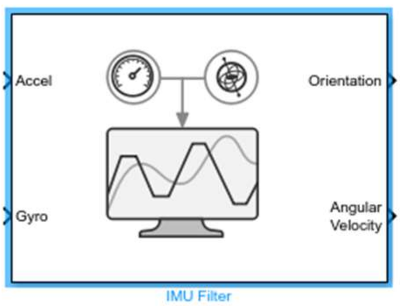
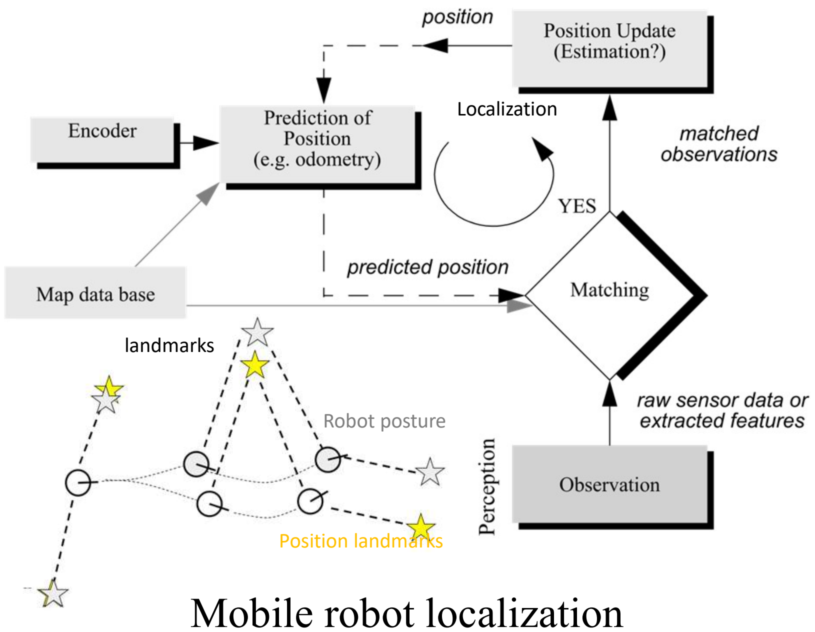
SEMTRON

SIX

Robot Localization

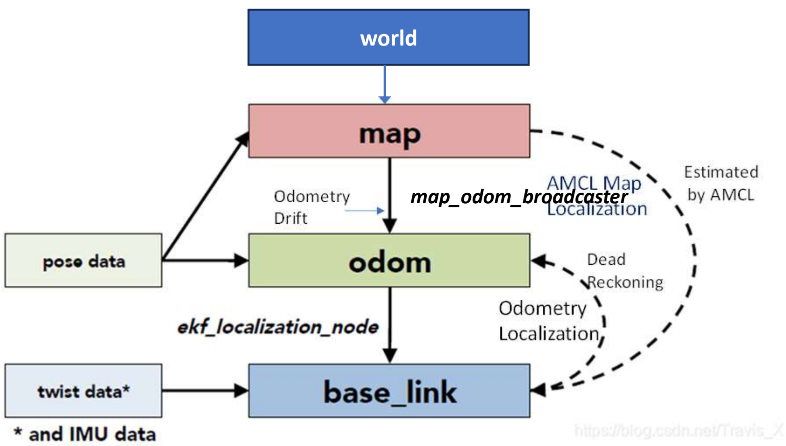
ROS Sensor Fusion



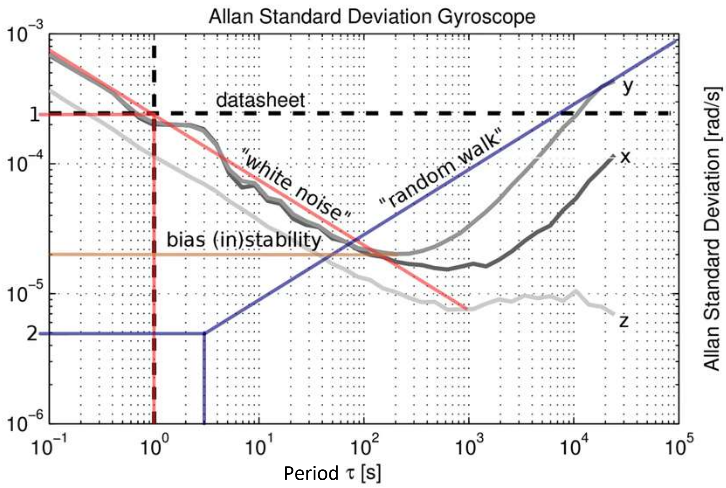


Mobile robot localization

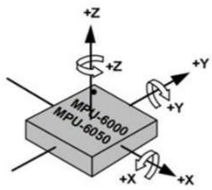
The localization problem comes in two flavors: *global localization* and *position tracking*



