

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



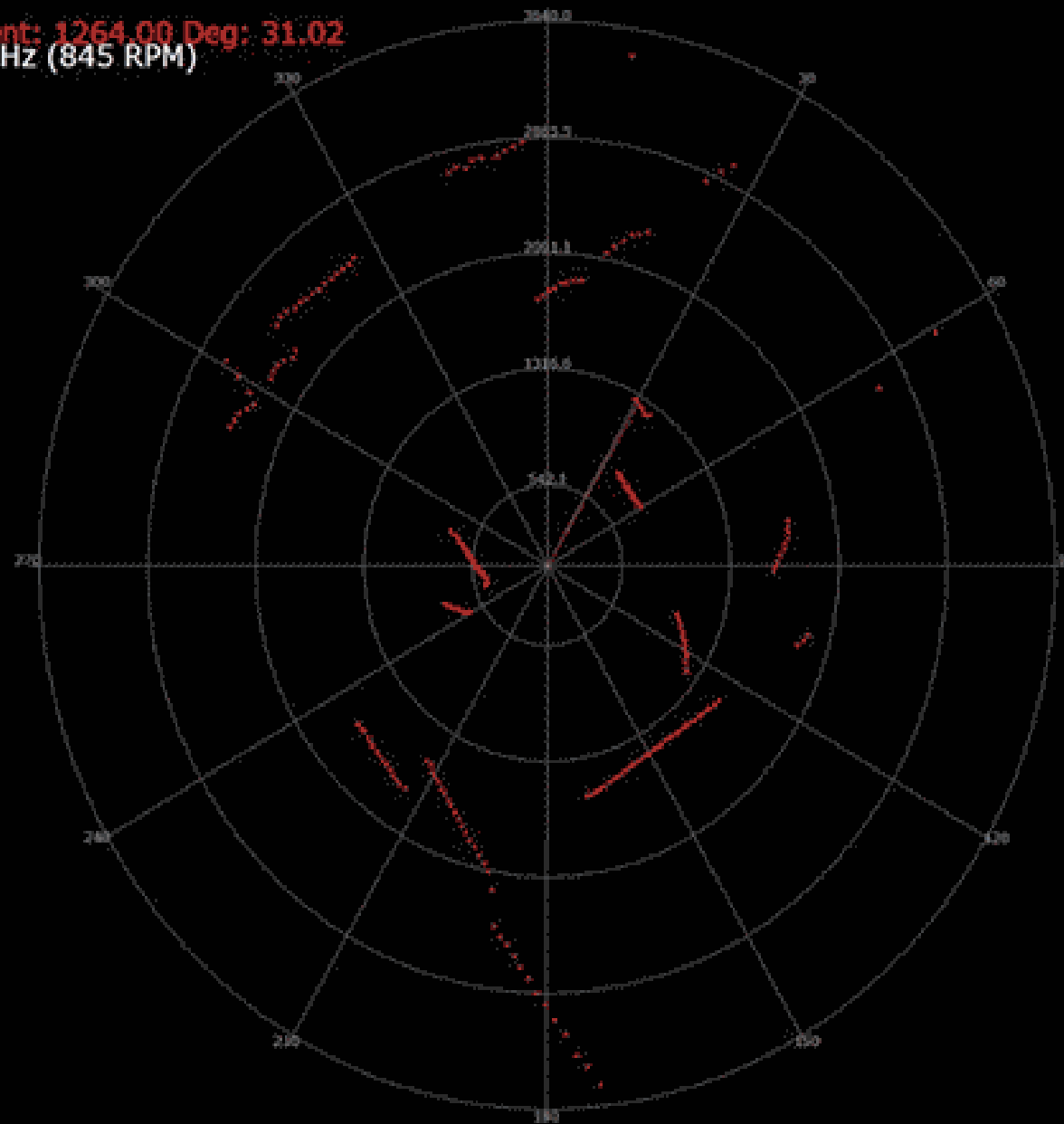
RPLIDAR A1



RPLIDAR A2

0.00
Current: 1264.00 Deg: 31.02
14.1 Hz (845 RPM)

4K



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

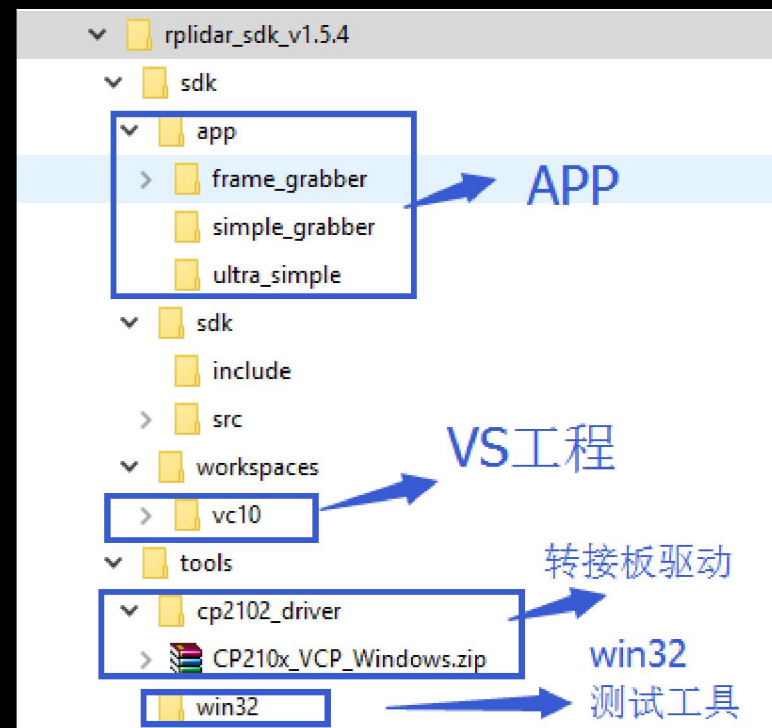
- 仅针对型号 A2M3/A2M4

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 <实际距离的 1%*	不适用	测量物体在 1.5 米以内 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



3D模型

RPLIDAR A2M4-R1 开发套装

[STL](#)

[2D PDF](#)

[3D PDF](#)

[IGS](#)



SDK

RPLIDAR SDK

最新版本：v1.5.4

发布时间：2016-6-2

[下载](#)



应用手册

ROS 包

注意：您仍然需要下载SDK才能使用该ROS软件包

[GitHub 仓库](#)



文档

[Datasheet](#)

[开发套装用户手册](#)

[通讯协议](#)

[SDK用户手册](#)

RPLidar Test Tool (win32)

The image shows the installation and operation of the RPLidar Test Tool (win32). It includes a Windows Explorer window showing the installation files, a Device Manager window showing the USB to UART Bridge, a Select Serial Port dialog box, and the RPLidar Test Tool interface displaying the current scan data.

1 Installation files: The Windows Explorer window shows the files in the `tools` directory. The files listed are:

Name	Date modified	Type	Size
x64	10/25/2013 1:19	File folder	
x86	10/25/2013 1:19	File folder	
CP210xVCPInstaller_x64.exe	10/25/2013 1:19	Application	1,020 KB
CP210xVCPInstaller_x86.exe	10/25/2013 1:19	Application	901 KB
dpintxaml	10/25/2013 1:19	XML Document	12 KB
ReleaseNotes.txt	10/25/2013 1:19	Text Document	10 KB
SLAS_License_Agreement_VCP_Windows...	10/25/2013 1:19	Text Document	9 KB
slabvcp.cat	10/25/2013 1:19	Security Catalog	12 KB
slabvcp.inf	10/25/2013 1:19	Setup Information	5 KB

2 Device Manager: The Device Manager window shows the `Ports (COM & LPT)` section. The `Silicon Labs CP210x USB to UART Bridge (COM3)` is highlighted.

3 Application Tools: The Application Tools window shows the files in the `tools` directory. The files listed are:

Name	Date modified	Type	Size
frame_grabber.exe	6/2/2016 11:44 AM	Application	218 KB
rplidar_driver.lib	6/2/2016 11:44 AM	Object File Library	290 KB
simple_grabber.exe	6/2/2016 11:44 AM	Application	93 KB
ultra_simple.exe	6/2/2016 11:44 AM	Application	90 KB

4 Select Serial Port: The Select Serial Port dialog box shows `COM3` selected.

5 RPLidar Test Tool: The RPLidar Test Tool interface shows the current scan data. The status bar at the bottom indicates `Ready`.

The RPLidar Test Tool interface displays the following information:

- Model: 36 FW: 1.18 HW: 1 Serial: BAD2E8C1E1839EF3C8E19AF36324700
- Current: 355.00 Deg: 116.11
- 7.5 Hz (447 RPM)
- 4K

The main display area shows a polar plot of the scan data, with a range of 0 to 300 degrees and a distance scale of 0 to 4552.4.

2、RPLidar drive package for ROS: rplidar_ros

rplidar_ros ROS wiki

rplidar

hydro indigo jade kinetic Documentation Status

Package Summary

✓ Released ✓ Continuous integration ✓ Documented

The rplidar ros package support rplidar and rplidar A2

- Maintainer status: maintained
- Maintainer: Slamtec ROS Maintainer <ros AT slamtec DOT com>
- Author:
- License: BSD
- Source: git https://github.com/robopeak/rplidar_ros.git (branch master)

rplidar_ros GitHub

Issue(closed)

Pull Request

Wiki

The screenshot shows the GitHub repository page for `robopeak / rplidar_ros`. The repository has 20 stars, 60 forks, and 65 pulls. The page includes tabs for Code, Issues (1), Pull requests (3), and Wiki. A yellow arrow points from the 'Issue(closed)' text to the 'Issues' tab. Another yellow arrow points from the 'Pull Request' text to the 'Pull requests' tab. A third yellow arrow points from the 'Wiki' text to the 'Wiki' tab. The repository statistics show 33 commits, 2 branches, 3 releases, and 8 contributors. The 'Clone or download' button is highlighted with a green box. The file list includes `launch`, `rviz`, `scripts`, `sdk`, `src`, `CHANGELOG.rst`, `CMakeLists.txt`, `LICENSE`, `README.md`, `package.xml`, and `rplidar-frame.png`.

