

Cartographer-SLAM mapping

This lesson uses the Raspberry Pi as an example.

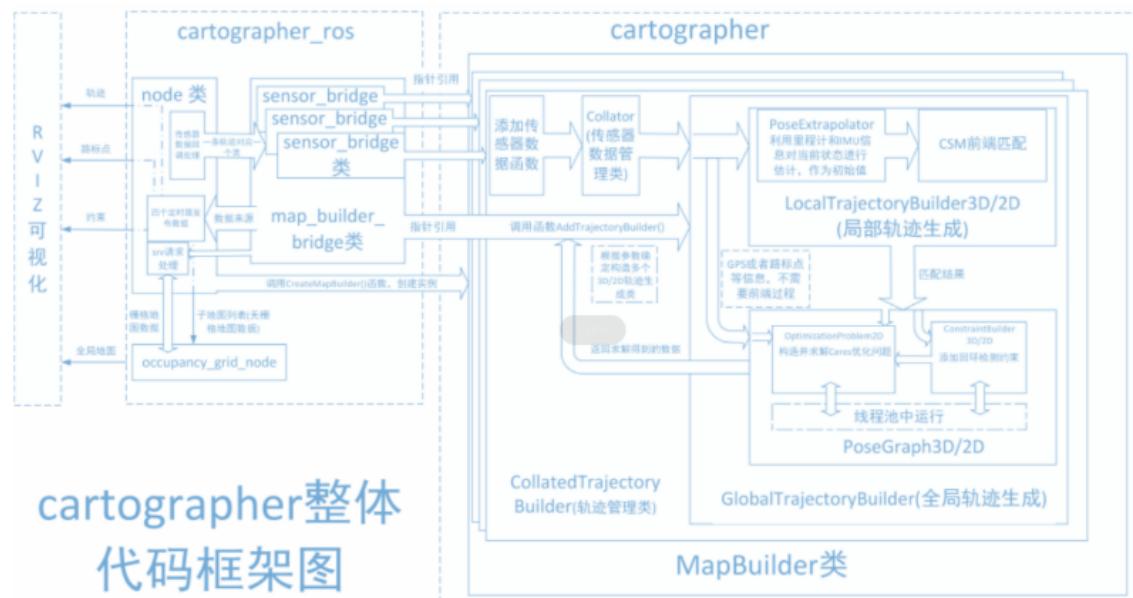
For Raspberry Pi and Jetson-Nano boards, you need to open a terminal on the host computer and enter the command to enter the Docker container. Once inside the Docker container, enter the commands mentioned in this lesson in the terminal. For instructions on entering the Docker container from the host computer, refer to [01. Robot Configuration and Operation Guide] -- [4.Enter Docker (For JETSON Nano and RPi 5)].

For RDKX5 and Orin boards, simply open a terminal and enter the commands mentioned in this lesson.

1. Algorithm Introduction

Cartographer is an open-source 2D and 3D SLAM (simultaneous localization and mapping) library from Google, supported by the ROS system. This mapping algorithm uses graph optimization (multi-threaded backend optimization and problem optimization built using Cere). It combines data from multiple sensors (such as LIDAR, IMU, and cameras) to simultaneously calculate the sensor positions and map the surrounding environment.

The Cartographer source code consists of three main parts: cartographer, cartographer_ros, and ceres-solver (backend optimization).



Cartographer uses a mainstream SLAM framework, specifically a three-step process consisting of feature extraction, loop closure detection, and backend optimization. A certain number of laser scans form a submap, and a series of submaps form the global map. While the short-term cumulative error of constructing submaps using laser scans is small, the long-term cumulative error of constructing the global map using submaps is significant. Therefore, loop closure detection is required to correct the positions of these submaps. The basic unit of loop closure detection is the submap, which uses the scan_match strategy. Cartographer focuses on creating submaps that fuse multi-sensor data (odometry, IMU, laser scans, etc.) and implementing the scan_match strategy for loop closure detection.

cartographer_ros runs under ROS and receives various sensor data as ROS messages. After processing, it publishes the data as messages, facilitating debugging and visualization.

2. Program Functionality

After running the program, the map creation interface will appear in rviz. Use the keyboard or gamepad to control the car's movements until the map is complete. Then, run the save map command to save the map.

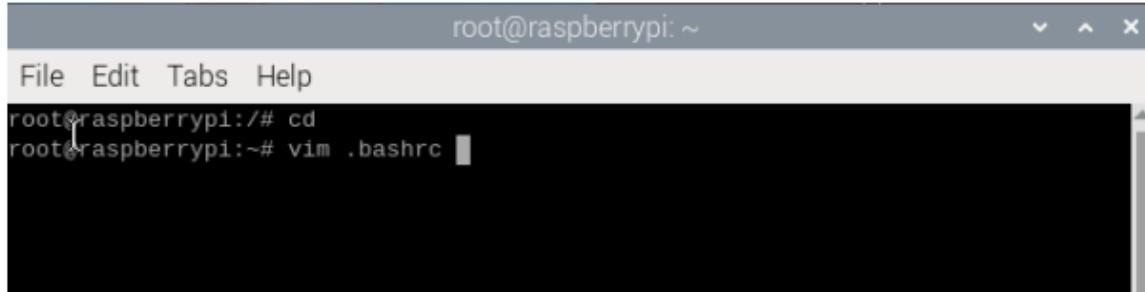
3. Pre-Use Configuration

This car is equipped with a USB camera, a depth camera, and two different types of lidar. However, since it cannot automatically identify the devices, you need to manually set the machine type and lidar model.

