

GOOD MORNING!

早上好!

안녕하세요!

DAY 3



DAY2 RECAP



DAY I

- Welcome
- Project Introduction
- Introduction to Project Development Process
- Business Requirement Development
- System Requirement Development
- System and Development environment Setup

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 DEMO

- 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 (MINI PROJECT)

- System(High Level) Design (Mini Project)
 - System Architectural Diagram
- Detail Design to Acceptance - Agile Development (SPRINTs)
 - Detection
 - AMR Control

DAY 4 (MINI PROJECT)

CODING, TEST & INTEGRATION

- Coding and Test all modules
- Porting to ROS
- And finally, Integration and Test of Detection Alert & AMR Controller

MINI PROJECT DEMO

- Prepare and demo completed project

프로젝트 RULE NUMBER ONE!!!

Have Fun Fun Fun!



DID YOU ACHIEVE SAME **FOV** AND
DIMENSION FOR BOTH DEPTH AND
RGB??



HOMEWORK CHECK

- **Achieve aligned RGB & Depth FOV**
- Object Detection
 - Collect various datasets (i.e. different topics/images sizes)
 - Create various models (i.e. v5, v8, v11, etc; arg: Epoch, Batch, Imgsz, augmentation, etc)
 - Analyze the results
 - Determine using key metrics which model best fit your solution
 - Using .pt file to predict/inference on pc
 - **Successfully publish the annotated image topic**
- Depth
 - **Find and display the distance to the center of the detected objects**
- Update System Requirement

SYSTEM REQUIREMENT PRESENTATION BY EACH TEAM

Using the posted notes and flipchart as needed

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
 - Approach target using camera and motor control

OPERATING AMR



AMR (TURTLEBOT4)

- [Features](#) · [User Manual](#)
- <https://turtlebot.github.io/turtlebot4-user-manual/overview/features.html>
- Review the content



SIMULATION DEMO



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

SETUP BASH

- Make sure bashrc has:
 - `ROS_DOMAIN_ID = Team Number(i.e. 1 or 2 or 3...6)`
- 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`

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

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 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`

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 REAL ROBOT (AUTONOMOUSLY)



SETUP BASH

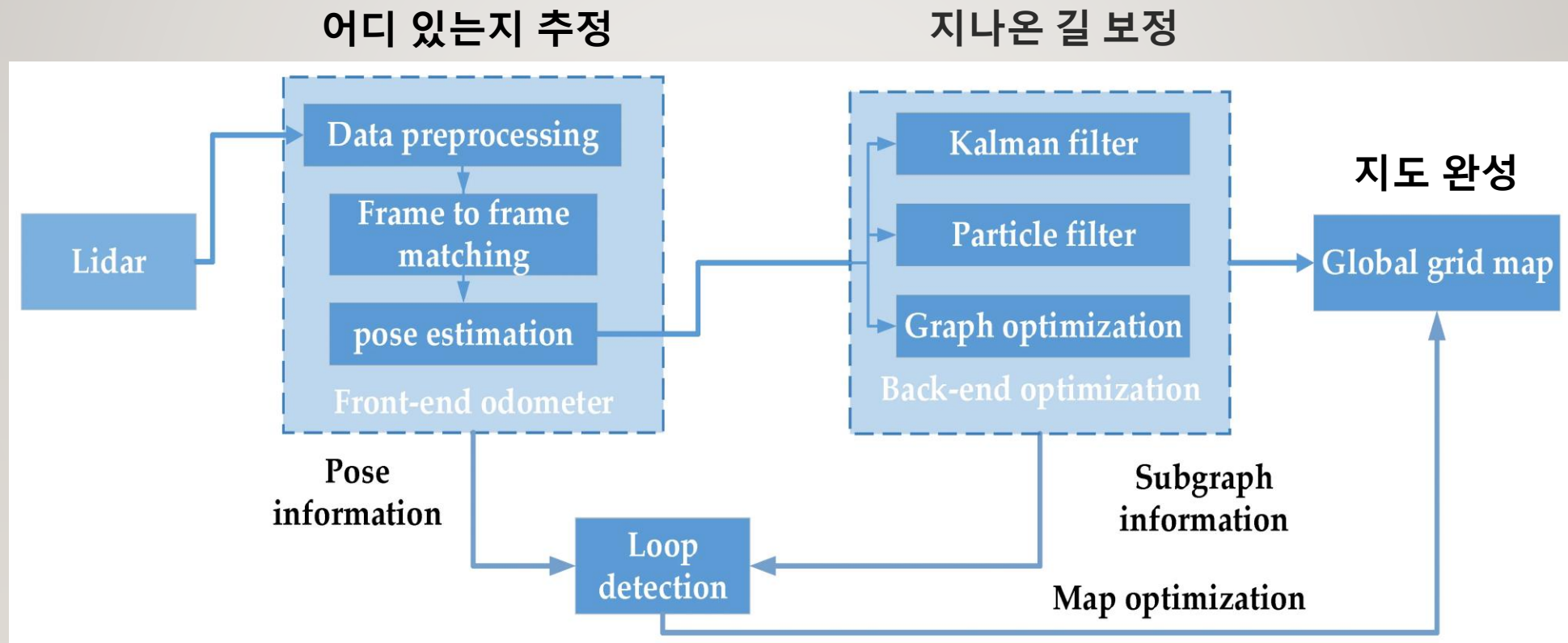
- Make sure bashrc has:
 - `ROS_DOMAIN_ID = 0`
- `echo "alias ros-restart=ros2 daemon stop; ros2 daemon start" >> ~/.bashrc`
- Make sure discovery setup.bash **is** sourced!
- `source ~/.bashrc`

DIGITAL MAPPING (SLAM)

