Assignment I
Robotics for IEM

September 2023

1 General Notice

1. Important Dates: This assignments starts on **14/09/2023** and ends at **28/09/2023**. This means you should hand in your assignment on *BRIGHTSPACE* no later than 23:59 at **28/09/2023**.

2. You need to hand in a mini-report (made in LaTeX) along with code files. The mini-report has to be brief, clear and easy to read. **We cannot grade what we cannot read.** In this mini-report, you only need to write down the answers to the questions below. In particular, you should write down how you get your answers (e.g., the computation process) rather than only the final results. You can include figures of your drawings in the mini-report, for instance for drawing frame assignments etc.

   Code template files will be provided. These template files provide frameworks and you only need to fill in what is required. DO NOT change the frameworks of the codes (e.g., the format of the inputs of a function).

3. Your mini-report will be graded by the TAs, but the code files will be graded automatically by Matlab scripts. This means that it is your responsibility to make sure that your codes run successfully without reporting any errors. **Unrunable (erroneous) codes and incorrect answers will be graded ZERO by the automatic scripts.** Incorrect answers are those of which the differences from the correct answers exceed some manually set threshold.

4. To avoid version conflicts, you are encouraged to use **MATLAB (2022 or higher)** in UWP, provided by the university, although other versions should work. The recommended robotics toolbox by Peter Corke is **RTB10.4.** A manual named RoboticsToolboxManual about the toolbox is available on *BRIGHTSPACE*.

2 Hand in Materials for this Assignment

Each student has to hand in a zipped folder on the corresponding assignment page on *BRIGHTSPACE*. The name of the this zipped folder should be according to the syntax *SNumber_Assignmenty.zip*. For example, if S123456 is submitting the first assignment, then the zipped folder should be named *S123456_Assignment1.zip*. The contents of the zipped folder is listed below.

- PDF file of the mini-report made in LaTeXwith the answers (and derivations) to the questions in Section 3 of this document.
- MATLAB Code files necessary for this specific assignment, being *fk.m* and *arm_creation_val.m*

3 Questions

Question 1 (40%)

Figure 1 shows a non-planar robot arm with two revolute joints. The base frame (0) and the end-effector frame (3) have been drawn.

1. Assign frames to the two joints. For the directions of the axis perpendicular to the paper, $\odot$ represents pointing vertically outward from the paper, like frame 3, and $\otimes$ pointing vertically inward to the paper, like frame 0. Put your answer in the mini-report. (10 %).

2. Give its Denavit-Hartenberg table. Put your answer in the mini-report. (10%).

3. Derive all neighboring homogeneous matrices ${}^{i-1}_{i}T$, $i = 1, 2, 3$, and find the 4×4 homogeneous transformation matrix ${}^{0}_{3}T$ from the base frame to the end-effector frame. Put the answers and derivations in the mini-report (10 %).

4. Fill the provided incomplete MATLAB function file *fk.m*. This function takes the two joint angles as input and returns the end-effector position, as a 3D vector. Assume the link lengths are $L_1 = L_2 = 1$. Give the position in $\begin{bmatrix} x \\ y \\ z \end{bmatrix}$ for the angles $\Theta = \begin{bmatrix} \theta_1 \\ \theta_2 \end{bmatrix} = \begin{bmatrix} \frac{\pi}{4} \\ \frac{\pi}{5} \end{bmatrix}$ and for $\Theta = \begin{bmatrix} \frac{\pi}{6} \\ \frac{\pi}{2} \end{bmatrix}$ and put the in the mini-report (10%).

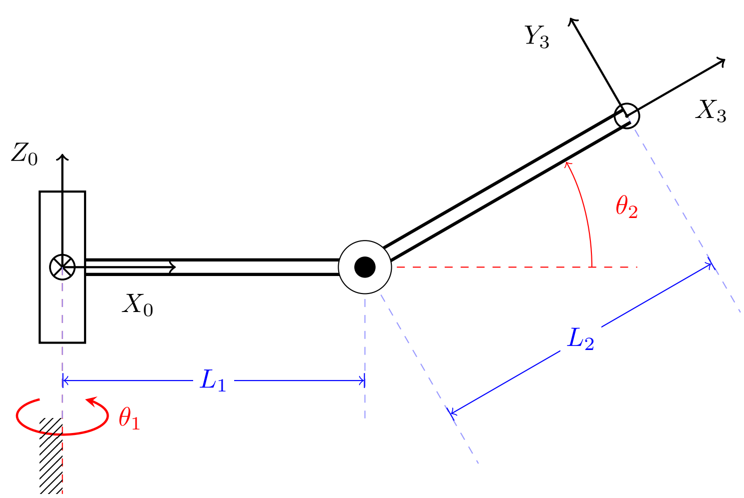

Figure 1: 2R robot (non-planar)

Question 2 (60%)

We will use the lightweight, low-cost robotic manipulator AX-18A SMART ROBOTIC ARM throughout the online lab session, shown in Figure 2. This question requires the use of the Robotics Toolbox developed by Peter Corke, which you can download here. The needed functionalities of the Toolbox are described in the manual downloadable from BRIGHTSPACE.

