10. rrt_exploration mapping algorithm

rrt_exploration： http://wiki.ros.org/rrt_exploration

rrt_exploration/Tutorials： http://wiki.ros.org/rrt_exploration/Tutorials

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

10.1 Introduction

RRT exploration is a search algorithm implemented based on the RRT path planning algorithm. The reason why the RRT algorithm is used is that RRT has a strong tendency to unknown areas. In RRT exploration, RRT is mainly used to generate boundary points, which is very beneficial for exploring boundary points. The so-called boundary point is the junction point between the explored and unknown areas. Here is a definition: for all areas, if they are explored, the area without obstacles is recorded as 0, and the area with obstacles is recorded as 1, the unknown area is recorded as -1, and at the beginning, the entire area is recorded as -1.

The framework of the Rapid Exploration Random Tree(RRT) algorithm is as follows:

- Global RRT frontier point detector node.
- Local RRT frontier point detector node.
- OpenCV-based frontier detector node.
- Filter node.

- Assign node.

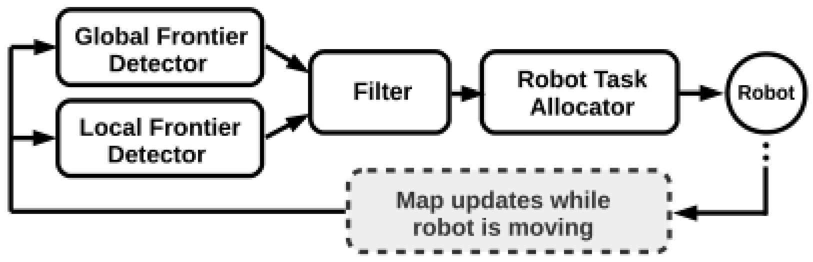


Fig. 1: Overall schematic diagram of the exploration algorithm

There are 3 types of nodes: nodes used to detect boundary points in the occupancy raster map, nodes used to filter detected points, and nodes used to assign points to robots.

10.2 Use

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

According to different models, you only need to set the purchased model in [.bashrc], X1(ordinary four-wheel drive) X3(Mike wheel) X3plus(Mike wheel mechanical arm) R2(Ackerman differential) and so on. Section takes X3 as an example

