ros_course_part2

01) quaternion
02) tf_tutorials
03) map_navigation

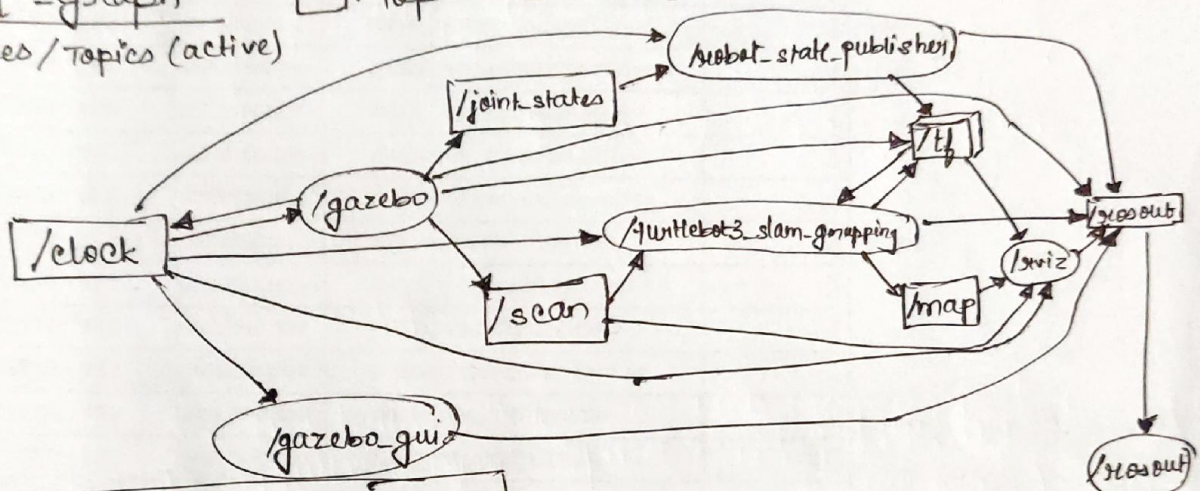
ANIS KOUBAA (Udemy)

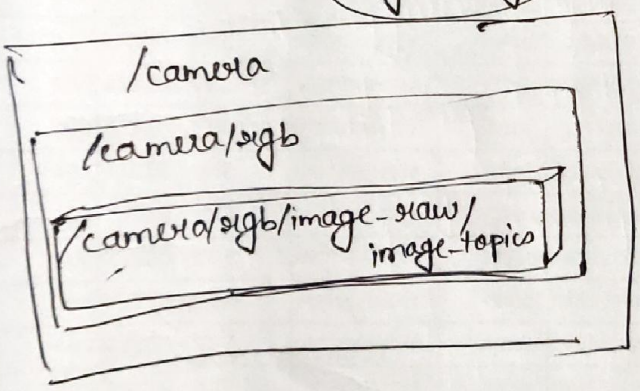
ROS for Beginners II: Localization, Navigation, SLAM

rqt_graph

□ : Topic ○ : Node

Nodes / Topics (active)





- Find location of robot: `rostopic echo /odom` / `rostopic echo /amcl_pose`

[map frame is the global frame that refers to the position of the robot]

- static obstacle - free path [we call global path planning]
- then executes the path using local path planner which also avoids dynamic obstacles ~~in this course~~

$$\begin{bmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{bmatrix}$$

Quaternion $s < v_1 | v_2 | v_3 >$

$q = s + v$

$q = s + v_1 i + v_2 j + v_3 k$

$i^2 = j^2 = k^2 = ijk = -1$

$q_0 = q_w = s$
$q_1 = q_x = v_1$
$q_2 = q_y = v_2$
$q_3 = q_z = v_3$

In ROS: notation

(x, y, z, w)

$q_x \; q_y \; q_z$ for s

- Euler Rotation Sequence
- Cardan Rotation Sequence
- Euler's Rotation Theorem
- Rodrigues Formula

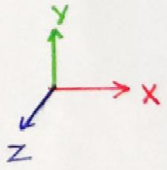
TF

- tf : It allows us to find the pose of any object in any frame using transformations.
- A robot is a collection of frames attached to its different joints.

