

GOOD MORNING!

早上好!

안녕하세요!

DAY 3



DAY I

- 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

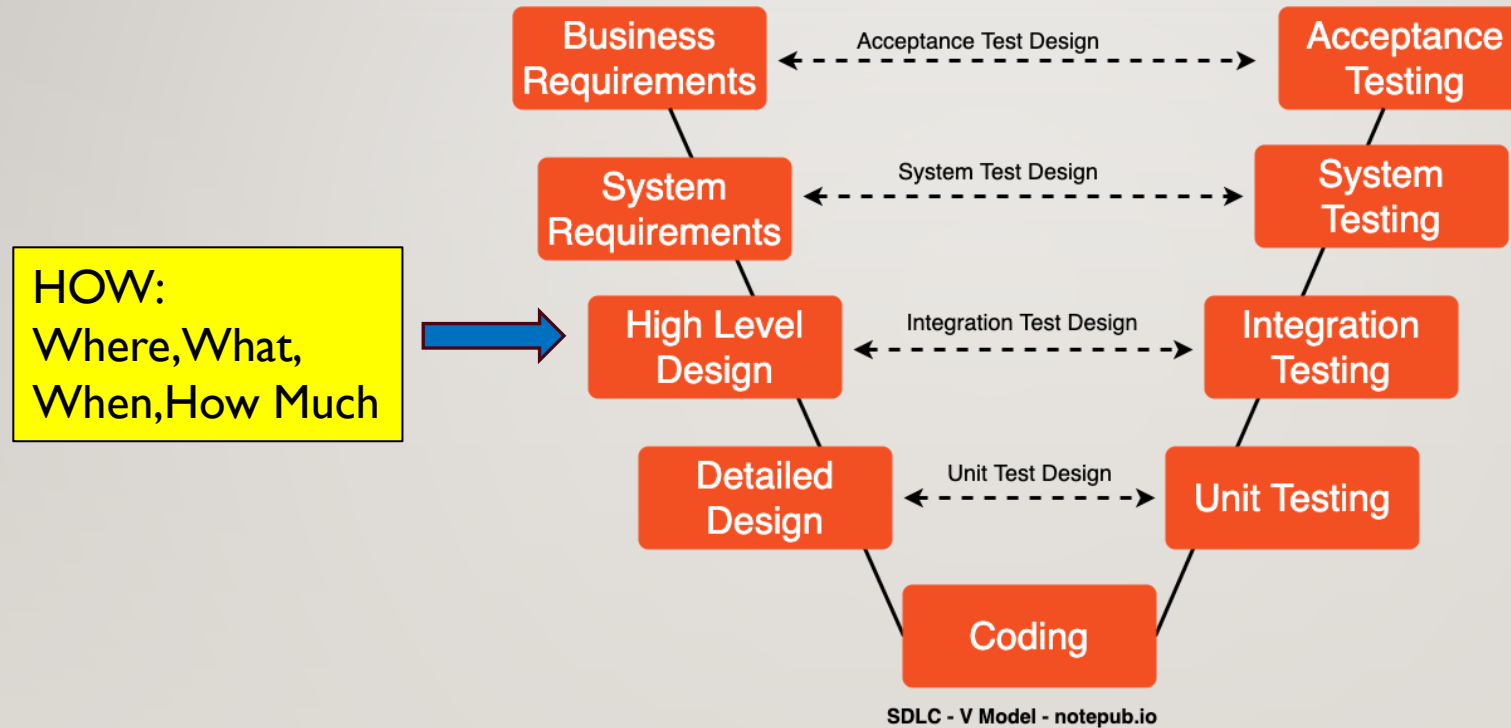
- Detection
- AMR Control

프로젝트 RULE NUMBER ONE!!!

Have Fun Fun Fun!



