GOOD MORNING!
早上好!
안녕하세요!

DAY 3

DAY2 RECAP

DAY 1

- 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

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

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)

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 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 = Team Number(i.e. 1 or 2 or 3…6)
- echo "alias **ros-restart**='ros2 daemon stop; ros2 daemon start'" >> ~/.bashrc
- Make sure discovery setup.bash **is** sourced!
- source ~/.bashrc

DIGITAL MAPPING (SLAM)

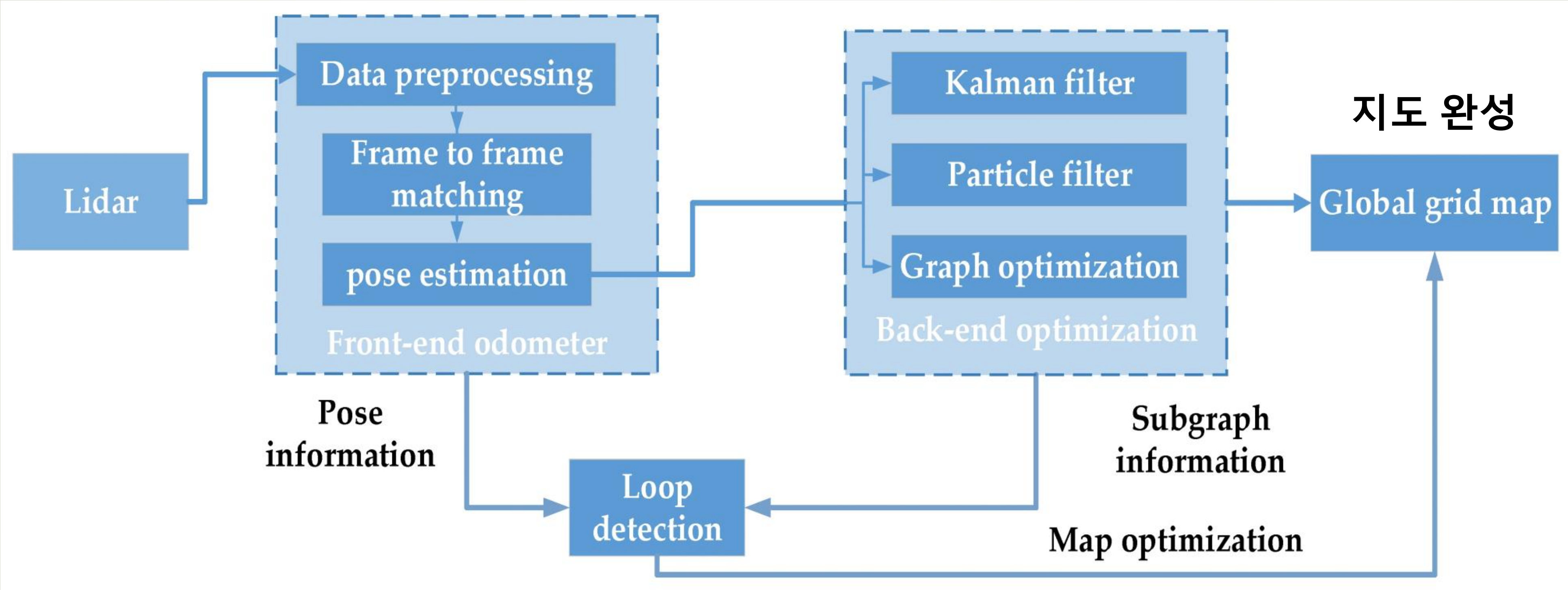
- Generating a map · User Manual
  https://turtlebot.github.io/turtlebot4-user-manual/tutorials/generate_map.html

