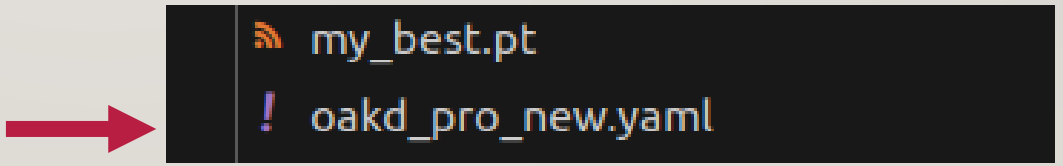
$ sudo cp oakd_pro_new.yaml oakd_pro.yaml

$ sudo reboot

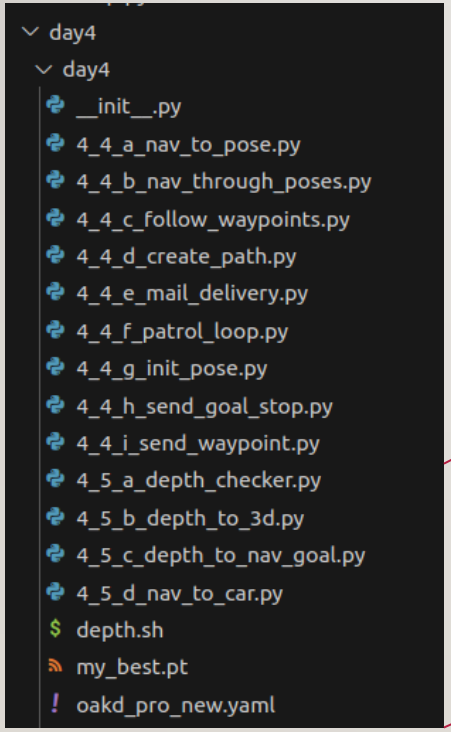
$ sudo systemctl status turtlebot4.service

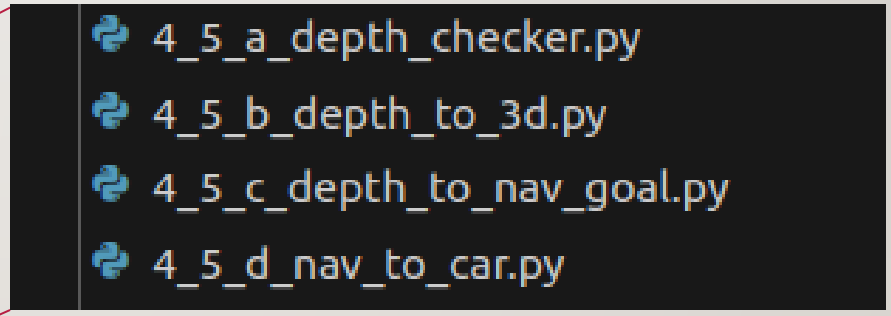
$ sudo systemctl restart turtlebot4.service

$ ros2 topic list



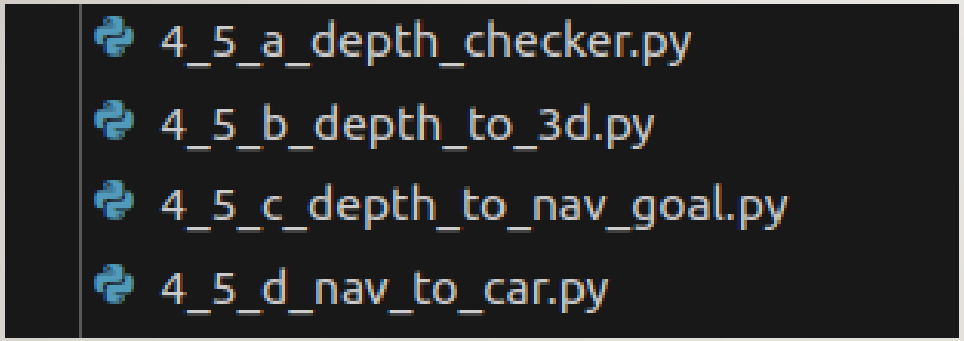
USING DEPTH (ROBOT)





Exercise: using the simulation code develop the code for the actual robot

USING DEPTH (ROBOT)



