GOOD MORNING!
早上好!
안녕하세요!

DAY 3

DAY 1

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

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

DAY 2 (MINI PROJECT)

WEB-CAM 기반 객체 인식 (IF NEEDED)

- YOLOv8 기반 데이터 수집/학습/deploy (Detection Alert)
  - 감시용 데이터 수집(rc_car, dummy, 등)
  - 감시용 데이터 라벨링
  - YOLOv8 기반 학습
  - YOLOv8 Object Detection

AMR-CAM 기반 객체 인식

- 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((rc_car, dummy, 등)
  - Tracking 데이터 라벨링
  - YOLOv8 기반 학습
  - YOLOv8 Object Tracking

DAY 3 (MINI PROJECT)

- Auto. Driving 시스템 학습
  - Digital Mapping of environment
  - Operate AMR (Sim. & Real)
  - Tutorial 실행
  - Detection, Depth and AMR 주행
  - 로봇 개발 환경에 적용 및 테스트 / 로봇 H/W, 제반 환경의 한계점 도출

TURTLEBOT4 시뮬레이션

- 환경 구축
- SLAM과 AutoSLAM으로 맵 생성
- Sim. Tutorial 실행
- Detection, Depth and AMR 주행 example

DAY 3 (MINI PROJECT)

REAL ROBOT

- Manually operating the AMR (Teleops)
- autonomous driving 시스템 with obstacle avoidance
  - Digital Mapping of environment
  - Launching Localization, Nav2, and using Rviz to operate a robot
  - Goal Setting and Obstacle Avoidance using Navigation

TUTORIAL

- Turtlebot4 API를 활용한 Initial Pose Navigate_to Pose 구현
- Turtlebot4 API를 활용한 Navigate_Through_pose, Follow Waypoints 구현

DAY 4

- Business Requirement Development
- System Requirement Development
- Time Management
- System(High Level) Design
- Begin Detail Design to Acceptance - Agile Development (SPRINTs)

DAY 4 (MINI PROJECT)

SYSTEM DESIGN

- Mini Project

DETAIL DESIGN

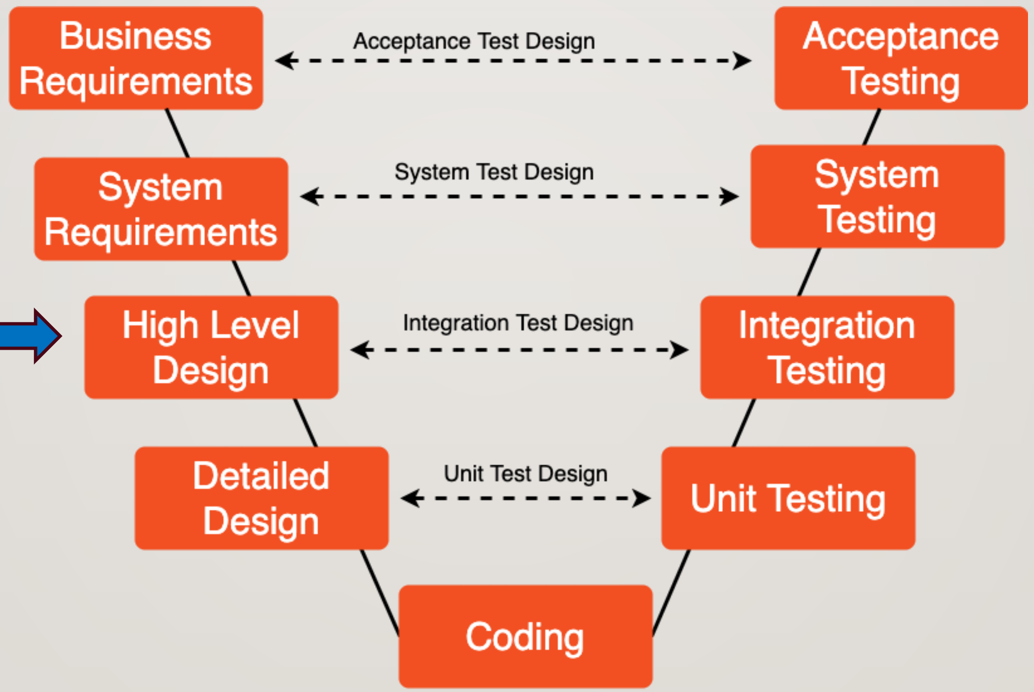
- Detection
- AMR Control

프로젝트 RULE NUMBER ONE!!!

Have Fun Fun Fun!

SW DEVELOPMENT PROCESS

HOW:
Where, What,
When, How Much



SDLC - V Model - notepub.io

EXAMPLE SYSTEM DESIGN DOCUMENT

System Design Document (SDD)

Project Title: Autonomous Mobile Robot (AMR) Security System
Version: 1.1
Date: [Insert Date]

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1. Overview

The Autonomous Mobile Robot (AMR) Security System is designed to provide autonomous patrolling, threat detection, and alerting within a secure area using a single AI-enabled robot. The system consists of one AMR equipped with necessary hardware and software components to operate independently, processing data on-board without the need for a central server.