[(red) : X-axis
(green) : Y-axis
(blue) : Z-axis]

- URDF: Language for the Description of frames and Transformation in a Robot Model

- tf package nodes
  - view_frames
  - tf_monitor
  - tf_echo
  - roswtf
  - static_transform_publisher



- view_frames

alias tf='cd /var/tmp && rosrun tf view_frames && evince frames.pdf &'

- Methods provided by tf package consider angle in radians

In code { tf.transformations.quaternion_from_euler(roll, pitch, yaw)
" . " . euler_from_quaternion(q)

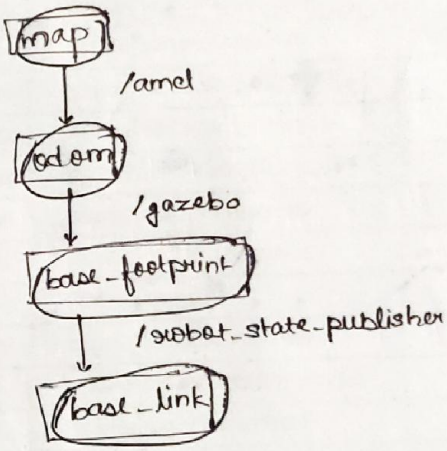
topic01_quaternion: scripts

✓tf_conversions.py
(The 2 tf functions mentioned later page)

✓tf_orientation_tb3_robot.py
(Takes pose from /odom
↓
orientation
↓
quaternion → euler
↓
prints yaw)

In view_frames.pdf,

/robot_state_publisher: node that publishes transformation based on URDF description



- tf_echo
  $ rosrun tf tf_echo odom camera_rgb_frame 2
  (echo rate ↑ optional)
  Gives homogeneous
- tf_monitor
  $ rosrun tf tf_monitor odom base_footprint
  Information about transformation such as publisher node, the average delay and the maximum delay.
  Also the statistics of all broadcasters.
  $ rosrun tf tf_monitor

- static_transform_publisher

Why this odd order?

Tab 1 : $ roscore

Tab 2 : $ rosrun tf static_transform_publisher (translation vector) 1 2 3 (Y) 0.1 (R) 0.2 (P) 0.3 frame_a frame_b 10

frame_a → parent, frame_b → child, 10 → broadcast frequency (10 times/s)

topic02_tf_tutorials : launch

- static_transform_publisher.launch
  - <node pkg="tf" type="static_transform_publisher" name="frame_a_to_frame_b" args="1 2 3 0.1 0.2 0.3 frame_a frame_b 10" />
- frame_a_to_frame_b_broadcaster.cpp .py
- listener.py
  - tf.TransformListener()
    - .waitForTransform(..) → 4 seconds max {in code}
    - .lookupTransform(..)
- tf.TransformBroadcaster()
  - .sendTransform(...)

Map-Based Navigation

Map based navigation

- Localization
- Mapping
- Motion/path planning
- SLAM
- Sensor Fusion

Reactive navigation

How does it work?

Three main packages of the navigation stack:-

- move_base : move to goal pose
- gmapping : creates maps ~~using laser scan data~~
- amcl : localization (using existing map)

- Occupancy Grid Map

SLAM approaches in ROS:-

- gmapping
- cartographer
- hector_slam

Cell — Unknown (grey) / Free (white) / Occupied (black)

- Quality of the sensors (odometry + laser scanner) affects the quality of the generated map

• Slam launch file includes (turtlebot3_slam.launch):

Packages:

turtlebot3_bringup
1. turtlebot3_remote.launch → needed for the tf relations within robot model

turtlebot3_slam
2. turtlebot3_$(arg slam_methods).launch
[gmapping, cartographer, hector, karto, frontier_exploration]
{Configuration basename ⇒ turtlebot3_lds_2d.lua}

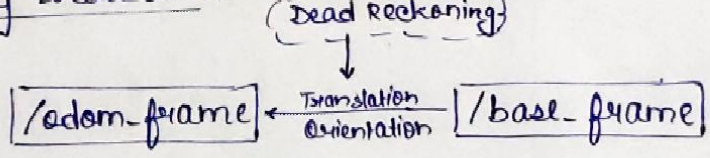
rviz
3. rviz (turtlebot3_$(arg slam_methods). rviz)

• How "amcl" works?