Open the [.bashrc] file

```
sudo vim .bashrc
```

Find the [ROBOT_TYPE] parameter and modify the corresponding model

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

10.2.1 Start

Start 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
```

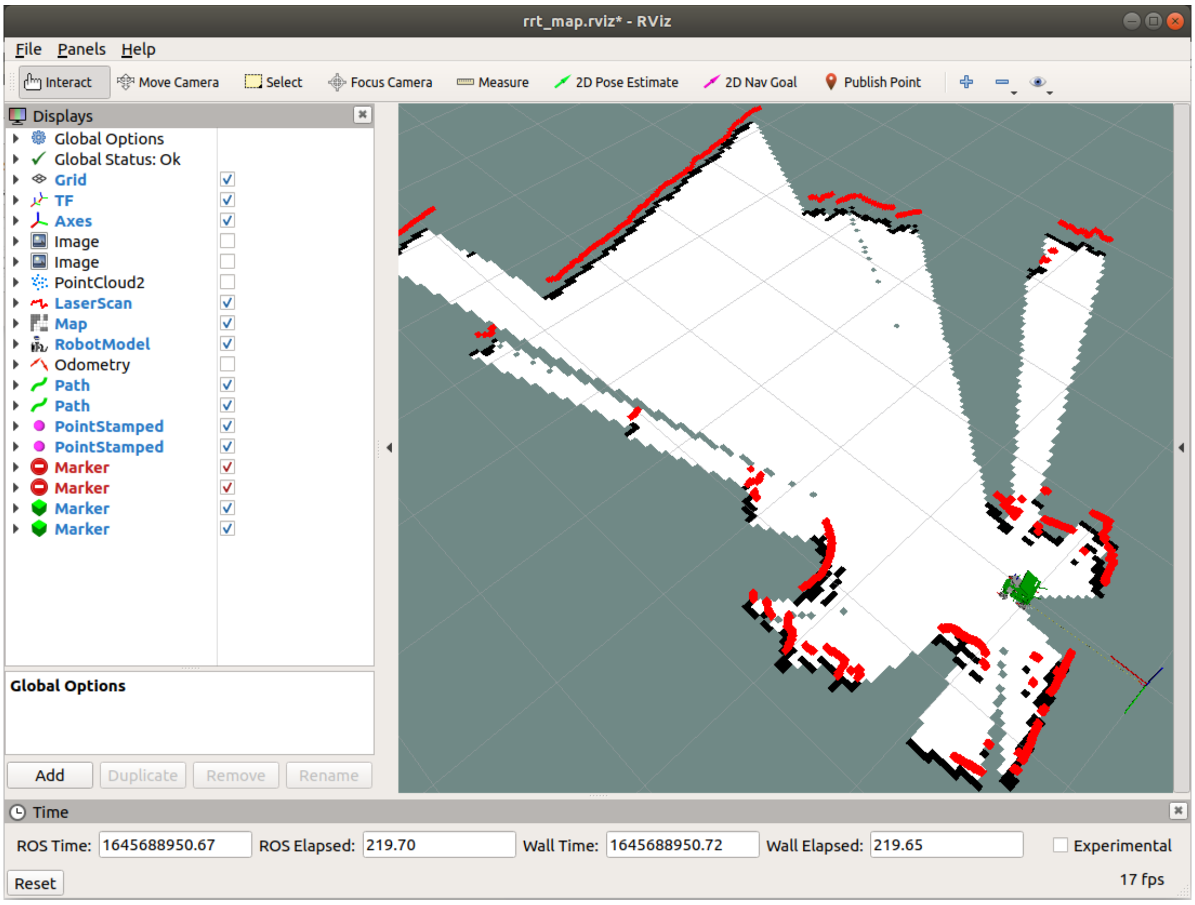
Mapping command(robot side)

```
roslaunch  yahboomcar_nav  rrt_exploration.launch  use_rviz:=false
```

- [use_rviz] parameter: whether to enable rviz visualization.

Open the visual interface(virtual machine side)