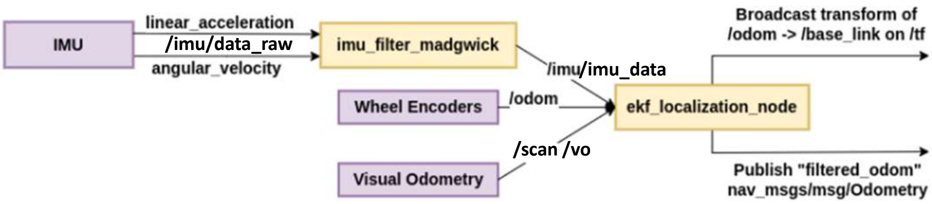
Robot localization



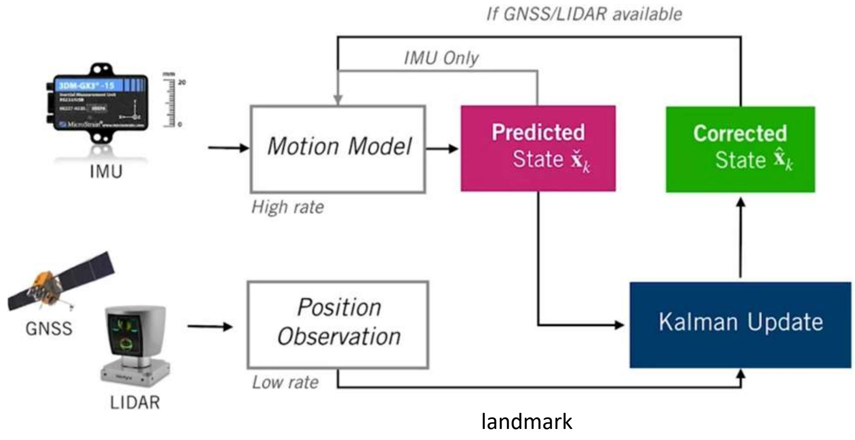
IMU noise model



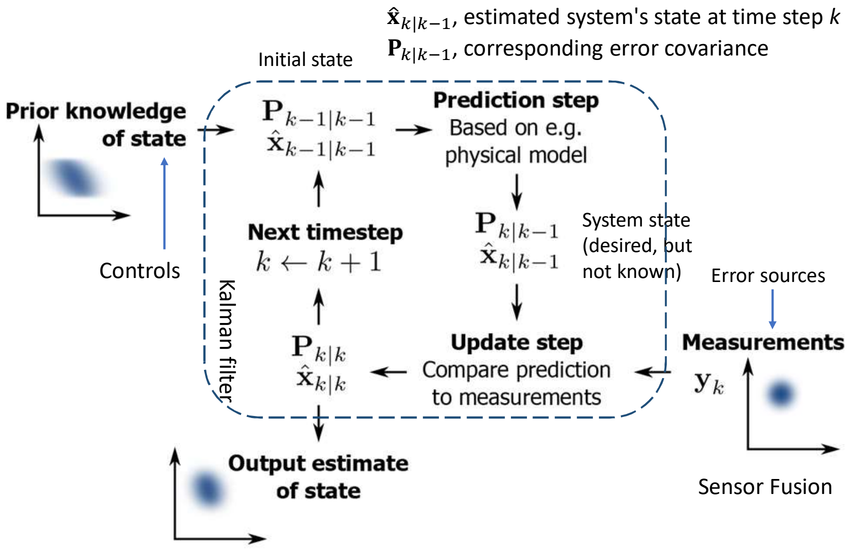
<origin xyz="0.085 -0.01 0.112" rpy="0 0 1.5707"/>



