MCE/EEC 647/747
Midterm Exam
Take-Home Portion
25 points

A PUMA robotic manipulator fitted with a laser beam will be used in the lab to measure world coordinates. Only the first three joints will be used. Figure 1 shows a plan view and a frontal view of the robot, along with coordinate frames according to the DH convention. A photo is shown in Fig. 2.

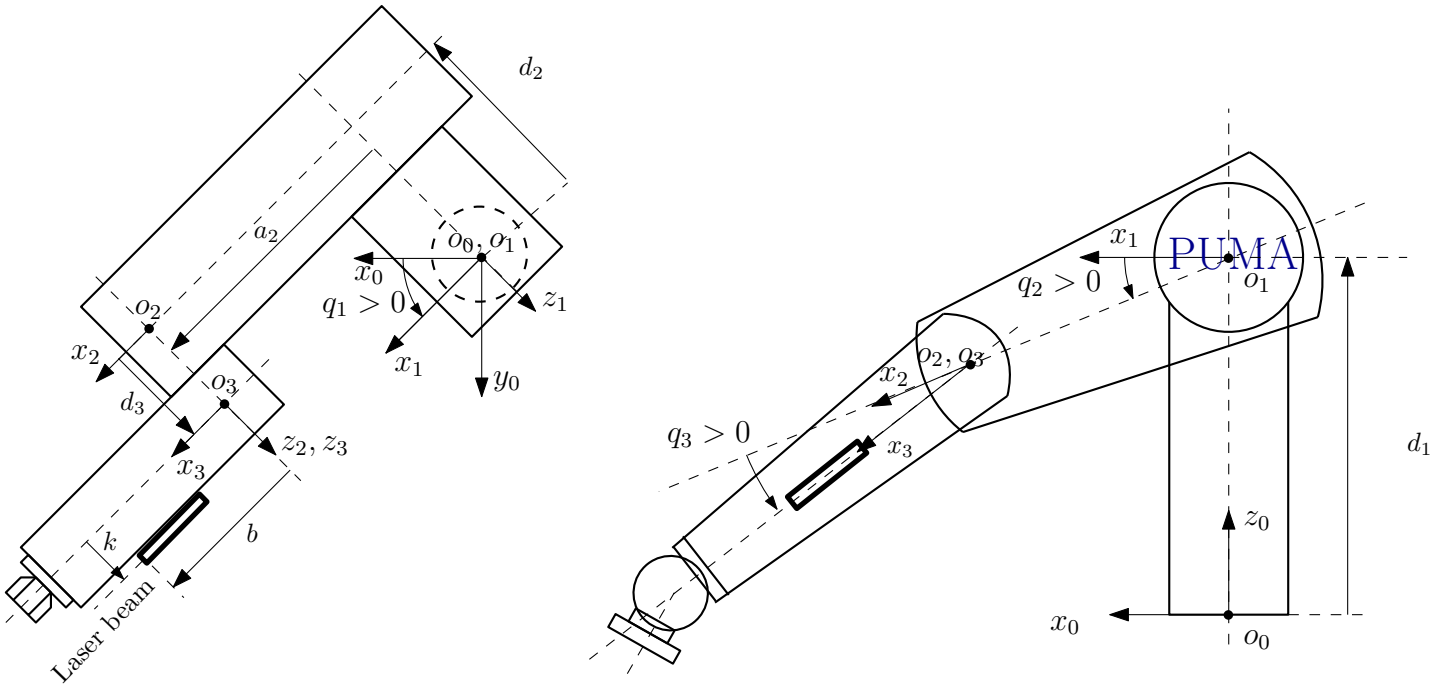

Figure 1: PUMA robot and frames

Table 1 lists all relevant dimensional parameters, some measured directly, some from Corke and Armstrong [1].

Length	Value (mm)
d_1	666
d_2	243.5
a_2	431.8
d_3	93.4
b	270
k	52.1

Table 1: PUMA length parameters

A manual control system has been prepared that allows precise pointing with the laser beam. The three joint angles corresponding to any desired beam direction are the only data that will be collected. That is:

- The distances between the light source and the chosen target points are not known, and direct measurement is not to be attempted.
- Nothing can be assumed about the relative orientations and distances between the world coordinate system and lab objects (walls, tables, etc).

A very accurate circle given by a racing bicycle wheel will be used as a reference. Only the radius of the circle will be known. As many points as necessary will be collected by pointing the laser at the wheel and reading the corresponding robot joint angles.

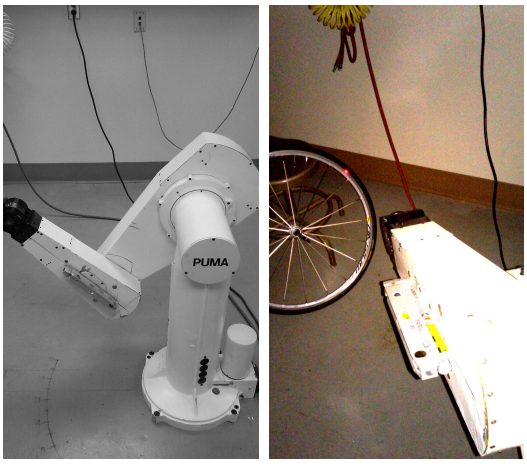

Figure 2: PUMA robot in the lab and laser pointing at a bicycle wheel

- This is a group activity, with up to 4 students per group. Different solutions are expected from each group.
- What is the minimum number of points to be taken along the wheel's circumference to determine their coordinates, the coordinates of the center and the distances between the points and the light source?
- In the lab, more points than the minimum will be taken. Carefully describe a sequence of calculations to be used to find the required information from the collected data.
- Table 2 shows data collected for a conventional bicycle wheel with a radius of 33 cm. Test your algorithm with this data. Provide the coordinates of every point and the center. The instructor's algorithm finds the center coordinates to be $c = [2.1192 \quad -0.9218 \quad 0.8367]^T$ meters. Your results may be slightly different, depending on the method.

This portion of the exam is due on March 17th (one report per group). One group member will be asked to give a 5-minute presentation explaining the solution approach. Also observe the following:

1. Each group will be allowed 45 minutes for data collection in the lab.
2. If any group finishes this portion early, the instructor will be available during the Spring break for data collection. Email to coordinate.
3. One class hour either on March 17 or March 19 is available for one group.
4. Data collection must be scheduled and completed by all groups by March 20th at the latest. Please coordinate with the instructor for time outside class hours (class office hours is an ideal time).
5. A separate lab guide will be provided.

Point	q_1	q_2	q_3
1	-0.379	-0.642	0.520
2	-0.227	-0.884	0.914
3	-0.513	0.495	-0.759
4	-0.478	0.519	-0.672

Table 2: Sample Data (radians)

References

[1] Corke, P.I. and Armstrong-Hélouvry, B. *A search for consensus among model parameters reported for the PUMA 560 robot*, Proc. IEEE 1994 Intl. Conf. Robotics and Automation, San Diego, California.