File	Description	Time
launch	update to RPLIDAR SDK 1.5.2	3 months ago
rviz	First release of RPLIDAR ROS package	2 years ago
scripts	update to RPLIDAR SDK 1.5.2	3 months ago
sdk	updated to SDK 1.5.4	2 months ago
src	update to RPLIDAR SDK 1.5.2	3 months ago
CHANGELOG.rst	updated to SDK 1.5.4	2 months ago
CMakeLists.txt	include catkin directories	11 months ago
LICENSE	Initial commit	2 years ago
README.md	added documentation about rplidar frame	a year ago
package.xml	updated to SDK 1.5.4	2 months ago
rplidar-frame.png	fixed rplidar-frame.png	a year ago

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

The screenshot shows a terminal window on the left and the RViz interface on the right. The terminal output includes the following sections:

```
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.

started roslaunch server http://X550JD:57655/

SUMMARY
=====

PARAMETERS
* /rostdistro: indigo
* /rosversion: 1.11.19
* /rplidarNode/angle_compensate: True
* /rplidarNode/frame_id: laser
* /rplidarNode/inverted: False
* /rplidarNode/serial_baudrate: 115200
* /rplidarNode/serial_port: /dev/ttyUSB0

NODES
/
  rplidarNode (rplidar_ros/rplidarNode)
  rviz (rviz/rviz)

auto-starting new master
process[rosout-1]: started with pid [18611]
ROS_MASTER_URI=http://localhost:11311

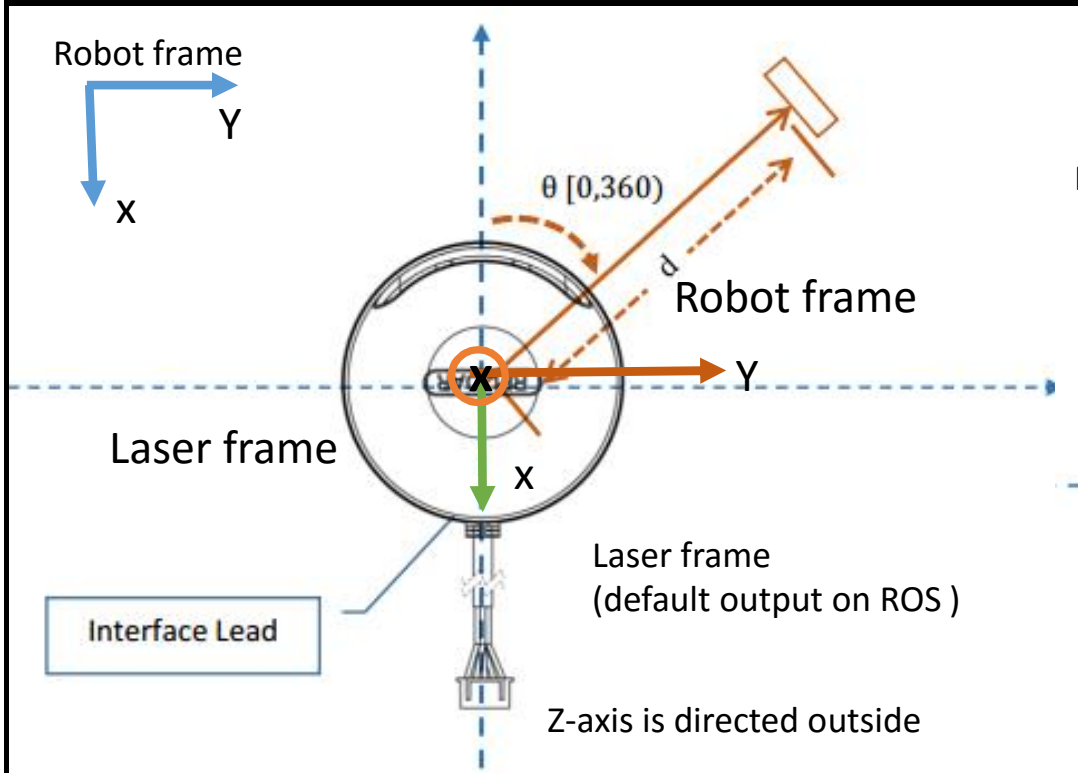
setting /run_id to 55a83e34-4a76-11e6-affb-08626614ffb2
process[rosout-1]: started with pid [18624]
started core service [/rosout]
process[rplidarNode-2]: started with pid [18627]
process[rviz-3]: started with pid [18636]
RPLidar health status : 0
```

The RViz interface shows the following configuration:

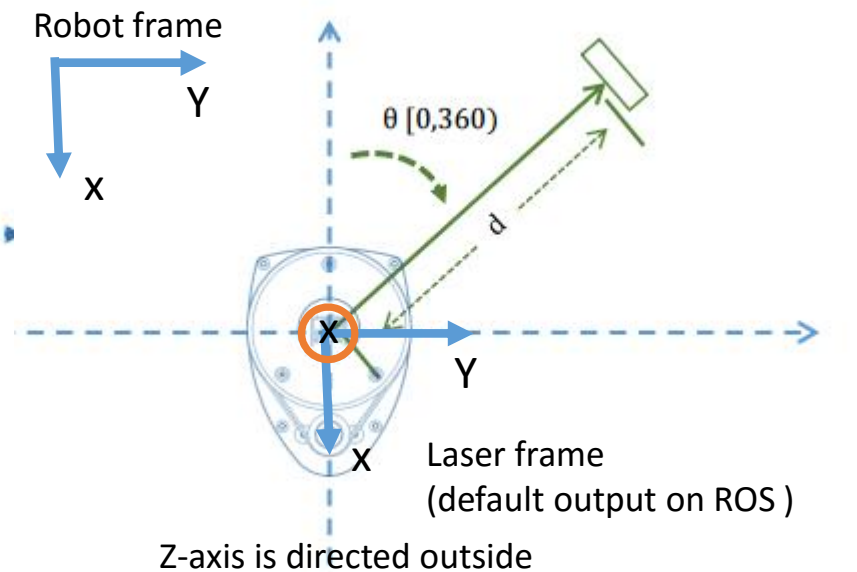
- Displays:**
 - Global Options:**
 - Fixed Frame: laser
 - Background Color: 48; 48; 48
 - Frame Rate: 30
 - Global Status: ☒
 - Grid: ☒
 - RPLidarLaser: ☒
 - Status: ☒ Status: Ok
 - Topic: /scan
 - Unreliable: ☐
 - Selectable: ☒
 - Style: Squares
 - Size (m): 0.03
 - Alpha: 1
 - Decay Time: 0
 - Position Transf...: XYZ
 - Color Transfo...: AxisColor
 - Queue Size: 1000
 - Axis: Z
 - Autocompute...: ☒
 - Use Fixed Fra...: ☒

The 3D visualization shows a point cloud of a chair, rendered in red, on a grid floor. The status bar at the bottom right indicates 30 fps.

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)

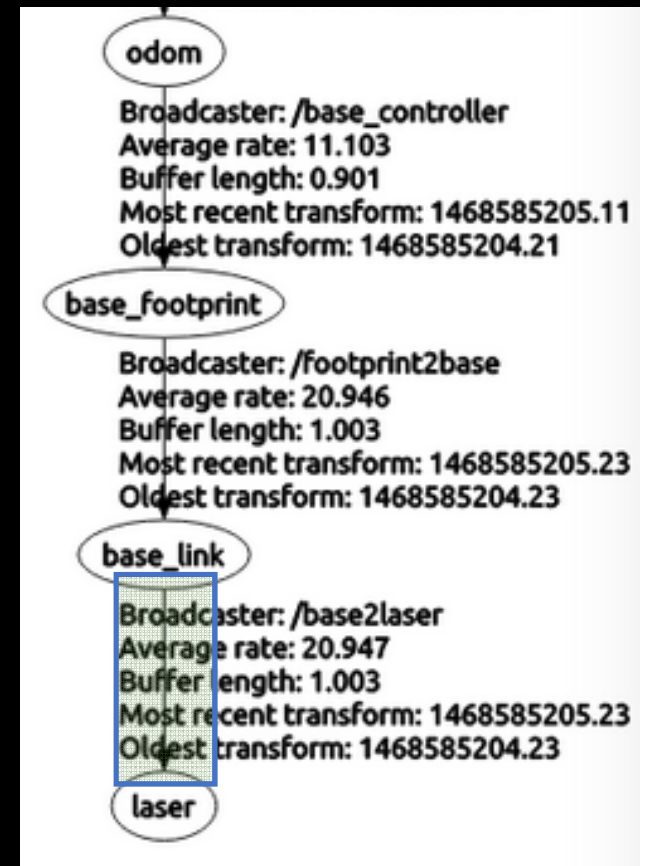
2. TF publish

(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)

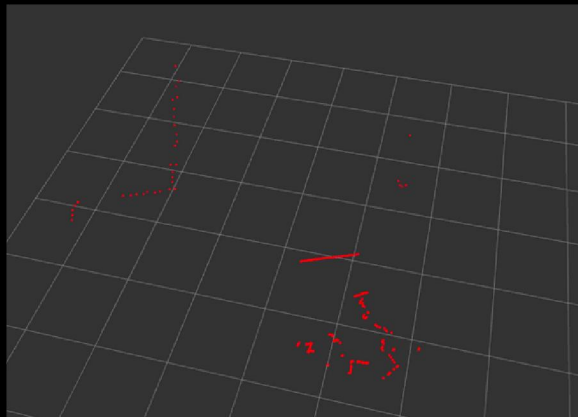


Launch_file 链接: <http://pan.baidu.com/s/1hswfHKK> 密码: r2d2

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)

roslaunch tf view_frames

rqt_graph

rostopic list

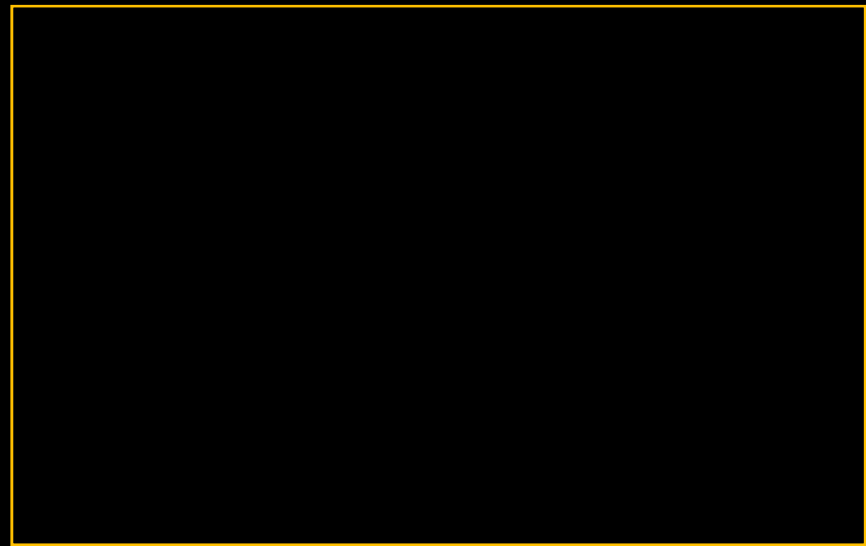
rqt

Check

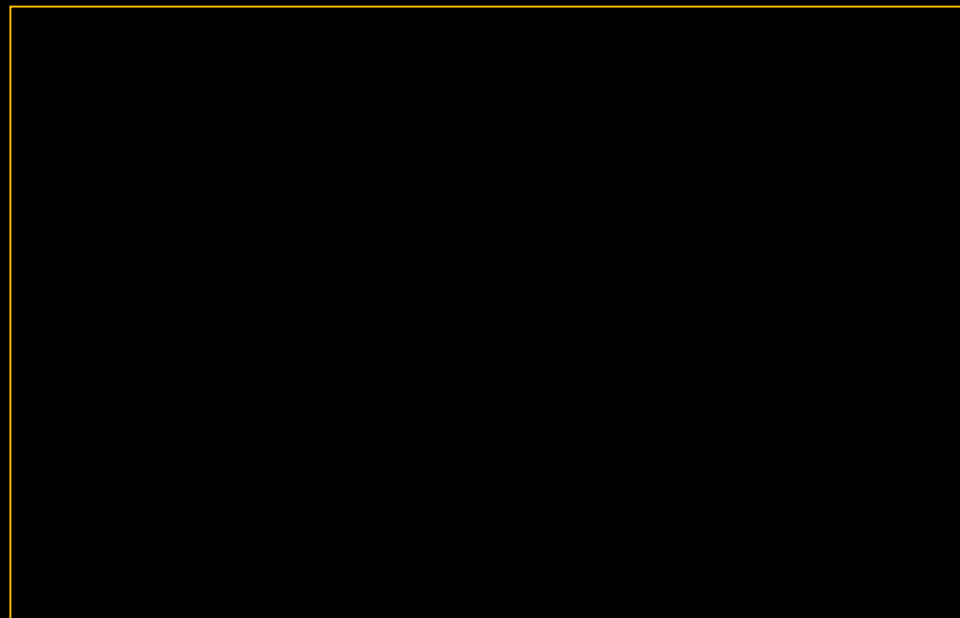
Running SLAM(videos) : Gmapping Hector slam_karto



