1. SLAM과 Cartographer의 개념

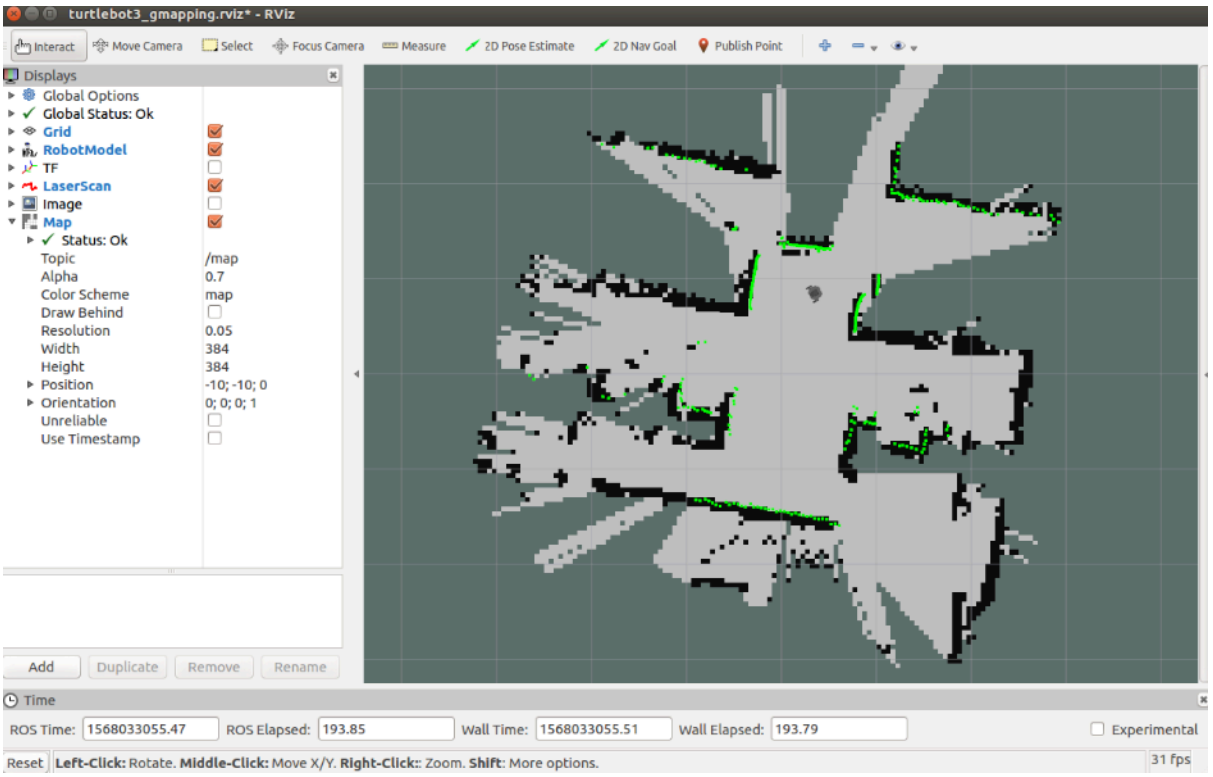
https://blog.naver.com/PostView.naver?blogId=ycpiglet&logNo=222153686510
https://blog.naver.com/ycpiglet/222139215170

1) SLAM (Simultaneous Localization And Mapping)
- 동시 위치 추정 및 지도 작성
- 로봇이 주변환경을 인식하고 스스로 위치를 파악하며 동시에 지도를 만들어가는 기술

2) Odometry
- 주행기록계
- 시작위치(출발점, 기준점)에 대한 상대적인 위치를 추정
- 모터 엔코더를 통한 회전수와 IMU(관성측정장비, MPU6050)로 기울기를 측정하여 움직이고 있는 사물의 위치를 추정

3) Cartographer
- 구글에서 개발한 SLAM라이브러리의 이름

4) ROS에서는
- Rviz tool(프로그램)을 안에서
- 구글에서 만든 Cartographer라는 SLAM 방식과
- Odometry이라는 엔코더, IMU 기반 위치 추정 방식을 사용하여
- 로봇의 위치파악과 지도 제작을 할 수 있다.