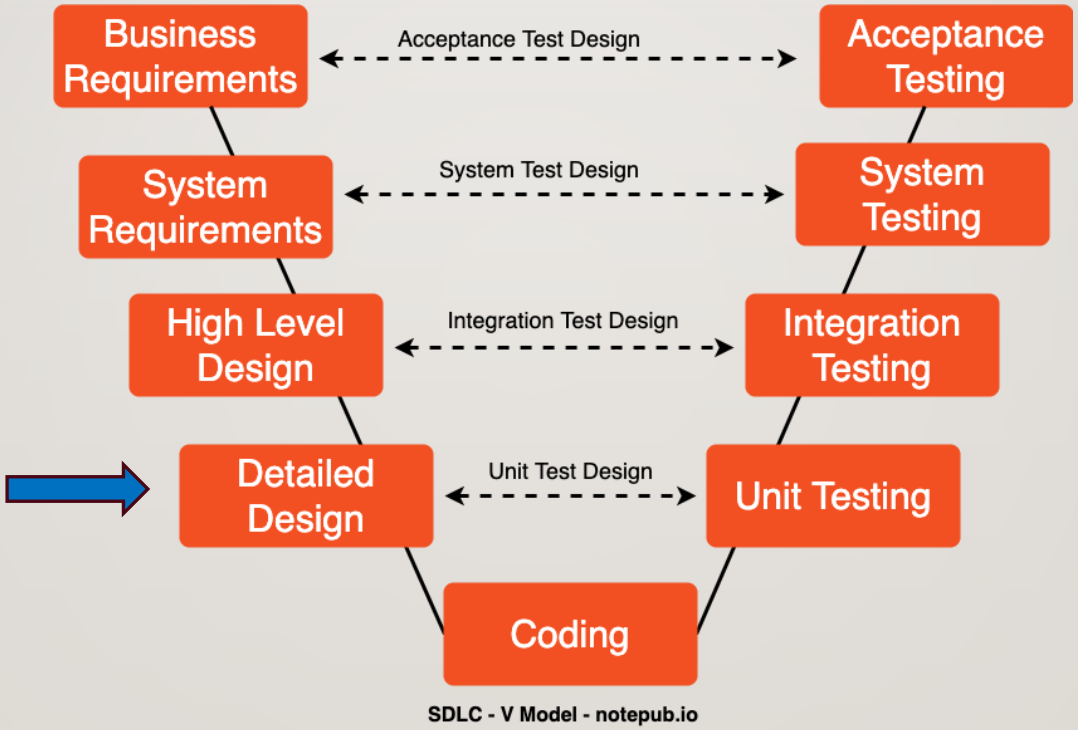
$ ros2 run day4 depth_checker --ros-args -r __ns:=/robot<n>

$ ros2 run day4 depth_to_3d --ros-args -r __ns:=/robot<n> -r /tf:=/robot<n>/tf –r /tf_static:=/robot<n>/tf_static

$ ros2 run day4 depth_to_goal --ros-args -r __ns:=/robot<n> -r /tf:=/robot<n>/tf –r /tf_static:=/robot<n>/tf_static

AMR CONTROLLER SPRINT

SPRINT 2 – AMR CONTROLLER



TEAM EXERCISE 6

Perform Detail Design of AMR Controller Module using Process Flow Diagram

DESIGN QUESTIONS:

- How do you start the robot?
  - Initial Position
- How do you find AMR current position and orientation?
- How do you sending Goals?
  - Single goal
  - Multiple goals
- How do you manual control of AMR Odometry?
  - How to move forward, backward, left and right???

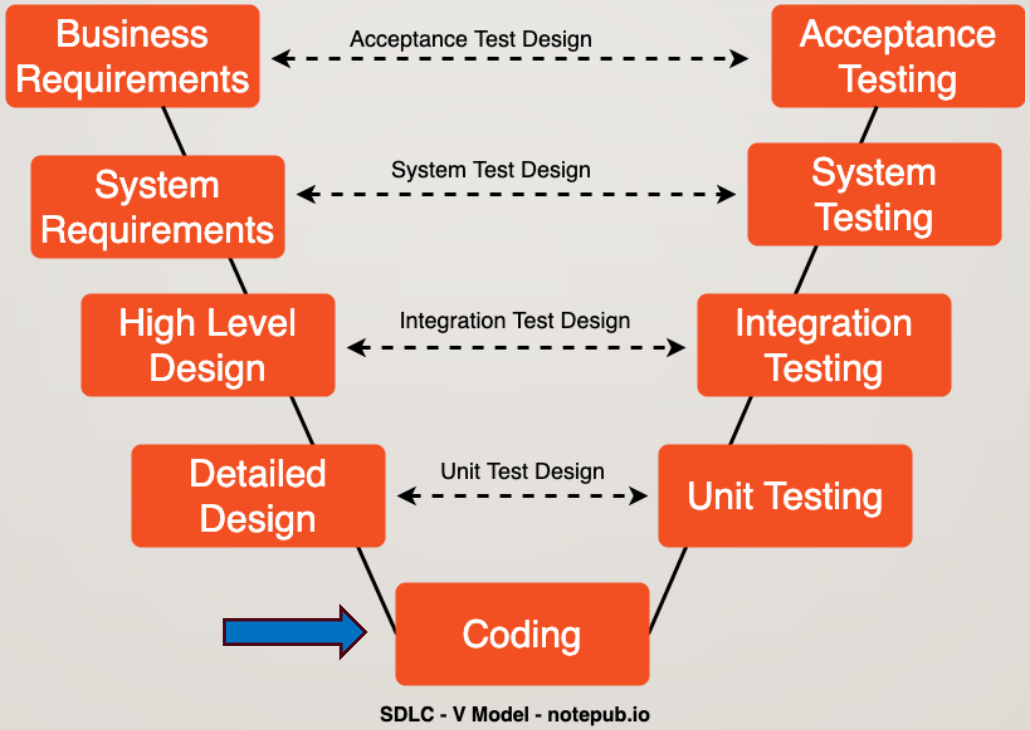
WHAT IS THE FOLLOW ALGORITHM?

