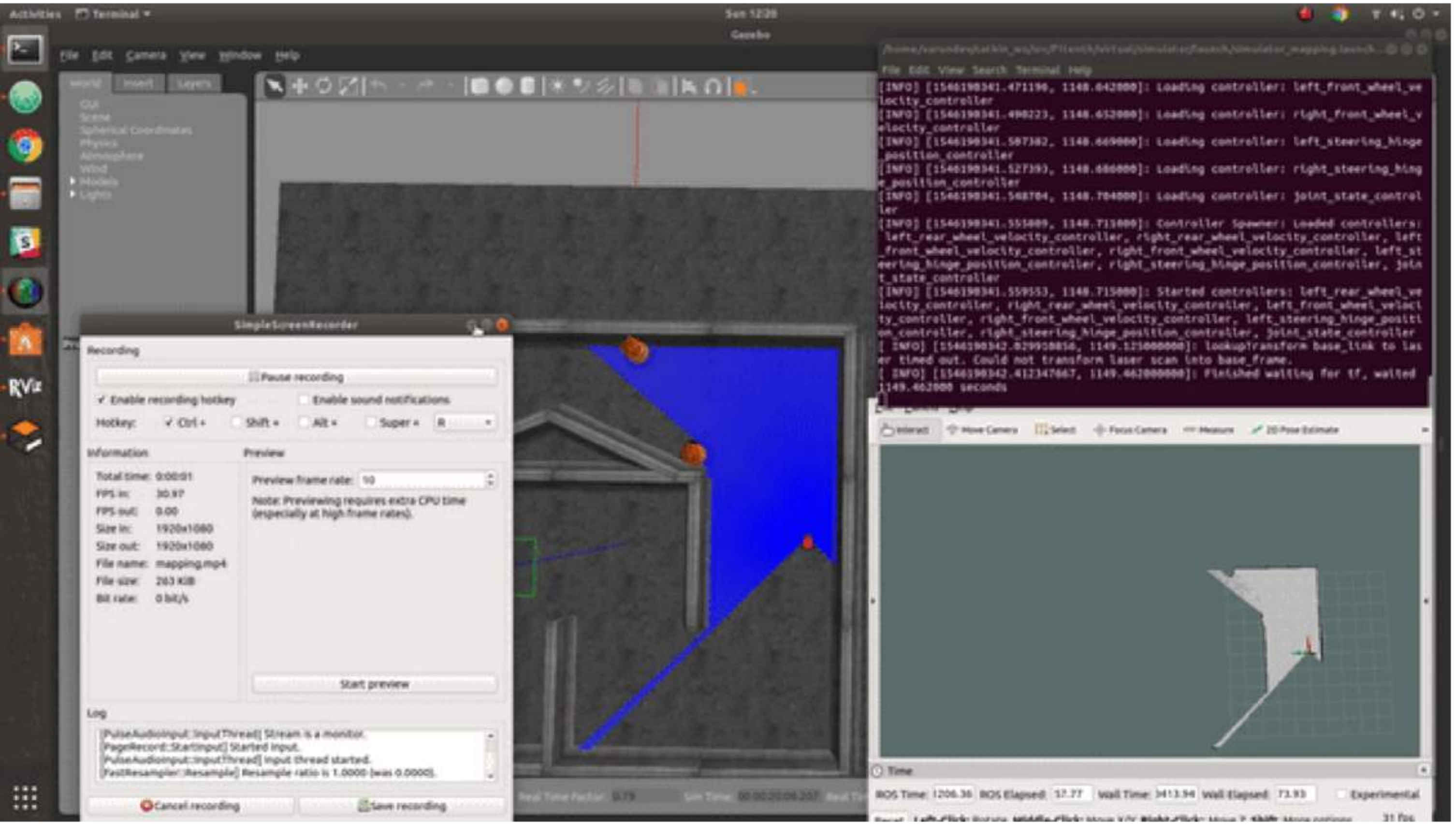


F1/10

Autonomous Racing

Simultaneous Mapping Localization & Planning

Varundev Sukhil

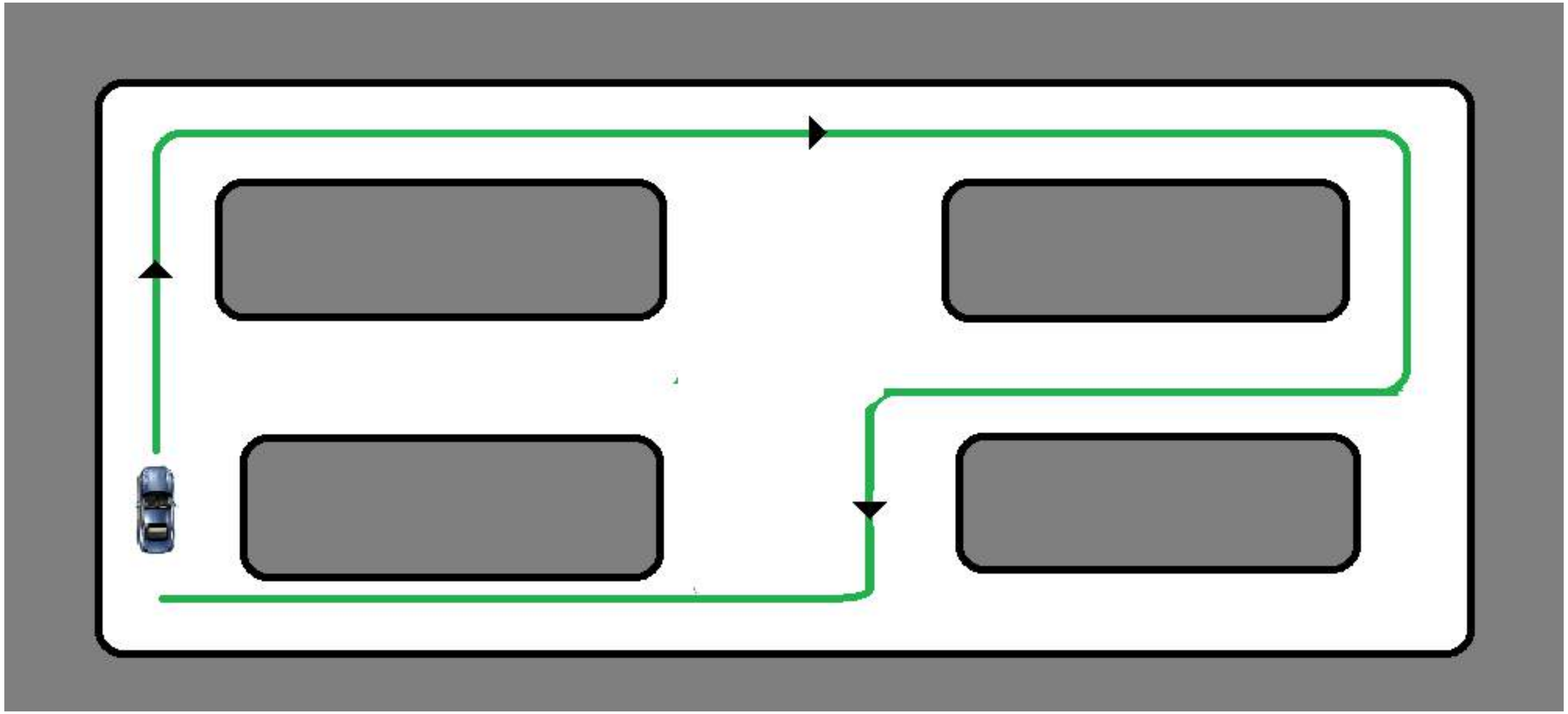
CS 4501/SYS 4582

Spring 2019

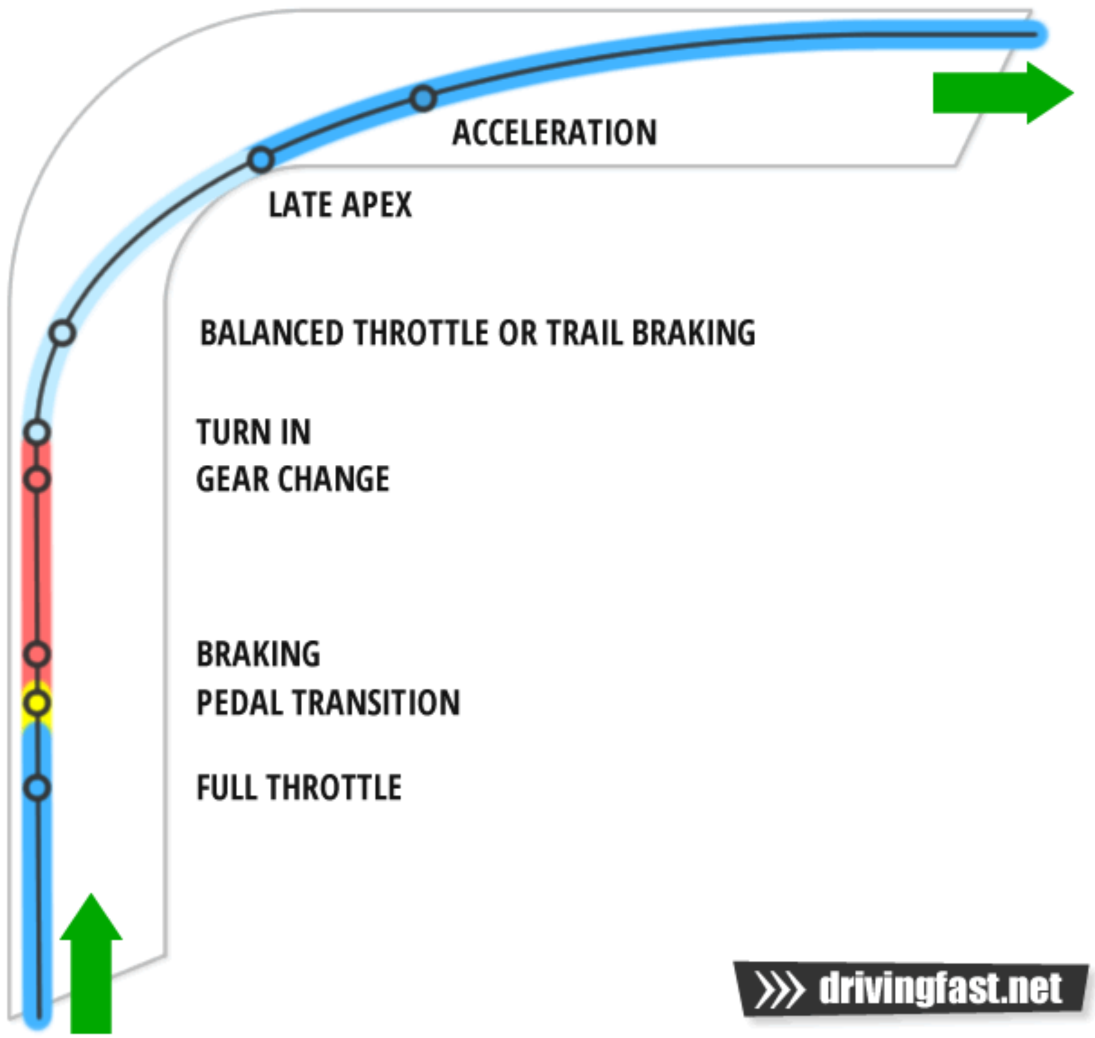
Rice Hall 120

Limitations : Basic Path Planning

- High Level Path Assignments
  - 2nd right, 2nd right, 1st right, 1st left, 1st right

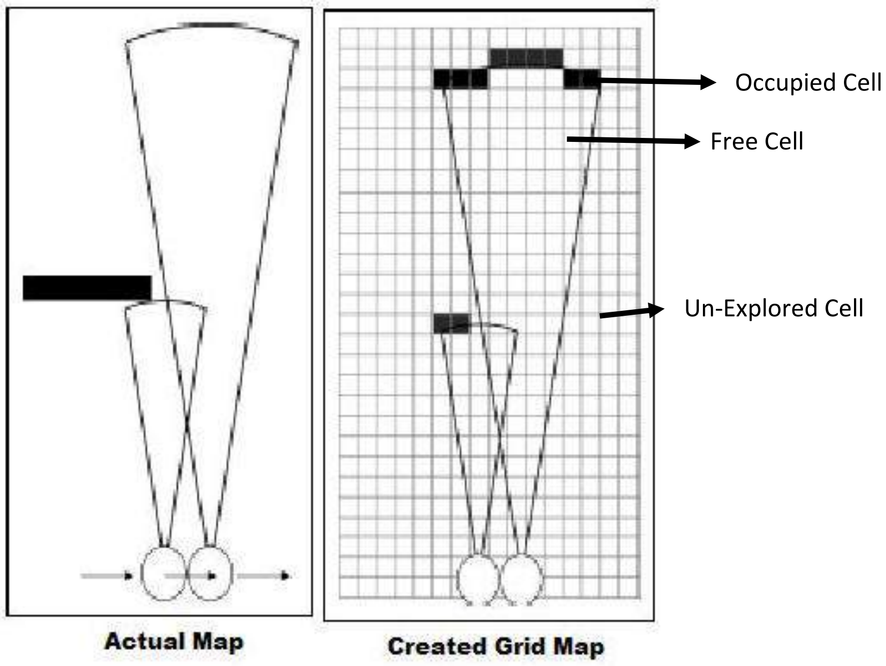


Race Lines


ACCELERATION
LATE APEX
BALANCED THROTTLE OR TRAIL BRAKING
TURN IN
GEAR CHANGE
BRAKING
PEDAL TRANSITION
FULL THROTTLE
drivingfast.net

Occupancy Grid Mapping

Measurement Model



- Measurement :

  $m_{x,y} = 1$ LiDAR hit

  $m_{x,y} = 0$ No occlusion

- Map Cell:

  Z = 1 Occupied

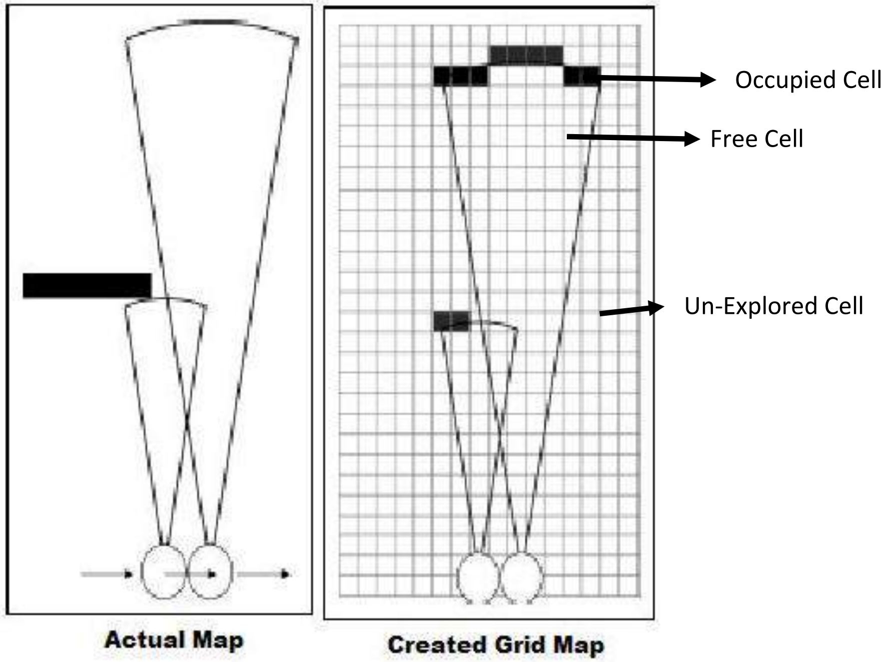
  Z = 0 UnExplored

  Z = -1 Free

- Measurement Model :