For Raspberry Pi and Jetson-Nano boards, you need to enter the Docker container first. For RDKX5 and Orin controllers, this is not necessary.

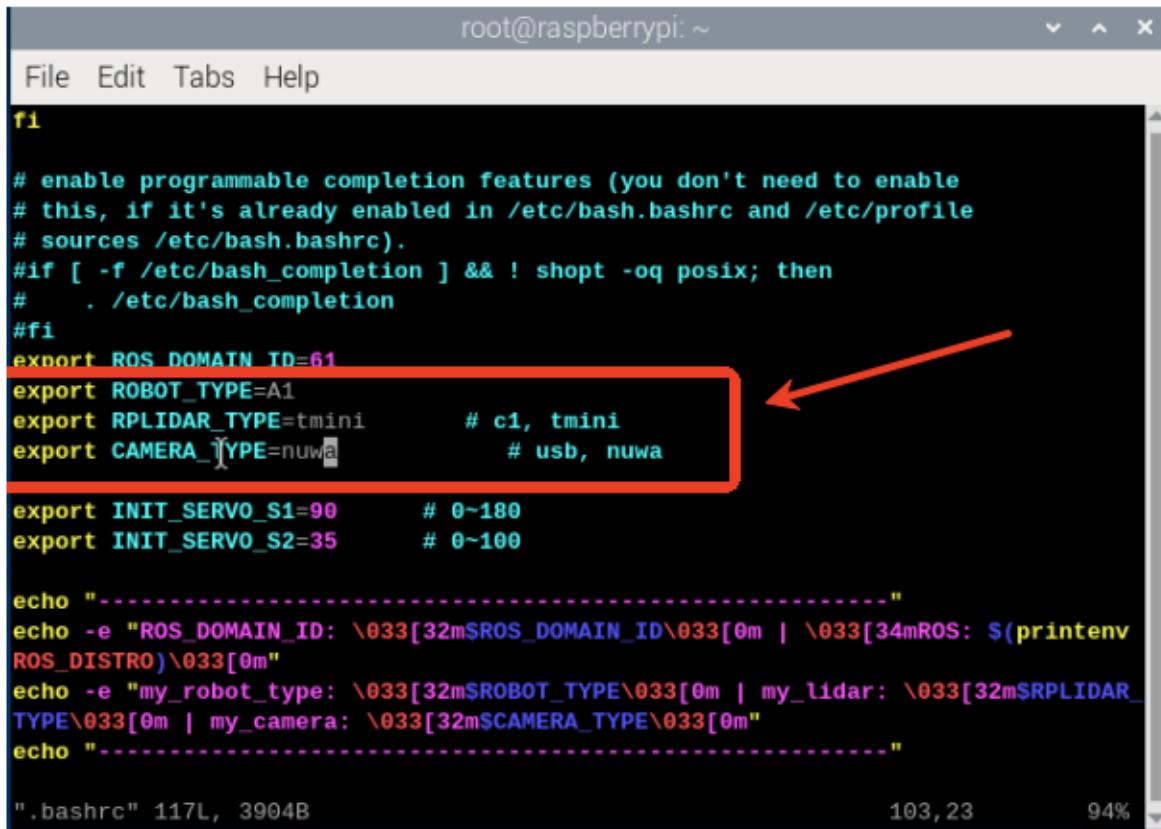
Change the following settings based on the car model, radar type, and camera type.

```
root@ubuntu:/# cd  
root@ubuntu:~# vim .bashrc
```



A screenshot of a terminal window titled "root@raspberrypi: ~". The window has a menu bar with "File", "Edit", "Tabs", and "Help". The main area shows the command "root@raspberrypi:/# vim .bashrc" being typed. The cursor is positioned after ".bashrc".

Find this location and press i on your keyboard to change the settings to the corresponding camera and radar models. The default settings are tmini and nuwa.



```

root@raspberrypi: ~
File Edit Tabs Help
fi

# enable programmable completion features (you don't need to enable
# this, if it's already enabled in /etc/bash.bashrc and /etc/profile
# sources /etc/bash.bashrc).
#if [ -f /etc/bash_completion ] && ! shopt -oq posix; then
#    . /etc/bash_completion
#fi
export ROS_DOMAIN_ID=61
export ROBOT_TYPE=A1
export RPLIDAR_TYPE=tmini      # c1, tmini
export CAMERA_TYPE=nuwa        # usb, nuwa

export INIT_SERVO_S1=90         # 0~180
export INIT_SERVO_S2=35         # 0~100

echo "-----"
echo -e "ROS_DOMAIN_ID: \033[32m$ROS_DOMAIN_ID\033[0m | \033[34mROS: $(printenv
ROS_DISTRO)\033[0m"
echo -e "my_robot_type: \033[32m$ROBOT_TYPE\033[0m | my_lidar: \033[32m$RPLIDAR_
TYPE\033[0m | my_camera: \033[32m$CAMERA_TYPE\033[0m"
echo "-----"
".bashrc" 117L, 3904B          103, 23           94%

```

After completing the modification, save and exit vim, then execute:

```

root@raspberrypi:~# source .bashrc
-----
ROS_DOMAIN_ID: 61 | ROS: humble
my_robot_type: M1 | my_lidar: tmini | my_camera: nuwa
-----
root@raspberrypi:~

```

```

root@raspberrypi:~# source .bashrc
-----
ROS_DOMAIN_ID: 61 | ROS: humble
my_robot_type: A1 | my_lidar: tmini | my_camera: nuwa
-----
root@raspberrypi:~#

```

4. Program Startup

4.1. Startup Command

For Raspberry Pi and Jetson-Nano boards, you need to enter the Docker container first. For RDKX5 and Orin controllers, this is not necessary.

