8. karto mapping algorithm

karto: http://wiki.ros.org/slam_karto

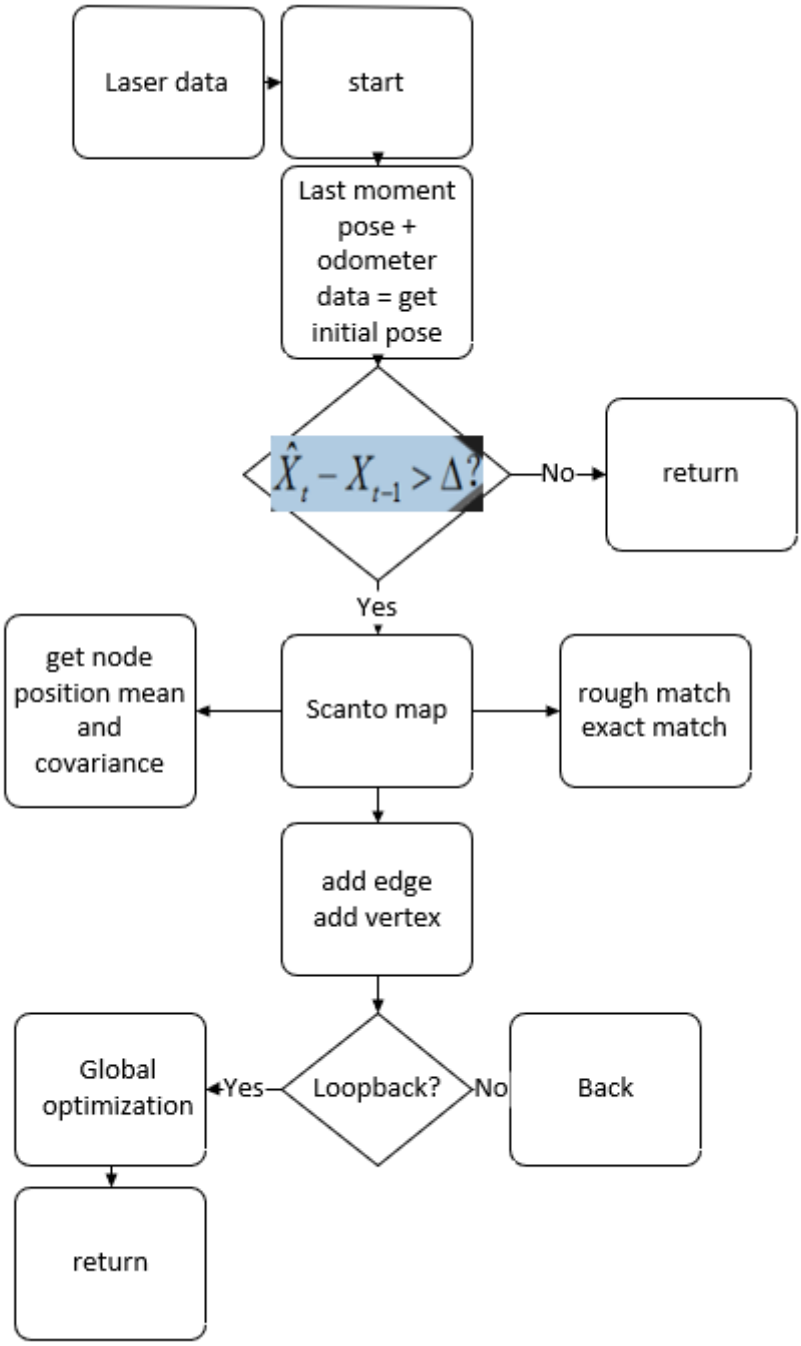
map_server: https://wiki.ros.org/map_server

8.1. Introduction

Karto is a 2D laser SLAM solution based on a sparse graph optimization method with loop closure detection. The graph optimization method uses the mean value of the graph to represent the map. Each node represents a position point of the robot trajectory and a sensor measurement data set. Each new node is added and the calculation is updated. Karto uses spa (karto_slam) or g2o (nav2d) optimization library, and the front-end and back-end use a single thread.

