

# CS 6301 Introduction to Robot Manipulation and Navigation Homework 4

Professor Yu Xiang

October 30, 2023

In this homework, write down your solutions for problems 1 and finish the coding problem 2. Upload your solutions and code to eLearning. Our TA will check your solutions and run your scripts to verify them.

## Problem 1

(4 points)

Rigid-body dynamics in an arbitrary frame. Exercise 8.3 in Lynch and Park, Modern Robotics.

**Steiner's theorem** says that, the inertia matrix  $\mathcal{I}_q$  about a frame aligned with  $\{b\}$ , but at a point  $q = (q_x, q_y, q_z)$  in  $\{b\}$ , is related to the inertia matrix  $\mathcal{I}_b$  calculated at the center of mass by

$$\mathcal{I}_q = \mathcal{I}_b + \mathbf{m}(q^T q I - q q^T), \quad (1.1)$$

where  $I$  is the  $3 \times 3$  identity matrix and  $\mathbf{m}$  is the mass of the body.

(1.1) Show that the following equation is a generalization of Steiner's theorem.

$$\mathcal{G}_a = [\text{Ad}_{T_{ba}}]^T \mathcal{G}_b [\text{Ad}_{T_{ba}}]. \quad (1.2)$$

(1.2) Given the dynamic equation for a single rigid body in the body frame

$$\mathcal{F}_b = \mathcal{G}_b \dot{\mathcal{V}}_b - [\text{Ad}_{\mathcal{V}_b}]^T \mathcal{G}_b \mathcal{V}_b \quad (1.3)$$

and Eq. (1.2), prove that

$$\mathcal{F}_a = \mathcal{G}_a \dot{\mathcal{V}}_a - [\text{Ad}_{\mathcal{V}_a}]^T \mathcal{G}_a \mathcal{V}_a. \quad (1.4)$$

## Problem 2

(6 points)

ROS programming, grasping of a block.

In this problem, you will learn using MoveIt to control a Fetch robot in ROS. **You can directly use Ubuntu, or Docker or virtual machine to install ROS according to your own set up.** Refer to the ROS wiki page if needed <http://wiki.ros.org/>.

(2.1) Mounting a host folder into Docker if you use Docker. For example, the following command will mount a folder in Windows “C:\data” as a folder “/data” in Docker:

- `docker run -it -v C:\data:/data ubuntu:ros`

In this way, you can save all your code in the host machine and use them in the Docker environment.

(2.2) Creating a ROS workspace. Reuse your workspace from the previous homework. A ROS workspace is a place to store your own ROS packages. Following the link here to create a ROS workspace [http://wiki.ros.org/catkin/Tutorials/create\\_a\\_workspace](http://wiki.ros.org/catkin/Tutorials/create_a_workspace). You should create the ROS workspace in the mounted folder from the host machine.

(2.3) Install and launch Fetch Gazebo Simulator by following the steps in Homework 2. Use terminator to start multiple windows.

- `roslaunch fetch_gazebo simple_grasp.launch`.

You shall see the Gazebo environment as in Figure 1.

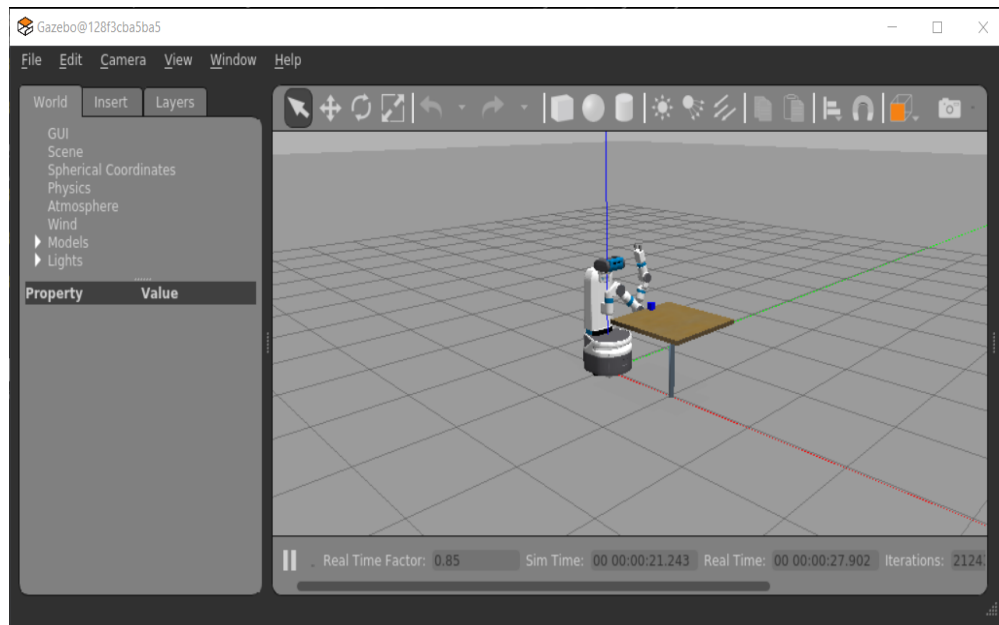


Figure 1: A Fetch Gazebo Interface.

