Exercise cooperative Robotics – Bimanual Manipulation

November 29, 2022

1 Introduction

In this exercise it's required to perform a bimanual manipulation by implementing the task priority algorithm considering two manipulators as a single robot. The manipulator adopted for this assignment is the Franka Panda by Emika, a versatile 7-DOF manipulator for researchers. Moreover, a simulation in python is provided, in order to visualize the two robots and test yours Matlab implementation.

2 System requirements and installation

For this assignment you have a folder called *bimanual_manipulation_exercise* in which you have the simulator and the matlab template code. In order to be able to complete the exercise you need to have:

- Matlab installed, version > 2019a with the following toolbox installed:
  - Robotic System Toolbox
  - DSP System Toolbox
- Ubuntu version > 18.04 (probably the simulator works with other distributions, but additional installations of python packages may be required.):
  - `python3` working
  - `pyBullet` installed
- To check the correct functioning of your python environment on Ubuntu simply type in a shell: `python3 --version` if a python version is retrieved the check is done, if not follows the guide: https://phoenixnap.com/kb/how-to-install-python-3-ubuntu.
- To install `pyBullet` simply digit in a shell: `pip install pybullet`.

Consider the possibility of using a virtual machine for the simulator if you don't have Ubuntu on your PC. Matlab can run on windows since the data are sended to the simulation using UDP communication.

3 Assignment

3.1 Introduction to the simulator

In order to run the visualization of the bimanual system simply go to the root of the exercise's folder *bimanual_manipulation_exercise* and type in a shell `python3 pybullet_simulation/franka_panda_simulation` to launch the simulator. You'll see a scene with two Franka Panda, the left Arm and the Right Arm see fig 1. Rotate the camera by pressing `ctrl+left_button` while dragging the mouse, move the camera by `ctrl+Alt+left_button` while dragging the mouse.

3.2 Exercise - Bimanual Manipulation

1. First you need to define the transformation matrices between the word frame and the two end-effector frames. The transformations between the word and the base of each robot must be computed knowing that:
   - The left arm base coincides with the word frame.
   - The right arm base is rotated of π w.r.t. z-axis and is positioned 1.05 meters along the x-axis see figure 3
   - The transformation from each base to the respectively end-effector is given in the code.
   - Notice the initial orientation of the end-effectors in the following figures 2 and 3
2. Define the tool frame for both manipulators, the tool frame must be oriented as the end-effector of the manipulator and placed at 10 cm from the end-effector frame along the z-axis, see figure 4.
3. The first objective is to move the tool frame of both manipulators to the grasping points. Define the tool goal frame such that the robot grasps the object at the closest end. HINT: you need only the length of the object to define the grasping point, which is equal to 10 cm. See figure 5.

$$^{w}\mathrm{o} = [0.5, 0, 0.59]; \tag{1}$$

$$length = 10cm; \tag{2}$$

4. Reach the grasping point with a suitable tool's orientation for bimanual manipulation

$$R_{goal}^{Left} = \begin{bmatrix} 0.9781 & 0 & -0.2079 \\ 0 & 1 & 0 \\ 0.2079 & 0 & 0.9781 \end{bmatrix} R_{goal}^{Right} = \begin{bmatrix} 0.9781 & 0 & 0.2079 \\ 0 & 1 & 0 \\ -0.2079 & 0 & 0.9781 \end{bmatrix} \tag{3}$$

Once the manipulator reach the grasping points the second phase of the mission should start. Now you have to implement the Bimanual Rigid Grasping task to carry the object as a rigid body.