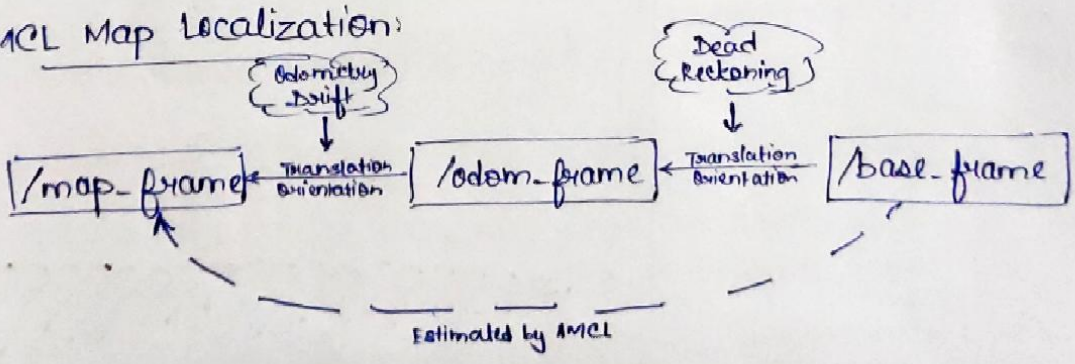
A] - AMCL tries to match the laser scans to the map thus ~~reducing~~ detecting if there is any drift in the pose estimate based on the odometry (dead reckoning).

- The drift is then compensated by publishing a transform between the map frame and the odom frame such that at the end the transform "map → base_frame" corresponds to the real pose of the robot in the world.

Odometry Localization:



AMCL Map Localization:



- map_server : package for publishing and manipulating maps
  map_saver : node inside map_server

tb3_map.pgm → grayscale image

tb3_map.yaml → occupied_thres, free_thres

- These 3 frames : base_frame, odom and map are mandatory for any robot navigation mission.

"delta" → resolution of the map
"0.05" means 0.05m or 5cm/px

lds: laser distance sensor

- 2D Pose Estimate → 2D Nav Goal

Motion Planners
- Global Path Planner (static obstacle-free path)
- Local Path Planner (avoid dynamic obstacles)

- Recovery Behaviour: initiated when the local planner finds obstacles while following the planned global path

clearing and marking processes

- Navigation launch file includes (turtlebot3_navigation.launch):

Packages:
turtlebot3_bringup
map_server
turtlebot3_navigation
turtlebot3_navigation
rviz

1. turtlebot3_remote.launch → robot model (like the tf relations), robot_state_publisher node
2. map_server (takes .yaml file as argument)
3. amcl launches [Adaptive Monte Carlo Localization] → uses particle filter to track pose of robot against a known map
4. move_base launches → Most important : represents the navigation stack (More on this)
5. rviz (turtlebot3_navigation.rviz)