SLAM 개요

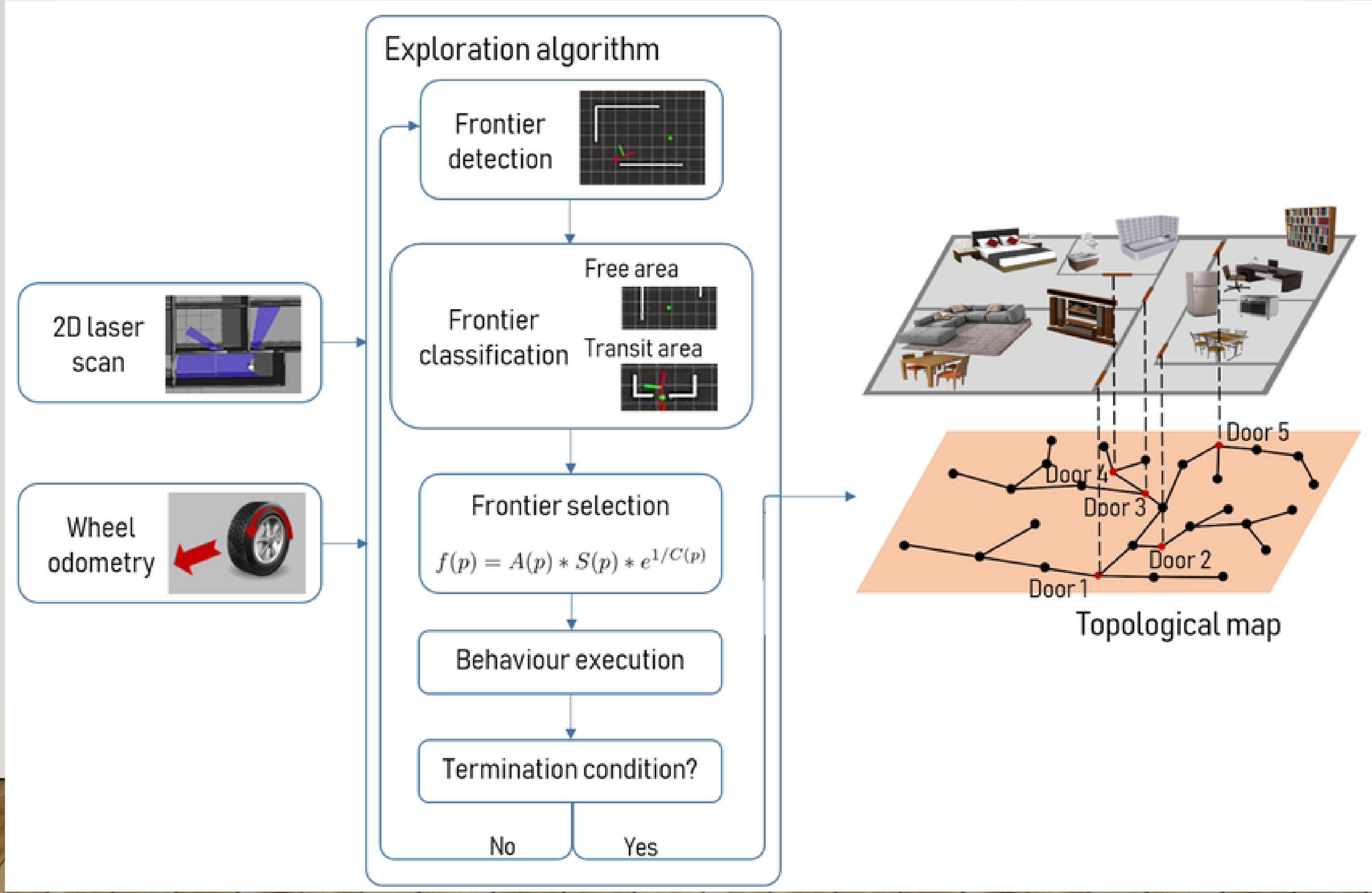
어디 있는지 추정

지나온 길 보정

지도 완성



AUTO SLAM CONCEPT/ALGORITHM



ALGORITHM DETAIL

- Map Subscription

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

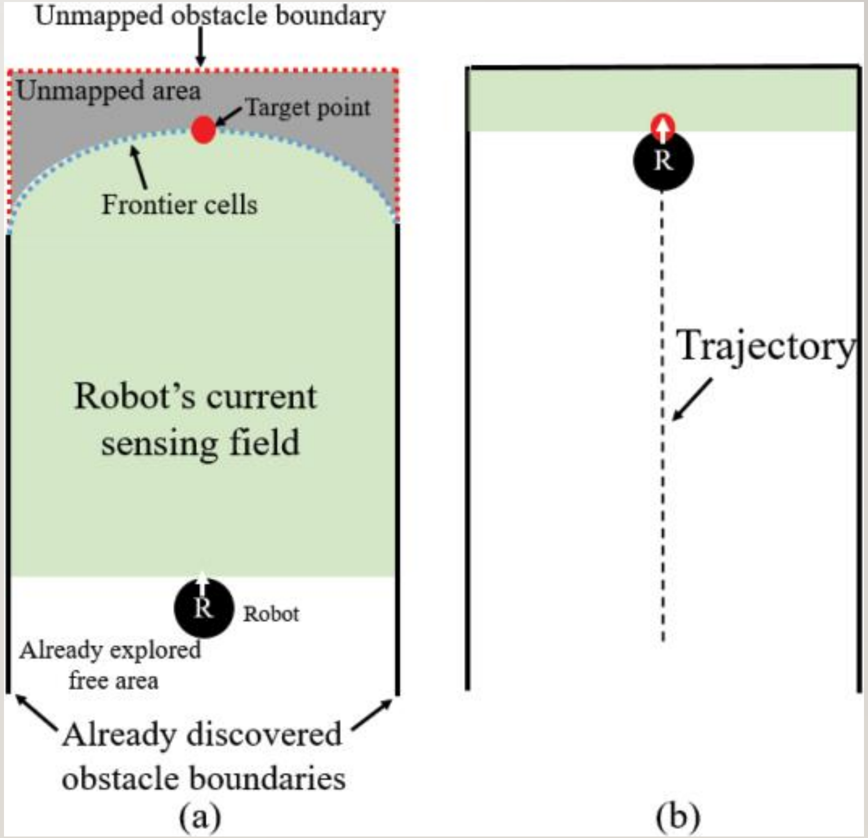
  - Free space: known, unoccupied areas
  - Occupied space: obstacles
  - Unknown space: unexplored

- Frontier Detection

The map is scanned for cells that:

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

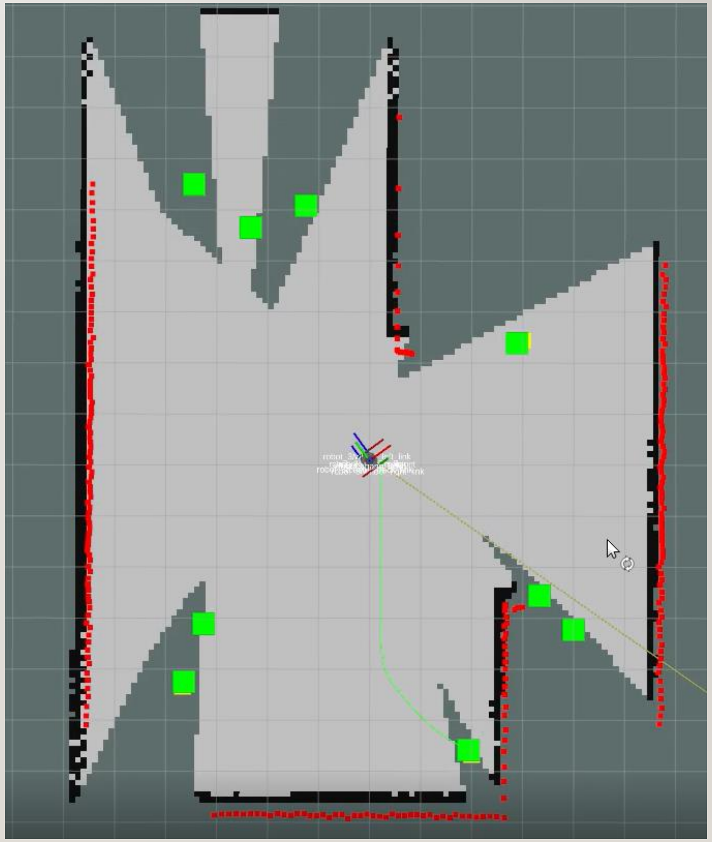
These are marked as frontier cells.



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

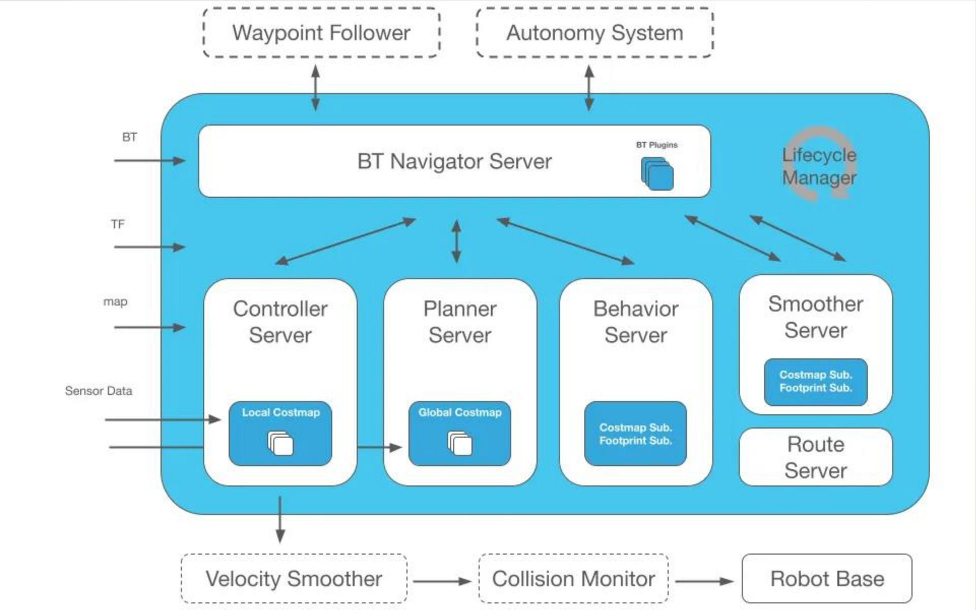
    Send as goal

    If goal fails → blacklist

  If (no frontiers or all blacklisted)

    Terminate exploration

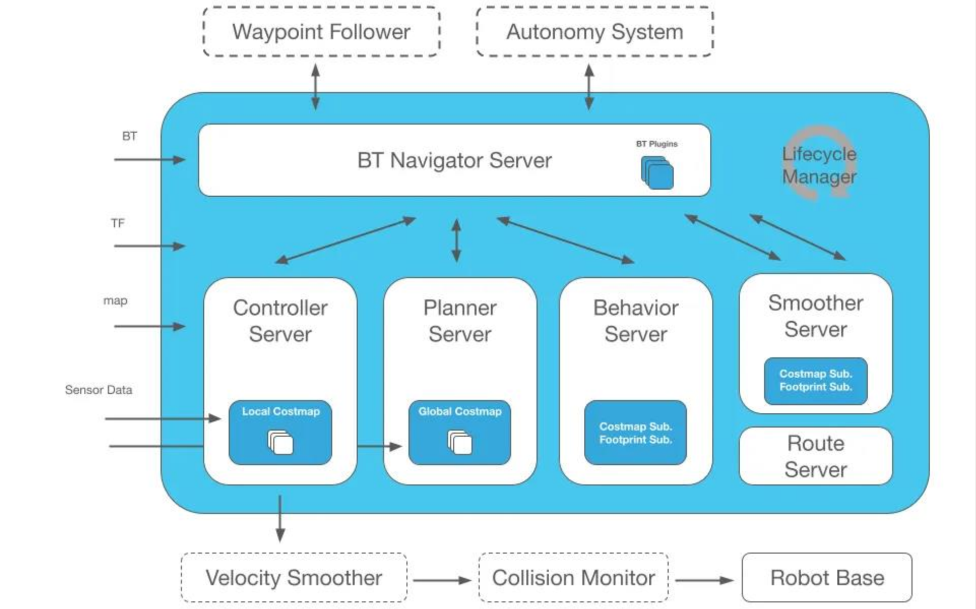
NAV2 IN ONE SENTENCE



- 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.