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2. System Architecture

Since the system consists of a single AMR, data processing, navigation, threat detection, and alerting are all performed locally on the AMR itself. The AMR communicates directly with a user interface on a PC via a local network (Wi-Fi) for monitoring, alerts, and manual override if required.

시스템 설계 문서 (SDD)

프로젝트 제목: 자율 이동 로봇(AMR) 보안 시스템
버전: 1.1
날짜: [날짜 삽입]

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1. 개요

자율 이동 로봇(AMR) 보안 시스템은 단일 AI 기반 로봇을 사용하여 보안 구역 내에서 자율 순찰, 위협 탐지 및 경고를 제공하도록 설계되었습니다. 시스템은 단일 AMR 이 독립적으로 작동할 수 있도록 필요한 하드웨어 및 소프트웨어 구성 요소로 구성되며, 중앙 서버 없이 데이터를 현장에서 처리합니다.

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2. 시스템 아키텍처

이 시스템은 단일 AMR 으로 구성되므로 데이터 처리, 네비게이션, 위협 탐지 및 경고가 모두 AMR 에서 로컬로 수행됩니다. AMR 은 모니터링, 알림 및 수동 제어를 위해 PC 의 사용자 인터페이스와 로컬 네트워크(Wi-Fi)를 통해 직접 통신합니다.

KEY SUBSYSTEM (MODULES) TO DEVELOP

- 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

VISUALIZATION – SYSTEM FUNCTIONAL PROCESS FLOW DIAGRAMS

- To-Be Functional Process Flow Diagram

  Detection Alert

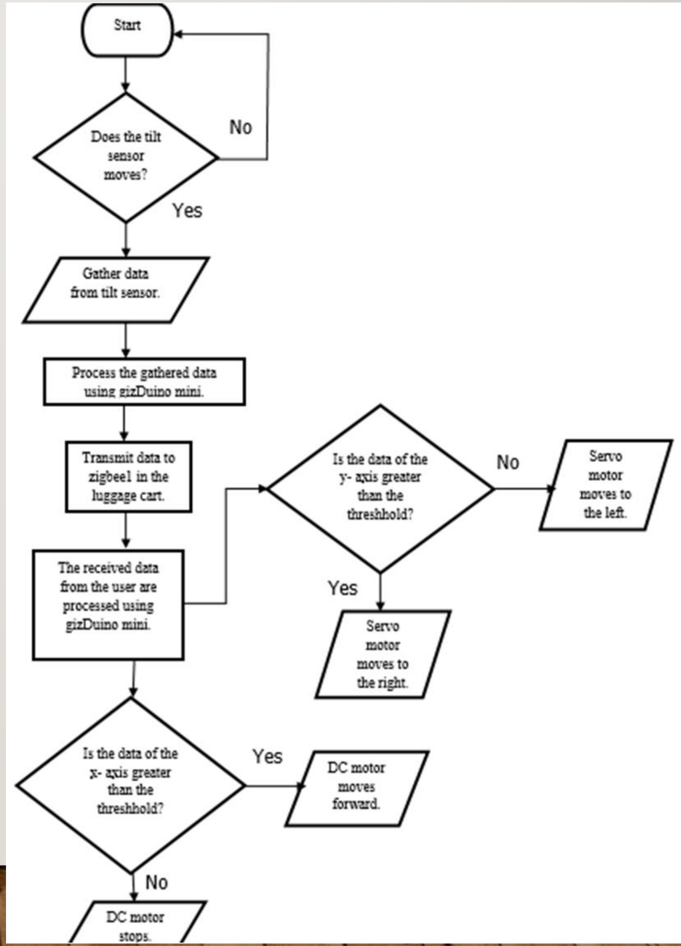
  AMR Controller

- Functions
- Interfaces

  Dataflow

- Testing

  Error and Exception Handling



EXERCISE:

Present your detection design using the functional process flow diagram

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

RUNNING IN SIMULATION

SETUP BASH

- Make sure bashrc has:
  - ROS_DOMAIN_ID = 0
- Make sure discovery setup.bash is **not** sourced!
- source ~/.bashrc