  $p(z|m_{x,y})$

Occupancy Grid Mapping



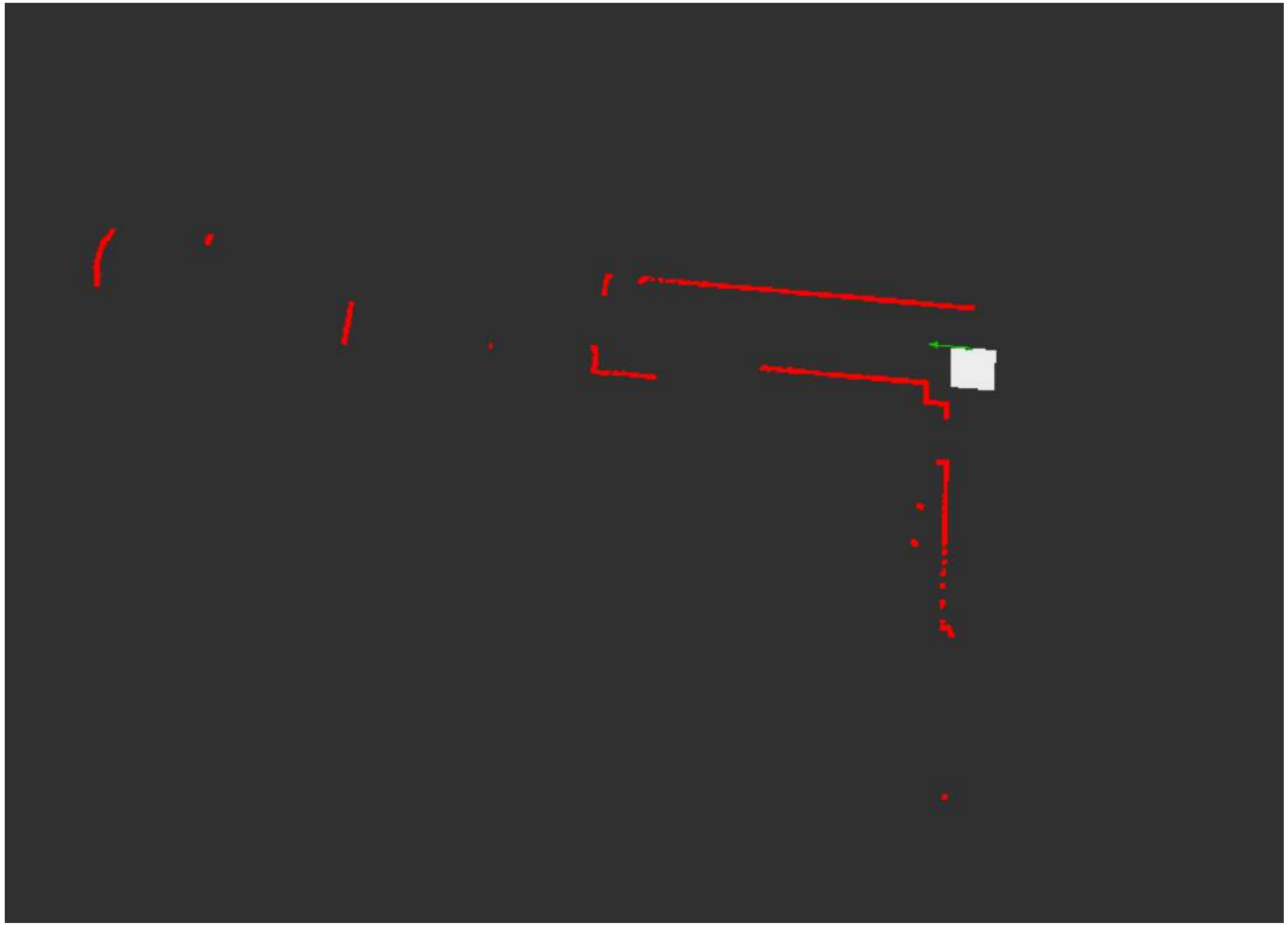
$$\log odd\_occ := \log \frac{p(z=1|m_{x,y}=1)}{p(z=1|m_{x,y}=0)}$$

$$\log odd\_free := \log \frac{p(z=-1|m_{x,y}=0)}{p(z=-1|m_{x,y}=1)}$$

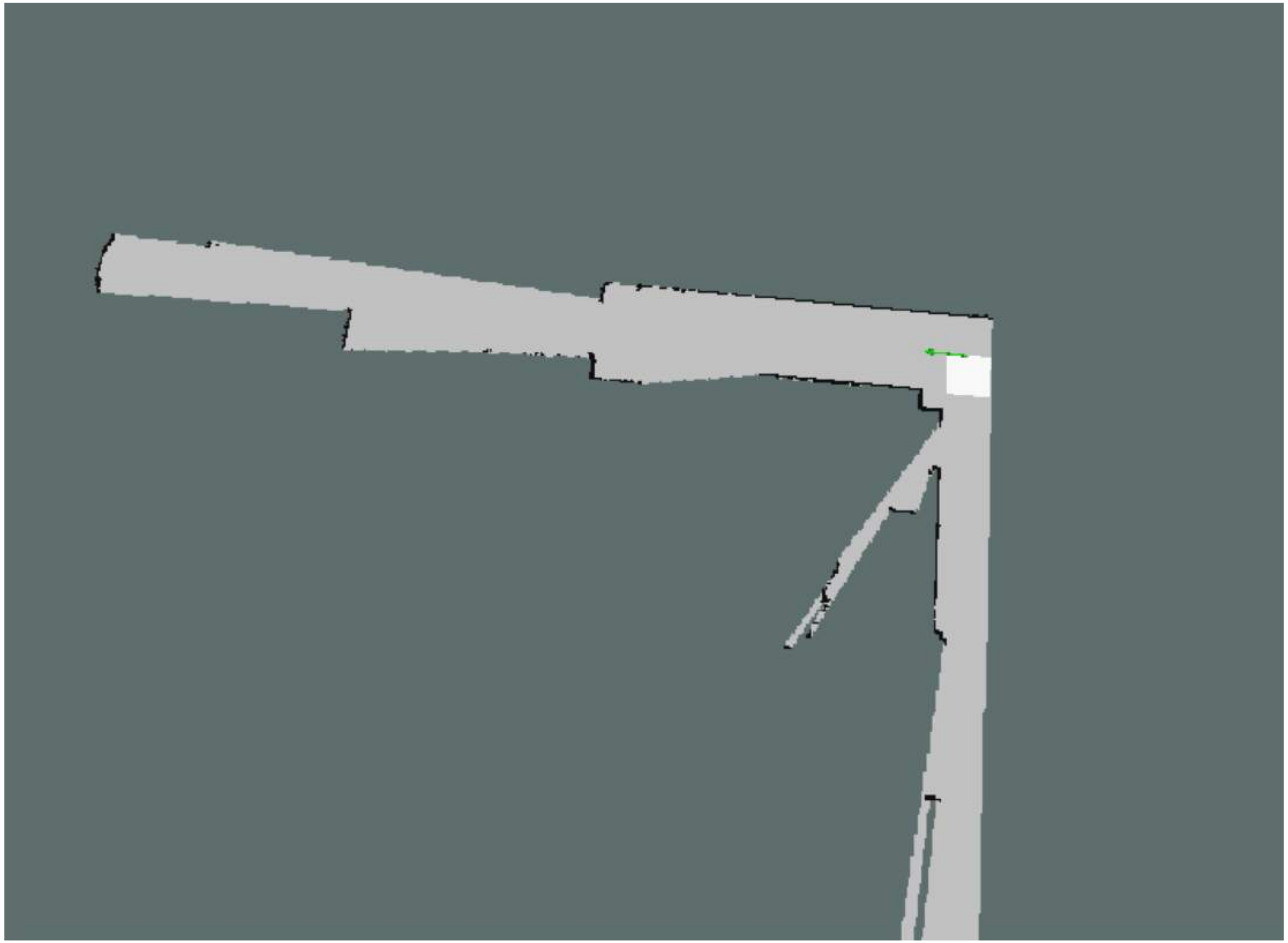
Log Probability for occupied cells

Log Probability for free cells

Registering the first Scan

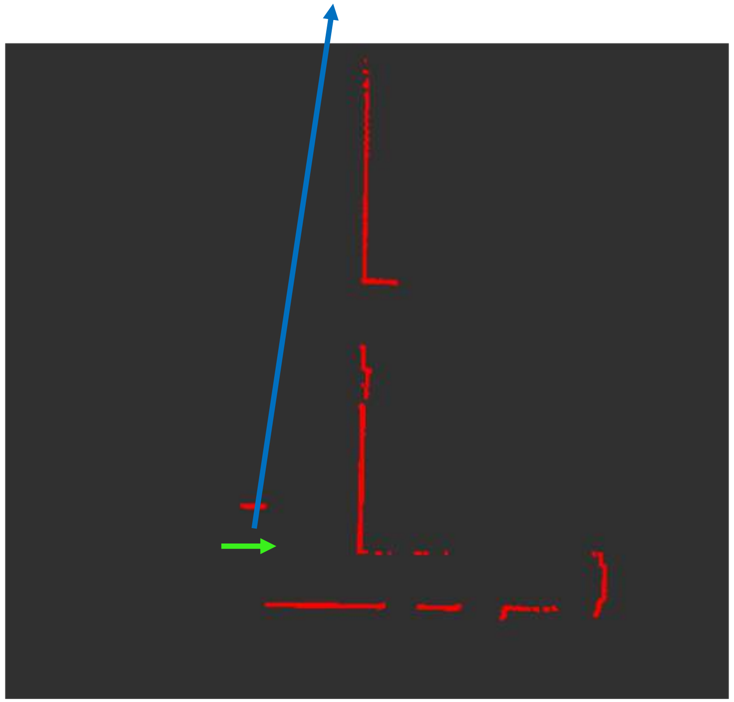


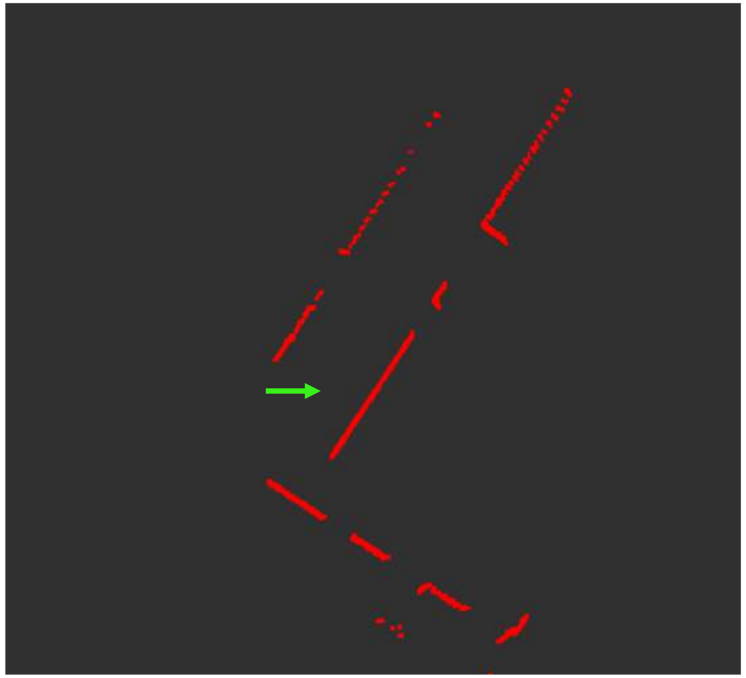
Registering the first Scan



Scan Matching

Pose of the Car at t = t1





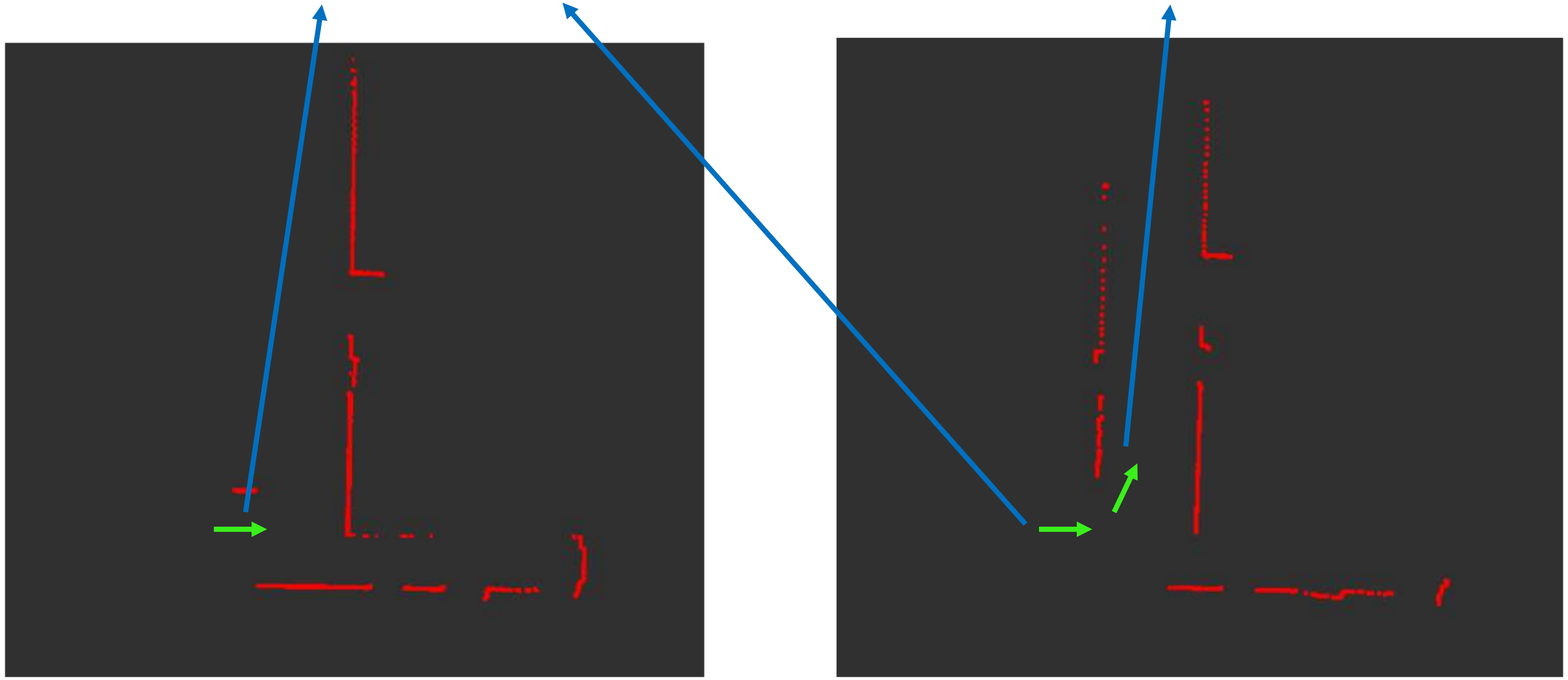
Laser Scans w.r.t car at Time t = t_1

Laser Scans w.r.t car at Time t = t_2

Scan Matching

Pose of the Car at t = t1

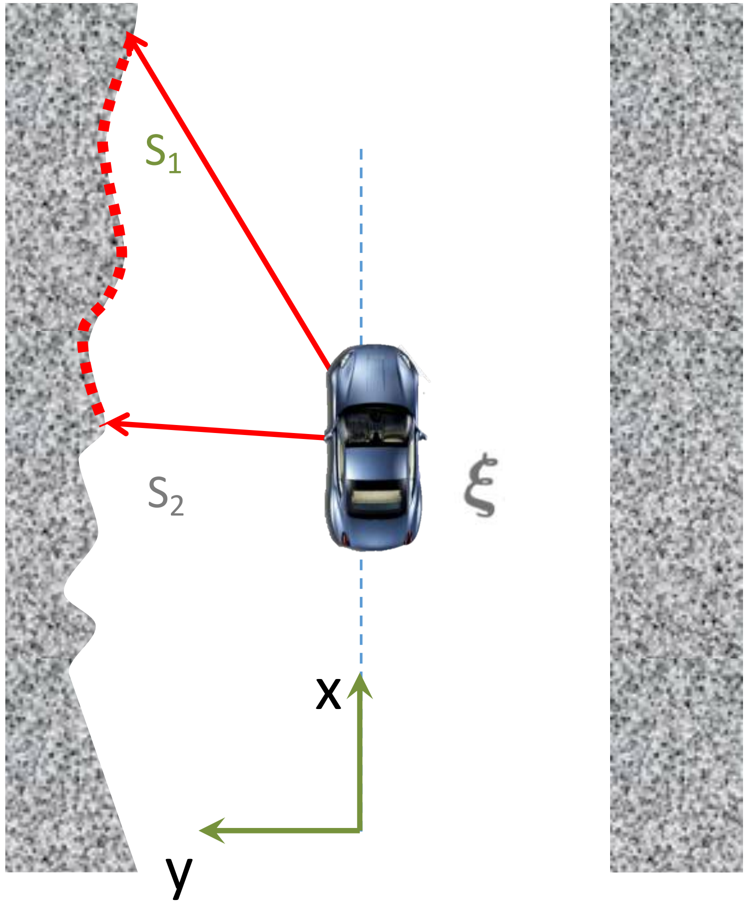
Pose of the Car at t=t2



Laser Scans w.r.t car at Time t = t_1

Laser Scans w.r.t car at Time t = t_2

Scan matching: Hector Slam



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

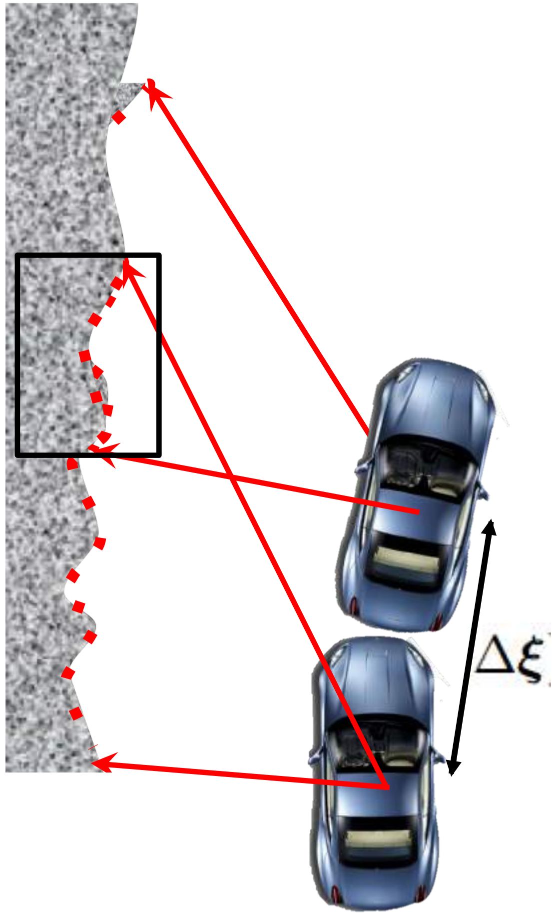
Impact coordinates of i^{th} scan in world frame

