**ROS navigation stack**

**Costmaps**

**Localization**

**Sending goal commands (from rviz)**

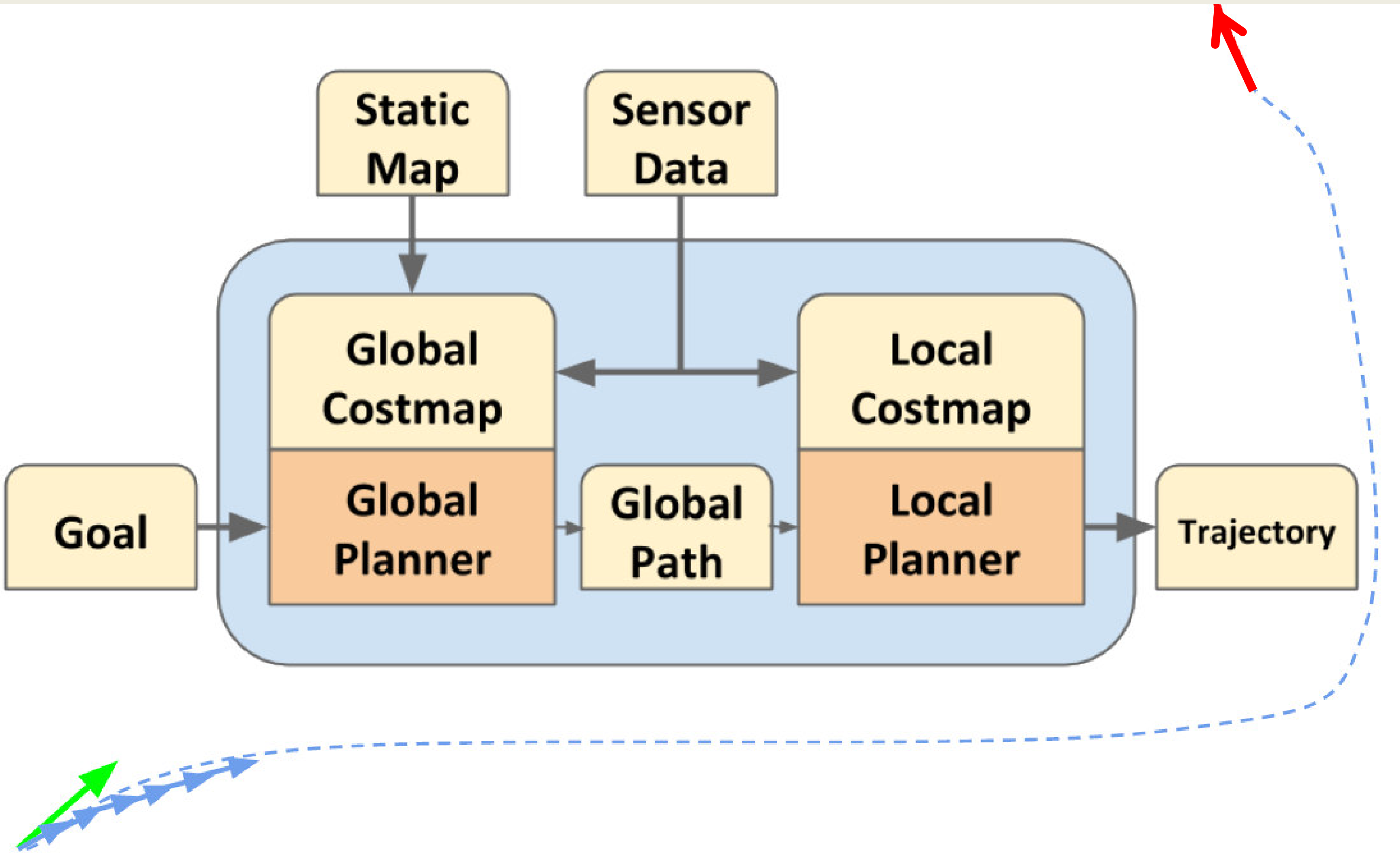
# Robot Navigation

- One of the most basic things that a robot can do is to move around the world.
- To do this effectively, the robot needs to know where it is and where it should be going
- This is usually achieved by giving the robot a **map** of the world, a **starting location**, and a **goal location**
- We'll look at how to make your robot autonomously navigate from one part of the world to another, using the map and the ROS navigation packages

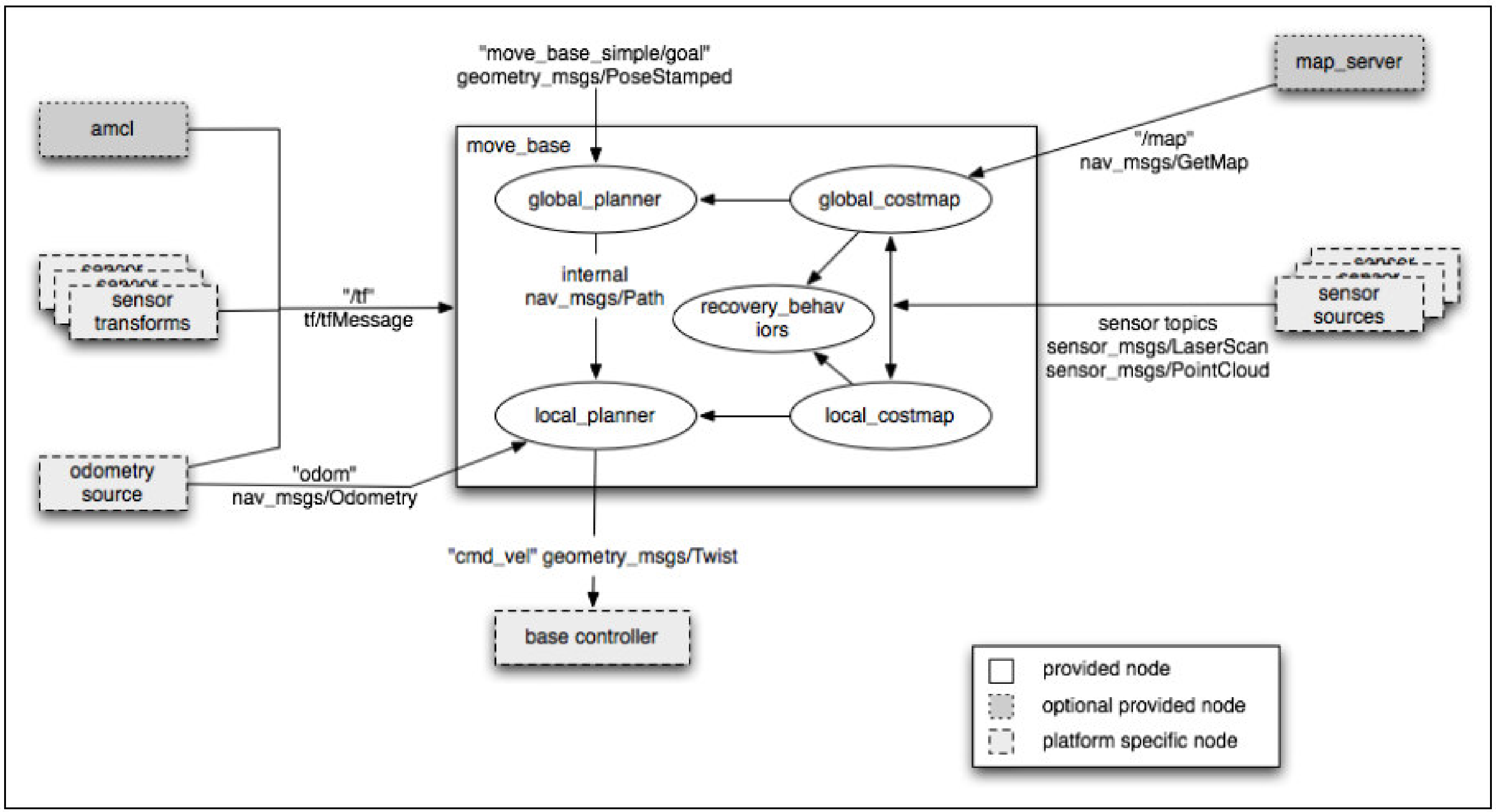
# ROS Navigation Stack

- [http://wiki.ros.org/navigation](http://wiki.ros.org/navigation)
- The goal of the navigation stack is to move a robot from one position to another position safely (without crashing or getting lost)
- It takes in information from the odometry and sensors, and a goal pose and outputs safe velocity commands that are sent to the robot
- ROS Navigation Introductory Video

