RPLidar For ROS Based SLAM and Navigation

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1、Introduce RPLidar

- RPLidar A1/A2 Performance and ToolKit

2、RPLidar Driver Package for ROS： rplidar_ros

- Introduce Package
- How to using it on Robot Base

3、 RPLidar for SLAM and Navigation

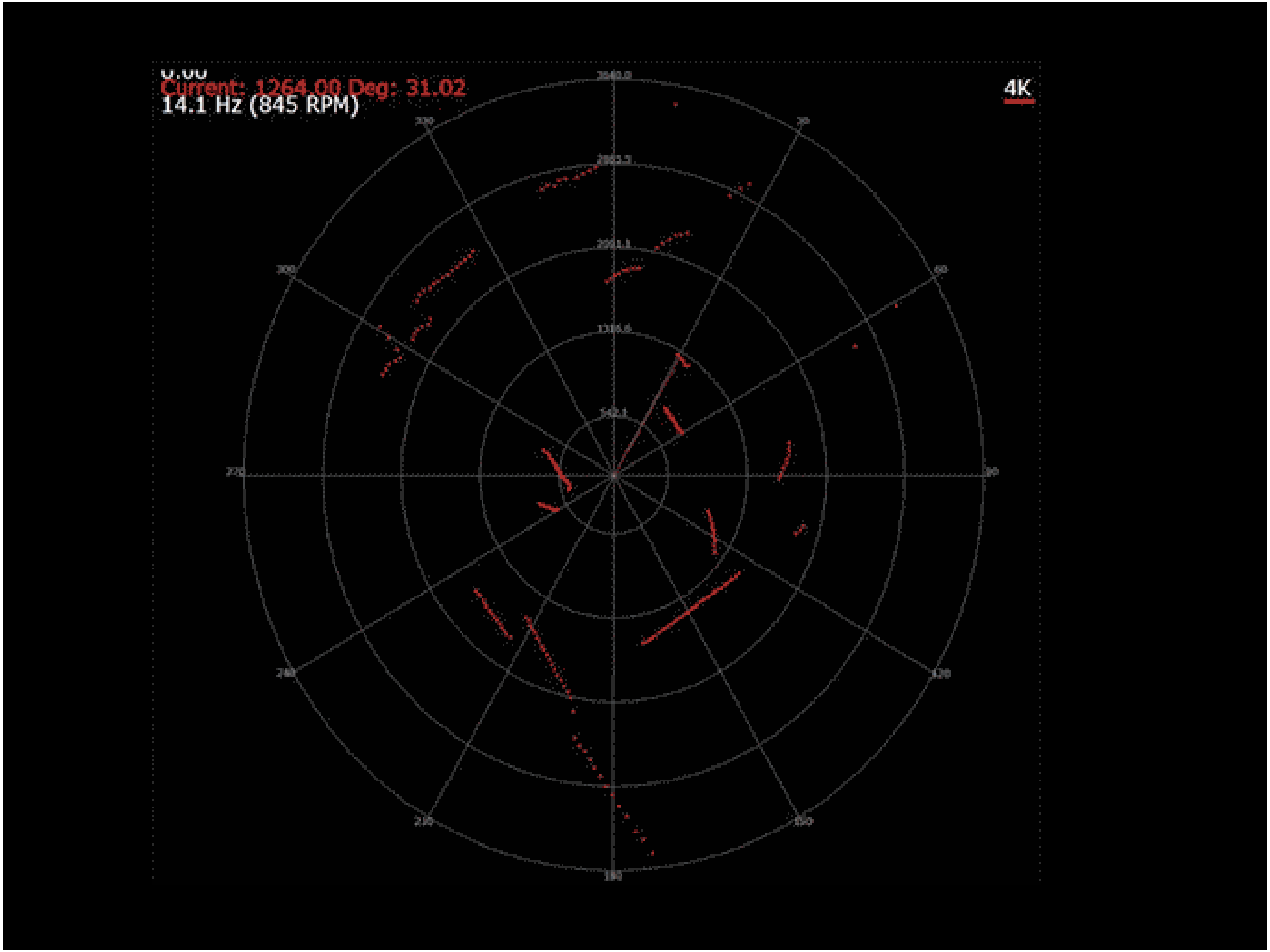
- RPLidar running SLAM: Gmapping/Hector/slam_Karto
- RPLidar running Navigation

4、SLAMWARE Solution for Mobile Robot

1、Introduce RPLidar

RPLIDAR A1

RPLIDAR A2


Current: 1264.00 Deg: 31.02
14.1 Hz (845 RPM)
4K
330
30
300
60
270
90
240
120
210
150
180
2640.0
2113.1
1585.1
1056.0
528.1

RPLidar A1

- 仅针对型号 A1M8

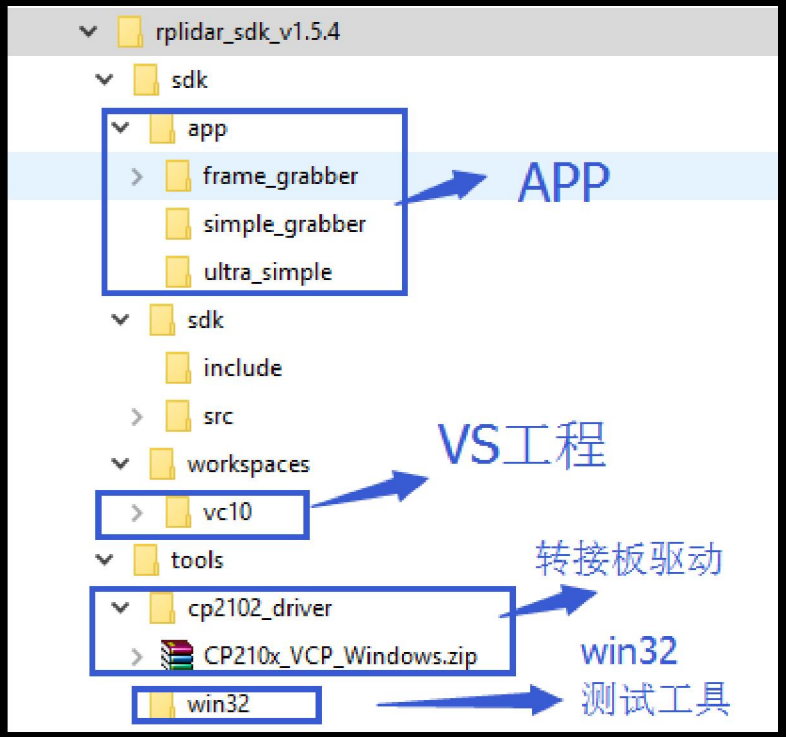
项目	单位	最小值	典型值	最大值	备注
测距范围	米(m)	待定	0.15 - 6	待定	基于白色高反光物体测得
扫描角度	度(Deg)	不适用	0-360	不适用	
测距分辨率	毫米 (mm)	不适用	<0.5	不适用	测量物体在 1.5 米以内
			<实际距离的 1%		全部量程范围内*
角度分辨率	度(Deg)	不适用	≤1	不适用	5.5hz 扫描时
单次测距时间	毫秒(ms)	不适用	0.5	不适用	
测量频率	赫兹(Hz)	不适用	≥2000	2010	
扫描频率	赫兹(Hz)	1	5.5	10	扫描 360 度的频率。典型值为一次扫描恰好 360 个采样点的情况

RPLidar A2

- 仅针对型号 A2M3/A2M4

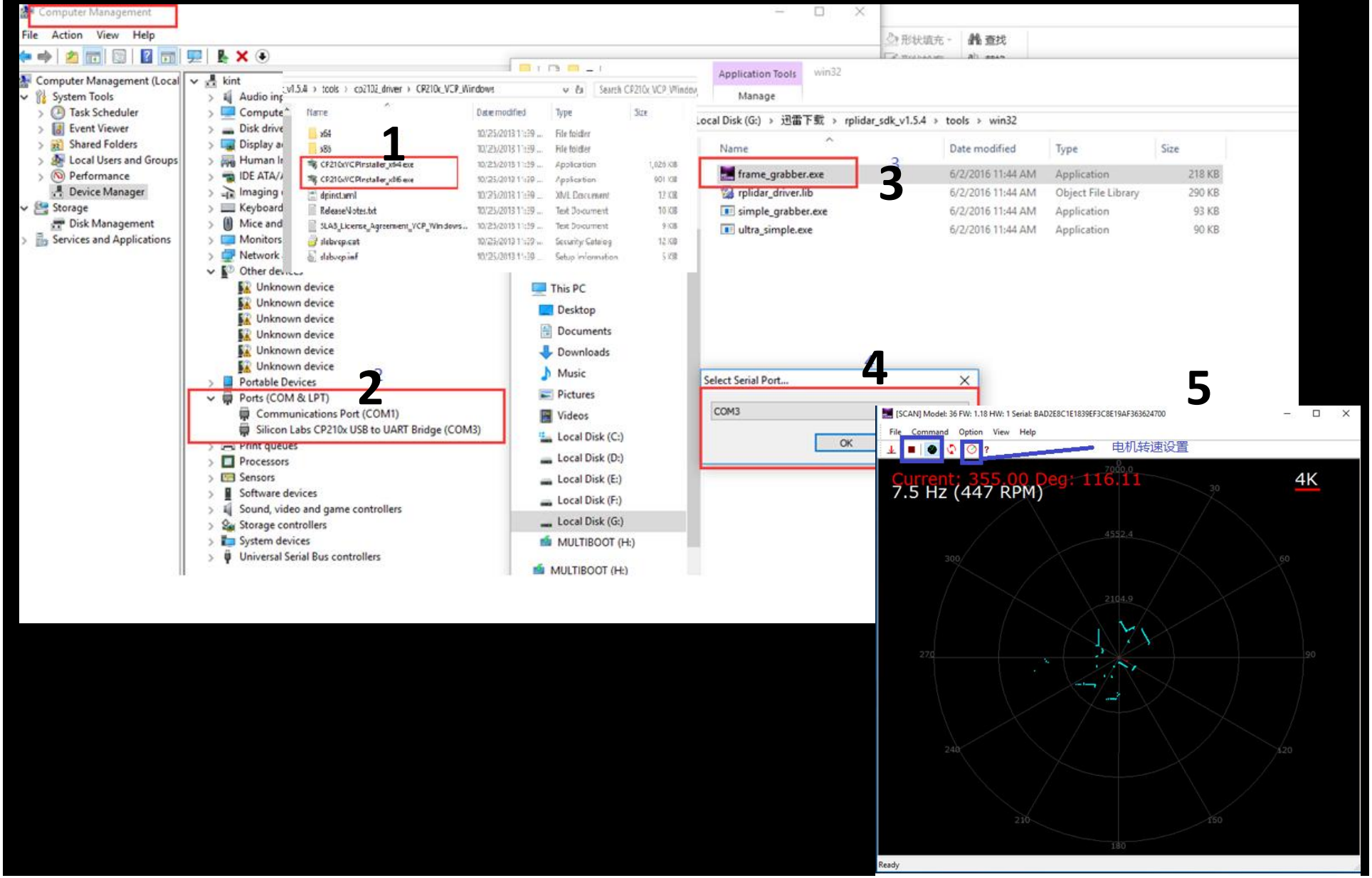
项目	单位	最小值	典型值	最大值	备注
测距范围	米(m)	待定	0.15 - 6	待定	基于白色高反光物体测得
扫描角度	度(Deg)	不适用	0-360	不适用	
测距分辨率	毫米 (mm)	不适用	<0.5	不适用	测量物体在 1.5 米以内
			<实际距离的 1%*		全部量程范围内*
角度分辨率	度(Deg)	0.45	0.9*	1.35	10hz 扫描时
单次测距时间	毫秒(ms)	不适用	0.25	不适用	
测量频率	赫兹(Hz)	2000	≥4000	4100	
扫描频率	赫兹(Hz)	5	10*	15	扫描一周的频率。典型值为一次扫描恰好 400 个采样点的情况

RPLidar SDK ToolKit



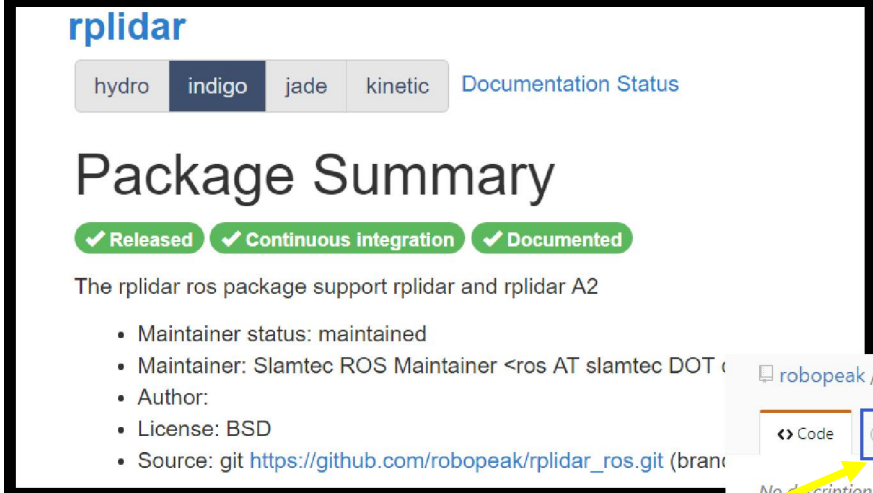
RPLIDAR SDK V1.5.4

RPLidar Test Tool (win32)

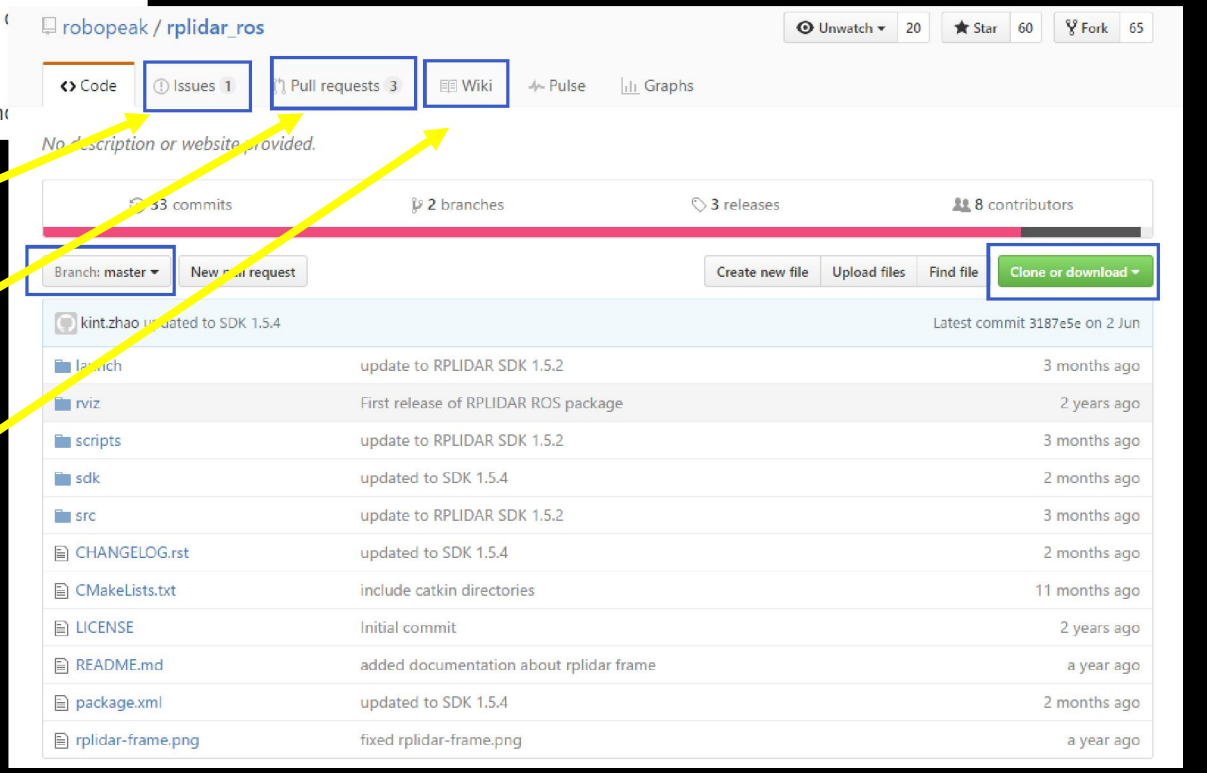


2、 RPLidar drive package for ROS： rplidar_ros

rplidar_ros ROS wiki



rplidar_ros GitHub



Issue(closed)