OPERATING A ROBOT(SIM) – GAZEBO

TERM1

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

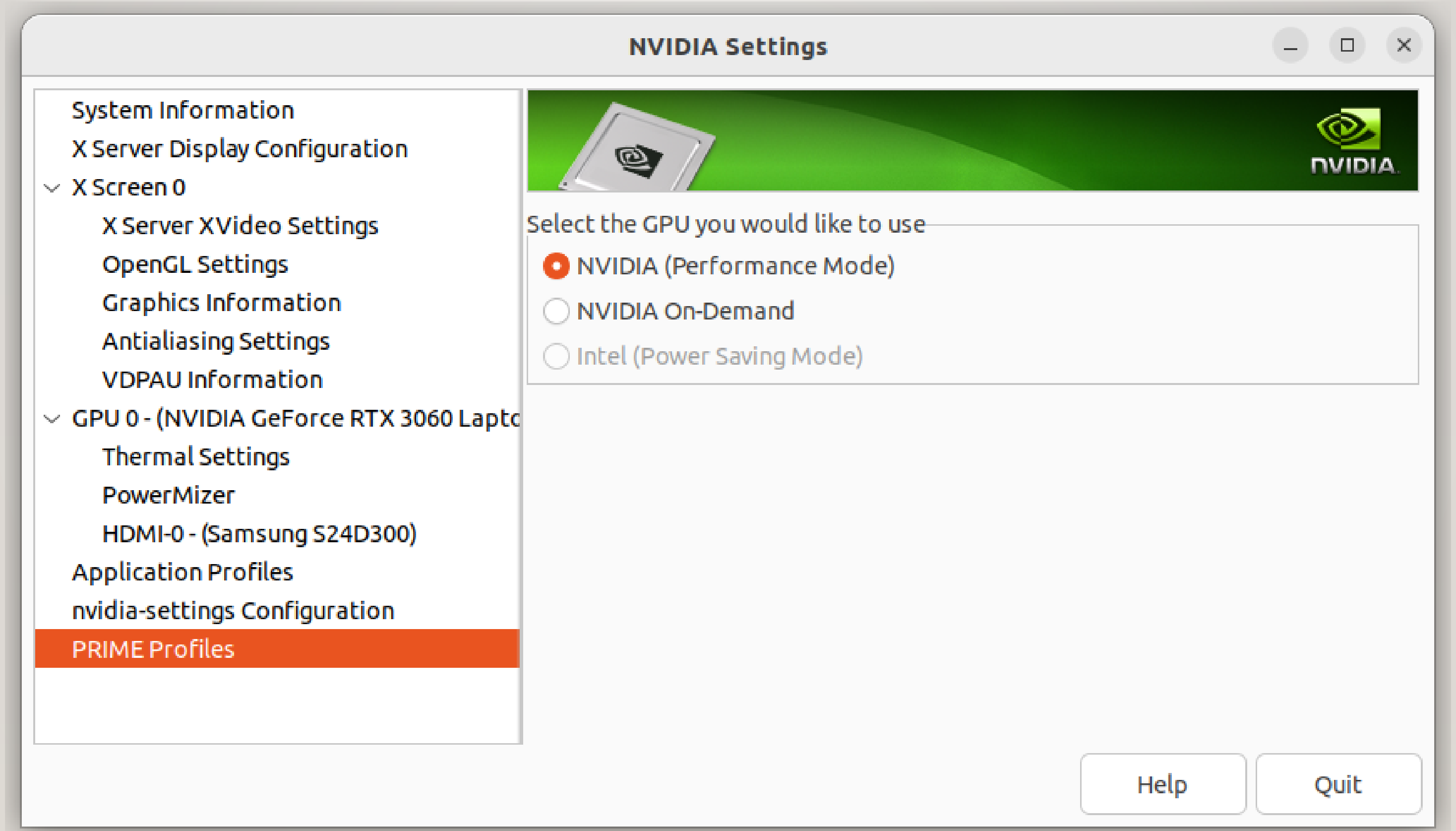
TERM2

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

OPERATING A ROBOT(SIM)

- Dock/Undock
- Manual Driving
  - Teleops
- Camera Display
  - RGB/Depth
- Navigation with rviz
  - 2D_Pose_Estimate (initial position)
  - Nav2_Goal

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**

ON GAZEBO

- Undock the robot
- Use keyboard to operate and complete the map

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)