2. 라즈베리파이5에 설치할 Tool

SLAM과 Navigation에 필요한 Tool을 모두 설치해준다.

```
sudo apt install ros-jazzy-gazebo-*
sudo apt install ros-jazzy-cartographer
sudo apt install ros-jazzy-cartographer-ros
sudo apt install ros-jazzy-navigation2
sudo apt install ros-jazzy-nav2-bringup
sudo apt install ros-jazzy-dynamixel-sdk
```

```
ros2oroca@ros2oroca-desktop:~$ sudo apt install ros-jazzy-gazebo-*
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
Note, selecting 'ros-jazzy-gazebo-msgs' for glob 'ros-jazzy-gazebo-*'
Note, selecting 'ros-jazzy-gazebo-ros-pkgs' for glob 'ros-jazzy-gazebo
-*'
```

```
ros2oroca@ros2oroca-desktop:~$ sudo apt install ros-jazzy-cartographer
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following packages were automatically installed and are no longer requi
red:
  libllvm17t64 libqrtr1 protection-domain-mapper python3-netifaces
  qrtr-tools
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  libabsl-dev libamd3 libbtf2 libcairo2-dev libcamd3 libccolamd3
```

```
ros2oroca@ros2oroca-desktop:~$ sudo apt install ros-jazzy-cartographer-ros
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following packages were automatically installed and are no longer requi
red:
  libllvm17t64 libqrtr1 protection-domain-mapper python3-netifaces
  qrtr-tools
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  ros-jazzy-cartographer-ros-msgs
The following NEW packages will be installed:
  ros-jazzy-cartographer-ros ros-jazzy-cartographer-ros-msgs
0 upgraded, 2 newly installed, 0 to remove and 0 not upgraded.
Need to get 3,390 kB of archives.
After this operation, 33.1 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://packages.ros.org/ros2/ubuntu noble/main arm64 ros-jazzy-cartog
```

```
ros2oroca@ros2oroca-desktop:~$ sudo apt install ros-jazzy-navigation2
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following packages were automatically installed and are no longer requi
red:
  libllvm17t64 libqrtr1 protection-domain-mapper python3-netifaces
  qrtr-tools
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  comerr-dev cppzmq-dev graphicsmagick-libmagick-dev-compat krb5-multidev
  libbenchmark-dev libbenchmark1.8.3 libbsd-dev libccd2
  libgeographiclib-dev libgeographiclib26 libgraphics-magick-perl
  libgraphicsmagick++-q16-12t64 libgraphicsmagick++1-dev
  libgraphicsmagick-q16-3t64 libgraphicsmagick1-dev libgssrpc4t64
  libhwy-dev libjxl-dev libkadm5clnt-mit12 libkadm5srv-mit12
  libkdb5-10t64 libkrb5-dev liblcms2-dev libmd-dev libnorm-dev libode-dev
  libode8t64 libomp-18-dev libomp-dev libomp5-18 libpgm-dev libsodium-dev
```

```
ros2oroca@ros2oroca-desktop:~$ sudo apt install ros-jazzy-nav2-bringup
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following packages were automatically installed and are no longer requi
red:
  libllvm17t64 libqrtr1 protection-domain-mapper python3-netifaces
  qrtr-tools
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  fonts-lato fonts-open-sans freeglut3-dev glslang-dev glslc libass9
  libavdevice-dev libavdevice60 libavfilter-dev libavfilter9 libbs2b0
  libcap-dev libccd-dev libdw-dev libelf-dev libfcl-dev libfcl0.7
  libfftw3-double3 libflite1 libfreeimage-dev libfreeimage3 libglut-dev
  libgts-dev libjack-jackd2-0 libjxr0t64 liblilv-0-0 libmysofa1
  liboctomap-dev liboctomap1.9t64 libogre-1.9-dev libogre-1.9.0t64
  libopenal-data libopenal1 libpcre16-3 libpcre3 libpcre3-dev libpcre32-3
  libpcrecpp0v5 libplacebo338 libpocketsphinx3 libpoco-dev
```

```
ros2oroca@ros2oroca-desktop:~$ sudo apt install ros-jazzy-dynamixel-sdk
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following packages were automatically installed and are no longer requi
red:
  libllvm17t64 libqrtr1 protection-domain-mapper python3-netifaces
  qrtr-tools
Use 'sudo apt autoremove' to remove them.
The following NEW packages will be installed:
  ros-jazzy-dynamixel-sdk
0 upgraded, 1 newly installed, 0 to remove and 0 not upgraded.
Need to get 42.9 kB of archives.
After this operation, 369 kB of additional disk space will be used.
Get:1 http://packages.ros.org/ros2/ubuntu noble/main arm64 ros-jazzy-dynami
xel-sdk arm64 3.7.40-6noble.20241218.082357 [42.9 kB]
Fetched 42.9 kB in 1s (37.0 kB/s)
```