# Overview of ROS Navigation



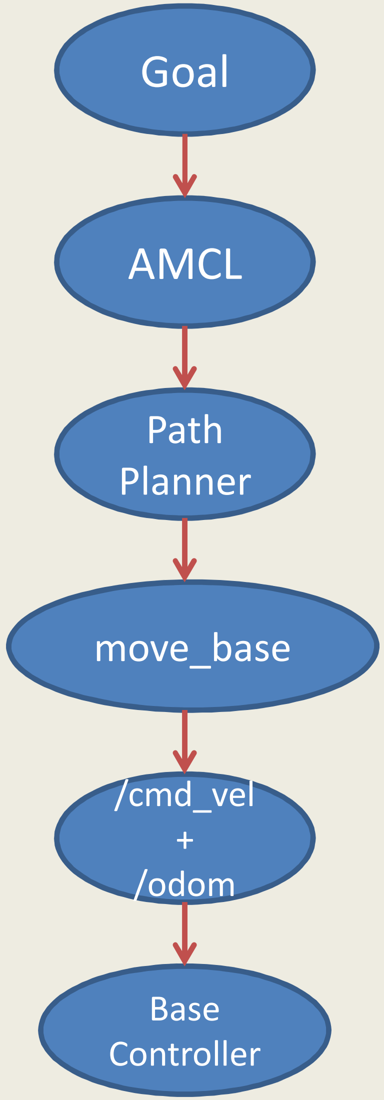
# ROS Navigation Stack



# Navigation Stack Main Components

| Package/Component | Description |
|---|---|
| map_server | offers map data as a ROS Service |
| gmapping | provides laser-based SLAM |
| amcl | a probabilistic localization system |
| global_planner | implementation of a fast global planner for navigation |
| local_planner | implementations of the Trajectory Rollout and Dynamic Window approaches to local robot navigation |
| move_base | links together the global and local planner to accomplish the navigation task |

# Navigation Main Steps



# Install Navigation Stack

- The navigation stack is not part of the standard ROS Indigo installation
- To install the navigation stack type:

```
$ sudo apt-get install ros-indigo-navigation
```

# Navigation Stack Requirements

<u>Three main hardware requirements</u>

- The navigation stack can only handle a **differential drive and holonomic wheeled robots**
  - It can also do certain things with biped robots, such as localization, as long as the robot does not move sideways
- A planar **laser** must be mounted on the mobile base of the robot to create the map and localization
  - Alternatively, you can generate something equivalent to laser scans from other sensors (**Kinect** for example)
- Its performance will be **best on robots that are nearly square or circular**

# Navigation Planners

- Our robot will move through the map using two types of navigation—global and local
- The **global planner** is used to create **paths for a goal** in the map or a far-off distance
- The **local planner** is used to create **paths in the nearby distances** and avoid obstacles

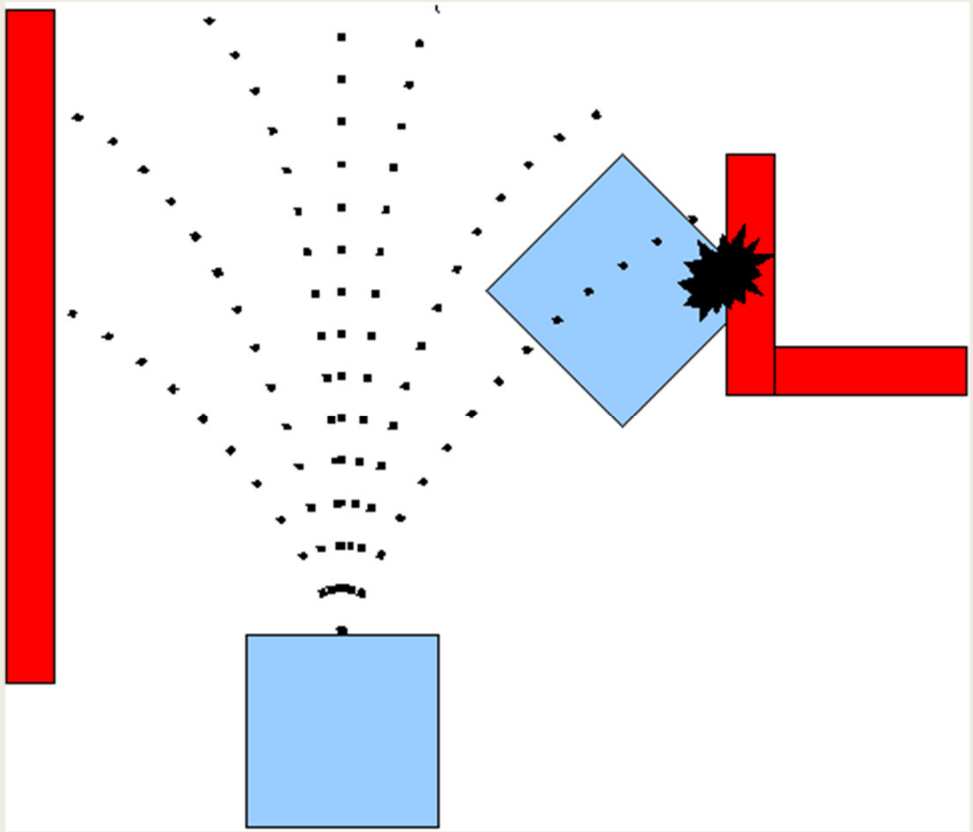
# Global Planner

- NavFn provides a fast interpolated navigation function that creates plans for a mobile base
- The **global plan** is computed **before the robot starts moving toward the next destination**
- The planner **operates on a costmap** to find a minimum cost plan from a start point to an end point in a grid, using **Dijkstra's algorithm**
- The global planner **generates a series of waypoints** for the local planner to follow

# Local Planner

- **Chooses appropriate velocity commands** for the robot to traverse **the current segment of the global path**
- Combines sensory and odometry data with both global and local cost maps
- **Can recompute the robot's path on the fly** to keep the robot from striking objects yet still allowing it to reach its destination
- Implements the **Trajectory Rollout and Dynamic Window** algorithm

# Trajectory Rollout Algorithm



Taken from ROS Wiki http://wiki.ros.org/base_local_planner

# Trajectory Rollout Algorithm

1. Discretely **sample in the robot's control space (dx,dy,dθ)**
2. For each sampled velocity, perform forward simulation from the robot's current state to **predict what would happen if the sampled velocity were applied for some (short) period of time**
3. **Evaluate each trajectory** resulting from the forward simulation, **using a metric** that incorporates characteristics such as: proximity to obstacles, proximity to the goal, proximity to the global path, and speed
4. **Discard illegal trajectories** (those that collide with obstacles)
5. **Pick the highest-scoring trajectory** and send the associated velocity to the mobile base
6. Rinse and repeat

# Local Planner Parameters

- The file **base_local_planner.yaml** contains a large number of ROS Parameters that can be set to customize the behavior of the base local planner
- Grouped into several categories:
  - robot configuration
  - **goal tolerance**
  - forward simulation
  - trajectory scoring
  - oscillation prevention
  - global plan

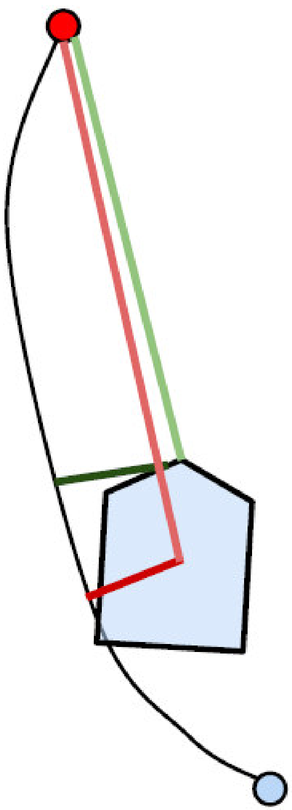
# Map Grid

- In order **to score trajectories efficiently**, a Map Grid is used.
- For each control cycle, a grid is created around the robot (the size of the local costmap), and the global path is mapped onto this area.
- This means **certain of the grid cells will be marked with distance 0 to a path point, and distance 0 to the goal.**
- A propagation algorithm then efficiently **marks all other cells with their Manhattan distance to the closest of the points marked with zero.**

# Oscillation Suppression

- Oscillation occur when in either of the x, y, or theta dimensions, positive and negative values are chosen consecutively.
- To prevent oscillations, when the robot moves in any direction, for the next cycles the opposite direction is marked invalid, until the robot has moved beyond a certain distance from the position where the flag was set.