Total of n scans

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

Map Value at coordinates given by S_i

Scan matching: Hector Slam



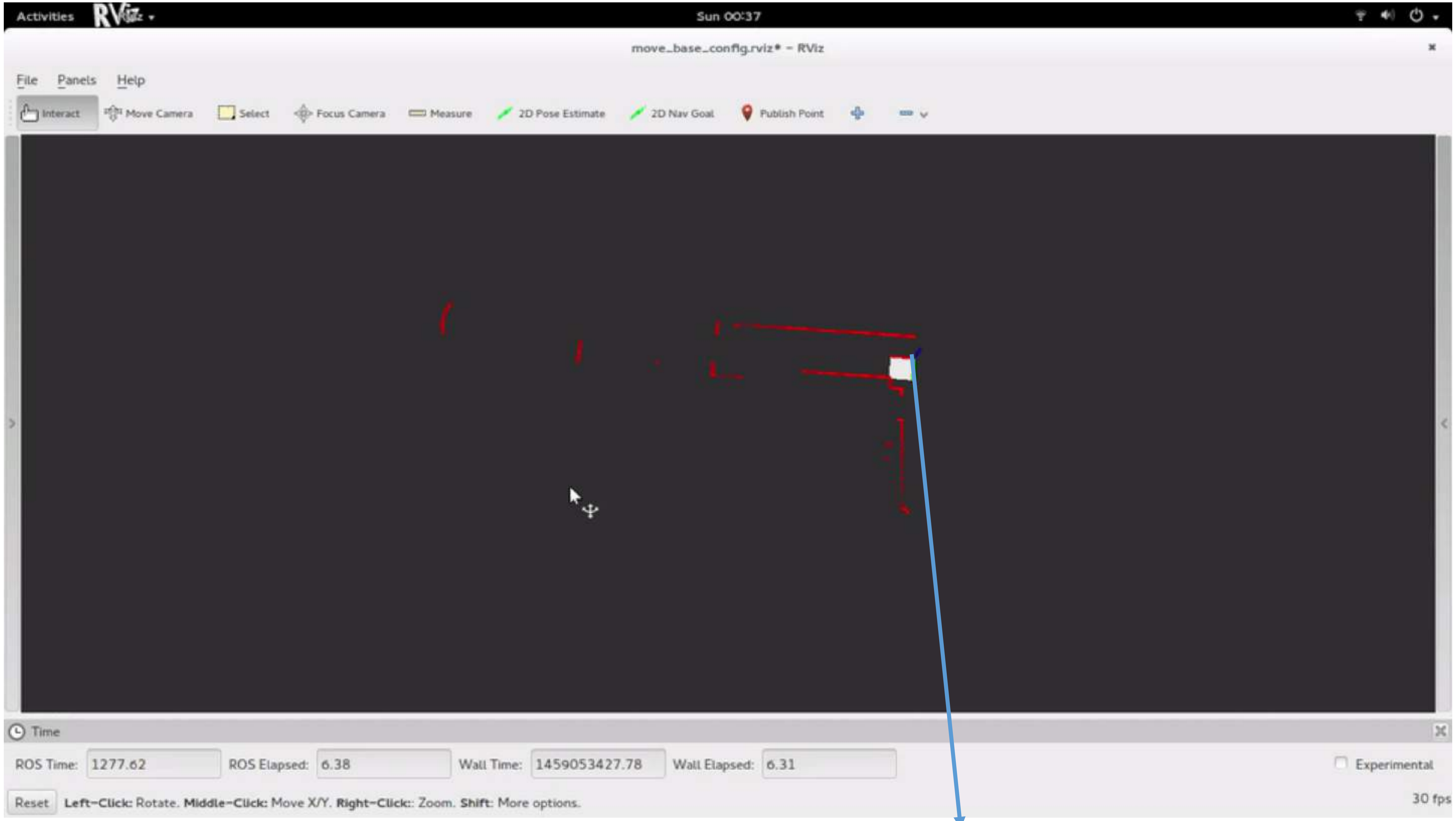
$$\sum_{i=1}^{n} \left[1 - M(\mathbf{S}_i(\boldsymbol{\xi} + \Delta\boldsymbol{\xi}))\right]^2 \rightarrow 0\,.$$

Taylor Expansion of Function M

Solving for Δξ to yields Gauss-Newton Equation

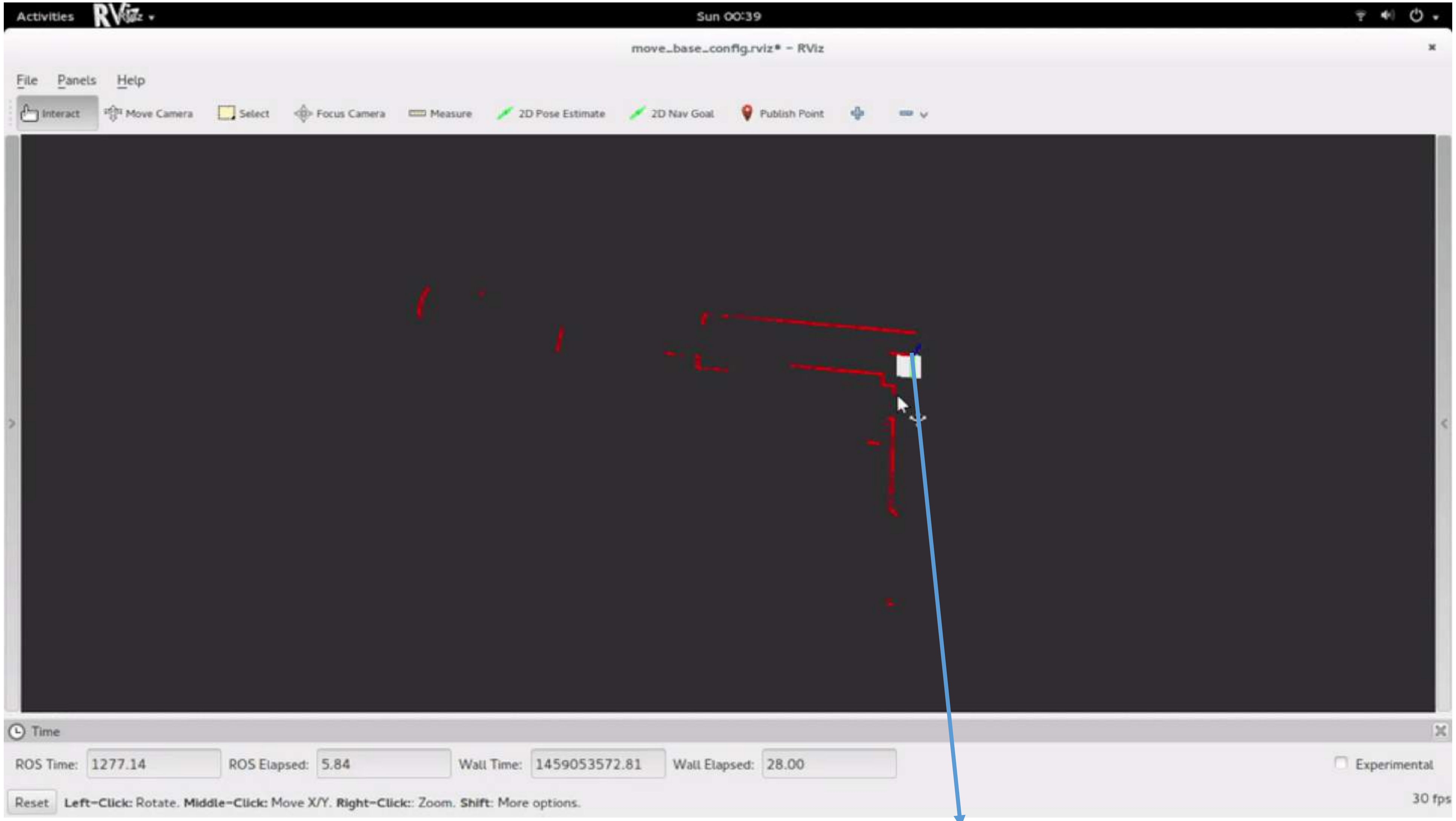
Evaluation of Gauss-Newton equation gives a step Δξ that minimizes the objective function

Raw LiDAR Scans



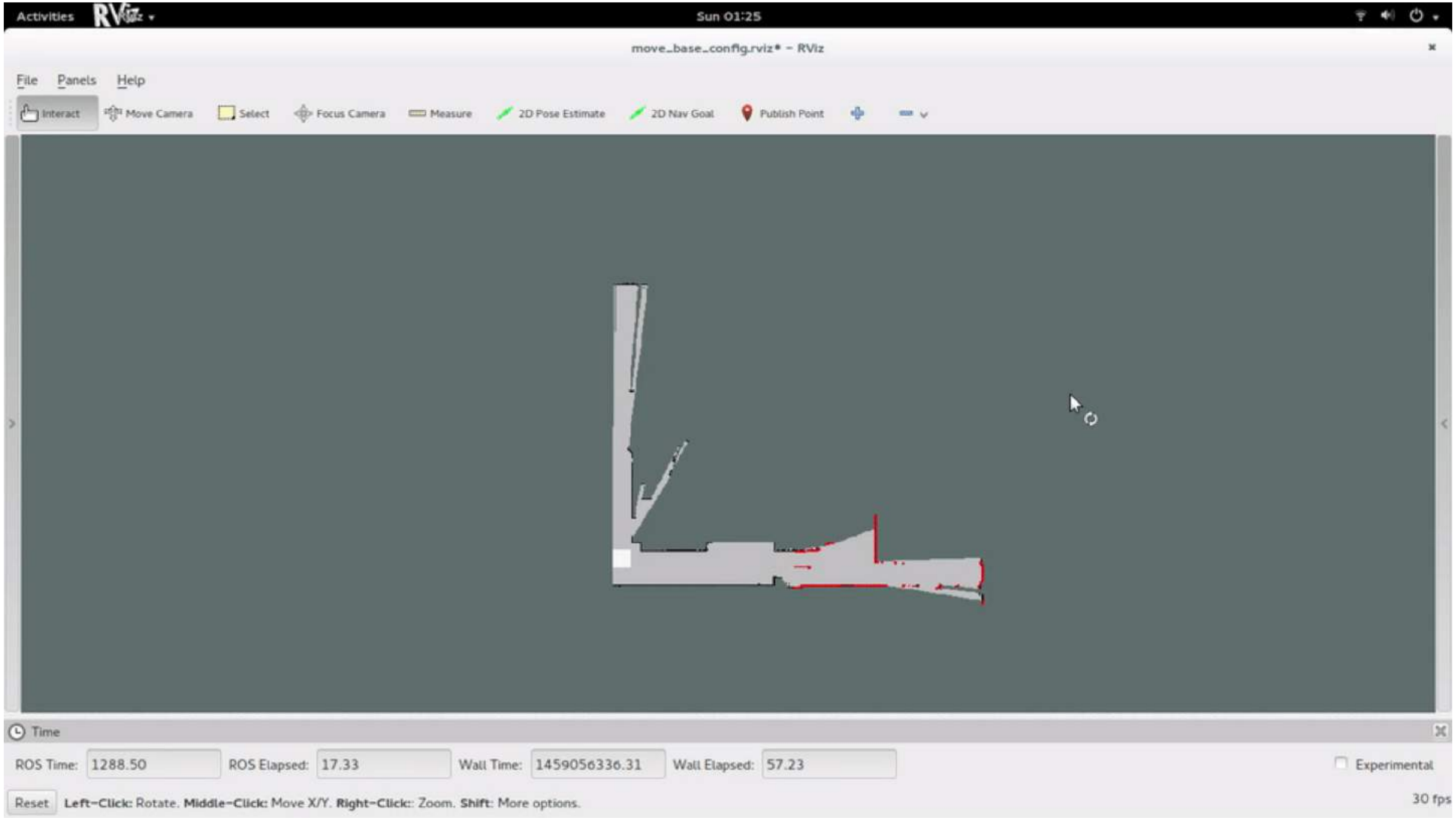
Baseframe Axes

Scans after transforming by Δξ at each stage

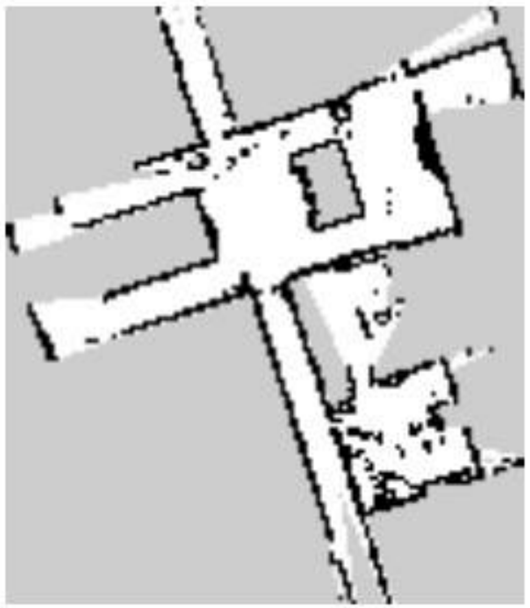


Mapframe Axes

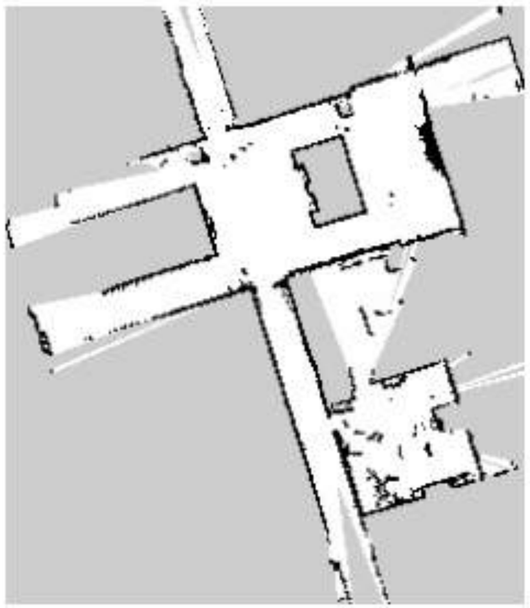
Map Update


Activities
Sun 01:25
move_base_config.rviz* - RViz
File
Panels
Help
Interact
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
2D Nav Goal
Publish Point
Time
ROS Time: 1288.50
ROS Elapsed: 17.33
Wall Time: 1459056336.31
Wall Elapsed: 57.23
Experimental
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click:: Zoom. Shift: More options.
30 fps