1. Define the object frame as a rigid body attached to the tool frame of each manipulator.
2. Define the rigid grasp task
3. Finally, you have to move the object to another position while both manipulators hold it firmly. Below the object goal position.

$$^{w}\mathrm{o}_{g} = [0.5, -0.5, 0.5] \tag{4}$$

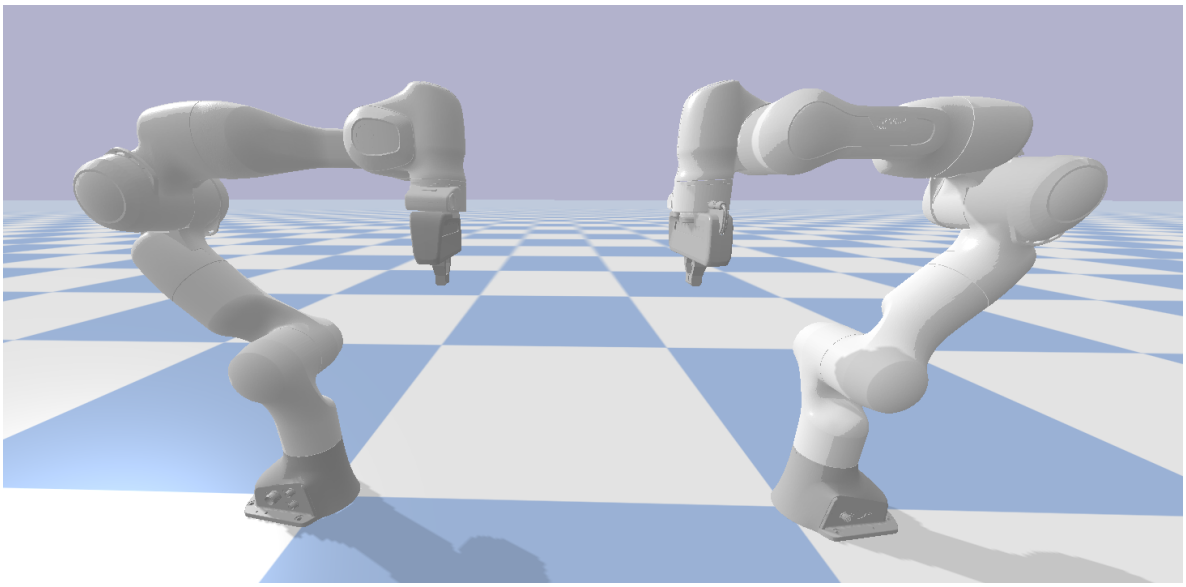

Figure 1: Left and Right Arm of the bimanual system

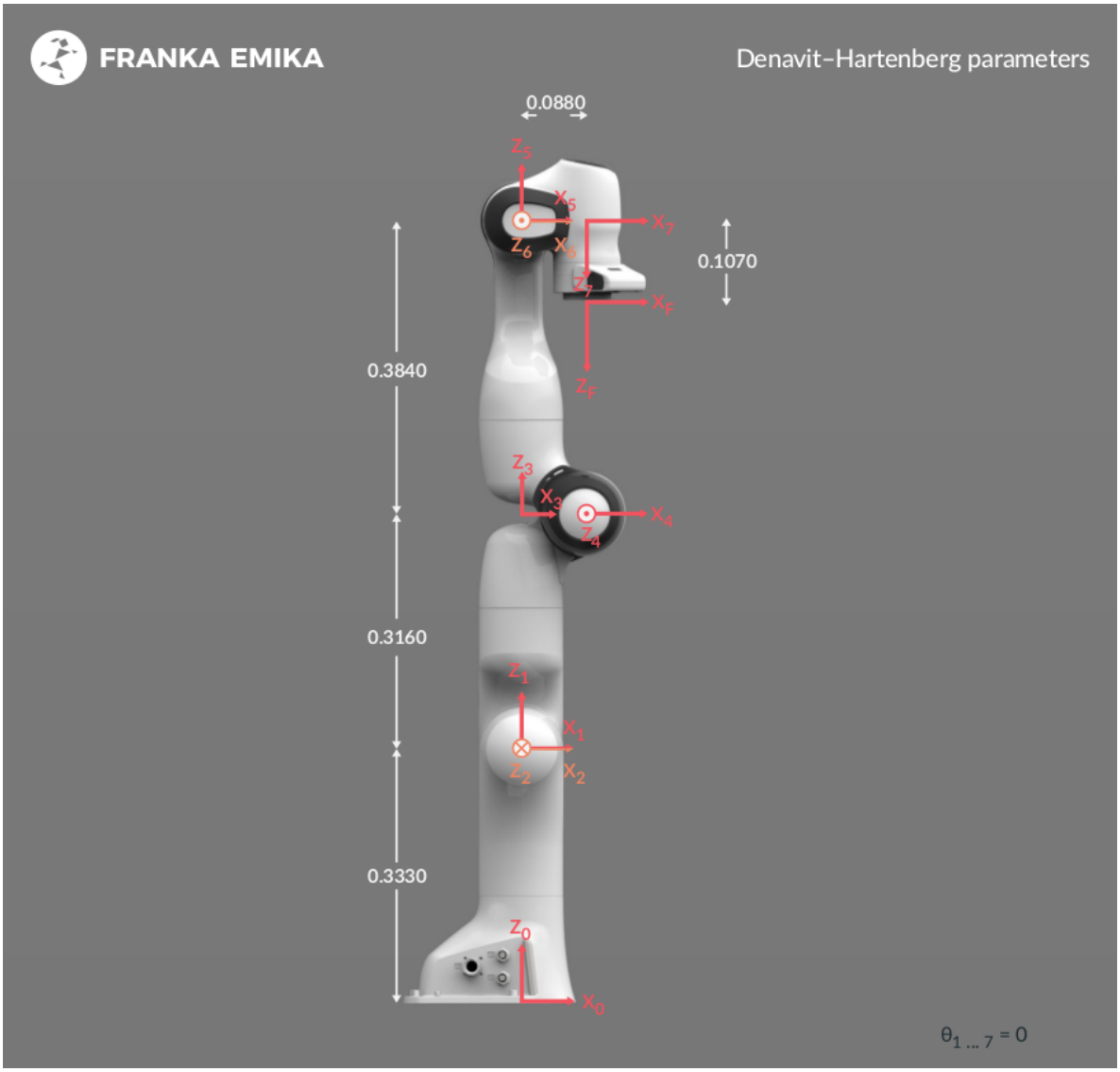

Figure 2: Robot Specifications

