IIT KHARAGPUR

Internship Assignment

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1 COMMON ASSIGNMENT

1.1 ROTATIONS

1. Question 1
   a) Euler Angles:
      - Advantage: More human understandable and intuitive and good to reduce into individual degrees of freedom.
      - Disadvantage: Ambiguity in representation and Gimbal Lock i.e. in lost degree of freedom in boundary cases of +/- 90 degrees. Also, trigonometric functions are slower to calculate than arithmetic.

   b) Unit Quaternions:
      - Advantage: More compact representation and avoids Gimbal Lock.
      - Disadvantage: Less Intuitive to understand and complicated mathematics. Also, representation of translation with rotation with quaternions is not elegant.

   c) Rotation Matrix
      - Advantage: All transformations can be represented and the mathematics is easy to understand.
      - Disadvantage: Order of rotation with respect to axis is important to be considered. Multiple representations of same rotation in matrix form. Redundant Representation.

   d) Axis/Angle Representation

- Advantage: Very intuitive to understand.
- Disadvantage: Applying the interpolation in rotation using this is difficult. Number of mathematical operations to perform rotation in this representation is more making it slow.

Code Link for further Questions - `https://github.com/sam17/CMU-Task/blob/master/Rotations/rotations`

2. Question 2

$$R^a = \begin{bmatrix} 0.353553 & -0.866025 & 0.353553 \\ 0.612372 & 0.5 & 0.612372 \\ -0.707107 & 0 & 0.707107 \end{bmatrix} \tag{1.1}$$

$$R^b = \begin{bmatrix} 1 & -0 & 0 \\ 0 & 0.5 & 0.866025 \\ 0 & -0.866025 & 0.5 \end{bmatrix} \tag{1.2}$$

3. Question 3

$$q^a = 0.800103 \quad -0.191342 \quad 0.331414 \quad 0.46194 \tag{1.3}$$

$$q^b = 0.866025 \quad -0.5 \quad 0 \quad 0 \tag{1.4}$$

No, Quaternions are not unique representations of rotations. There are two representations of a quaternion, itself and it's negation.

4. Question 4

$$q^c = 0.597239 \quad -0.565758 \quad 0.0560427 \quad 0.565758 \tag{1.5}$$

$$q^d = 0.597239 \quad -0.565758 \quad 0.517982 \quad 0.234345 \tag{1.6}$$

No, they are not same since quaternion multiplication is not commutative.

5. Question 5

$$q^f = 0.800103 \quad -0.191342 \quad 0.331414 \quad 0.46194 \tag{1.7}$$

From (1.3) and (1.7),

$$q^a = q^f$$

1.2 Planning Concepts

- Question 1

  The distinction between constraints and objectives is that a constraint is a design target that must be met for the design to be successful. In contrast, an objective is a design target where more (or less) is better. However, constraints can often be converted into objectives if needed to solve the optimization problem like in Lagrangian functions, the constraints are added to the objective to create a new objective function which is solved for new constraints obtained.

- Question 2

  Homotopy classes of trajectories arise due to presence of obstacles in an environment. Two trajectories connecting the same start and goal coordinates are in the same homotopy class if they can be smoothly deformed into one another without intersecting any obstacle in the environment, otherwise they are in different homotopy classes.

  In motion planning, it is important to distinguish between trajectories of different homotopy classes, as well as identify the different homotopy classes in an environment (e.g., trajectories that go left around a circle in two dimensions versus right) so that planning of the path constrained to different classes can be done differently and efficiently and also to avoid certain homotopy classes which are not feasible.

  Also, a study of homotopy classes ensures a mathematical representation for applying constraints and solving for trajectories within a class along with searching for a trajectory with least cost path becomes simpler due to the classification into classes.

- Question 3

  Motion Planning can be represented as an optimization problem with constraints. Constraints are important to reduce the search space https://github.com/sam17/CMU-Task/blob/master/Rotations/rotationsfor solution trajectories/paths and these constraints are propagated by using sensing information from environment. This set of information from environment got from interaction with environment is called information gain.