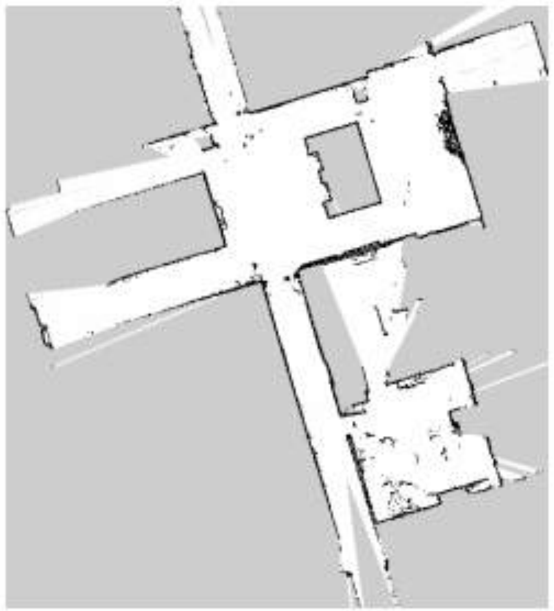
Multi-Resolution Map Representation



20 cm Grid Cell

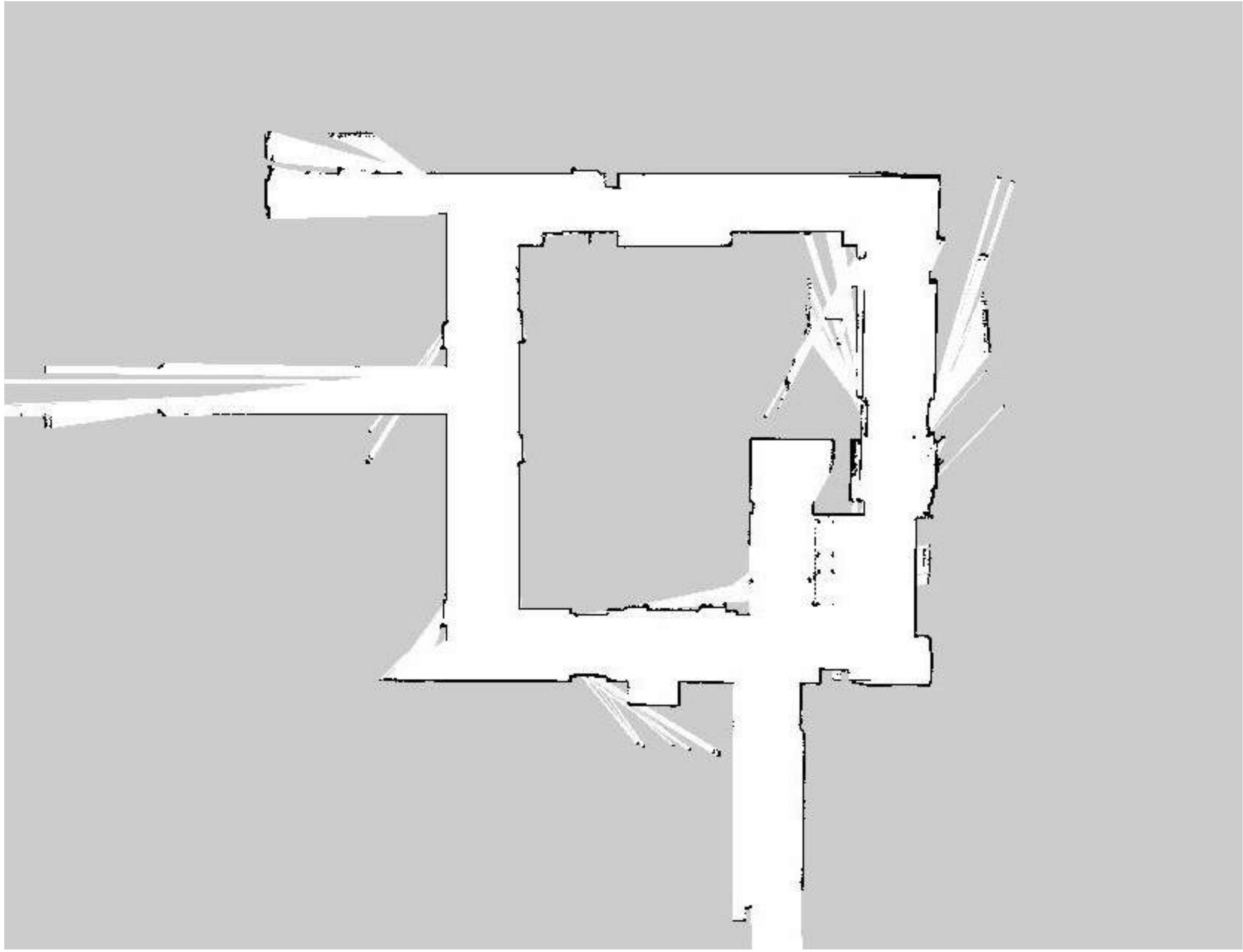


10 cm Grid Cell

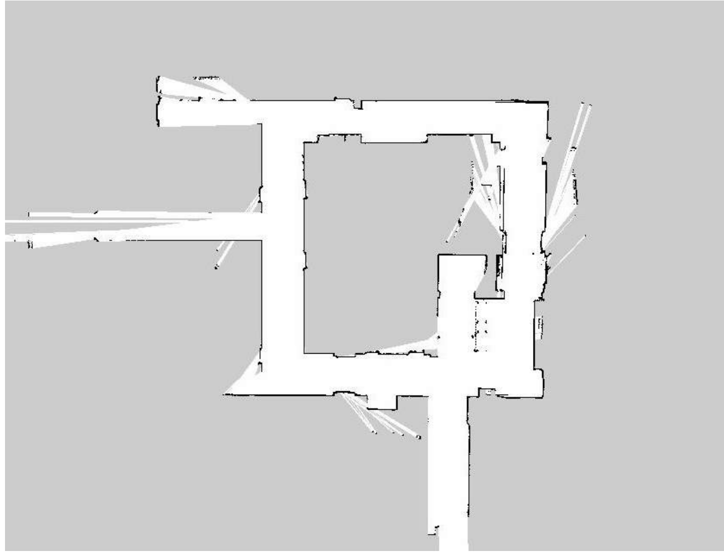


5 cm Grid Cell

Saving the map

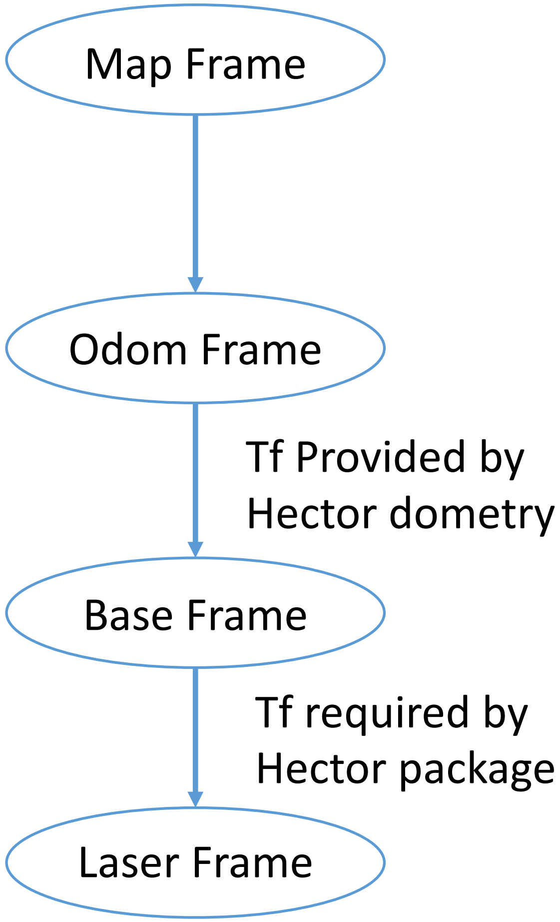


Saving the map



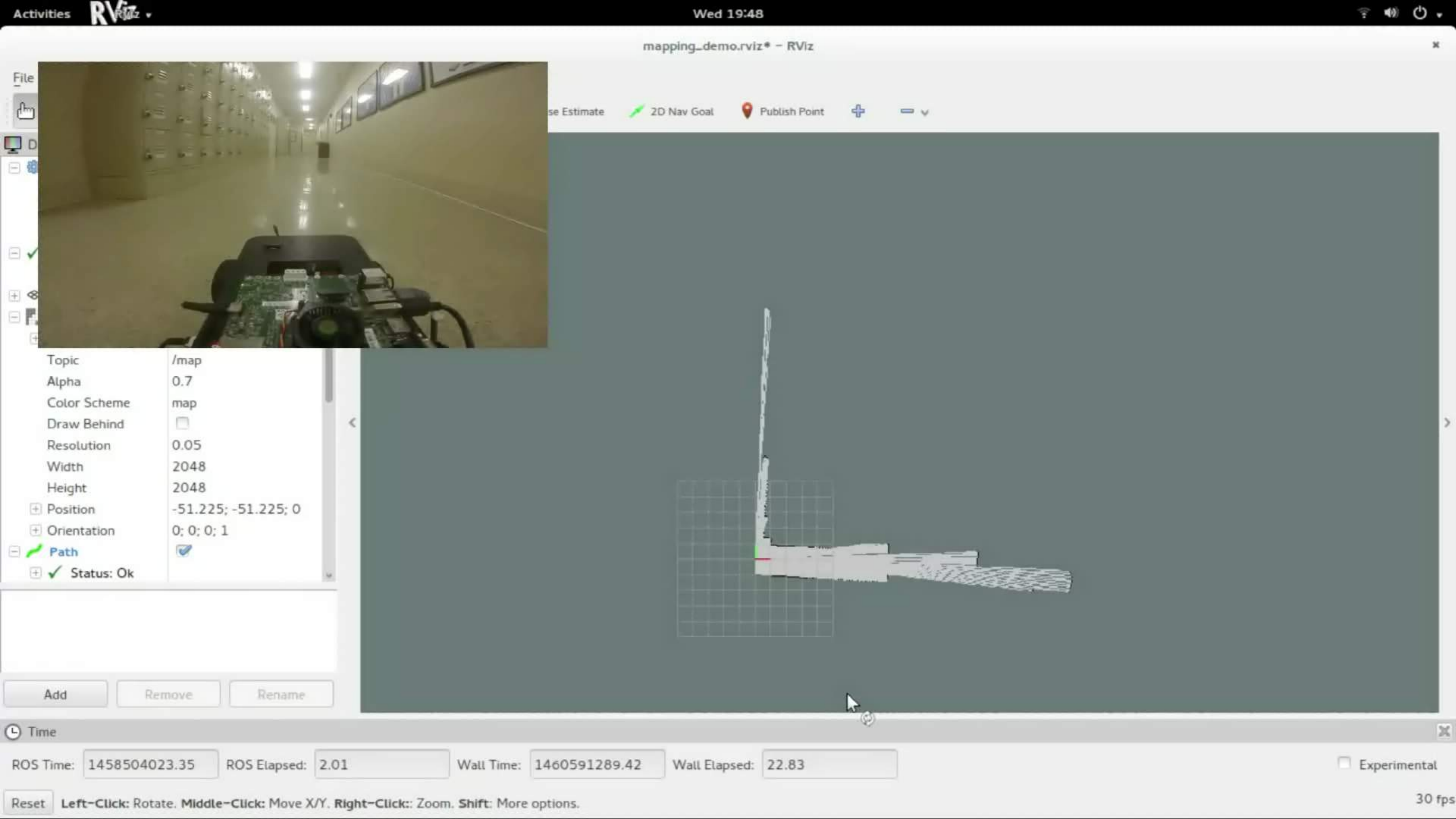
- ROS Package called
  MAP Server
- Allows saving a map currently being published over /map topic
- The saved map can be loaded for future tasks.

System Tf tree



Parameters for Hector SLAM : ROS

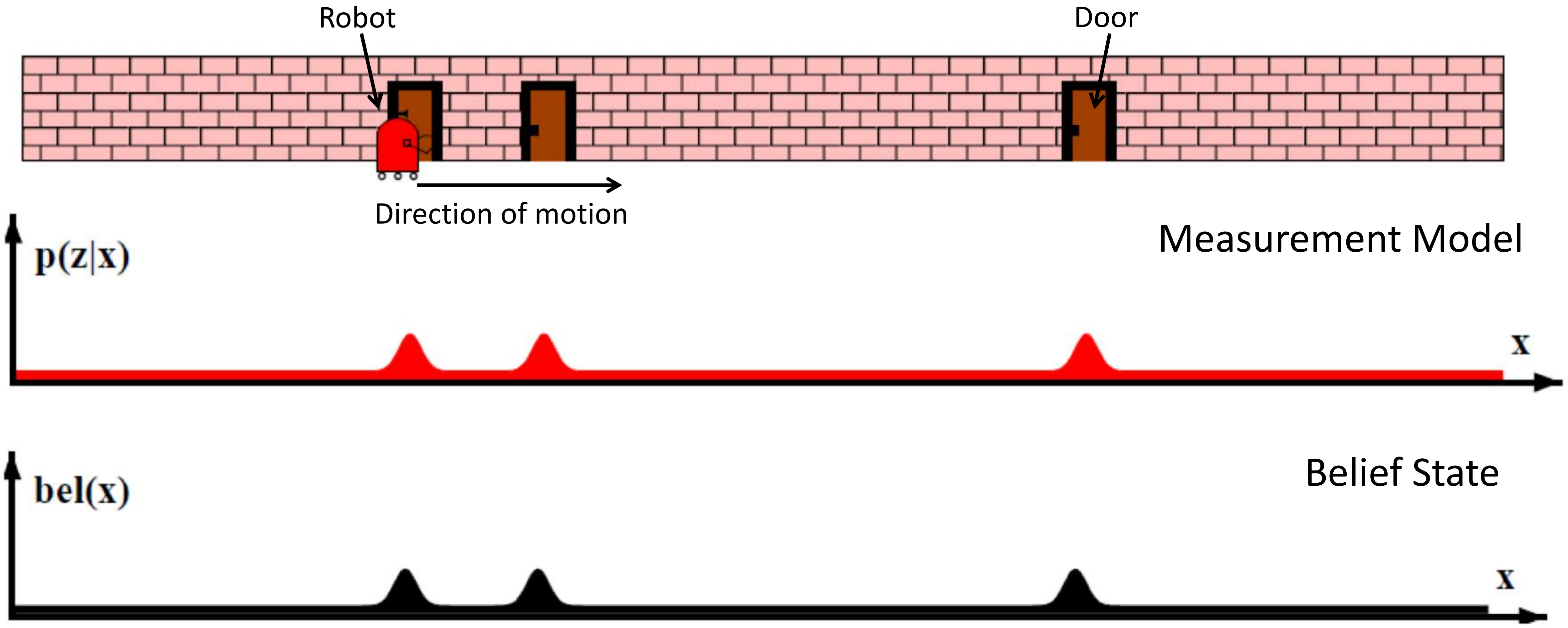
- map resolution
- map_update_distance_thresh
- map_update_angle_thresh
- laser_max_dist
- update_factor_free
- update_factor_occupied


Activities
Wed 19:48
mapping_demo.rviz* – RViz
File
se Estimate
2D Nav Goal
Publish Point
Topic
/map
Alpha
0.7
Color Scheme
map
Draw Behind
Resolution
0.05
Width
2048
Height
2048
Position
-51.225; -51.225; 0
Orientation
0; 0; 0; 1
Path
Status: Ok
Add
Remove
Rename
Time
ROS Time:
1458504023.35
ROS Elapsed:
2.01
Wall Time:
1460591289.42
Wall Elapsed:
22.83
Experimental
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click:: Zoom. Shift: More options.
30 fps