Pull Request

Wiki

rplidar_ros

Topic:

scan (sensor_msgs/LaserScan)

Services:

stop_motor (std_srvs/Empty)

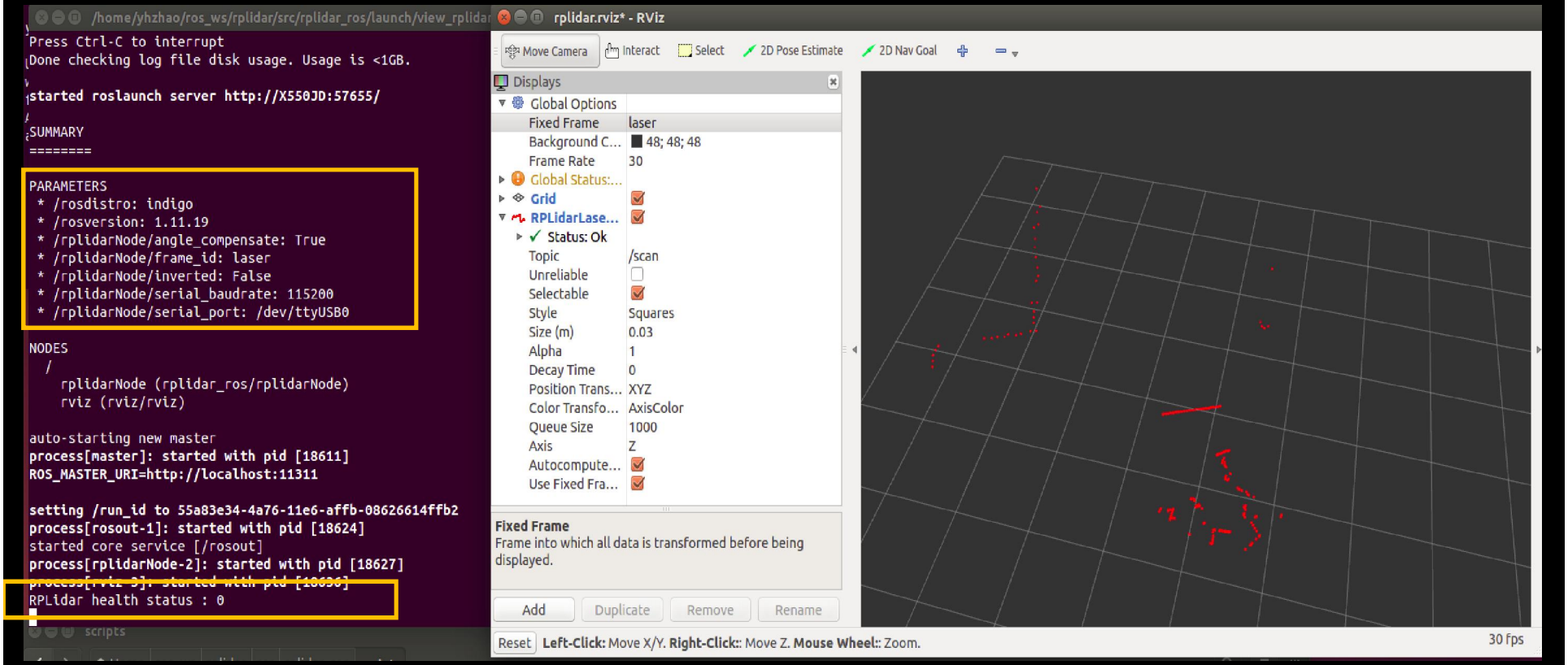
start_motor (std_srvs/Empty)

rplidar.launch

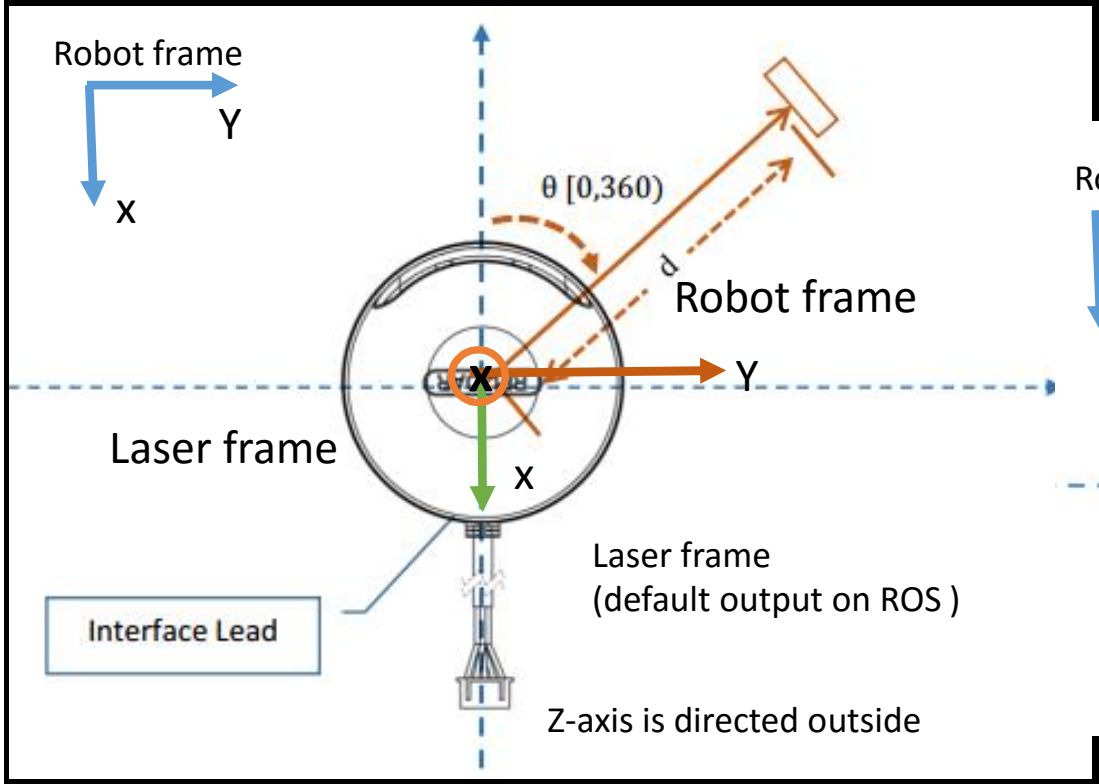
```
<launch>
  <node name="rplidarNode"          pkg="rplidar_ros"  type="rplidarNode" output="screen">
  <param name="serial_port"         type="string" value="/dev/ttyUSB0"/>
  <param name="serial_baudrate"     type="int"    value="115200"/>
  <param name="frame_id"            type="string" value="laser"/>
  <param name="inverted"            type="bool"   value="false"/>
  <param name="angle_compensate"    type="bool"   value="true"/>
  </node>
</launch>
```

view_rplidar.launch

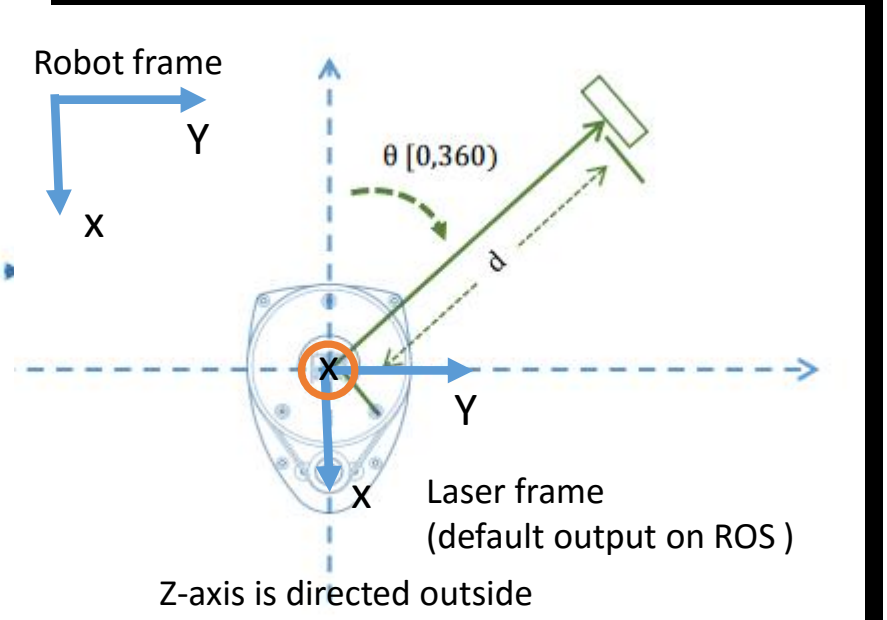
rplidar_ros start status: Health status: 0



How to install RPLidar： TF



RPLidar A2



RPLidar A1

RPLidar install on base：TF

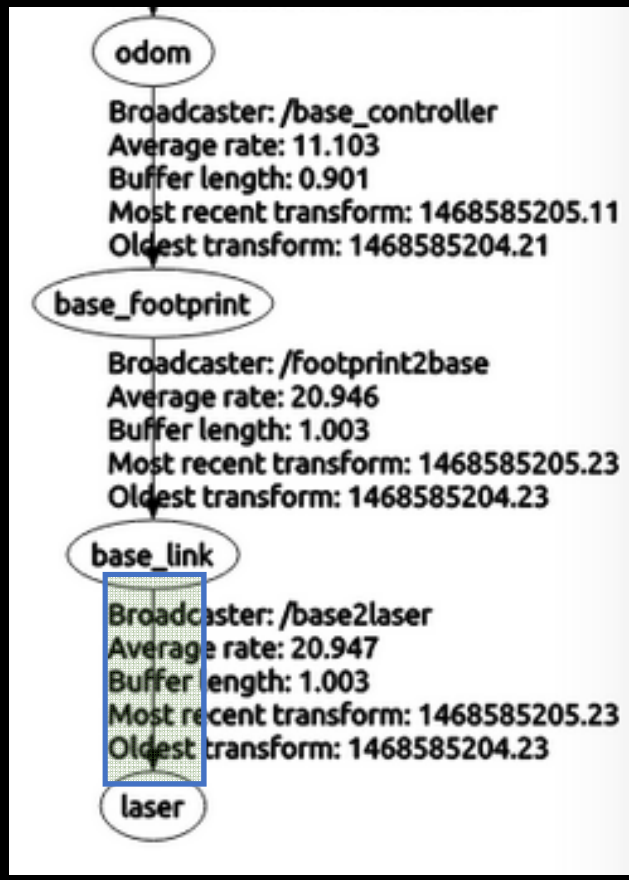
TF: RPLidar with Base

1.Setup model:URDF

URDF(user-defined reference frame **)**

2.TF publish

（static_transform_publisher）




```
<node name="base2laser" pkg="tf"
type="static_transform_publisher"
args="0.07 0 0 0 0 0 1 /base_link /laser 50"/>
```

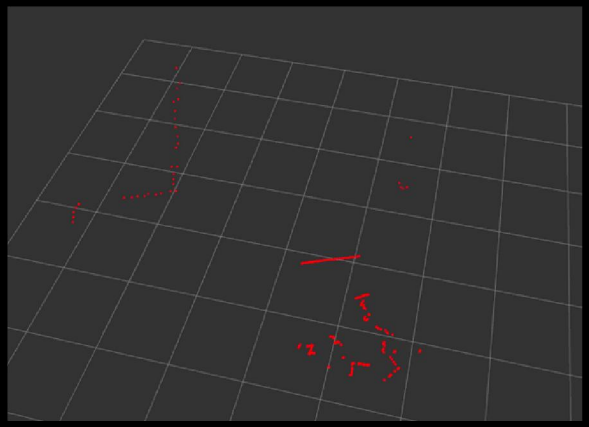
x y z qx qy qz qw frame_id child_frame_id period(milliseconds)

Launch_file 链接: http://pan.baidu.com/s/1hswfHKK 密码: r2d2

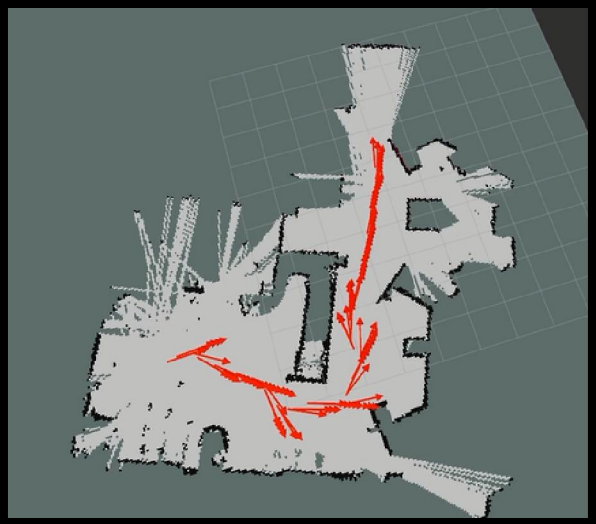
rplidar_ros ？ SLAM

3、RPLidar For SLAM/Navigation

RVIZ : Different Display



rplidar_ros



SLAM

Navigation

ROSbag DataSet： RPLidar A2 + SDP

Explore

链接: http://pan.baidu.com/s/1gfl2z3H 密码: if46

Configure Launch file for RPLidar A2 to SLAM

Gmapping + Hector + Slam_karto

Configure

Topic: /scan

TF （ frame_ID 、 transform）: base->laser

Configure param: max_range(6.0), min_range(0.15)