The ROS version of Karto_SLAM, in which the Spare Pose Adjustment (SPA) used is related to scan matching and loop closure detection. The more landmarks there are, the greater the memory requirements. However, compared with other methods, the graph optimization method has greater advantages in mapping in large environments because it only contains point graphs (robot poses), and the map is obtained after the pose is obtained.

overall program framework



8.2. Use

Note: When building a map, the slower the speed, the better the effect (note that the rotation speed should be slower). If the speed is too fast, the effect will be poor.

According to different models, you only need to set the purchased model in [.bashrc], X1 (normal four-wheel drive) X3 (Mailun) Take X3 as an example

```
#Raspberry Pi 5 master needs to enter docker first, please perform this step
#If running the script into docker fails, please refer to ROS/07, Docker tutorial
~/run_docker.sh
```

Open the [.bashrc] file

```
sudo vim .bashrc
```

Find the [ROBOT_TYPE] parameters and modify the corresponding car model

```
export ROBOT_TYPE=X3 # ROBOT_TYPE: X1 X3 X3plus R2 X7
```

Note: Due to the difference in radar laser data between 4ROS radar and A1 radar, you need to modify the karto source code part before it can run normally and modify the file.

```
sudo gedit ~/software/library_ws/src/open_karto-
melodic/include/open_karto/Karto.h
```

Locate line 4165, the source code is,

```
void Update()
     {
       m_NumberOfRangeReadings = static_cast<kt_int32u>
(math::Round((GetMaximumAngle() -

GetMinimumAngle())
                                                                    /
GetAngularResolution())+1);
     }
```

Need to be changed to,

```
  void Update()
     {
       m_NumberOfRangeReadings = static_cast<kt_int32u>
(math::Round((GetMaximumAngle() -

GetMinimumAngle())

/GetAngularResolution()));
     }
```

After saving, switch to the ~/software/library_ws directory and use catkin_make to compile.

```
cd ~/software/library_ws
catkin_make
```

8.2.1. Start

Start the command (robot side). For the convenience of operation, this section takes [mono + laser + yahboomcar] as an example.

```
roslaunch yahboomcar_nav laser_bringup.launch # laser + yahboomcar
roslaunch yahboomcar_nav laser_usb_bringup.launch # mono + laser + yahboomcar
roslaunch yahboomcar_nav laser_astrapro_bringup.launch # Astra + laser +
yahboomcar
```

Mapping command (robot side)

<PI5 needs to open another terminal to enter the same docker container

1. In the above steps, a docker container has been opened. You can open another terminal on the host (car) to view:

```
docker ps -a
```

```
jetson@ubuntu:~$ docker ps -a
CONTAINER ID   IMAGE                                 COMMAND       CREATED      STATUS       PORTS     NAMES
5b698ea10535   yahboomtechnology/ros-foxy:3.3.9   "/bin/bash"   3 days ago   Up 9 hours             ecstatic_lewin
jetson@ubuntu:~$
```

2. Now enter the docker container in the newly opened terminal:

```
docker exec -it 5b698ea10535 /bin/bash
```

```
jetson@ubuntu:~$ docker ps -a
CONTAINER ID   IMAGE                                 COMMAND       CREATED      STATUS       PORTS     NAMES
5b698ea10535   yahboomtechnology/ros-foxy:3.3.9   "/bin/bash"   3 days ago   Up 9 hours             ecstatic_lewin
jetson@ubuntu:~$ docker exec -it 5b698ea10535 /bin/bash
-------------------------------------------------------
my_robot_type: x3 | my_lidar: a1 | my_camera: astrapro
-------------------------------------------------------
root@ubuntu:/#
```