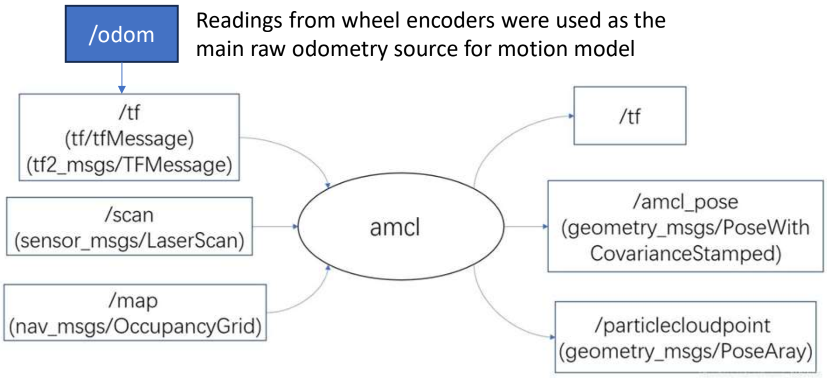
IMU noise model



Kalman-filter localization



Typical Kalman filter applications



Global localization

9

Particle Filtering

$$\mathrm{bel}(x) \leftarrow \alpha \mathrm{p}(z|x)\mathrm{bel}^{-}(x)$$

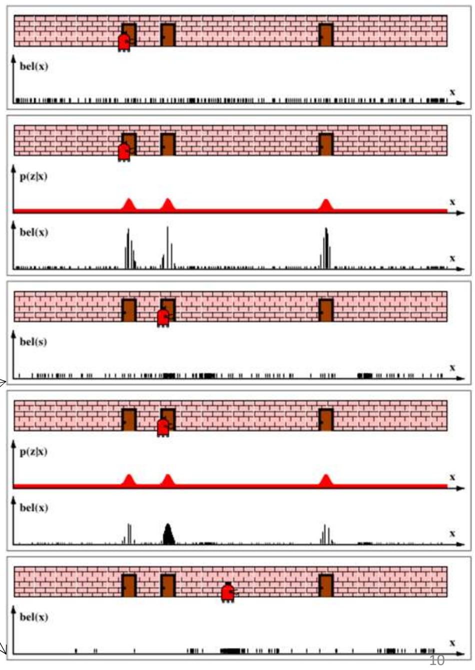
$$w \leftarrow \frac{\alpha \mathrm{p}(z|x)\mathrm{bel}^{-}(x)}{\mathrm{bel}^{-}(x)} = \alpha \mathrm{p}(z|x)$$