Check

```
rosrun tf view_frames
rqt_graph
rostopic  list
rqt
```

Running SLAM(videos) : Gmapping Hector slam_karto

Gmapping

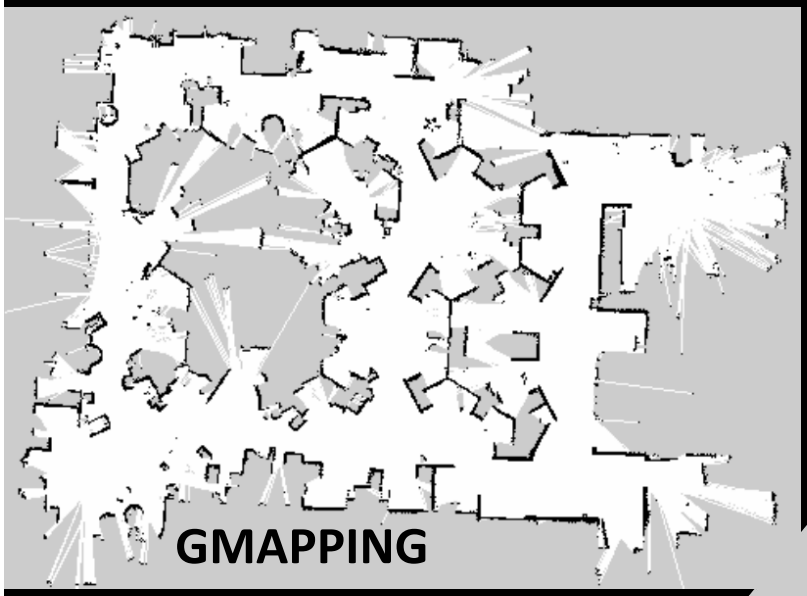
Hector

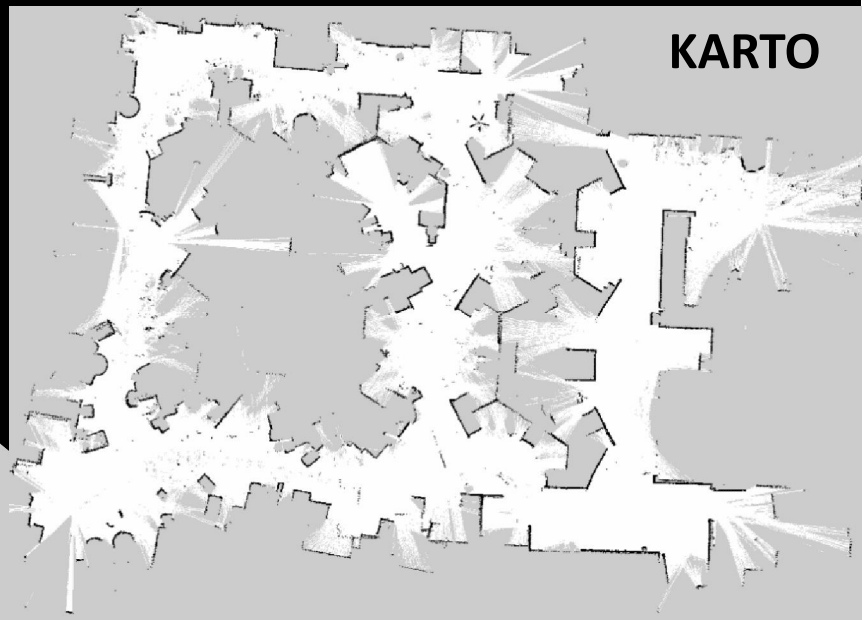
Karto

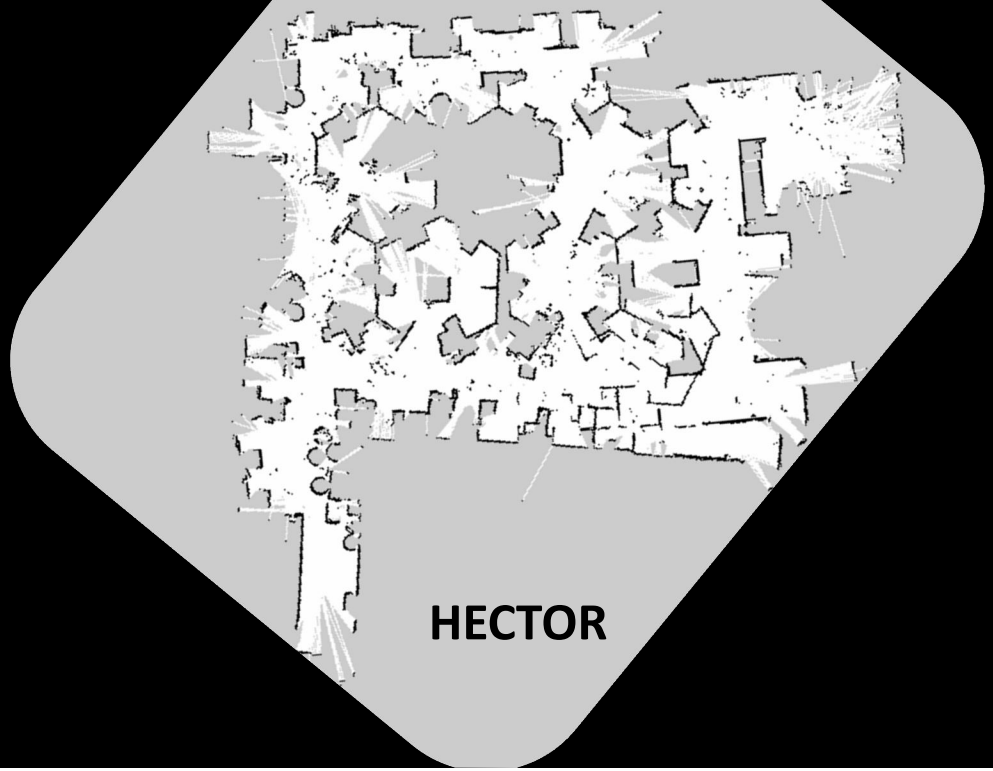
ROSbag SLAM record： RPLidar A2 + SDP + gmapping/hector/karto

链接: http://*pan.baidu.com/s/1o8dCCaQ 密码: vd1q*

MAPs





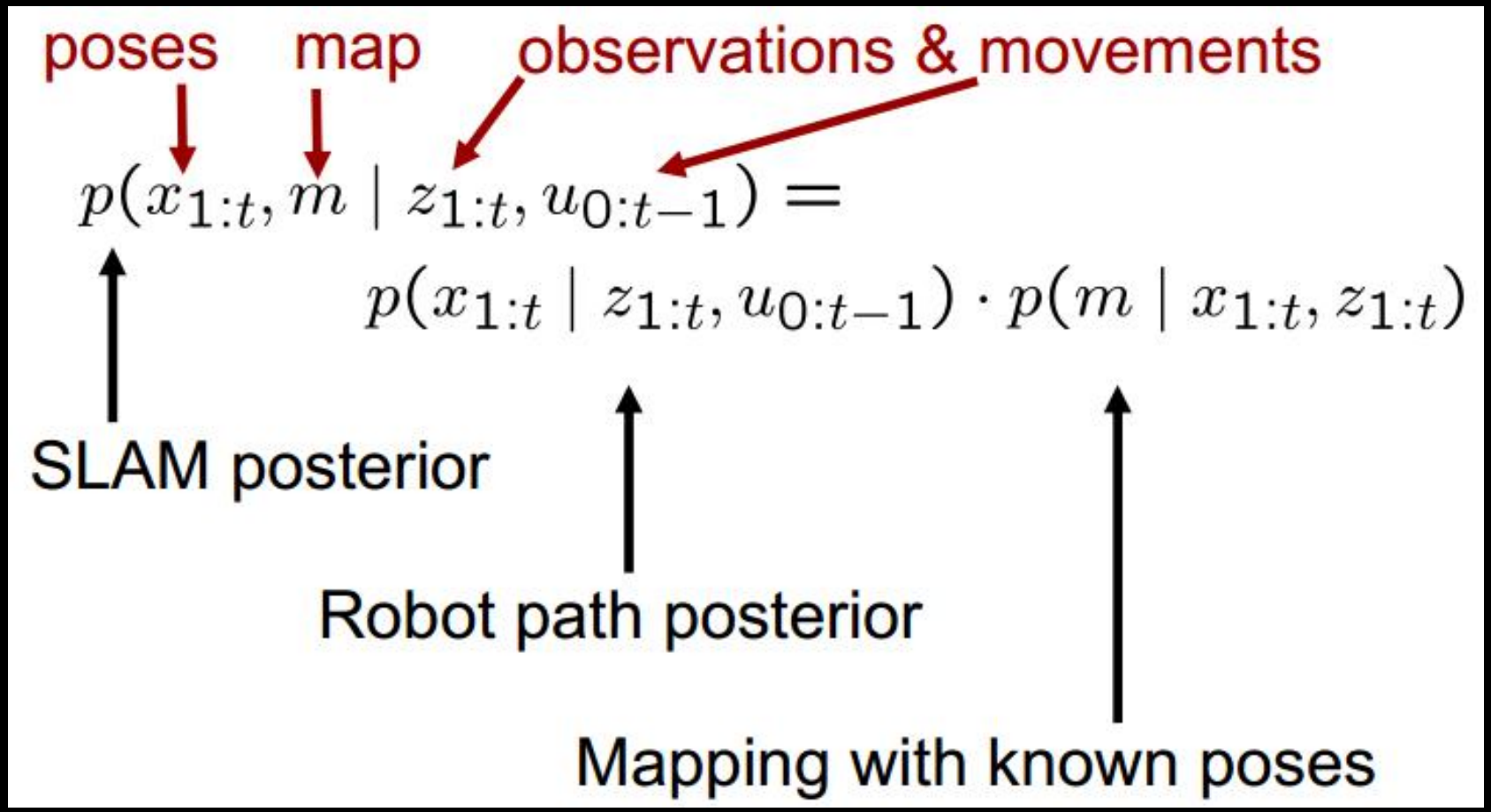


LASER 2D-SLAM Algorithm simple Analysis

Gmapping	Hector	Karto
RBPF	Multi-resolution- maps	Multi-search
SGD/ ICP	Guass-Newton	CSM
Motion model + observation model	IncreasedMap	loopClosure
scanMatcherMap		SPA/G2O
Map Display		poseMap
Gmapping	**Hector**	**Karto**
ros-perception/slam_**gmapping**	tu-darmstadt-ros-pkg **hector_slam**	ros-perception **slam_karto**
ros-perception/openslam_**gmapping**		ros-perception **open_karto**
		skasperski **navigation_2d**

Gmapping

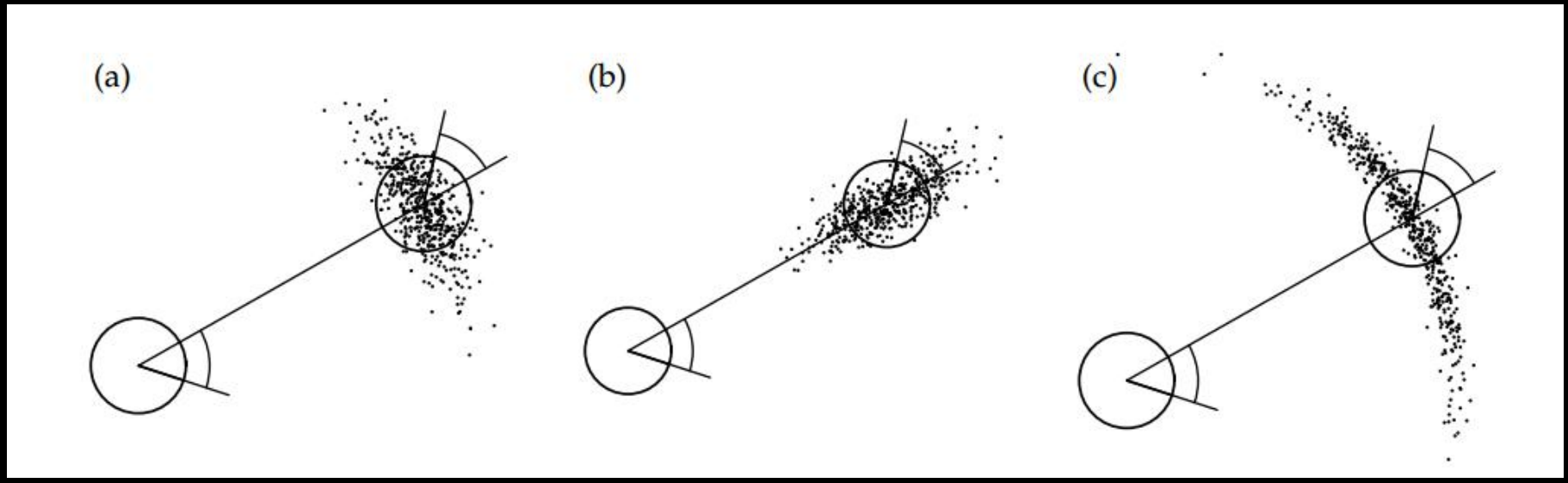
Rao-Blackwellized Particle Filters(RBPF)



Gmapping

MCL / Particle Filters(PF)

Sampling : Motion model(odom)

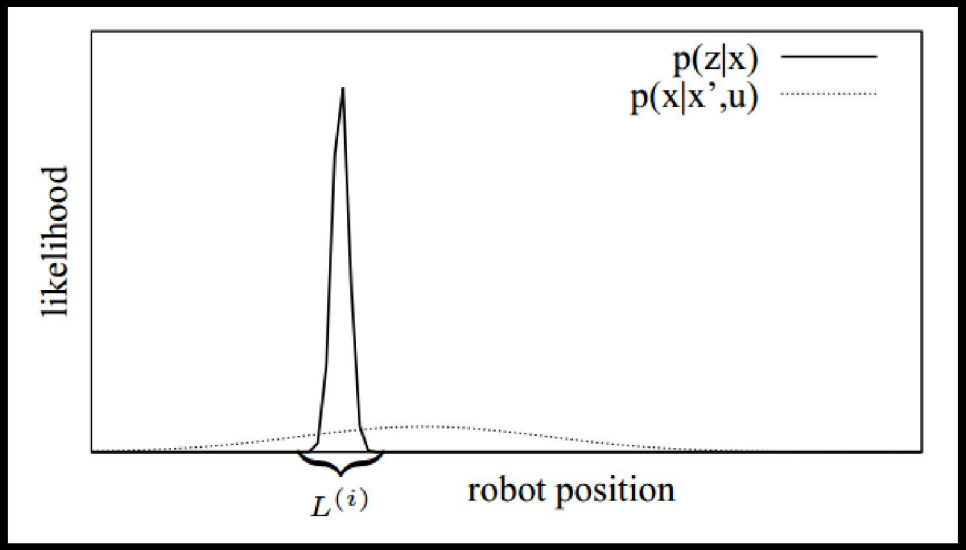


The number of particles → **small**

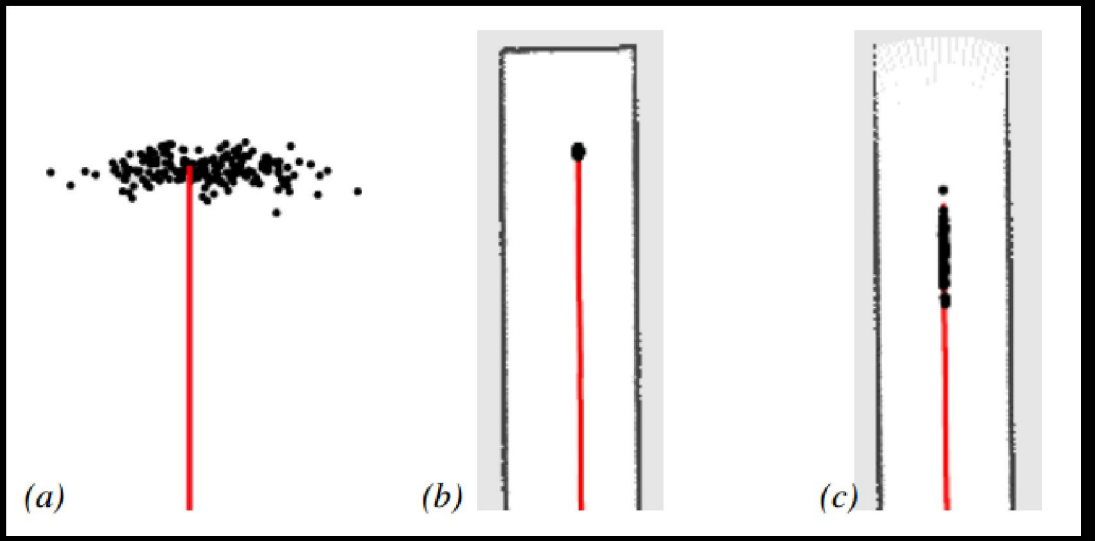
Gmapping

MCL : Particle Filters(PF)

