ENPM662 - Fall 2022

Homework - 03

Due: 28th October 2022 Points/Weightage: 5 points

1. Position Kinematics – UR10 [3.5 points]

Here, your task is to setup the forward position kinematics of the UR10e robot from Universal Robots (see Fig. 1) to describe the pose (pose + orientation) of the end-effector (*Frame {n}*) with respect to the base frame (*Frame {0}*) of the robot. The robot contains 6 revolute joints, which is exactly the minimum number of joints required to achieve any position and orientation in 3D Cartesian space.

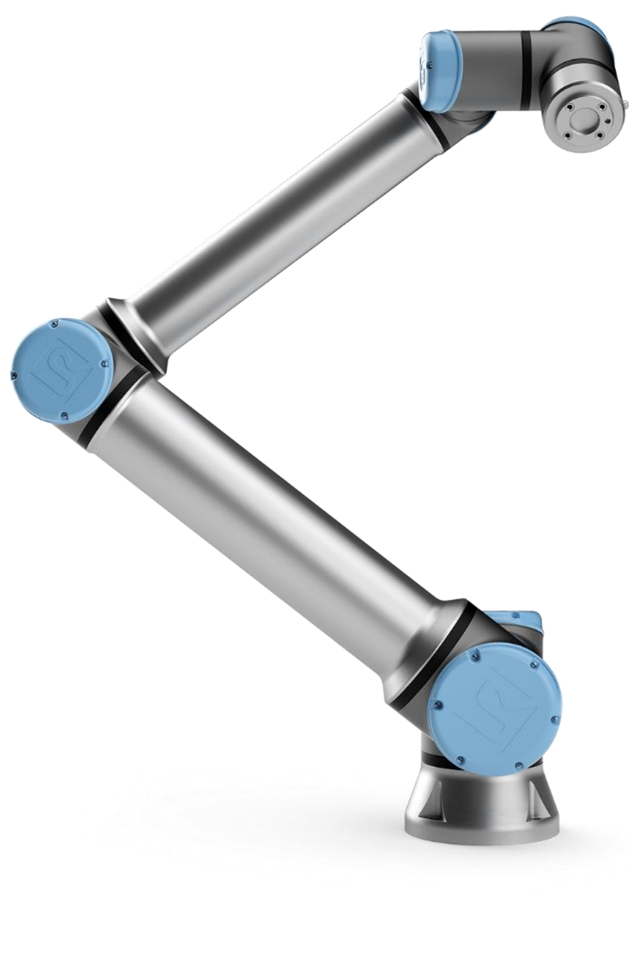

Fig. 1: UR10e cobot

Using the **standard form (Spong)** of the Denavit-Hartenberg (D-H) convention, assign the coordinate frames for each link of the robot in its home configuration (all joint angles are zero, as shown in Fig. 2) and set up the D-H table for the assigned frames. Using **Python's SymPy library**, set up the following and validate your equations parametrically for **5 geometrically known configurations** (rotate joints by 90 degrees).

1. Draw all the D-H coordinate frames for Fig. 2.
    a. Assign the frames on the corresponding orange circles with the right choice of the Z axis
    b. The base frame {0} is included in Fig. 2. The final end-effector frame {n} can simply replicate the frame preceding it.
2. Write down the D-H table.
3. Show all the <u>successive</u> link transformation matrices, $^{i-1}\mathbf{T}_i$.
4. Show the final transformation matrix between the base frame and the end-effector frame, $^{0}T_{n}$.