Importance re-sampling

$$\mathrm{bel}^{-}(x) \leftarrow \int \mathrm{p}(x|u,x')\mathrm{bel}(x')dx'$$

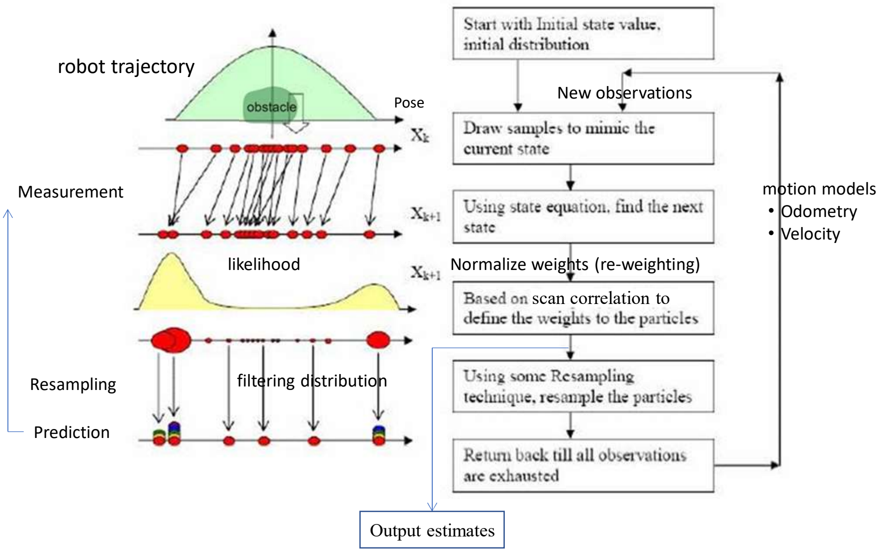
Robot motion

where u, robot action/control

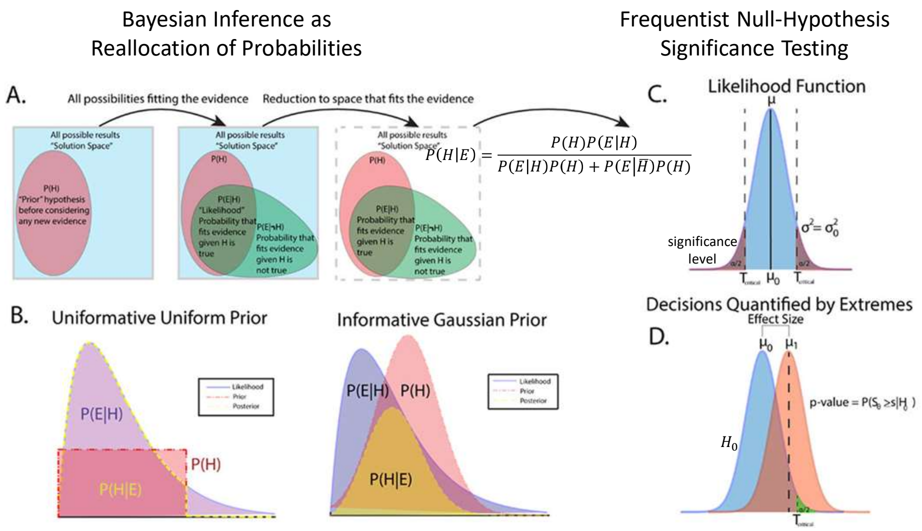


Monte Carlo Localization

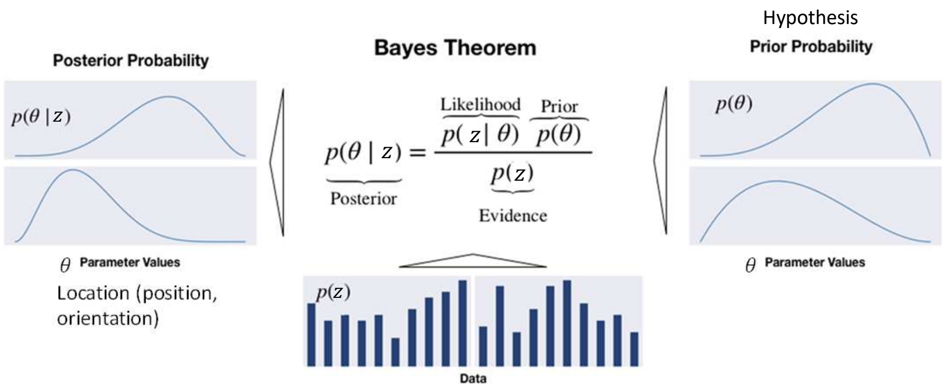
10



Adaptive Monte Carlo Localization



Probabilistic robotics

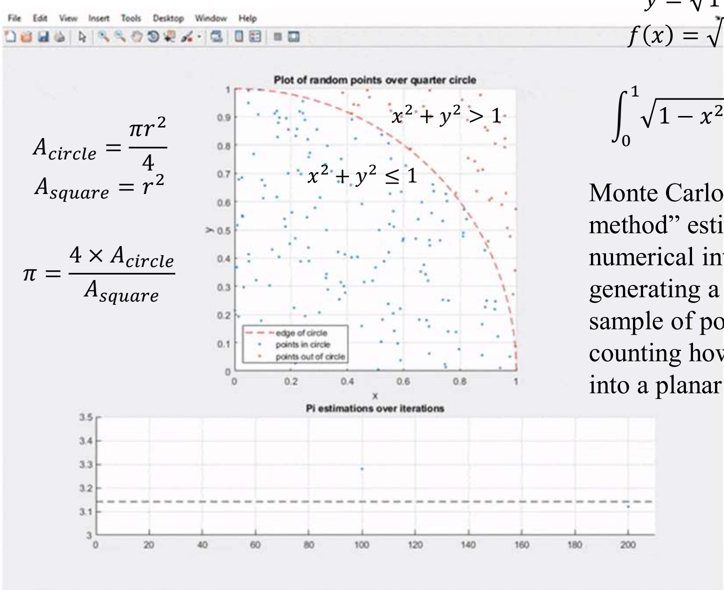


Location (position, orientation)

Odometry, Velocity

Probabilistic robotics

$$y = \sqrt{1 - x^2}$$
$$f(x) = \sqrt{1 - x^2}$$



$$A_{circle} = \frac{\pi r^2}{4}$$
$$A_{square} = r^2$$
$$\pi = \frac{4 \times A_{circle}}{A_{square}}$$

$x^2 + y^2 > 1$

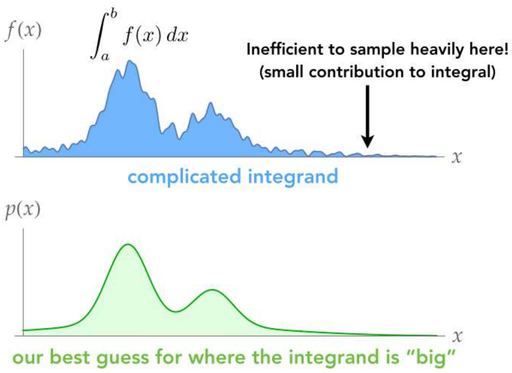
$x^2 + y^2 \leq 1$

$$\int_0^1 \sqrt{1 - x^2}\, dx = \frac{\pi}{4}$$

Monte Carlo “area method” estimates numerical integrals by generating a uniform sample of points and counting how many fall into a planar region

Importance Sampling

Simple idea: sample the integrand according to how much we expect it to contribute to the integral.