Enter the Docker container (see [Docker course] --- [4. Docker Startup Script] for steps).

All the following commands must be executed within the same Docker container (see [Docker course] --- [3. Docker Submission and Multi-Terminal Access] for steps).

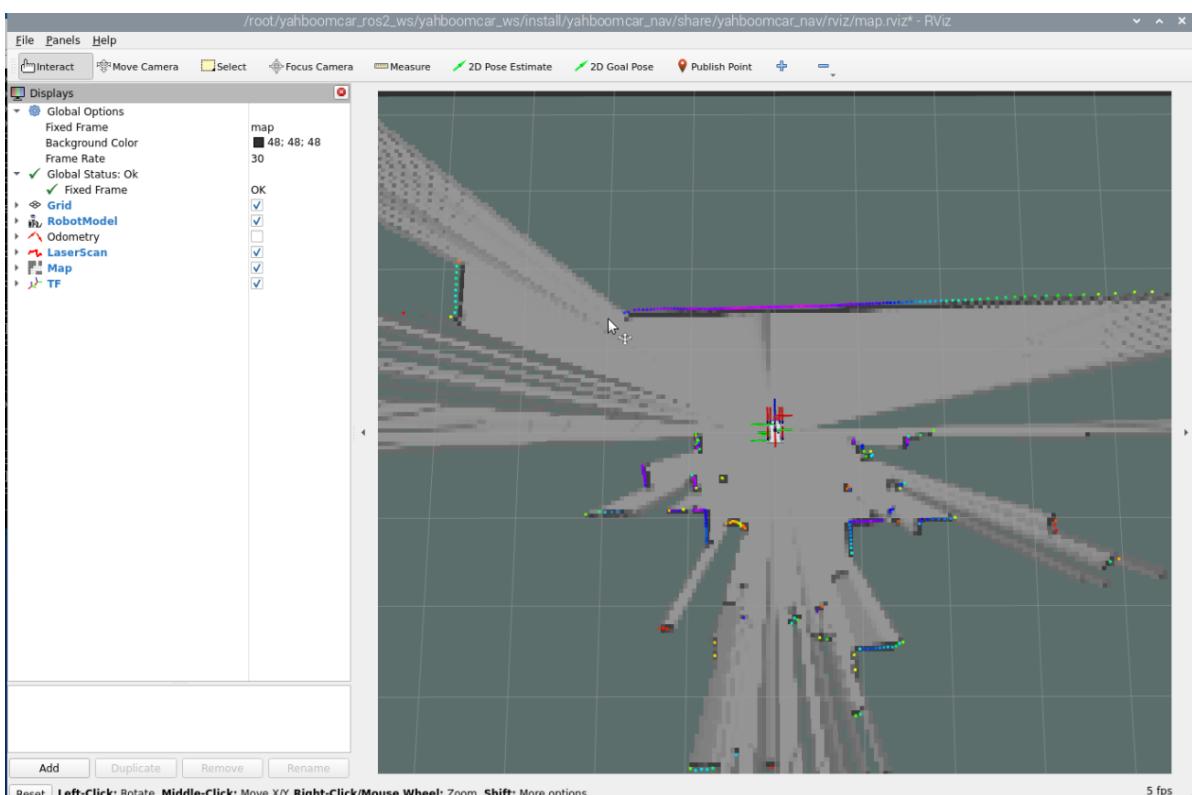
Start Mapping

```
ros2 launch yahboomcar_nav map_cartographer_launch.py
```

```
root@raspberrypi: ~
File Edit Tabs Help
[cartographer_node-10] [INFO] [1754992198.324240249] [cartographer logger]: I0812 17:49:58.000000 84716 configuration_file_resolver.cc:126] Found '/root/yahboomcar_ros2_ws/software/library_ws/install/cartographer/share/cartographer/configuration_files/trajectory_builder_3d.lua' trajectory_builder_3d.lua'.
[cartographer_node-10] [INFO] [1754992198.414717598] [cartographer logger]: I0812 17:49:58.000000 84716 map_builder_bridge.cpp:151] Added trajectory with ID '0'.
[ydlidar_ros2_driver_node-7] [YDLIDAR] Lidar running correctly! The health status: good
[joint_state_publisher-1] [INFO] [1754992198.644228005] [joint_state_publisher]: Waiting for robot_description to be published on the robot_description topic...
[ydlidar_ros2_driver_node-7] [YDLIDAR] Baseplate device info
[ydlidar_ros2_driver_node-7] Firmware version: 1.2
[ydlidar_ros2_driver_node-7] Hardware version: 1
[ydlidar_ros2_driver_node-7] Model: Tmini Plus
[ydlidar_ros2_driver_node-7] Serial: 2025021500090139
[imu_filter_madgwick_node-4] [INFO] [1754992198.811280755] [imu_filter_madgwick]: First IMU message received.
[joy_node-6] [INFO] [1754992198.828650700] [joy_node]: No haptic (rumble) available, skipping initialization
[joy_node-6] [INFO] [1754992198.828792421] [joy_node]: Opened joystick: Controller. deadzone: 0.050000
[ydlidar_ros2_driver_node-7] [YDLIDAR] Current scan frequency: 10.00Hz
[ydlidar_ros2_driver_node-7] [YDLIDAR] Lidar init success, Elapsed time 962 ms
[ydlidar_ros2_driver_node-7] [YDLIDAR] Create thread 0xFA4068E0
[ydlidar_ros2_driver_node-7] [YDLIDAR] Successed to start scan mode, Elapsed time 2096 ms
[ydlidar_ros2_driver_node-7] [YDLIDAR] Fixed Size: 404
[ydlidar_ros2_driver_node-7] [YDLIDAR] Sample Rate: 4.00K
[ydlidar_ros2_driver_node-7] [YDLIDAR] Successed to check the lidar, Elapsed time 0 ms
[ydlidar_ros2_driver_node-7] [2025-08-12 17:50:01][info] [YDLIDAR] Now lidar is scanning...
[cartographer_node-10] [INFO] [1754992201.074539309] [cartographer logger]: I0812 17:50:01.000000 84716 ordered_multi_queue.cc:172] All sensor data for trajectory 0 is available starting at '638905890009774930'.
[cartographer_node-10] [WARN] [1754992201.076218965] [cartographer logger]: W0812 17:50:01.000000 84716 pose_extrapolator.cc:168] Queue too short for velocity estimation. Queue duration: 0 s
[cartographer_node-10] [INFO] [1754992201.078030194] [cartographer logger]: I0812 17:50:01.000000 84716 pose_graph_2d.cc:148] Inserted submap (0, 0).
```