SW DEVELOPMENT PROCESS



EXAMPLE SYSTEM DESIGN DOCUMENT

System Design Document (SDD)❧

Project Title: Autonomous Mobile Robot (AMR) Security System↓

Version: 1.1↓

Date: [Insert Date]❧

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.❧

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]❧

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 AMR이 독립적으로 작동할 수 있도록 필요한 하드웨어 및 소프트웨어 구성 요소로 구성되며, 중앙 서버 없이 데이터를 현장에서 처리합니다.❧

2. 시스템 아키텍처❧

이 시스템은 단일 AMR으로 구성되므로 데이터 처리, 네비게이션, 위협 탐지 및 경고가 모두 AMR에서 로컬로 수행됩니다. AMR은 모니터링, 알림 및 수동 제어를 위해 PC의 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

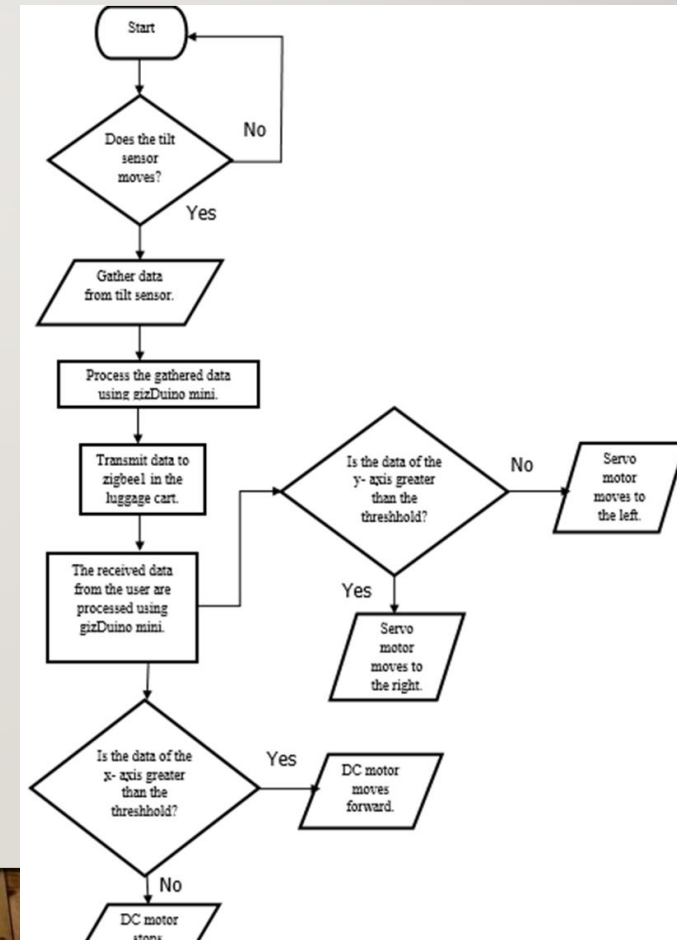
- Receive messages and act accordingly
- Move using (SLAM) with Obstruction avoidance
- Target Acquisition (Obj. Det.) and Tracking
- Follow target using camera and motor control

VISUALIZATION – SYSTEM FUNCTIONAL PROCESS FLOW DIAGRAMS

- To-Be Functional Process Flow Diagram

Detection Alert
AMR Controller

- **F**unctions
 - **I**nterfaces
 - **T**esting
- Dataflow
- 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`