Topic 03_map_navigation :
- navigate_goal.py
- navigate_goal.cpp

Writing a ROS Node for Robot Navigation

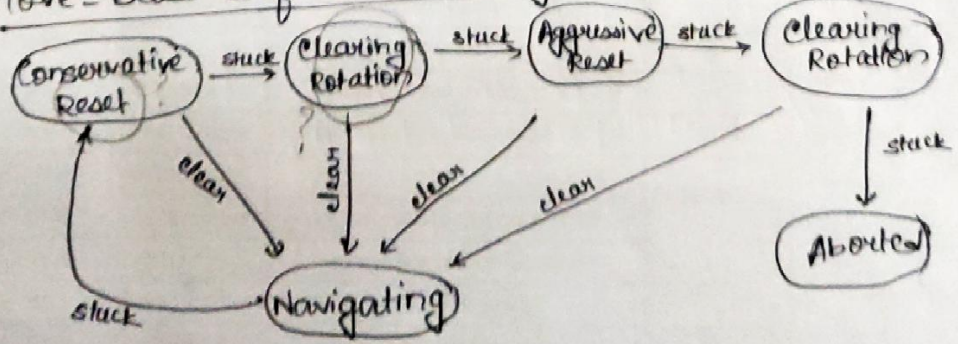
Q1] How to determine coordinates of goal location?

- Graphical (counting grid squares)
- (ii) `$ rostopic echo initialpose` [In Rviz, 2D Pose Estimate at goal location]
- (iii) `$ rostopic echo amcl_pose` } In the script "navigate.py"

Method:
move_to_goal (x_goal, y_goal)

1. actionlib client
   - ↳ defines a client-server application where tasks are pre-emptable
     - ↳ means they can be interrupted
   - ↳ communication is fully asynchronous
2. "move_base" → navigation stack server
   [Reason why move_base is actionLib and not rosservice]
3. MoveBaseAction → action_feedback
   - action_goal
   - action_result
4. MoveBaseGoal
5. set reference frame of robot [V. Imp] = "map"
   Timestamp
   Point (x, y, z)
   goal.target_pose.pose.orientation.x = 0.0
   ⋮

- Move_base Default Recovery Behaviours



- Robot setup to support the ROS Navigation Stack

(Would be more relevant later)

Provide node

- global_planner
- local_planner
- recovery behaviours
- global_costmap
- local_costmap

Optional provided node

- amcl
- map_server

Platform specific node

- sensor transforms
- Odometry source
- sensor sources

} Parts that need to be set up

LAST SECTION] Configuration & Tuning of the Navigation Stack Parameters

{ (Reference): ROS Navigation Tuning Guide ~ Kaiyu Zheng

- Tuning Max/Min Velocities & Accelerations

```
$ roscd turtlebot3_navigation
$ cd param
$ more dwa_local_planner_params_waffle
```

- Global Planner Parameter Tuning

nav_core :: BaseGlobalPlanner

- initialize
- makePlan
- makePlan (with cost)
- destructor

[Another thread here: "Writing a Global Path Planner as a Plugin in ROS"]

3 built-in global planners

① carrot_planner

② navfn
- Djikstra's

③ global_planner
- can use grid path
- support of A*

- Local Path Planner Overview

nav_core :: BaseLocalPlanner

- initialize
- isGoalReached
- computeVelocityCommands
- setPlan
- destructor

- DWA Algorithm
[Dynamic Window Approach] ~ Dieter Fox

- $\begin{bmatrix} v \\ \omega \end{bmatrix}$ (random values ↓ then forward simulations)
- highest-scoring trajectory

- Tuning the Simulation Time of the DWA Algorithm
time allowed for the robot to move with the sampled velocities

- DWA Trajectory Scoring

* cost = path_distance_bias × (distance to path from the endpoint of the trajectory)
{local trajectories closer to global path}
+ goal_distance_bias × (distance to local goal from the endpoint of the trajectory)
{trajectory closer to the goal, may be far from global path}
+ occdist_scale × (maximum obstacle cost along the trajectory in obstacle cost (0-254))
(occlusion distance)
{help selecting trajectories far from obstacles}

- Tuning the DWA Trajectory Scores ⟶ in the yaml file
$ rosrun rqt_reconfigure rqt_reconfigure *
↓
allows to change parameter values dynamically without changing configuration files

1) init_node : rospy.init_node('node_name', anonymous=True)
2) Subscriber → callback (msg)
3) spin : rospy.spin()

rospy.Subscriber('topic_name', MessageType, callbackFunction)