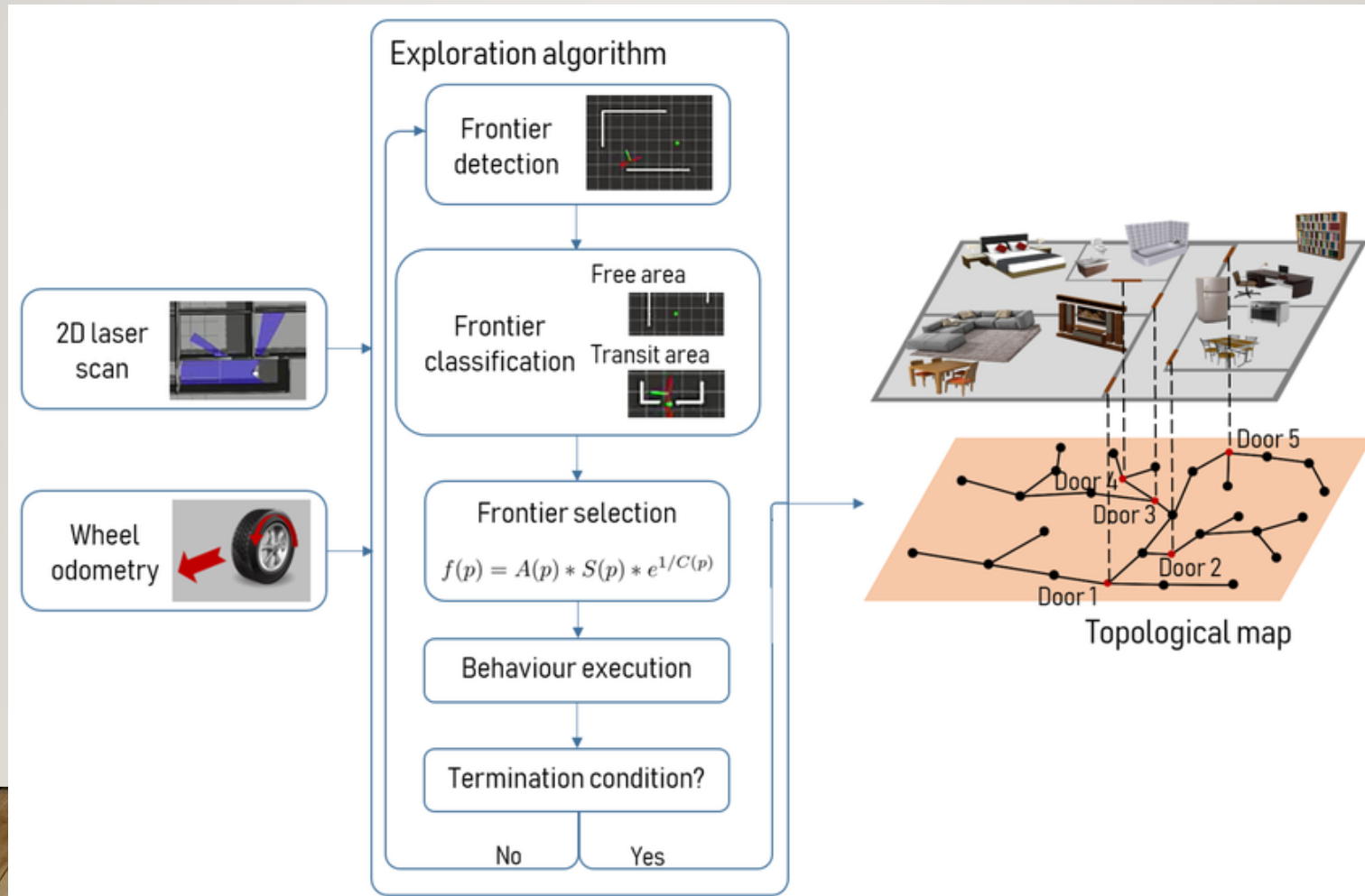
- [Generating a map · User Manual](https://turtlebot.github.io/turtlebot4-user-manual/tutorials/generate_map.html)

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

SLAM 개요



AUTO SLAM CONCEPT/ALGORITHM



ALGORITHM DETAIL

- Map Subscription

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

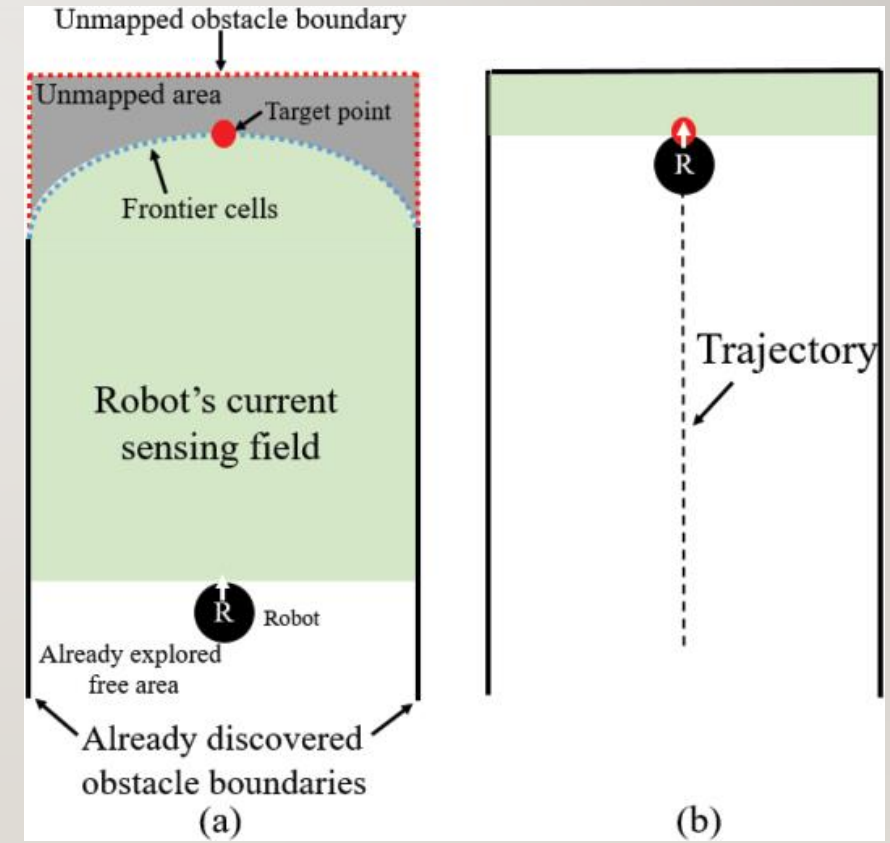
- Free space: known, unoccupied areas
- Occupied space: obstacles
- Unknown space: unexplored

- Frontier Detection

The map is scanned for cells that:

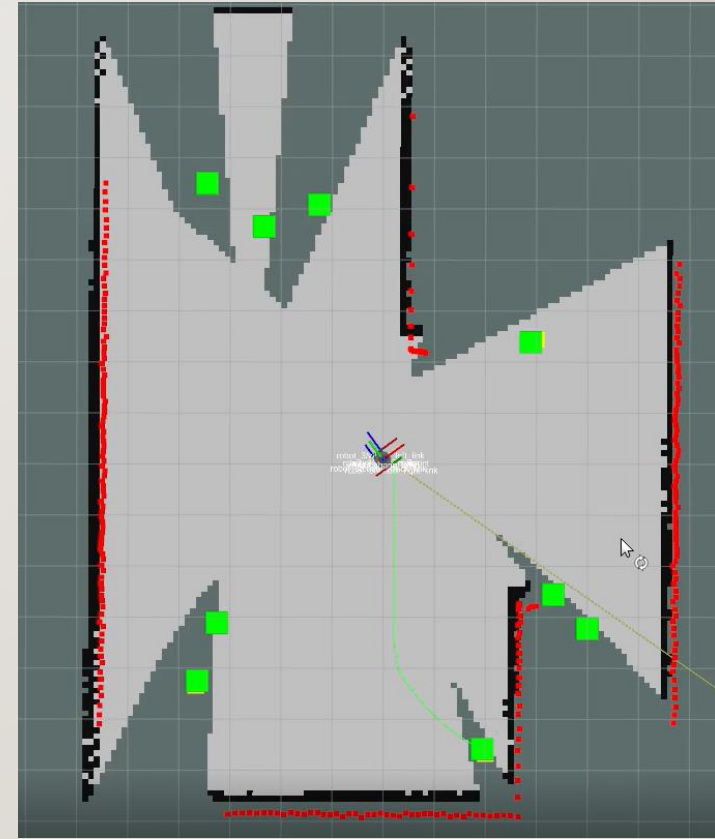
- Are free, and
- Are adjacent to at least one unknown cell.