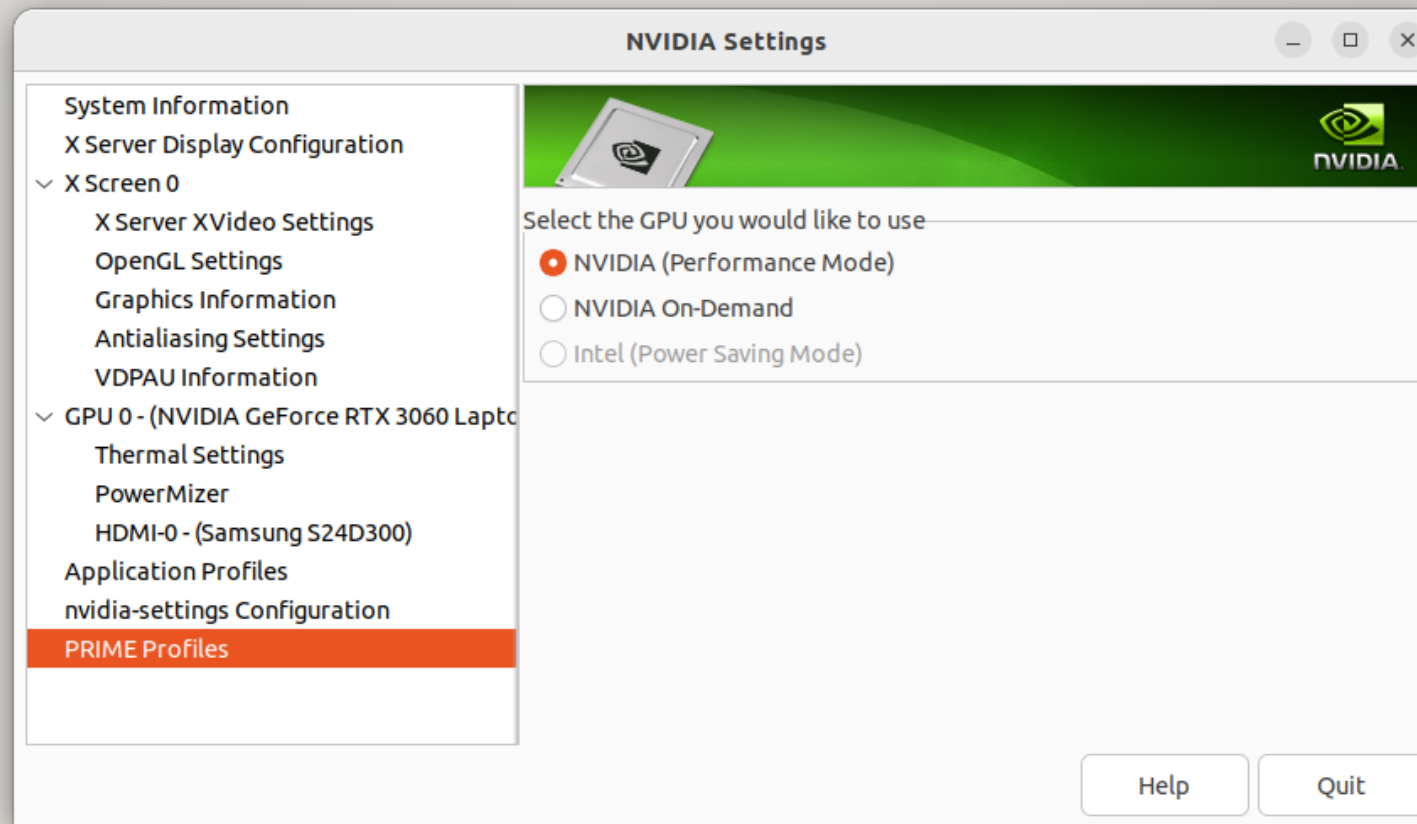
TERM2

- `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)

TERMI

- `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)