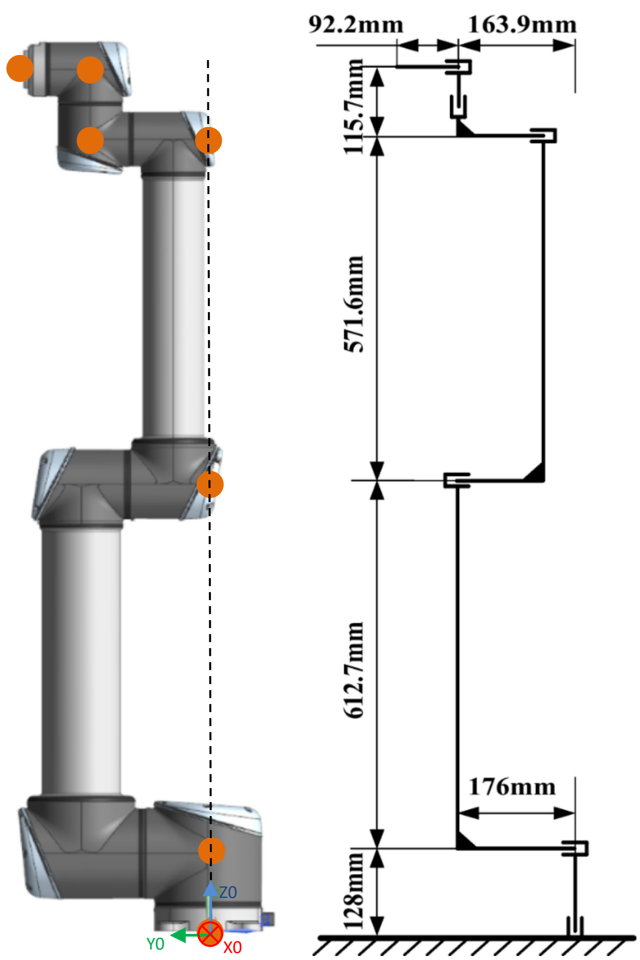

Fig. 2: UR10 - Home configuration

2. Position Kinematics - KUKA [1.5 points]

As done previously for the UR10 cobot, set up the forward position kinematics for the below Franka Emika Panda robot (a 7 DOF robot), using the **standard form (Spong)** of the D-H convention.

1. Draw all the D-H coordinate frames for Fig. 3.
    a. The base frame {0} is included in Fig. 3. The final end-effector frame {n} can simply replicate the frame preceding it.
2. Write down the D-H table.

You **do not** need to show the homogeneous transformation matrices **nor** perform the geometric validation as done previously.

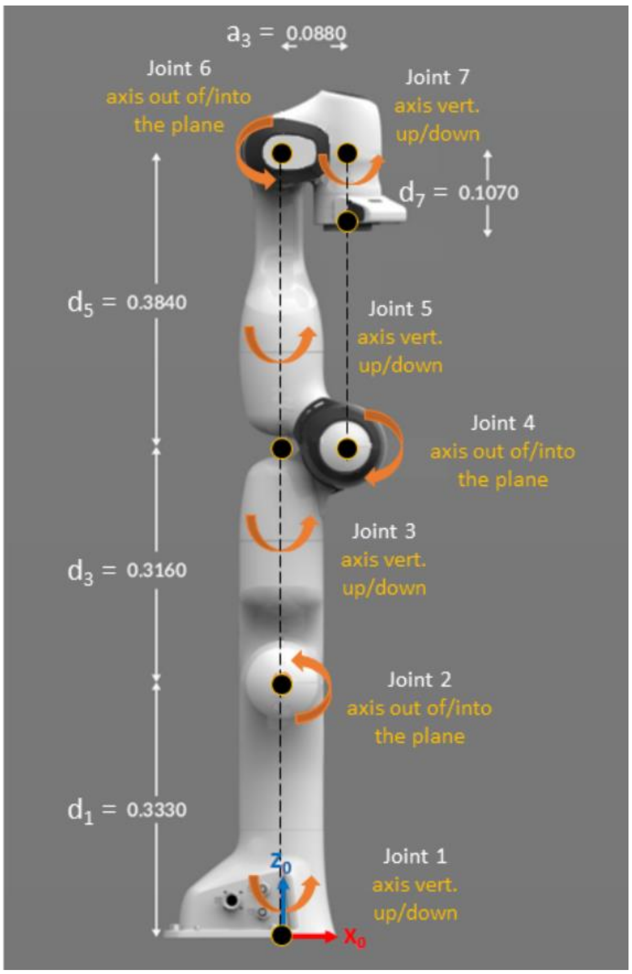

Fig.3: Panda Robot - Home configuration

(Optional) To visualize the assigned frames and verify the setup D-H table, the Peter Corke Robotics Toolbox for MATLAB contains functions that enable visualizing any robot given a D-H table and functions to compute forward and inverse kinematics. **Here** are tutorials for you to explore this toolbox to assist you in the learning of this course, you can also check the course page and software sessions for additional information.

3. Deliverables

- A **PDF** report containing the answers to all the questions above (preferably typed). For results that are large or tedious to write manually, you may simply include a screenshot of that matrix as displayed in the terminal output after running your code.
  - Name your report: ***<your-directoryID>_hw3_report.pdf*** [Note: Directory ID ≠ UID!]
- All codes used for **Q1 (UR10)**. These codes **must** print the matrices obtained in Q1.3 and Q1.4 to the terminal (use *pprint* from SymPy to pretty print your matrices), along with the geometric validation (any 5 known configurations).
- Submit the above in 2 files (do not zip them up, drag both the files and submit them on ELMS as a single submission)
  - Structure:
    - *<your-directoryID>_hw3_report.pdf*
    - *<your-directoryID>_hw3_code.py —> should contain all codes (.py) used for Q1*
    - *<your-directoryID>_hw3_readme —> optional md or txt file with code execution instructions*