Path planning

Robotics instructional lab #4

Spring 2022

In this lab, you will plan a path of the robotic arm to pick an object and position it in a different location on the table.

1 Background

1.1 Configuration and task space

A configuration of the robot is the set of joint values. Therefore, the Configuration space (or *C-space*) is the space of all possible configurations of a robot. Formally, the configuration space is defined by $\mathcal{C} \subset \mathbb{R}^m$ where m is the number of joints.

The task space is a space in which the robot's task can be naturally expressed. For example, if the task is to control the position of the tip of a marker on a board, then task space is the Euclidean plane. If the task is to control the position and orientation of the gripper, then the task space is the 6-dimensional space of rigid body configurations.

1.2 Linear path in the configuration space

Given start and goal configurations $\mathbf{q}_s, \mathbf{q}_g \in \mathcal{C}$ where $m = 6$, $\mathbf{q}_s = (\theta_{s,1}, \ldots, \theta_{s,6})^T$ and $\mathbf{q}_g = (\theta_{g,1}, \ldots, \theta_{g,6})^T$, we can plan a linear path in $\mathcal{C}$. A linear path for joint θ_i is given by

$$\theta_i(t) = \theta_{s,i}(1-t) + \theta_{g,i}t \tag{1}$$

where $t \in [0, 1]$. One can compute the set of $N + 2$ way-points along the line with t=$\{0, t_1, \ldots, t_N, 1\}$.

1.3 Linear path for the gripper in the task space

Given start and goal positions of the gripper $\mathbf{p}_s, \mathbf{p}_g \in \mathbb{R}^3$, the linear path is

$$x(t) = x_s(1-t) + x_g t \tag{2}$$

$$y(t) = y_s(1-t) + y_g t \tag{3}$$

$$z(t) = z_s(1-t) + z_g t \tag{4}$$

where $\mathbf{p} = (x, y, z)^T$ and $t \in [0, 1]$. A discretized path is done similar to the C-space.

1.4 Polynomial path

Let σ be either a pose coordinate of the gripper or joint angle, an n-order polynomial path from σ_s to σ_g is defined as

$$\sigma(t) = a_0 + a_1 t + a_2 t^2 + \ldots + a_n t^n. \tag{5}$$

To find the $n+1$ coefficients of the polynomial $\{a_0, \ldots, a_n\}$, one must define $n+1$ constraints. To constrain, for example, positions σ_s, σ_g and velocities v_s, v_g, we find the coefficients of an $n = 3$-order polynomial by solving

$$\sigma(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3. \tag{6}$$

with

$$\sigma(0) = \sigma_s \tag{7}$$
$$\dot{\sigma}(0) = v_s \tag{8}$$
$$\sigma(T_g) = \sigma_g \tag{9}$$
$$\dot{\sigma}(T_g) = v_g \tag{10}$$

where T_g is the desired motion time. Substituting, for instance, (7) into (6) would yield $a_0 = \sigma_s$.

2 Prerequisites

In file **lab04_student.py**, fill:

- Function `traj_gen_config` to generate a linear and polynomial path from $\mathbf{q}_1$ to $\mathbf{q}_2$.
- Function `traj_gen_task` to generate a linear and polynomial path from $\mathbf{p}_1$ to $\mathbf{p}_2$.

Prerequisites are a mandatory in order to carry out the lab .

3 Lab instructions

You are required to plan a motion for the robot to move from a random location, pick up a cube and place it at another location. Do the following:

1. Place the cube somewhere on the table.
2. Open the GUI (from the first lab), manually move the robot to the following key poses and record them:
   - Random start pose.
   - Pick-up pose (gripper perpendicular to table).

- Placing-down pose.
- Any other desired pose.

3. Use functions `traj_gen_config` and `traj_gen_task` to plan a path for the robot to complete the task. Make sure to use both linear and polynomial paths.

4. Run and record the path three times (**Keep your finger on the e-stop to prevent collisions**).

4 Report requirements

The lab report should include the following:

1. Describe the process of the lab.

2. Describe your calculations and structure of your planned path.

3. In a 3D plot, show the following:
   - Planned path of the gripper.
   - Put markers at the key poses.
   - Real paths of the gripper.
   - Include legend and axes labels.

4. Compute the average error between the planned path and the real ones. Explain.

5. Explain the advantages and disadvantages of using this for of path planning.

6. Provide a summary for your results.