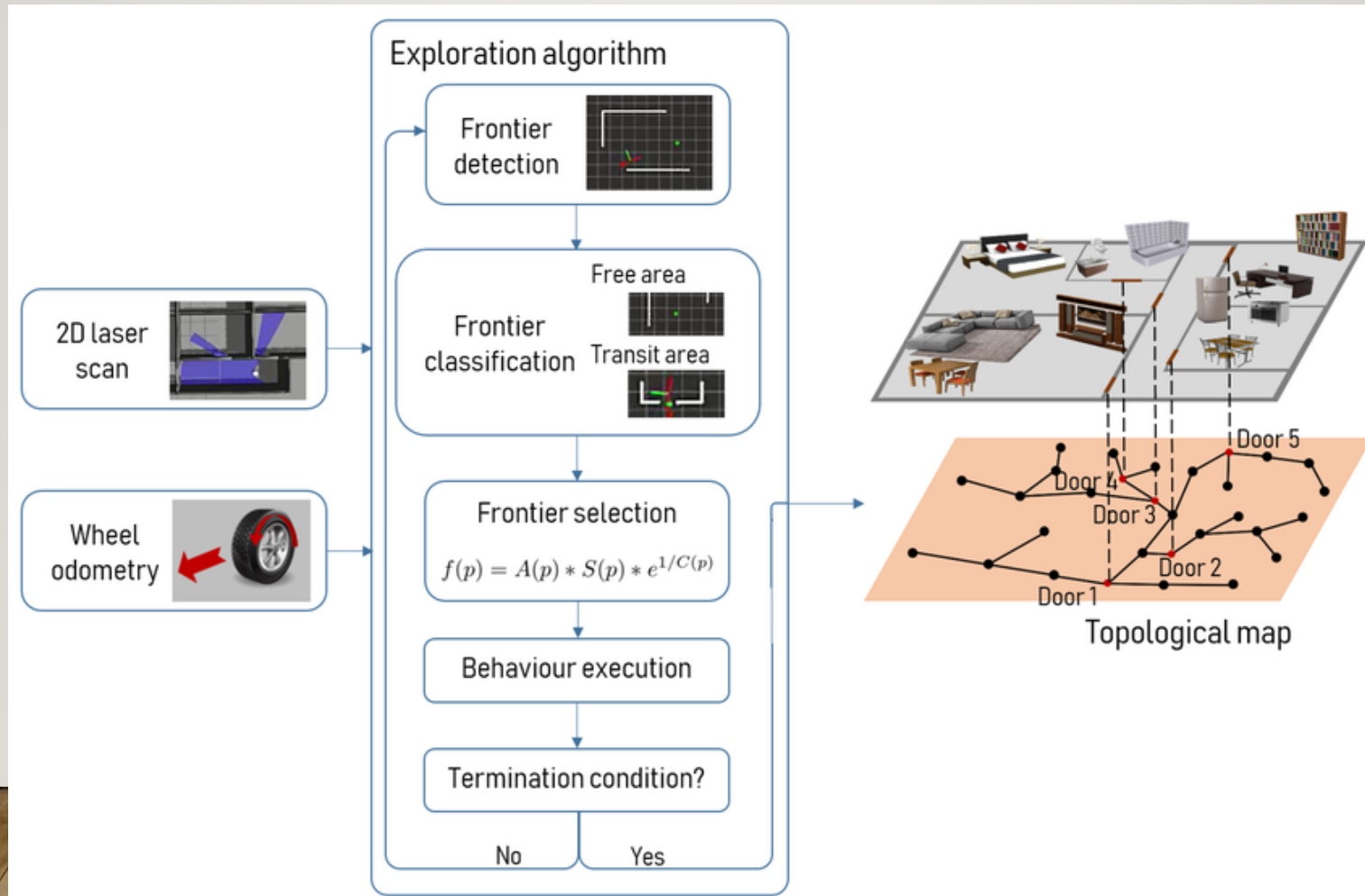
TERM1

- `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:

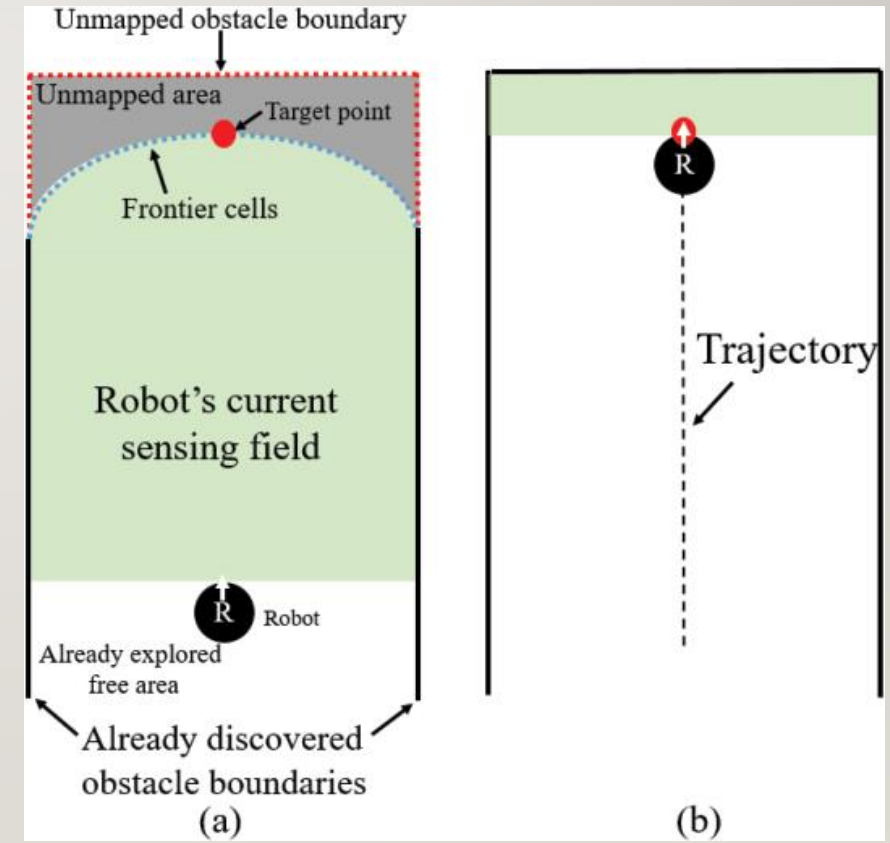
- Free space: known, unoccupied areas
- Occupied space: obstacles
- Unknown space: unexplored

- Frontier Detection

The map is scanned for cells that:

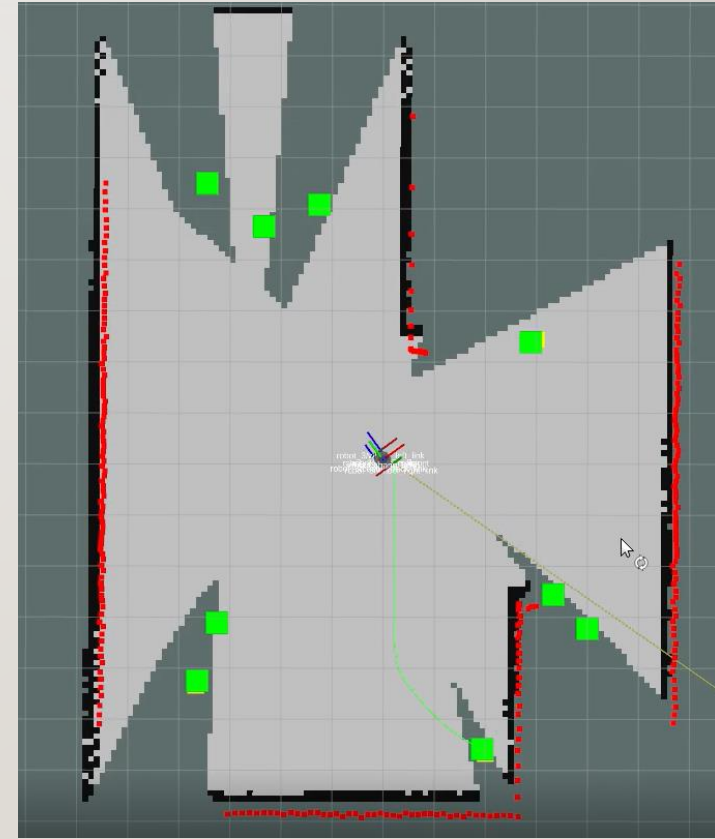
- Are free, and
- Are adjacent to at least one unknown cell.

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)

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)
 - <https://turtlebot.github.io/turtlebot4-user-manual/tutorials/driving.html>
- Navigation with SLAM



UNDOCKING AND DOCKING THE ROBOT

TERMINAL I

- Undocking

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

TERMINAL I

- 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)