Gmapping



Hector

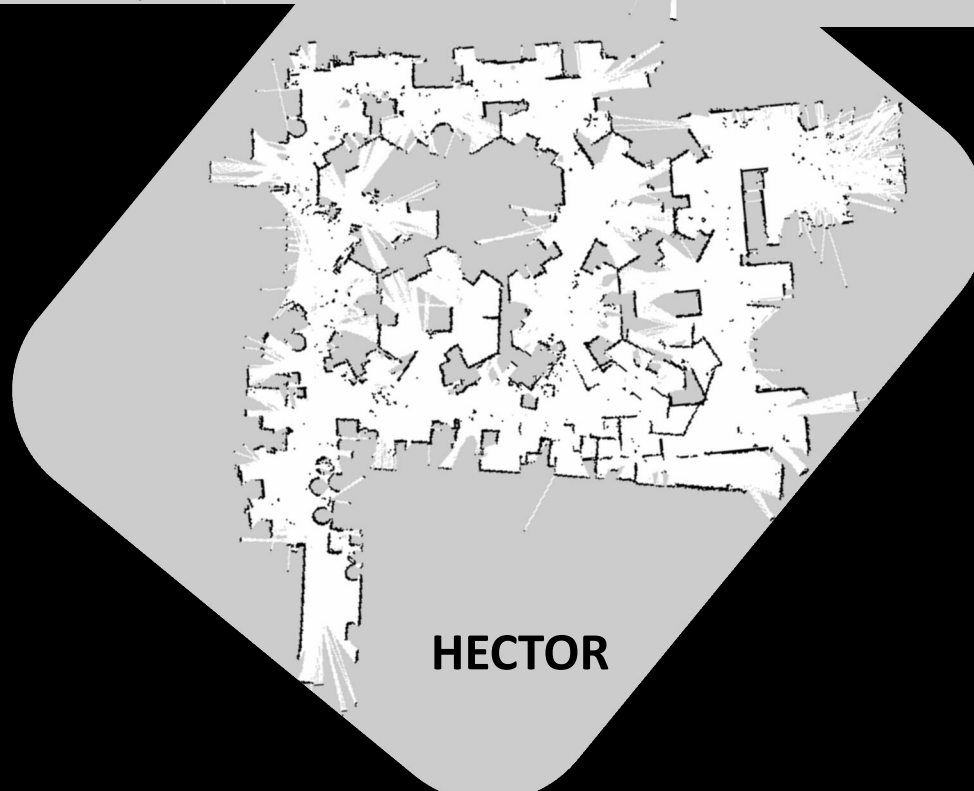
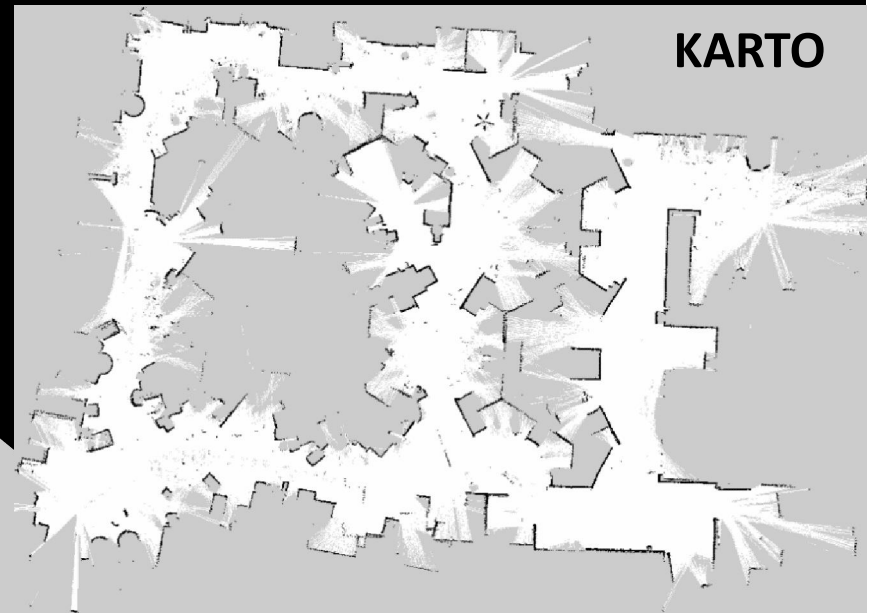
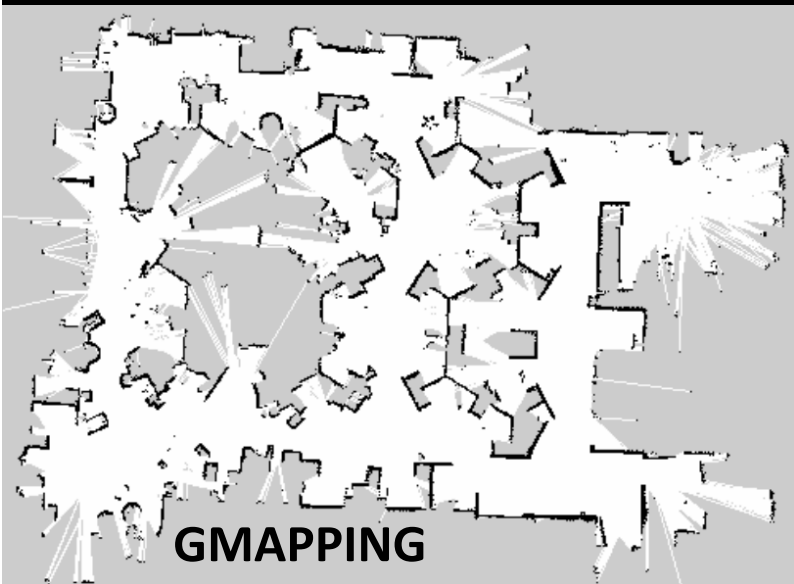


Karto

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

RBPF

SGD/ ICP

Motion model +
observation model

scanMatcherMap

Map Display

Gmapping

[ros-perception/slam_gmapping](#)

[ros-perception/openslam_gmapping](#)

Hector

Multi-resolution- maps

Guass-Newton

IncreasedMap

Hector

[tu-darmstadt-ros-pkg_hector_slam](#)

Karto

Multi-search

CSM

loopClosure

SPA/G2O

poseMap

Karto

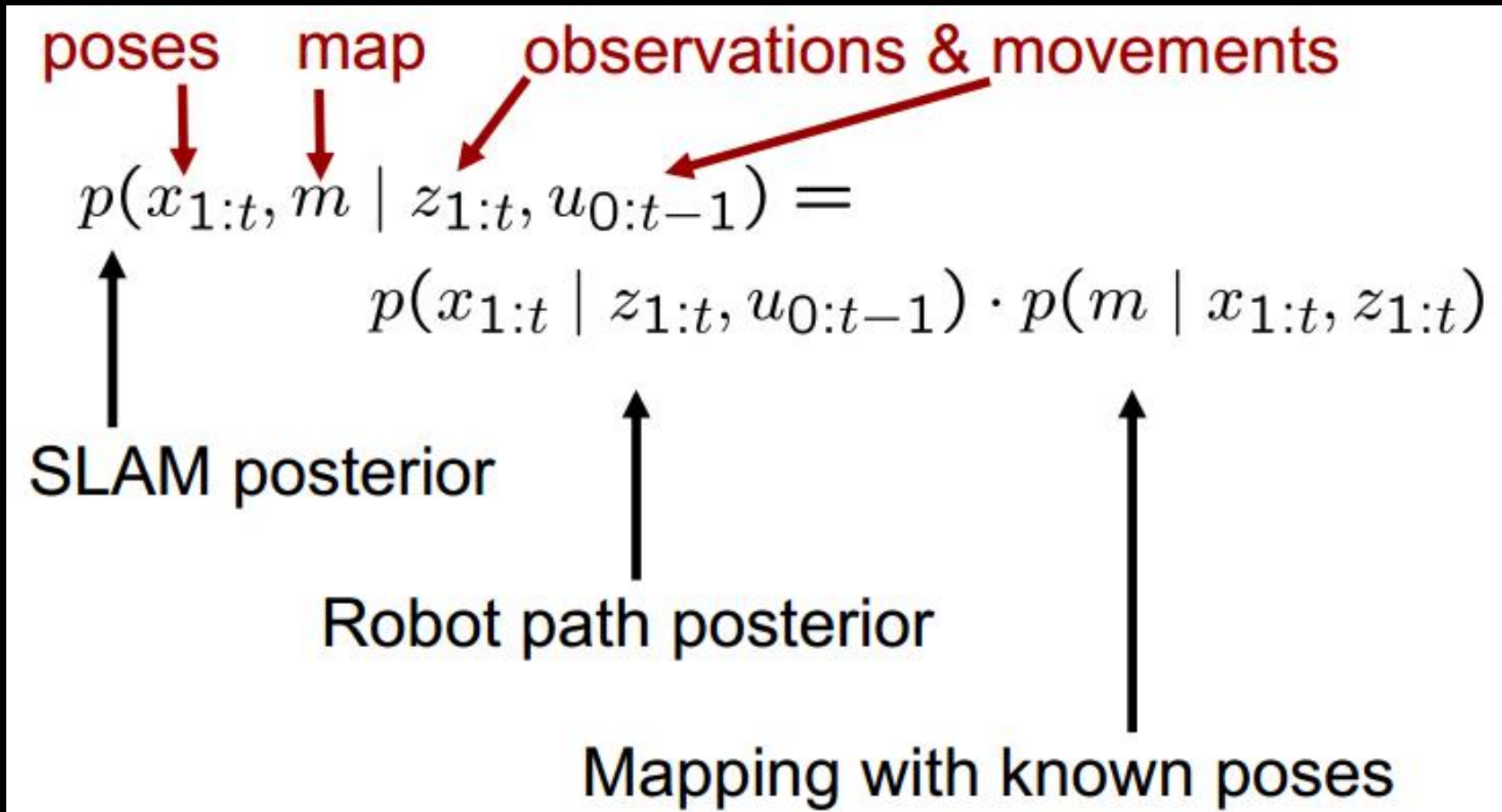
[ros-perception_slam_karto](#)

[ros-perception_open_karto](#)

[skasperski_navigation_2d](#)

Gmapping

Rao-Blackwellized Particle Filters(RBPF)