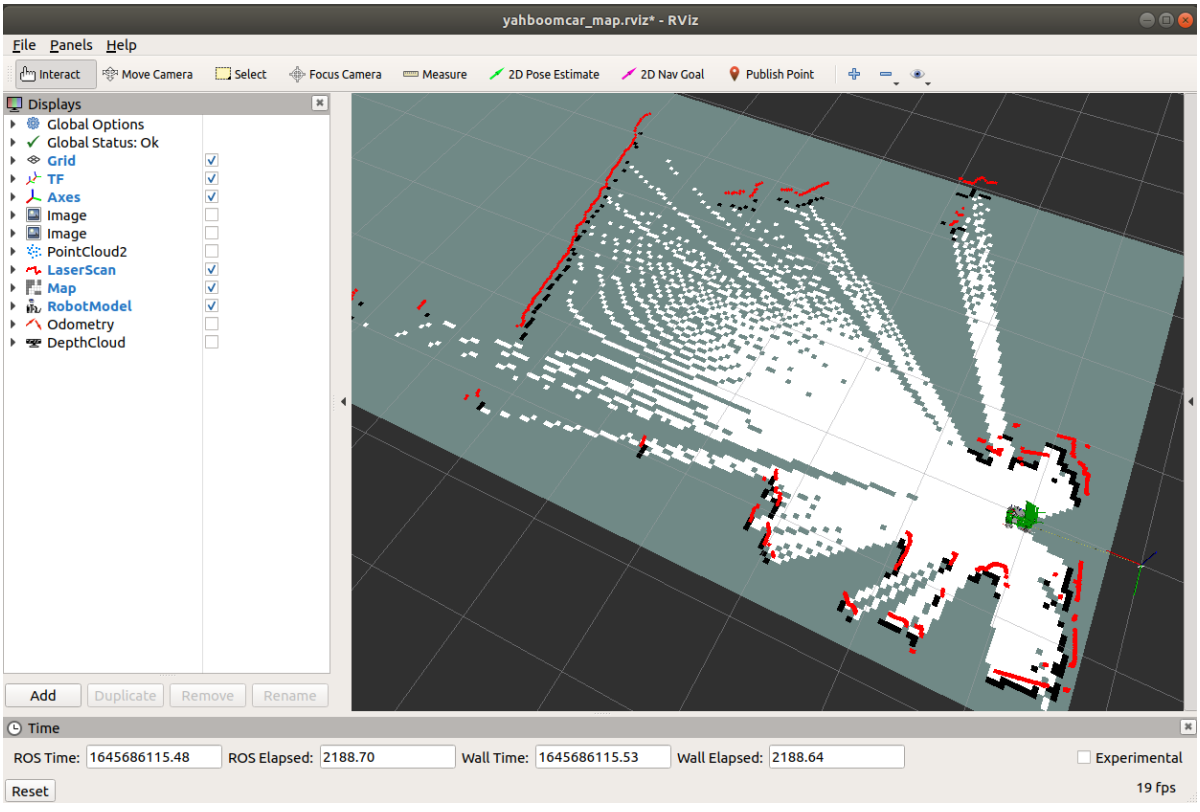
After successfully entering the container, you can open countless terminals to enter the container.

```
roslaunch yahboomcar_nav yahboomcar_map.launch use_rviz:=false map_type:=karto
```

- [use_rviz] parameter: whether to enable rviz visualization.
- [map_type] parameter: Set the mapping algorithm [karto].

Turn on the visual interface (virtual machine side)

```
roslaunch yahboomcar_nav view_map.launch
```



The gap at the back of the robot is due to the obstruction caused by the installation position of the display screen, so a certain range of radar data is blocked. The shielding range can be adjusted, or it can not be blocked according to the actual situation. For specific operations, see [01. Radar Basic Course].

8.2.1. Controlling the robot

- Keyboard controls robot movement

```
rosrun teleop_twist_keyboard teleop_twist_keyboard.py # System integration
roslaunch yahboomcar_ctrl yahboom_keyboard.launch # Custom
```

- Control the robot movement with the handle

Make the robot cover the area to be mapped and the map should be as closed as possible.

There may be some scattered points during the mapping process. If the mapping environment is well closed, relatively regular, and the movement is slow, the scattering phenomenon will be much smaller.