Note: p(x) must be non-zero where f(x) is non-zero

Basic Monte Carlo:

$$\frac{b-a}{N}\sum_{i=1}^{N} f(X_i)$$

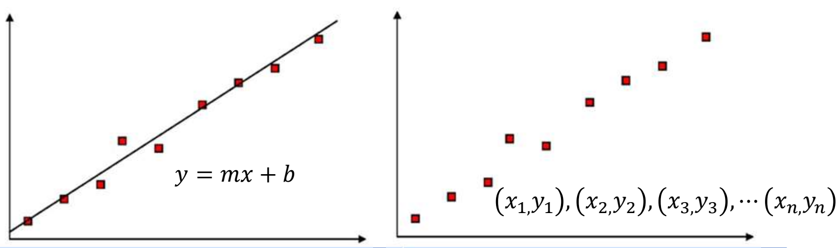
(x_i are sampled *uniformly*)

Importance-Sampled Monte Carlo:

$$\frac{1}{n}\sum_{i=1}^{n} \frac{f(x_i)}{p(x_i)}$$

(x_i are sampled proportional to *p*)

"If I sample x less frequently, each sample should count for more."

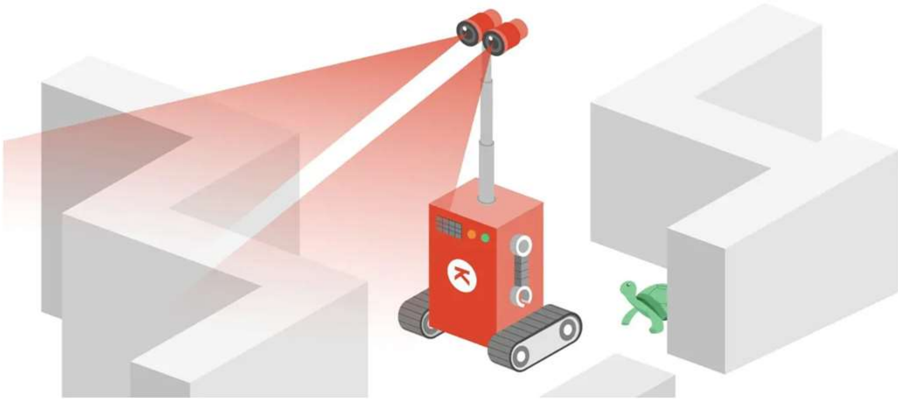


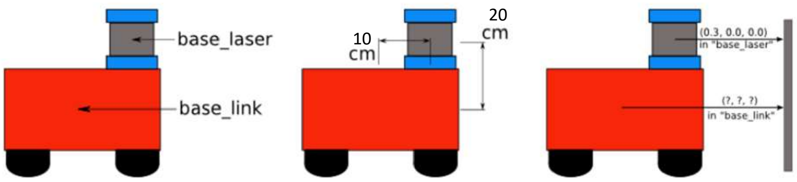
Kalman filter/ Markov Localization	Particle filter
Represent robot's belief by probability distribution over possible positions	Randomly generate a cloud of points (Sampling)
Use Bayes rule and convolution to update belief whenever robot senses or moves	Push these points through the *nonlinear* transformation
Belief is only approximate – kinematic state spaces is real valued & multidimensional nature	
Computation cost and memory utilization is higher	Sample set is high in global localization but small during tracking
Local position tracking	Global localization