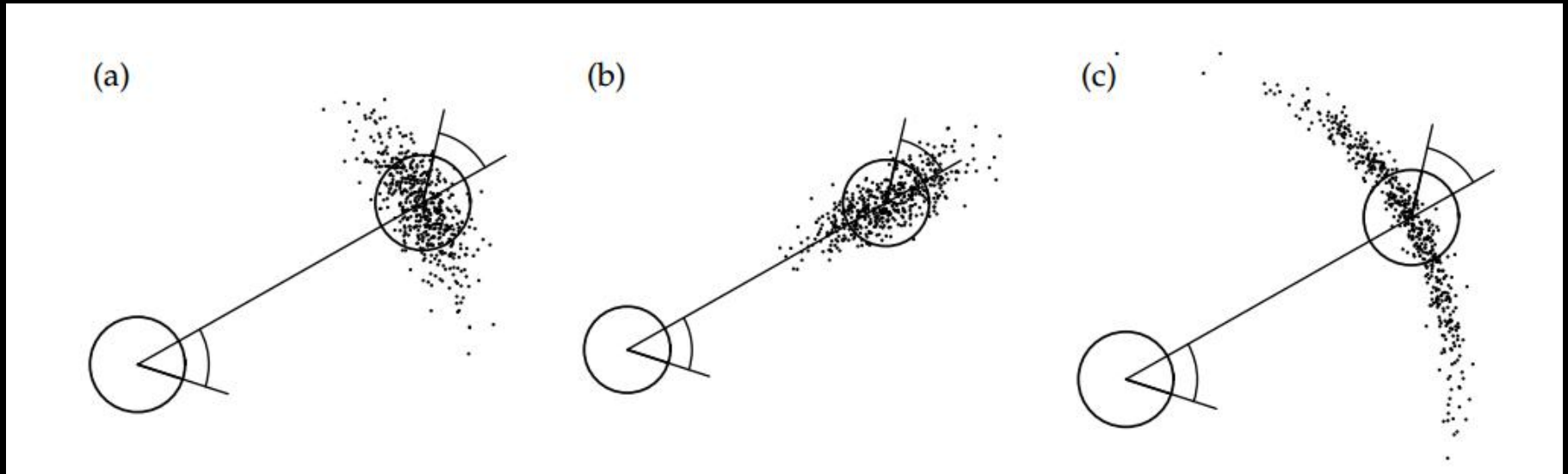


Gmapping

MCL / Particle Filters(PF)

Sampling :

Motion model(odom)

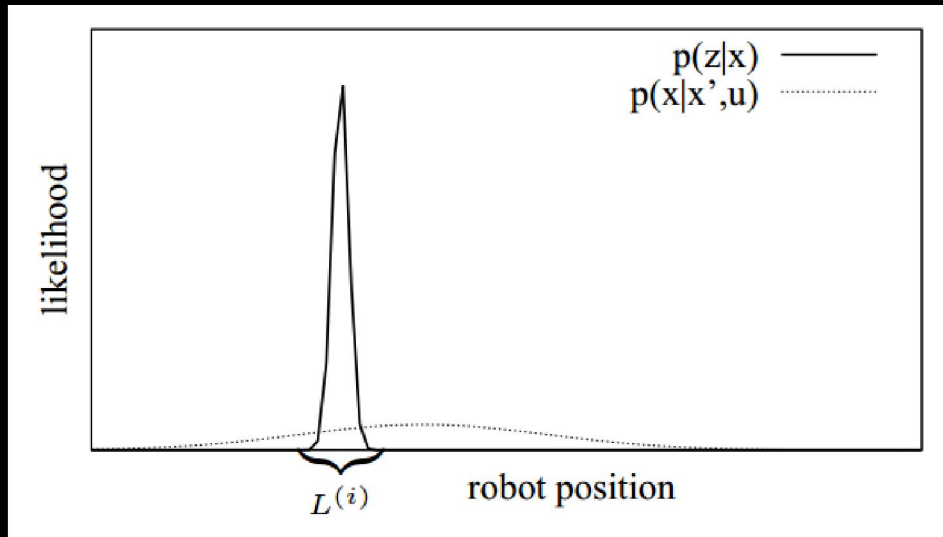


The number of particles → small

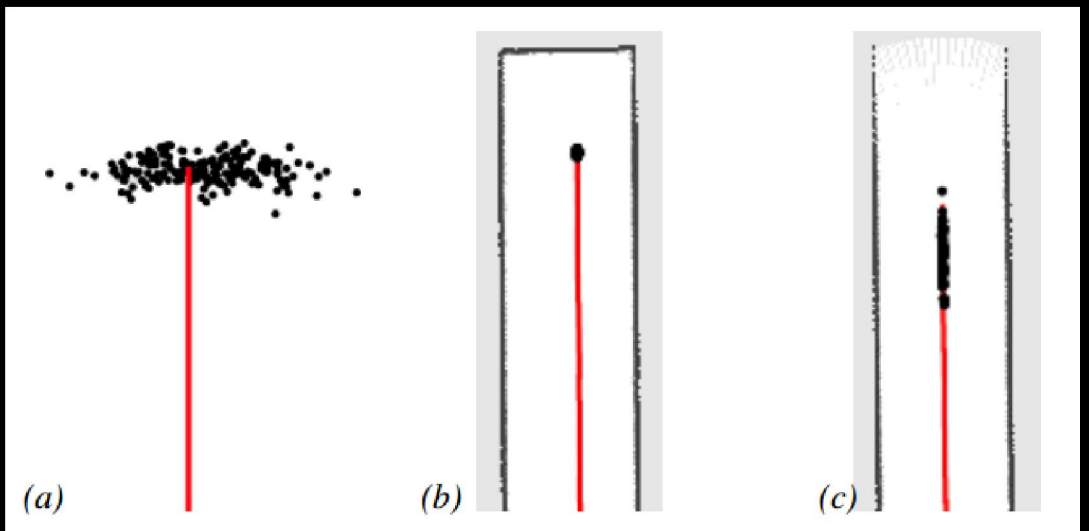
Gmapping

MCL : Particle Filters(PF)

Improve Odom



Observed during mapping



Scan Matcher (SGD/ICP)

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

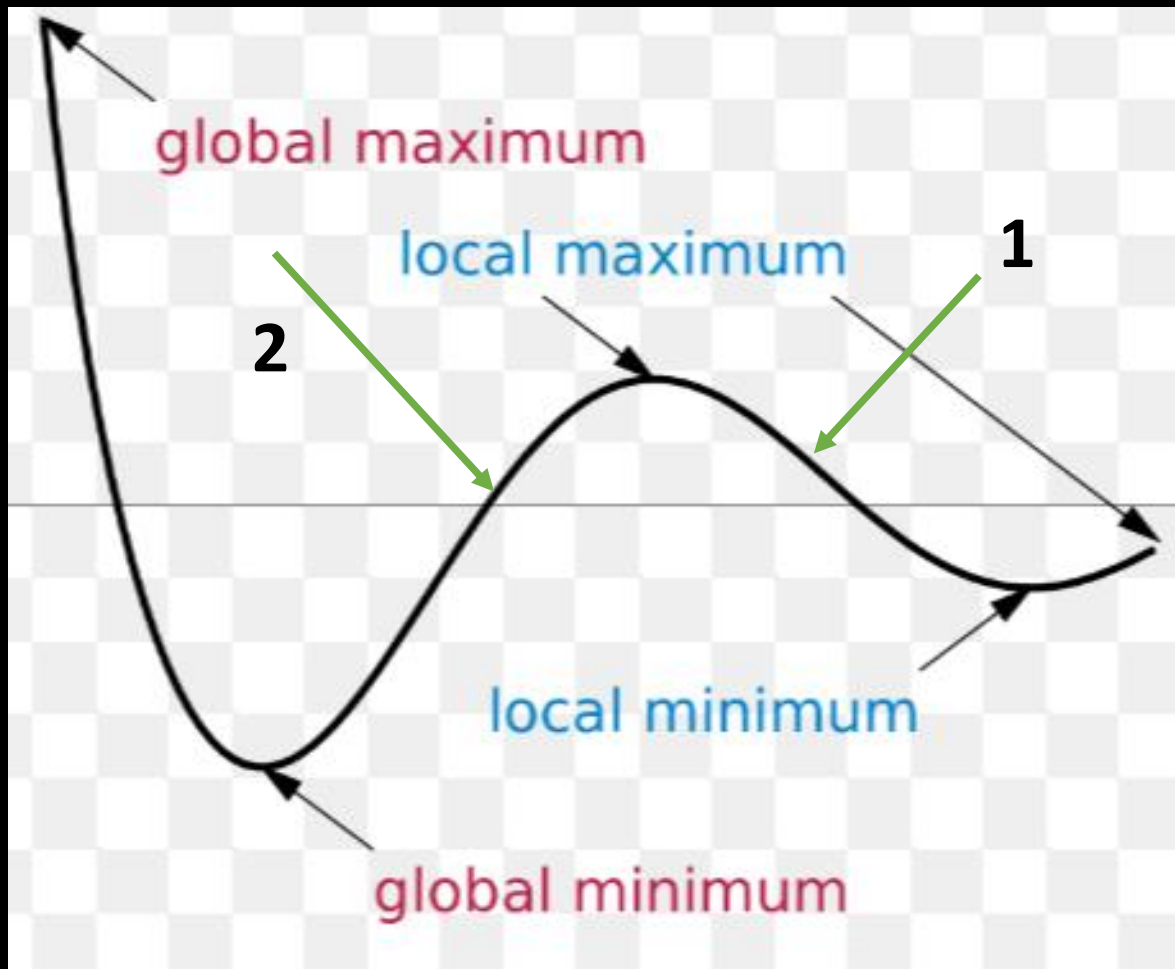
- $bestPose = x_{init}$
- $bestScore = s(bestPose, z, m)$
- $searchStep = initialSearchStep$
- $iterations = 0$
- while ($iterations < maxIterations$)
 - $maxMoveScore = bestScore$
 - $bestMovePose = bestPose$
 - for move in (*Backward, Forward, Left, Right, RotateLeft, RotateRight*)
 - * $testPose = computePose(bestPose, move)$
 - * $score = s(testPose, z, m)$
 - * 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?

Focus: Matcher / Observation

updateTreeWeights / Resample

updateTreeWeights : Normalize (max + distance)

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

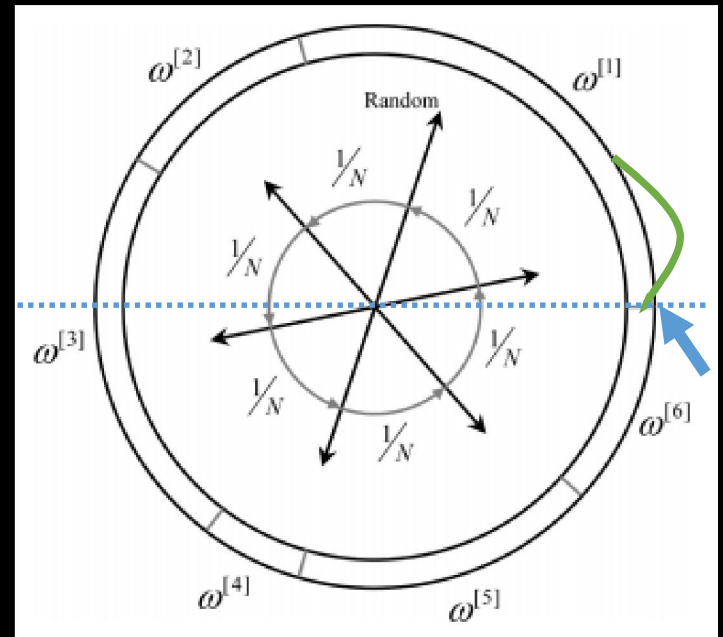
N_{eff} (effective number of particles)

$N_{\text{eff}} < \text{threshold}$: Particle deletion

Resample :

Roulette wheel resampling

Stochastic universal



Map update : Based Frequency

computeActiveArea : mapCell $\rightarrow$ pointer memory

MapSize :

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

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

Cell Update : Statistics (acc n visits)