8.2.1. Map saving

```
rosrun map_server map_saver -f ~/yahboomcar_ws/src/yahboomcar_nav/maps/my_map # The first way
bash ~/yahboomcar_ws/src/yahboomcar_nav/maps/map.sh # The second way
```

The map will be saved to the ~/yahboomcar_ws/src/yahboomcar_nav/maps/ folder, a pgm image and a yaml file.

map.yaml

```
image: map.pgm
resolution: 0.05
origin: [-15.4,-12.2,0.0]
Negate: 0
occupied_thresh: 0.65
free_thresh: 0.196
```

Parameter analysis:

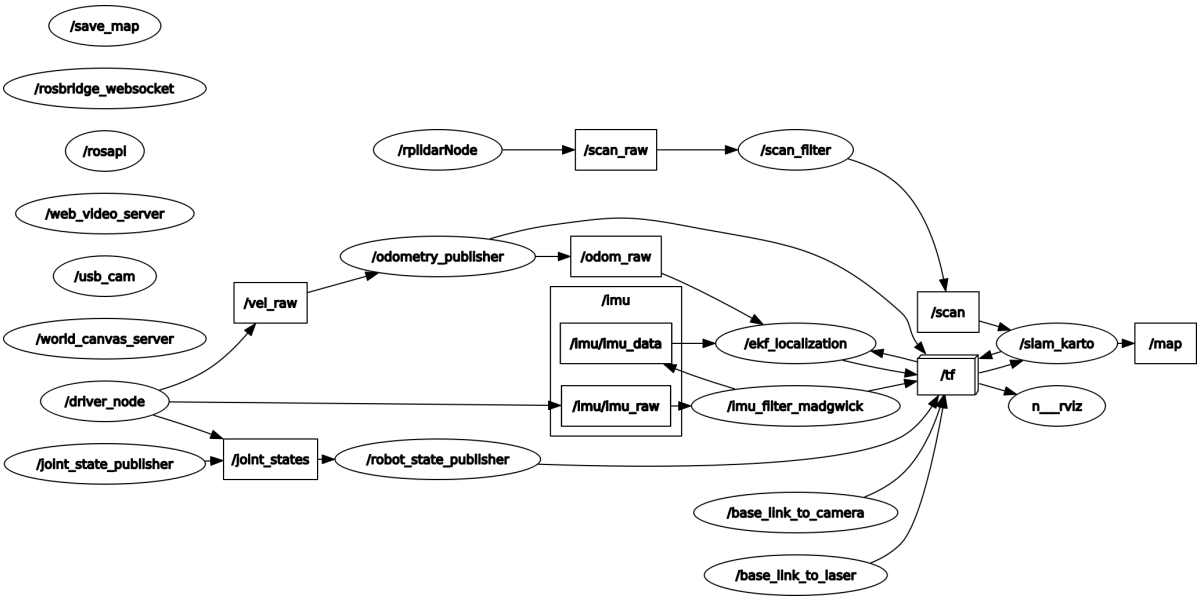
- image: The path of the map file, which can be an absolute path or a relative path.
- resolution: resolution of the map, meters/pixel
- Origin: 2D pose (x, y, yaw) in the lower left corner of the map. The yaw here is rotated counterclockwise (yaw=0 means no rotation). Many parts of the current system ignore the yaw value.
- negate: whether to reverse the meaning of white/black and free/occupied (the interpretation of the threshold is not affected)
- occupied_thresh: Pixels with an occupation probability greater than this threshold will be considered fully occupied.
- free_thresh: Pixels with occupancy probability less than this threshold will be considered completely free.

8.3. Topics and services

Topic Subscription	Type	Description
scan	sensor_msgs/LaserScan	Depth data of lidar scan
tf	tf/tfMessage	Used for conversion between lidar coordinate system, base coordinate system, and odometer coordinate system
Topic Post	**Type**	**Description**
map_metadata	nav_msgs/MapMetaData	Publish map Meta data
map	nav_msgs/OccupancyGrid	Publish map raster data
visualization_marker_array	visualization_msgs/MarkerArray	Publish pose diagram
Service	**Type**	**Description**
dynamic_map	nav_msgs/GetMap	Get map data

Node view

```
rqt_graph
```



8.4. Configuration parameters

- Common parameters

Parameters	Type	Default value	Description
~base_frame	string	"base_link"	Robot base coordinate system
~map_frame	string	"map"	Map coordinate system
~odom_frame	string	"odom"	Odometer coordinate system
~throttle_scans	int	1	Process 1 per this many scans (set this to a higher number to skip more scans)