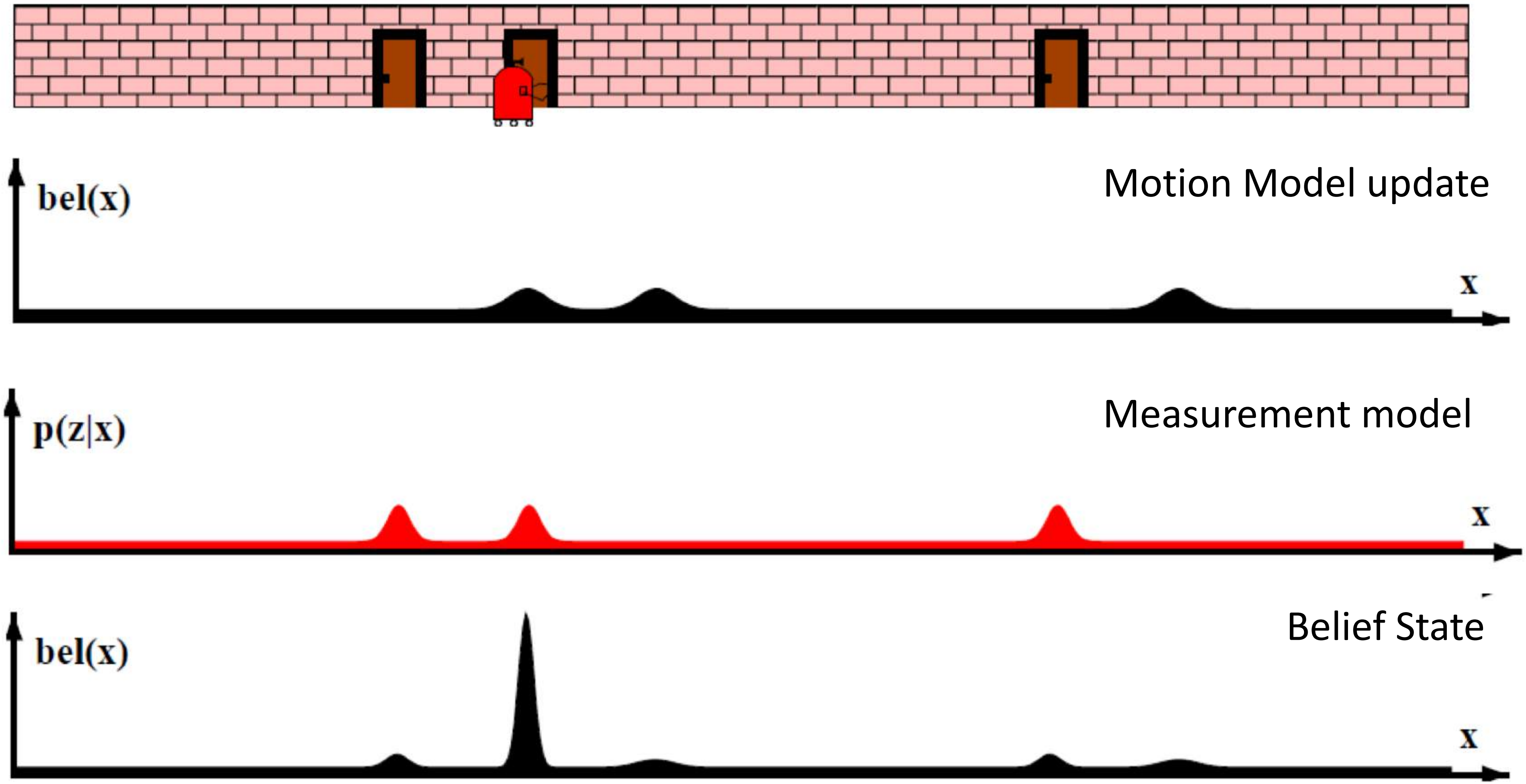
Particle Filter

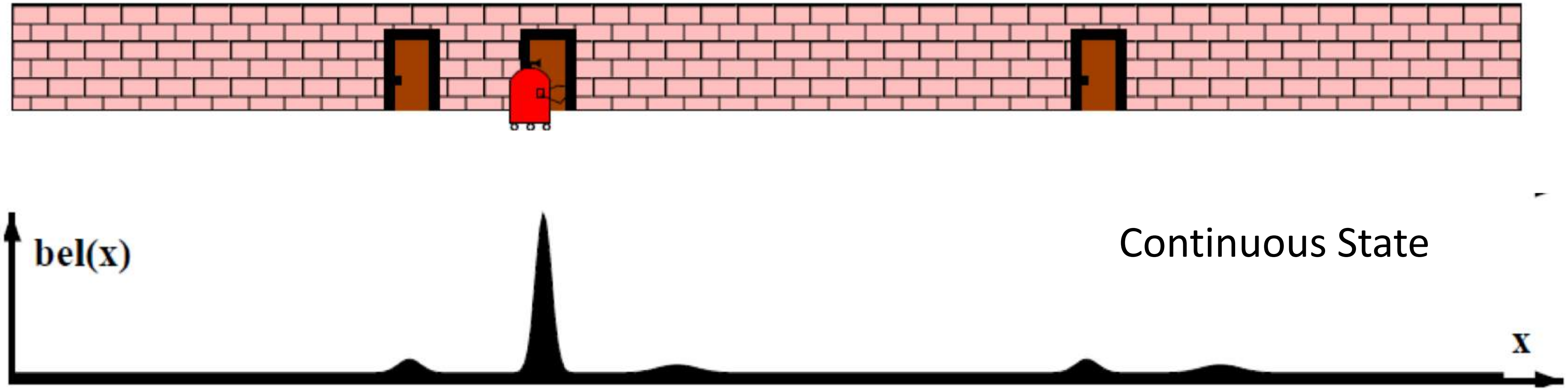
A Toy Example in 1 Dimension

At time t = 1



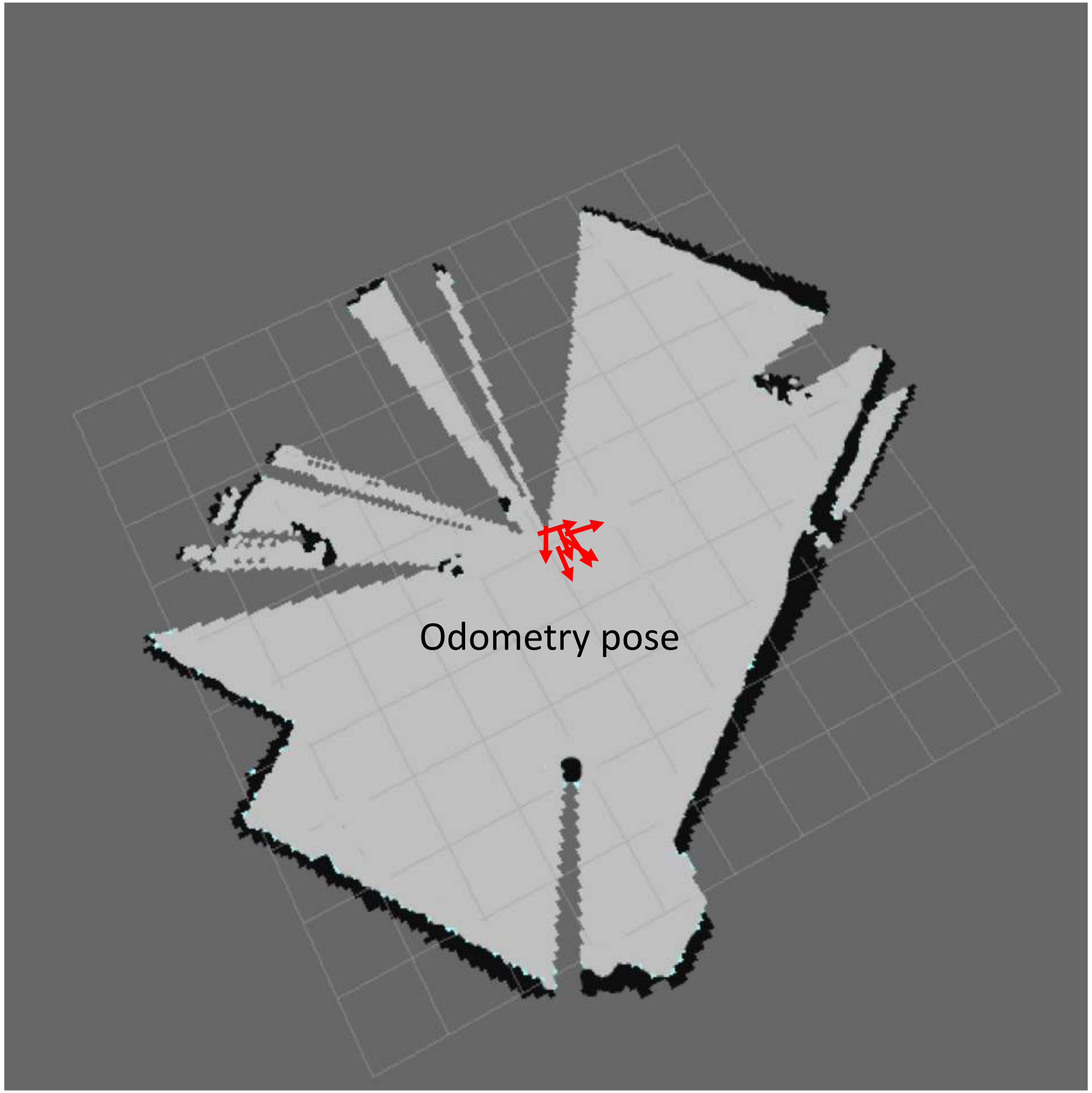
At time t = 2, robot moves forward a certain distance





Continuous State

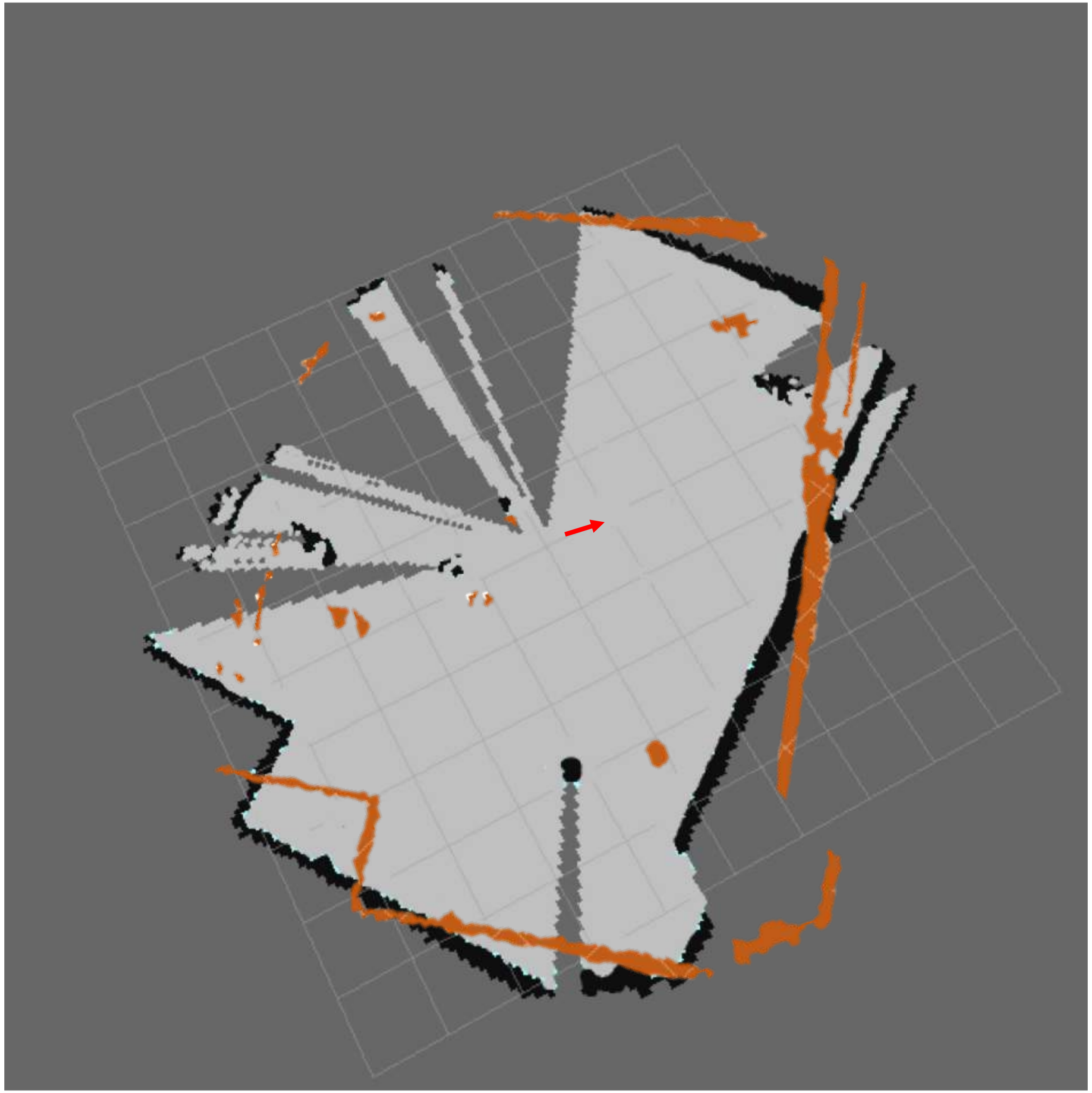
Particle Filter in 2D



Scan Correlation

$$W = \frac{\sum_m \sum_n (Amn - \overline{A})(Bmn - \overline{B})}{\sqrt{\left(\sum_m \sum_n \left(A_{mn} - \overline{A}\right)^2\right)\left(\sum_m \sum_n \left(B_{mn} - \overline{B}\right)^2\right)}}$$

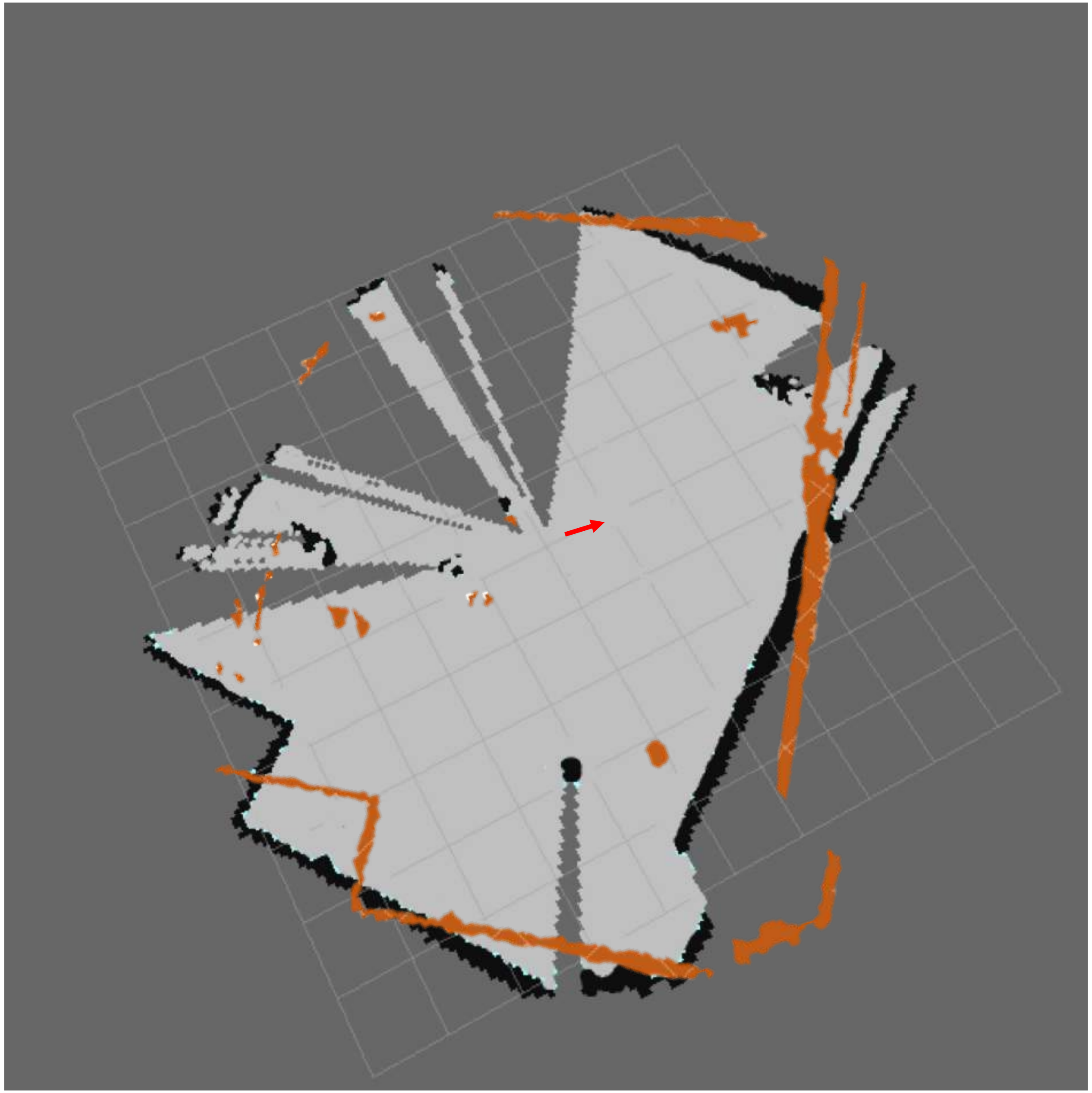
Particle Weight



Scan Correlation

$$W = \frac{\sum_m \sum_n (Amn - \overline{A})(Bmn - \overline{B})}{\sqrt{\left(\sum_m \sum_n \left(A_{mn} - \overline{A}\right)^2\right)\left(\sum_m \sum_n \left(B_{mn} - \overline{B}\right)^2\right)}}$$