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

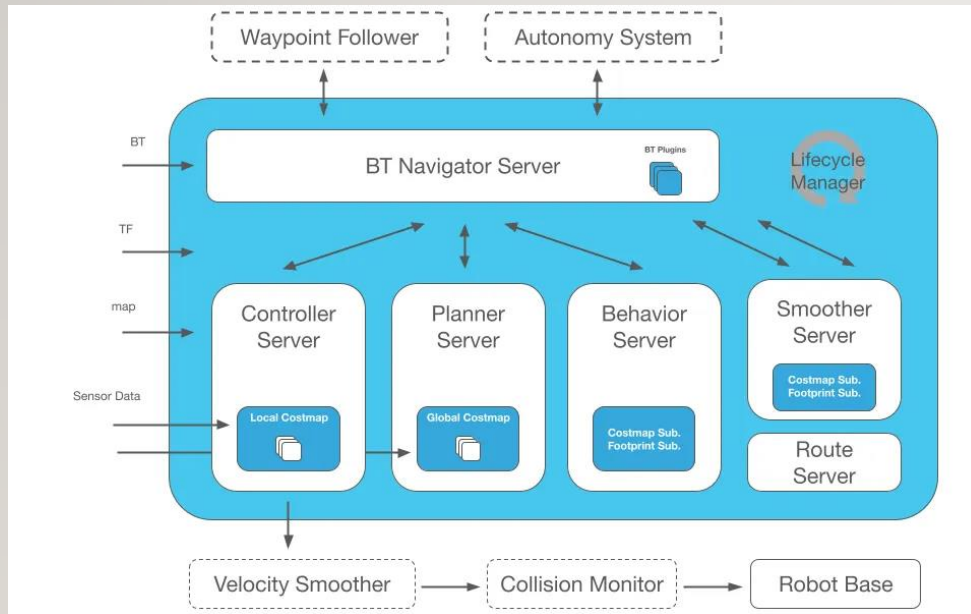
- Send as goal

- If goal fails → blacklist

- If (no frontiers or all blacklisted)

- Terminate exploration

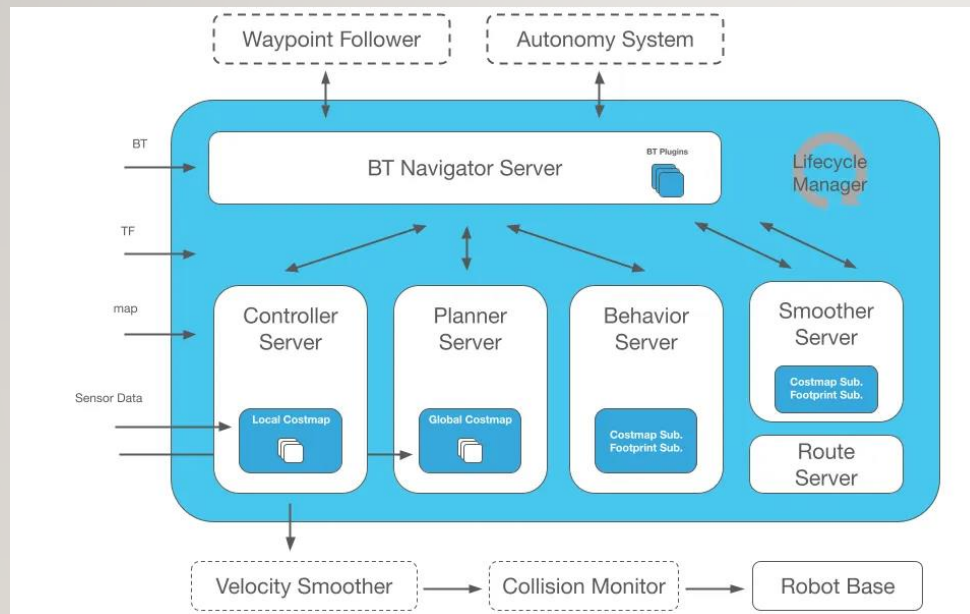
NAV2 IN ONE SENTENCE



- Nav2 turns a goal into safe motion by splitting thinking, reacting, and safety into separate servers.
- One system, many roles
- Behavior Trees coordinate everything
- No single node “drives” the robot

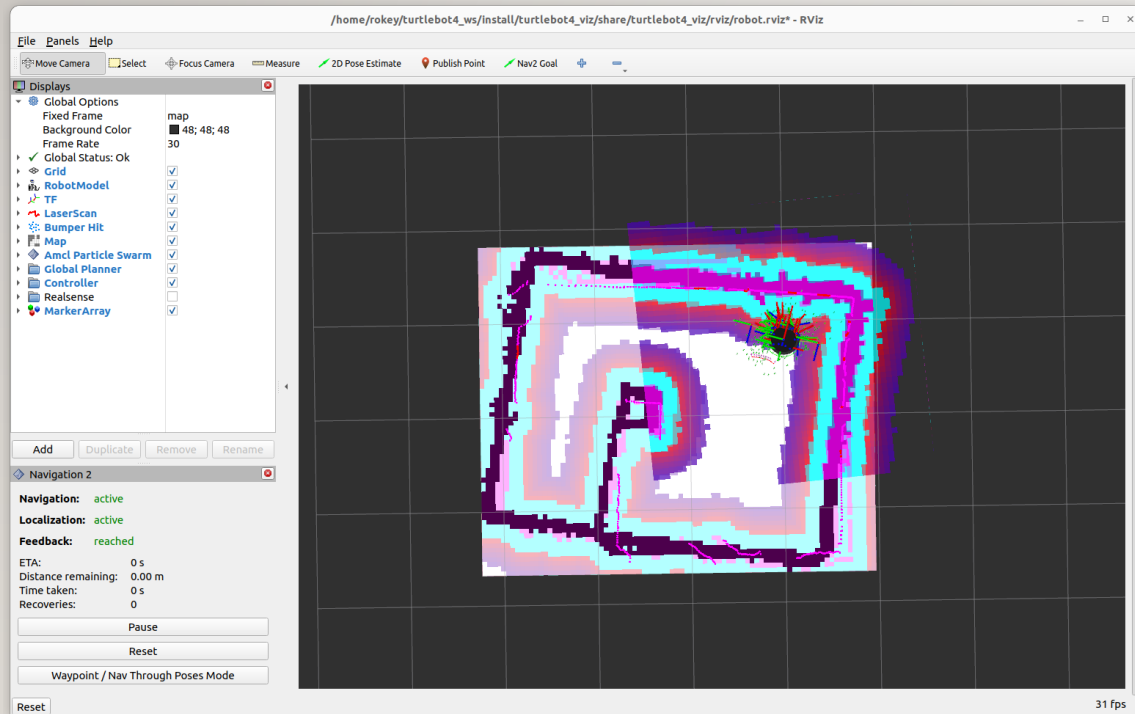
Mental model first. Details later.

WHO DOES WHAT (CORE SERVERS)



- **BT Navigator**
Orchestrates the mission using a Behavior Tree
 - **Planner Server**
Computes a global path using the **global costmap**
 - **Controller Server**
Converts the path into velocities using the **local costmap**
- Rule: planner thinks far, controller reacts now.