Probabilistic robotics

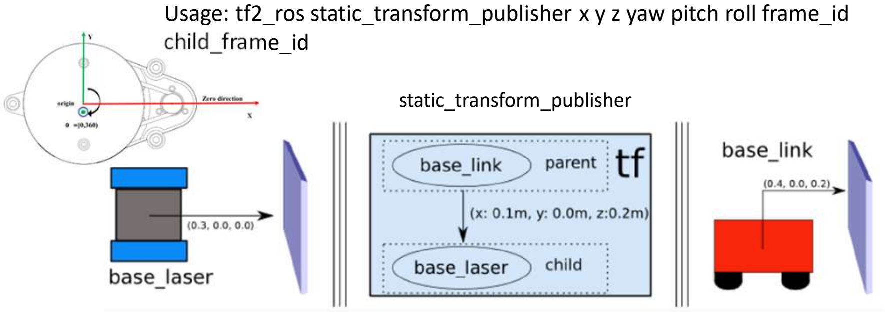
SEMTRON

Navigation

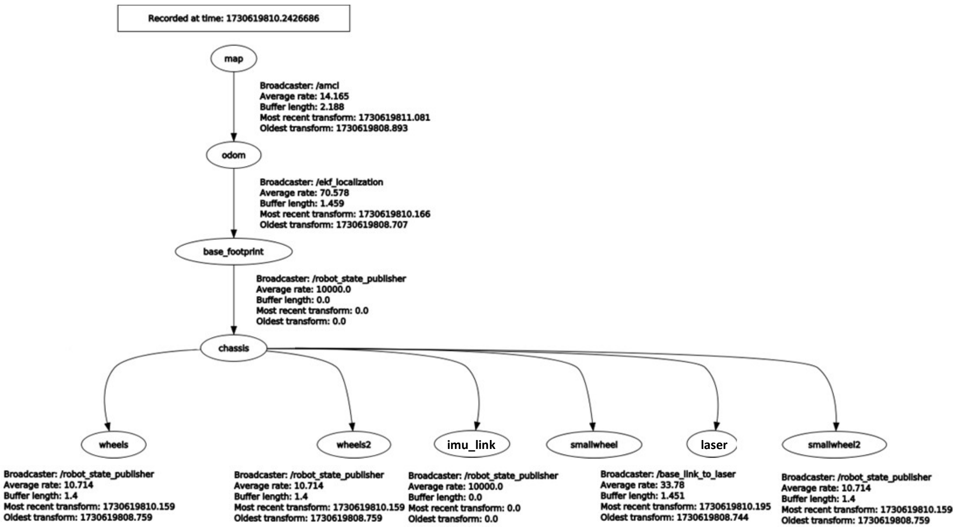




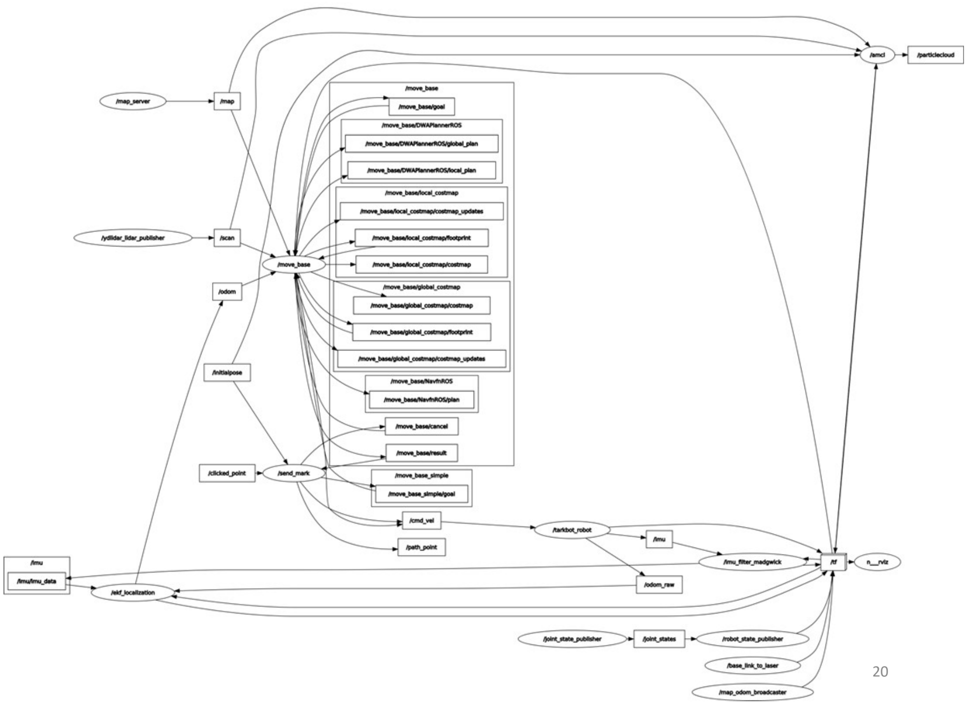
Usage: tf2_ros static_transform_publisher x y z yaw pitch roll frame_id child_frame_id