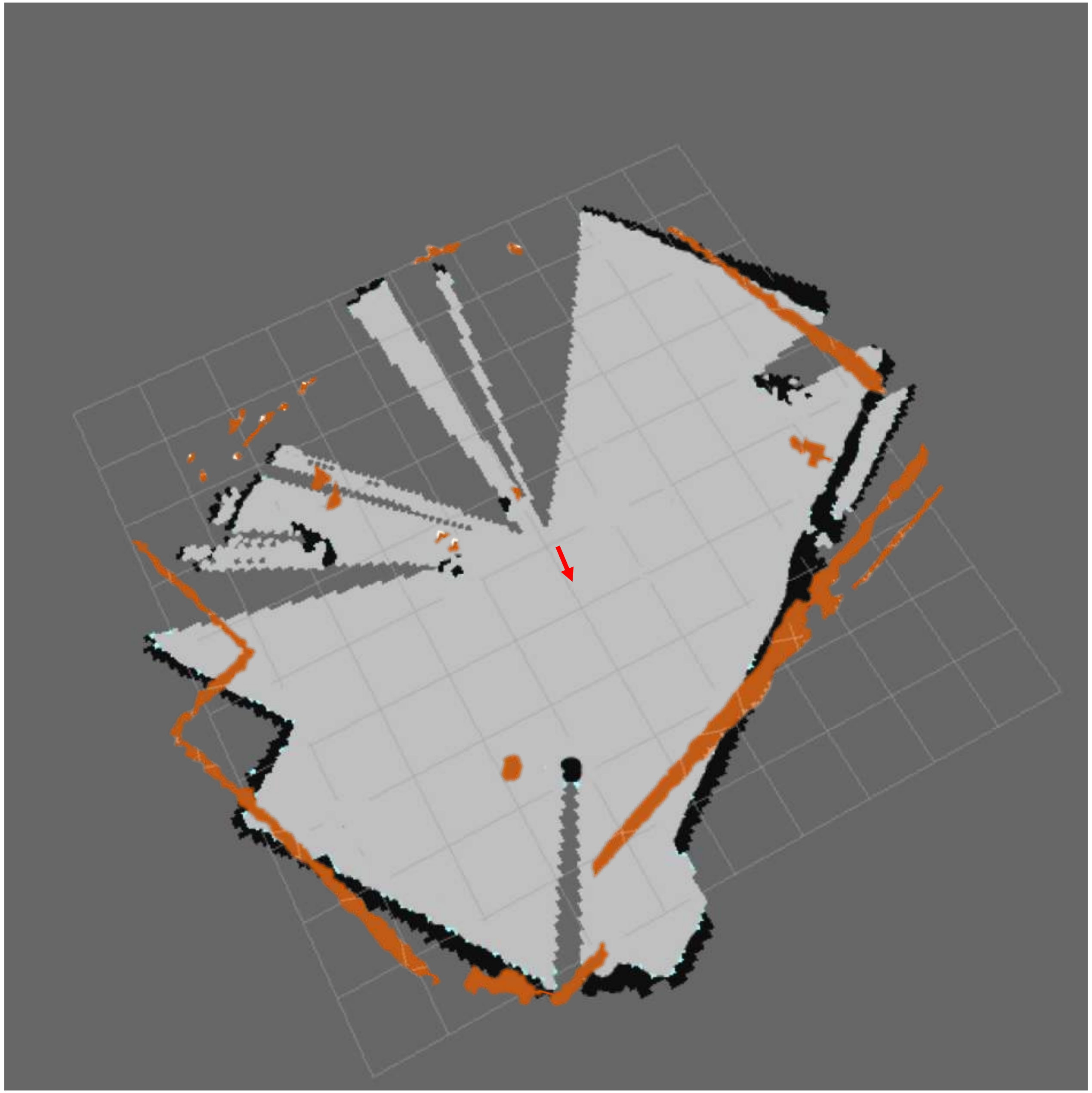
Particle	Weight
Particle 1	W_1



Scan Correlation

$$W = \frac{\sum_m \sum_n (Amn - \overline{A})(Bmn - \overline{B})}{\sqrt{\left(\sum_m \sum_n \left(A_{mn} - \overline{A}\right)^2\right)\left(\sum_m \sum_n \left(B_{mn} - \overline{B}\right)^2\right)}}$$

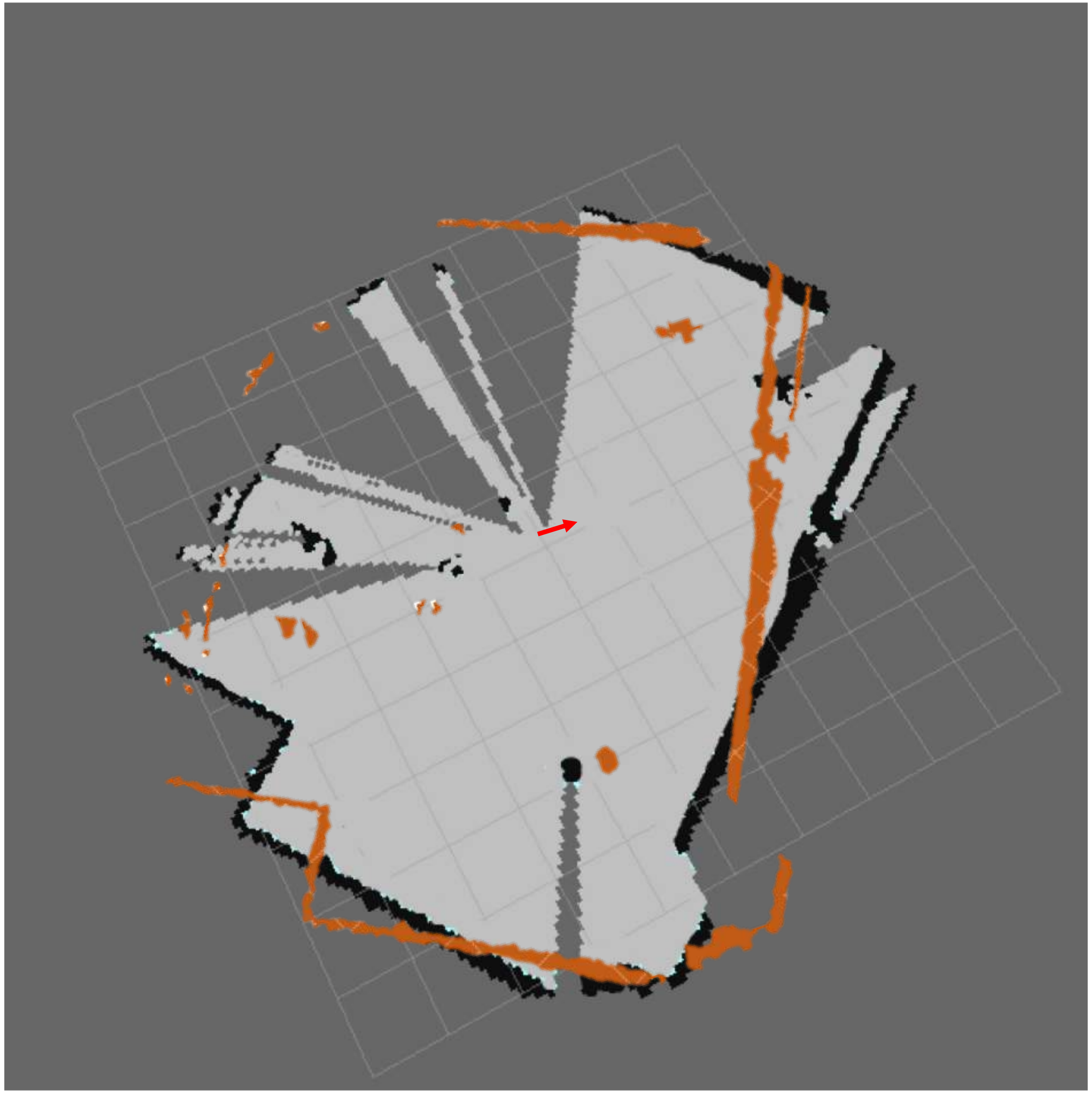
Particle	Weight
Particle 1	W_1
Particle 2	W_2



Scan Correlation

$$W = \frac{\sum_m \sum_n (Amn - \overline{A})(Bmn - \overline{B})}{\sqrt{\left(\sum_m \sum_n \left(A_{mn} - \overline{A}\right)^2\right)\left(\sum_m \sum_n \left(B_{mn} - \overline{B}\right)^2\right)}}$$

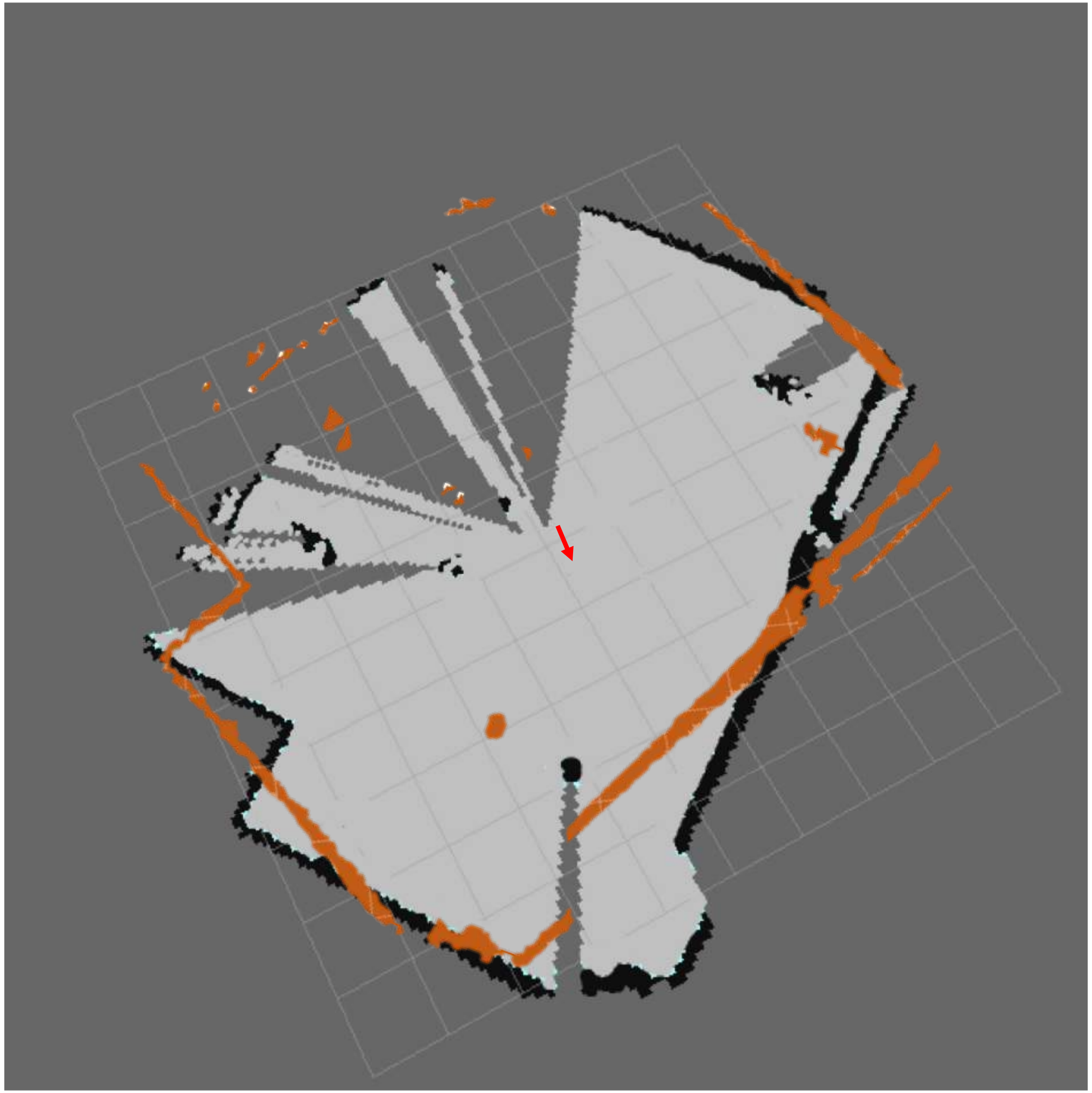
Particle	Weight
Particle 1	W_1
Particle 2	W_2
Particle 3	W_3



Scan Correlation

$$W = \frac{\sum_m \sum_n (Amn - \overline{A})(Bmn - \overline{B})}{\sqrt{\left(\sum_m \sum_n (A_{mn} - \overline{A})^2\right)\left(\sum_m \sum_n (B_{mn} - \overline{B})^2\right)}}$$

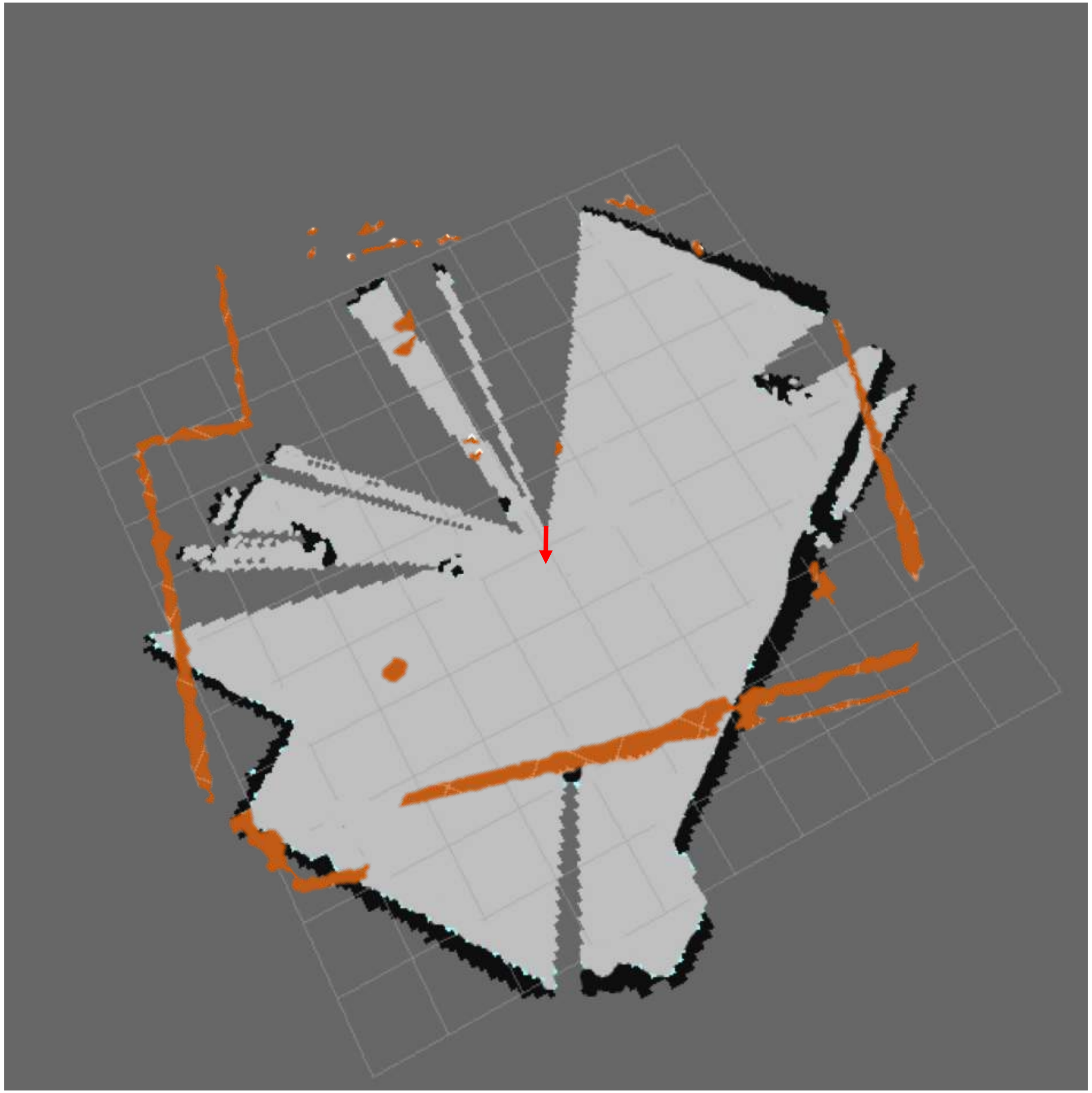
Particle	Weight
Particle 1	W_1
Particle 2	W_2
Particle 3	W_3
Particle 4	W_4