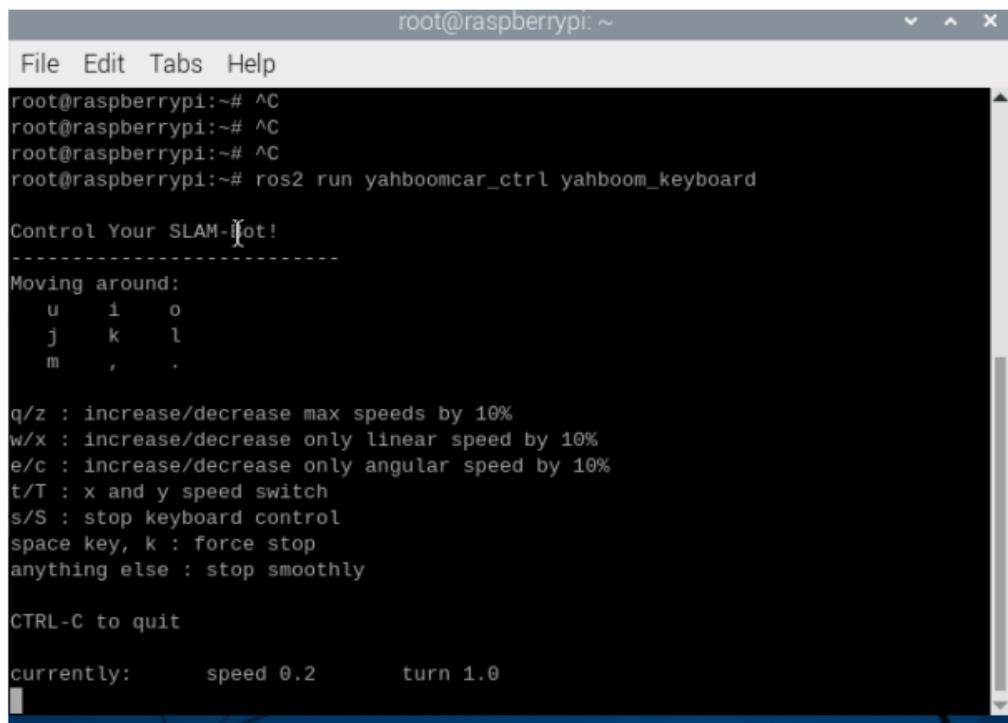
Enter the command to start rviz visualization mapping.

```
ros2 launch yahboomcar_nav display_map.launch.py
```