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>

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

```
139
140 local_costmap:
141 local_costmap:
142 ros__parameters:
143 update_frequency: 5.0
144 publish_frequency: 2.0
145 global_frame: odom
146 robot_base_frame: base_link
147 use_sim_time: True
148 rolling_window: true
149 width: 3
150 height: 3
151 resolution: 0.06
152 robot_radius: 0.175
153 plugins: ["static_layer", "voxel_layer", "inflation_layer"]
154 inflation_layer:
155 plugin: "nav2_costmap_2d::InflationLayer"
156 cost_scaling_factor: 4.0
157
158 #inflation_radius: 0.45
159 inflation_radius: 0.25
160 #changed by aak
161
162 voxel_layer:
163 plugin: "nav2_costmap_2d::VoxelLayer"
164 enabled: True
```



# TUTORIAL

---

```
3_2_a_nav_to_pose.py
3_2_b_nav_through_poses.py
3_2_c_follow_waypoints.py
3_2_d_create_path.py
3_2_e_mail_delivery.py
3_2_f_patrol_loop.py
```

## TERMINAL 4

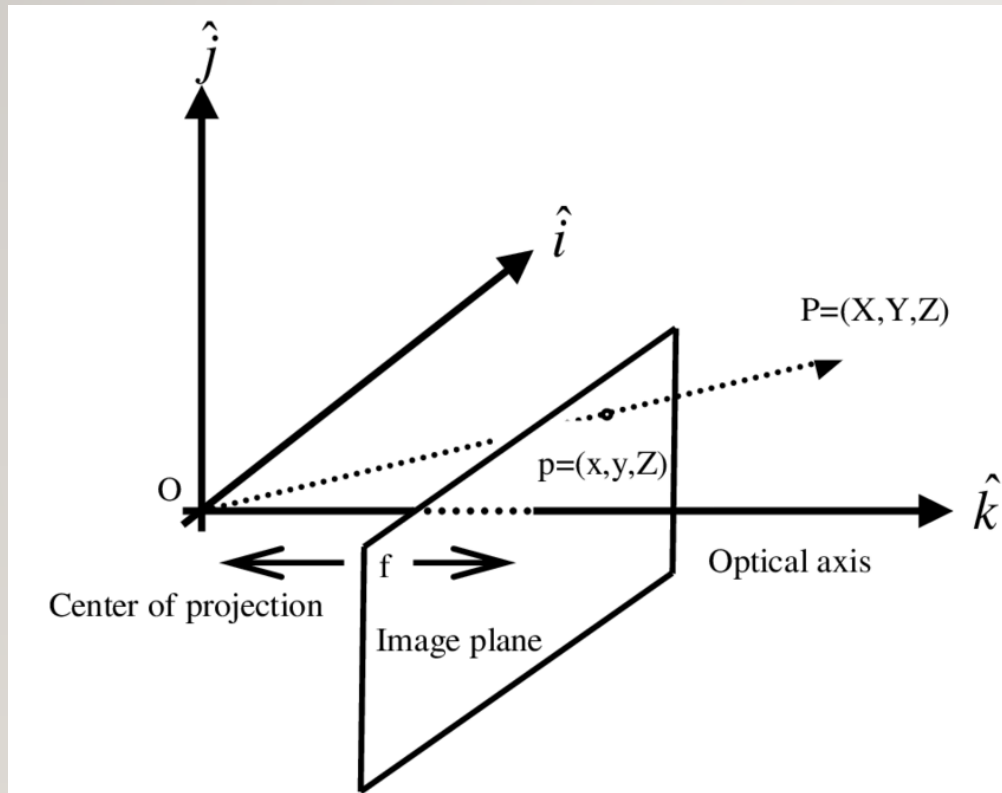
```
$ ros2 run day3 create_path --ros-args -r __ns:=/robot<n>
$ ros2 run day3 nav_to_poses --ros-args -r __ns:=/robot<n>
$ ros2 run day3 follow_waypoints --ros-args -r
__ns:=/robot<n>
$ ros2 run day3 nav_through_poses --ros-args -r