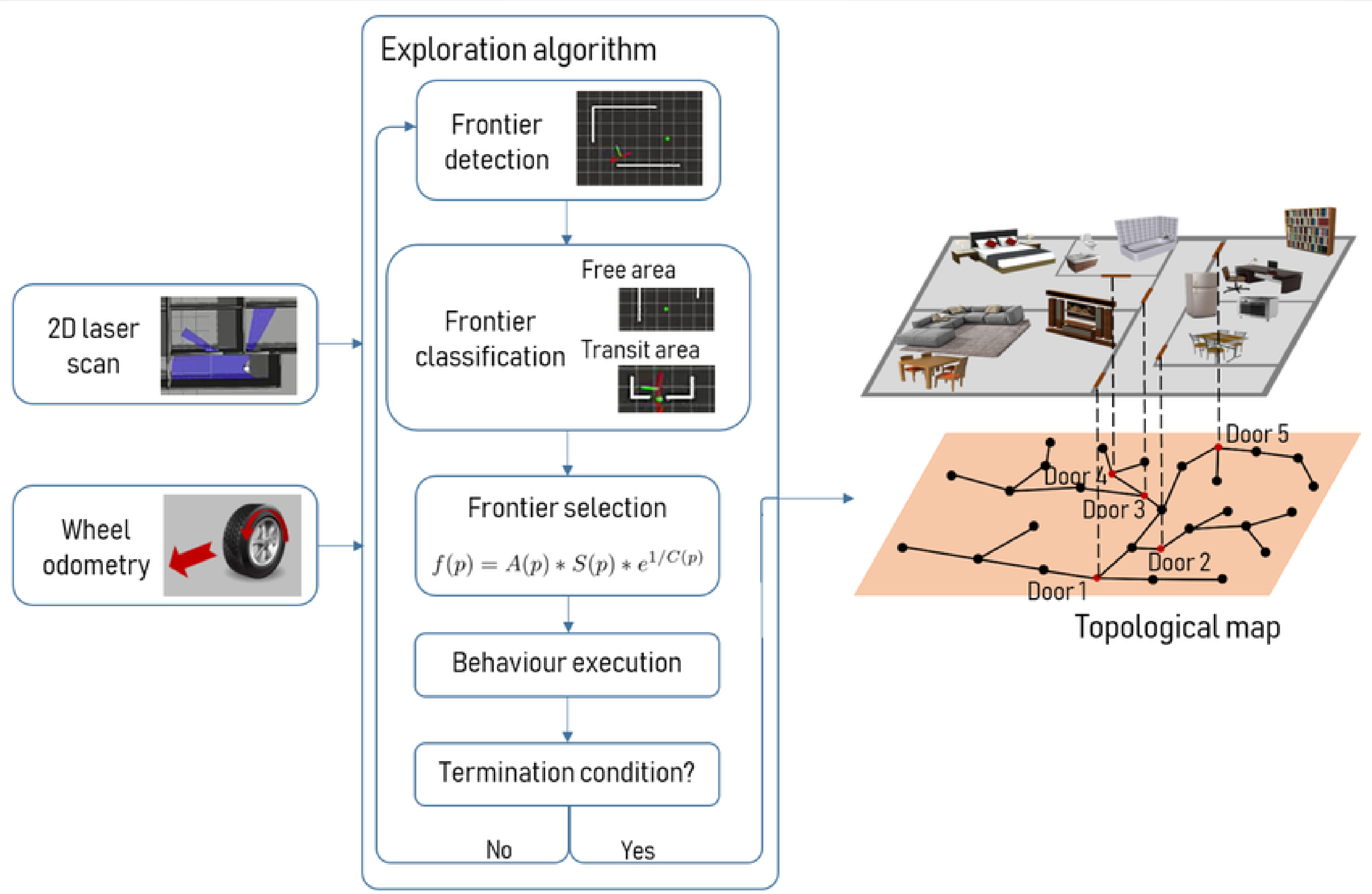
TERM1

- ros2 launch turtlebot4_ignition_bringup turtlebot4_ignition.launch.py **nav2:=true slam:=true rviz:=true**
- Undock the robot
- Set init pose from rviz

TERM2

- ros2 launch explore_lite explore.launch.py

AUTO SLAM CONCEPT/ALGORITHM



ALGORITHM DETAIL

- Map Subscription

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

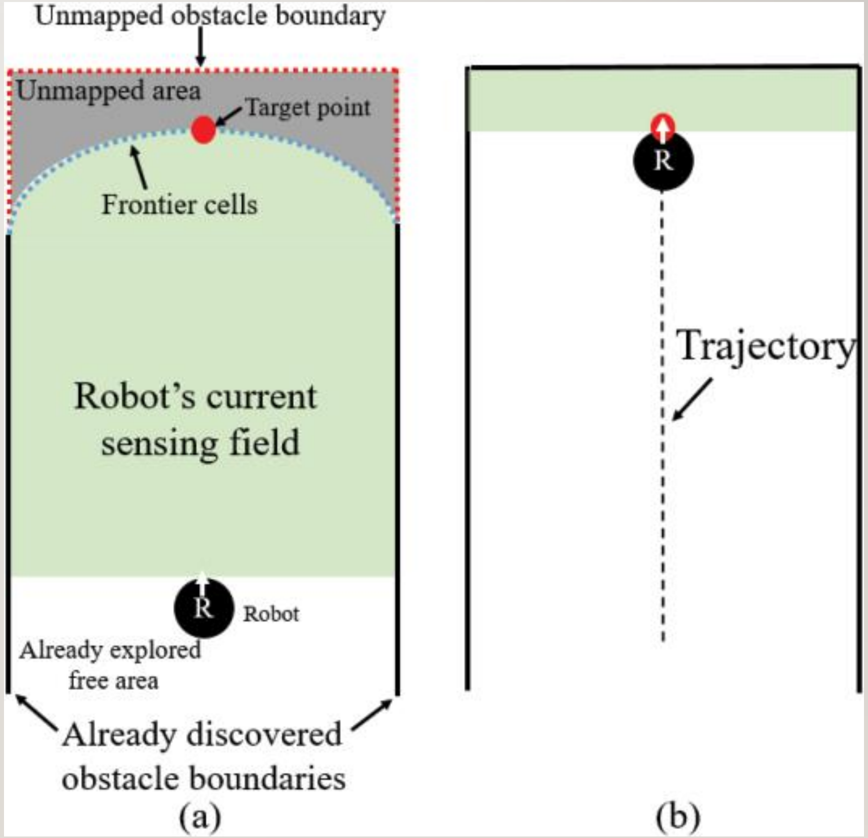
  - Free space: known, unoccupied areas
  - Occupied space: obstacles
  - Unknown space: unexplored