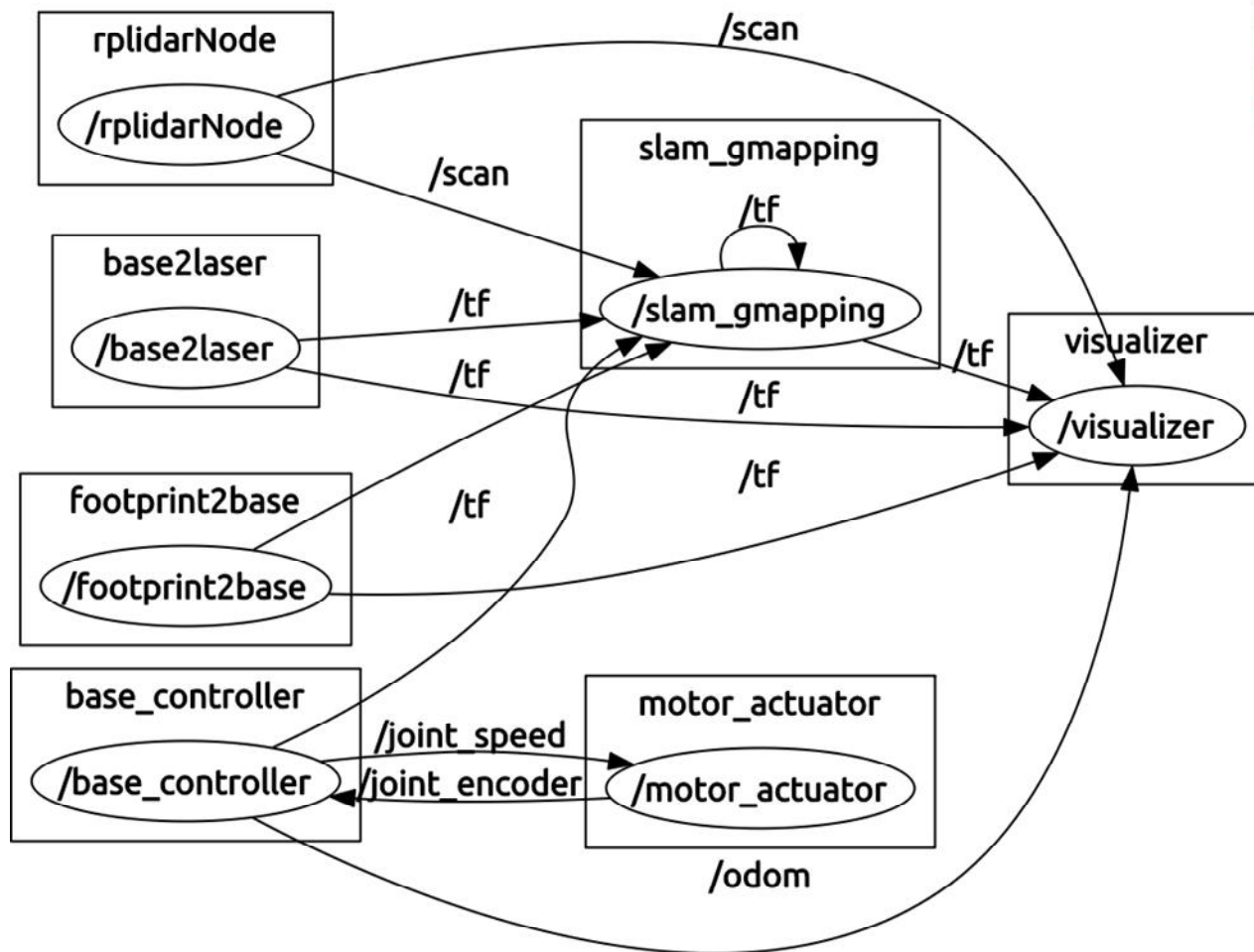
$$m_t^{x,y} = (b_t^{x,y}, v_t^{x,y}) = \begin{cases} (b_t^{x,y} + 1, v_t^{x,y} + 1) & \text{if occupied} \\ (b_t^{x,y}, v_t^{x,y} + 1) & \text{if free} \end{cases}$$

MapDisplay: BestParticle(pose, smap, readings)

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

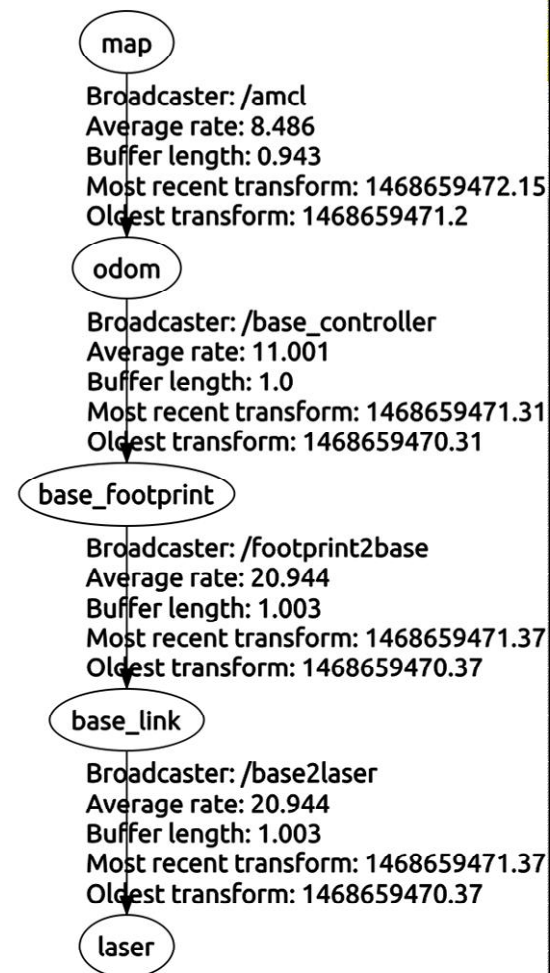
Tnode : all reading

rqt_graph



TF

Recorded at time: 1468659471.34



```

<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

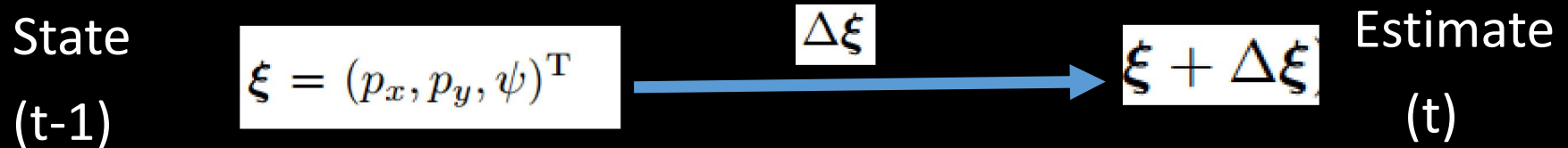
Demand

Laser frequent

Move slowly

Map memory constant

ScanMatcher (Gaussian-Newton)



**Optimization
Function:**

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

Measure error:

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

Active map_cell:
(t)

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

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

ScanMatcher (Gaussian-Newton)

Taylor

Expansion:

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

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

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

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

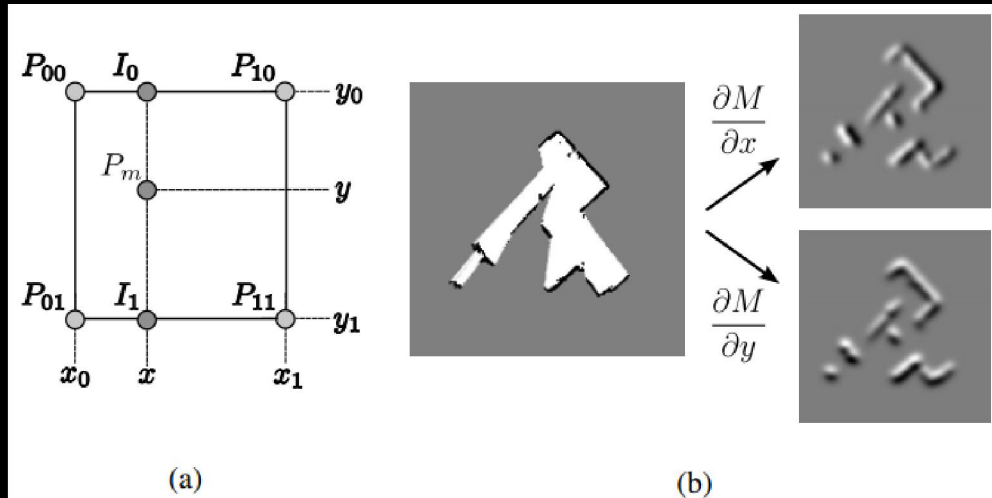


Fig. 2. (a) Bilinear filtering of the occupancy grid map. Point P_m is the point whose value shall be interpolated. (b) Occupancy grid map and spatial derivatives.

$$P = \text{occ}/(\text{occ}+\text{free})$$

$$\begin{aligned} \frac{\partial M}{\partial x}(P_m) &\approx \frac{y - y_0}{y_1 - y_0} (M(P_{11}) - M(P_{01})) \\ &\quad + \frac{y_1 - y}{y_1 - y_0} (M(P_{10}) - M(P_{00})) \\ \frac{\partial M}{\partial y}(P_m) &\approx \frac{x - x_0}{x_1 - x_0} (M(P_{11}) - M(P_{10})) \\ &\quad + \frac{x_1 - x}{x_1 - x_0} (M(P_{01}) - M(P_{00})) \end{aligned}$$

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)"/>
```