Scan Correlation

$$W = \frac{\sum_m \sum_n (Amn - \overline{A})(Bmn - \overline{B})}{\sqrt{\left(\sum_m \sum_n (A_{mn} - \overline{A})^2\right)\left(\sum_m \sum_n (B_{mn} - \overline{B})^2\right)}}$$

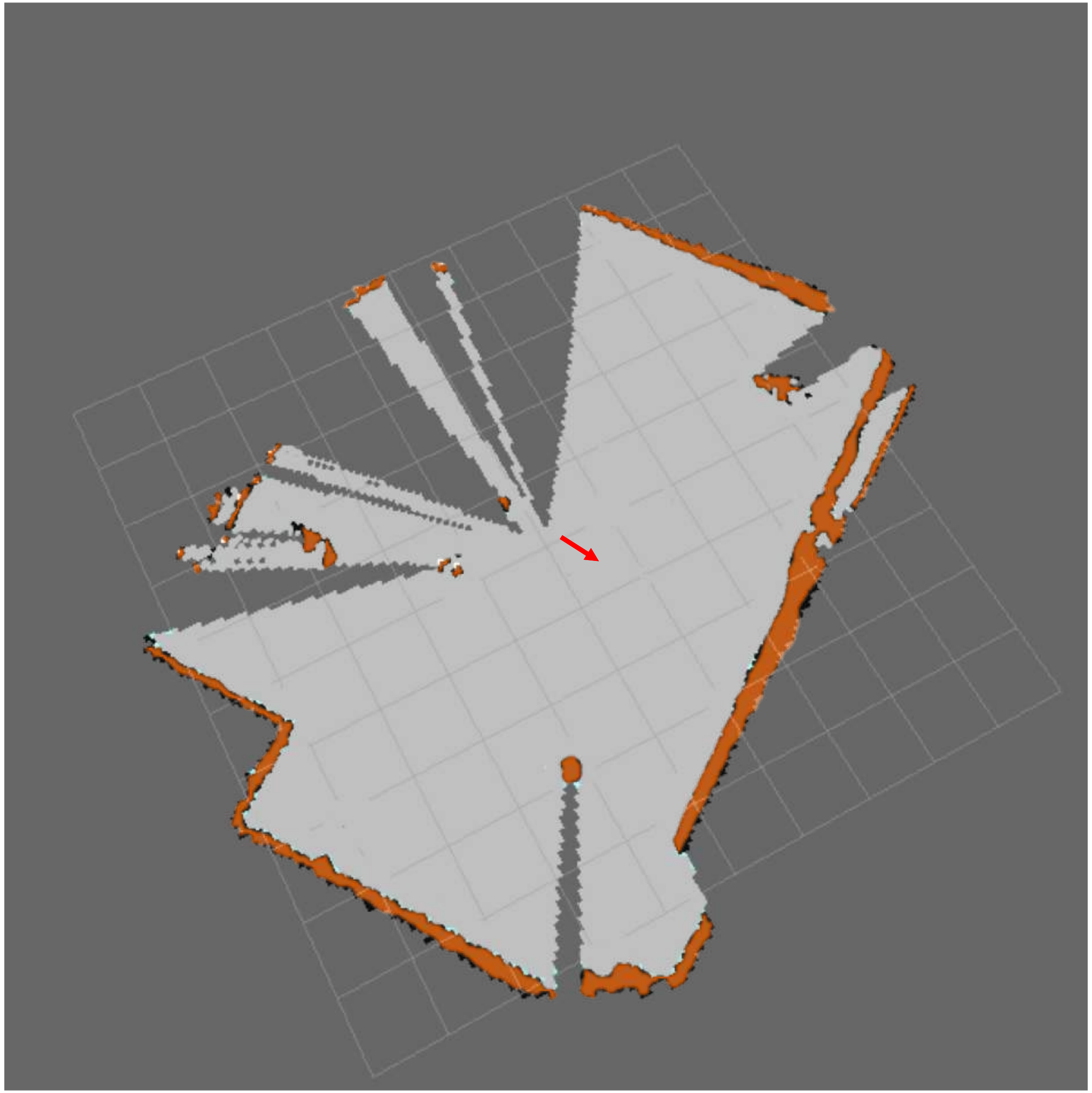
Particle	Weight
Particle 1	W_1
Particle 2	W_2
Particle 3	W_3
Particle 4	W_4
Particle 5	W_5



Scan Correlation

$$W = \frac{\sum_m \sum_n (Amn - \overline{A})(Bmn - \overline{B})}{\sqrt{\left(\sum_m \sum_n \left(A_{mn} - \overline{A}\right)^2\right)\left(\sum_m \sum_n \left(B_{mn} - \overline{B}\right)^2\right)}}$$

Particle	Weight
Particle 1	W_1
Particle 2	W_2
Particle 3	W_3
Particle 4	W_4
Particle 5	W_5
Particle 6	W_6

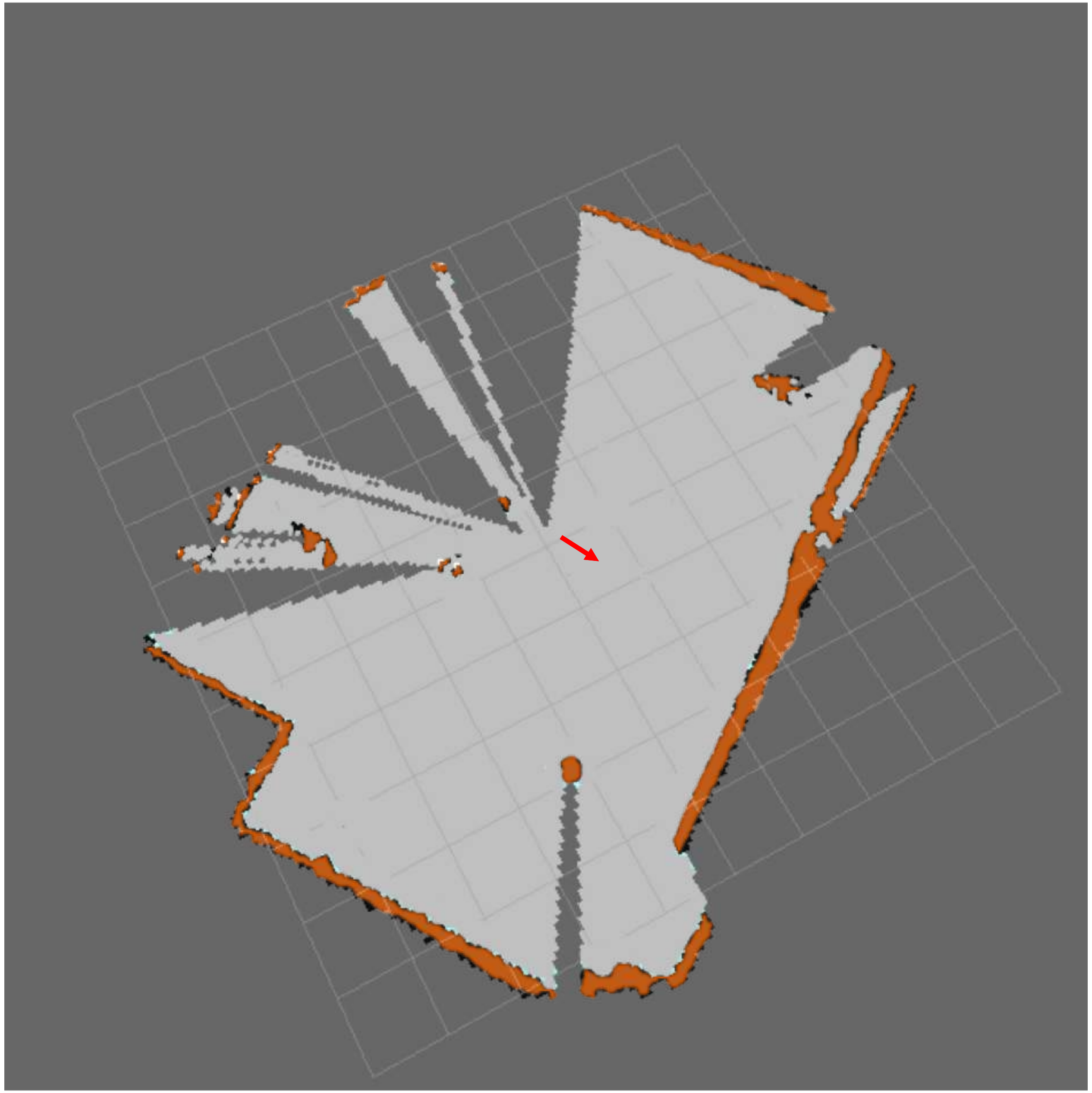


Scan Correlation

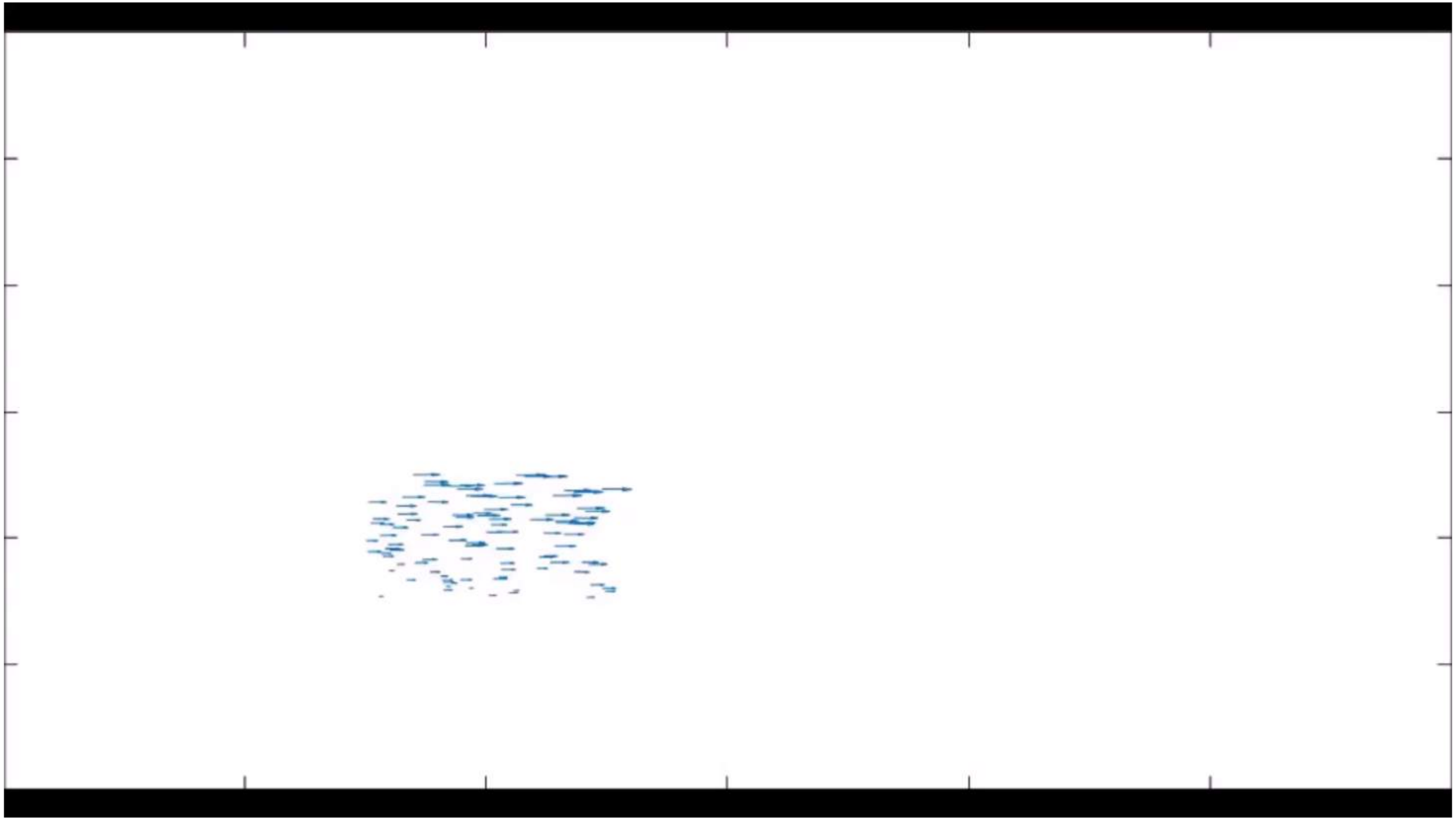
$$W = \frac{\sum_m \sum_n (Amn - \overline{A})(Bmn - \overline{B})}{\sqrt{\left(\sum_m \sum_n \left(A_{mn} - \overline{A}\right)^2\right)\left(\sum_m \sum_n \left(B_{mn} - \overline{B}\right)^2\right)}}$$

Particle	Weight
Particle 1	W_1
Particle 2	W_2
Particle 3	W_3
Particle 4	W_4
Particle 5	W_5
Particle 6	W_6

$$W_t \leftarrow W_{t\,-\,1_\times} Wt$$



Particles



Particle Filters in ROS

- Adaptive Monte Carlo Localization Package
- Localization for a robot moving in a 2D space
- Localizes against a pre-existing map

AMCL Parameters

`min_particles`

Default: 100

The minimum number of particles to be used for calculating correlation

`max_particles`

Default: 500

The maximum number of particles to be used for calculating correlation

AMCL Parameters

`update_min_d`

Default: 0.2m

The minimum translation movement required by the vehicle before an pose update is published

`update_min_a`

Default: $\pi/_6$ radians

The minimum angular movement required by the vehicle before an pose update is published