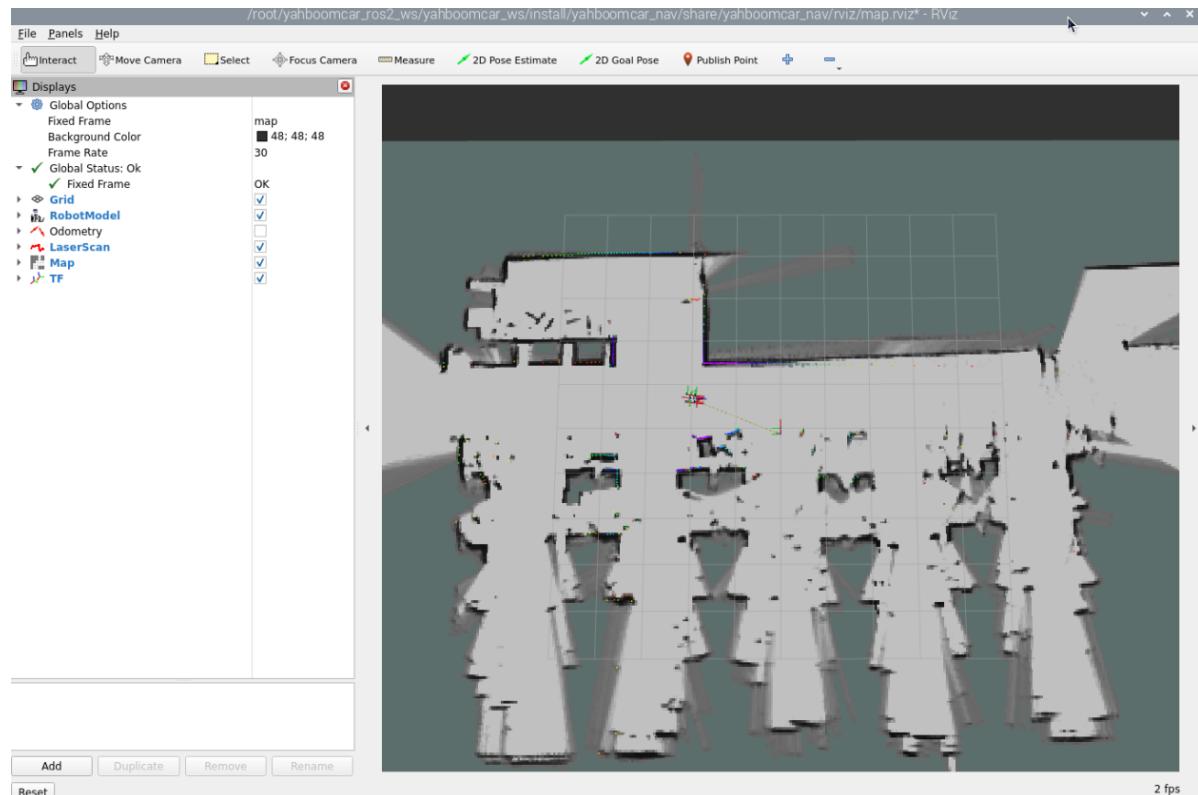
The program has controller control enabled by default. If you're using a controller, you can now connect it directly to the receiver for control. If you prefer keyboard control, enter this in the terminal:

```
#keyboard  
ros2 run yahboomcar_ctrl yahboom_keyboard
```



```
root@raspberrypi: ~  
File Edit Tabs Help  
root@raspberrypi:~# ^C  
root@raspberrypi:~# ^C  
root@raspberrypi:~# ^C  
root@raspberrypi:~# ros2 run yahboomcar_ctrl yahboom_keyboard  
  
Control Your SLAM-Iot!  
-----  
Moving around:  
    u    i    o  
    j    k    l  
    m    ,    .  
  
q/z : increase/decrease max speeds by 10%  
w/x : increase/decrease only linear speed by 10%  
e/c : increase/decrease only angular speed by 10%  
t/T : x and y speed switch  
s/S : stop keyboard control  
space key, K : force stop  
anything else : stop smoothly  
  
CTRL-C to quit  
  
currently:      speed 0.2      turn 1.0
```

Then control the car to slowly navigate the area to be mapped.



After mapping, enter the following command to save the map. In the terminal, enter:

```
ros2 launch yahboomcar_nav save_map.launch.py
```

```

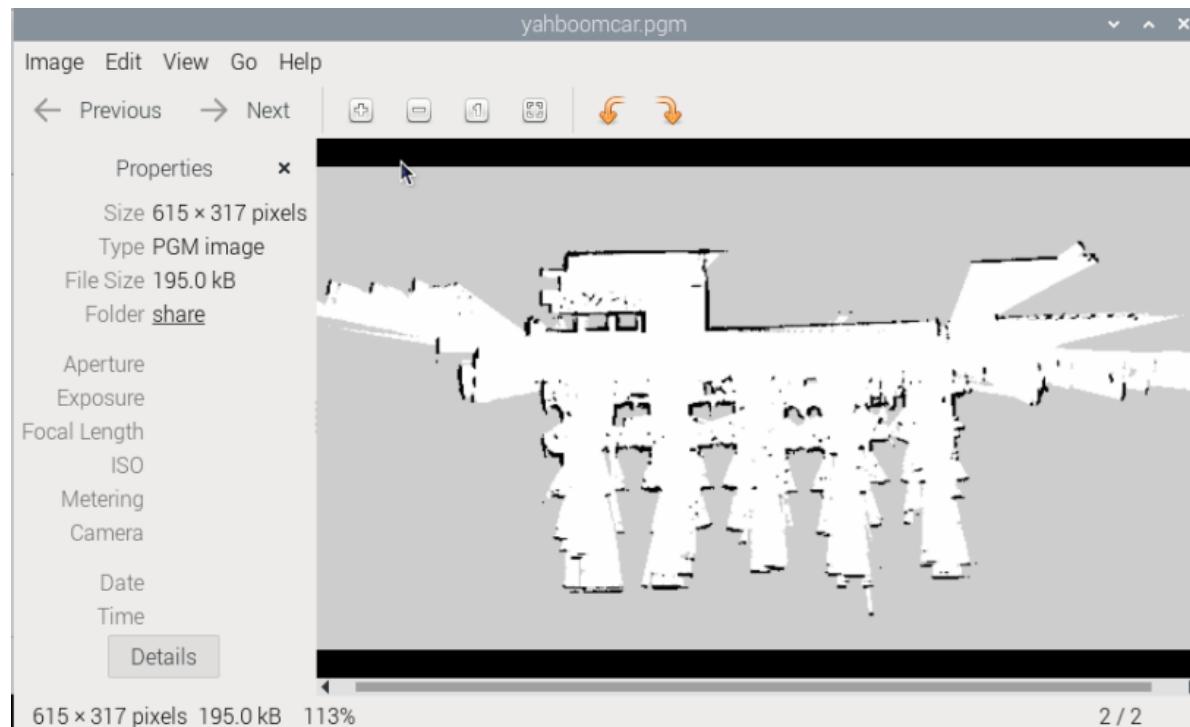
root@raspberrypi: / 
File Edit Tabs Help
[INFO] [map_saver_cli-1]: process started with pid [85580]
[map_saver_cli-1] [INFO] [1754993160.071993975] [map_saver]: 
[map_saver_cli-1]      map_saver lifecycle node launched.
[map_saver_cli-1]      Waiting on external lifecycle transitions to activate
[map_saver_cli-1]      See https://design.ros2.org/articles/node_lifecycle.html for more information.
[map_saver_cli-1] [INFO] [1754993160.072179828] [map_saver]: Creating
[map_saver_cli-1] [INFO] [1754993160.072646034] [map_saver]: Configuring
[map_saver_cli-1] [INFO] [1754993160.076916391] [map_saver]: Saving map from 'map' topic to '/root/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar' file
[map_saver_cli-1] [WARN] [1754993160.077106800] [map_saver]: Free threshold unspecified. Setting it to default value: 0.250000
[map_saver_cli-1] [WARN] [1754993160.077128078] [map_saver]: Occupied threshold unspecified. Setting it to default value: 0.650000
[map_saver_cli-1] [WARN] [1754993160.101062396] [map_io]: Image format unspecified. Setting it to: pgm
[map_saver_cli-1] [INFO] [1754993160.101142767] [map_io]: Received a 317 X 615 map @ 0.05 m/pix
[map_saver_cli-1] [INFO] [1754993160.241443101] [map_io]: Writing map occupancy data to /root/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar.pgm
[map_saver_cli-1] [INFO] [1754993160.244221227] [map_io]: Writing map metadata to /root/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar.yaml
[map_saver_cli-1] [INFO] [1754993160.251699343] [map_io]: Map saved
[map_saver_cli-1] [INFO] [1754993160.251775899] [map_saver]: Map saved successfully
[map_saver_cli-1] [INFO] [1754993160.253474927] [map_saver]: Destroying
[INFO] [map_saver_cli-1]: process has finished cleanly [pid 85580]
root@raspberrypi:/#