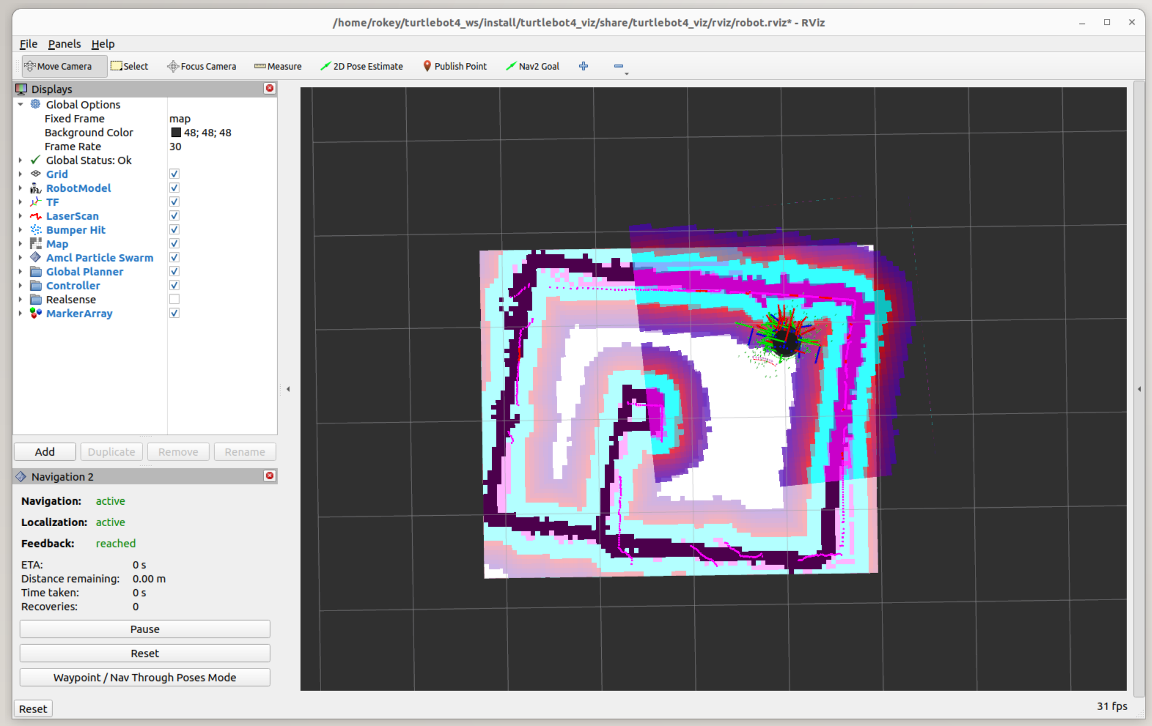
WHO DOES WHAT (CORE SERVERS)



- **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.