Improve Odom



Observed during mapping



Scan Matcher (SGD/ICP)

$$x_t^* = \underset{x_t}{\operatorname{argmax}}\, p(z_t \mid x_t, m_{t-1}) \cdot p(x_t \mid x_{t-1}^*, u_{t-1})$$

- $bestPose = x_{\text{init}}$
- $bestScore = s(bestPose, z, m)$
- $searchStep = initialSearchStep$
- $iterations = 0$
- while $(!iterations < maxIterations)$
  - $maxMoveScore = bestScore$
  - $bestMovePose = bestPose$
  - for $move$ in $(Backward, Forward, Left, Right, RotateLeft, RotatrRight)$
    - $testPose = computePose(bestPose, move)$
    - $score = s(testPose, z, m)$
    - if $(maxMoveScore < score)$
      - $maxMoveScore = score$
      - $bestMovePose = testPose$
  - if $(bestScore < maxMoveScore)$
    - $bestScore < maxMoveScore$
    - $bestPose = bestMovePose$
  - else
    - $searchStep = searchStep/2$
    - $iterations++$

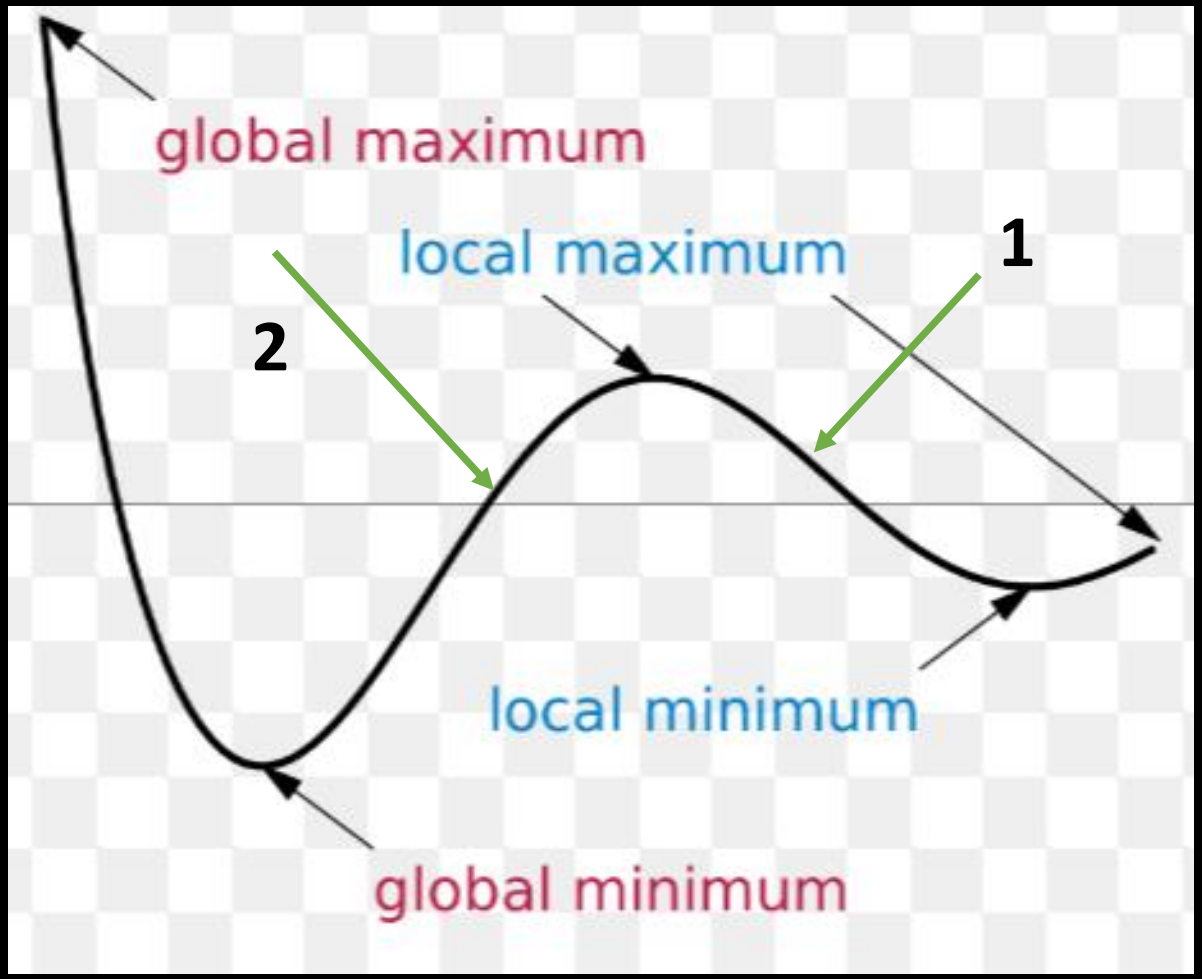
Simple Gradient Descent

Iteration number

Local minimal value

Score Function

Global minimal / Local minimal



Odom

+

PF

Score(m,p,r) / likelihoodAndScore(w,m,p,r)

Total score: $s(x, z, m) = \sum_i s(x, z^i, m)$

Cell score: $s(x, z^i, m) = e^{d^2/\sigma}$

Observation map Point $\hat{z}^i = x \oplus z^i$

mapCell (accumulator) **cell.mean**

Closest to $\hat{z}^i$ (kernelSize)

$(x, y)^T$

$$d^2 = (\hat{z}^i - (x, y)^T))^T \cdot (\hat{z}^i - (x, y)^T))$$

EndPoint : hit && free (threshold) => found?

Focuse: Matcher / Observation

updateTreeWeights / Resample

updateTreeWeights ：Normalize (max + distance)

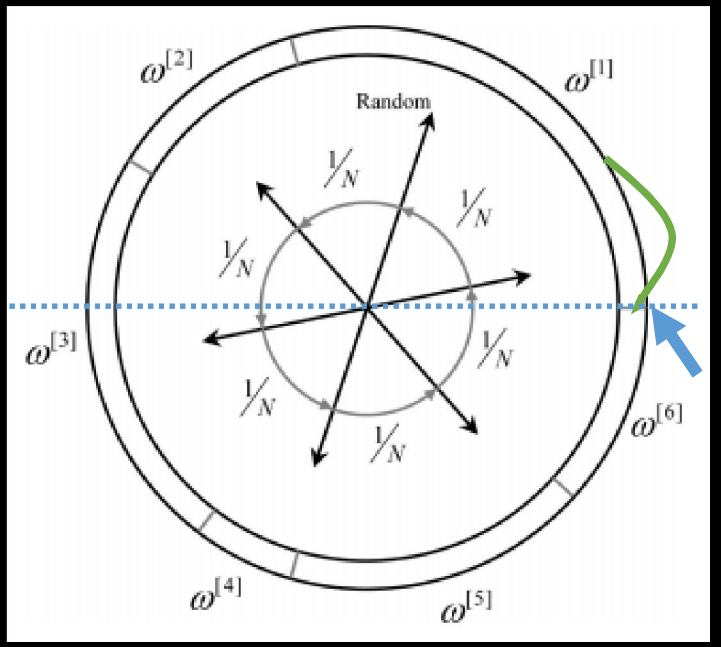
$$N_{\text{eff}} = \frac{1}{\sum_{i=1}^{N} \left(\tilde{w}^{(i)}\right)^2},$$

Neff （effective number of particles）

Neff < threshold : Particle deletion

Resample :

- Roulette wheel resampling
- Stochastic universal



Map update : Based Frequancy

computeActiveArea ： mapCell → pointer memory

MapSize :

PatchIndex : gridLine(p0, p1, &line);

registerScan: gridLine(p0, p1, &line);

Cell Update : Statistics（acc n visits ）

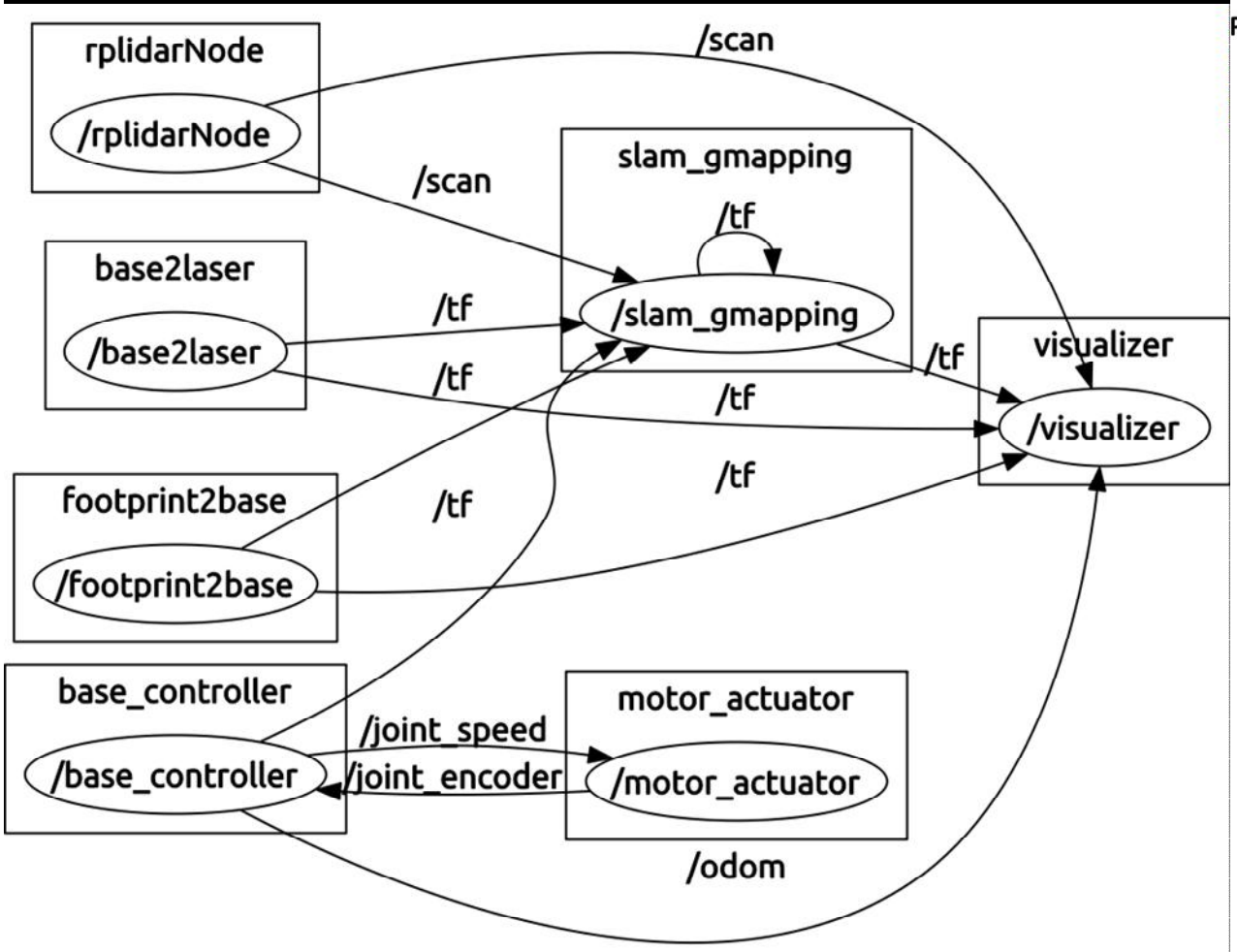
$$m_t^{x,y} = (b_t^{x,y}, v_t^{x,y}) = \begin{cases} (b_t^{x,y} + 1, v_t^{x,y} + 1) & \text{if occupied} \\ (b_t^{x,y}, v_t^{x,y} + 1) & \text{if free} \end{cases}$$

MapDisplay: BestParticle(pose, smap, readings)

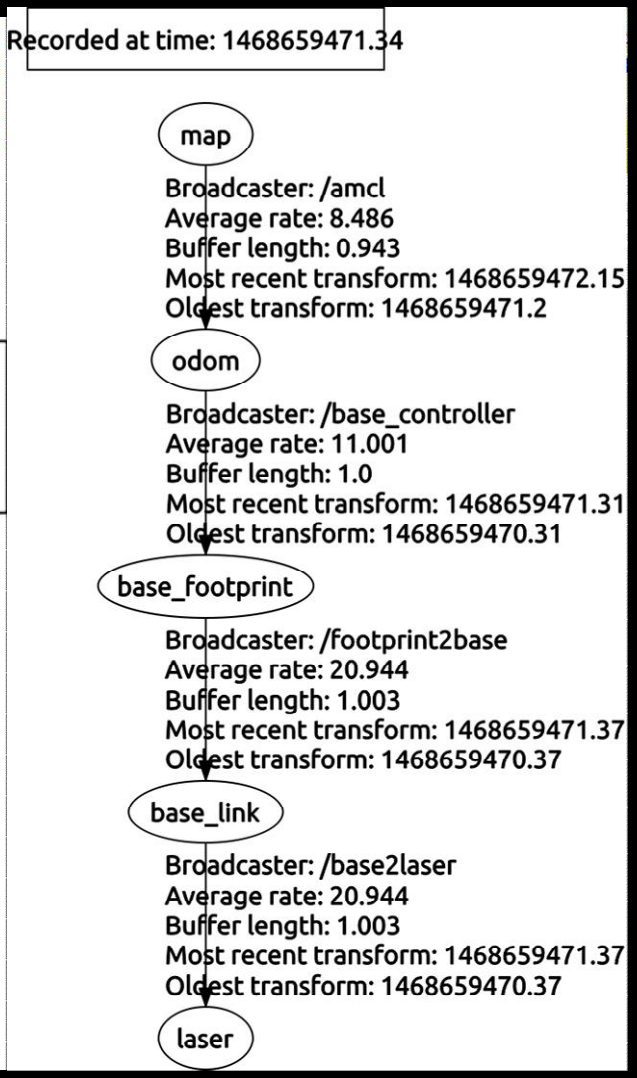
$$p(m_t^{x,y}) = \frac{b_t^{x,y}}{v_t^{x,y}}$$

Tnode： all reading

rqt_graph


rplidarNode
/rplidarNode
/scan
/scan
slam_gmapping
/tf
/slam_gmapping
base2laser
/base2laser
/tf
/tf
/tf
/tf
visualizer
/visualizer
/tf
footprint2base
/footprint2base
/tf
base_controller
/base_controller
/joint_speed
/joint_encoder
motor_actuator
/motor_actuator
/odom