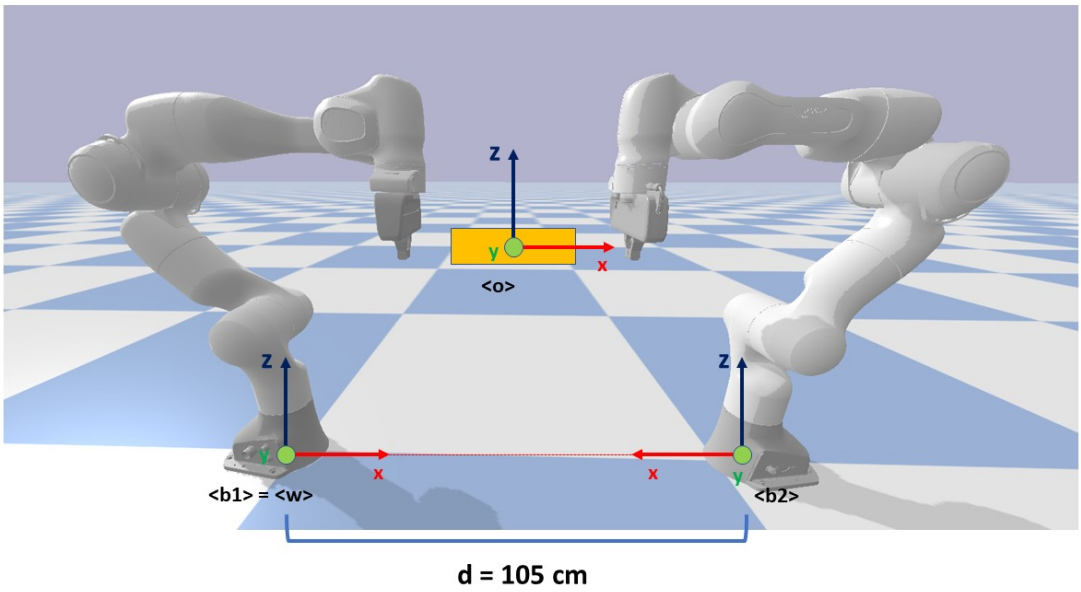

Figure 3: Basic transformation matrices

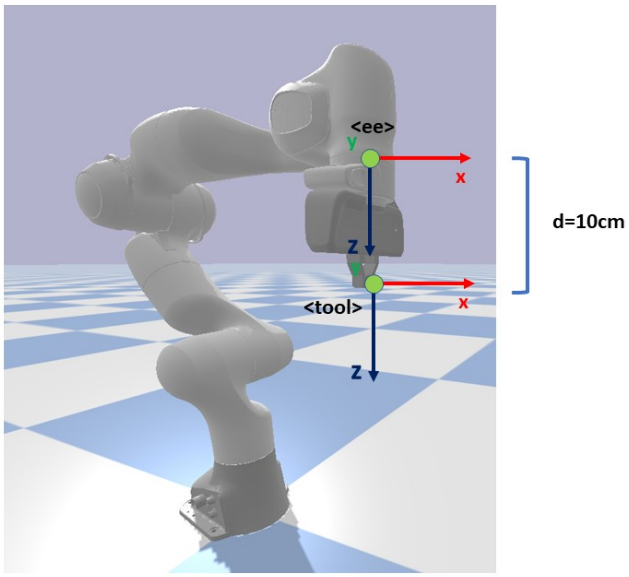

Figure 4: E-E frame and Tool frame of Left Arm

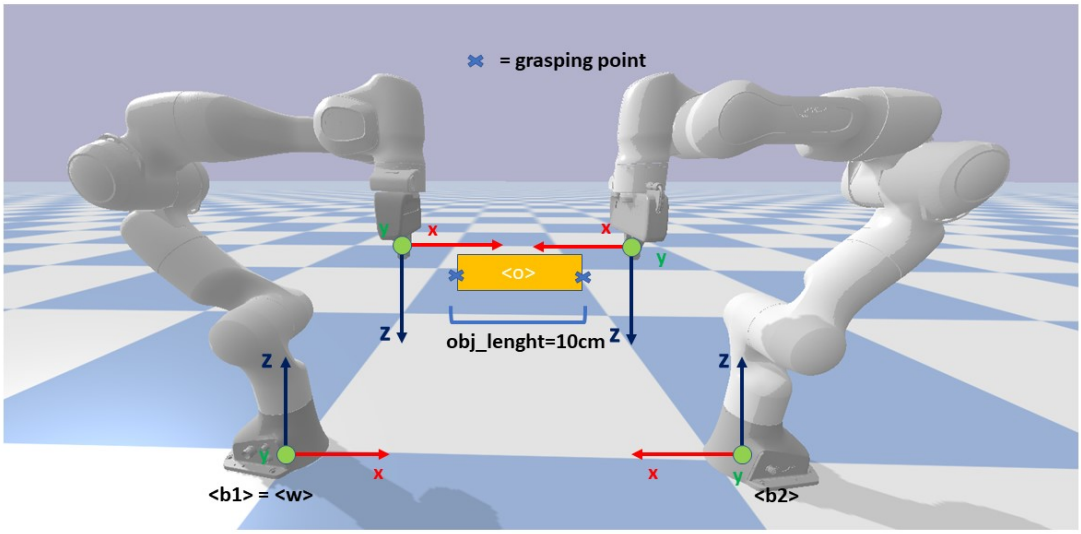

Figure 5: Tool frame positioning