COST MAPS: TWO VIEWS OF THE SAME WORLD



- **Global Costmap**
 - Static, slow, conservative
 - Used for planning
- **Local Costmap**
 - Dynamic, fast, sensor-driven
 - Used for control

Same environment. Different time horizons.


SIMPLE NAV2 PARAM ADJUSTMENT

```
$ cd
```

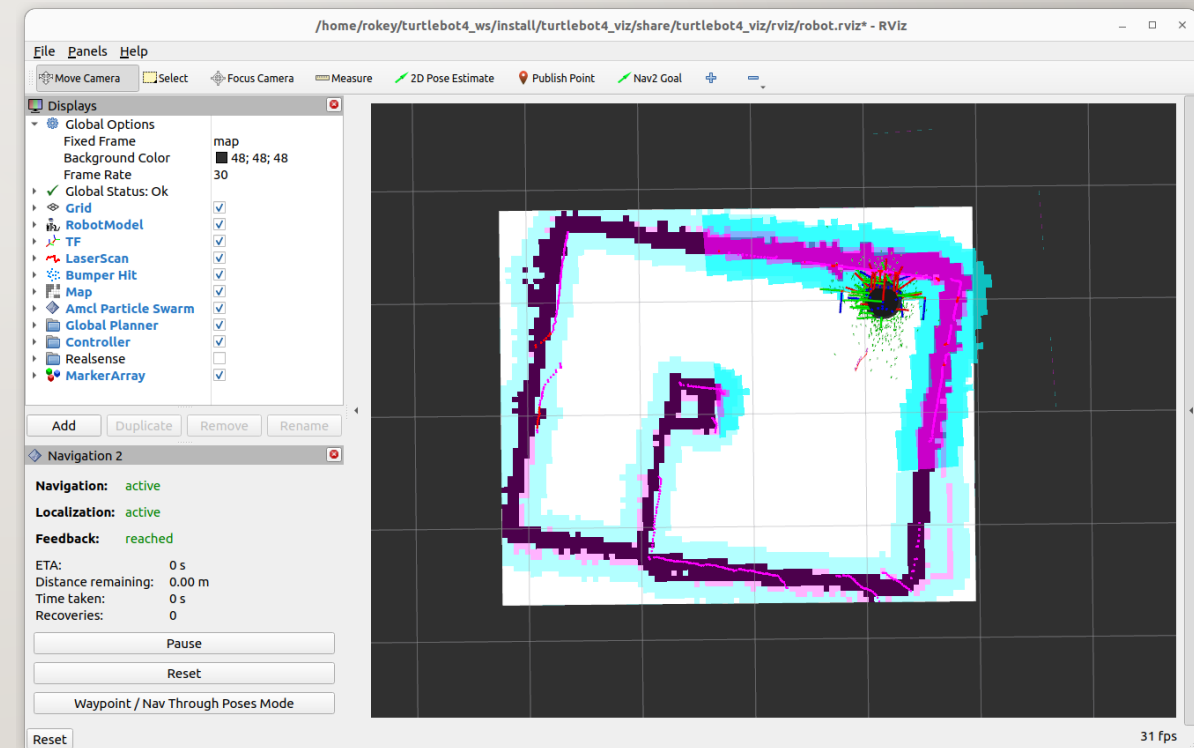
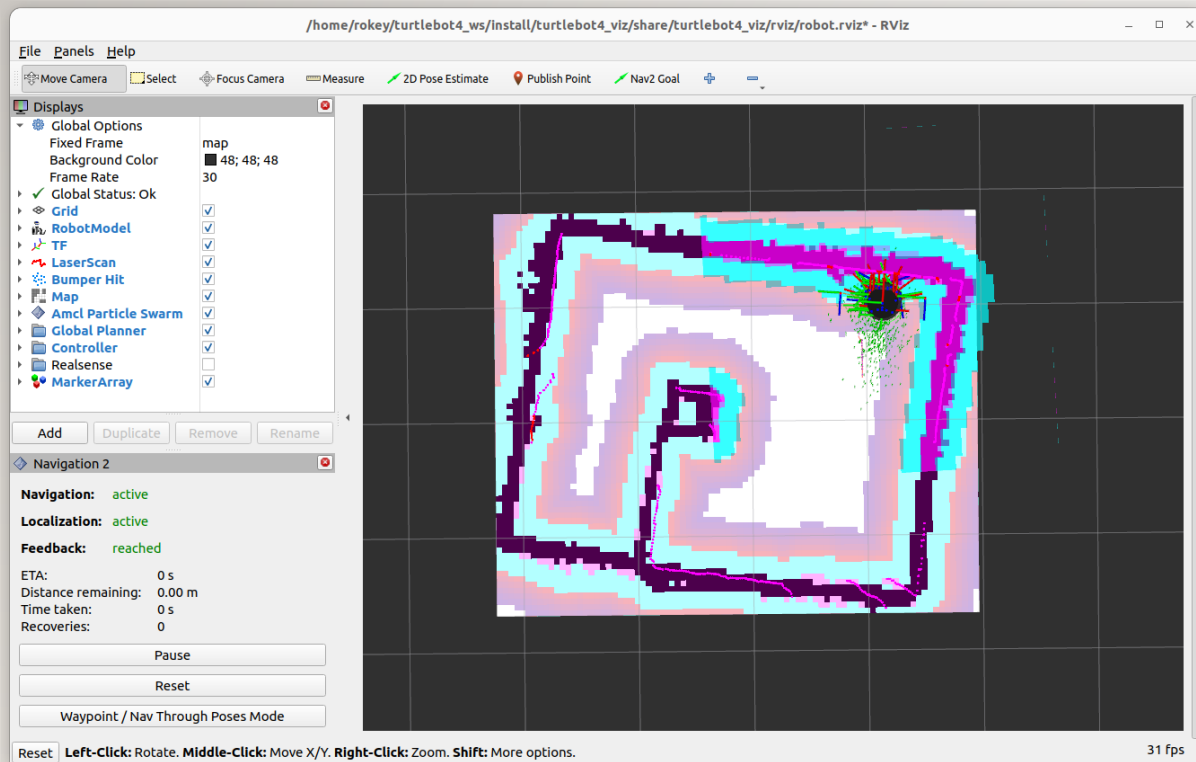
```
~/turtlebot4_ws/src/turtlebot4/turtlebot4_navigation/config
```