```

A map named yahboomcar will be saved. This map is saved in:

~/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar.yaml

Two files will be generated, one named yahboomcar.pgm. The map is as follows. (For RDK X5 and Orin , you can directly double-click to view the map. For Raspberry Pi and Jetson nano, you need to copy this file to the /root/share shared folder on Docker and then view it on the host machine.)



yahboom_map.yaml, take a look at the yaml contents.

```

image: yahboomcar.pgm
mode: trinary
resolution: 0.05
origin: [-9.02, -15.5, 0]
negate: 0
occupied_thresh: 0.65
free_thresh: 0.25

```

- image: The image representing the map, i.e., yahboomcar.pgm
- mode: This property can be one of trinary, scale, or raw, depending on the selected mode. Trinary is the default mode.
- resolution: The resolution of the map, in meters/pixels.
- origin: The 2D pose (x, y, yaw) of the lower left corner of the map. The yaw value here is counterclockwise (yaw=0 means no rotation). Currently, many parts of the system ignore the yaw value.
- negate: Whether to invert the meaning of white/black and free/occupied (this does not affect the interpretation of thresholds).
- occupied_thresh: Pixels with an occupied probability greater than this threshold are considered fully occupied.
- free_thresh: Pixels with an occupied probability less than this threshold are considered completely free.

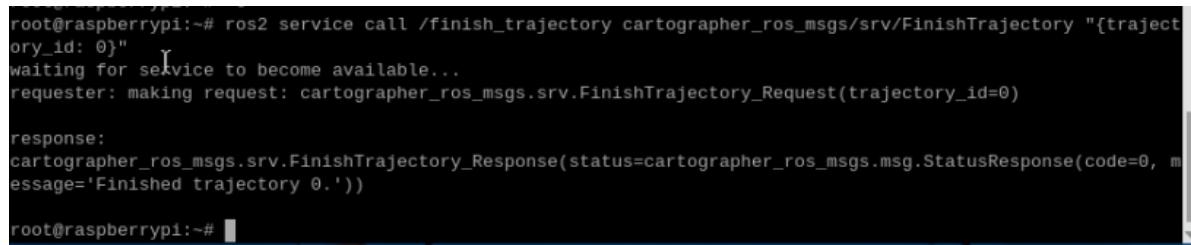
4.2. Saving the Rapid Relocation Map

Then enter the following command to stop building the map.

```

ros2 service call /finish_trajectory cartographer_ros_msgs/srv/FinishTrajectory
  "{trajectory_id: 0}"

```



```

root@raspberrypi:~# ros2 service call /finish_trajectory cartographer_ros_msgs/srv/FinishTrajectory "{trajectory_id: 0}"
[...]
requester: making request: cartographer_ros_msgs.srv.FinishTrajectory_Request(trajectory_id=0)

response:
cartographer_ros_msgs.srv.FinishTrajectory_Response(status=cartographer_ros_msgs.msg.StatusResponse(code=0, message='Finished trajectory 0.'))

```

Then enter the following command to save the pbstream file.

```

#Raspberry Pi, Jetson Nano
ros2 service call /write_state cartographer_ros_msgs/srv/WriteState "{filename:
  '/root/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar.pbstream'}"
#ORIN
ros2 service call /write_state cartographer_ros_msgs/srv/WriteState "{filename:
  '/home/jetson/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar.pbstream'}"
#RDK X5
ros2 service call /write_state cartographer_ros_msgs/srv/WriteState "{filename:
  '/home/sunrise/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar.pbstream'}"

```

```

root@raspberrypi:~# ros2 service call /finish_trajectory cartographer_ros_msgs/srv/FinishTrajectory "[trajectory_id: 0]"
waiting for service to become available...
requester: making request: cartographer_ros_msgs.srv.FinishTrajectory_Request(trajectory_id=0)

response:
cartographer_ros_msgs.srv.FinishTrajectory_Response(status=cartographer_ros_msgs.msg.StatusResponse(code=0, message='Finished trajectory 0.'))
[...]
root@raspberrypi:~# ros2 service call /write_state cartographer_ros_msgs/srv/WriteState "{filename: '/root/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar.pbstream'}"
waiting for service to become available...
requester: making request: cartographer_ros_msgs.srv.WriteState_Request(filename='/root/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar.pbstream', include_unfinished_submaps=False)

response:
cartographer_ros_msgs.srv.WriteState_Response(status=cartographer_ros_msgs.msg.StatusResponse(code=0, message="State written to '/root/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar.pbstream'."))
root@raspberrypi:~#

```

The path of the filename parameter is the path where the map's pbstream file is saved.