3. ROS2-Jazzy에 맞게 코드 수정

- 라즈베리파이5는 우분투24.04만 지원하고, ROS2-Jazzy를 사용하기 때문에 cartographer 라이브러리 명칭도 살짝 바뀌었다.
- 따라서 monicar2_cartographer/launch폴더에서 occupancy_grid.launch.py 내용 중 `executable='occupancy_grid_node'` → `executable='cartographer_occupancy_grid_node'` `name='occupancy_grid_node'` → `name='cartographer_occupancy_grid_node'` 으로 수정한다.

```python
def generate_launch_description():
    use_sim_time = LaunchConfiguration('use_sim_time', default='false')
    resolution = LaunchConfiguration('resolution', default='0.01')
    publish_period_sec = LaunchConfiguration('publish_period_sec', default='1.0')

    return LaunchDescription([
        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'),

        DeclareLaunchArgument(
            'use_sim_time',
            default_value='false',
            description='Use simulation (Gazebo) clock if true'),

        Node(
            package='cartographer_ros',
            executable='occupancy_grid_node',
            name='occupancy_grid_node',
            output='screen',
            parameters=[{'use_sim_time': use_sim_time}],
            arguments=['-resolution', resolution, '-publish_period_sec', publish_period_sec]
        ),
    ])
```

수정 전

```python
def generate_launch_description():
    use_sim_time = LaunchConfiguration('use_sim_time', default='false')
    resolution = LaunchConfiguration('resolution', default='0.01')
    publish_period_sec = LaunchConfiguration('publish_period_sec', default='1.0')

    return LaunchDescription([
        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'),

        DeclareLaunchArgument(
            'use_sim_time',
            default_value='false',
            description='Use simulation (Gazebo) clock if true'),

        Node(
            package='cartographer_ros',
            executable='cartographer_occupancy_grid_node',
            name='cartographer_occupancy_grid_node',
            output='screen',
            parameters=[{'use_sim_time': use_sim_time}],
            arguments=['-resolution', resolution, '-publish_period_sec', publish_period_sec]
        ),
    ])
```

수정 후

4. launch파일 실행

라즈베리파이5에서 터미널을 3개를 열고 각 터미널에 다음과 같이 launch를 한다.