- Frontier Detection

The map is scanned for cells that:

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

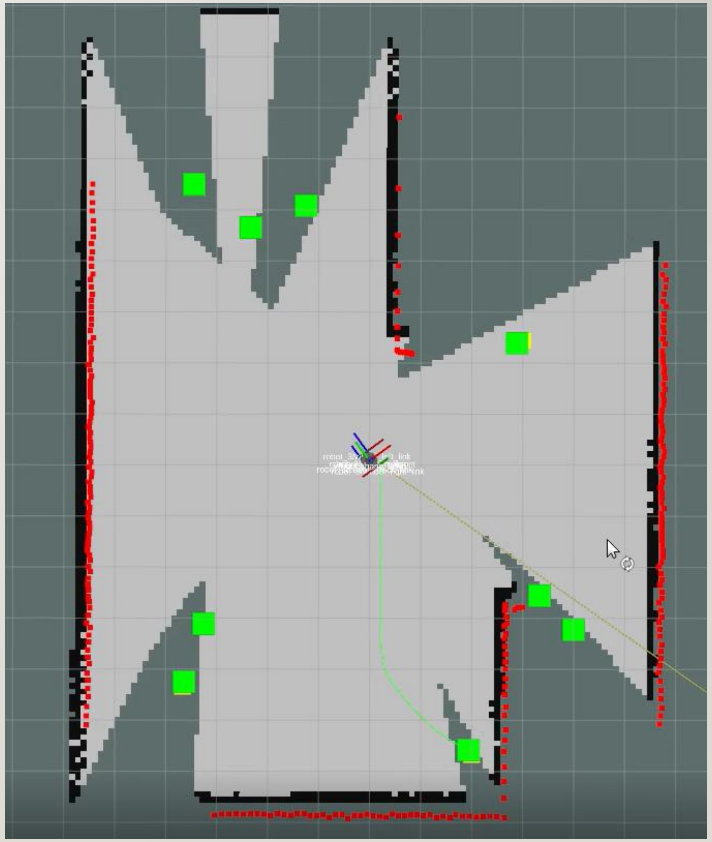
These are marked as frontier cells.



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

DIGITAL MAPPING WITH AUTO – SLAM (SIM)

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'"

CHECKING DIGITAL MAP (SIM)

CHECK IF CORRECT

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

Or,

$ eog <map-path>/map.pgm

TUTORIAL(SIM)

- TurtleBot 4 Navigator · User Manual

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

TUTORIAL(SIM)

TERMINAL 1

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

- Undock and set init pose

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

OPERATING THE REAL ROBOT

SETUP BASH

- Make sure bashrc has:
  - ROS_DOMAIN_ID = 0
- echo “alias **ros-restart**=‘ros2 daemon stop; ros2 daemon start’" >> ~/.bashrc
- Make sure discovery setup.bash **is** sourced!
- source ~/.bashrc

CONTROLLING THE AMR MOVEMENT

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

- Navigation with SLAM

UNDOCKING AND DOCKING THE ROBOT

TERMINAL 1

- Undocking

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

TERMINAL 1

- Docking

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

DRIVING YOUR ROBOT

TERMINAL 2

$ 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 (MANUAL 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>**

- Undock and set init pose

TERMINAL 3

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

DIGITAL MAPPING (MANUAL SLAM)

- 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

TERMINAL 4

$ 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>**

- Undock and set init pose

TERMINAL 3

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

$ **ros-restart** #execute if fails/as needed

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>

NAVIGATION W/ MAP

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

TERMINAL 1

$ ros2 launch turtlebot4_navigation localization.launch.py namespace:=robot<n> map:=$HOME/Documents/room/room_map.yaml

TERMINAL 2

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

- Undock and set init pose

TERMINAL 3

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

$ **ros-restart** #execute if fails/as needed

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_viz view_robot.launch.py namespace:=/robot <n>