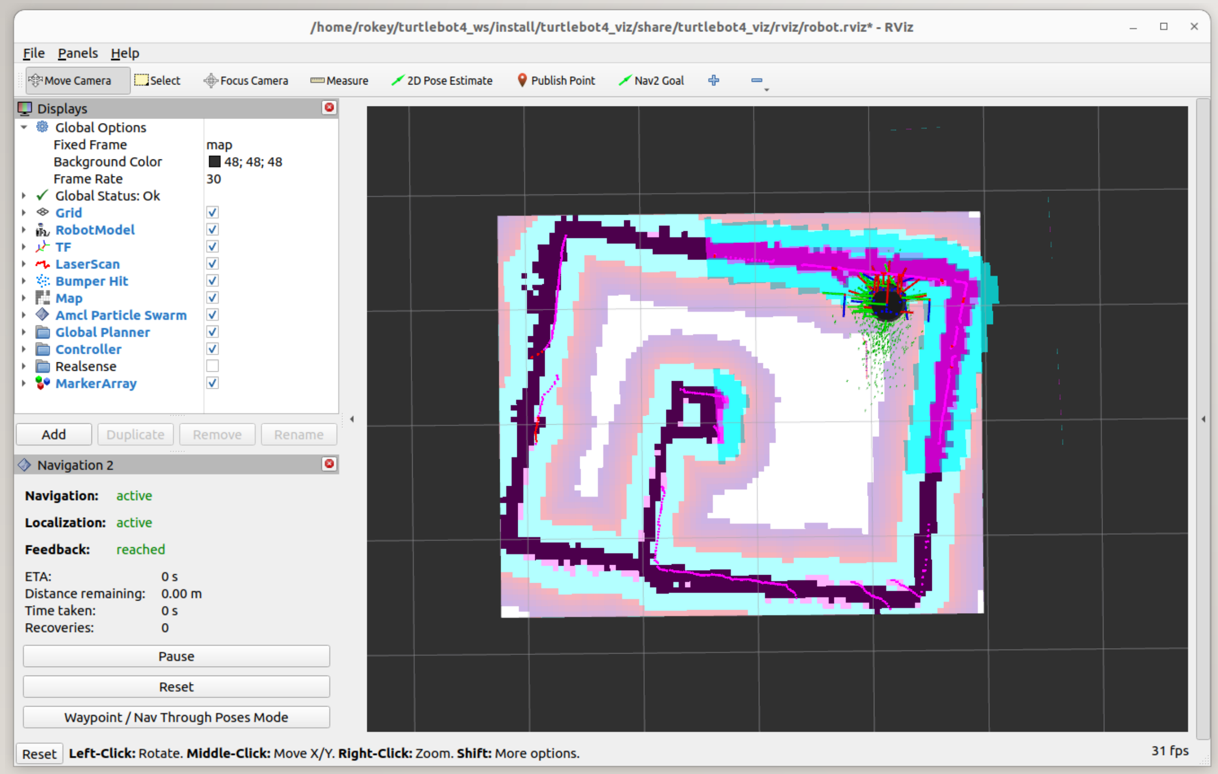
SIMPLE NAV2 PARAM ADJUSTMENT

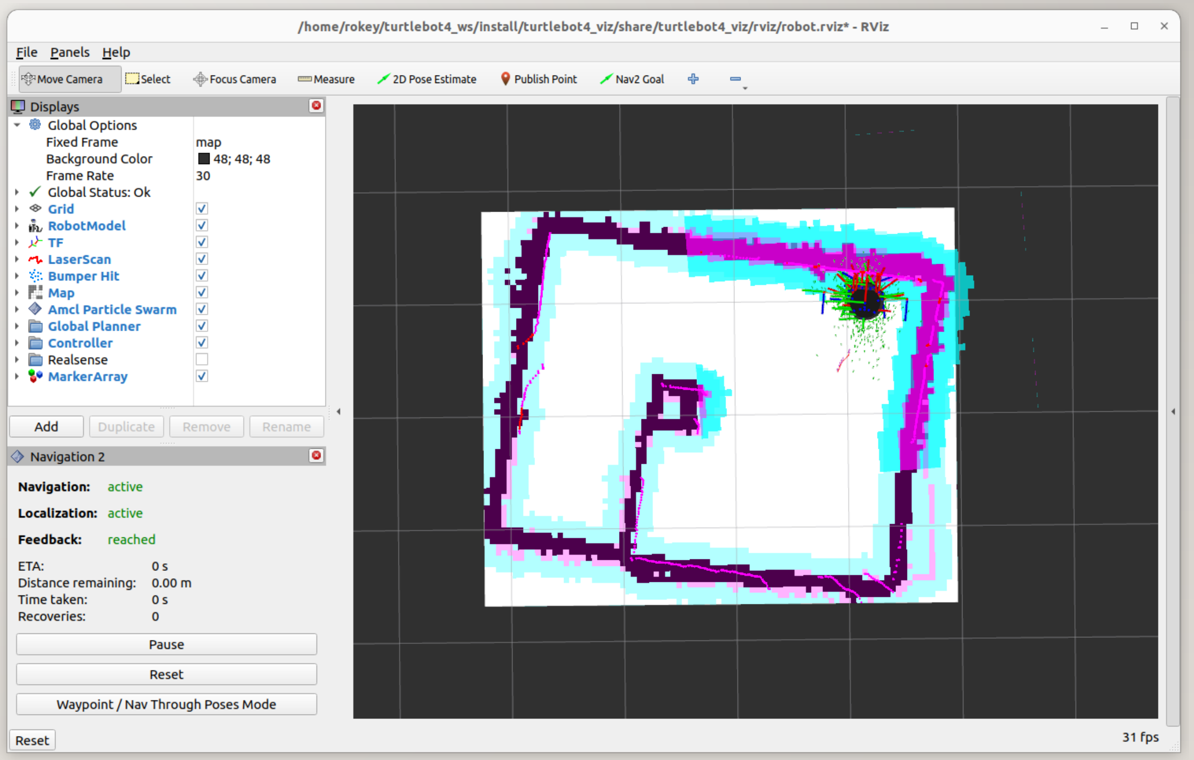
$ cd ~/turtlebot4_ws/src/turtlebot4/turtlebot4_navigation/config

- Change/adjust "inflation_radius" to fit your environment

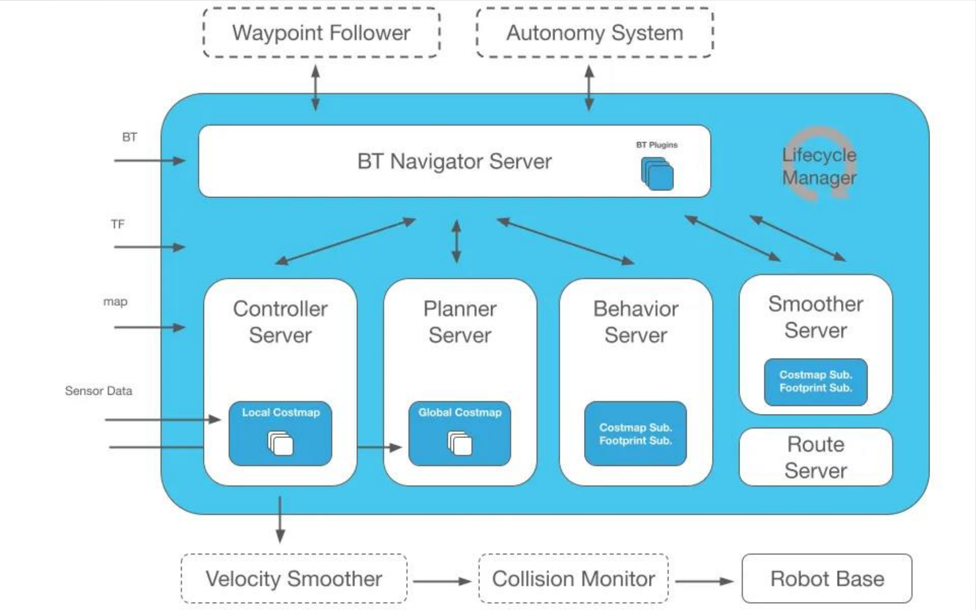
```yaml

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
```

COST MAPS WITH PARAMETER ADJUSTMENTS





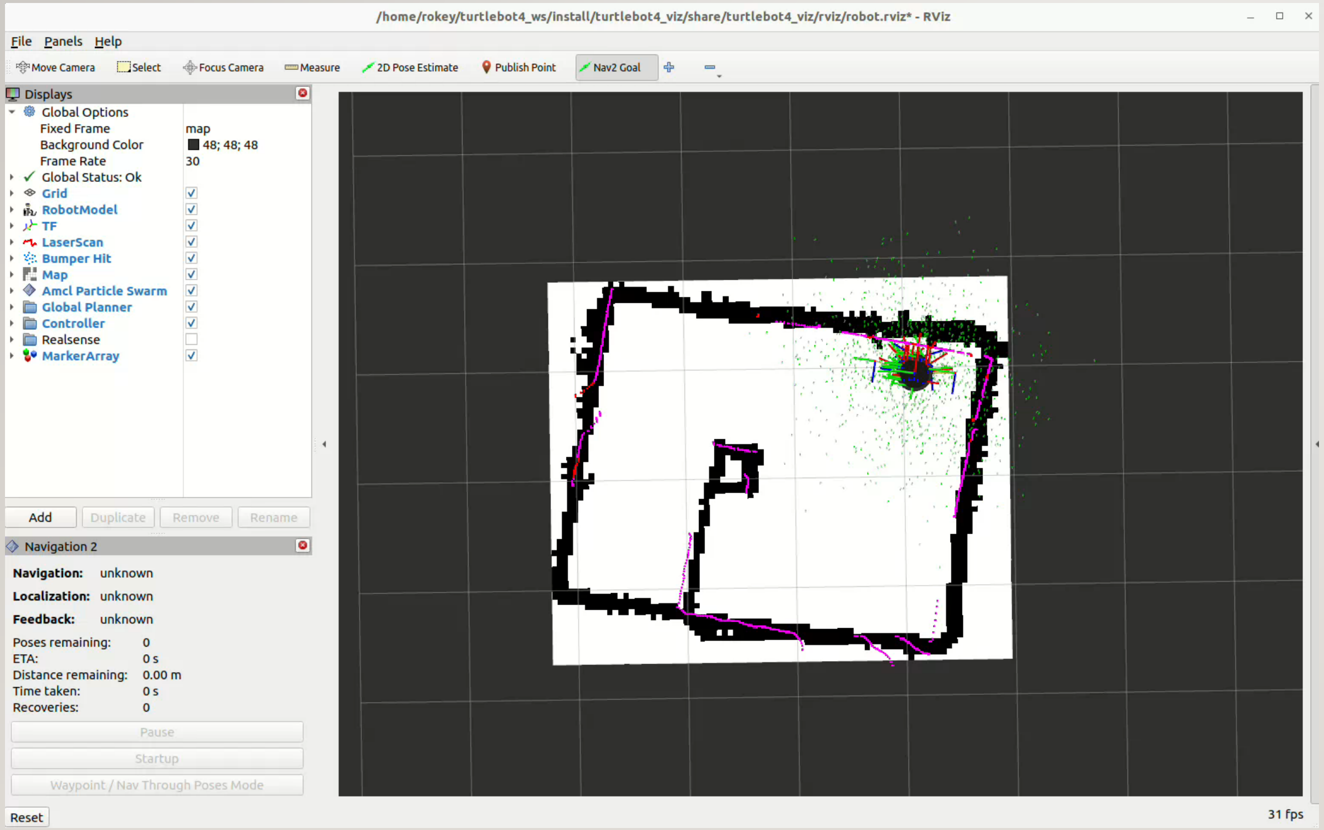
HANDLING REALITY (RECOVERY + SAFETY)



- **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.