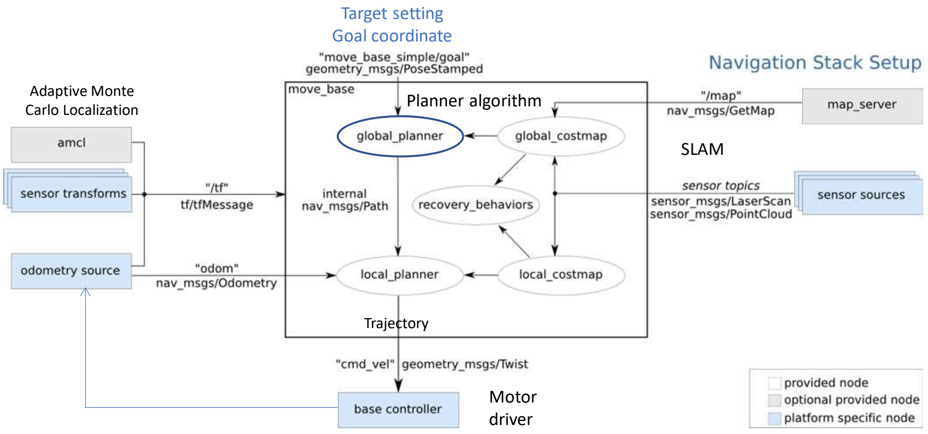
Sensor frame transform



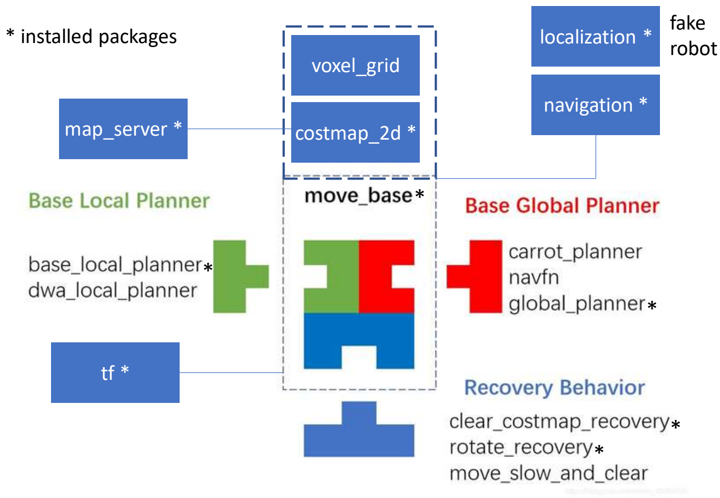
Recorded at time: 1730619810.2426686
map
Broadcaster: /amcl
Average rate: 14.165
Buffer length: 2.188
Most recent transform: 1730619811.081
Oldest transform: 1730619808.893
odom
Broadcaster: /ekf_localization
Average rate: 70.578
Buffer length: 1.459
Most recent transform: 1730619810.166
Oldest transform: 1730619808.707
base_footprint
Broadcaster: /robot_state_publisher
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
chassis
wheels
wheels2
imu_link
smallwheel
laser
smallwheel2
Broadcaster: /robot_state_publisher
Average rate: 10.714
Buffer length: 1.4
Most recent transform: 1730619810.159
Oldest transform: 1730619808.759
Broadcaster: /robot_state_publisher
Average rate: 10.714
Buffer length: 1.4
Most recent transform: 1730619810.159
Oldest transform: 1730619808.759
Broadcaster: /robot_state_publisher
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
Broadcaster: /base_link_to_laser
Average rate: 33.78
Buffer length: 1.451
Most recent transform: 1730619810.195
Oldest transform: 1730619808.744
Broadcaster: /robot_state_publisher
Average rate: 10.714
Buffer length: 1.4
Most recent transform: 1730619810.159
Oldest transform: 1730619808.759



/amcl
/particlecloud
/map_server
/map
/move_base
/move_base/goal
/move_base/DWAPlannerROS
/move_base/DWAPlannerROS/global_plan
/move_base/DWAPlannerROS/local_plan
/move_base/local_costmap
/move_base/local_costmap/costmap_updates
/ydlidar_lidar_publisher
/scan
/move_base/local_costmap/footprint
/move_base
/move_base/local_costmap/costmap
/odom
/move_base/global_costmap
/move_base/global_costmap/costmap
/move_base/global_costmap/footprint
/initialpose
/move_base/global_costmap/costmap_updates
/move_base/NavfnROS
/move_base/NavfnROS/plan
/move_base/cancel
/move_base/result
/clicked_point
/send_mark
/move_base_simple
/move_base_simple/goal
/cmd_vel
/tarkbot_robot
/imu
/path_point
/imu
/imu/imu_data
/imu_filter_madgwick
/tf
n___rviz
/ekf_localization
/odom_raw
/joint_state_publisher
/joint_states
/robot_state_publisher
/base_link_to_laser
/map_odom_broadcaster