- Undock and set init pose

TERMINAL 3

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

SIMPLE NAV2 PARAM ADJUSTMENT

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

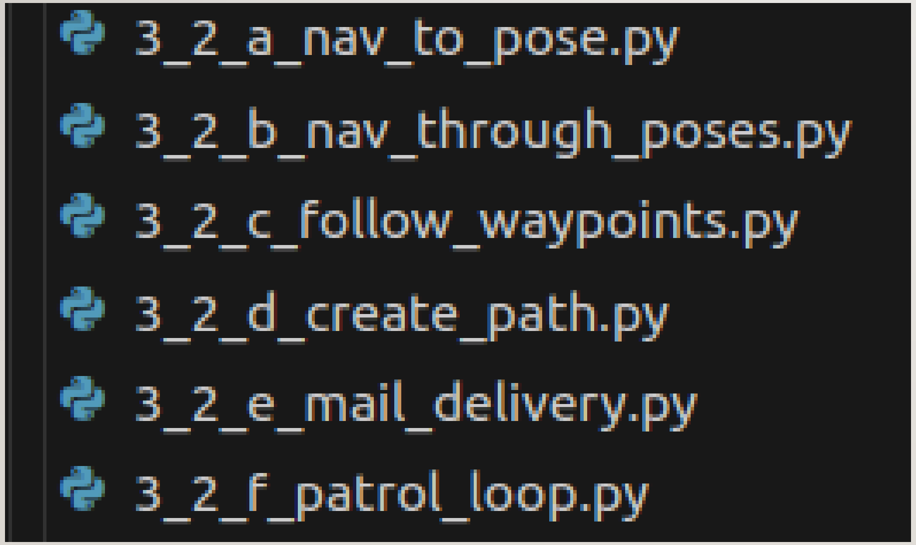
- Change/adjust "inflation_radius" to fit your environment

```
local_costmap:
  local_costmap:
    ros__parameters:
      update_frequency: 5.0
      publish_frequency: 2.0
      global_frame: odom
      robot_base_frame: base_link
      use_sim_time: True
      rolling_window: true
      width: 3
      height: 3
      resolution: 0.06
      robot_radius: 0.175
      plugins: ["static_layer", "voxel_layer", "infl
      inflation_layer:
        plugin: "nav2_costmap_2d::InflationLayer"
        cost_scaling_factor: 4.0

        #inflation_radius: 0.45
        inflation_radius: 0.25
        #changed by aak

      voxel_layer:
        plugin: "nav2_costmap_2d::VoxelLayer"
        enabled: True
```