```
roslaunch yahboomcar_nav view_rrt_map.launch
```

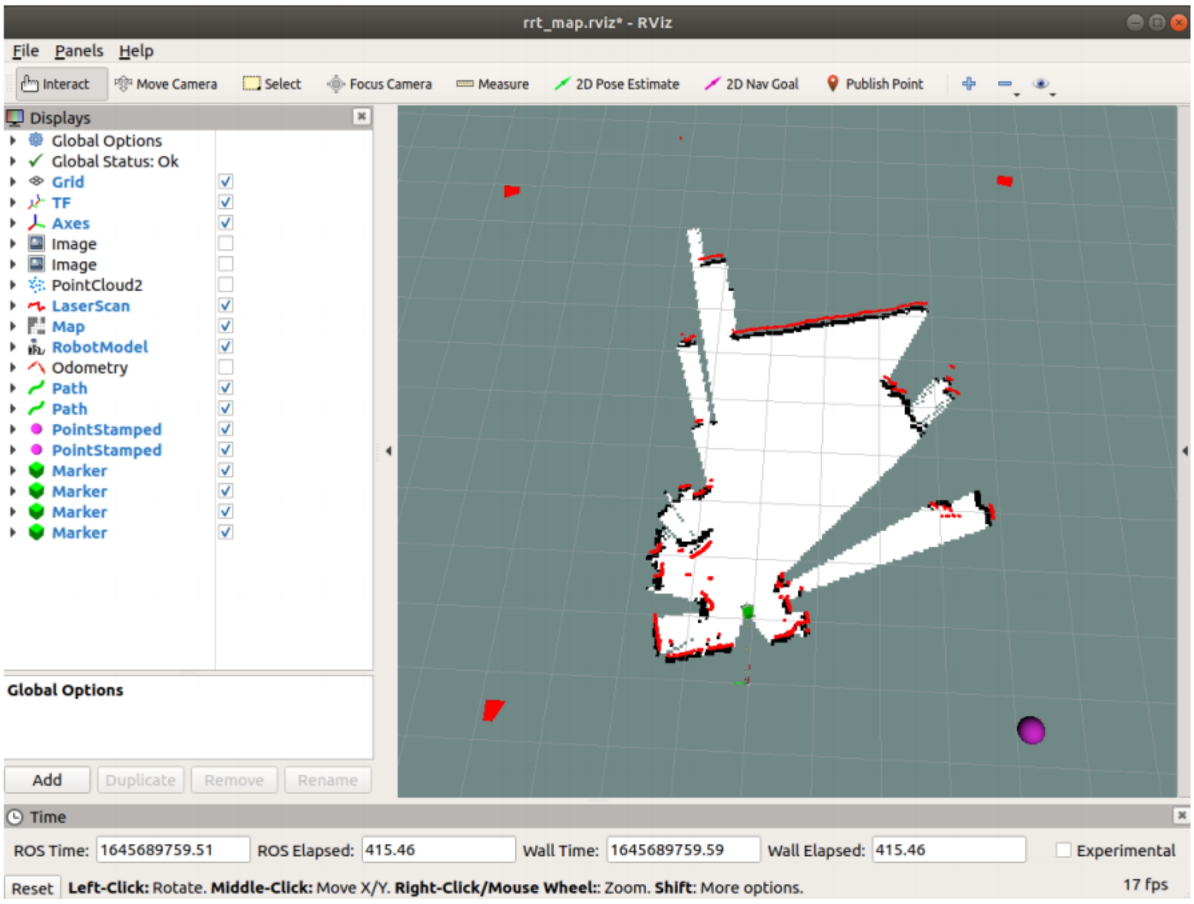


Global Options
Global Status: Ok
Grid ✓
TF ✓
Axes ✓
Image ☐
Image ☐
PointCloud2 ☐
LaserScan ✓
Map ✓
RobotModel ✓
Odometry ☐
Path ✓
Path ✓
PointStamped ✓
PointStamped ✓
Marker ✓
Marker ✓
Marker ✓
Marker ✓

ROS Time: 1645688950.67 ROS Elapsed: 219.70 Wall Time: 1645688950.72 Wall Elapsed: 219.65 ☐ Experimental

The gap at the back of the robot is due to the occlusion of the installation position of the display screen, so a certain range of Lidar data is shielded. The shielding range can be adjusted or not shielded according to the actual situation. For details, see [01. Lidar Basic Course].

10.2.2 Mapping



Global Options
Global Status: Ok
Grid ✓
TF ✓
Axes ✓
Image ☐
Image ☐
PointCloud2 ☐
LaserScan ✓
Map ✓
RobotModel ✓
Odometry ☐
Path ✓
Path ✓
PointStamped ✓
PointStamped ✓
Marker ✓
Marker ✓
Marker ✓
Marker ✓

ROS Time: 1645689759.51 ROS Elapsed: 415.46 Wall Time: 1645689759.59 Wall Elapsed: 415.46 ☐ Experimental