Figure 2: AX18A Robotic Arm

1. Assign frames for the robot arm in the schematic Figure 3, frame 1 is already assigned. Note that the robot in Figure 3 is not in zero-configuration. Put your answers (drawings) in the mini-report. (15%)
2. Determine the Denavit-Hartenberg parameters and put the DH-table in the report (We use the configuration as in Figure 3, which has offsets). (12.5%)
3. Derive the corresponding neighboring transformation matrices ${}^{i-1}_{i}T$, $i = 1, ..., 6$. put your answers in the mini-report. (12.5%)
4. Consider an arbitrarily defined robotic arm with a combination of prismatic and revolute joints. How does each of the DH parameters change as the robot moves in the reachable workspace? What is the significance of each of the four DH parameters? (10%)
5. Fill the provided incomplete MATLAB script arm_creation_val.m. Your task is to use the DH parameters and the Robotics Toolbox, create the model of the robotic arm (name the arm pArb). Then plot it in the zero configuration (see Figure 4). To plot the gripper you can use the command pArb.tool from the toolbox. Assume the link length parameters are $L_1 = 17, L_2 = 17, L_3 = 7, L_4 = 4, L_5 = 4, L_6 = 9$ (lengths in cm). (10%)

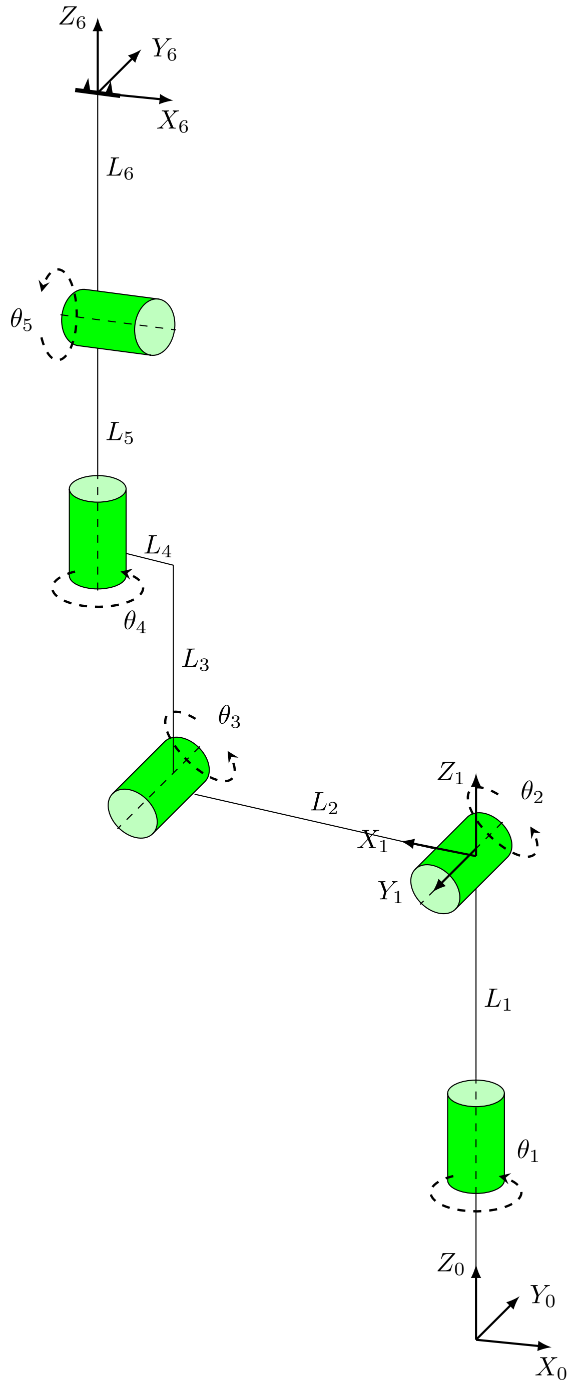

Figure 3: AX18A schematic, the following offsets exists from the zero configuration: $\theta_2 = \frac{\pi}{2}, \theta_3 = -\frac{\pi}{2}$

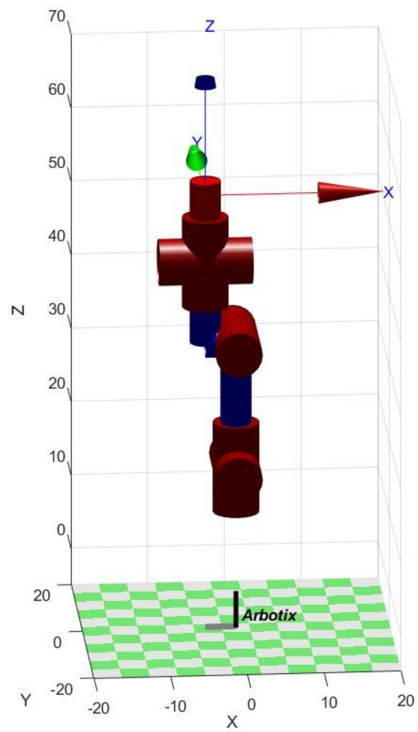

Figure 4: pArb plotted in zero configuration in the Robotics Toolbox MATLAB