- Left/Right?
- Forward/Backward?
- Velocity?
- Camera position?
- Depth? Local/Global Coordinate transform?

DETAIL DESIGN REVIEW BY EACH TEAM

Using the process flow diagram present team's design

SPRINT 2 – AMR CONTROLLER



DESIGN HINTS:

- How do you start the robot?

```
# Start on dock
if not navigator.getDockedStatus():
    navigator.info('Docking before intialising pose')
    navigator.dock()

# Set initial pose
initial_pose = navigator.getPoseStamped([0.0, 0.0], TurtleBot4Directions.NORTH)
navigator.setInitialPose(initial_pose)
```

DESIGN HINTS:

- How do you find AMR current position and orientation?
  - Echo topic: amcl_pose
  - Use Rviz Publish Points & Echo clicked_points
  - Etc…

DESIGN HINTS:

- How do you sending Goals?
  - Single goal

```
# Wait for Nav2
navigator.waitUntilNav2Active()
```

```
    # Set goal poses
    # goal_pose = navigator.getPoseStamped([-13.0, 9.0], TurtleBot4Directions.EAST)
    goal_pose = navigator.getPoseStamped([-1.7, -0.1], TurtleBot4Directions.EAST)

#   x: 2.0924954414367676
#   y: 4.481560230255127
# [x,y]=[-1.707,-0.106]

    # Undock
    navigator.undock()

    # Go to each goal pose
    navigator.startToPose(goal_pose)
```

DESIGN HINTS:

- How do you sending Goals?
  - Single goal
  - Multiple goals

```
# Set goal poses
goal_pose = []
goal_pose.append(navigator.getPoseStamped([-1.7, -0.1], TurtleBot4Directions.EAST))
goal_pose.append(navigator.getPoseStamped([-1.1, 1.6], TurtleBot4Directions.NORTH))
goal_pose.append(navigator.getPoseStamped([-1.0, 0.05], TurtleBot4Directions.NORTH_WEST))
```

```
# Undock
navigator.undock()

# Navigate through poses
navigator.startThroughPoses(goal_pose)
```

```
# Follow Waypoints
navigator.startFollowWaypoints(goal_pose)
```

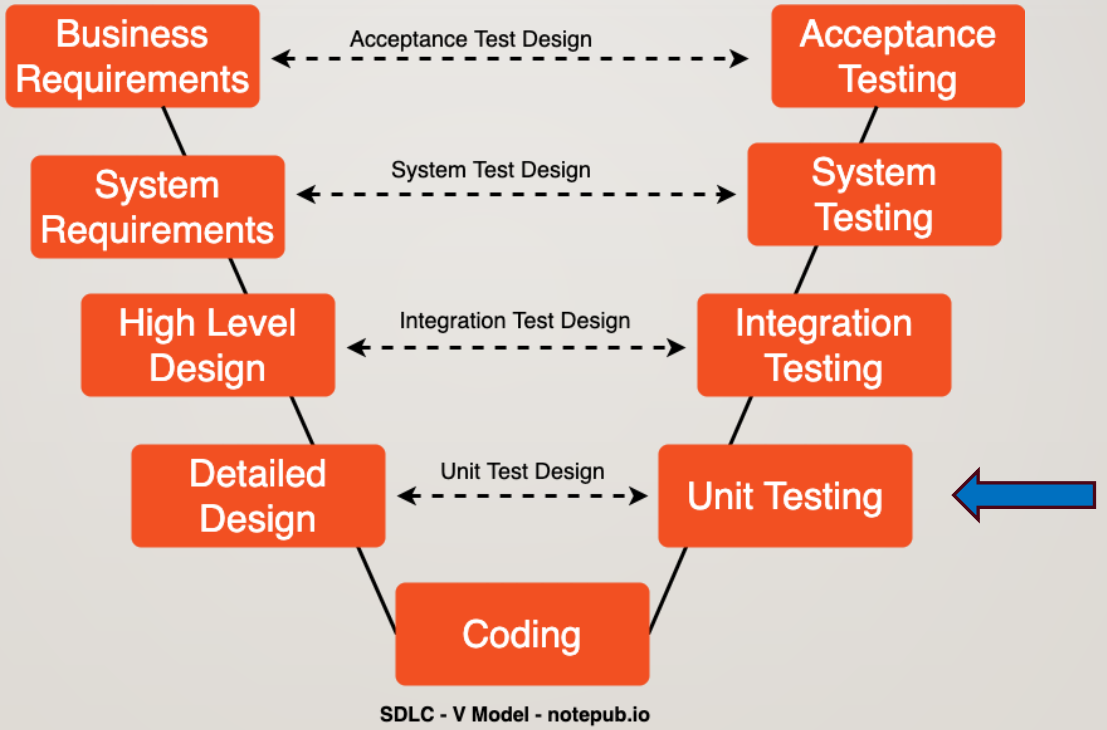
DESIGN HINTS:

- How do you manual control of AMR Odometry?
  - How to move forward, backward, left and right???
- Use teleops to move the robots
  - Echo topic: cmd_vel
- geometry_msgs.msg
  - Twist
    - twist.linear.x = <+/-n>
    - twist.angular.z = <+/-n>
  - self.cmd_publisher.publish(twist)

EXPECTED OUTCOME

AMR navigates to avoid obstacles, ignores dummies, track, and follow target

SPRINT 2 – AMR CONTROLLER



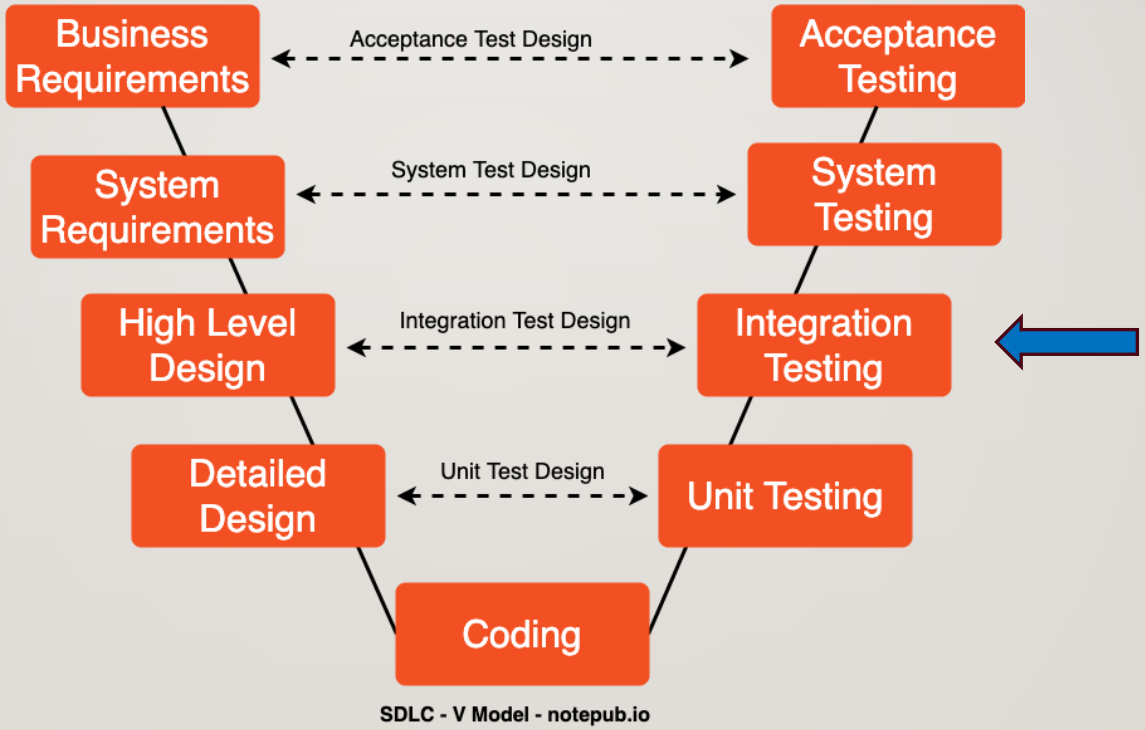
TEAM EXERCISE 7

Perform coding and testing of AMR Controller Module

RESULTS & CODE REVIEW BY EACH TEAM

Show actual results against the expected results and explain the code generated

SPRINT 1&2 – DETECTION ALERT/AMR CONTROLLER INTEGRATION & TEST



EXPECTED OUTCOME

- Detection Alert and AMR Controller able to pass topics for necessary actions between

TEAM EXERCISE 8

Perform integrate and test of Detection Alert and AMR Controller Modules

RESULTS & CODE REVIEW BY EACH TEAM

Show actual results against the expected results and explain the code written

프로젝트 RULE NUMBER ONE!!!

Are we still having FUN!