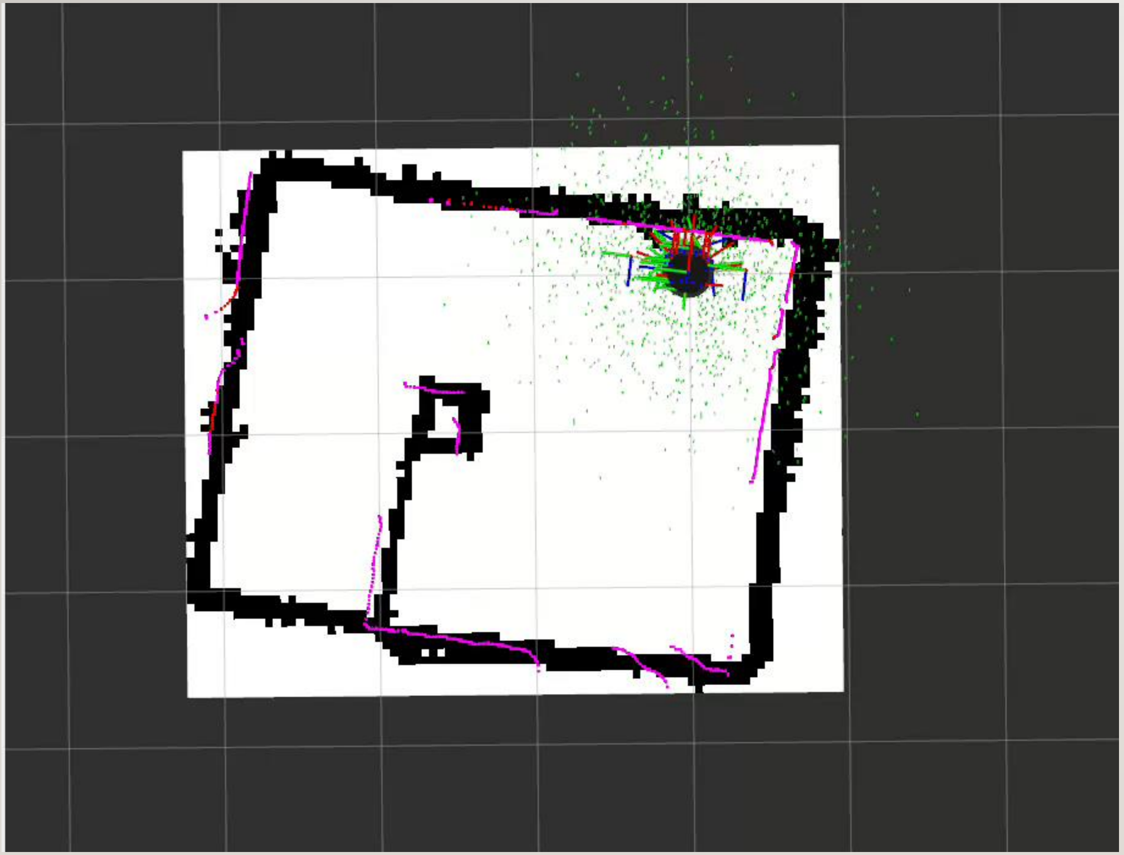
END-TO-END FLOW

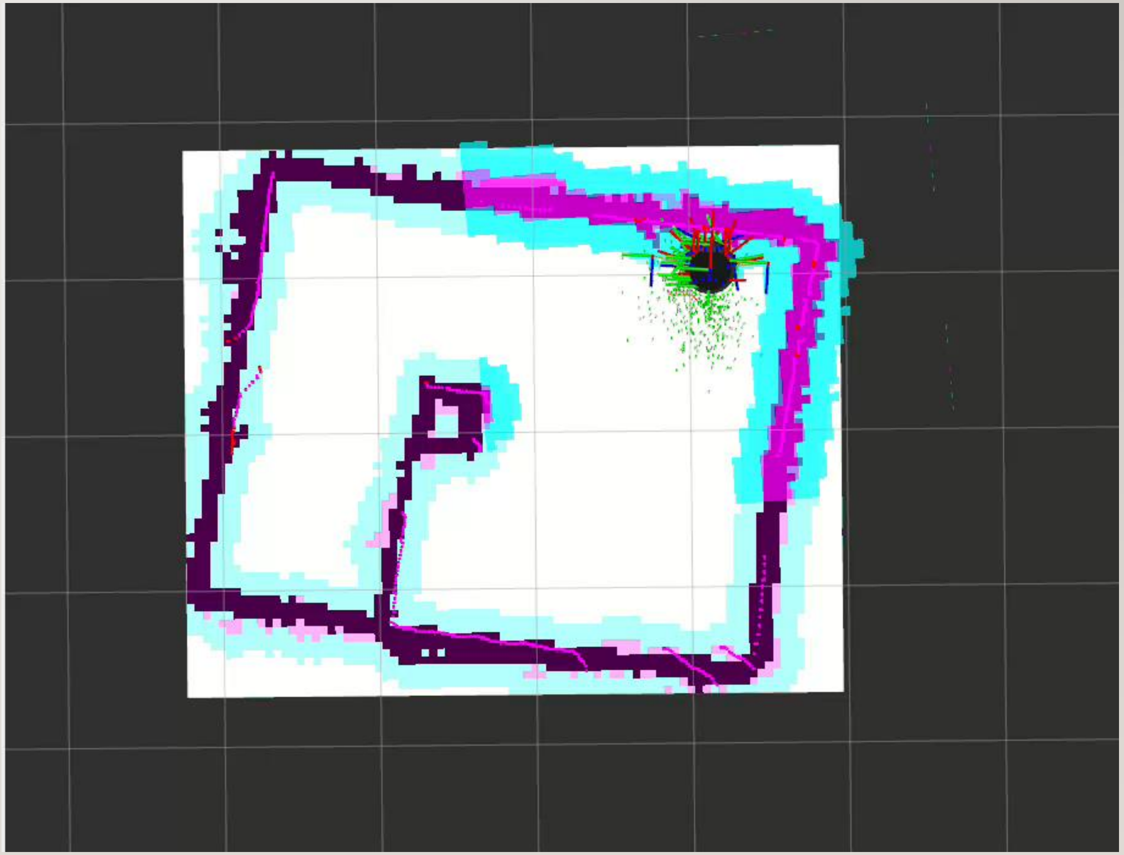


1. Goal arrives
2. BT selects actions
3. Planner creates path
4. Controller drives
5. Safety filters motion
6. Behavior recovers if needed