- Change/adjust “inflation_radius” to fit your environment

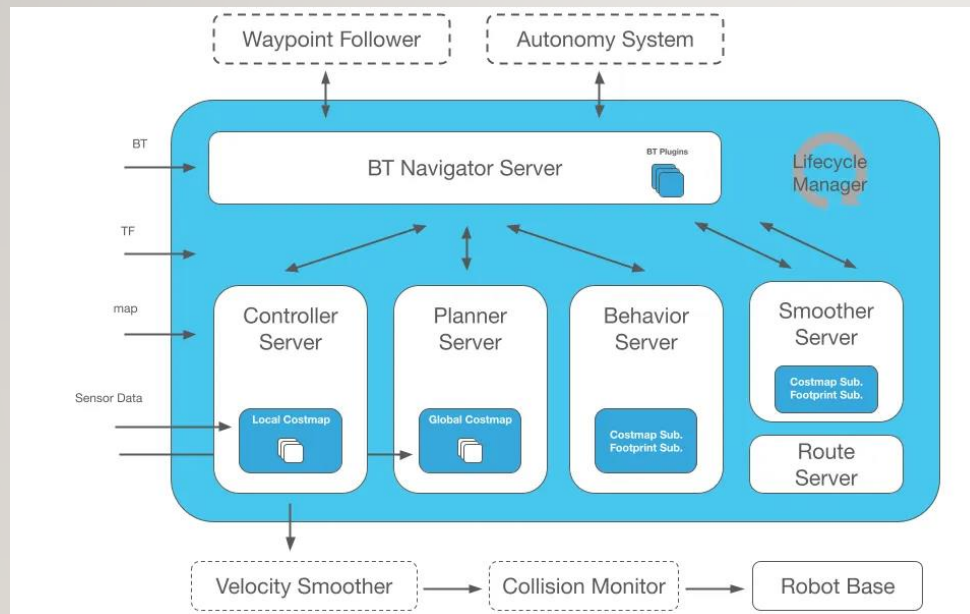
```
139
140 local_costmap:
141   local_costmap:
142     ros__parameters:
143       update_frequency: 5.0
144       publish_frequency: 2.0
145       global_frame: odom
146       robot_base_frame: base_link
147       use_sim_time: True
148       rolling_window: true
149       width: 3
150       height: 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
```



COST MAPS WITH PARAMETER ADJUSTMENTS



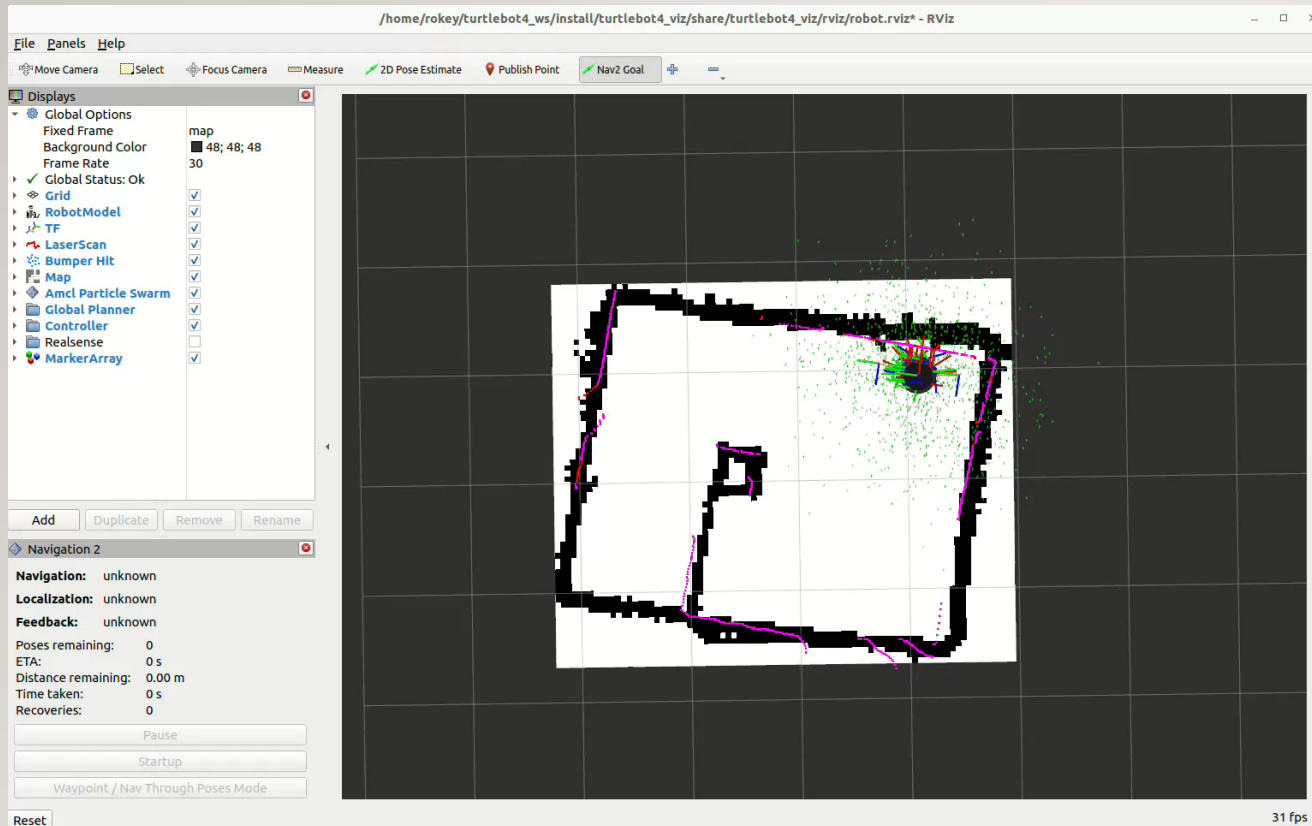
HANDLING REALITY (RECOVERY + SAFETY)



- **Behavior Server**
 - Spin, back up, wait, clear costmaps
 - Triggered when progress fails
- **Safety Chain**
 - Velocity smoother
 - Collision monitor
 - Robot base veto power

Intelligence suggests. Safety decides.