1) 1번째 터미널

```
ros2 launch monicar2_localization ekfPose.launch.py initPose:='false'
```

```
ros2oroca@ros2oroca-desktop:~$ ros2 launch monicar2_localization ekfPose.launch.py
initPose:='false'
[INFO] [launch]: All log files can be found below /home/ros2oroca/.ros/log/2025-02-
13-01-15-19-382889-ros2oroca-desktop-41436
[INFO] [launch]: Default logging verbosity is set to INFO
[INFO] [imuconverter-2]: process started with pid [41440]
[INFO] [odomPublisher-4]: process started with pid [41442]
[INFO] [rviz2ClickTo2d-5]: process started with pid [41443]
[INFO] [micro_ros_agent-1]: process started with pid [41439]
[INFO] [rplidar_node-3]: process started with pid [41441]
[INFO] [robot_state_publisher-6]: process started with pid [41444]
[micro_ros_agent-1] [1739376919.578787] info     | TermiosAgentLinux.cpp | init
                | running...             | fd: 10
[micro_ros_agent-1] [1739376919.579312] info     | Root.cpp           | set_verbose
_level        | logger setup           | verbose_level: 4
```

2) 2번째 터미널

```
ros2 launch monicar2_cartographer cartographer.launch.py
```

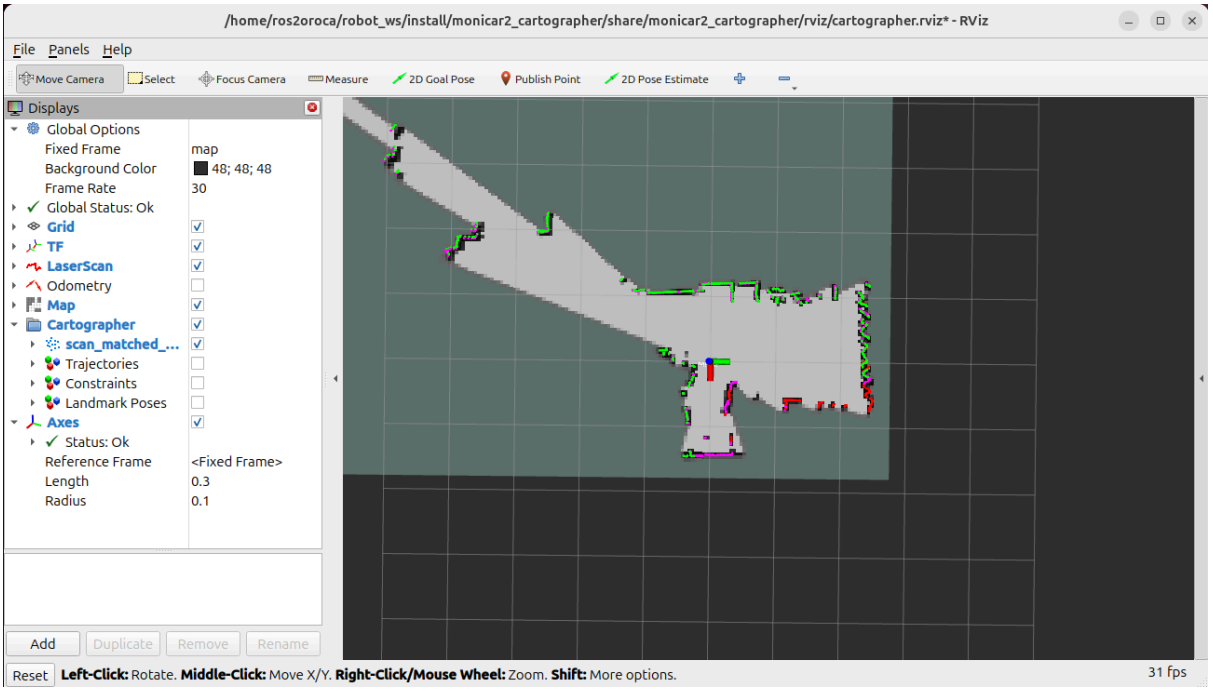
```
ros2oroca@ros2oroca-desktop:~$ ros2 launch monicar2_cartographer cartographer.launc
h.py
[INFO] [launch]: All log files can be found below /home/ros2oroca/.ros/log/2025-02-
13-01-48-50-191422-ros2oroca-desktop-43633
[INFO] [launch]: Default logging verbosity is set to INFO
[INFO] [cartographer_occupancy_grid_node-1]: process started with pid [43636]
[INFO] [cartographer_node-2]: process started with pid [43637]
[cartographer_occupancy_grid_node-1] [rcl] [WARN] [1739378930.384538296]: Invalid v
alue '0' specified for 'ROS_AUTOMATIC_DISCOVERY_RANGE', assuming localhost only
[cartographer_node-2] [rcl] [WARN] [1739378930.417699907]: Invalid value '0' specif
ied for 'ROS_AUTOMATIC_DISCOVERY_RANGE', assuming localhost only
[cartographer_node-2] [cartographer logger] [INFO] [1739378930.503050109]: I2025021
```