# Scoring Trajectories



Weighted Sum =

oscillation_cost

+ costmap_cost

+ goal_distance_cost

+ path_distance_cost

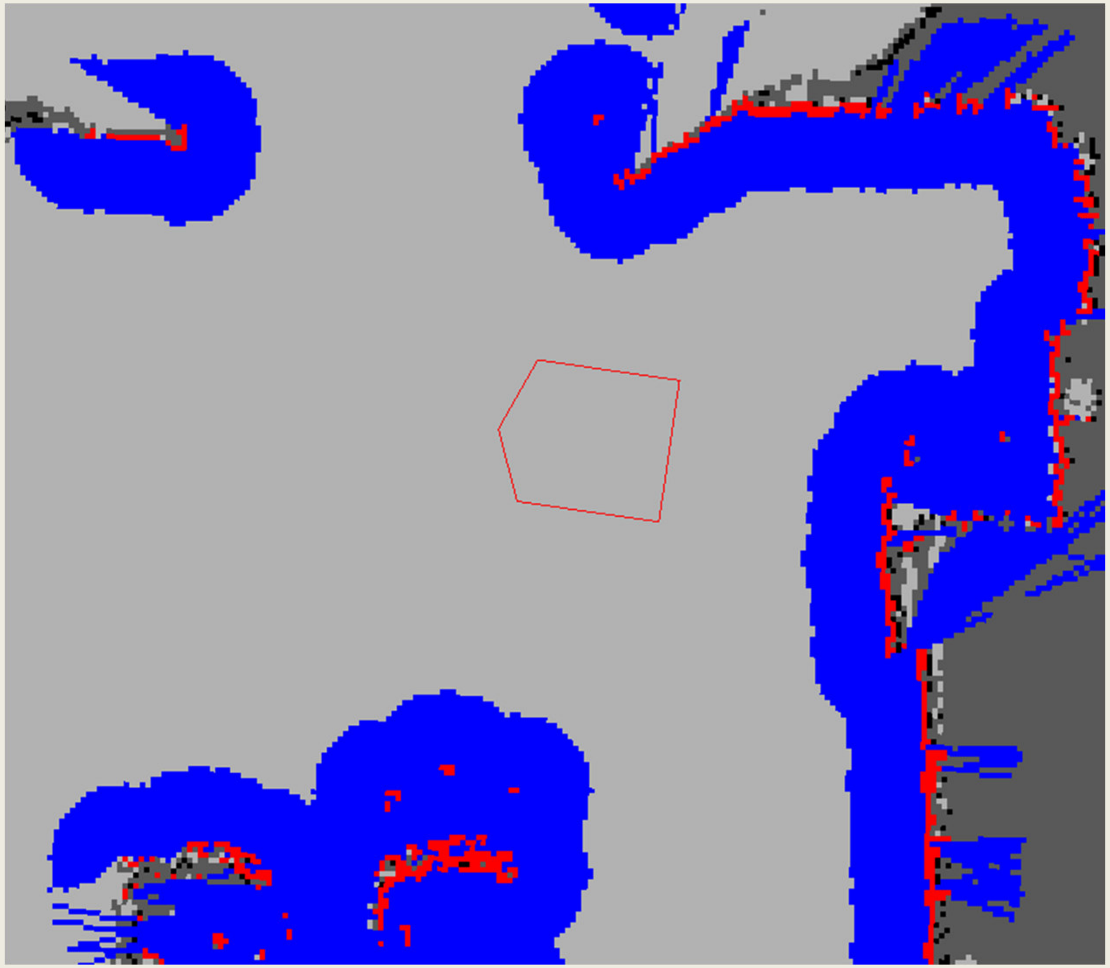
+ goal_alignment_cost

+ path_alignment_cost

# Costmap

- A data structure that **represents places that are safe** for the robot to be in a grid of cells
- It is **based on the occupancy grid map** of the environment and **user specified inflation radius**
- There are two types of costmaps in ROS:
  - **Global costmap** is used for global navigation
  - **Local costmap** is used for local navigation
- **Each cell in the costmap has an integer value in the range [0 (FREE_SPACE), 255 (UNKNOWN)]**
- Managed by the [costmap_2d](costmap_2d) package

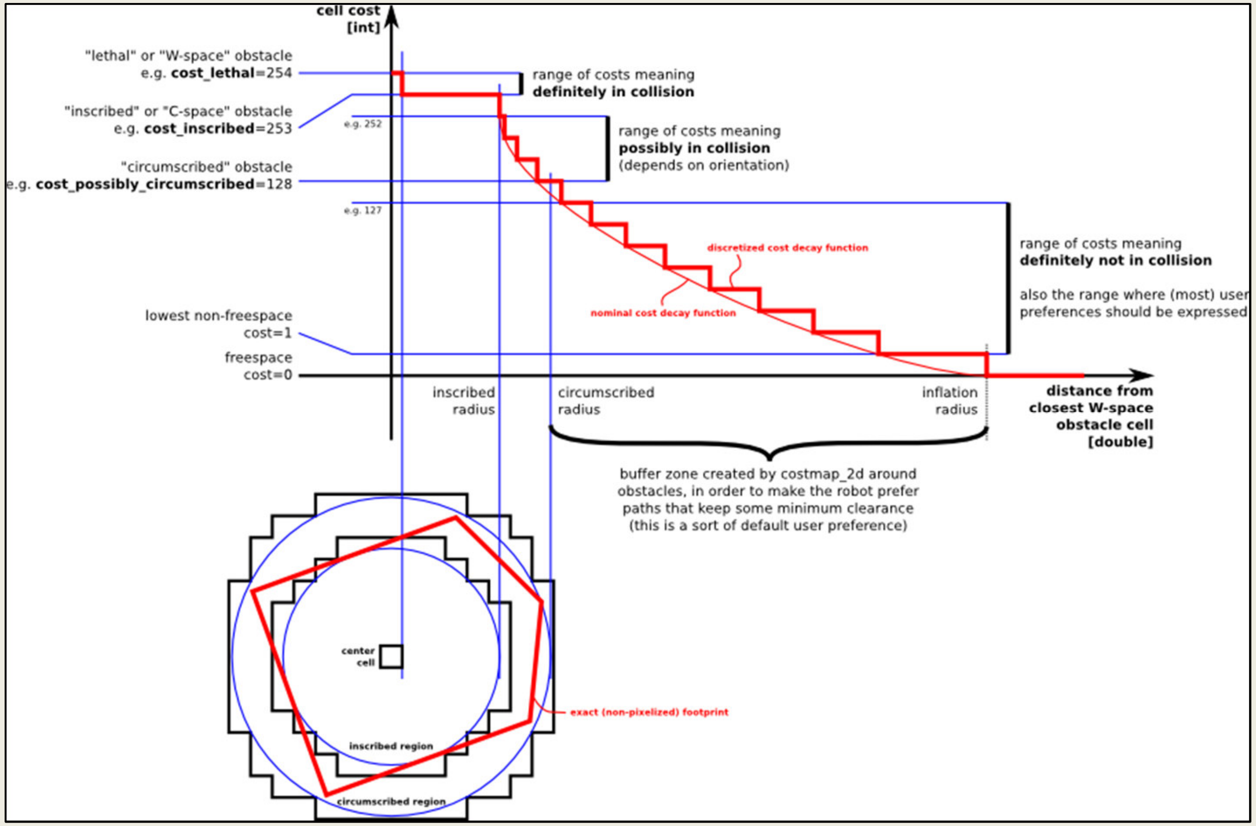
# Costmap Example



Taken from ROS Wiki http://wiki.ros.org/costmap_2d

# Inflation

- Inflation is the process of propagating cost values out from occupied cells that decrease with distance