(2.4) Install MoveIt and the `fetch_ros` package by following the steps in Homework 3 and then launch MoveIt planning by

- `roslaunch fetch_moveit_config move_group.launch`

You need to see the output as in Figure 2 that indicates the planning is ready.

```

Loading 'move_group/ApplyPlanningSceneService'...
Loading 'move_group/ClearOctomapService'...
Loading 'move_group/MoveGroupCartesianPathService'...
Loading 'move_group/MoveGroupExecuteTrajectoryAction'...
Loading 'move_group/MoveGroupGetPlanningSceneService'...
Loading 'move_group/MoveGroupKinematicsService'...
Loading 'move_group/MoveGroupMoveAction'...
Loading 'move_group/MoveGroupPickPlaceAction'...
Loading 'move_group/MoveGroupPlanService'...
Loading 'move_group/MoveGroupQueryPlannersService'...
Loading 'move_group/MoveGroupStateValidationService'...
[ INFO] [1664982441.120508400, 28.597000000]:
*****
* MoveGroup using:
*   - ApplyPlanningSceneService
*   - ClearOctomapService
*   - CartesianPathService
*   - ExecuteTrajectoryAction
*   - GetPlanningSceneService
*   - KinematicsService
*   - MoveAction
*   - PickPlaceAction
*   - MotionPlanService
*   - QueryPlannersService
*   - StateValidationService
*****
[ INFO] [1664982441.130923000, 28.610000000]: MoveGroup context using planning plugin ompl_in
terface/OMPLPlanner
[ INFO] [1664982441.132081200, 28.610000000]: MoveGroup context initialization complete
You can start planning now!

```

Figure 2: Output by launching `roslaunch fetch_moveit_config move_group.launch`.

(2.5) Up to now, you shall have the Gazebo and Moveit running. In this coding assignment, you need to use the pose of the demo cube computed from Homework 2 and `trac_ik` [https://bitbucket.org/traclabs/trac\\_ik/src/master/](https://bitbucket.org/traclabs/trac_ik/src/master/) for inverse kinematics from Homework 3 to grasp the demo cube.

You will use `move_group.go(joint_goal, wait=True)` to control the robot for grasping. This function will move the robot to the `joint_goal`. So we need to figure out `joint_goal` for grasping the demo cube. Figure 3 shows 3 tfs of the base link, the wrist roll link and the demo cube. The wrist roll link is the end-effector frame for inverse kinematics. Therefore, you need to figure out how to place the wrist roll link to grasp the cube. The distance between the wrist roll link and the finger tip is about 15cm. Once you decide the transformation for the wrist roll link in the robot base, you can use `trac_ik` to compute the `joint_goal`. Then the python script will move the robot to the `joint_goal`, close the gripper and move the arm back to the starting pose.

Download the `grasp_block.py` and the `gripper.py` from eLearning. Finish the implementation of the **TODOs** in the python script. Then you can run the python script. Figure 4 shows a Gazebo scene of running the script.

**Submission guideline: Upload your implemented `grasp_block.py` file and the screen capture of Gazebo after running the script to eLearning.**

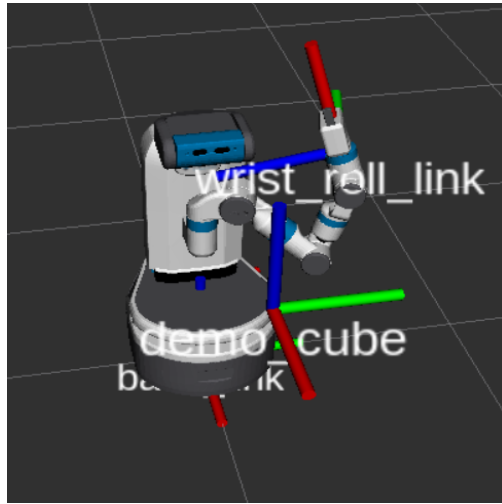


Figure 3: base\_link, wrist\_roll\_link and demo\_cube.

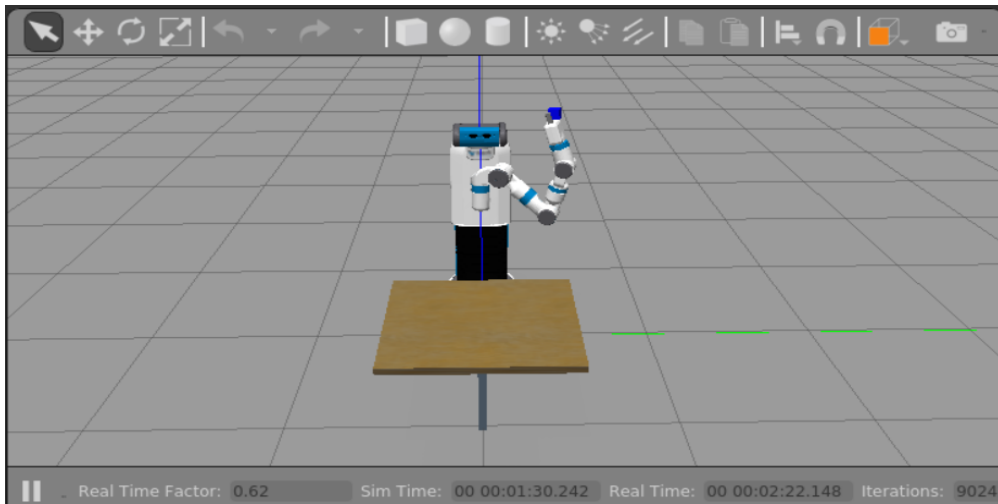


Figure 4: A Gazebo scene of picking up the cube.