TF


Recorded at time: 1468659471.34
map
Broadcaster: /amcl
Average rate: 8.486
Buffer length: 0.943
Most recent transform: 1468659472.15
Oldest transform: 1468659471.2
odom
Broadcaster: /base_controller
Average rate: 11.001
Buffer length: 1.0
Most recent transform: 1468659471.31
Oldest transform: 1468659470.31
base_footprint
Broadcaster: /footprint2base
Average rate: 20.944
Buffer length: 1.003
Most recent transform: 1468659471.37
Oldest transform: 1468659470.37
base_link
Broadcaster: /base2laser
Average rate: 20.944
Buffer length: 1.003
Most recent transform: 1468659471.37
Oldest transform: 1468659470.37
laser

```
<launch>
    <param name="use_sim_time" value="false"/>
    <node pkg="gmapping" type="slam_gmapping"
name="slam_gmapping" output="screen">
      <!--remap from="scan" to="base_scan"/-->
      <param name="map_update_interval" value="5.0"/>
      <param name="maxUrange" value="6.0"/>
      <param name="sigma" value="0.05"/>
      <param name="kernelSize" value="1"/>
      <param name="lstep" value="0.05"/>
      <param name="astep" value="0.05"/>
      <param name="iterations" value="5"/>
      <param name="lsigma" value="0.075"/>
      <param name="ogain" value="3.0"/>
      <param name="lskip" value="0"/>
      <param name="minimumScore" value="50"/>
      <param name="srr" value="0.1"/>
      <param name="srt" value="0.2"/>
      <param name="str" value="0.1"/>
      <param name="stt" value="0.2"/>
      <param name="linearUpdate" value="1.0"/>
      <param name="angularUpdate" value="0.5"/>
      <param name="temporalUpdate" value="3.0"/>
      <param name="resampleThreshold" value="0.5"/>
      <param name="particles" value="30"/>
      <param name="xmin" value="-5.0"/>
      <param name="ymin" value="-5.0"/>
      <param name="xmax" value="5.0"/>
      <param name="ymax" value="5.0"/>
      <param name="delta" value="0.05"/>
      <param name="llsamplerange" value="0.01"/>
      <param name="llsamplestep" value="0.01"/>
      <param name="lasamplerange" value="0.005"/>
      <param name="lasamplestep" value="0.005"/>
    </node>
    <node name="visualizer" pkg="rviz" type="rviz" args="-d
$(find sdp_navigation)/rviz/navigation.rviz"/>
</launch>
```

Configure param

Hector SLAM

Only scan

Multi-Resolution Map

ScanMatcher (Guass-Newton)

IncreasedMap

Features

Demand

Laser frequent

Move slowly

Map memory constant

ScanMatcher (Gaussian-Newton)

State (t-1)

$$\xi = (p_x, p_y, \psi)^{\mathrm{T}}$$

$\Delta\xi$

$$\xi + \Delta\xi$$

Estimate (t)

Optimization Function:

$$\xi^* = \underset{\xi}{\operatorname{argmin}} \sum_{i=1}^{n} \left[1 - M(\mathbf{S}_i(\xi))\right]^2$$

Measure error:

$$\sum_{i=1}^{n} \left[1 - M(\mathbf{S}_i(\xi + \Delta\xi))\right]^2 \to 0\,.$$

Active map_cell: (t)

$$\mathbf{S}_i(\xi) = \begin{pmatrix} \cos(\psi) & -\sin(\psi) \\ \sin(\psi) & cos(\psi) \end{pmatrix} \begin{pmatrix} s_{i,x} \\ s_{i,y} \end{pmatrix} + \begin{pmatrix} p_x \\ p_y \end{pmatrix}$$

$$\frac{\partial S_i(\xi)}{\partial \xi} = \begin{pmatrix} 1 & 0 & -\sin(\psi)s_{i,x} - \cos(\psi)s_{i,y} \\ 0 & 1 & \cos(\psi)s_{i,x} - \sin(\psi)s_{i,y} \end{pmatrix}$$

ScanMatcher (Gaussian-Newton)

$$\sum_{i=1}^{n} [1 - M(\mathbf{S}_i(\boldsymbol{\xi} + \Delta\boldsymbol{\xi}))]^2 \to 0\,.$$

Taylor Expansion:

$$\sum_{i=1}^{n} \left[1 - M(\mathbf{S}_i(\boldsymbol{\xi})) - \nabla M(\mathbf{S}_i(\boldsymbol{\xi})) \frac{\partial \mathbf{S}_i(\boldsymbol{\xi})}{\partial \boldsymbol{\xi}} \Delta\boldsymbol{\xi})\right]^2 \to 0\,.$$

Partial Derivative :

$$2 \sum_{i=1}^{n} \left[\nabla M(\mathbf{S}_i(\boldsymbol{\xi})) \frac{\partial \mathbf{S}_i(\boldsymbol{\xi})}{\partial \boldsymbol{\xi}}\right]^T \left[1 - M(\mathbf{S}_i(\boldsymbol{\xi})) - \nabla M(\mathbf{S}_i(\boldsymbol{\xi})) \frac{\partial \mathbf{S}_i(\boldsymbol{\xi})}{\partial \boldsymbol{\xi}} \Delta\boldsymbol{\xi})\right] = 0$$

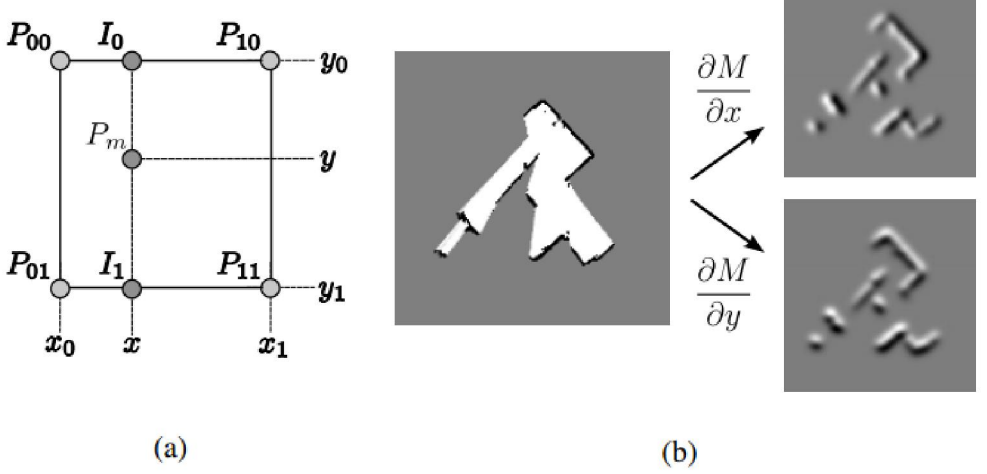
Estimate : (t)

$$\Delta\boldsymbol{\xi} = \mathbf{H}^{-1} \sum_{i=1}^{n} \left[\nabla M(\mathbf{S}_i(\boldsymbol{\xi})) \frac{\partial \mathbf{S}_i(\boldsymbol{\xi})}{\partial \boldsymbol{\xi}}\right]^T [1 - M(\mathbf{S}_i(\boldsymbol{\xi}))]$$

$$\mathbf{H} = \sum_{i=1}^{n} \left[\nabla M(\mathbf{S}_i(\boldsymbol{\xi})) \frac{\partial \mathbf{S}_i(\boldsymbol{\xi})}{\partial \boldsymbol{\xi}}\right]^T \left[\nabla M(\mathbf{S}_i(\boldsymbol{\xi})) \frac{\partial \mathbf{S}_i(\boldsymbol{\xi})}{\partial \boldsymbol{\xi}}\right]$$

Map Access

$$M(P_m) \approx \frac{y - y_0}{y_1 - y_0}\left(\frac{x - x_0}{x_1 - x_0}M(P_{11}) + \frac{x_1 - x}{x_1 - x_0}M(P_{01})\right) + \frac{y_1 - y}{y_1 - y_0}\left(\frac{x - x_0}{x_1 - x_0}M(P_{10}) + \frac{x_1 - x}{x_1 - x_0}M(P_{00})\right)$$



(a) (b)

Fig. 2. (a) Bilinear filtering of the occupancy grid map. Point P_m is the point whose value shall be interpolated. (b) Occupancy grid map and spatial derivatives.

P = occ/(occ+free)

$$\frac{\partial M}{\partial x}(P_m) \approx \frac{y - y_0}{y_1 - y_0}(M(P_{11}) - M(P_{01})) + \frac{y_1 - y}{y_1 - y_0}(M(P_{10}) - M(P_{00}))$$

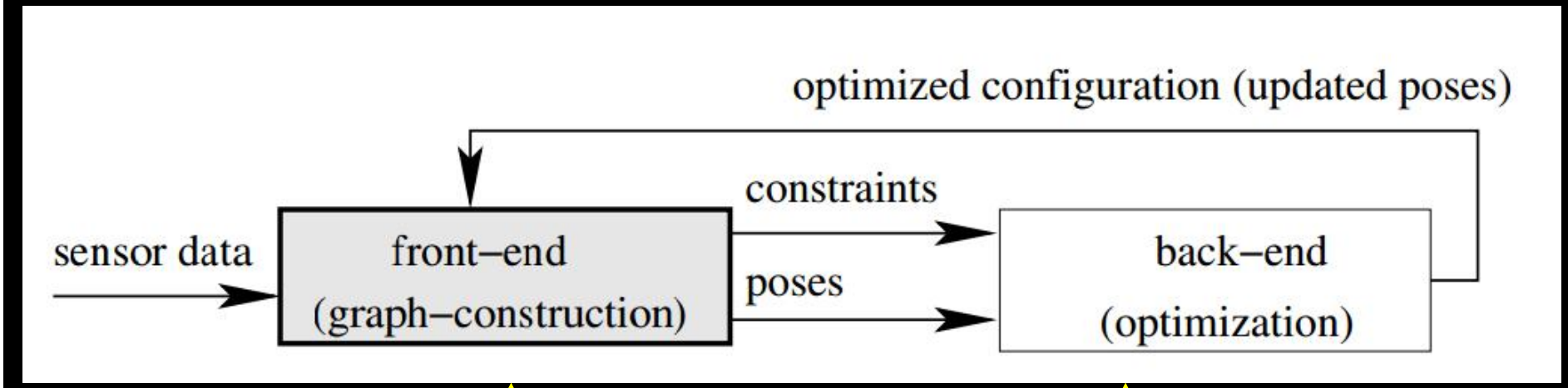
$$\frac{\partial M}{\partial y}(P_m) \approx \frac{x - x_0}{x_1 - x_0}(M(P_{11}) - M(P_{10})) + \frac{x_1 - x}{x_1 - x_0}(M(P_{01}) - M(P_{00}))$$

Configure param of Hector_mapping

```
<!-- Author:  Kint Zhao @SLAMTEC      Jan.29.2016     -->
<launch>
  <arg name="tf_map_scanmatch_transform_frame_name"
default="odom laser"/>
  <arg name="base_frame" default="base_link"/>
  <arg name="odom_frame" default="odom"/>
  <arg name="pub_map_odom_transform" default="true"/>
  <arg name="scan_subscriber_queue_size" default="5"/>
  <arg name="scan_topic" default="scan"/>
  <arg name="map_size" default="800"/>

  <node pkg="hector_mapping" type="hector_mapping"
name="hector_mapping" output="screen">

    <!-- Frame names -->
    <param name="map_frame" value="map" />
    <param name="base_frame" value="$(arg base_frame)" />
    <param name="odom_frame" value="$(arg odom_frame)" />

    <!-- Tf use -->
    <param name="use_tf_scan_transformation" value="true"/>
    <param name="use_tf_pose_start_estimate" value="false"/>
    <param name="pub_map_odom_transform" value="$(arg
pub_map_odom_transform)"/>

    <!-- Map size / start point -->
    <param name="map_resolution" value="0.050"/>
    <param name="map_size" value="$(arg map_size)"/>
    <param name="map_start_x" value="0.5"/>
    <param name="map_start_y" value="0.5" />
    <param name="map_multi_res_levels" value="2" />
```

```
    <!-- Map update parameters -->
    <param name="update_factor_free" value="0.4"/>
    <param name="update_factor_occupied" value="0.9" />
    <param name="map_update_distance_thresh" value="0.4"/>
    <param name="map_update_angle_thresh" value="0.06" />
    <param name="laser_z_min_value" value = "-1.0" />
    <param name="laser_z_max_value" value = "1.0" />

    <param name="laser_max_dist" value = "5.8" />
    <param name="laser_min_dist" value = "0.15" />

    <!-- Advertising config -->
    <param name="advertise_map_service" value="true"/>

    <param name="scan_subscriber_queue_size" value="$(arg
scan_subscriber_queue_size)"/>
    <param name="scan_topic" value="$(arg scan_topic)"/>

    <!-- Debug parameters -->
    <!--
      <param name="output_timing" value="false"/>
      <param name="pub_drawings" value="true"/>
      <param name="pub_debug_output" value="true"/>
    -->
    <param name="tf_map_scanmatch_transform_frame_name"
value="$(arg tf_map_scanmatch_transform_frame_name)" />
  </node>

<node name="visualizer" pkg="rviz" type="rviz" args="-d $(find
sdp_navigation)/rviz/navigation.rviz"/>
</launch>
```

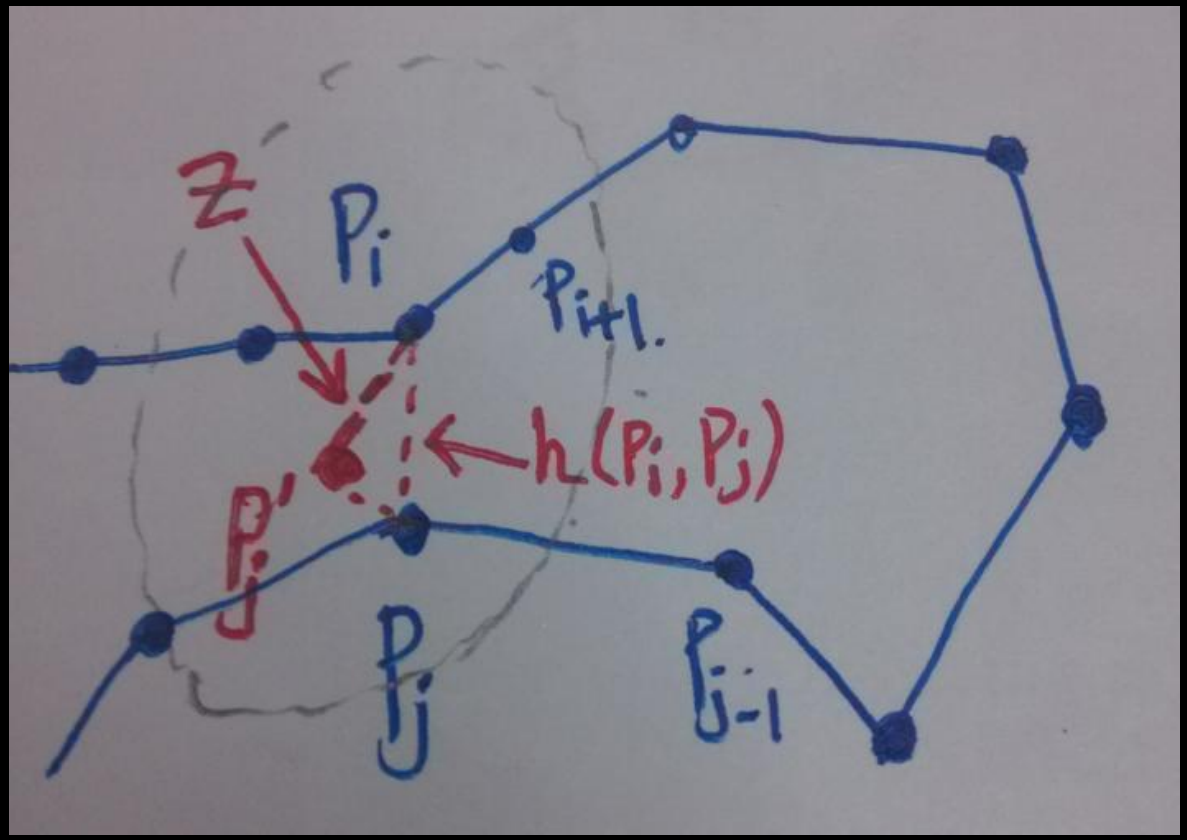
Slam_karto ： POSE-GRAPH



Scan Matcher
Loop closure（global/local）

Non-linear
optimization

Constraint ： scanToMap



Robot pose ：

$$c_i = \left[t_i^T, \theta_i \right]^T = \left[x_i, y_i, \theta_i \right]^T$$

Offset of c_i and c_j :
（ Constraint ）

$$h\left(c_i, c_j\right) = \begin{bmatrix} R_i^T \left(t_j - t_i \right) \\ \theta_j - \theta_i \end{bmatrix}$$

$$e_{ij} \equiv z_{ij} - h\left(c_i, c_j\right)$$

Add Links

KeyScan: 机器人运动一定的距离或角度

addScans: 将chain laser生成map(occupy), **scanToMap**的方式调整odom预测的pose.