  Information gain is the data/information about the surroundings obtained from sensors on a robot which are reduced to constraints for motion planning. Presence of these constraints allows better decisions for motion planning as it can give the necessary data to classify homotopy classes and apply constraints to solve the optimization problem of motion planning.

- Question 4

  D* Lite repeatedly determines shortest paths between the current vertex of the robot and the goal vertex as the edge costs of a graph change while the robot moves towards the goal vertex making it a deterministic algorithm unlike RRT* that grows a tree rooted at the starting configuration by using random samples from the search space.

RRT* propagates trees randomly sampling nodes and adding them to node set but in situations where the environment and weight of the edges change, RRT* cannot give an optimal solution and will need to recompute the whole search space for the new set of edge weights.However, D* Lite does not make any assumptions about how the edge costs change, whether they go up or down, whether they change close to the current vertex of the robot or far away from it, or whether they change in the world or only because the robot revised its initial estimates.

2 Perception

2.1 Plane Segmentation

Git Repository for Code: `https://github.com/sam17/CMU-Task/blob/master/plane_segmentation_tutorial/src/simplePlaneFitting.cpp`

Approach I passed the coefficients calculated for every plane to the visualizing function and then calculated the slope of the normal and plotted them on the plane.

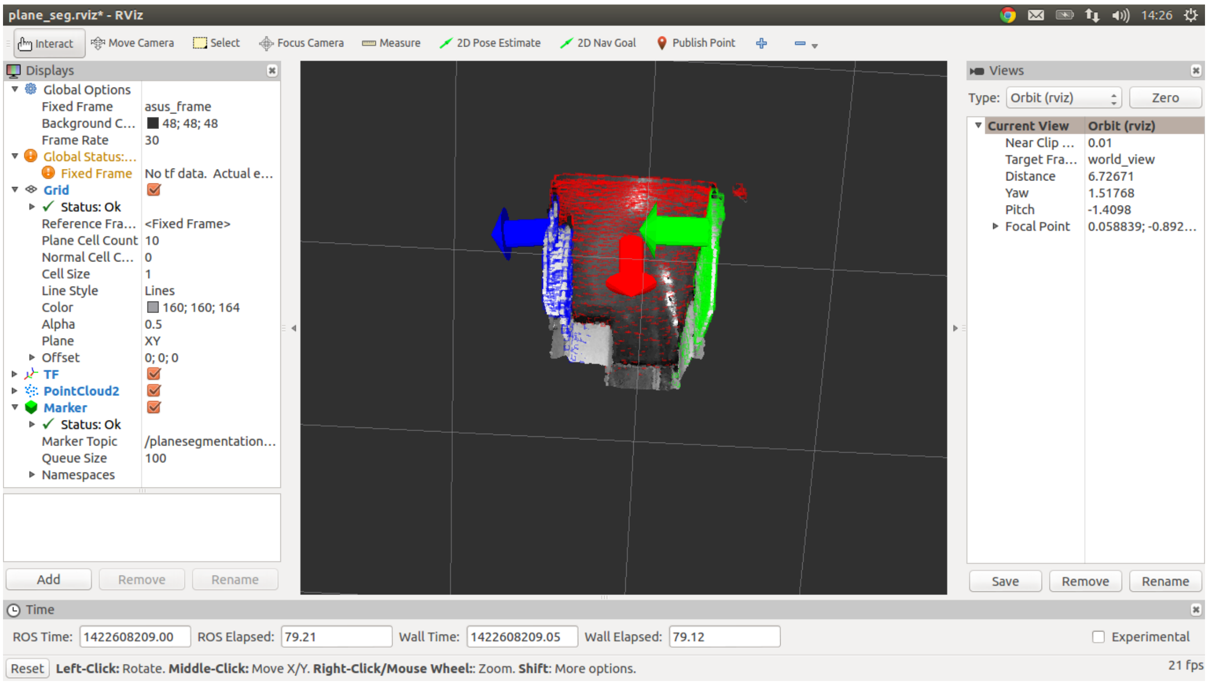

Figure 2.1: Screen-shot