3) 3번째 터미널

```
ros2 launch monicar2_cartographer cartographer_rviz.launch.py
```

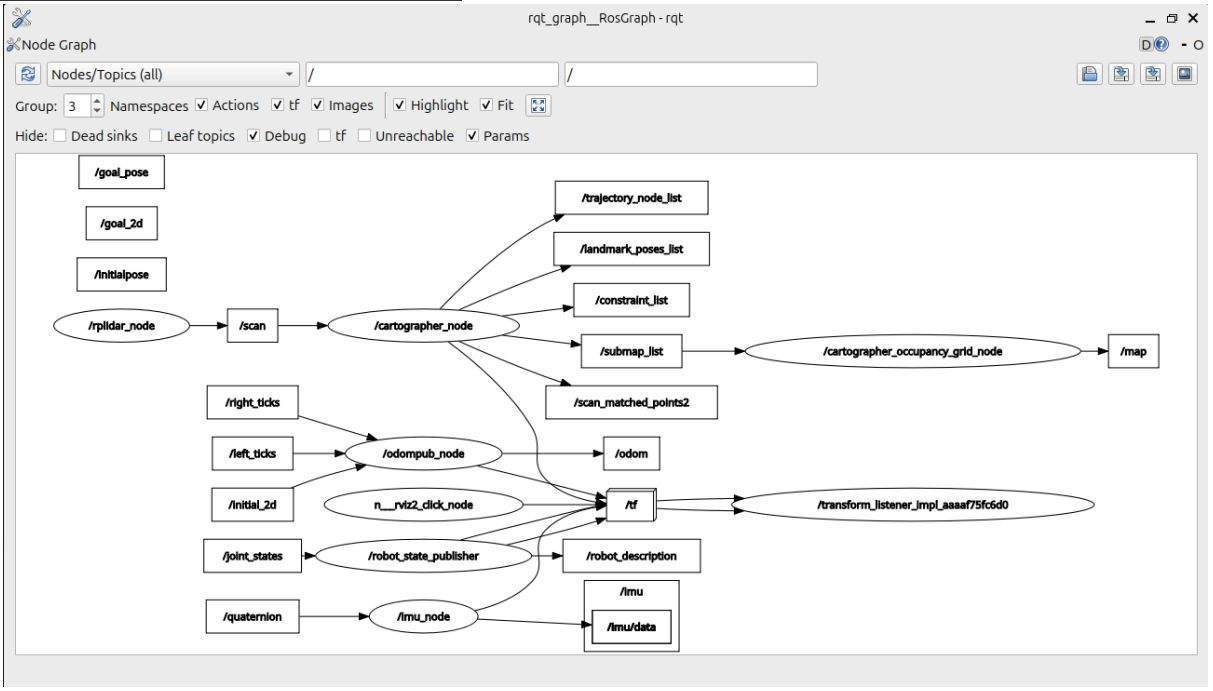
```
ros2oroca@ros2oroca-desktop:~$ ros2 launch monicar2_cartographer cartographer_rviz.
launch.py
[INFO] [launch]: All log files can be found below /home/ros2oroca/.ros/log/2025-02-
13-01-50-15-484550-ros2oroca-desktop-43765
[INFO] [launch]: Default logging verbosity is set to INFO
[INFO] [rviz2-1]: process started with pid [43768]
[rviz2-1] [rcl] [WARN] [1739379015.807351950]: Invalid value '0' specified for 'ROS
_AUTOMATIC_DISCOVERY_RANGE', assuming localhost only
[rviz2-1] [rviz2] [INFO] [1739379016.060488684]: Stereo is NOT SUPPORTED
[rviz2-1] [rviz2] [INFO] [1739379016.060760743]: OpenGl version: 3.1 (GLSL 1.4)
[rviz2-1] [rviz2] [INFO] [1739379016.094255682]: Stereo is NOT SUPPORTED
[rviz2-1] [rviz2] [INFO] [1739379016.236702432]: Subscribing to: /scan_matched_poin
```

