Assignment III – CSC376 – Fall 2019

Fundamentals of Robot Design
Department of Mathematical and Computational Sciences
University of Toronto Mississauga

Abstract

This assignment covers Module 7 - Motion Planning. It consists of two parts. In the first part, a serial manipulator has to move from one position to the next target position while avoiding collision with the environment. In the second part, write a concise report which summarizes your approach and results. By the submission of this assignment you should:

- be able to implement a widespread probabilistic complete motion planner.
- understand the chosen motion planner.
- use the API of the V-REP simulation environment.

Remember to write your full names and student numbers prominently on your submission. To avoid suspicions of plagiarism: at the beginning of your submission, clearly state any resources (people, print, electronic) outside of your group, the course notes, and the course staff, that you consulted.

For Assignment II and Assignment III you are allowed to work in groups of 2 students or by yourself. Please note that the group cannot be changed between those two assignments. For assignment handling, group forming, and submissions use MarkUs:

`https://mcsmark.utm.utoronto.ca/csc376f19`.

Please upload your submission as a single `.pdf` file alongside with an updated git-repository containing your code on MarkUs. By uploading, you confirm that this is your original work without using any references other than the listed ones.

Answer each question completely, always justifying your claims and reasoning and explaining your calculation/derivation. Furthermore, use meaningful and explanatory comments to go along your submitted code. Your solution will be graded not only on correctness, but also on clarity. Answers that are technically correct but hard to understand will not receive full marks. Mark values for each question are contained in the [square brackets].

______________________	______________________	______________________
Name 1	Name 2 (if applicable)	Date

Due Date: Nov 29, 2019 (11:59pm)

Prerequisites

In order to deepen your understanding of motion planning for serial robot arms, we continue using the V-REP simulation environment [1]. A predefined V-REP scene is provided on MarkUs. The scene is depicted in Figure 1. Copy the V-REP scene to '`/{V-REP-Installation-Destination}/scenes/`'. Throughout this assignment, you will implement a motion planner for a serial robot arm.

Part I: Probabilistic Complete Motion Planning

(80 points)

The task is to implement a probabilistic complete motion planner as presented in the lecture, which determines a sequence of configurations to move the robot from a start position to a desired goal position in the provided V-REP scene `AssignmentIII.ttt` (see Figure 1). You can decide which probabilistic complete motion planner you want to implement. Please note, that even though the scene is static, you are also welcome to implement a motion planner which is typically used for dynamic environments (single-query).

You can build upon your code framework from Assignment II to implement the following additional functions for this Assignment:

- `planMotion` gets a start and goal robot configuration as input and determines a sequence of collision free robot configurations using the probabilistic complete motion planning method of your choice
- `isCollisionFree` checks whether the input robot configuration is collision free and returns `true` if no collision is detected and `false` otherwise. Hint: The V-REP API provides functionalities to check distances between objects in the scene that you can use to realize your collision checker.
- `sampleRobotConfiguration` returns a randomly sampled robot configuration respecting its joint limits
- `runConfigurationSequence` sends a sequence of robot configurations (determined by `planMotion`) to V-REP using the API

