

Humanoid Robots

Exercise Sheet 9 - Reachability Maps and Inverse Reachability Maps

Exercise 17 (20 points)

In this exercise, we will compute reachability maps and inverse reachability maps for the robot arm with three links from exercise 16:

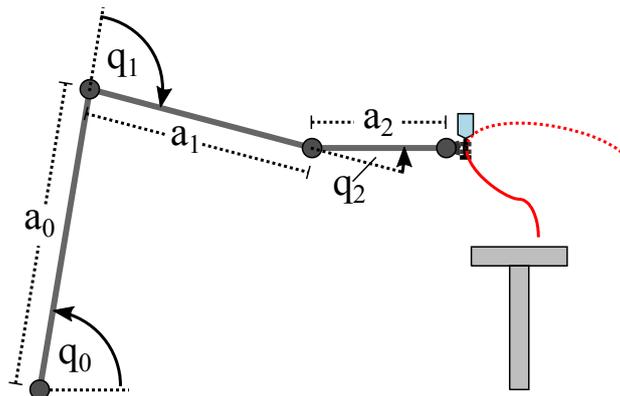


Figure 1: Robot arm with three joints

Reachability map

Compute the reachability map of the endeffector with respect to the robot's base according to the following steps:

- a) Implement the method `sampleConfiguration` for choosing a random configuration of the robot's joints (q_0, q_1, q_2) and return the configuration as a vector. The joint angles should be sampled uniformly within the following bounds:

joint	min	max
q_0	0	$+\frac{\pi}{2}$
q_1	$-\pi$	$+\pi$
q_2	$-\pi$	$+\pi$

- b) Compute the following measurement of manipulability for a given joint configuration in `computeManipulability()`:

$$\text{score} := 1 - \frac{1}{4\pi} (|4q_0 - \pi| + |q_1| + |q_2| + |e_\theta|) \quad (1)$$

(This manipulability measurement favors configurations where q_0 is near 45 degrees and penalizes configurations with pointed angles between links.)

- c) Implement the method `computeRM` that computes the reachability map of the endeffector by iterating the following steps:
- Sample a joint configuration.
 - Compute the end effector pose with the `forwardKinematics` method.
 - Check that the end effector is above the ground (i.e., $e_y > 0$). If the end effector collides with the ground, then sample again. (You don't have to perform other checks such as self-collisions, object collisions, etc. in this exercise.)
 - Compute the manipulability score for the configuration.
 - Add the configuration to the reachability map with the `addToRM` method.

With the Gnuplot script in `scripts/plot-rm.gp` or in the Wiki you can inspect the resulting reachability map. The robot's base is located at the origin and the colors represent the manipulability of the possible end effector poses.

Inverse reachability map

For the sake of simplicity, we assume that the robot arm is mounted on a wheeled base so that we do not have to deal with stance feet and swing feet.

The inverse reachability map indicates suitable positions where the base of the robot has to be located so that the gripper can reach the desired object. Using this map, the robot can first drive to a suitable place near the table and then grasp the drink.

- d) Implement the method `computeIRM`. The voxels of the reachability map are given to the method as an argument. For each configuration stored in the reachability map, add an entry to the inverse reachability map as follows:
- Compute the end effector pose from the configuration's joint angles with the `forwardKinematics` method.
 - Convert the end effector pose to a homogeneous transformation matrix, find the inverse, and convert the inverted transformation matrix back to the pose of the robot's base (b_x, b_y, b_θ). The result is the pose of the base expressed in the coordinate system of the gripper.
 - Add the base pose together with the joint angles and the manipulability score to the inverse reachability map by calling the `addToIRM` method.

With the Gnuplot script in `scripts/plot-irm.gp` and the plot in the Wiki you can inspect the resulting inverse reachability map. The robot's gripper is located at the origin and the colors represent the possible base poses that are suitable for reaching the object in the coordinate frame of the gripper.

Deadline: 20 July 2017, 11:59 am