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

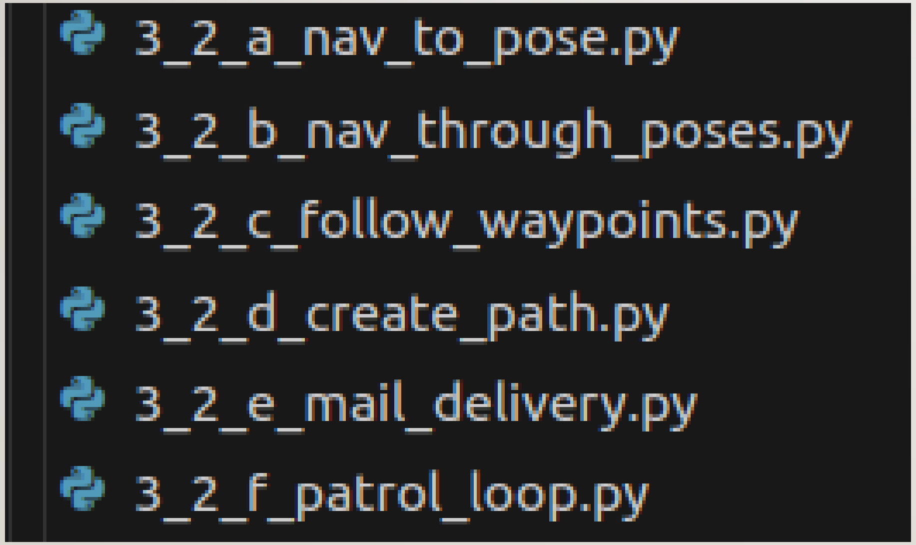
$ ros2 launch turtlebot4_viz view_robot.launch.py namespace:=/robot <n>

- Set Init Pose using 2D_PoseEstimate
- Undock Robot

TERMINAL 3

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

TUTORIAL (ROBOT) EXAMPLE CLI



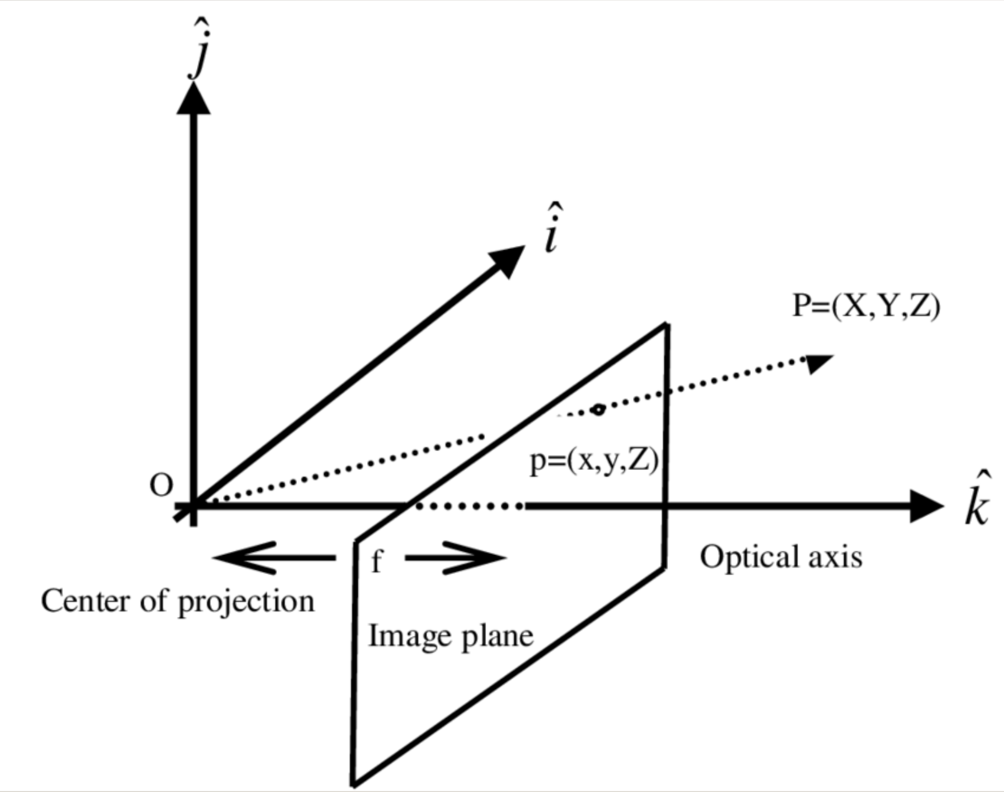
TERMINAL 4

- $ 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)

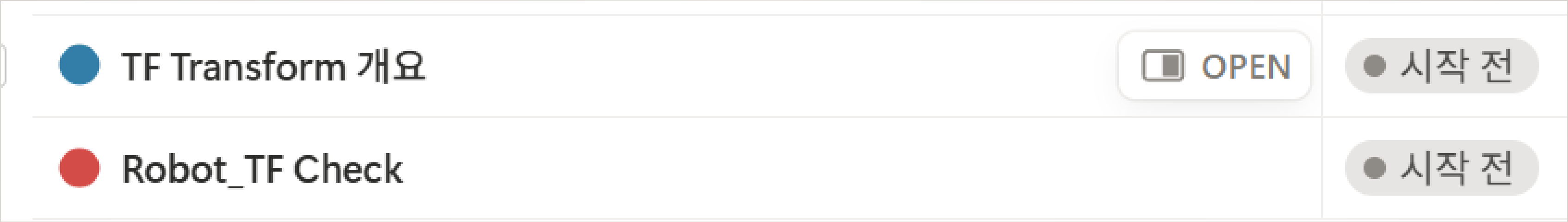
USING DEPTH TO GET MAP COORDINATES (TF TRANSFORM)