Left-Click: Rotate. **Middle-Click:** Move X/Y. **Right-Click/Mouse Wheel:**: Zoom. **Shift**: More options.

Click [Publish Point] on the [rviz] interface, and then click on the map. Each time you click a point on the map, you must first select [Publish Point]. the **clockwise or counterclockwise** last point is near the car. After selecting five points as required, the robot begins to explore and build a map.

10.2.3 Map save

After the construction is completed, the map is automatically saved and returned to zero. The map is saved to the folder ~/yahboomcar_ws/src/yahboomcar_nav/maps with the name rrt_map, which can be modified in the [simple.launch] file.

rrt_map.yaml

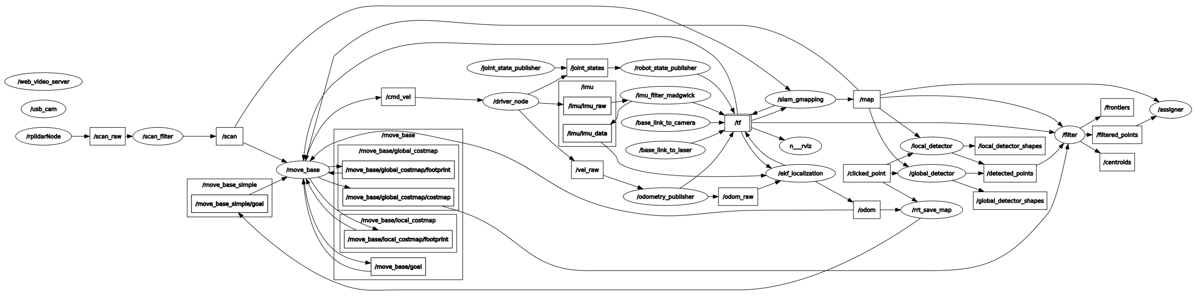
```
image :  map.pgm
resolution :  0.05
origin : [-15.4, -12.2, 0.0]
negate :  0
occupied_thresh :  0.65
free_thresh:   0.196
```

Parameter parsing:

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

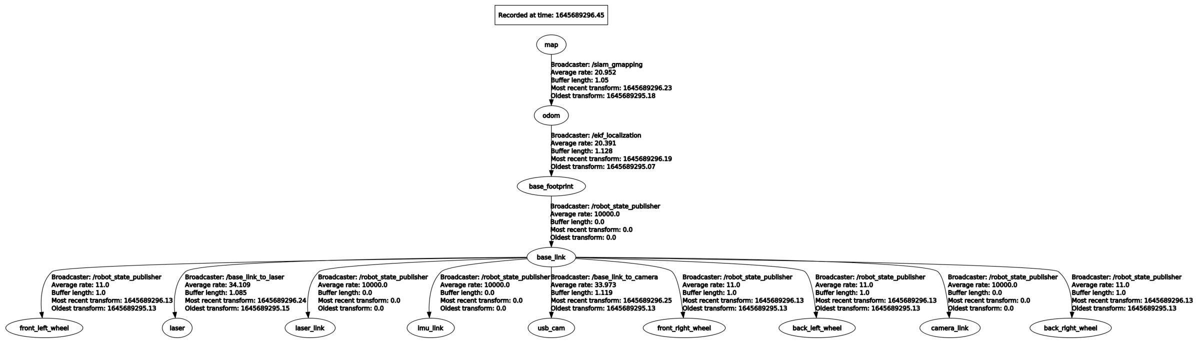
10.2.4 Node View