# Map Updates

- The **costmap performs map update cycles** at the rate specified by the **update_frequency** parameter
- In each cycle:
  - **sensor data comes in**
  - **marking and clearing operations are perfomed** in the underlying occupancy structure of the costmap
  - this **structure is projected into the costmap** where the appropriate cost values are assigned as described above
  - **obstacle inflation is performed** on each cell with a LETHAL_OBSTACLE value
    - This consists of propagating cost values outwards from each occupied cell out to a user-specified inflation radius

# Costmap Parameters Files

- Configuration of the costmaps consists of three files:
  - costmap_common_params.yaml
  - global_costmap_params.yaml
  - local_costmap_params.yaml
- http://wiki.ros.org/costmap_2d/hydro/obstacles

- [Navigasyon Video]

# Localization

- Localization is the problem of estimating the pose of the robot relative to a map
- Localization is not terribly sensitive to the exact placement of objects so it can handle small changes to the locations of objects
- ROS uses the **amcl** package for localization

# AMCL

- amcl is a probabilistic localization system for a robot moving in 2D
- It implements the adaptive **Monte Carlo localization** approach, which uses a particle filter to track the pose of a robot against a known map
- The algorithm and its parameters are described in the book **Probabilistic Robotics** by Thrun, Burgard, and Fox (http://www.probabilistic-robotics.org/)
- Currently amcl works only with laser scans
  - However, it can be extended to work with other sensors

# AMCL

- amcl takes in a laser-based map, laser scans, and transform messages, and outputs pose estimates
- Subscribed topics:
  - scan – Laser scans
  - tf – Transforms
  - initialpose – Mean and covariance with which to (re-) initialize the particle filter
  - map – the map used for laser-based localization
- Published topics:
  - amcl_pose – Robot's estimated pose in the map, with covariance.
  - Particlecloud – The set of pose estimates being maintained by the filter

# move_base

- The move_base package lets you **move a robot to desired positions** using the navigation stack
- The move_base node **links together a global and local planner** to accomplish its navigation task
- It may **optionally perform recovery behaviors** when the robot perceives itself as stuck

# P3AT Navigation

- Navigation package includes demos of map building using gmapping and localization with amcl, while running the navigation stack
- In **nav_params** subdirectory it contains configuration files for P3AT navigation
- Sizin uygulamanızda **nav_params** klasöründeki parametreler değiştirilerek testler yapılacak.

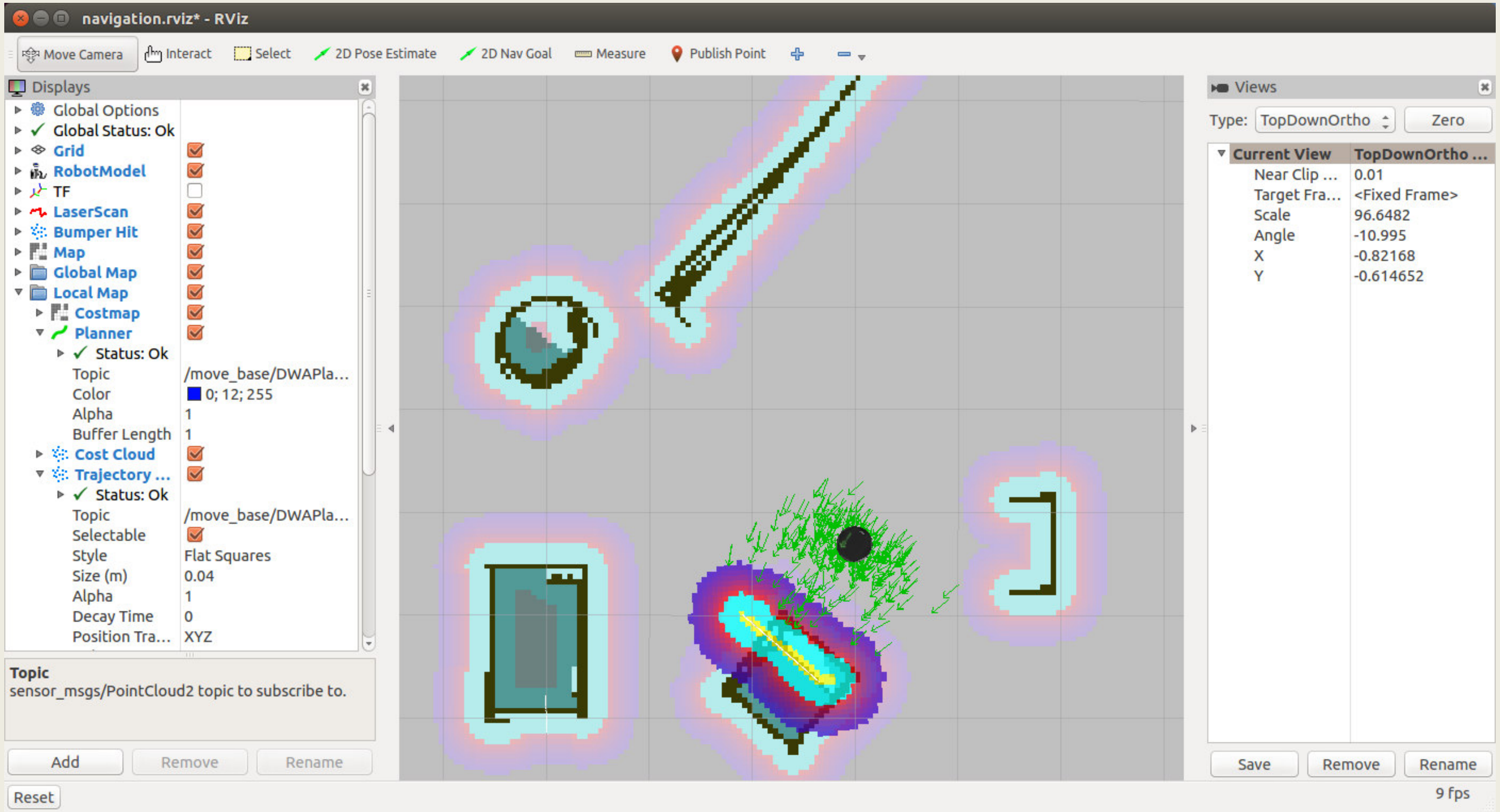
# Navigation Configuration Files

| Configuration File | Description |
|---|---|
| global_planner_params.yaml | global planner configuration |
| navfn_global_planner_params.yaml | navfn configuration |
| dwa_local_planner_params.yaml | local planner configuration |
| costmap_common_params.yaml<br>global_costmap_params.yaml<br>local_costmap_params.yaml | costmap configuration files |
| move_base_params.yaml | move base configuration |
| amcl.launch.xml | amcl configuration |

# rviz with Navigation Stack

- rviz allows you to:
  - Provide an approximate location of the robot (when starting up, the robot doesn't know where it is)
  - Send goals to the navigation stack
  - Display all the visualization information relevant to the navigation (planned path, costmap, etc.)