CAMERA INTRINSIC AND REPROJECTION

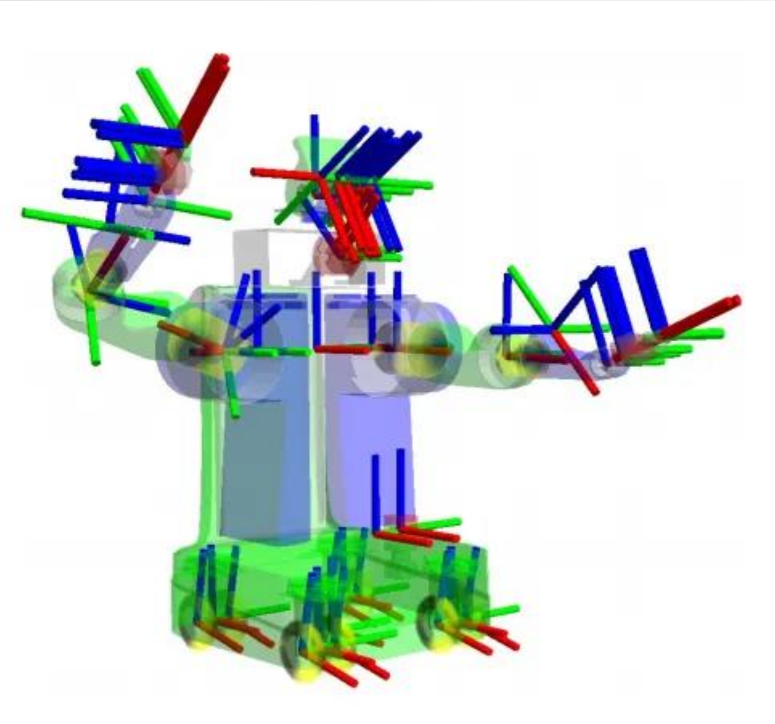


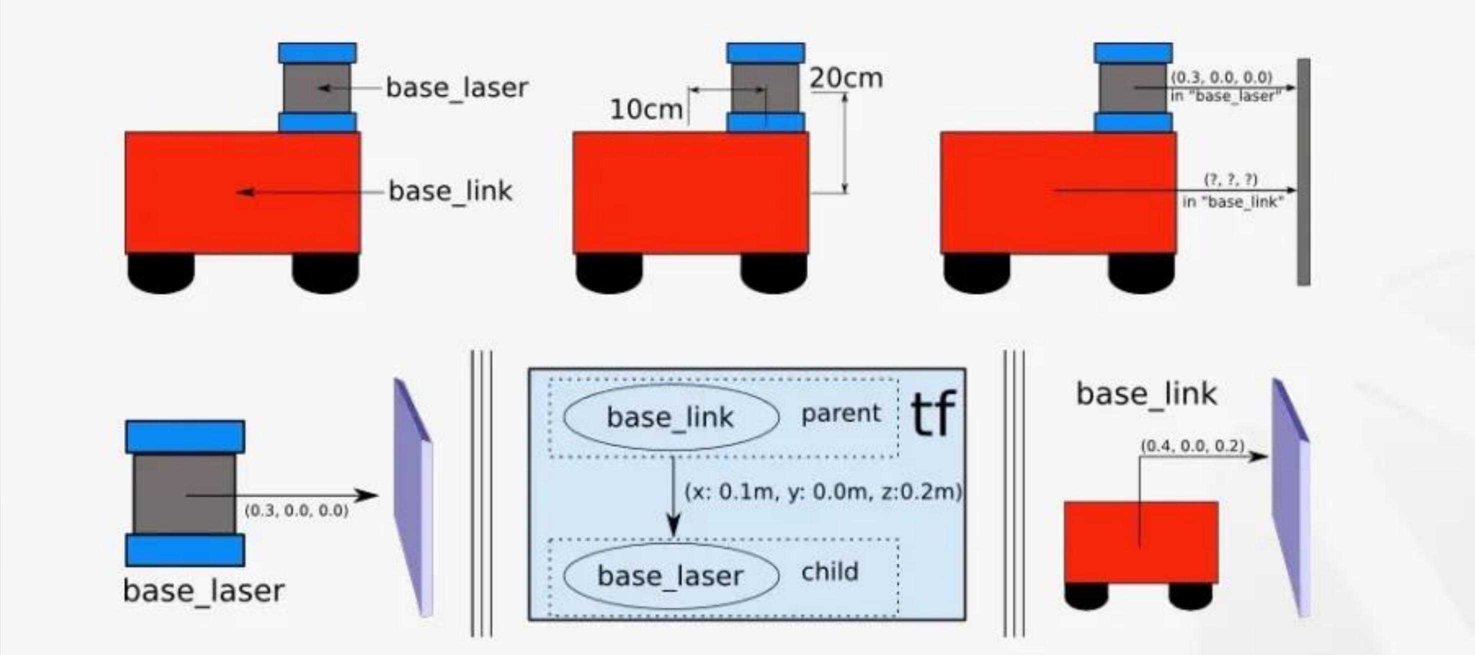
$$X = \frac{(u - c_x) \cdot Z}{f_x}, \quad Y = \frac{(v - c_y) \cdot Z}{f_y}, \quad Z = Z$$

TF TRANSFORM 개요



TF (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.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>

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: ~ 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: ~ 100x8

```
ROS2 humble is activated!
(base) rokey@rokey-Victus-by-HP-Laptop-16-d1xxx:~$ ros2 launch turtlebot4_navigation localization.la
unch.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: ~ 101x18

```
ROS2 humble is activated!
(base) rokey@rokey-Victus-by-HP-Laptop-16-d1xxx:~$ 추가 작업 내용
```

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
```