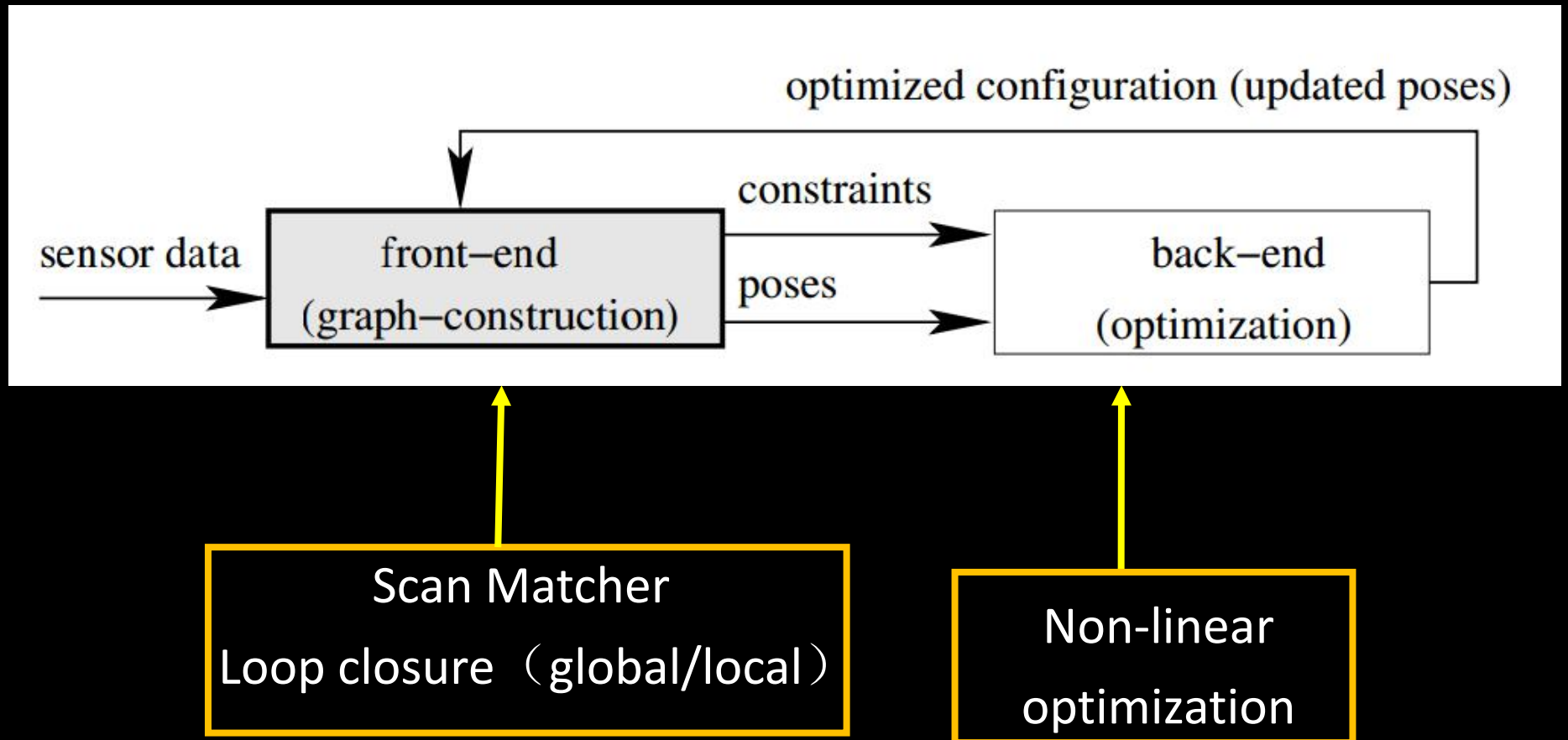
```
<!-- Debug parameters -->
```

```
<!--
<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



Constraint : scanToMap

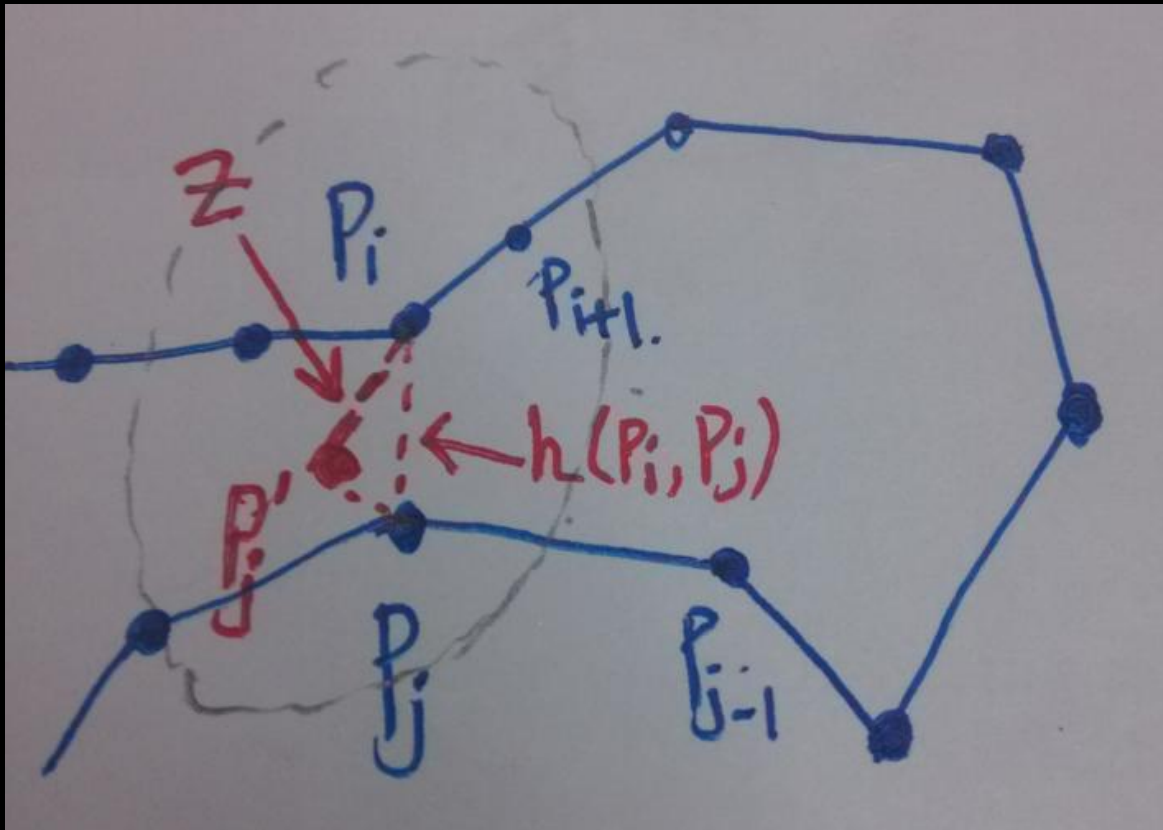
Robot pose :

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

Offset of c_i and c_j :
(Constraint)

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

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



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 previous 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:

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

where

$$H \equiv J^T \Lambda J$$

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

$$\Lambda = \text{diag}(\Lambda_{ij}, ij \in E)$$

$$c = c + \Delta c$$

```
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>

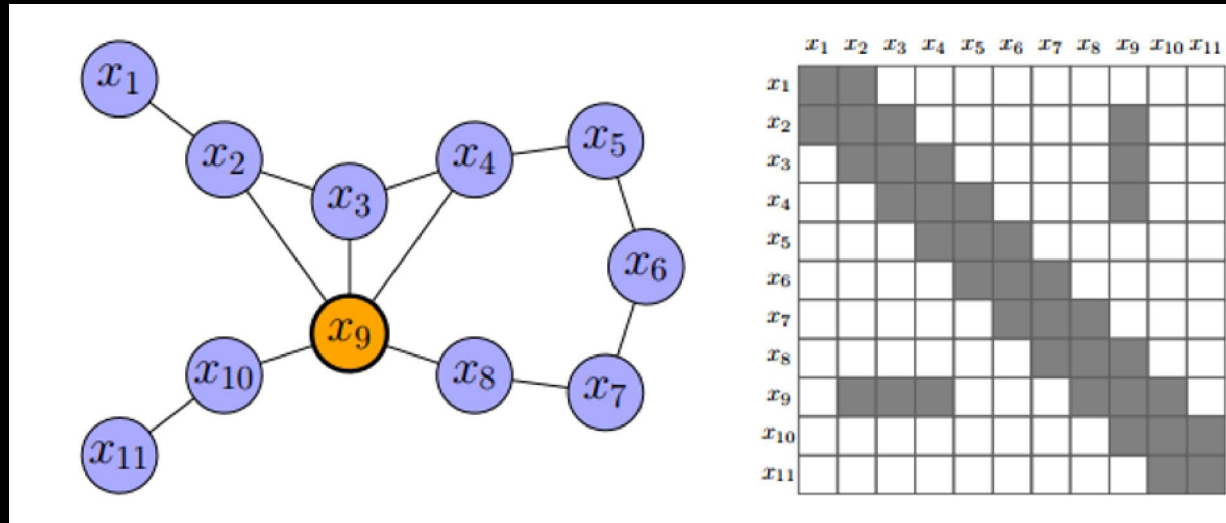
  <node name="visualizer" pkg="rviz" type="rviz" args="-d $(find
sdp_navigation)/rviz/navigation.rviz"/>
</launch>
```

```
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



$$\begin{bmatrix} 1 & 0 & 4 & 0 \\ 0 & 5 & 0 & 2 \\ 0 & 0 & 0 & 1 \\ 6 & 8 & 0 & 0 \end{bmatrix} \Rightarrow \begin{array}{|c|c|c|c|c|c|c|c|} \hline \text{col_ptr} & 0 & & 2 & & 4 & 5 & 7 \\ \hline \text{row_ind} & 0 & 3 & 1 & 3 & 0 & 1 & 2 \\ \hline \text{val} & 1 & 6 & 5 & 8 & 4 & 2 & 1 \\ \hline \end{array}$$

CSparse
Compressed Column Storage

Pose Graph Compression

Spatial Decimation / Information Filter



Cyrill Stachniss 2012

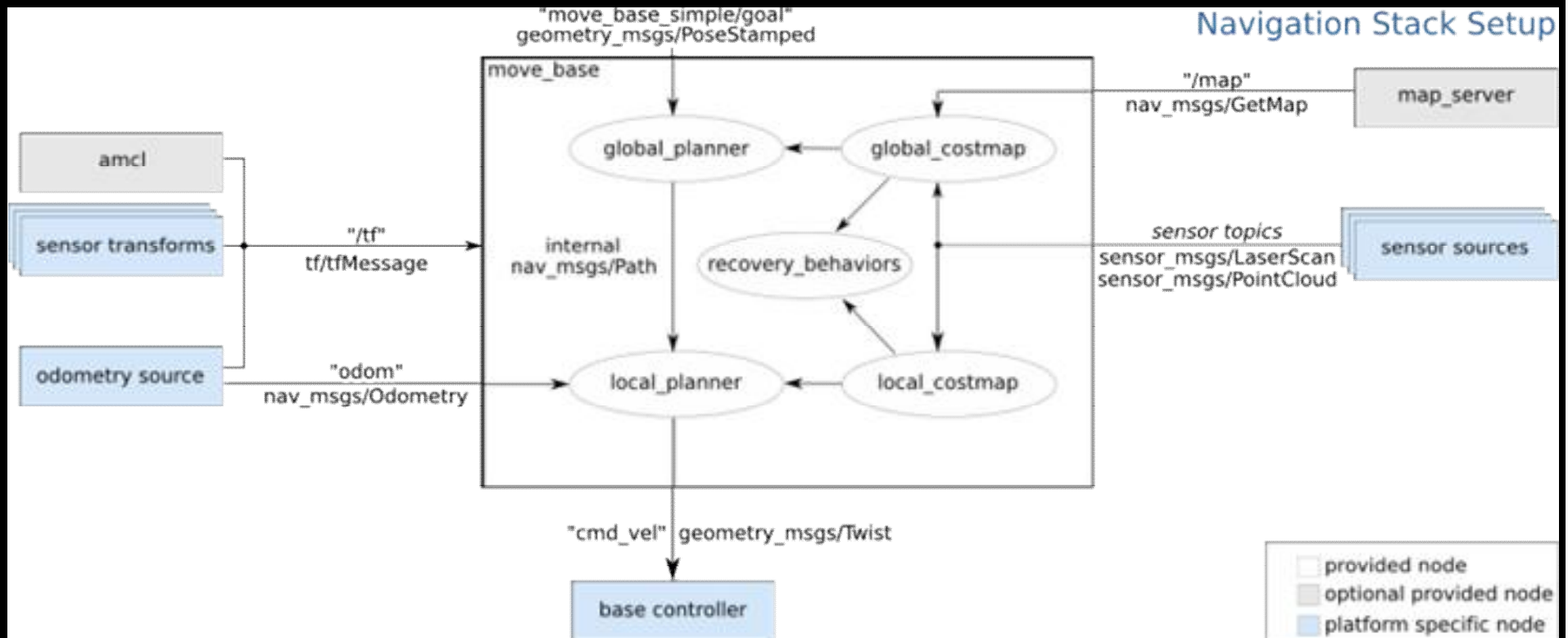
RPLidar A2 running Navigation: (amcl + move_base)