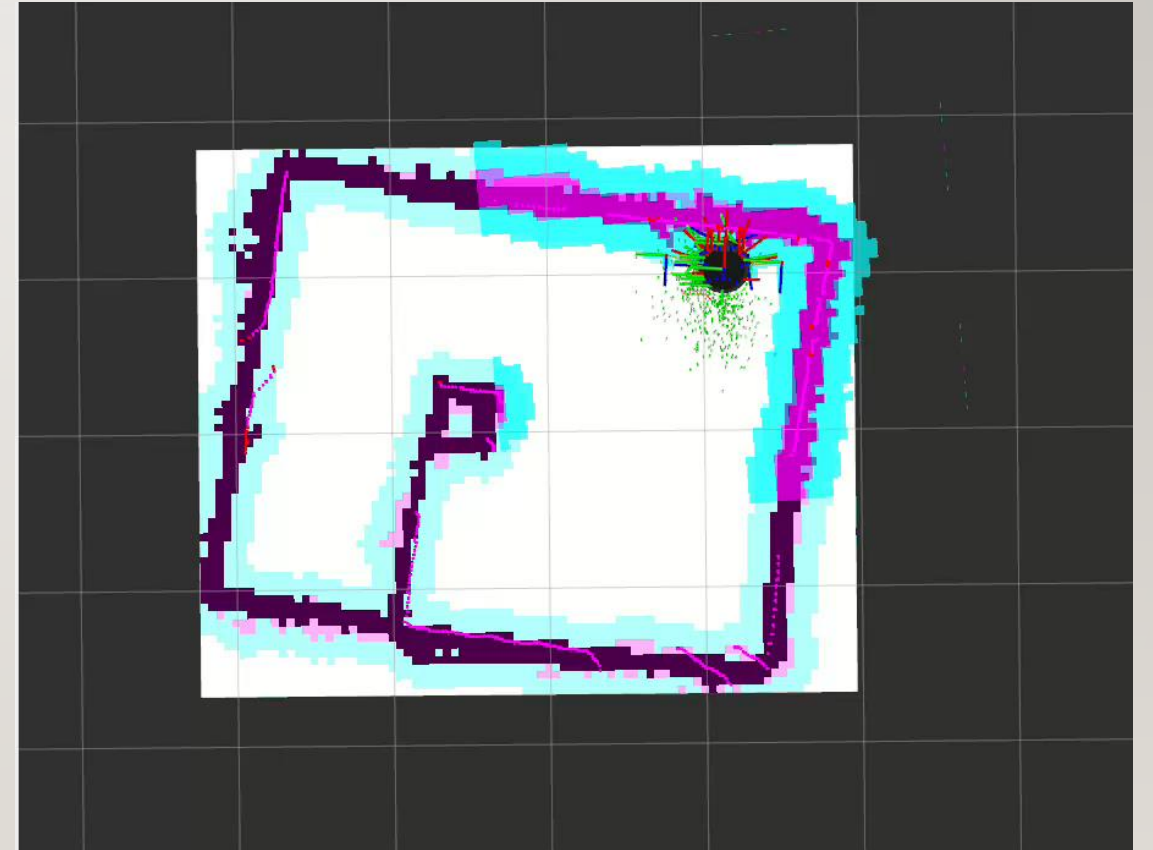
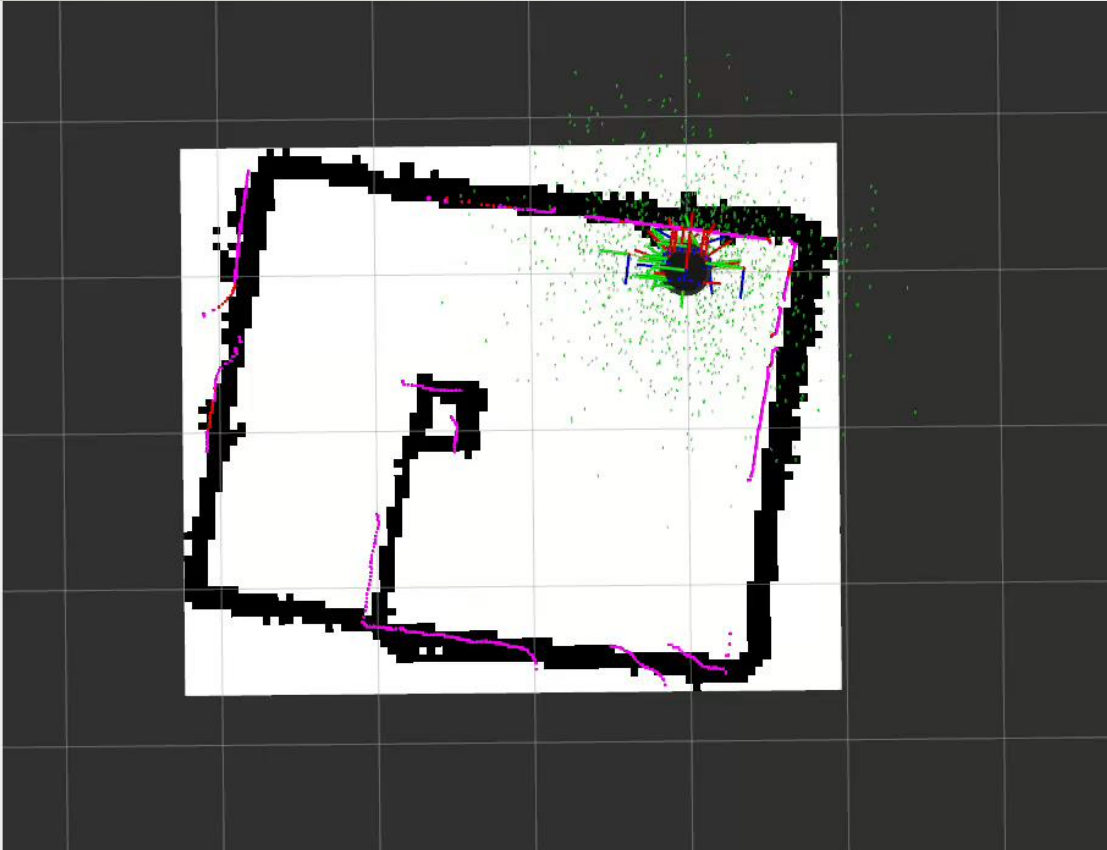
END-TO-END FLOW



1. Goal arrives
2. BT selects actions
3. Planner creates path
4. Controller drives
5. Safety filters motion
6. Behavior recovers if needed

Loop until success or failure.

END-TO-END FLOW WITH PARAMETER ADJUSTMENT



EXERCISE: PERFORM SLAM TO NAVIGATION

DAY 3 - SLAM & Navigation

Aa 이름

☀ 상태

● SLAM 개요

● 완료

● Robot_SLAM

● 완료

● Auto SLAM 개요

● 완료

● Robot SLAM_explore_lite

● 완료

● Nav2 개요

● 완료

● Robot_Navigation

● 완료

EXERCISE : RUN TUTORIAL ON REAL ROBOT

Make copy and Update the **simulation** tutorial code provided to successfully execute in the project environment with **real robot**

Tutorial Codes are found in:

**\$HOME/turtlebot4_ws/src/turtlebot4_tutorials/turtlebot4_python_tutorials/
turtlebot4_python_tutorials**

SETUP BASH(ROBOT)

- Make sure bashrc has:
 - ROS_DOMAIN_ID = Team Number(i.e. 1 or 2 or 3...6)
- Make sure discovery setup.bash **is** sourced!
- source ~/.bashrc

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>
```
- [Set Init Pose using 2D\\_PoseEstimate](#)
  - [Undock Robot](#)

## TERMINAL 3

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

# TUTORIAL (ROBOT) EXAMPLE CLI

---