Link to previsous scan

Link to Running scans

RunningScan chain：一定数量且距当前一定距离内的激光数据链。滑动窗口式抛 距离最远的scan。

Link to other near chains

NearChain: 以当前节点开始广度优先的方式从graph中遍历相邻的一定距离范围内所有节点，依据当前id从sensorManager中分别递增与递减寻找一定范围内的chain，生成nearLinkScans.

Loop Closure：

1) 依据当前的Vertex, 从Graph中找到与之相邻的所有vertex(一定距离范围内).

2) 采取广度优先搜索的方式，将相邻（next）与相连（adjacentVertices）添加进 nearLinkedScans.

3) 从sensorManager中取从前到后，依据id序号挑选与当前在一定距离范围内，且不在 nearLinkedScans中的candidateScans, 当数量达到一定size，返回。

4）loopScanMatcher进行scanTomap的匹配，当匹配response 和covariance达到一定要求 认为闭环检测到。得到调整的correct pose.

5）Add link to loop：调整边（全局闭环）

6) 触发correctPose: spa优化

karto_slam(SPA) / nav_2d_karto（TBB+G2O）

- Optimizer： SPA(Sparse Pose Adjustment)

Objective function:

$$F(c,e)=\sum_{i,j\in E} e_{ij}^{T}\Lambda_{ij}e_{ij}$$

Continuable Levenberg-Marquardt:

$$\left(H+\lambda\cdot H_{diag}\right)\Delta c=J^{T}\Lambda e$$

where

$$\mathbf{H}\equiv\mathbf{J}^{\top}\mathbf{\Lambda}\mathbf{J}$$

$$J=\partial e/\partial c$$

$$\Lambda=\mathrm{diag}\left(\Lambda_{\mathrm{ij}},ij\in E\right)$$

$$c=c+\Delta c$$

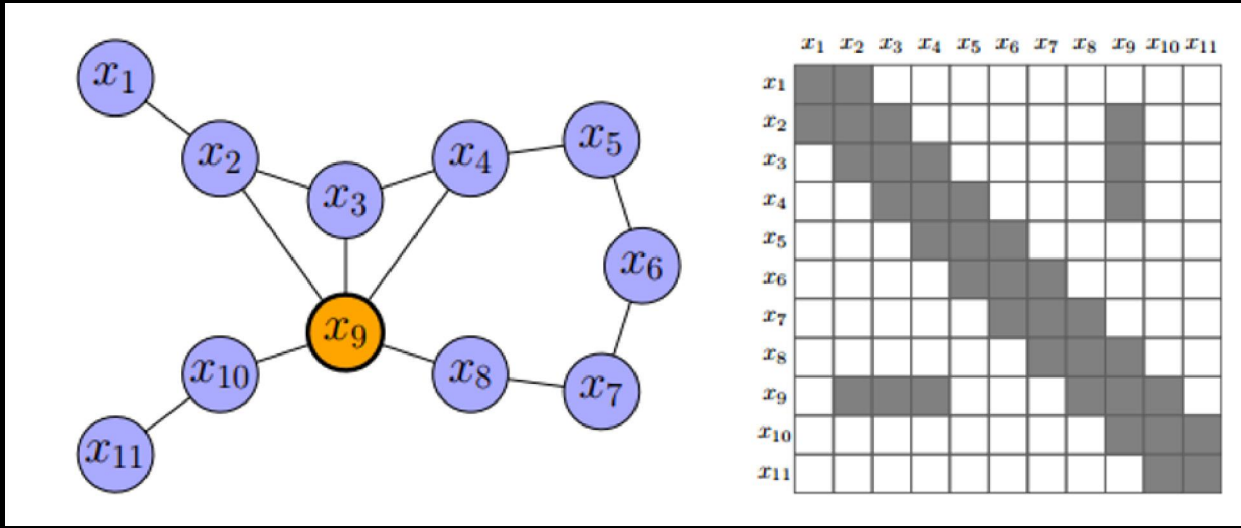
```
sudo apt-get install  libcsparse3.1.2 libcxsparse3.1.2
libsuitesparse-dev
```

Configure param of slam_karto

```
<launch>
  <node pkg="slam_karto" type="slam_karto" name="slam_karto"
output="screen">
    <remap from="scan" to="scan"/>
    <param name="odom_frame" value="odom"/>
    <param name="map_update_interval" value="25"/>
    <param name="resolution" value="0.025"/>
    <rosparam command="load" file="$(find
sdp_navigation)/param/karto_mapper_params.yaml" />
  </node>

<node name="visualizer" pkg="rviz" type="rviz" args="-d $(find
sdp_navigation)/rviz/navigation.rviz"/>
</launch>
```

```
use_scan_matching: true
use_scan_barycenter: true
minimum_travel_distance: 0.3
minimum_travel_heading: 0.4   # 0.2
scan_buffer_size: 67
scan_buffer_maximum_scan_distance: 20.0
link_match_minimum_response_fine: 0.6
link_scan_maximum_distance: 4
correlation_search_space_dimension: 2
correlation_search_space_resolution: 0.05
correlation_search_space_smear_deviation: 0.03

do_loop_closing: true
loop_match_minimum_chain_size: 5
loop_match_maximum_variance_coarse: 0.4
loop_match_minimum_response_coarse: 0.4
loop_match_minimum_response_fine: 0.6
loop_search_space_dimension: 10   # 2.8
loop_search_space_resolution: 0.1
loop_search_space_smear_deviation: 0.03
loop_search_maximum_distance: 4.0

distance_variance_penalty: 0.3
angle_variance_penalty: 0.35
fine_search_angle_offset: 0.00349
coarse_search_angle_offset: 0.349
coarse_angle_resolution: 0.0349
minimum_angle_penalty: 0.9
minimum_distance_penalty: 0.5
use_response_expansion: false
```

Sparse



$$\begin{bmatrix} 1 & 0 & 4 & 0 \\ 0 & 5 & 0 & 2 \\ 0 & 0 & 0 & 1 \\ 6 & 8 & 0 & 0 \end{bmatrix} \Rightarrow$$

col_ptr	0		2		4	5		7
row_ind	0	3	1	3	0	1	2	
val	1	6	5	8	4	2	1	

CSparse

Compressed Column Storage

Pose Graph Compression

Spatial Decimation / Information Filter

Cyrill Stachniss 2012

RPLidar A2 running Navigation: (amcl + move_base)