4) 실행된 **rviz** 화면



5) 터미널을 하나 더 열고 **rqt_graph**를 호출하자.

```
rqt_graph
```

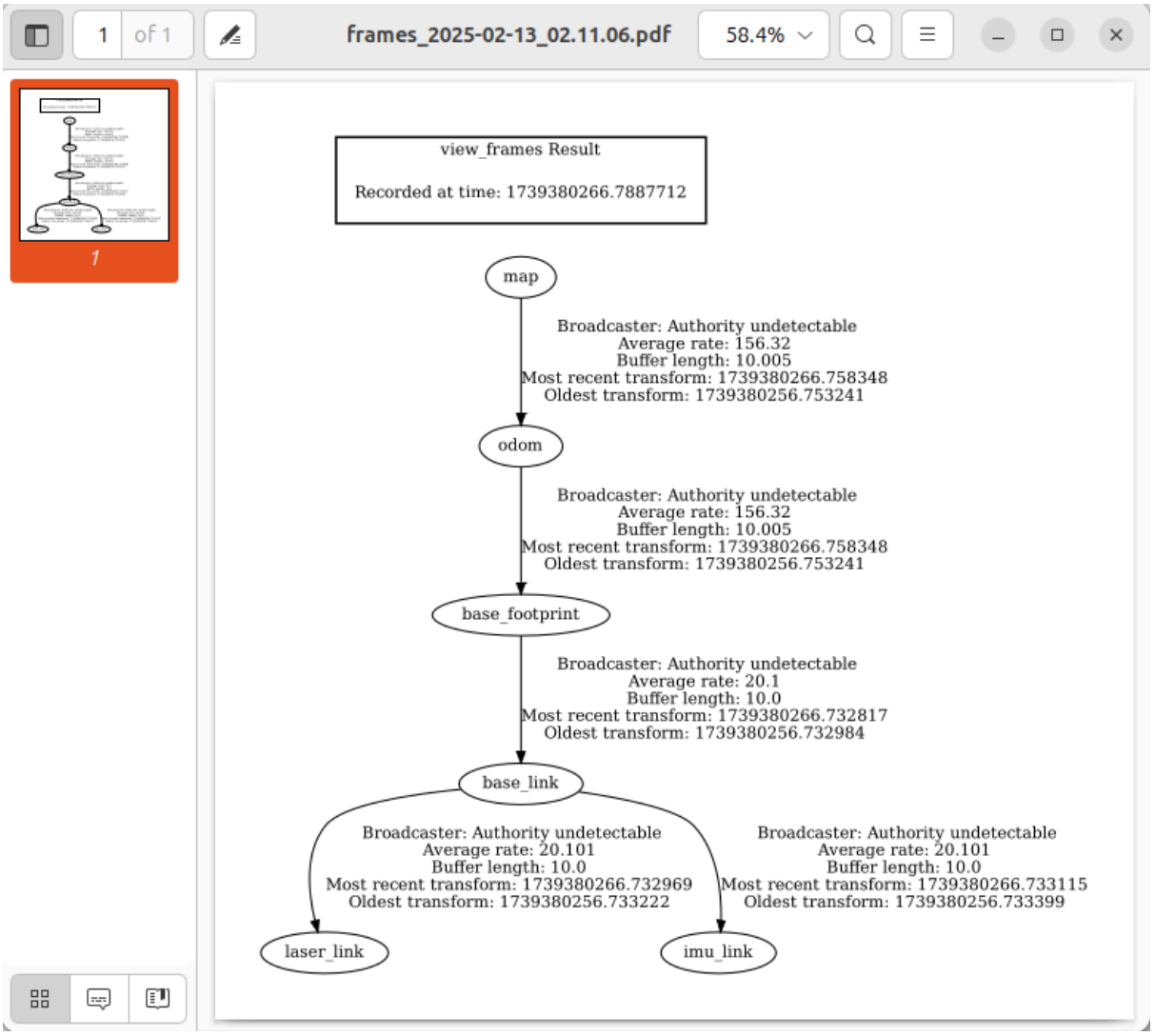


6) TF(Transform) 프레임들의 관계를 시각화하기 위해 다음 명령어로 **pdf**파일을 생성성

```
ros2 run tf2_tools view_frames
evince frames.pdf
```

```
ros2oroca@ros2oroca-desktop:~$ ros2 run tf2_tools view_frames
[rcl] [WARN] [1739380261.044962995]: ROS_LOCALHOST_ONLY is deprecated but still
honored if it is enabled. Use ROS_AUTOMATIC_DISCOVERY_RANGE and ROS_STATIC_PEERS
 instead.
[rcl] [WARN] [1739380261.045010032]: 'localhost_only' is enabled, 'automatic_dis
covery_range' and 'static_peers' will be ignored.
[view_frames] [INFO] [1739380261.745836260]: Listening to tf data for 5.0 second
s...
[view_frames] [INFO] [1739380266.752261009]: Generating graph...
```

```
ros2oroca@ros2oroca-desktop:~$ ls
Desktop    Pictures    frames_2025-02-13_02.11.06.gv   work
Documents  Public      frames_2025-02-13_02.11.06.pdf
Downloads  Templates   robot_ws
Music      Videos      snap
ros2oroca@ros2oroca-desktop:~$ evince frames_2025-02-13_02.11.06.pdf
```



5. map 저장하기

map을 저장하기 위해서는 아래 명령을 사용한다.

```
ros2 run nav2_map_server map_saver_cli -f my_room_map
```

```
ros2oroca@ros2oroca-desktop:~$ cd ~/robot_ws/
ros2oroca@ros2oroca-desktop:~/robot_ws$ ros2 run nav2_map_server map_saver_cli -f my_room_map