__ns:=/robot<n>
$ ros2 run day3 mail_delivery --ros-args -r __ns:=/robot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

# USING DEPTH

---



# CAMERA INTRINSIC AND REPROJECTION



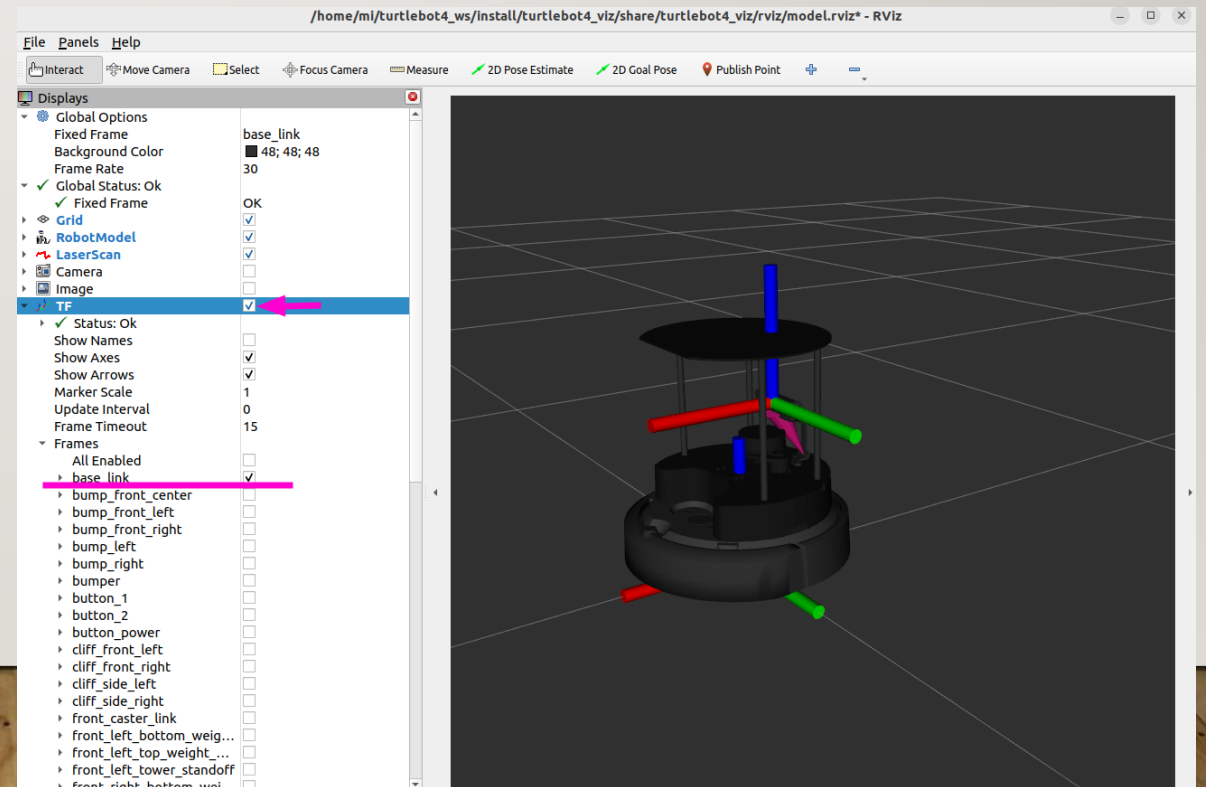
$$X = \frac{(u - c_x) \cdot Z}{f_x}, \quad Y = \frac{(v - c_y) \cdot Z}{f_y}, \quad Z = Z$$



# 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

```
3_1_a_depth_checker.py
3_1_b_depth_to_3d.py
3_1_c_depth_to_nav_goal.py
3_1_d_nav_to_person.py
```

\*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)

---

- 3\_1\_a\_depth\_checker.py
- 3\_1\_b\_depth\_to\_3d.py
- 3\_1\_c\_depth\_to\_nav\_goal.py
- 3\_1\_d\_nav\_to\_person.py
- 3\_2\_a\_nav\_to\_pose.py
- 3\_2\_b\_nav\_through\_poses.py
- 3\_2\_c\_follow\_waypoints.py
- 3\_2\_d\_create\_path.py
- 3\_2\_e\_mail\_delivery.py
- 3\_2\_f\_patrol\_loop.py
- 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

- 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

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

# 프로젝트 RULE NUMBER ONE!!!

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Are we still having  
**FUN!**