Navigation

monitoring and controlling the movement from one place to another

Perceptual environment： **map / sensor(rplidar,sonar,camera,bumper)**

Analysis environment： **costmap(global/local)**

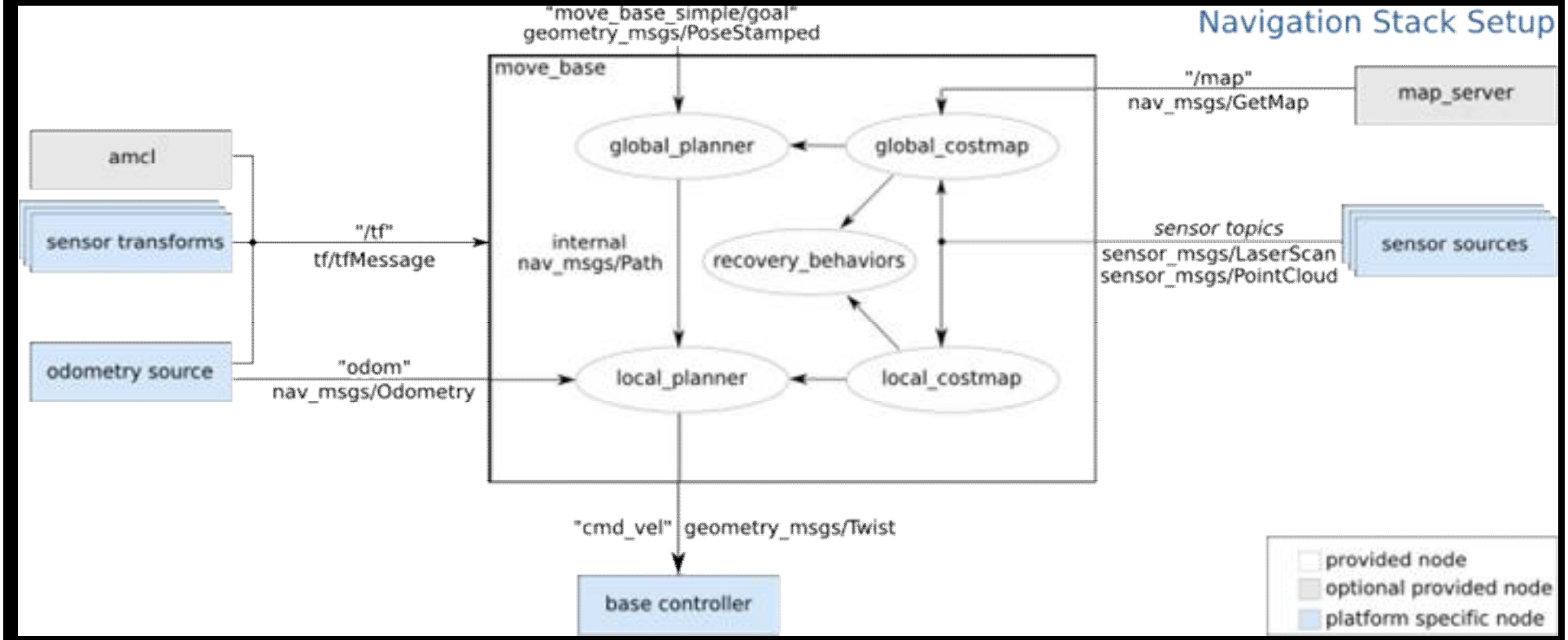
Localization： **AMCL(current) / Goal**

Path： **Global Planner**

Action： **Local Planner**

ActionServer /actionlib

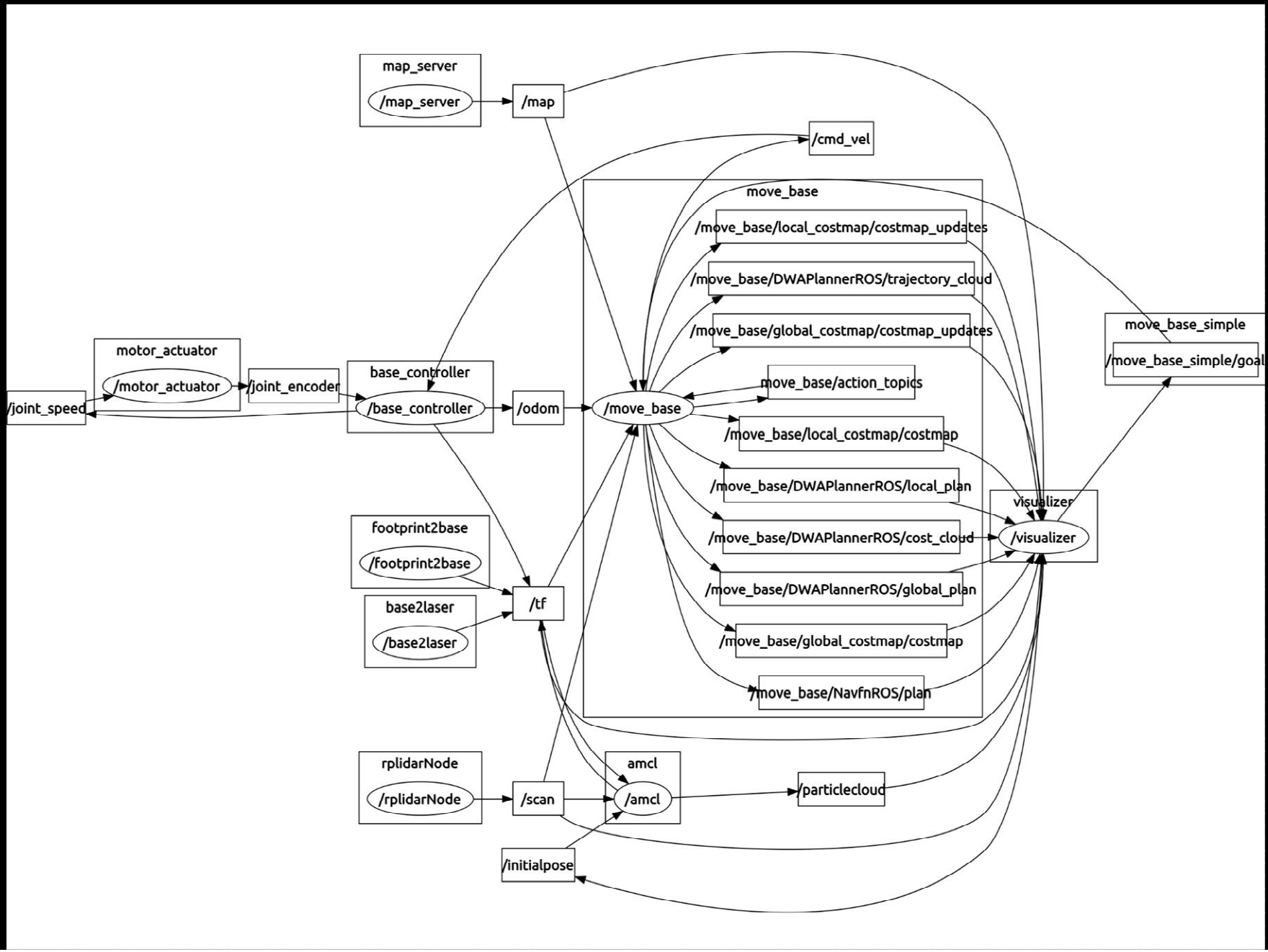
Framework of move_base



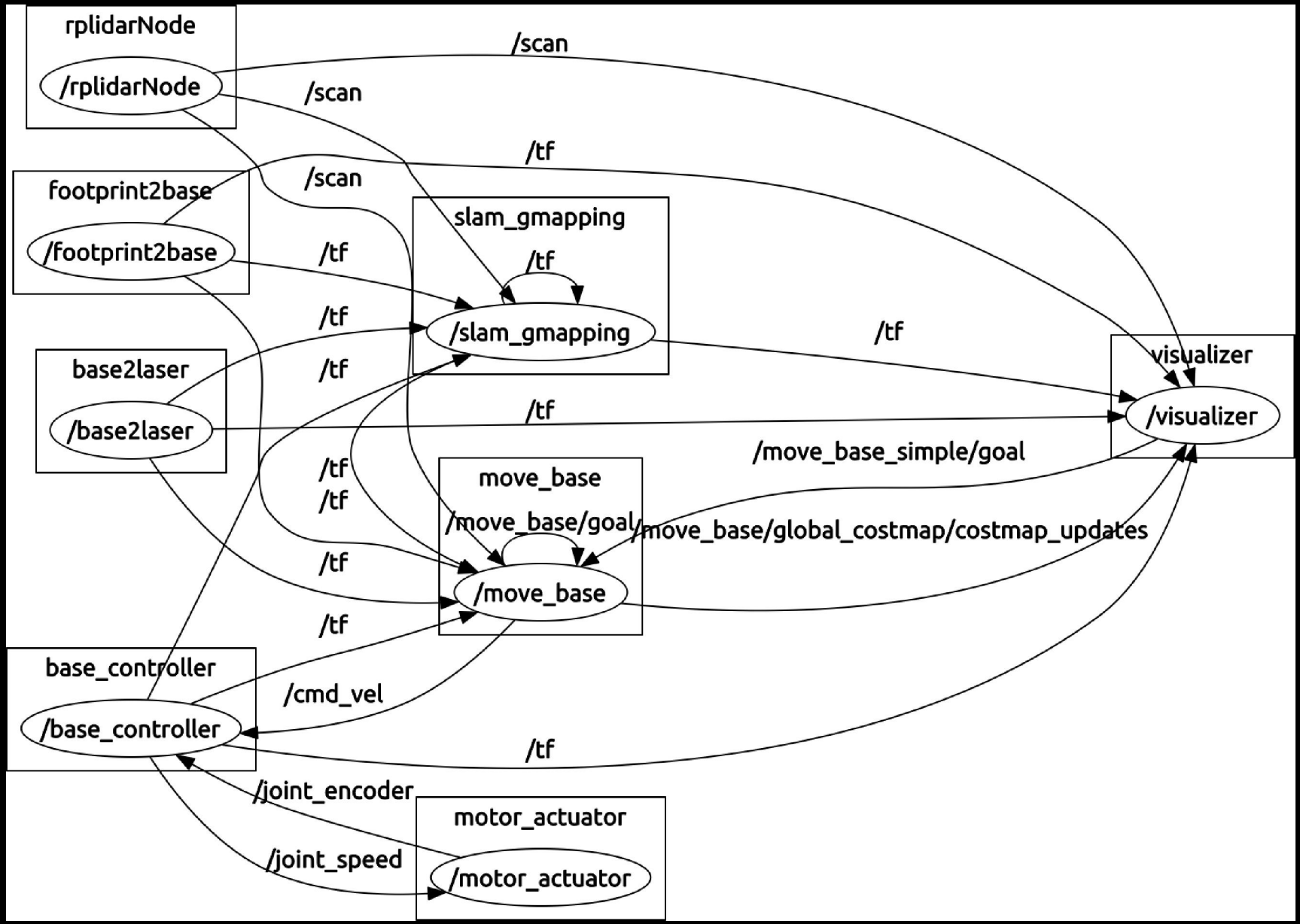
AMCL + map_server + move_base + ROBOT(base + sensor)

SLAM + move_base + ROBOT(base + sensor)

AMCL + map_server + move_base + ROBOT(base + sensor)

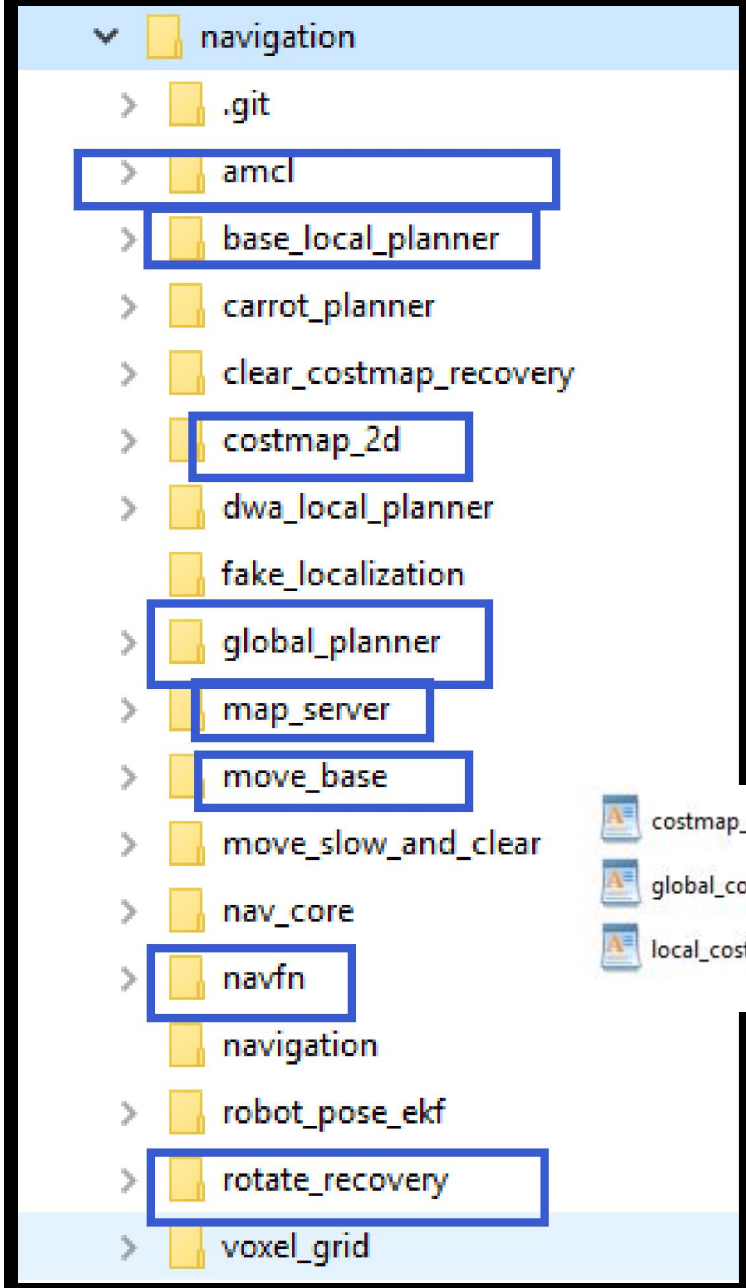


SLAM + move_base + ROBOT(base + sensor)

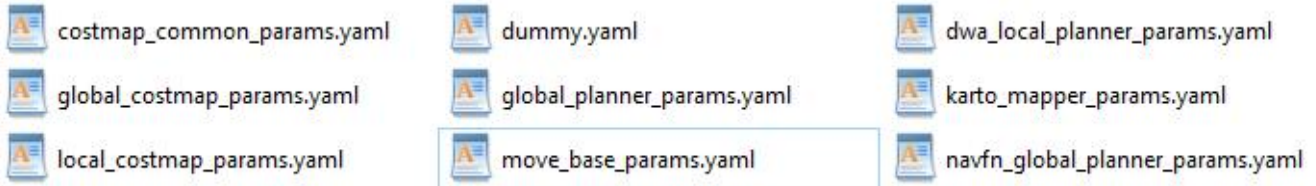


RPLidar A2 running Navigation:

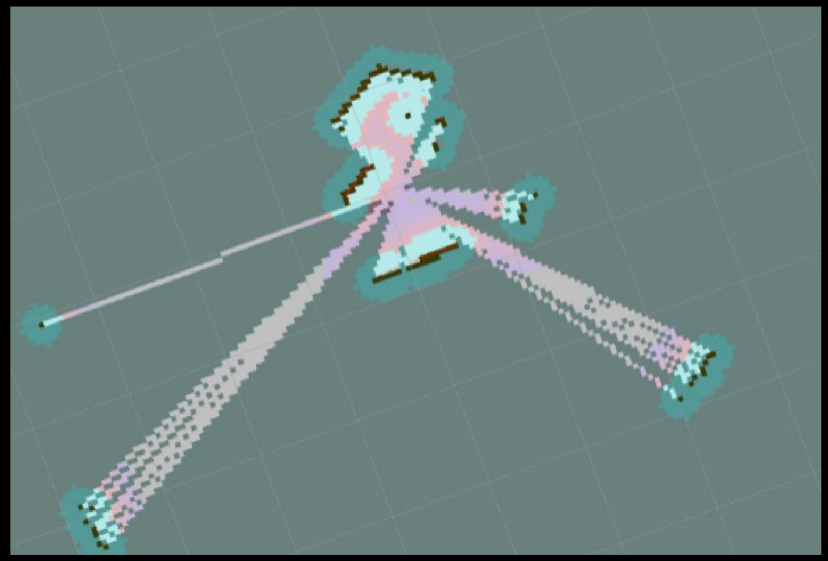
(amcl + move_base)

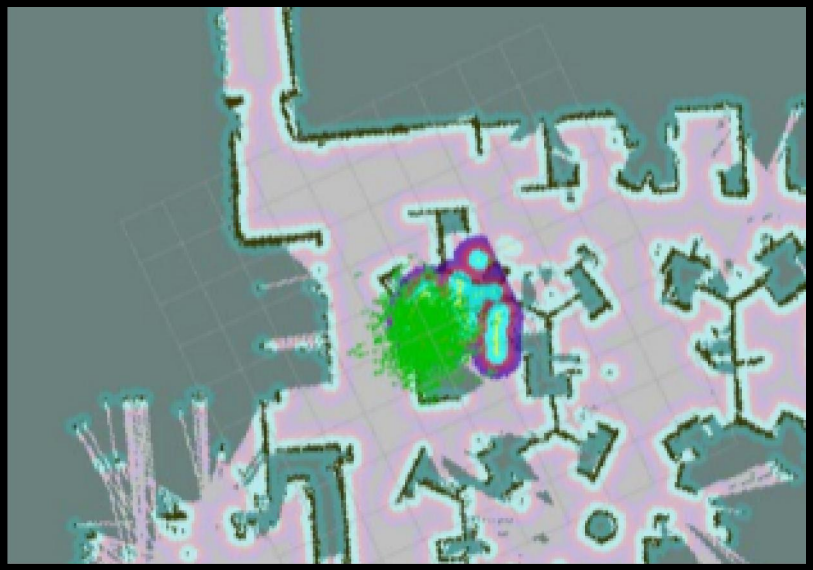



```
<launch>
  <arg name="custom_param_file" default="$(find
sdp_navigation)/param/dummy.yaml"/>

  <!-- Map server -->
  <arg name="map_file" default="$(find
sdp_navigation)/map/gmapping.yaml"/>
  <node name="map_server" pkg="map_server" type="map_server"
args="$(arg map_file)" />

  <arg name="initial_pose_x" default="0.0"/> <!-- Use 17.0 for
willow's map in simulation -->
  <arg name="initial_pose_y" default="0.0"/> <!-- Use 17.0 for
willow's map in simulation -->
  <arg name="initial_pose_a" default="0.0"/>
  <include file="$(find
sdp_navigation)/launch/includes/amcl.launch.xml">
    <arg name="initial_pose_x" value="$(arg initial_pose_x)"/>
    <arg name="initial_pose_y" value="$(arg initial_pose_y)"/>
    <arg name="initial_pose_a" value="$(arg initial_pose_a)"/>
  </include>

  <include file="$(find
sdp_navigation)/launch/includes/move_base.launch.xml">
    <arg name="custom_param_file" value="$(arg
custom_param_file)"/>
  </include>

</launch>
```



RPLidar A2 running Navigation: Notice





p_navigation › src › sdp_navigation › param

Name	Date modified	Type	Size
costmap_common_params.yaml	7/17/2016 11:56 AM	YAML File	2 KB
dummy.yaml	7/16/2016 3:26 PM	YAML File	1 KB
dwa_local_planner_params.yaml	7/16/2016 3:26 PM	YAML File	3 KB
global_costmap_params.yaml	7/16/2016 3:26 PM	YAML File	1 KB
global_planner_params.yaml	7/16/2016 3:26 PM	YAML File	2 KB
karto_mapper_params.yaml	7/14/2016 4:11 PM	YAML File	2 KB

```
topic: scan
marking: true
clearing: true
min_obstacle_height: 0.0 #0.25
max_obstacle_height: 2.0 #0.35
```

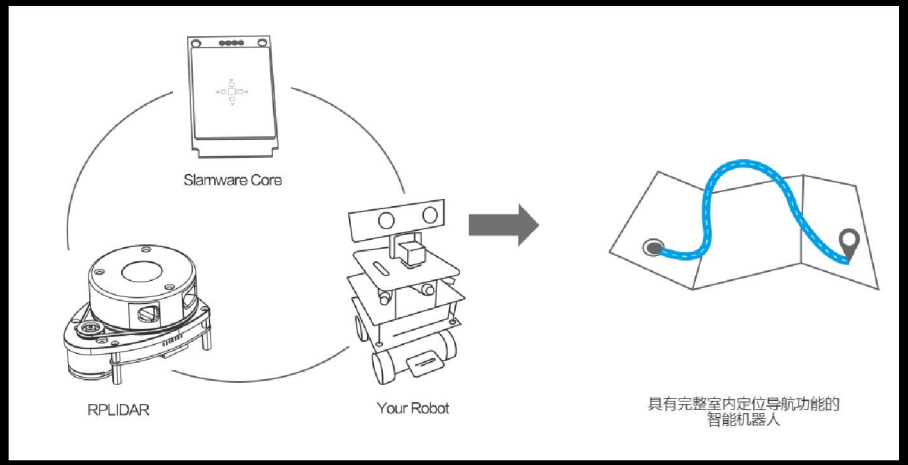
Local_costmap all zero :

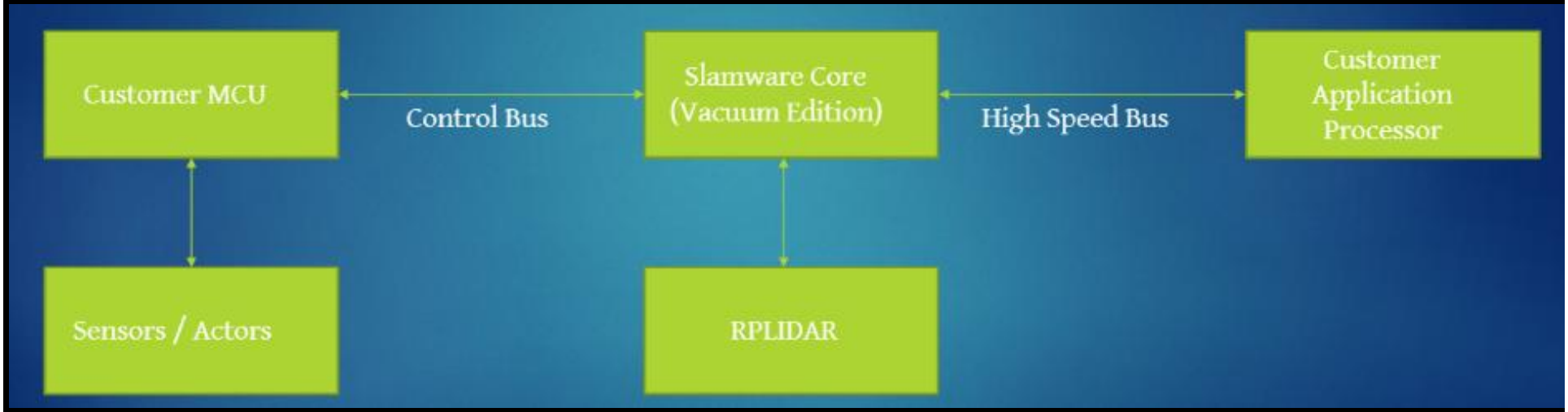
Map type: voxel (3D)