[map_saver] [INFO] [1739382333.063407768]:
        map_saver lifecycle node launched.
        Waiting on external lifecycle transitions to activate
        See https://design.ros2.org/articles/node_lifecycle.html for more information.
[map_saver] [INFO] [1739382333.066285604]: Creating
[map_saver] [INFO] [1739382333.066935446]: Configuring
[map_saver] [INFO] [1739382333.080124686]: Saving map from 'map' topic to 'my_room_map' file
[map_saver] [WARN] [1739382333.080424135]: Free threshold unspecified. Setting it to default va
lue: 0.250000
[map_saver] [WARN] [1739382333.080468673]: Occupied threshold unspecified. Setting it to defaul
t value: 0.650000
[map_io] [WARN] [1739382333.598550153]: Image format unspecified. Setting it to: pgm
[map_io] [INFO] [1739382333.598670655]: Received a 143 X 193 map @ 0.05 m/pix
[map_io] [INFO] [1739382333.630835956]: Writing map occupancy data to my_room_map.pgm
[map_io] [INFO] [1739382333.632767280]: Writing map metadata to my_room_map.yaml
[map_io] [INFO] [1739382333.634192429]: Map saved
[map_saver] [INFO] [1739382333.634252004]: Map saved successfully
[map_saver] [INFO] [1739382333.637279546]: Destroying
```

my_room_map.yaml파일이 잘 저장되었는지 확인한다.

```
ls
```

```
ros2oroca@ros2oroca-desktop:~/robot_ws$ ls ~/robot_ws/
build  install  log  my_room_map.pgm  my_room_map.yaml  src
```