# ENPM662 - Fall 2022

## Homework - 03

Due: $28^{th}$ October 2022 Points/Weightage: 5 points

## 1. Position Kinematics - Panda [3.5 points]

Here, your task is to setup the forward position kinematics of the Franka Emika Panda (see Fig. 1) robot 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 7 revolute joints, which is more than the minimum number of joints required to achieve any position and orientation in 3D Cartesian space.

Fig. 1: Franka Emika Panda 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** and assuming the **link lengths (*a* & *d*) as variables**, 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 black circles with the right choice of the Z axis for the positive sense of joint rotation (orange arrows, Fig. 2)
    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 successive link transformation matrices, $^{i-1}\mathbf{T}_i$.
4. Show the final transformation matrix between the base frame and the end-effector frame, $^{0}T_{n}$.

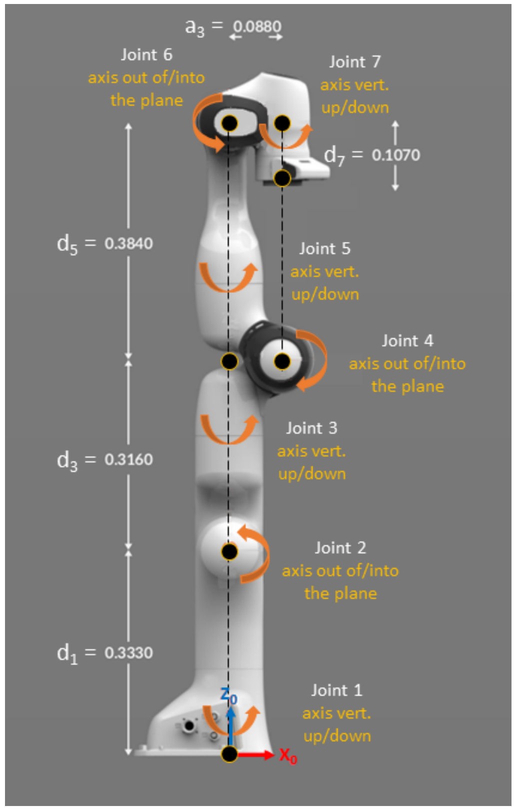


Fig. 2: Panda Robot - Home configuration

(Orange arrows indicate the positive sense of joint rotation)

## 2. Position Kinematics - KUKA [1.5 points]

As done previously for the Panda cobot, set up the forward position kinematics for the below [KUKA LBR iiwa robot]() (also 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.

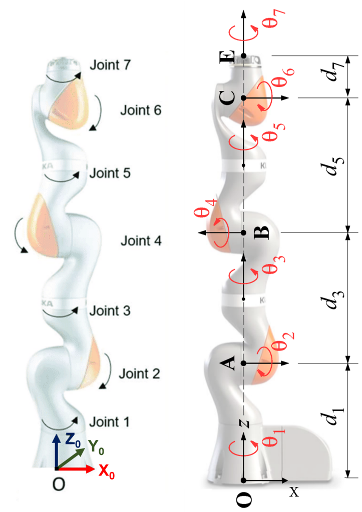


Fig.3: Kuka Robot - Home configuration

(The picture on the left contains Frame {0} and the one on the right contains the positive sense of joint rotation)

**(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** and **here** are tutorials for you to explore this toolbox to assist you in the learning of this course!

# 3. Deliverables

- A **PDF** report containing the answers to all of the questions above (either hand-written or 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 (Panda)**. 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).
  - Include a *readme* file that briefly describes how to run your code(s) and if any dependencies need to be installed.
- Submit the above in a .zip file with the name: ***<your-directoryID>_hw3.zip***
  - Folder Structure:
    - *<your-directoryID>_hw3.zip / readme.MD (or readme.txt)*
    - *<your-directoryID>_hw3.zip / <your-directoryID>_hw3_report.pdf*
    - *<your-directoryID>_hw3.zip / code —> should contain all codes (.py) used for Q1*