```
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>
```

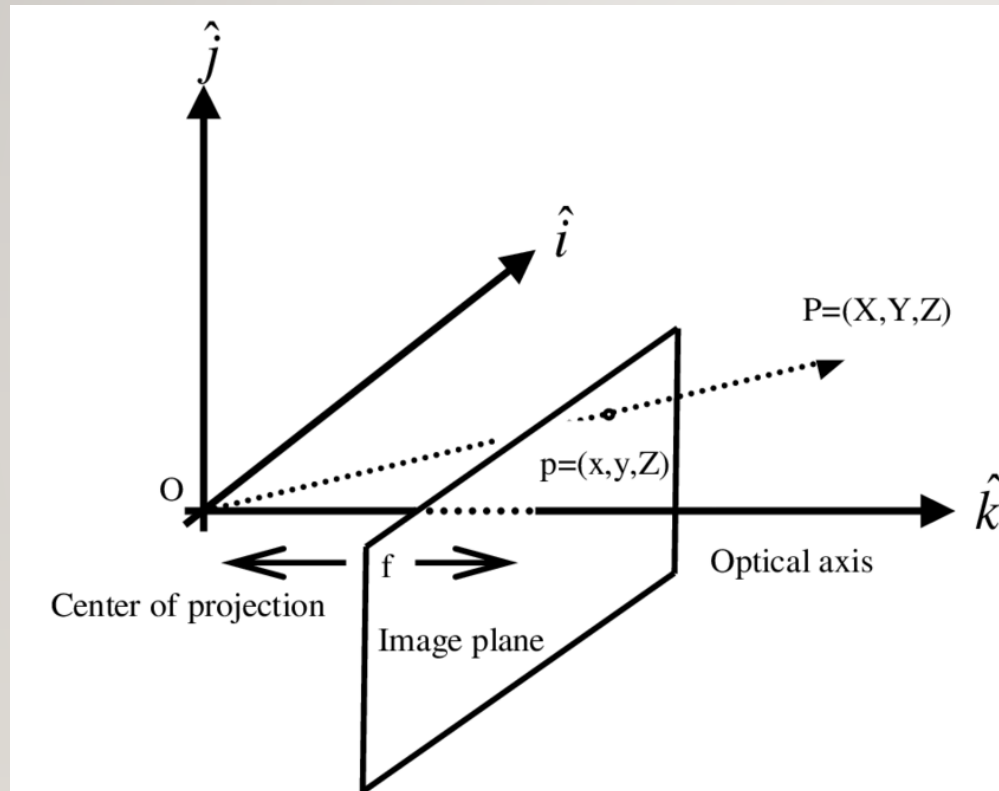
**HINT:** Just need to find new coordinates for the goal(s)

# USING DEPTH TO GET MAP COORDINATES (TF TRANSFORM)

---



# CAMERA INTRINSIC AND REPROJECTION



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

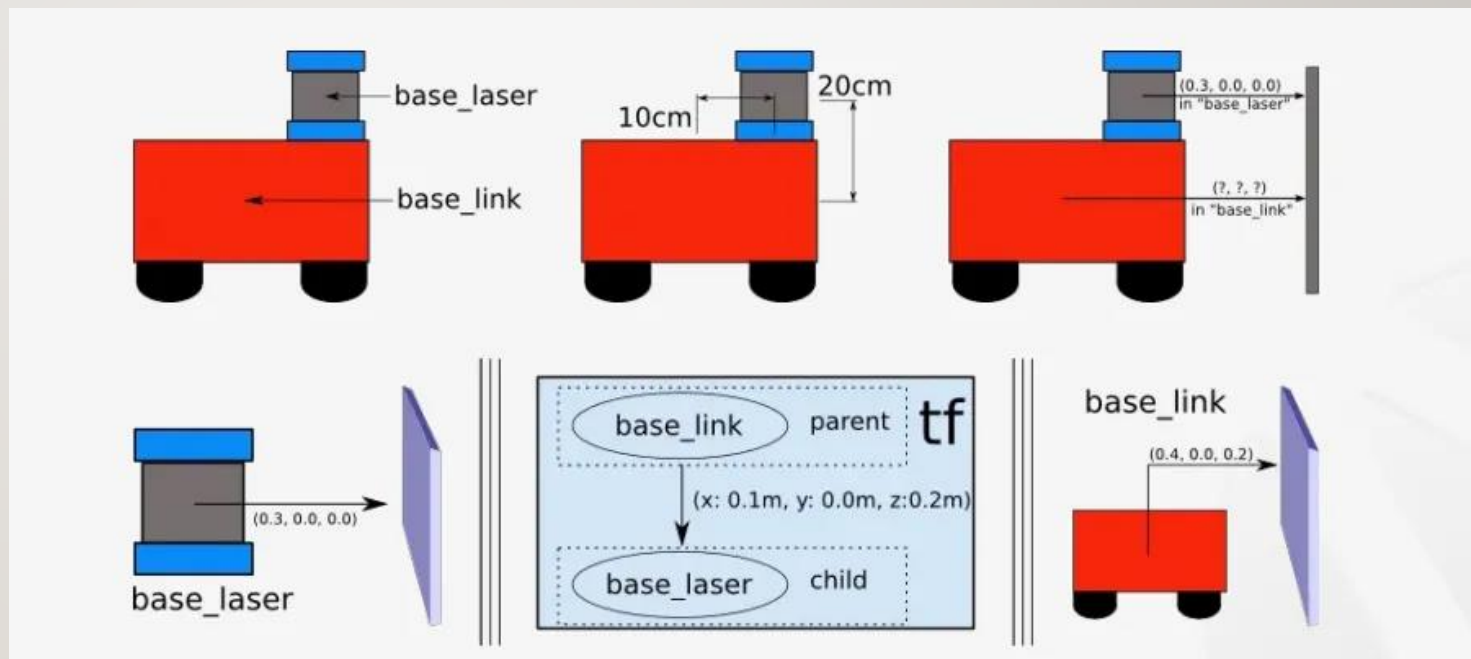
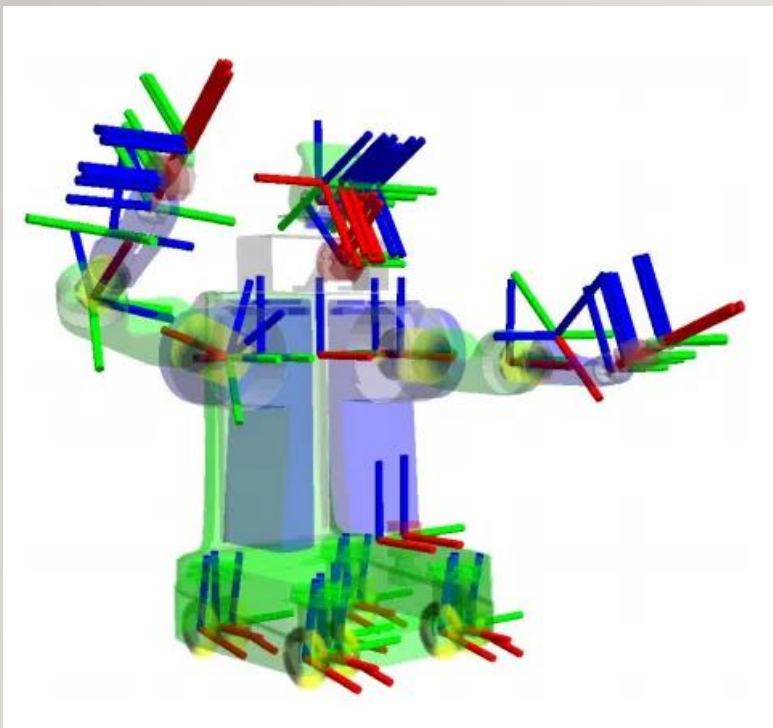
# TF TRANSFORM 개요

---

|                   |      |        |
|-------------------|------|--------|
| ● TF Transform 개요 | OPEN | ● 시작 전 |
| ● Robot_TF Check  |      | ● 시작 전 |



# TF (ROBOT TRANSFORM) 개요



# USING DEPTH (SIM)

---

```
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
```

## TERMINAL 2 (

```
$ ros2 run <pkg_name> <exec_name>
```

For example,

```
$ ros2 run day3 nav_to_person
```

# DEPTH/TRANSFORM EXERCISE

---

Make copy and Update the **simulation** depth code provided to successfully execute in the project environment with **real robot**

Simulation Depth Codes are found on **Github**

# USING DEPTH (ROBOT)

---

## TERMINAL 1

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

## TERMINAL 2