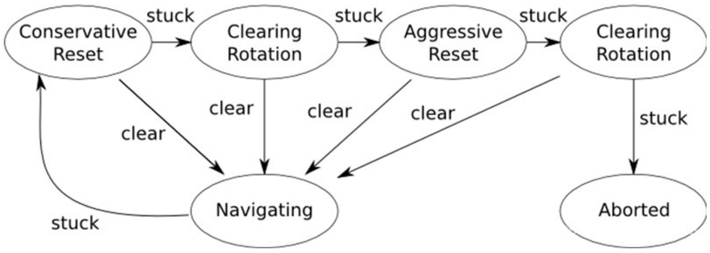


ROS navigation stack



move_base Package

move_base Default Recovery Behaviors



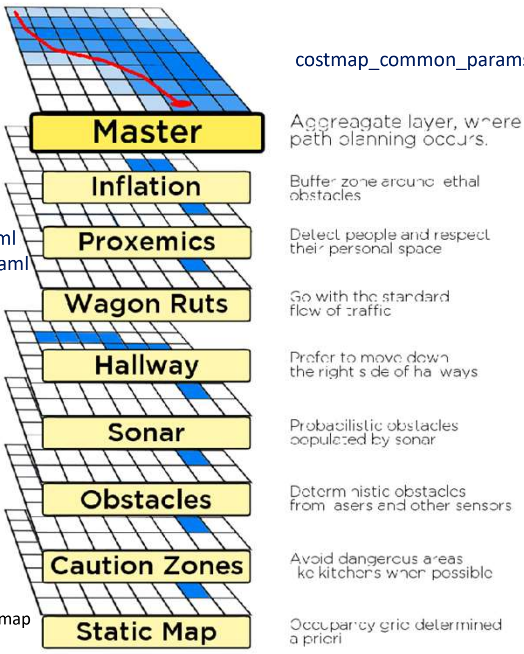
move_base Package

23

costmap_common_params.yaml

costmap_2d

local_costmap_params.yaml
global_costmap_params.yaml



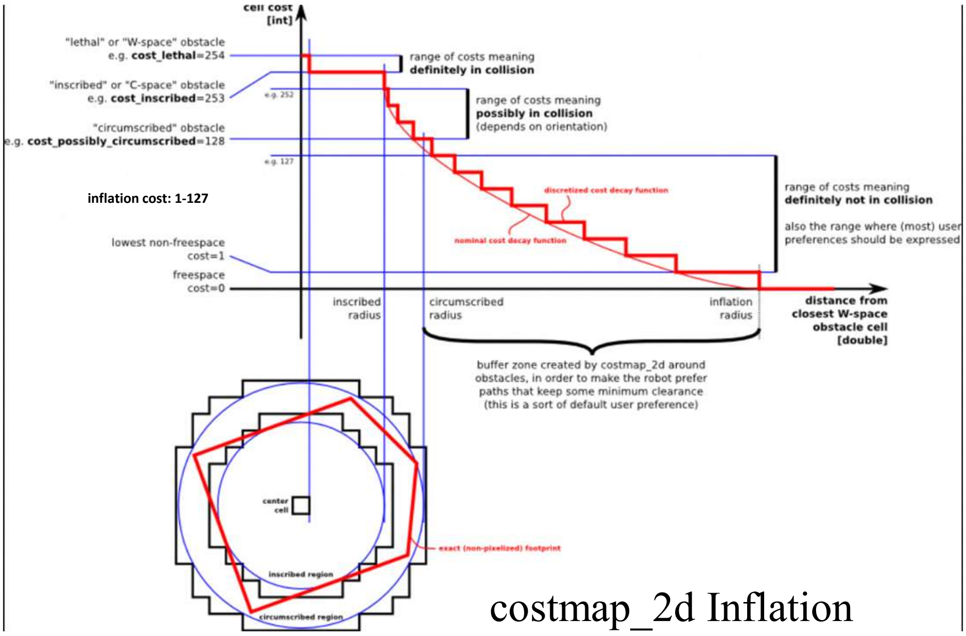
inflation_layer

obstacle_layer

static_layer

occupancy grid map
(OGM)

24



costmap_2d Inflation

25