Finally, enter the following command to convert the pbstream file to a pgm file.

```

#Raspberry Pi, jetson nano
ros2 run cartographer_ros cartographer_pbstream_to_ros_map -
map_filestem=/root/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar -
pbstream_filename=/root/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/
/yahboomcar.pbstream -resolution=0.05
#ORIN
ros2 run cartographer_ros cartographer_pbstream_to_ros_map -
map_filestem=/home/jetson/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar -
pbstream_filename=/home/jetson/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_n
av/maps/yahboomcar.pbstream -resolution=0.05
#RDK X5
ros2 run cartographer_ros cartographer_pbstream_to_ros_map -
map_filestem=/home/sunrise/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/m
aps/yahboomcar -
pbstream_filename=/home/sunrise/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_n
av/maps/yahboomcar.pbstream -resolution=0.05

```

```

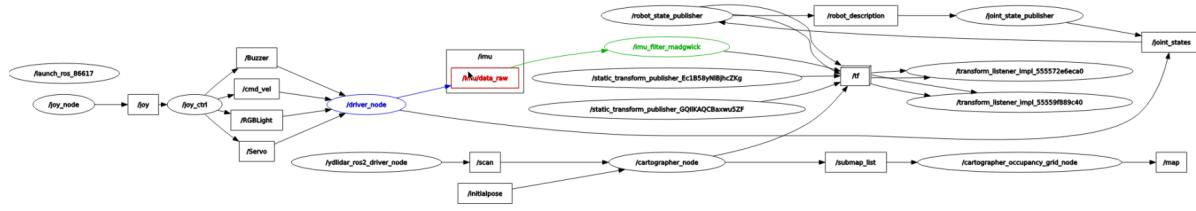
root@raspberrypi:~/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps# ros2 run cartographer_ros cartographer_pbstream_to_ros_map -m
ap_filestem=/root/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps/yahboomcar -pbstream_filename=/root/yahboomcar_ros2_ws/yahboomc
ar_ws/src/yahboomcar_nav/maps/yahboomcar.pbstream -resolution=0.05
[0812 18:25:50.912467 96695 pbstream_to_ros_map_main.cpp:44] Loading submap slices from serialized data.
[0812 18:25:50.930706 96695 pbstream_to_ros_map_main.cpp:52] Generating combined map image from submap slices.
root@raspberrypi:~/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/maps#

```

5. View the Node Communication Graph

In the terminal, enter:

```
ros2 run rqt_graph rqt_graph
```



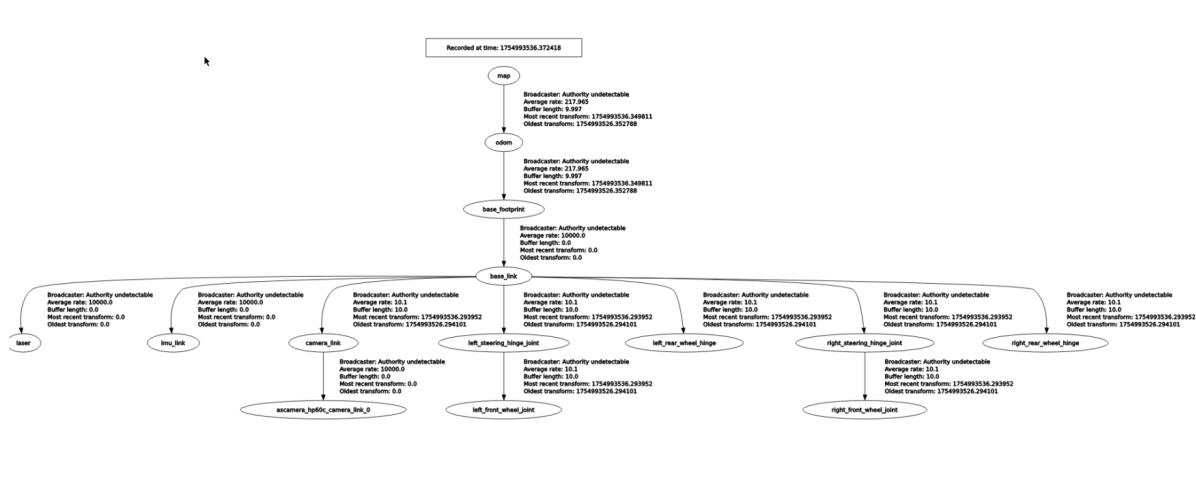
If the graph does not display initially, select [Nodes/Topics (all)] and click the refresh button in the upper left corner.

6. View the TF tree

Enter in the terminal:

```
ros2 run rqt_tf_tree rqt_tf_tree
```

After the program finishes running, a TF conversion interface will appear.