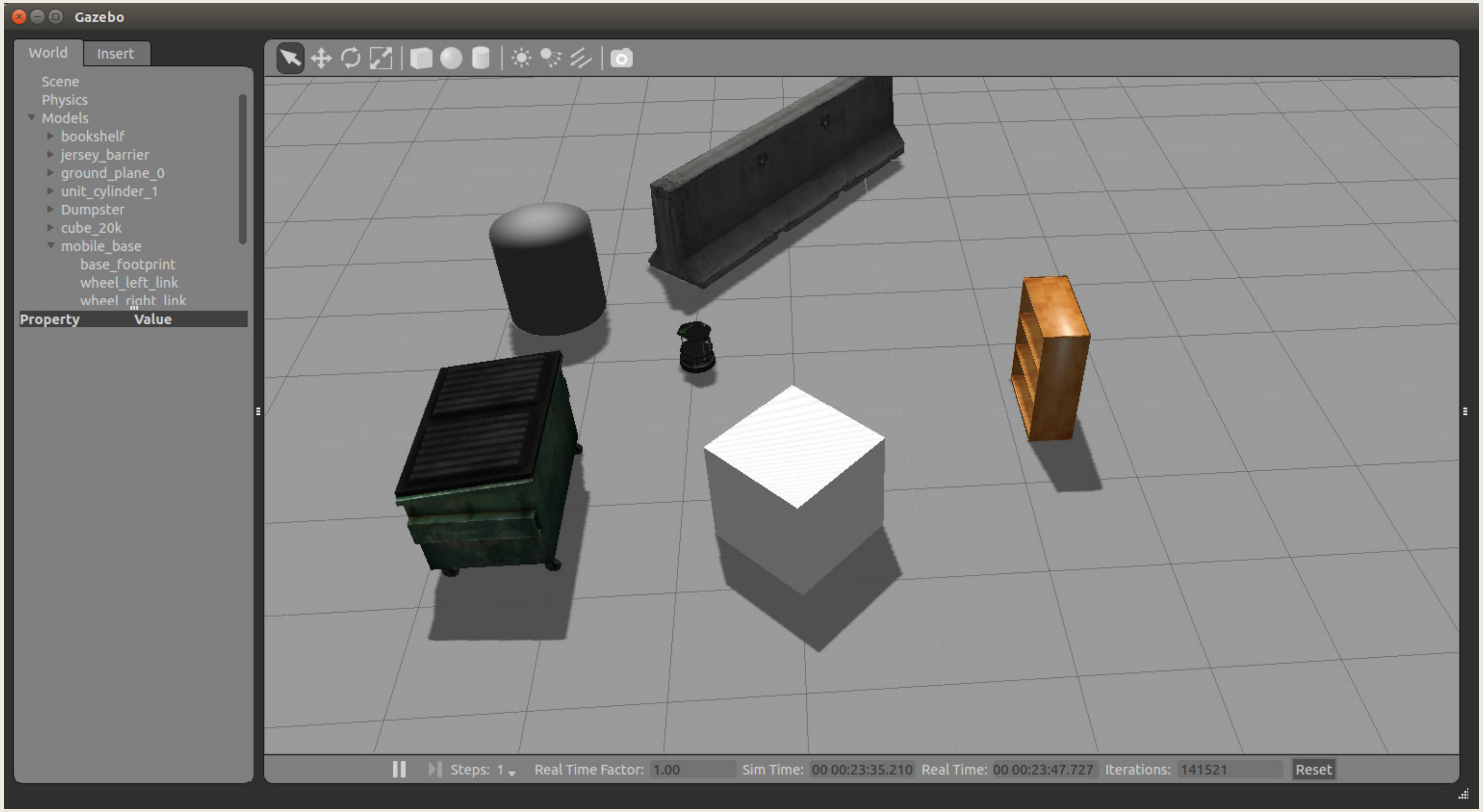
# rviz with Navigation Stack



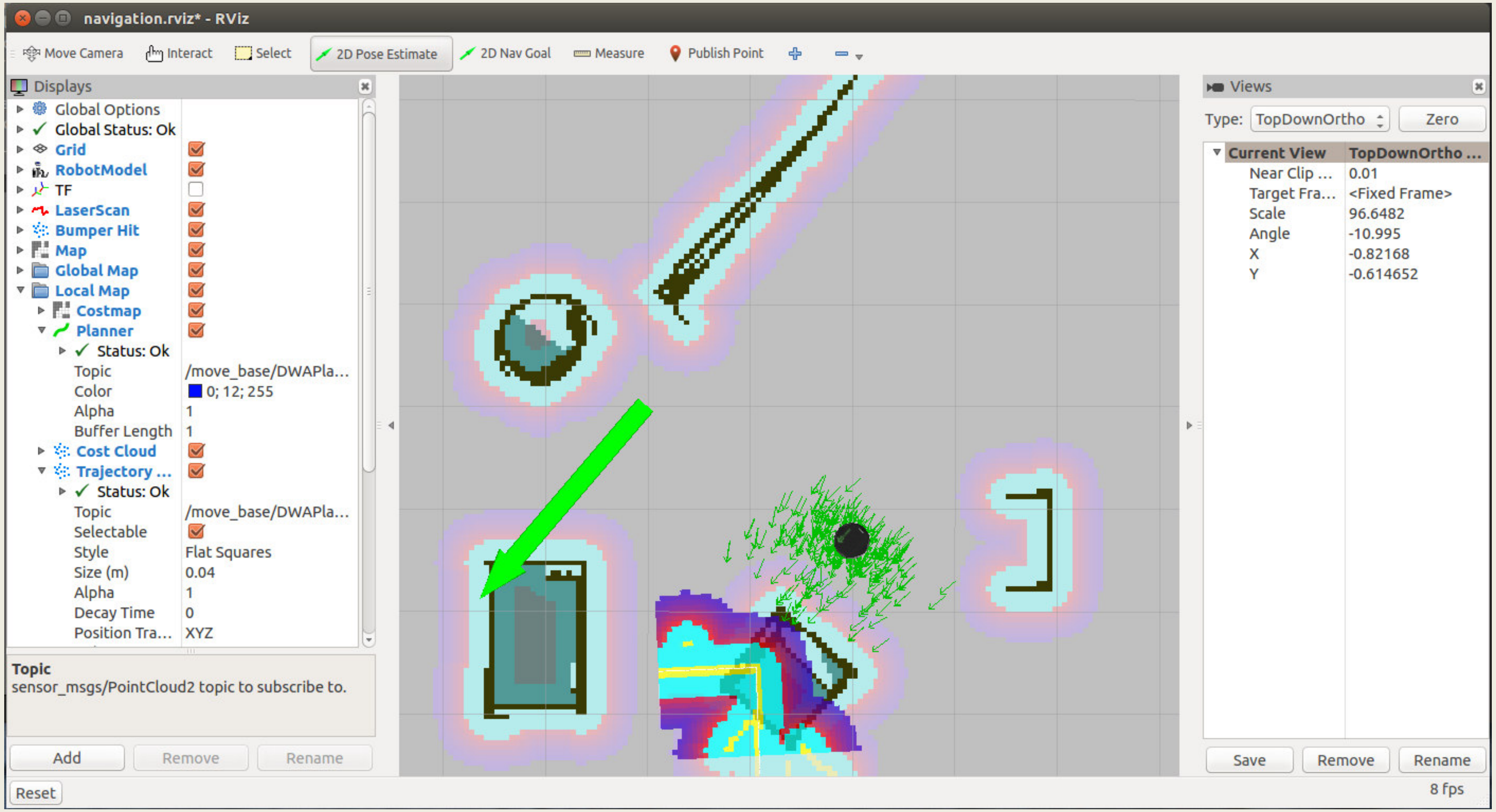
# Localize the Robot

- When starting up the robot doesn't know where it is
- For example, let’s move the robot in Gazebo to (-1,-2)
- Now to provide it its approximate location on the map:
  - Click the "2D Pose Estimate" button
  - Click on the map where the robot approximately is and drag in the direction the robot is pointing
- You will see a collection of arrows which are hypotheses of the position of the robot
- The laser scan should line up approximately with the walls in the map
  - If things don't line up well you can repeat the procedure