TUTORIAL

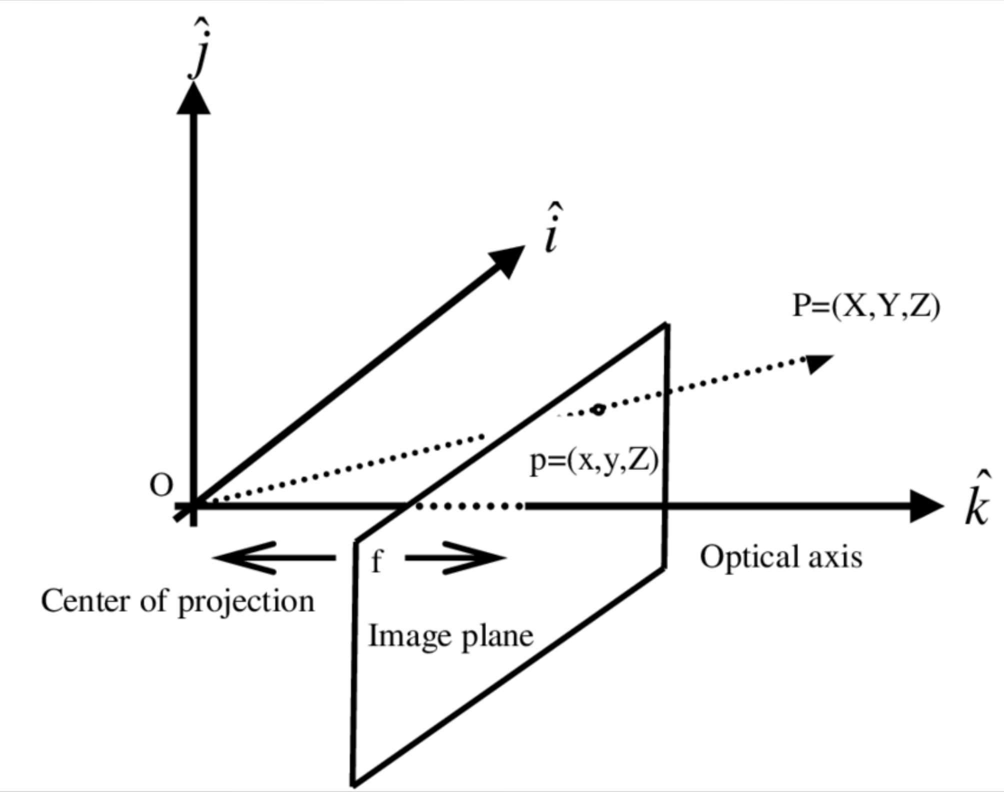


TERMINAL 4

- $ ros2 run day3 create_path --ros-args -r __ns:=/robot<n>
- $ ros2 run day3 nav_to_poses --ros-args -r __ns:=/robot<n>
- $ ros2 run day3 follow_waypoints --ros-args -r __ns:=/robot<n>
- $ ros2 run day3 nav_through_poses --ros-args -r __ns:=/robot<n>
- $ ros2 run day3 mail_delivery --ros-args -r __ns:=/robot<n>
- $ ros2 run day3 patrol_loop --ros-args -r __ns:=/robot<n>

USING DEPTH

CAMERA INTRINSIC AND REPROJECTION

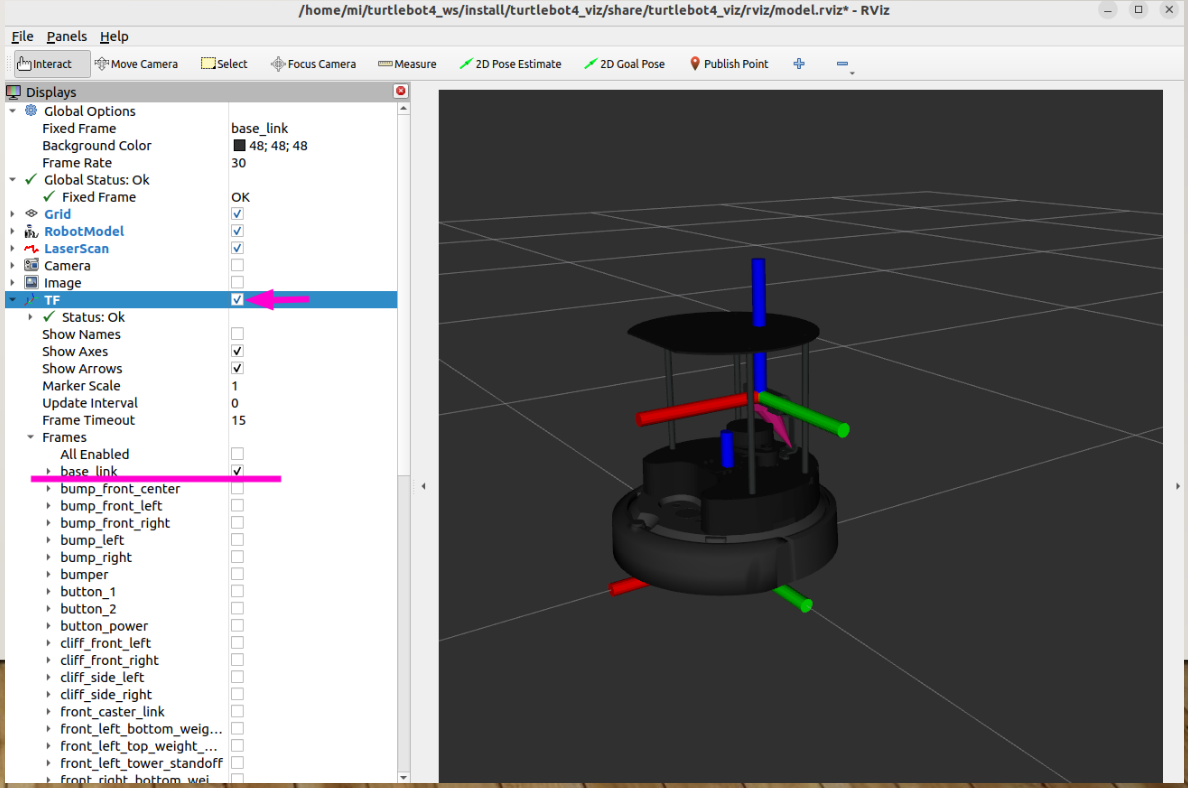


$$X = \frac{(u - c_x) \cdot Z}{f_x}, \quad Y = \frac{(v - c_y) \cdot Z}{f_y}, \quad Z = Z$$

ROS TRANSFORM EXPLAINED

- Transform Explained

  https://indecisive-freedom-6e8.notion.site/Transform-Explained-1f38e215779c803ba95df4921332d670