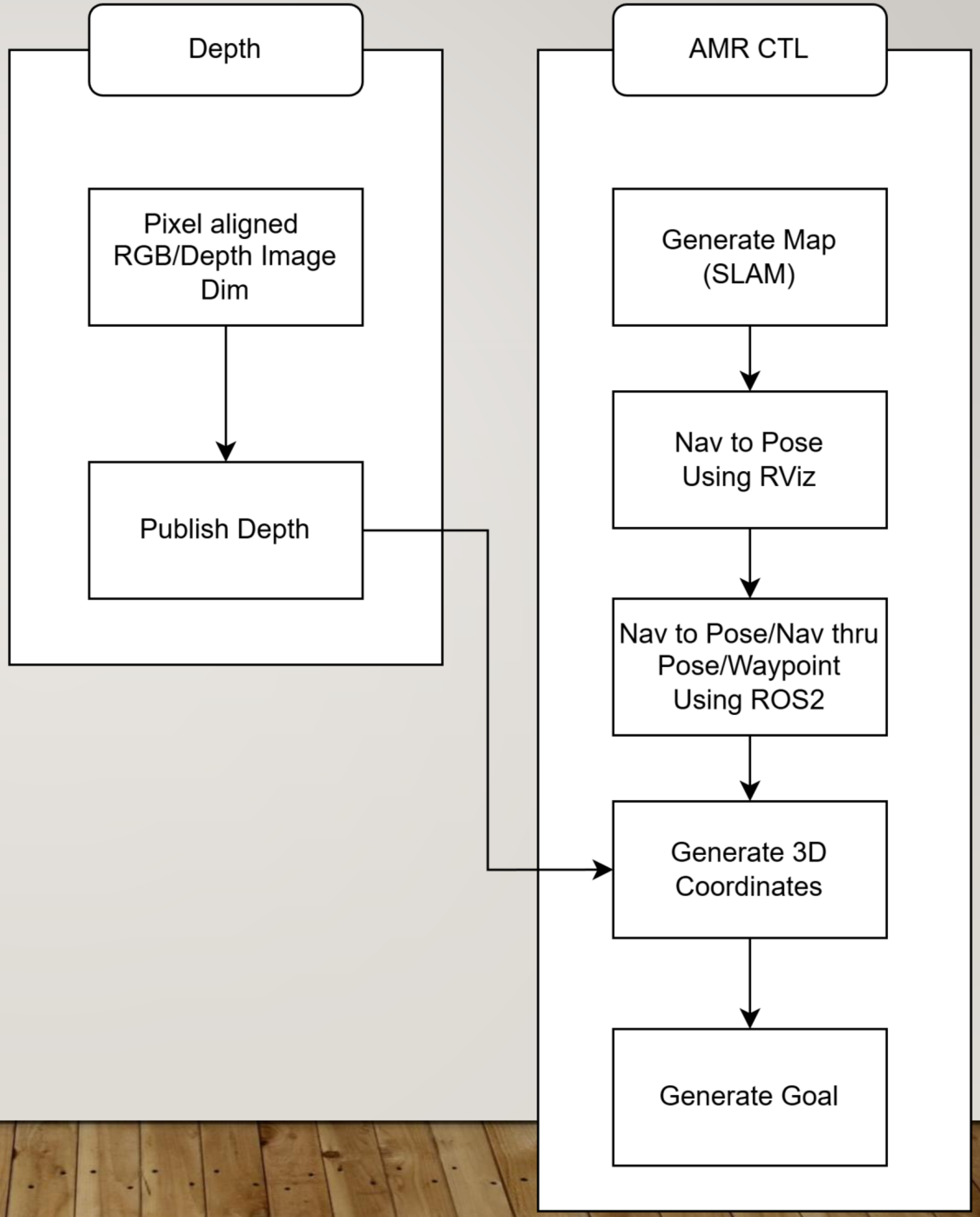
Nav

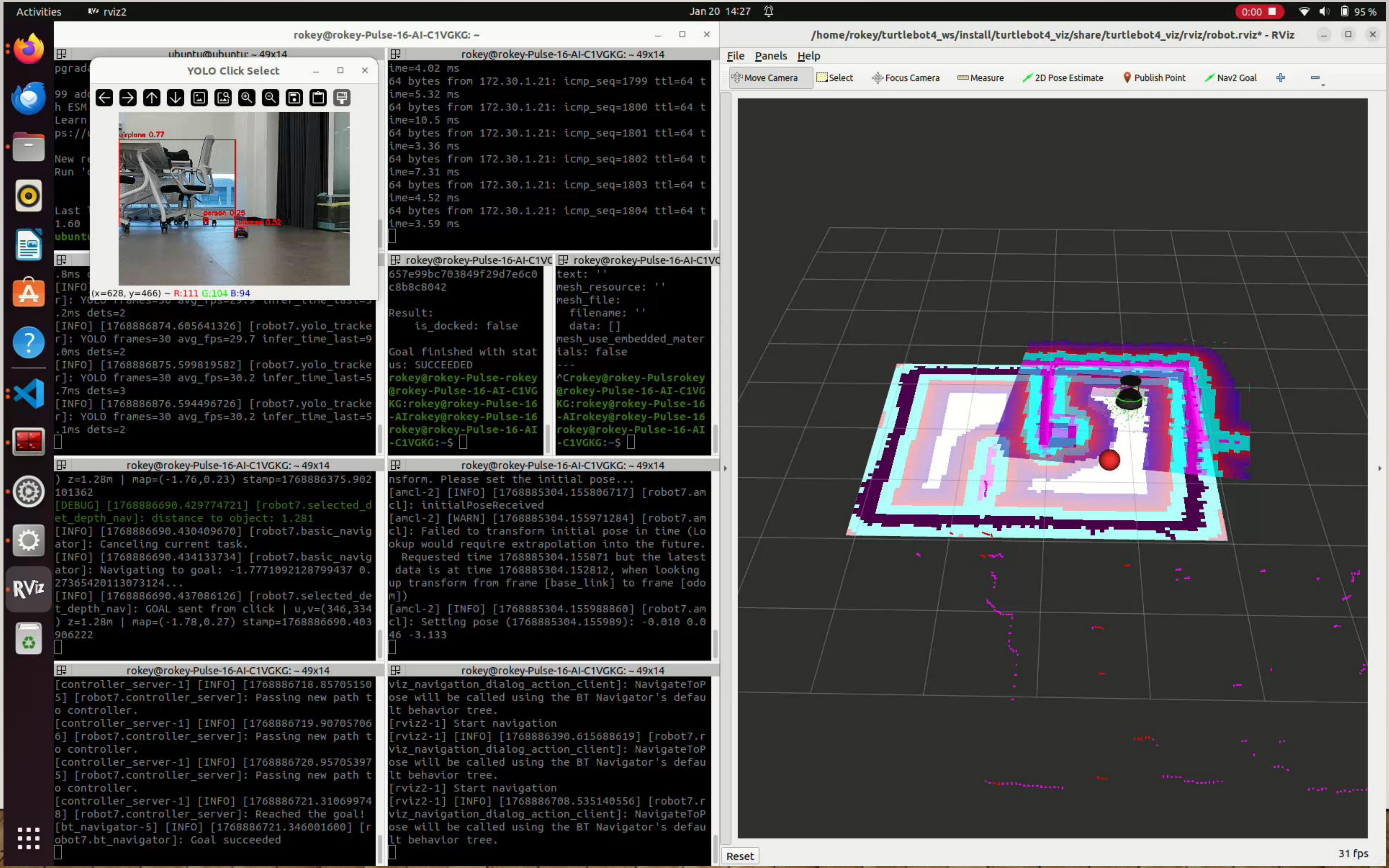
Recommended Terminator Layout

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




Activities
rviz2
Jan 20 14:27
0:00
95 %
rokey@rokey-Pulse-16-AI-C1VGKG: ~
ubuntu@ubuntu: ~ 49x14
YOLO Click Select
airplane 0.77
(x=628, y=466) ~ R:111 G:104 B:94
rokey@rokey-Pulse-16-AI-C1VGKG: ~ 49x14
ime=4.02 ms
64 bytes from 172.30.1.21: icmp_seq=1799 ttl=64 t
ime=5.32 ms
64 bytes from 172.30.1.21: icmp_seq=1800 ttl=64 t
ime=10.5 ms
64 bytes from 172.30.1.21: icmp_seq=1801 ttl=64 t
ime=3.36 ms
64 bytes from 172.30.1.21: icmp_seq=1802 ttl=64 t
ime=7.31 ms
64 bytes from 172.30.1.21: icmp_seq=1803 ttl=64 t
ime=4.52 ms
64 bytes from 172.30.1.21: icmp_seq=1804 ttl=64 t
ime=3.59 ms
.2ms dets=2
[INFO] [1768886874.605641326] [robot7.yolo_tracker]: YOLO frames=30 avg_fps=29.7 infer_time_last=9.0ms dets=2
[INFO] [1768886875.599819582] [robot7.yolo_tracker]: YOLO frames=30 avg_fps=30.2 infer_time_last=5.7ms dets=3
[INFO] [1768886876.594496726] [robot7.yolo_tracker]: YOLO frames=30 avg_fps=30.2 infer_time_last=5.1ms dets=2
657e99bc703849f29d7e6c0c8b8c8042
Result:
is_docked: false
Goal finished with status: SUCCEEDED
text: ''
mesh_resource: ''
mesh_file:
filename: ''
data: []
mesh_use_embedded_materials: false
rokey@rokey-Pulse-16-AI-C1VGKG: ~ 49x14
) z=1.28m | map=(-1.76,0.23) stamp=1768886375.902101362
[DEBUG] [1768886690.429774721] [robot7.selected_det_depth_nav]: distance to object: 1.281
[INFO] [1768886690.430409670] [robot7.basic_navigator]: Canceling current task.
[INFO] [1768886690.434133734] [robot7.basic_navigator]: Navigating to goal: -1.7771092128799437 0.27365420113073124...
[INFO] [1768886690.437086126] [robot7.selected_det_depth_nav]: GOAL sent from click | u,v=(346,334) z=1.28m | map=(-1.78,0.27) stamp=1768886690.403906222
nsform. Please set the initial pose...
[amcl-2] [INFO] [1768885304.155806717] [robot7.amcl]: initialPoseReceived
[amcl-2] [WARN] [1768885304.155971284] [robot7.amcl]: Failed to transform initial pose in time (Lookup would require extrapolation into the future. Requested time 1768885304.155871 but the latest data is at time 1768885304.152812, when looking up transform from frame [base_link] to frame [odom])
[amcl-2] [INFO] [1768885304.155988860] [robot7.amcl]: Setting pose (1768885304.155989): -0.010 0.046 -3.133
[controller_server-1] [INFO] [1768886718.857051505] [robot7.controller_server]: Passing new path to controller.
[controller_server-1] [INFO] [1768886719.907057066] [robot7.controller_server]: Passing new path to controller.
[controller_server-1] [INFO] [1768886720.957053975] [robot7.controller_server]: Passing new path to controller.
[controller_server-1] [INFO] [1768886721.310699748] [robot7.controller_server]: Reached the goal!
[bt_navigator-5] [INFO] [1768886721.346001600] [robot7.bt_navigator]: Goal succeeded
viz_navigation_dialog_action_client]: NavigateToPose will be called using the BT Navigator's default behavior tree.
[rviz2-1] Start navigation
[rviz2-1] [INFO] [1768886390.615688619] [robot7.rviz_navigation_dialog_action_client]: NavigateToPose will be called using the BT Navigator's default behavior tree.
[rviz2-1] Start navigation
[rviz2-1] [INFO] [1768886708.535140556] [robot7.rviz_navigation_dialog_action_client]: NavigateToPose will be called using the BT Navigator's default behavior tree.
/home/rokey/turtlebot4_ws/install/turtlebot4_viz/share/turtlebot4_viz/rviz/robot.rviz* - RViz
File
Panels
Help
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
Publish Point
Nav2 Goal
Reset
31 fps

프로젝트 RULE NUMBER ONE!!!

Are we still having FUN!