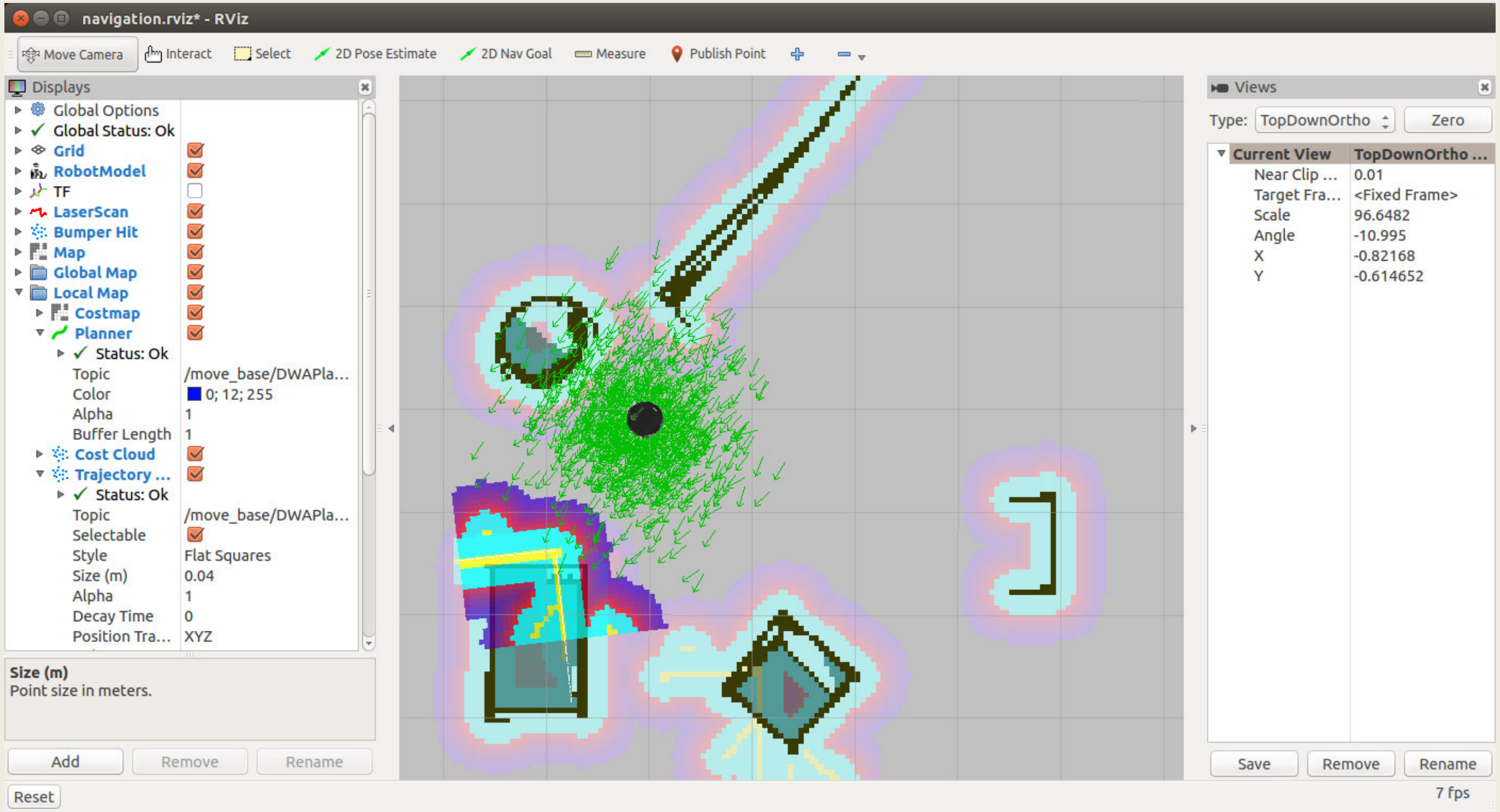
# Localize the Robot



# Localize the Robot

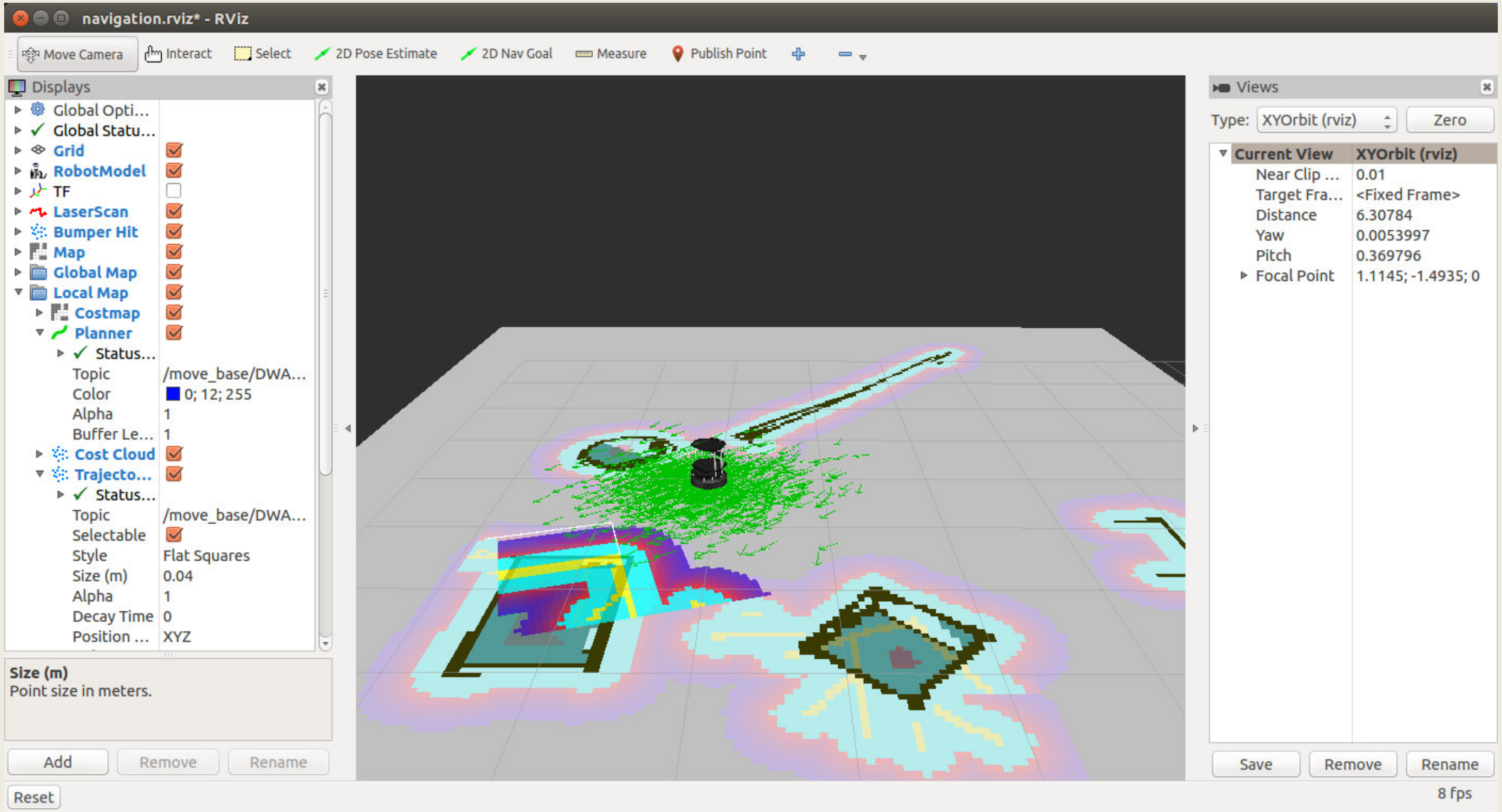


# Localize the Robot



# Localize the Robot

- You can change the current view (on right panel):