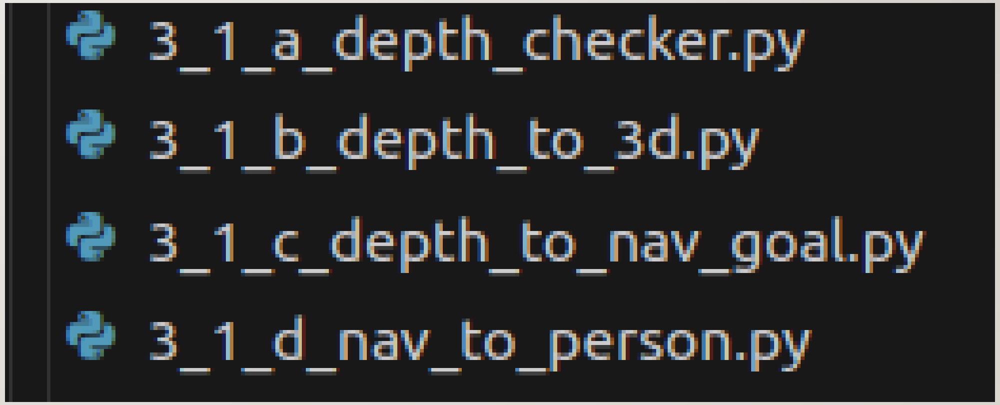


USING DEPTH (SIM)

TERMINAL 1

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

TERMINAL 2



*create a necessary ROS2 package and run

SETUP BASH(SIM)

- Make sure bashrc has:
  - ROS_DOMAIN_ID = 0

- Make sure discovery setup.bash is **not** sourced!

- source ~/.bashrc

SETUP BASH(ROBOT)

- Make sure bashrc has:
  - ROS_DOMAIN_ID = 0

- Make sure discovery setup.bash **is** sourced!

- source ~/.bashrc

USING DEPTH (ROBOT)

TERMINAL 1

$ ros2 launch turtlebot4_navigation localization.launch.py namespace:=/robot<n> map:=$HOME/Documents/room/room_map.yaml

TERMINAL 2

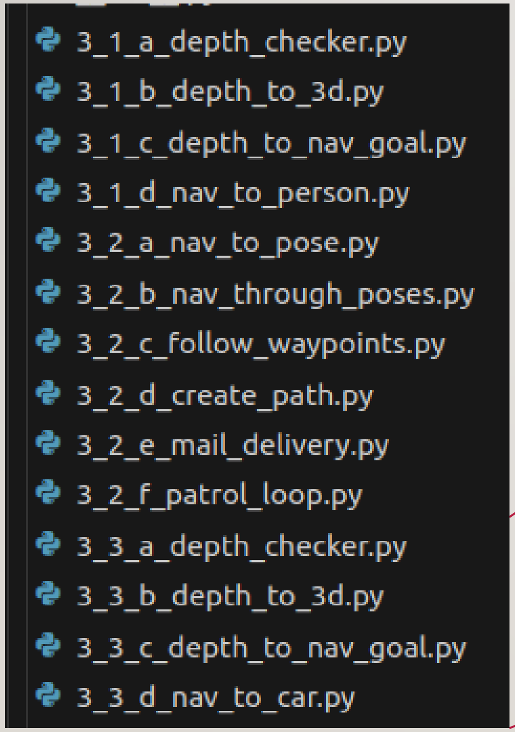
$ ros2 launch turtlebot4_viz view_robot.launch.py namespace:=/robot <n>

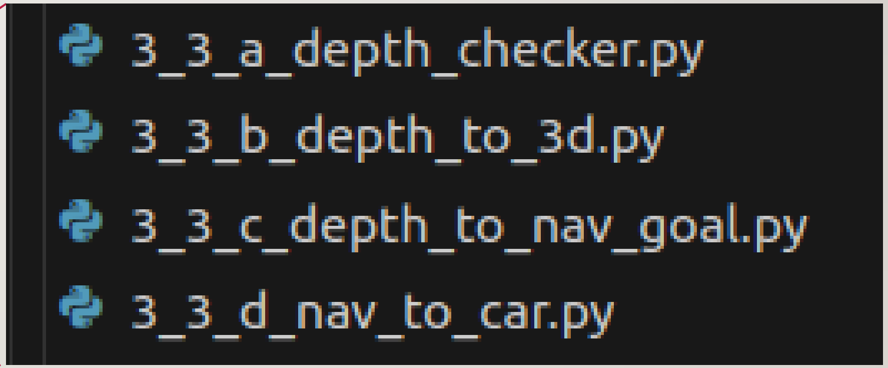
- Set Init Pose using 2D_PoseEstimate

TERMINAL 3

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

USING DEPTH (ROBOT)





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

USING DEPTH (ROBOT)

- 3_3_a_depth_checker.py
- 3_3_b_depth_to_3d.py
- 3_3_c_depth_to_nav_goal.py
- 3_3_d_nav_to_car.py

$ 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**

프로젝트 RULE NUMBER ONE!!!

Are we still having FUN!