```
rqt_graph
```



10.2.5 View tf tree

```
rosrun rqt_tf_tree rqt_tf_tree
```


Recorded at time: 1645689296.45
map
Broadcaster: /slam_gmapping
Average rate: 20.952
Buffer length: 1.05
Most recent transform: 1645689296.23
Oldest transform: 1645689295.18
odom
Broadcaster: /ekf_localization
Average rate: 20.391
Buffer length: 1.128
Most recent transform: 1645689296.19
Oldest transform: 1645689295.07
base_footprint
Broadcaster: /robot_state_publisher
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
base_link
Broadcaster: /robot_state_publisher
Average rate: 11.0
Buffer length: 1.0
Most recent transform: 1645689296.13
Oldest transform: 1645689295.13
front_left_wheel
Broadcaster: /base_link_to_laser
Average rate: 34.109
Buffer length: 1.085
Most recent transform: 1645689296.24
Oldest transform: 1645689295.15
laser
Broadcaster: /robot_state_publisher
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
laser_link
Broadcaster: /robot_state_publisher
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
imu_link
Broadcaster: /base_link_to_camera
Average rate: 33.973
Buffer length: 1.119
Most recent transform: 1645689296.25
Oldest transform: 1645689295.13
usb_cam
Broadcaster: /robot_state_publisher
Average rate: 11.0
Buffer length: 1.0
Most recent transform: 1645689296.13
Oldest transform: 1645689295.13
front_right_wheel
Broadcaster: /robot_state_publisher
Average rate: 11.0
Buffer length: 1.0
Most recent transform: 1645689296.13
Oldest transform: 1645689295.13
back_left_wheel
Broadcaster: /robot_state_publisher
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
camera_link
Broadcaster: /robot_state_publisher
Average rate: 11.0
Buffer length: 1.0
Most recent transform: 1645689296.13
Oldest transform: 1645689295.13
back_right_wheel

10.3 global_rrt_frontier_detector

10.3.1. Introduction

The global_rrt_frontier_detector node takes an occupancy grid and finds frontier points(i.e. exploration targets) in it. It publishes detected points so that filter nodes can process them. In a multi-robot configuration, only one instance of the node is running. If desired, running additional instances of the global boundary detector can increase the speed of boundary point detection.

10.3.2 Topics and Services

Subscribe to topics	**type**	**describe**
map	nav_msgs/OccupancyGrid	Topic names are defined by the ~map_Topic parameter. It is the name of the topic that the node receives.
clicked_point	geometry_msgs/PointStamped	The area to be probed by the global_rrt_frontier_detector node. This topic is where the node receives the five points that define the area. The first four points are the four points that define the square area to be explored, and the last point is the starting point of the tree. After these five points are announced, the RRT will begin to probe the border points.
Post a topic	**type**	**describe**
detected_points	geometry_msgs/PointStamped	Post the topic of detected boundary points.
shapes	visualization_msgs/Marker	Post RRT hypothetical linetypes to view with Rviz.

10.3.3 Configuration parameters

parameter	type	Defaults	describe
~map_topic	string	"/robot_1/map"	This node receives the map topic map name
~ eta	float	5.0	This parameter controls the growth rate of the RRT used to detect boundary points, in meters. This parameter should be set according to the map size, a very large value will cause the tree to grow faster and thus detect border points faster, but a larger growth rate also means that the tree will lose small corner points in the map

10.4 local_rrt_frontier_detector

10.4.1 Introduction

This node is similar to global_rrt_frontier_detector. However, it works differently because here the tree keeps getting reset every time a boundary point is detected. This node will run along the Global Boundary Detector node, which is responsible for quickly detecting boundary points located near the robot.

In a multi-robot configuration, each robot runs a local probe instance. So for a team of 3 robots, there will be 4 nodes for detecting boundary points; 3 local detectors and 1 global detector. If needed, running additional instances of the local boundary detector can increase the speed of boundary point detection. All detectors will publish detected boundary points("/detected_points") on the same topic.

10.4.2 Topics and Services

Subscribe to topics	type	describe
map	nav_msgs/OccupancyGrid	The name of the map topic to which this node is subscribed.
clicked_point	geometry_msgs/PointStamped	Similar to global_rrt_frontier_detector node
Post a topic	**type**	**describe**
detected_points	geometry_msgs/PointStamped	Post the topic of detected boundary points.
shapes	visualization_msgs/Marker	Post RRT hypothetical linetypes to view with Rviz.

10.4.3 Configuration parameters

parameter	type	Defaults	describe
~/robot_1/base_link	string	"/robot_1/base_link"	Connect to the frame of the robot. Every time the RRT tree is reset, it will start from the current robot position obtained in this coordinate system.
~map_topic	string	"/robot_1/map"	This node receives the map topic map name
~ eta	float	5.0	This parameter controls the growth rate of the RRT used to detect boundary points, in meters. This parameter should be set according to the map size, a very large value will cause the tree to grow faster and thus detect border points faster, but a larger growth rate also means that the tree will lose small corner points in the map