Parameters	Type	Default value	Description
~map_update_interval	float	5.0	The time in seconds between map updates. Lowering this number will update the occupancy grid more frequently, but will increase the computational load.
~resolution	float	0.05	Map resolution (meters per occupied grid block)
~delta	float	0.05	Map resolution (meters per occupied grid block). Same as resolution. Defined for compatibility with gmapping parameter names.
~transform_publish_period	float	0.05	The time in seconds between transform publications.
use_scan_matching	bool	true	Whether to use the scan matching algorithm, generally set to true, the mapper algorithm can correct the noise and errors of the odometer and laser. In some simulation environments with accurate sensor data, the scan matching algorithm will achieve worse results (because the use of Gaussian blur reduces the observation confidence of high-precision sensors), and it is recommended to turn it off (just add noise to the simulation environment).
use_scan_barycenter	bool	true	Defines the distance between scans using the centroid of the scan endpoints.
minimum_travel_distance	double	0.2	Set the minimum travel between scans.
minimum_travel_heading	double	deg2rad(10)=0.087266461	Set the minimum angle between scans.
scan_buffer_size	int	70	Set the length of ScanBuffer, approximately equal to scan_buffer_maximum_scan_distance/minimum_travel_distance
scan_buffer_maximum_scan_distance	double	20.0	Setting the maximum length of ScanBuffer is similar to Size
link_match_minimum_response_fine	double	0.8	Set the minimum response threshold for the minimum scans connection
link_scan_minimum_distance	double	10.0	Set the maximum distance between scans of two connections. If it is greater than this value, the response threshold of the two will not be considered
loop_search_maximum_distance	double	4.0	Maximum distance for loop detection. Scans less than this distance from the current position will be considered matching loop closures.
do_loop_closing	bool	true	Whether to enable loop closing detection
loop_match_minimum_chain_size	int	10	The lowest chain size for loop detection
loop_match_maximum_variance_coarse	double	math::Square(0.4)=0.16	The maximum covariance value of coarse matching during loop matching. If it is less than this value, it is considered a feasible solution
loop_match_minimum_response_coarse	double	0.8	The minimum response for coarse matching during loop matching. A response value greater than this value will start coarse precision loop optimization
loop_match_minimum_response_fine	double	0.8	The minimum response threshold for loop matching. High accuracy will only start when it is greater than this value

- Correction parameters

Parameters	Type	Default value	Description
correlation_search_space_dimension	double	0.3	Set the search range size of Correlation Grid
correlation_search_space_resolution	double	0.01	Set the resolution of the Correlation Grid
correlation_search_space_smear_deviation	double	0.03	Set the Correlation Grid blur level

- Loopback parameters

Parameters	Type	Default value	Description
loop_search_space_dimension	double	8.0	Loop detection space range size
loop_search_space_resolution	double	0.05	Loop detection spatial resolution
loop_search_space_smear_deviation	double	0.03	Loop detection blur level

- Scan Matcher parameters

Parameters	Type	Default value	Description
distance_variance_penalty	double	sqrt(0.3)=0.09 (less than 1.0)	Compensation coefficient for odometer during scan-matching
angle_variance_penalty	double	sqrt(deg2rad(20))=0.17453292	Compensation coefficient for angle during scan-matching
fine_search_angle_offset	double	deg2rad(0.2)=0.0017453292	Fine search angle range
coarse_search_angle_offset	double	deg2rad(20)=0.17453292	Coarse search angle range
coarse_angle_resolution	double	deg2rad(2)=0.017453292	Coarse search angle resolution
minimum_angle_penalty	double	0.9	minimum angle penalty
minimum_distance_penalty	double	0.5	Minimum distance penalty
use_response_expansion	bool	false	Whether to increase the search scope if no good matches are found

8.5, TF transformation

Required TF transformation	Description
laser-->base_link	Usually a fixed value, the transformation between the lidar coordinate system and the base coordinate system, generally published by robot_state_publisher or static_transform_publisher

Required TF transformation	**Description**
base_link-->odom	Transformation between the map coordinate system and the robot odometer coordinate system, estimating the robot's pose in the map
Published by TF Transform	**Description**
map-->odom	The current estimate of the robot pose within the map frame (only provided if parameter "pub_map_odom_transform" is true).

View tf tree

```
rosrun rqt_tf_tree rqt_tf_tree
```