AMCL Parameters

`initial_pose_x` Default: 0

`initial_pose_y` Default: 0

`initial_pose_a` Default: 0

The initial mean position of the particles to initialize the particle filter

AMCL Parameters

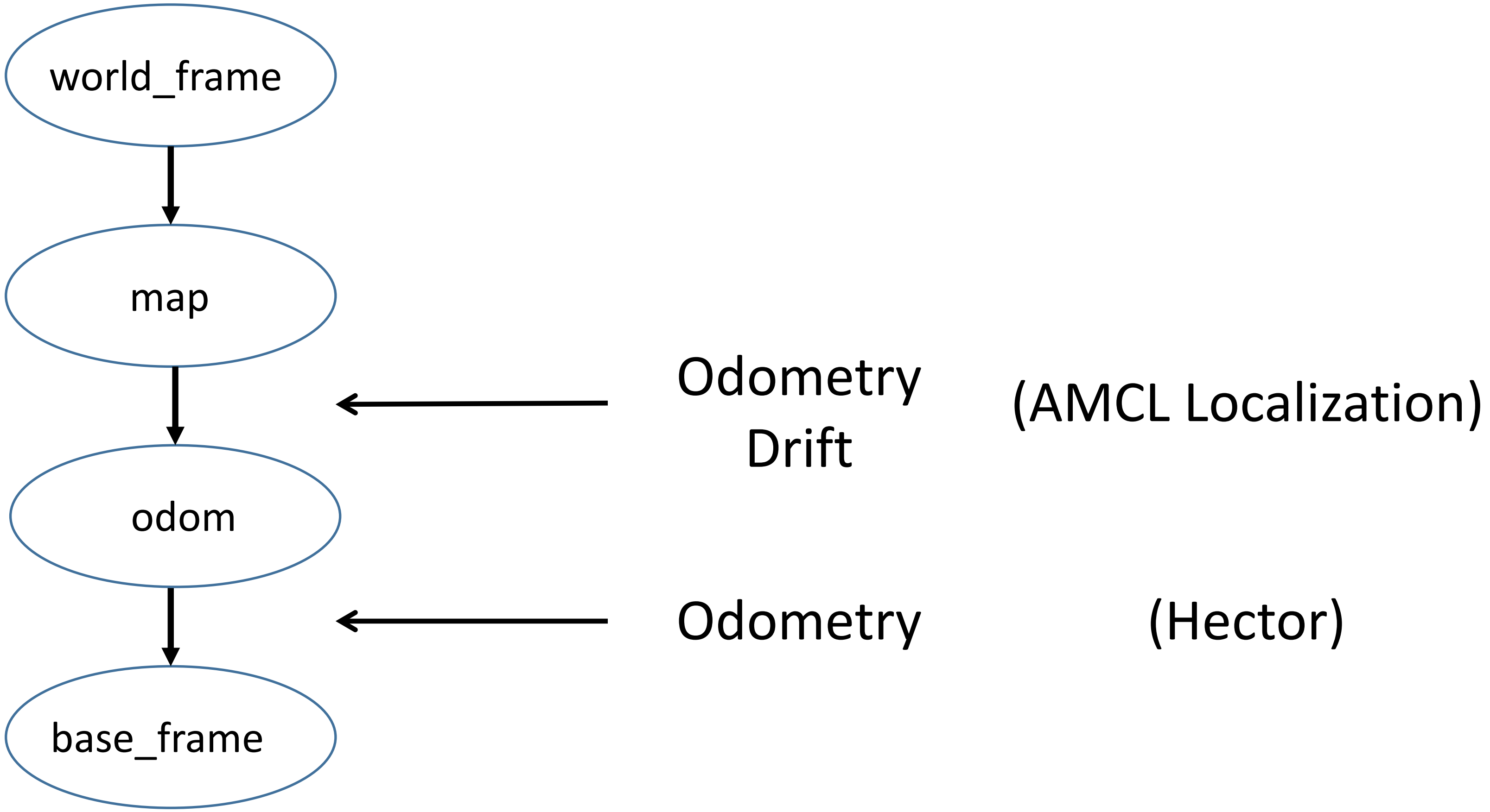
`initial_cov_xx` Default: 0

`initial_cov_yy` Default: 0

`initial_cov_aa` Default: 0

The covariance of particles distributed around the mean

Tf tree – Where does AMCL fit in



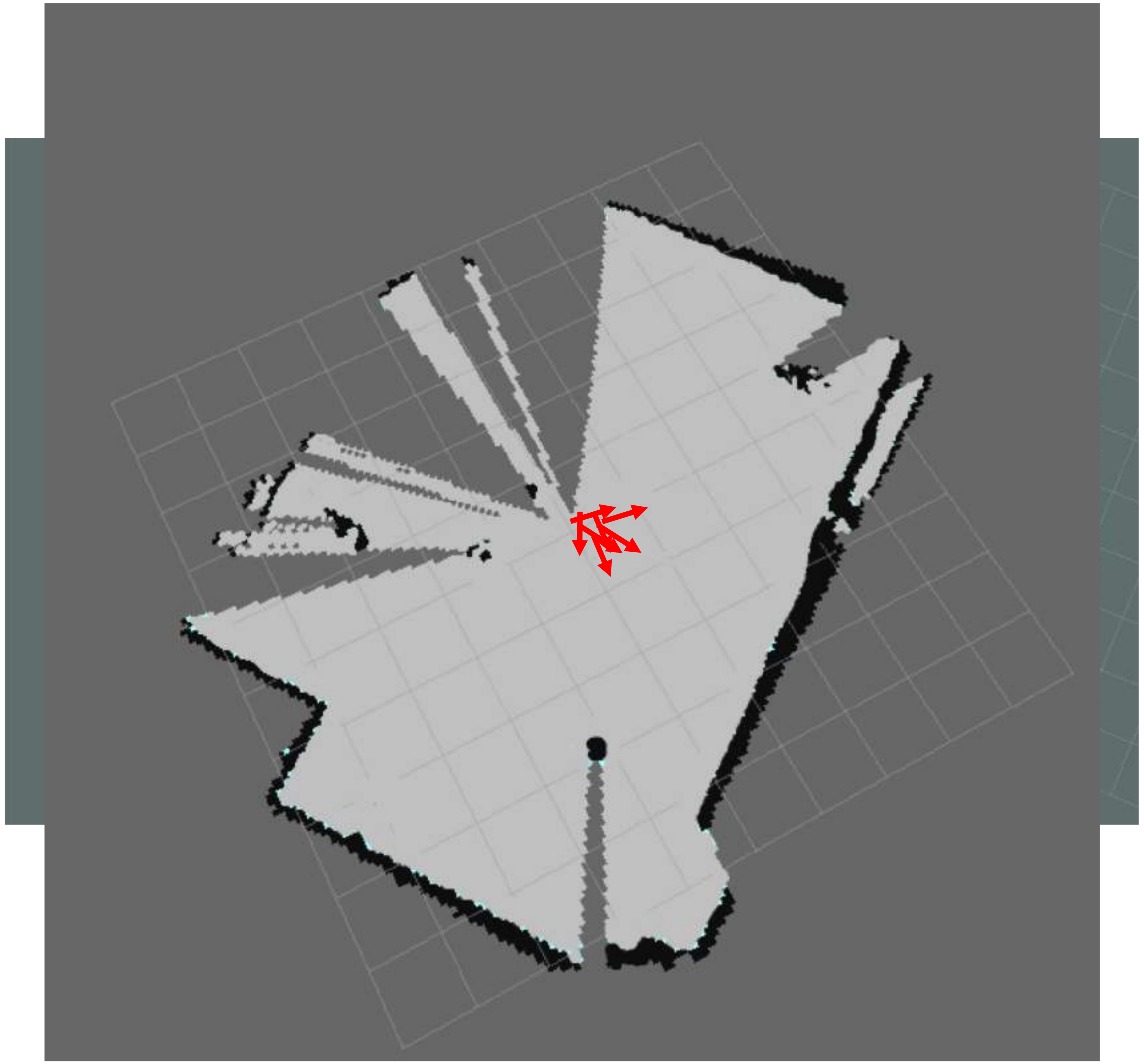
Input and Output Parameters

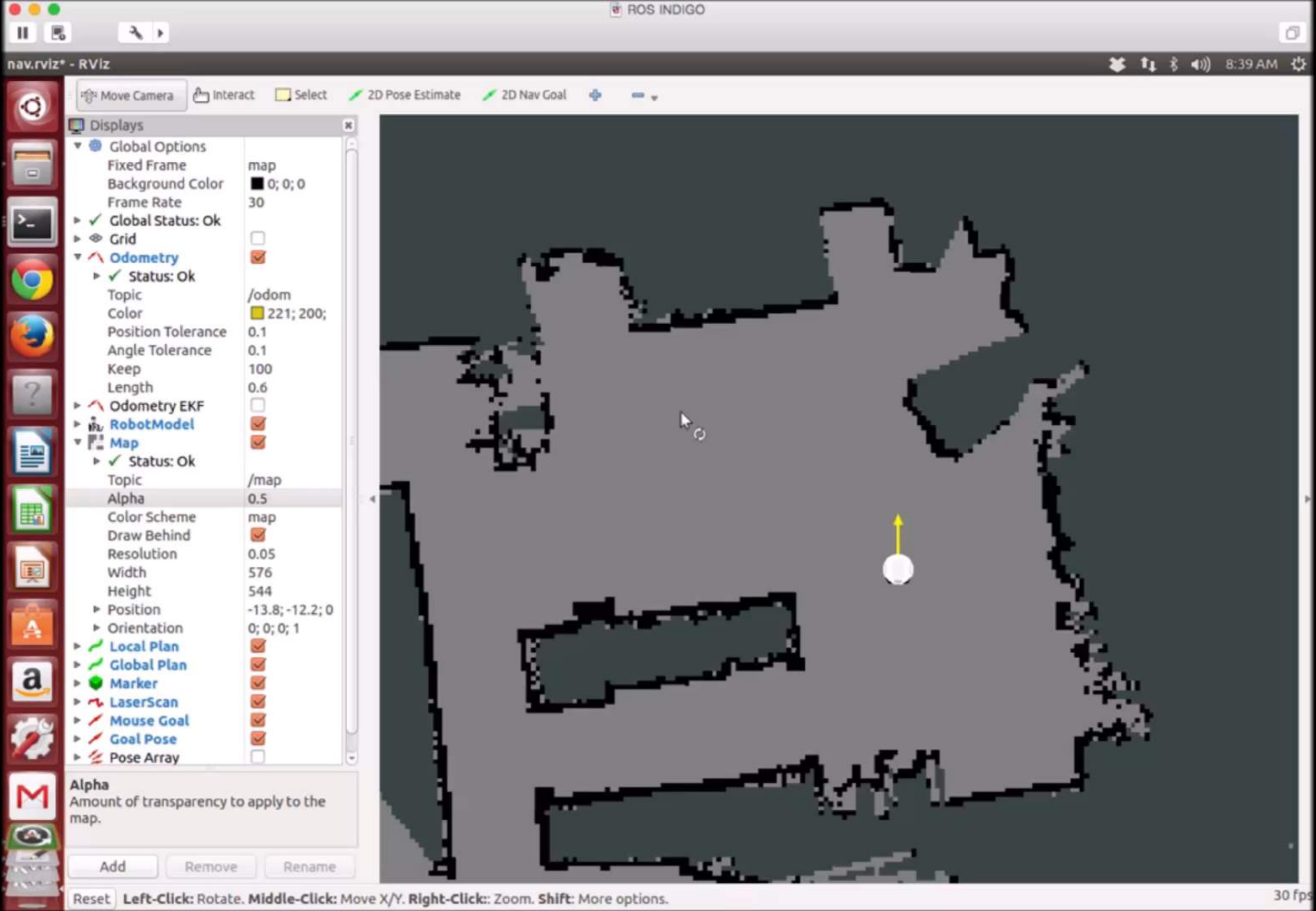
Input Parameters:

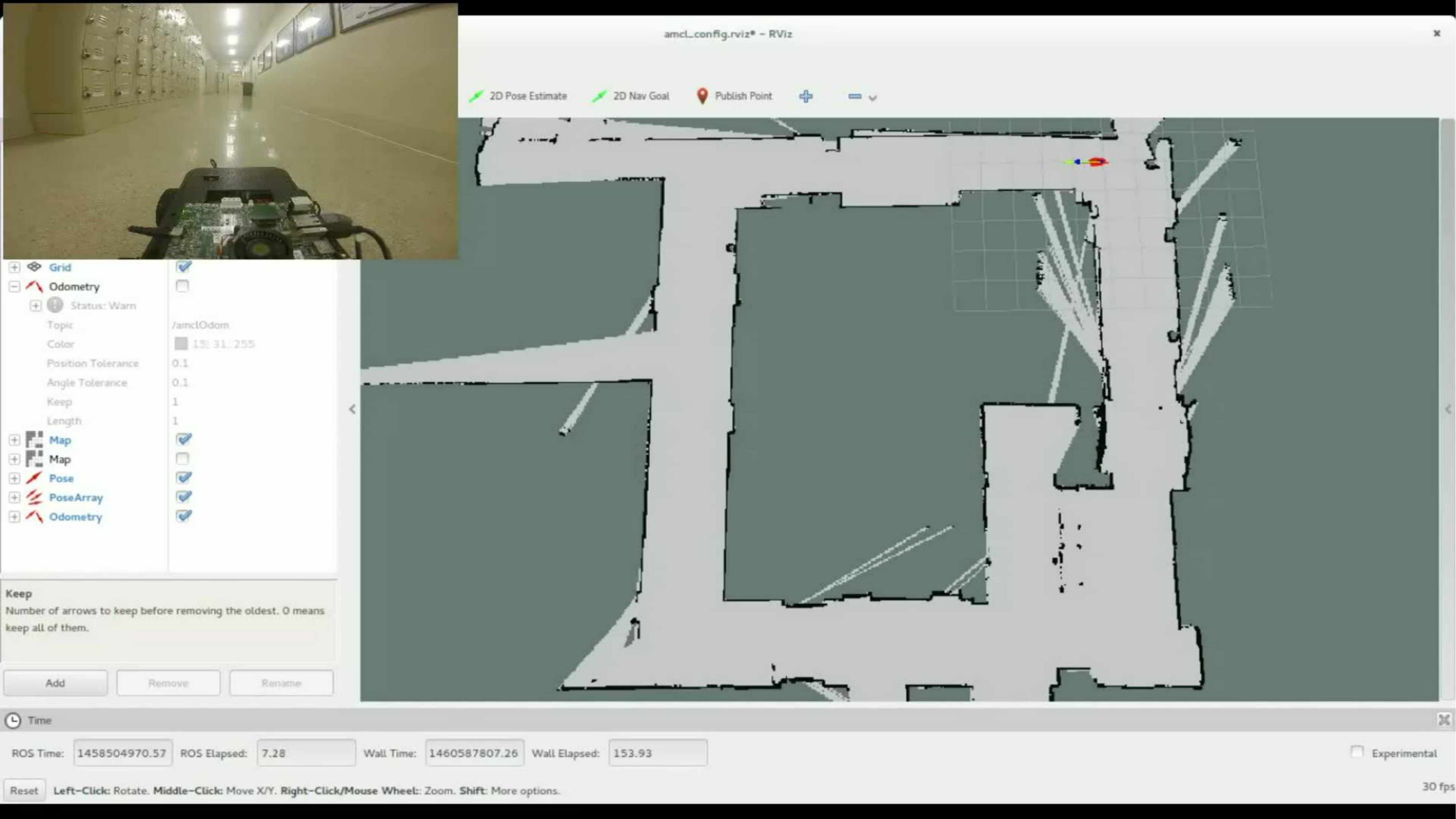
1. Laser Scan
2. Dead Reckoning/Odometry
3. Map

Output Parameters:

1. AMCL pose
2. Particle Cloud




ROS INDIGO
nav.rviz* - RViz
8:39 AM
Move Camera
Interact
Select
2D Pose Estimate
2D Nav Goal
Displays
Global Options
Fixed Frame
map
Background Color
0; 0; 0
Frame Rate
30
Global Status: Ok
Grid
Odometry
Status: Ok
Topic
/odom
Color
221; 200;
Position Tolerance
0.1
Angle Tolerance
0.1
Keep
100
Length
0.6
Odometry EKF
RobotModel
Map
Status: Ok
Topic
/map
Alpha
0.5
Color Scheme
map
Draw Behind
Resolution
0.05
Width
576
Height
544
Position
-13.8; -12.2; 0
Orientation
0; 0; 0; 1
Local Plan
Global Plan
Marker
LaserScan
Mouse Goal
Goal Pose
Pose Array
Alpha
Amount of transparency to apply to the map.
Add
Remove
Rename
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click:: Zoom. Shift: More options.
30 fps


amcl_config.rviz* - RViz
2D Pose Estimate
2D Nav Goal
Publish Point
Grid
Odometry
Status: Warn
Topic
/amclOdom
Color
15; 31; 255
Position Tolerance
0.1
Angle Tolerance
0.1
Keep
1
Length
1
Map
Map
Pose
PoseArray
Odometry
Keep
Number of arrows to keep before removing the oldest. 0 means keep all of them.
Add
Remove
Rename
Time
ROS Time:
1458504970.57
ROS Elapsed:
7.28
Wall Time:
1460587807.26
Wall Elapsed:
153.93
Experimental
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel:: Zoom. Shift: More options.
30 fps