Min_obstacle_height

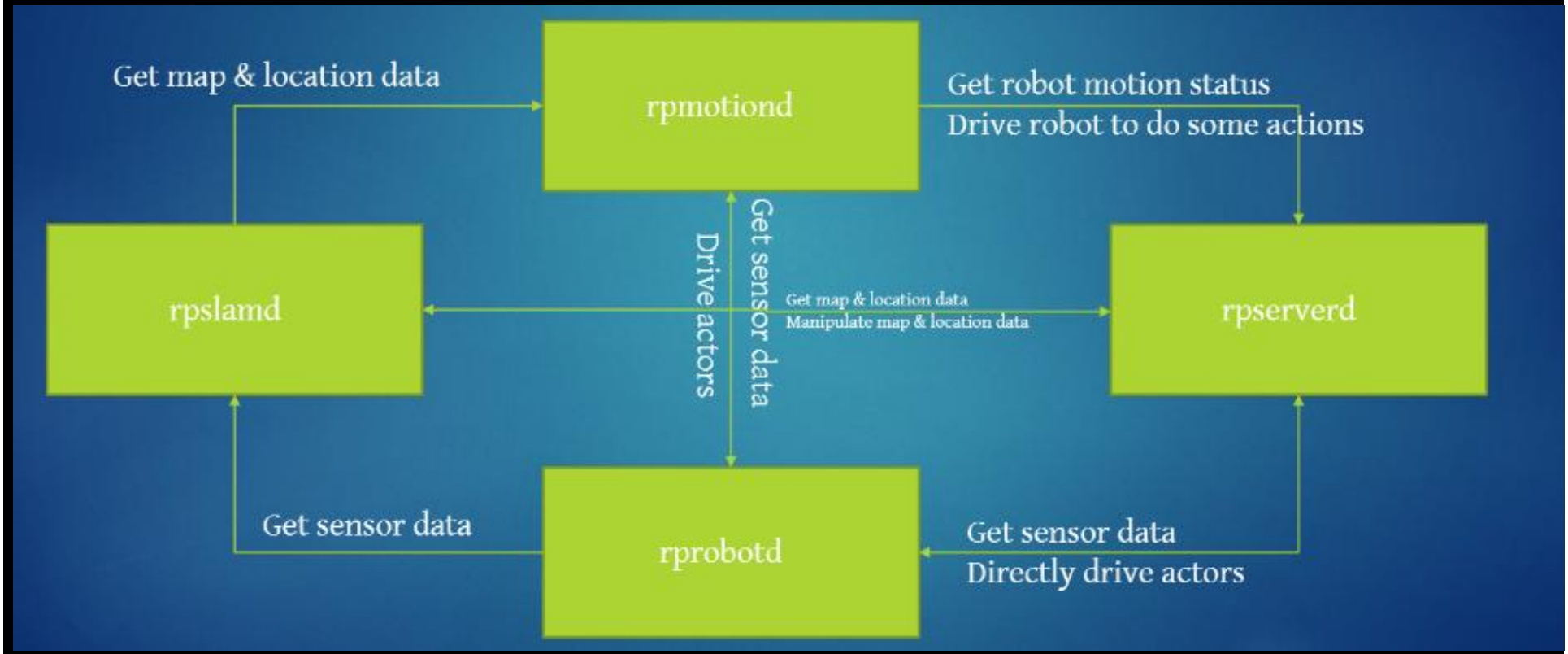
Max_obstacle_height

4. SLAMWARE solution for localization and navigation

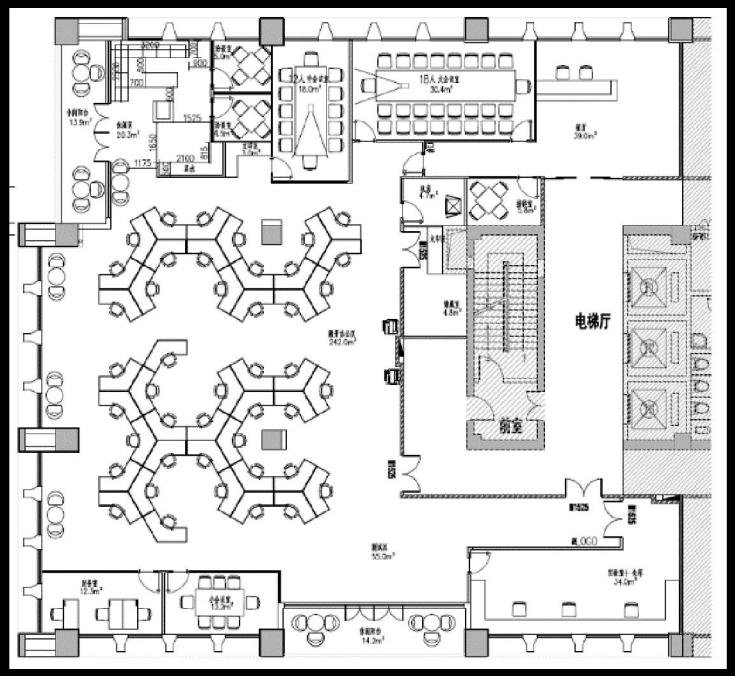




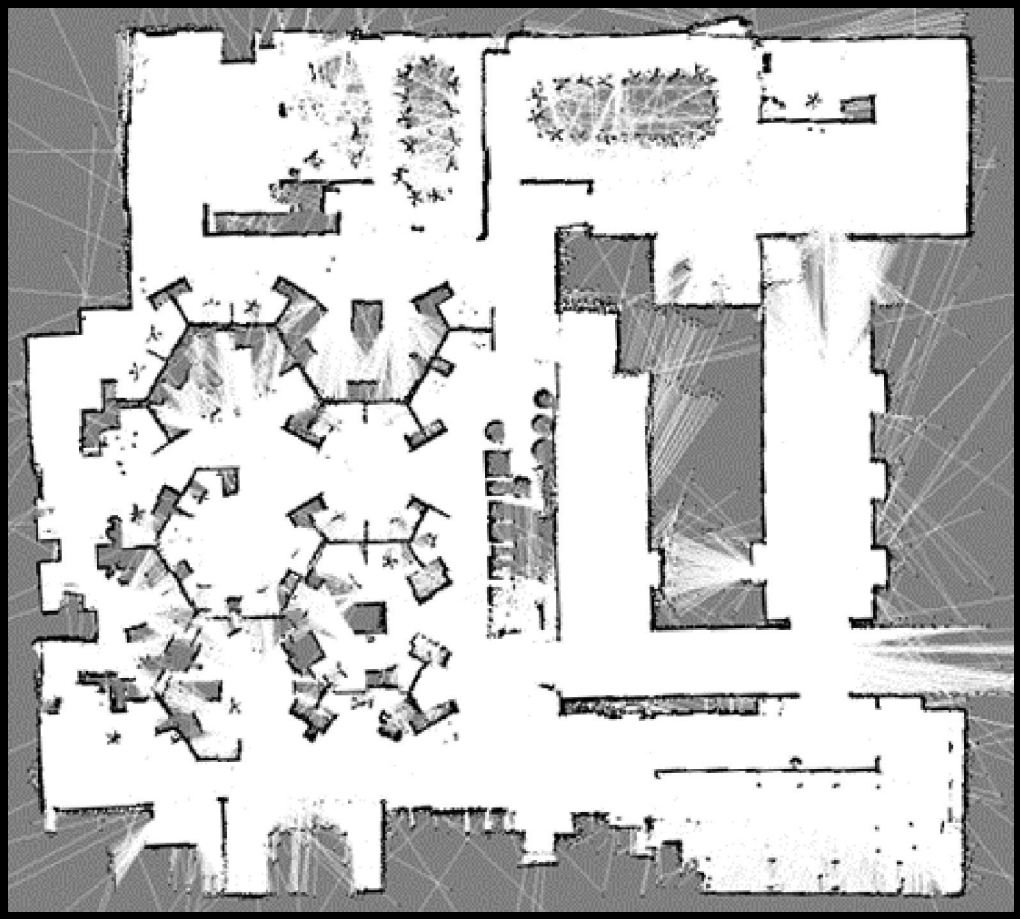
SLAMWARE solution for localization and navigation



SLAMWARE solution for localization and navigation



Design



SLAMWARE BUILDE

ISSUE 1： Power

```
started core service [/rosout]
process[rplidarNode-2]: started with pid [19387]
process[rviz-3]: started with pid [19400]
Error, cannot retrieve rplidar health code: 80008002
[rplidarNode-2] process has died [pid 19387, exit code 255, cmd /home/yhzhao/ros_ws/rplidar/devel/lib
/rplidar_ros/rplidarNode __name:=rplidarNode __log:=/home/yhzhao/.ros/log/e1284c9a-4a78-11e6-ad55-086
26614ffb2/rplidarNode-2.log].
log file: /home/yhzhao/.ros/log/e1284c9a-4a78-11e6-ad55-08626614ffb2/rplidarNode-2*.log
^C[rviz-3] killing on exit
[rosout-1] killing on exit
[master] killing on exit
shutting down processing monitor...
... shutting down processing monitor complete
done
yhzhao@X550JD:~$
```

Check your power: current

ISSUE2： Authority

```
started core service [/rosout]
process[rplidarNode-2]: started with pid [16292]
process[rviz-3]: started with pid [16300]
Error, cannot bind to the specified serial port /dev/ttyUSB0.
[rplidarNode-2] process has died [pid 16292, exit code 255, cmd /home/yhzhao/ros
_ws/rplidar/devel/lib/rplidar_ros/rplidarNode __name:=rplidarNode __log:=/home/y
hzhao/.ros/log/89cb440c-4a73-11e6-91e2-08626614ffb2/rplidarNode-2.log].
log file: /home/yhzhao/.ros/log/89cb440c-4a73-11e6-91e2-08626614ffb2/rplidarNode
-2*.log
^C[rviz-3] killing on exit
[rosout-1] killing on exit
[master] killing on exit
shutting down processing monitor...
... shutting down processing monitor complete
done
yhzhao@X550JD:~$ roslaunch rplidar_ros view_rplidar.launch
```

Check USB Authority

Sudo chmode

```
yhzhao@X550JD: ~
yhzhao@X550JD:~$ ls -l /dev/ttyUSB*
crw-rw---- 1 root dialout 188, 0  7月 15 16:31 /dev/ttyUSB0
crw-rw---- 1 root dialout 188, 1  7月 15 16:31 /dev/ttyUSB1
```

```
yhzhao@X550JD: ~
yhzhao@X550JD:~$ ls -l /dev/ttyUSB*
crwxrwxrwx 1 root dialout 188, 1  7月 15 18:51 /dev/ttyUSB1
crwxrwxrwx 1 root dialout 188, 2  7月 15 18:51 /dev/ttyUSB2
yhzhao@X550JD:~$
```

USB REMAP: udev

```
sudo cp `rospack find rplidar_ros`/scripts/rplidar.rules  /etc/udev/rules.d
```

```
# set the udev rule , make the device_port be fixed by rplidar
#
KERNEL=="ttyUSB*", ATTRS{idVendor}=="10c4", ATTRS{idProduct}=="ea60", MODE:="0777", SYMLINK+="rplidar"
```

lsusb

udevadm info --attribute-walk --path=/sys/bus/usb-serial/devices/ttyUSB0

```
    SUBSYSTEMS=="usb"
    DRIVERS=="cp210x"
    ATTRS{bInterfaceClass}=="ff"
    ATTRS{bInterfaceSubClass}=="00"
    ATTRS{bInterfaceProtocol}=="00"
    ATTRS{bNumEndpoints}=="02"
    ATTRS{supports_autosuspend}=="1"
    ATTRS{bAlternateSetting}==" 0"
    ATTRS{bInterfaceNumber}=="00"
    ATTRS{interface}=="CP2102 USB to UART Bridge Controller"
KERNEL=="ttyUSB*", KERNELS=="1-2.1", MODE:="0777",SYMLINK+="slamtec_base_"
KERNEL=="ttyUSB*", KERNELS=="1-2.2", MODE:="0777",SYMLINK+="slamtec_laser_"
```

```
yhzhao@X550JD:~/ros_ws/rplidar/src/scripts$ ls -l /dev|grep ttyUSB
lrwxrwxrwx  1 root root           7  7月 15 19:18 rplidar -> ttyUSB0
lrwxrwxrwx  1 root root           7  7月 15 19:18 slamtec_base_ -> ttyUSB0
lrwxrwxrwx  1 root root           7  7月 15 19:18 slamtec_laser_ -> ttyUSB1
crwxrwxrwx  1 root dialout 188,   0  7月 15 19:18 ttyUSB0
crwxrwxrwx  1 root dialout 188,   1  7月 15 19:18 ttyUSB1
```

ISSUE 3 : Specify Output Angle

Rplidar_ros is the official derive package of RPLidar A1/A2 ,

which output 360° datas .

Advice:

1) Filter process in your application program.
2) Fork the source code, change the publish_scan function.

Refrence

- https://github.com/ros-perception/slam_karto
- http://wiki.ros.org/move_base
- http://wiki.ros.org/navigation?distro=kinetic
- http://wiki.ros.org/rplidar
- https://github.com/robopeak/rplidar_ros
- http://www.slamtec.com/
- http://wiki.ros.org/hector_slam
- http://blog.csdn.net/zyh821351004/article/details/51945143
- http://blog.csdn.net/zyh821351004/article/category/2737261 （ROS ）
- http://blog.csdn.net/heyijia0327/article/category/2768679 （用ROS开发自己的机器人）
- http://blog.csdn.net/csshell2002/article/category/5801947 （ movebase导航和地图数据的使用）
- http://blog.exbot.net/archives/1129（拿**ROS navigation** 玩自主导航攻略）
- Konolige K, Grisetti G, Kümmerle R, et al. Efficient sparse pose adjustment for 2D mapping[C]//Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ International Conference on. IEEE, 2010: 22-29.
- Santos J M, Portugal D, Rocha R P. An evaluation of 2D SLAM techniques available in robot operating system[C]//2013 IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR). IEEE, 2013: 1-6.
- Grisetti G, Stachniss C, Burgard W. Improved techniques for grid mapping with rao-blackwellized particle filters[J]. IEEE transactions on Robotics, 2007, 23(1): 34-46.
- Thrun S. Probabilistic robotics[J]. Communications of the ACM, 2002, 45(3): 52-57.
- Kohlbrecher S, Von Stryk O, Meyer J, et al. A flexible and scalable slam system with full 3d motion estimation[C]//2011 IEEE International Symposium on Safety, Security, and Rescue Robotics. IEEE, 2011: 155-160.
- Kretzschmar H, Stachniss C. Information-theoretic compression of pose graphs for laser-based SLAM[J]. The International Journal of Robotics Research, 2012, 31(11): 1219-1230.
- My CSDN： http://blog.csdn.net/zyh821351004

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