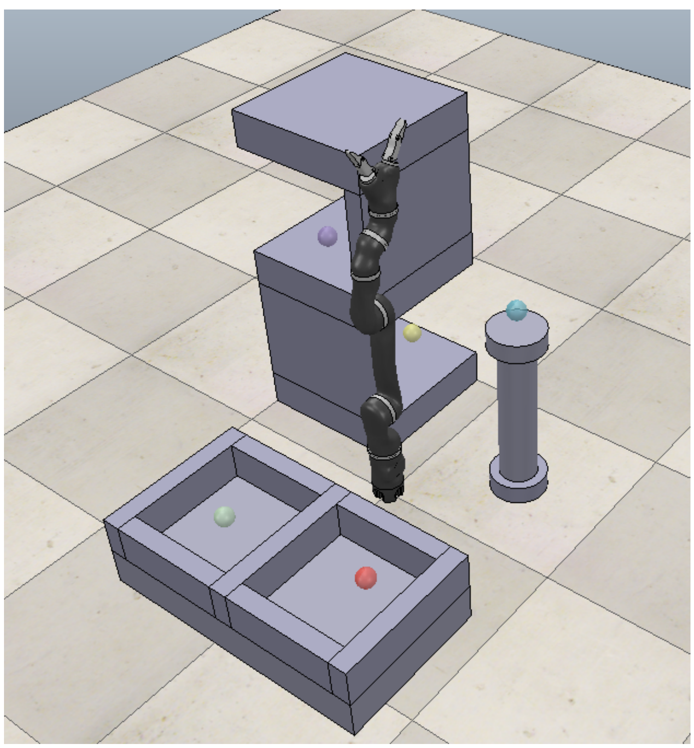

Figure 1: Scene with Mico robot from Kinova Robotics Inc. in its home position in an environment with target positions.

To test your motion planner, a set of five color-coded desired robot positions is provided in Table 1. You can choose any pair to query the motion planner, where one acts as the start configuration and one acts as the goal configuration. Choose as least five distinct pairs to demonstrate that your motion planner works.

In the provided V-REP scene (`AssignmentIII.ttt`) you will find multiple objects in addition to the target positions: a shelf with two targets, i.e. `Position_4` and `Position_5`, a pedestal with the blue target, i.e. `Position_3`, and a box with remaining targets `Position_1` and `Position_2`. The robot is the Mico robot from Kinova Robotics Inc. which you already familiarized yourself with in the course of `Assignment II`. The scene is depicted in Figure 1. Table 1 lists the position of all targets.

Table 1: Positions of each target and a corresponding robot configuration. Note, that all listed robot configurations consider the offset stated in Table 2.

name	color	position in metres			joint values in degrees					
		x	y	z	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6
`Position_1`	red	0.35	0.25	0.15	-111.8	43.8	-92	173.5	-390	-142.4
`Position_2`	green	0.4	-0.15	0.15	-59.4	53.4	-55	204.6	-445	-348.1
`Position_3`	blue	-0.225	0.25	0.55	-90.9	-1.7	76.6	126.2	-110.8	-42.19
`Position_4`	yellow	-0.35	-0.2	0.215	-83.2	-59.6	87.9	413.1	-252.8	-246.6
`Position_5`	purple	-0.15	-0.275	0.6	6.55	-14.7	-74	618.1	-60.1	-573.3

Note, that you have to respect the range of each joint angle, if joint angles are randomly generated. These are stated in Table 2. Furthermore, our defined home position depicted in Figure 1 (the robot is completely straight) differs from the simulated robot's home position in V-REP. To align our defined home position with V-REP, we have to consider the offset for each joint stated in Table 2. Note, that the defined joint limits have to be adjusted accordingly.

Table 2: Offsets to align the defined home position of this Assignment (robot straight) with the home position of the simulated robot in V-REP. Joint limits for each joint of the simulated robot in V-REP. Adjusted joint limits for the robot with our defined home position (robot is straight) which take the offsets for each joint into account. If no joint limits are stated, the corresponding joint can realize a full rotation from $-\pi$ to π.

joint	offset in rad	joint range in rad	adjusted joint range in rad
1	$\frac{-\pi}{2}$	–	–
2	π	$[0.82, 5.46]$	$[-2.32, 2.31]$
3	π	$[0.33, 5.95]$	$[-2.81, 2.80]$
4	0	–	–
5	0	–	–
6	0	–	–

Part II: Short report

(20 points)

Write a concise report summarizing your approach, encountered difficulties, and results. Which probabilistic complete motion planner did you implement and why? Include a table indicating at the pairs of target positions and screen shots of the motion sequences determined with your motion planner.

References

[1] Rohmer, E., Singh, S.P. and Freese, M., "V-REP: A versatile and scalable robot simulation framework." In *IEEE/RSJ International Conference on Intelligent Robots and Systems*, pp. 1321–1326, 2013.