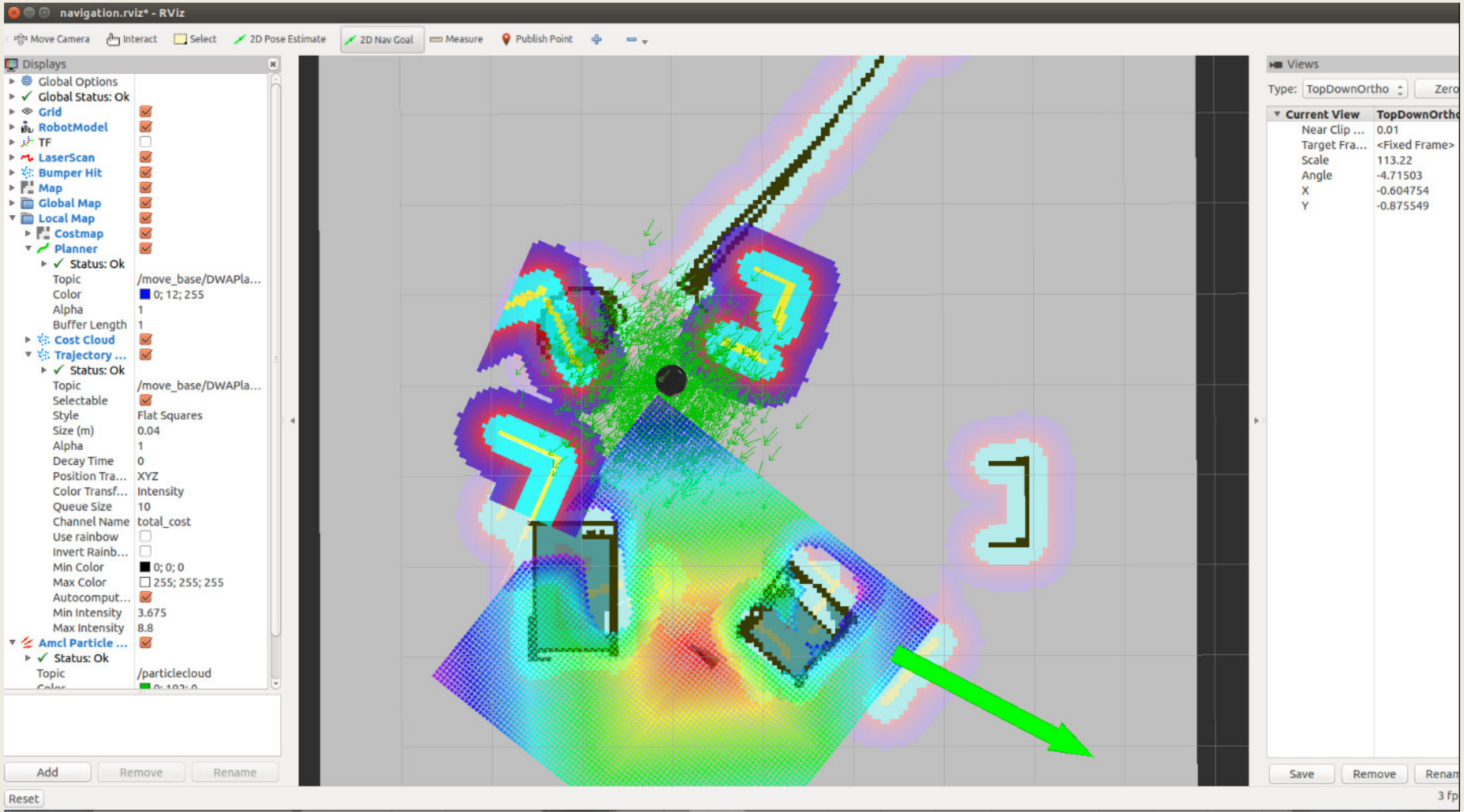
# Particle Cloud in rviz

- The **Particle Cloud** display shows the particle cloud used by the robot's localization system
- The spread of the cloud represents the localization system's uncertainty about the robot's pose
- As the robot moves about the environment, this cloud should shrink in size as additional scan data allows amcl to refine its estimate of the robot's position and orientation
- **To watch the particle cloud in rviz**:
  - Click Add Display and choose Pose Array
  - Set topic name to /particlecloud

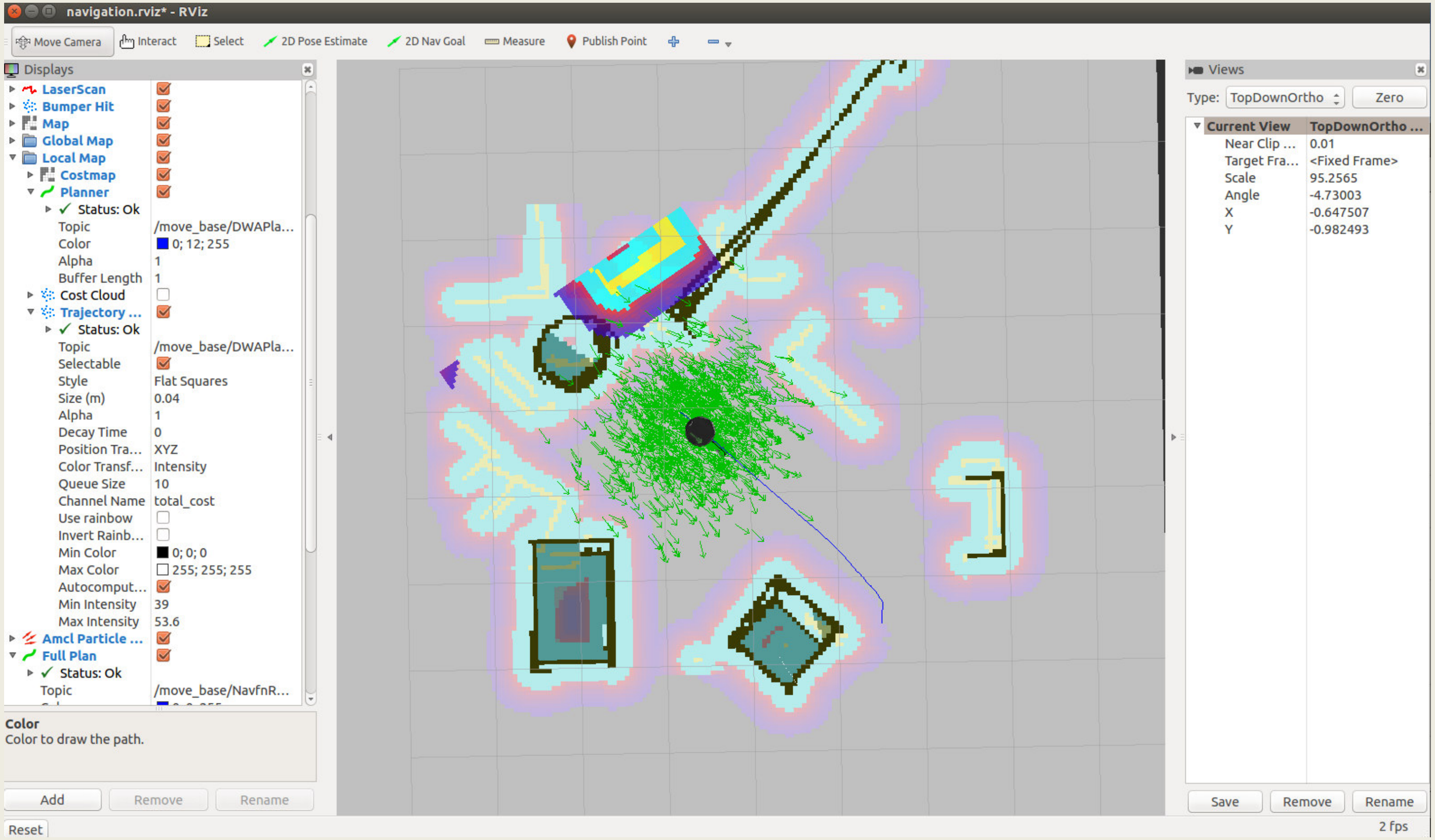
# Send a Navigation Goal

- With the robot localized, it can then autonomously plan through the environment
- To send a goal:
  - Click the "**2D Nav Goal**" button
  - Click on the map where you want the robot to drive and drag in the direction where it should be pointing at the end
- If you want to stop the robot before it reaches it's goal, send it a goal at it's current location