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

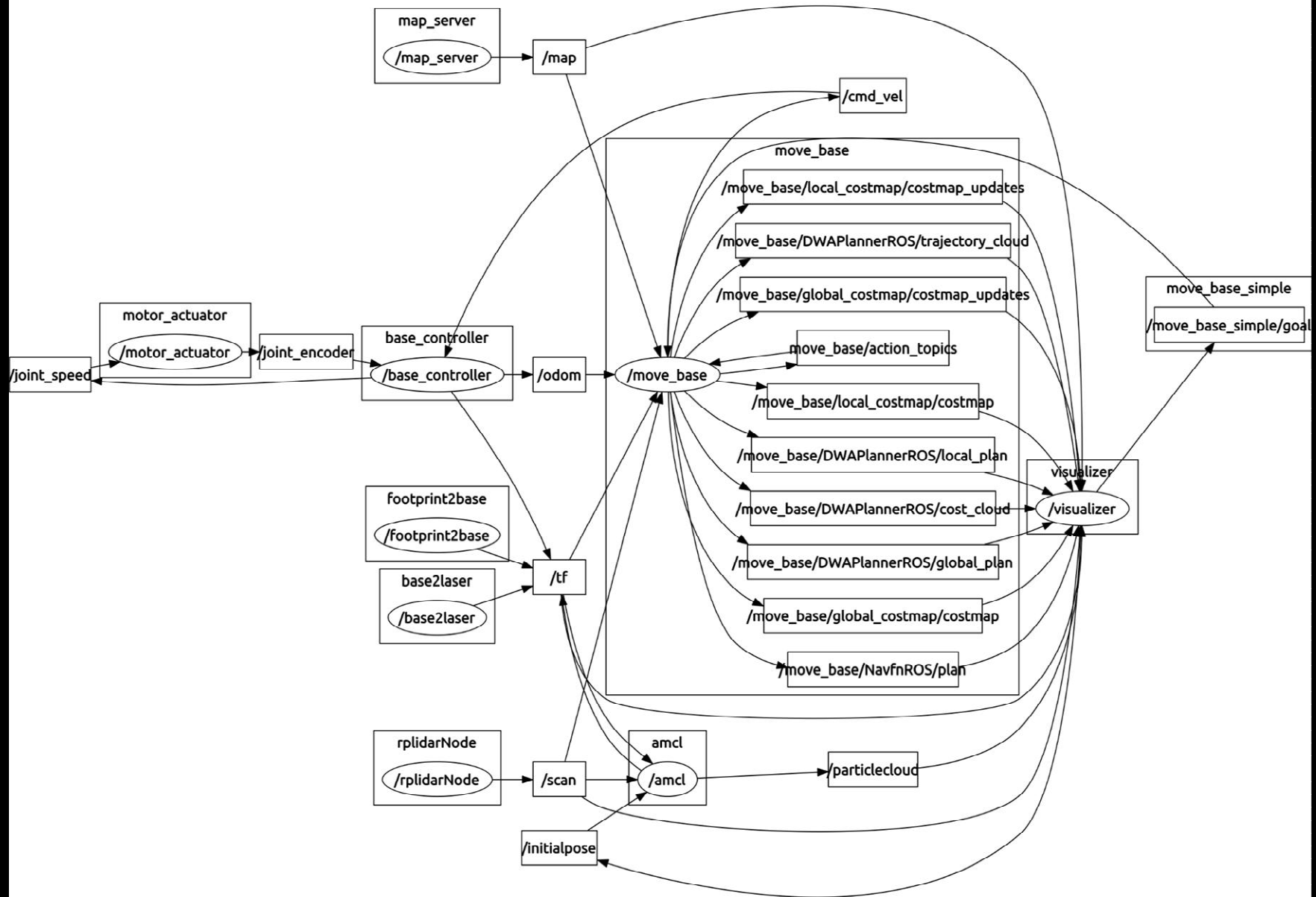
Framework of move_base



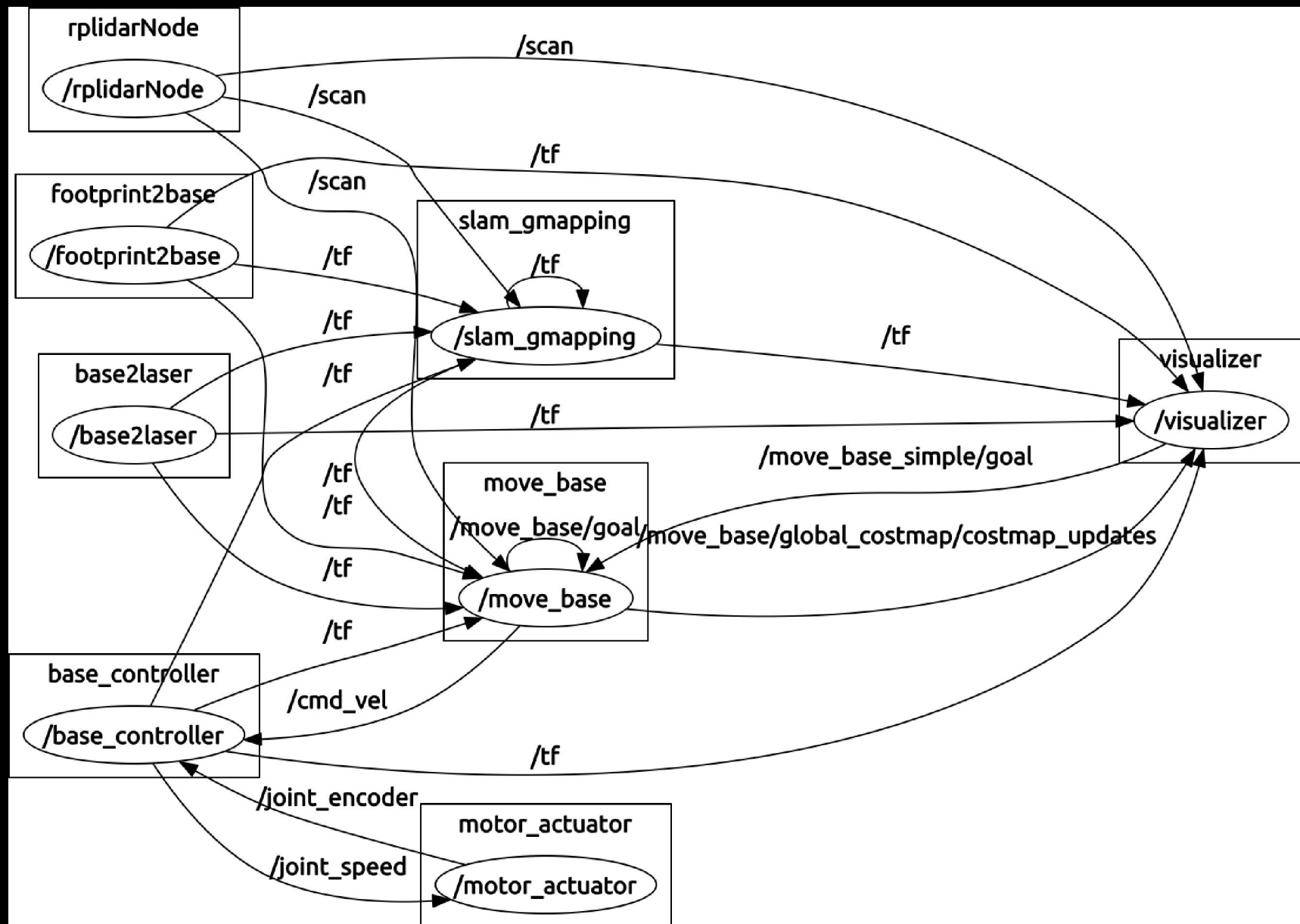
AMCL + map_server + move_base + ROBOT(base + sensor)

SLAM + move_base + ROBOT(base + sensor)

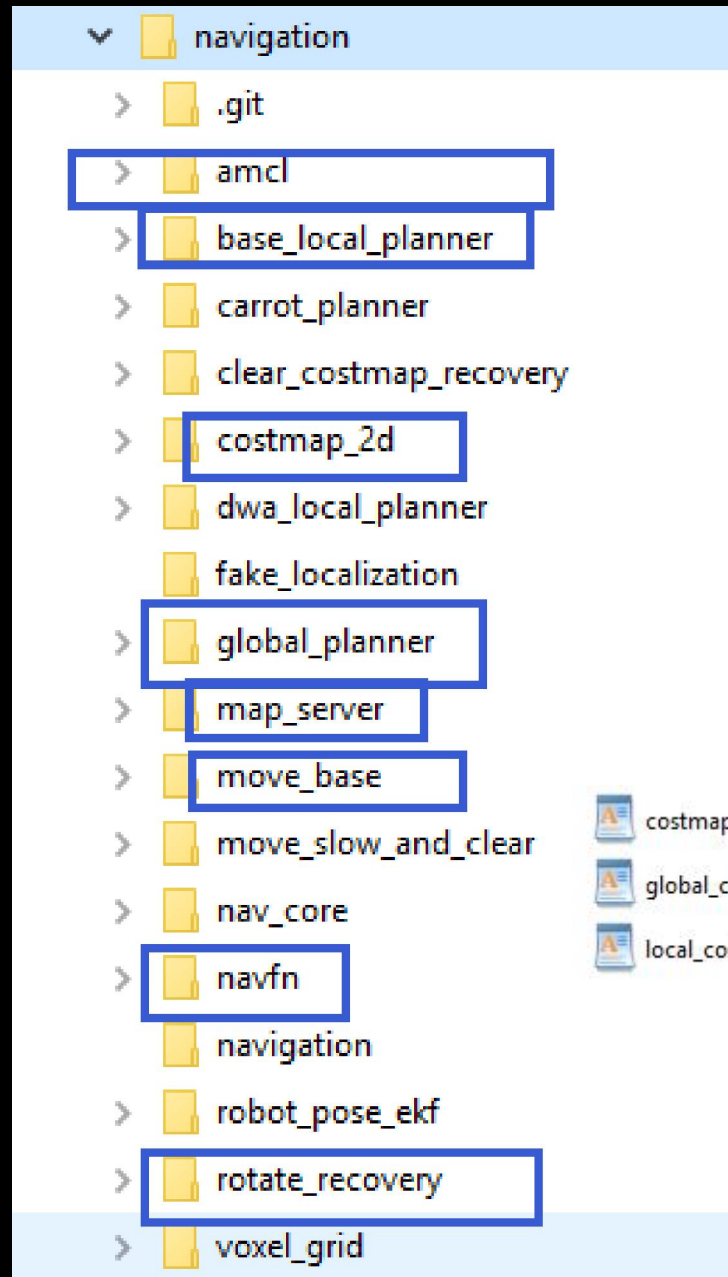
AMCL + map_server + move_base + ROBOT(base + sensor)