7. Code Analysis

This section only explains the map_cartographer_launch.py file for map creation. The file path is:

```
~/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/launch/map_cartographer_launch.py
```

map_cartographer_launch.py

```
import os
from ament_index_python.packages import get_package_share_directory
from launch import LaunchDescription
from launch.actions import IncludeLaunchDescription
from launch.launch_description_sources import PythonLaunchDescriptionSource

def generate_launch_description():

    # Load the map configuration
    map_yaml = os.path.join(get_package_share_directory('yahboomcar_map'), 'map.yaml')

    # Create the launch description
    ld = LaunchDescription([
        # Include the map configuration
        IncludeLaunchDescription(
            PythonLaunchDescriptionSource(map_yaml),
            launch_arguments={
                'yaml_file': map_yaml
            }
        )
    ])

    return ld
```

```

    package_launch_path
    =os.path.join(get_package_share_directory('yahboomcar_nav'), 'launch')

    laser_bringup_launch =
    includeLaunchDescription(PythonLaunchDescriptionSource(
        [package_launch_path, '/laser_bringup_no_odom_launch.py']))
    )

    cartographer_launch =
    includeLaunchDescription(PythonLaunchDescriptionSource(
        [package_launch_path, '/cartographer_launch.py']))
    )

    return LaunchDescription([laser_bringup_launch, cartographer_launch])

```

This runs the launch file - cartographer_launch, which is located at

```
~/yahboomcar_ross2_ws/yahboomcar_ws/src/yahboomcar_nav/launch/cartographer_launch.py
```

```

import os
from ament_index_python.packages import get_package_share_directory
from launch import LaunchDescription
from launch.actions import DeclareLaunchArgument
from launch_ros.actions import Node
from launch.substitutions import LaunchConfiguration
from launch.actions import IncludeLaunchDescription
from launch.launch_description_sources import PythonLaunchDescriptionSource
from launch.substitutions import ThisLaunchFileDir

def generate_launch_description():
    use_sim_time = LaunchConfiguration('use_sim_time', default='false')
    package_path = get_package_share_directory('yahboomcar_nav')
    configuration_directory = LaunchConfiguration('configuration_directory',
default=os.path.join(
                                package_path, 'params'))
    configuration_basename = LaunchConfiguration('configuration_basename',
default='1ds_2d.lua')

    resolution = LaunchConfiguration('resolution', default='0.05')
    publish_period_sec = LaunchConfiguration(
        'publish_period_sec', default='1.0')

    return LaunchDescription([
        DeclareLaunchArgument(
            'configuration_directory',
            default_value=configuration_directory,
            description='Full path to config file to load'),
        DeclareLaunchArgument(
            'configuration_basename',
            default_value=configuration_basename,
            description='Name of lua file for cartographer'),
        DeclareLaunchArgument(
            'use_sim_time',
            default_value='false',

```

```

        description='Use simulation (Gazebo) clock if true'),

    Node(
        package='cartographer_ros',
        executable='cartographer_node',
        name='cartographer_node',
        output='screen',
        parameters=[{'use_sim_time': use_sim_time}],
        arguments=['-configuration_directory', configuration_directory,
                   '-configuration_basename', configuration_basename]),

    DeclareLaunchArgument(
        'resolution',
        default_value=resolution,
        description='Resolution of a grid cell in the published occupancy
grid'),

    DeclareLaunchArgument(
        'publish_period_sec',
        default_value=publish_period_sec,
        description='OccupancyGrid publishing period'),

    IncludeLaunchDescription(
        PythonLaunchDescriptionSource(
            [ThisLaunchFileDir(), '/occupancy_grid_launch.py']),
        launch_arguments={'use_sim_time': use_sim_time, 'resolution':
resolution,
                          'publish_period_sec': publish_period_sec}.items(),
        ),
    ]
)

```

This mainly involves running the cartographer_node mapping node and occupancy_grid_launch.py, and also loading the parameter configuration file, which is located at

```
~/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_nav/params/lds_2d.lua
```

lds_2d.lua,

```

include "map_builder.lua"
include "trajectory_builder.lua"

options = {
    map_builder = MAP_BUILDER,
    trajectory_builder = TRAJECTORY_BUILDER,
    map_frame = "map",
    tracking_frame = "base_footprint",
    published_frame = "base_footprint",
    odom_frame = "odom",
    provide_odom_frame = true,
    publish_frame_projected_to_2d = false,
    use_odometry = false,
    use_nav_sat = false,
    use_landmarks = false,
    num_laser_scans = 1,
    num_multi_echo_laser_scans = 0,
}

```

```
    num_subdivisions_per_laser_scan = 1,
    num_point_clouds = 0,
    lookup_transform_timeout_sec = 0.2,
    submap_publish_period_sec = 0.3,
    pose_publish_period_sec = 5e-3,
    trajectory_publish_period_sec = 30e-3,
    rangefinder_sampling_ratio = 1.,
    odometry_sampling_ratio = 1.,
    fixed_frame_pose_sampling_ratio = 1.,
    imu_sampling_ratio = 1.,
    landmarks_sampling_ratio = 1.,
}

MAP_BUILDER.use_trajectory_builder_2d = true

TRAJECTORY_BUILDER_2D.min_range = 0.1
TRAJECTORY_BUILDER_2D.max_range = 10.0
TRAJECTORY_BUILDER_2D.missing_data_ray_length = 0.5
TRAJECTORY_BUILDER_2D.use_imu_data = false
TRAJECTORY_BUILDER_2D.use_online_correlative_scan_matching = true
TRAJECTORY_BUILDER_2D.motion_filter.max_angle_radians = math.rad(0.1)

POSE_GRAPH.constraint_builder.min_score = 0.7
POSE_GRAPH.constraint_builder.global_localization_min_score = 0.7

--POSE_GRAPH.optimize_every_n_nodes = 30

return options
```