10.5 frontier_opencv_detector

10.5.1 Introduction

This node is another edge detector, but it is not based on RRT. This node uses OpenCV tools to detect boundary points. It is designed to run alone, in a multi-bot configuration, only one instance should be running(running other instances of this node will not make any difference).

Originally, this node was implemented for comparison with RRT-based boundary detectors. Running this node along the RRT detectors(local and global) can increase the speed of boundary point detection.

Note: You can run any type and number of detectors, all of which will be published on the same topic that the filter node(explained in the next section) subscribes to. The filter, on the other hand, passes the filtered boundary points to the assignor in order to command the robot to explore these points.

10.5.2 Topics and Services

Subscribe to topics	type	describe
map	nav_msgs/OccupancyGrid	The name of the map topic to which this node is subscribed.
Post a topic	**type**	**describe**
detected_points	geometry_msgs/PointStamped	Post the topic of detected boundary points.
shapes	visualization_msgs/Marker	Post RRT hypothetical linetypes to view with Rviz.

10.5.3 Configuration parameters

parameter	type	Defaults	describe
~map_topic	string	"/robot_1/map"	This node receives the map topic map name

10.6 filter

10.6.1 Introduction

This node node receives detected boundary points from all detectors, filters these points, and passes them to the assign node to command the robot. Filtering includes removing old and invalid points, as well as removing redundant points.

10.6.2 Topics and Services

Subscribe to topics	type	describe
map	nav_msgs/OccupancyGrid	Topic names are defined by the ~map_Topic parameter. It is the name of the topic that the node receives.
robot_x/move_base_node /global_costmap/costmap	nav_msgs/OccupancyGrid	x is the number of the robot. This node subscribes to the topic of all costmaps for all robots, so costmaps are required. Normally, costmaps should be published by navigation(there will be one costmap per robot when navigation is turned on on a robot). For example, if n_robots=2, the nodes will subscribe to: robot_1/move_base_node/global_costmap/costmap and robot_2/move_base_node/global_costmap/costmap. The costmap is used to remove invalid points. Note: The namespace of all nodes corresponding to robots should start with robot_x.
detected_points	geometry_msgs/PointStamped	The topic name defined by ~goals_topic. It is the topic on which the filter node receives boundary detection points.
Post a topic	**type**	**describe**
frontiers	visualization_msgs/Marker	The filter node only publishes topics of filtered boundary points.
centroids	visualization_msgs/Marker	The filter node publishes the topic of the received boundary points.
filtered_points	MsgLink(msg/type)	All filtered points are sent to the assigner node of this topic as an array of points.

10.6.3 Configuration parameters

parameter	type	Defaults	describe
~map_topic	string	"/robot_1/map"	This node receives the map topic map name
~costmap_clearing_threshold	float	70.0	Costmap cleanup threshold
~info_radius	float	1.0	The information radius used to calculate the information gain of the boundary point.
~goals_topic	string	/detected_points	Defines the topic the node receives to detect boundary points
~n_robots	float	1.0	Number of robots
~namespace	string		Namespaces
~namespace_init_count	float	1.0	index of namespace
~rate	float	100.0	Node cycle rate(in Hz).

10.7 Assign

10.7.1 Introduction

This node receives target detection targets, i.e. filtered boundary points issued by the filtering node, and commands the robot accordingly. The evaluator node commands the robot via move_base_node. That's why navigation is initiated on the robot.

10.7.2 Topics and Services

Subscribe to topics	type	describe
map	nav_msgs/OccupancyGrid	Topic names are defined by the ~map_Topic parameter. It is the name of the topic that the node receives.
frontiers_topic	nav_msgs/OccupancyGrid	The topic name is defined by the ~frontiers_topic parameter

10.7.3 Configuration parameters

parameter	type	Defaults	describe
~map_topic	string	"/robot_1/map"	This node receives the map topic map name
~info_radius	float	1.0	The information radius used to calculate the information gain of the boundary point.
~info_multiplier	float	3.0	The unit is meters. This parameter is used to emphasize the importance of the information gain of the boundary point relative to the cost (expected travel distance to the boundary point).
~hysteresis_radius	float	3.0	The unit is meters. This parameter defines the lag radius.
~hysteresis_gain	float	2.0	The unit is meters. This parameter defines the hysteresis gain.
~frontiers_topic	string	/filtered_points	This node receives topics for boundary points.
~n_robots	float	1.0	Number of robots
~namespace	string		Namespaces
~namespace_init_count	float	1.0	Starting indexing of bot names.
~delay_after_assignement	float	0.5	The unit is seconds. It defines the amount of delay after each robot assignment.
~global_frame	string	"/map"	for the global coordinate system. In a single bot, it is the same as the "map_topic" parameter. In the case of multiple robots, the coordinate system name corresponds to the global coordinate system name.