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>
```

costmap_common_params.yaml

dummy.yaml

dwa_local_planner_params.yaml

global_costmap_params.yaml

global_planner_params.yaml

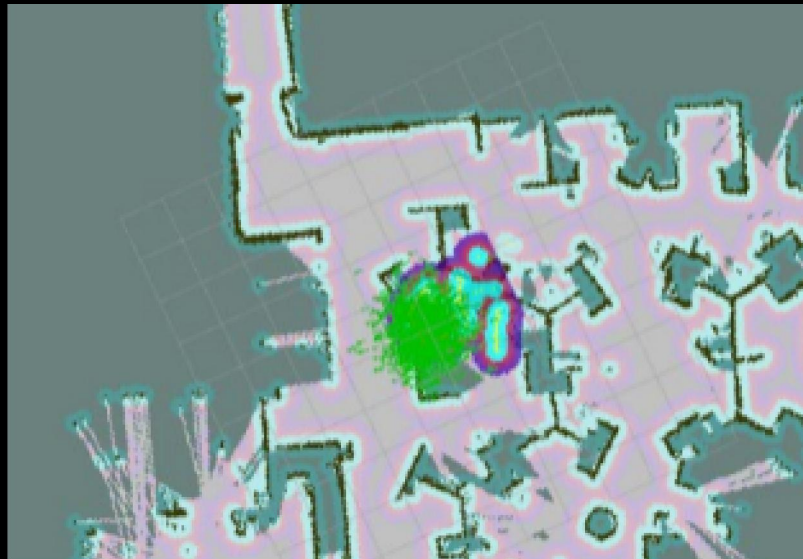
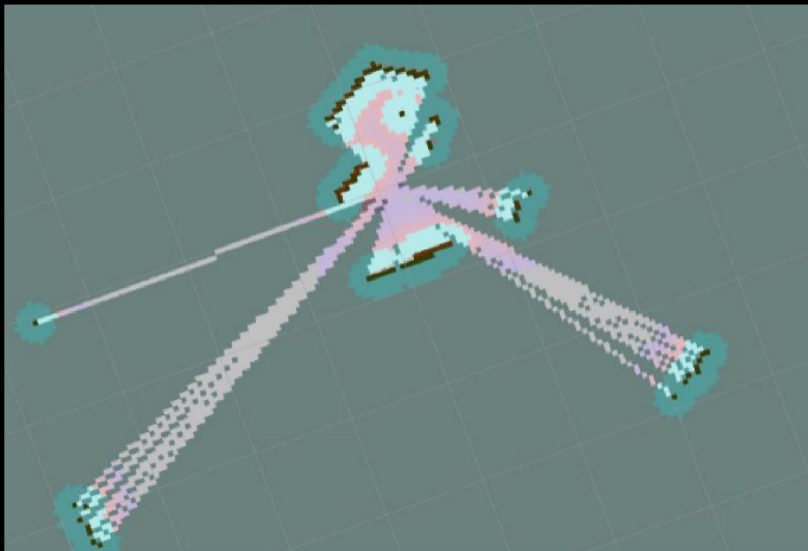
karto_mapper_params.yaml

local_costmap_params.yaml

move_base_params.yaml

navfn_global_planner_params.yaml

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

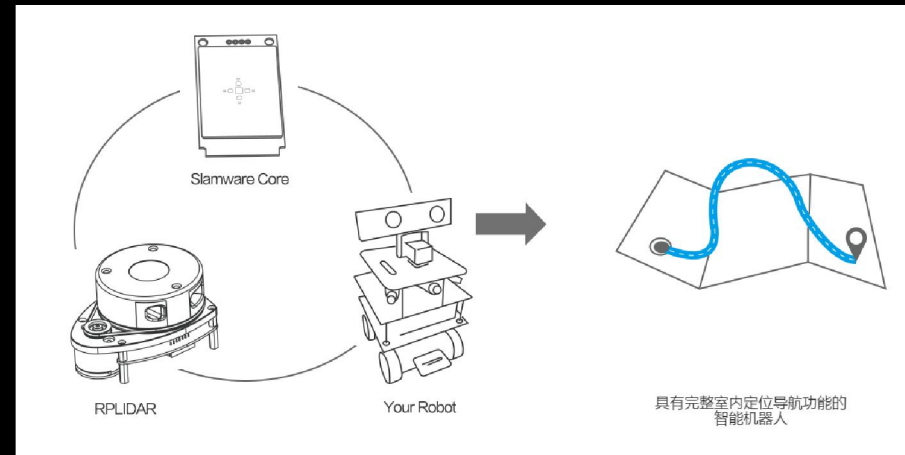
Local_costmap all zero :

Map type: voxel (3D)

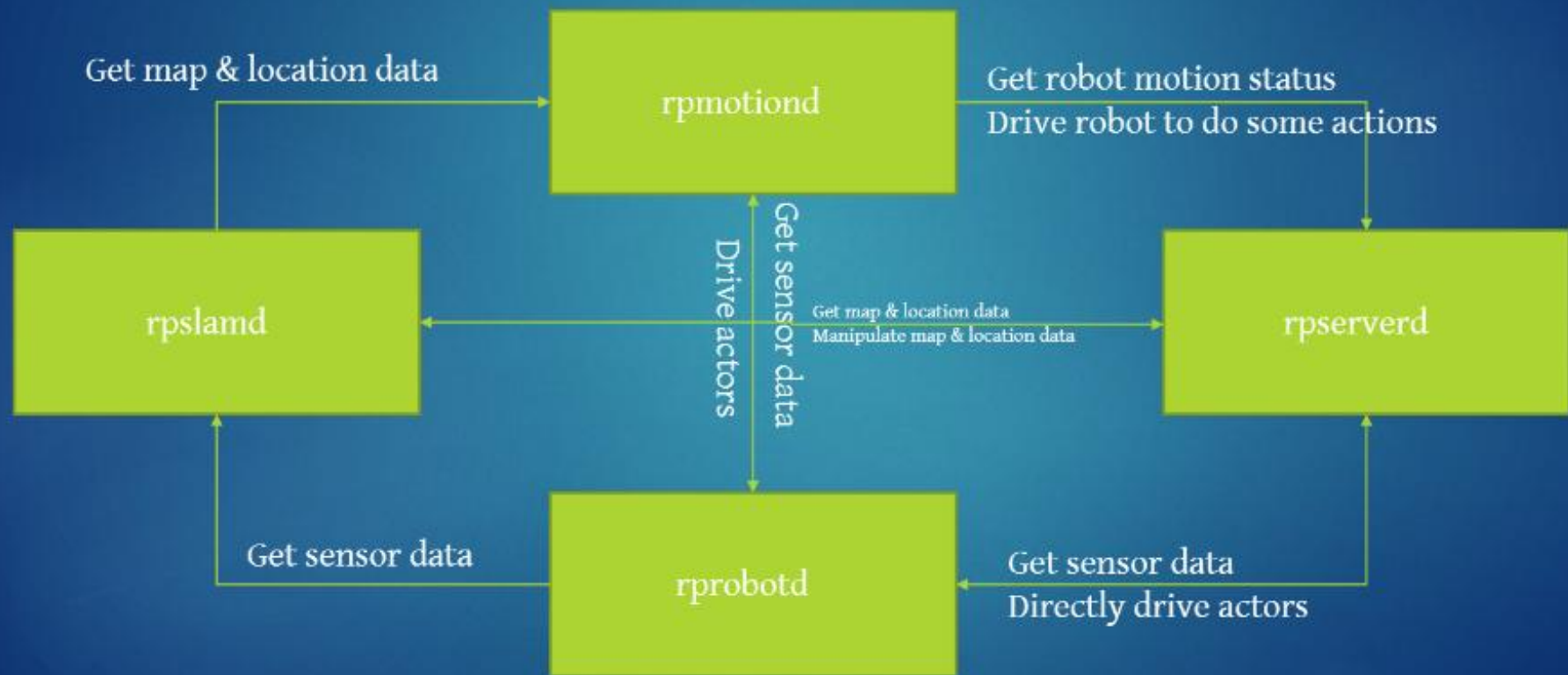
Min_obstacle_height

Max_obstacle_height

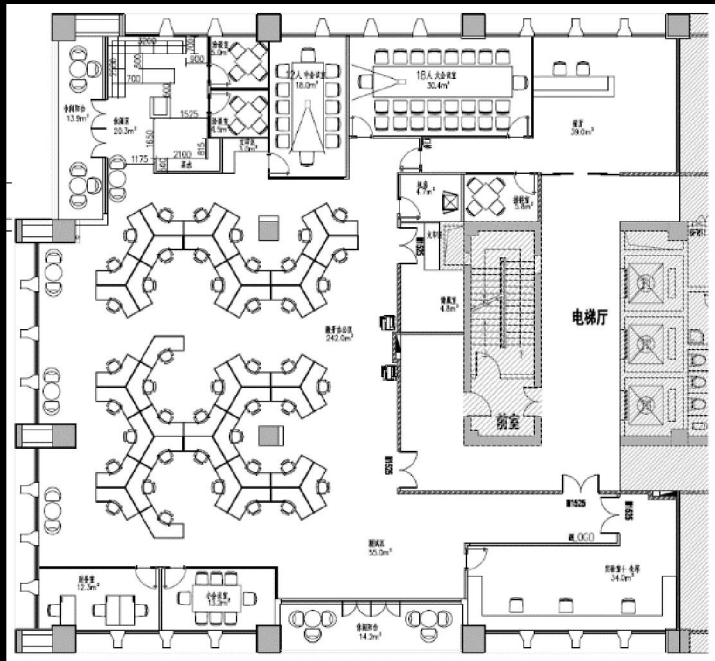
4. SLAMWARE solution for localization and navigation



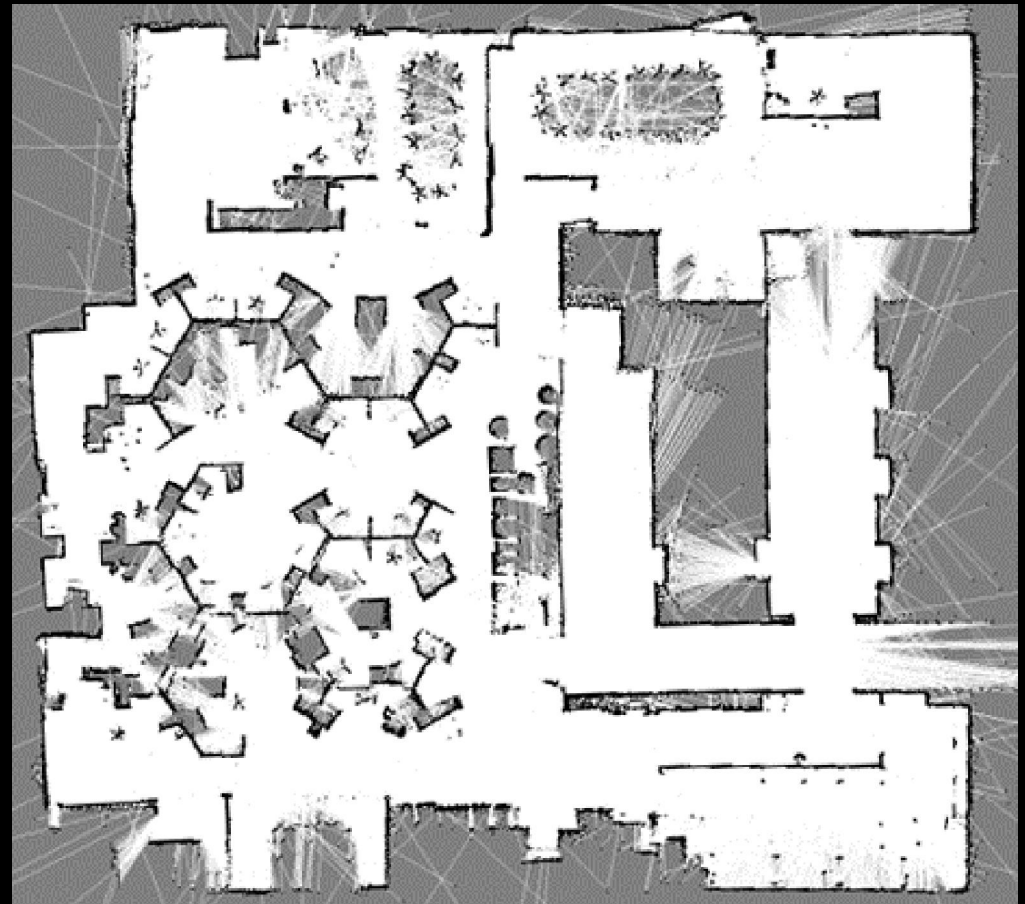
SLAMWARE solution for localization and navigation



SLAMWARE solution for localization and navigation



Design



SLAMWARE BUILD

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 155, 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/yhzhao/.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.

Reference

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- 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.
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- 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.
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- My CSDN: <http://blog.csdn.net/zyh821351004>



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