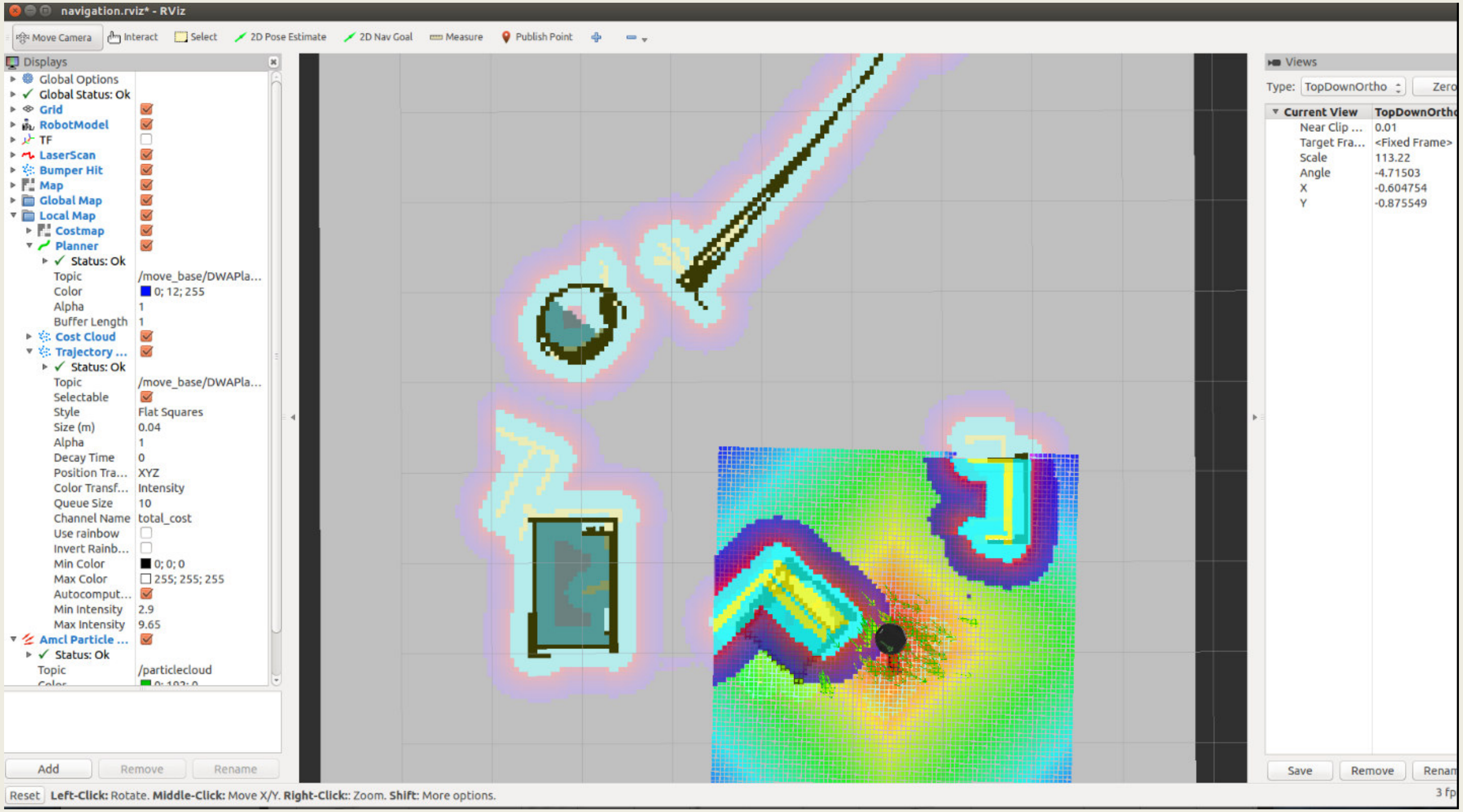
# Send a Navigation Goal



# Robot Moves to Destination

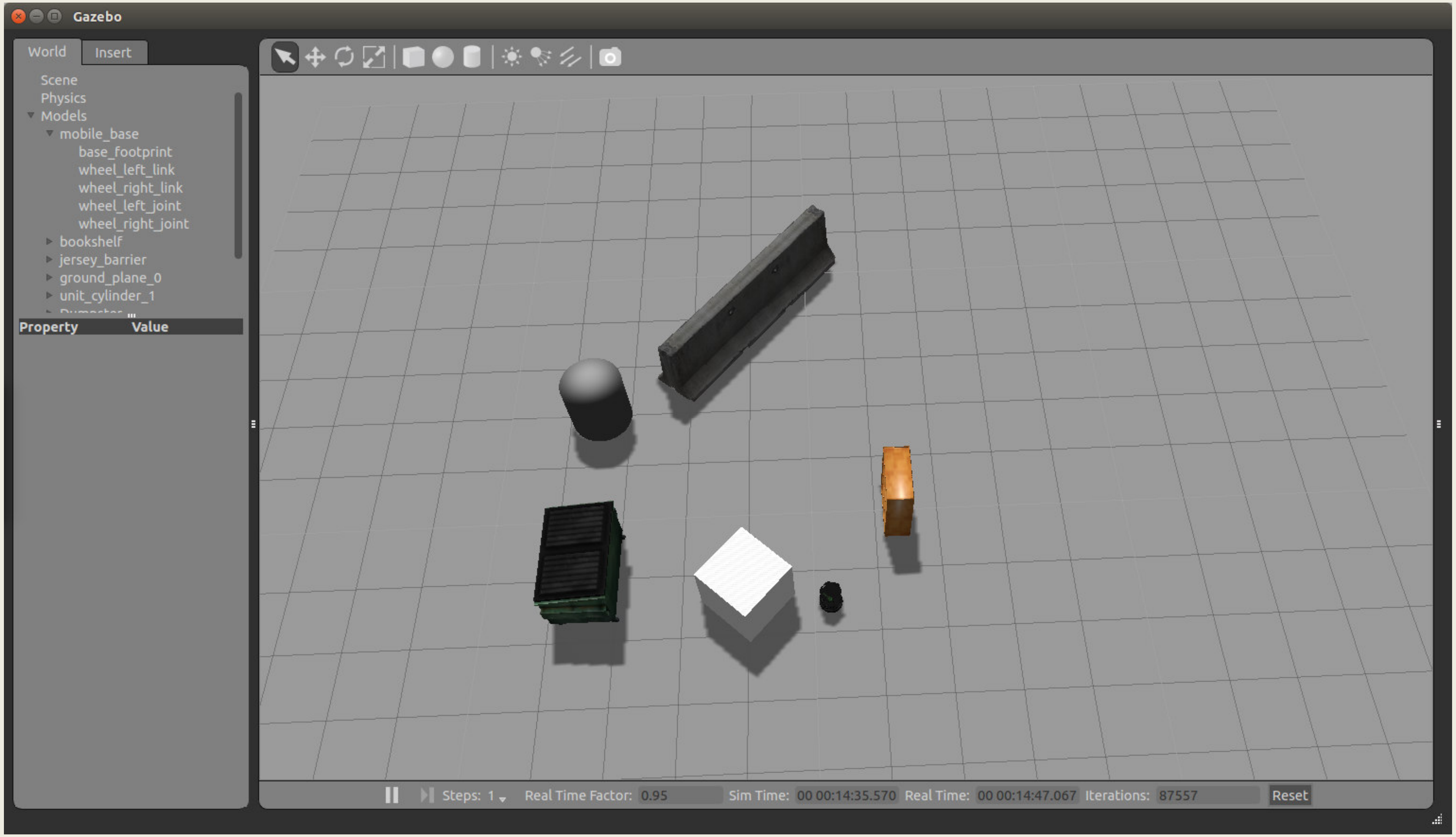


# Final Pose



navigation.rviz* - RViz
Move Camera
Interact
Select
2D Pose Estimate
2D Nav Goal
Measure
Publish Point
Displays
Global Options
Global Status: Ok
Grid
RobotModel
TF
LaserScan
Bumper Hit
Map
Global Map
Local Map
Costmap
Planner
Status: Ok
Topic
/move_base/DWAPla...
Color
0; 12; 255
Alpha
1
Buffer Length
1
Cost Cloud
Trajectory ...
Status: Ok
Topic
/move_base/DWAPla...
Selectable
Style
Flat Squares
Size (m)
0.04
Alpha
1
Decay Time
0
Position Tra...
XYZ
Color Transf...
Intensity
Queue Size
10
Channel Name
total_cost
Use rainbow
Invert Rainb...
Min Color
0; 0; 0
Max Color
255; 255; 255
Autocomput...
Min Intensity
2.9
Max Intensity
9.65
Amcl Particle ...
Status: Ok
Topic
/particlecloud
Add
Remove
Rename
Views
Type: TopDownOrtho
Current View
Near Clip ...
0.01
Target Fra...
<Fixed Frame>
Scale
113.22
Angle
-4.71503
X
-0.604754
Y
-0.875549
Save
Remove
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click:: Zoom. Shift: More options.

# Final Pose In Gazebo



# Navigation Plans in rviz

- **NavFn Plan**
  - Displays the **full plan** for the robot computed by the global planner
  - Topic: /move_base_node/NavfnROS/plan
- **Global Plan**
  - Shows the **portion of the global plan** that the local planner is currently pursuing
  - Topic: /move_base_node/TrajectoryPlannerROS/global_plan
- **Local Plan**
  - Shows **the trajectory associated with the velocity commands** currently being commanded to the base by the local planner
  - Topic: /move_base_node/TrajectoryPlannerROS/local_plan

# Navigation Plans in rviz