- ```
$ ros2 launch turtlebot4_viz view_robot.launch.py  
namespace:=/robot <n>
```
- [Set Init Pose using 2D_PoseEstimate](#)
 - [Undock Robot](#)

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

Simulation Code

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

Provided Code

Provided code can be found on Github

USING DEPTH/TRANSFORM (ROBOT) EXAMPLE CLI

```
3_3_a_depth_checker.py
3_3_b_depth_to_3d.py
3_3_c_depth_to_nav_goal.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
```

rokey@rokey-Victus-by-HP-Laptop-16-d1xxx: ~

ubuntu@ubuntu: ~ 100x8

Learn more about enabling ESM Apps service at <https://ubuntu.com/esm>

New release '24.04.3 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Tue Dec 23 15:55:40 2025 from 192.168.107.67

ubuntu@ubuntu:~\$ 터틀봇4 우분투 접속

rokey@rokey-Victus-by-HP-Laptop-16-d1xxx: ~ 100x8

ROS2 humble is activated!

(base) rokey@rokey-Victus-by-HP-Laptop-16-d1xxx:~\$ ros2 launch turtlebot4_navigation localization.launch.py \

namespace:=/robot<n> \

map:=\$HOME/<map_directory>/<map_name>.yaml Localization

rokey@rokey-Victus-by-HP-Laptop-16-d1xxx: ~ 100x8

ROS2 humble is activated!

(base) rokey@rokey-Victus-by-HP-Laptop-16-d1xxx:~\$ ros2 launch turtlebot4_viz view_robot.launch.py n

amespace:=/robot<n> Rviz

rokey@rokey-Victus-by-HP-Laptop-16-d1xxx: ~ 100x8

ROS2 humble is activated!

(base) rokey@rokey-Victus-by-HP-Laptop-16-d1xxx:~\$ ros2 launch turtlebot4_navigation nav2.launch.py

namespace:=/robot<n> params_file:=\$HOME/<your_ws_dir>/<your_nav_config_filename>.yaml Nav

rokey@rokey-Victus-by-HP-Laptop-16-d1xxx: ~ 101x18

(base) rokey@rokey-Victus-by-HP-Laptop-16-d1xxx:~\$ ping 192.168.107.57

PING 192.168.107.57 (192.168.107.57) 56(84) bytes of data.

64 bytes from 192.168.107.57: icmp_seq=1 ttl=64 time=19.2 ms

64 bytes from 192.168.107.57: icmp_seq=2 ttl=64 time=22.7 ms

64 bytes from 192.168.107.57: icmp_seq=3 ttl=64 time=4.88 ms

64 bytes from 192.168.107.57: icmp_seq=4 ttl=64 time=2.17 ms

ping(또는 네트워크) 모니터링

rokey@rokey-Victus-by-HP-Laptop-16-d1xxx: ~ 101x18

ROS2 humble is activated!

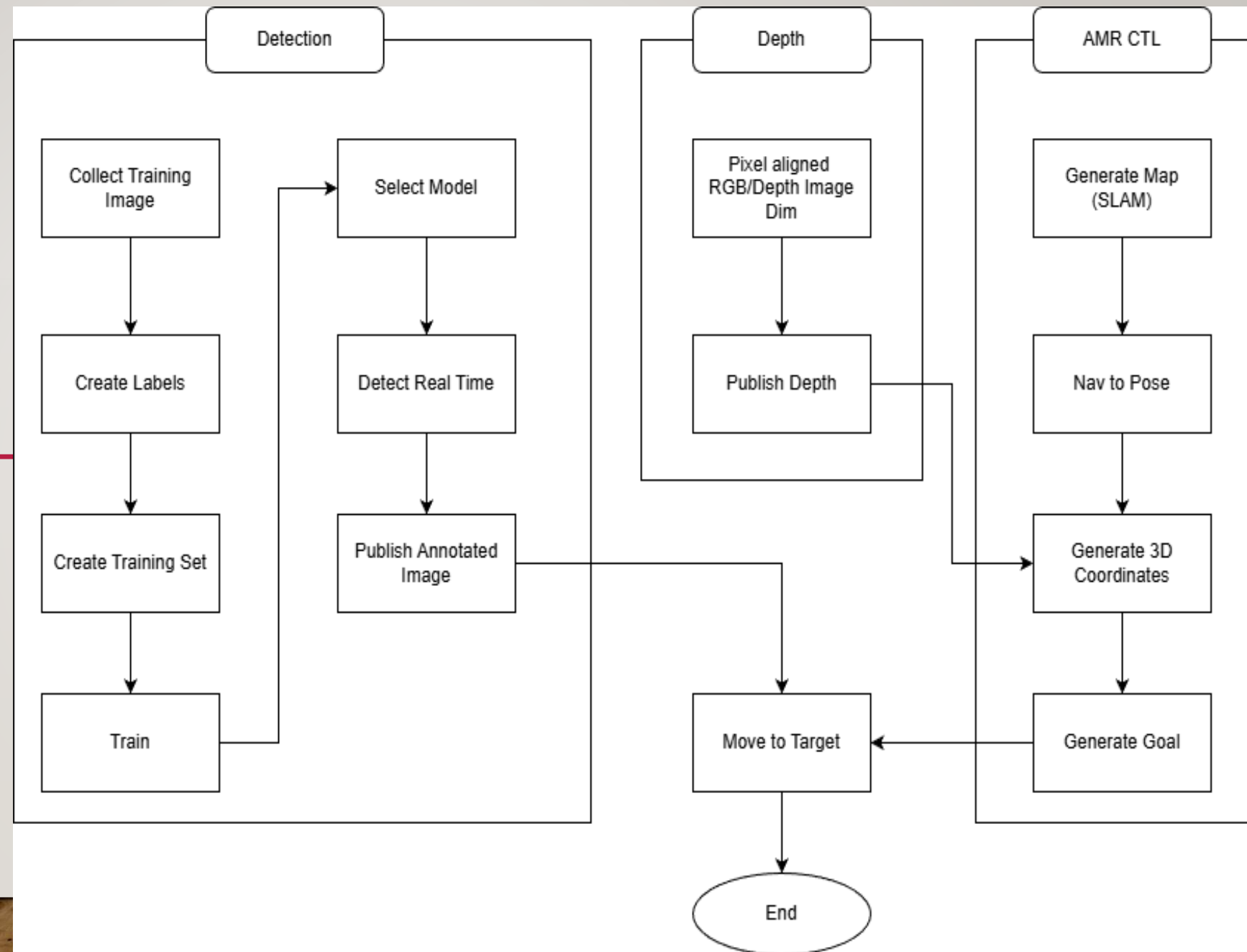
(base) rokey@rokey-Victus-by-HP-Laptop-16-d1xxx:~\$ 추가 작업 내용

Recommended
Terminator
Layout

HOMEWORK

- Create an AMR control code
 - AMR receives an event and undocks
 - Init Pose is set
 - AMR moves to a goal position
 - AMR able to approach a target
 - **Design a way to get information about the target**
 - **Design an approach algorithm**
 - **Test**
- Update System Requirement

TASKS TO BE PERFORMED



프로젝트 RULE NUMBER ONE!!!

Are we still having
FUN!

