# Assignment 6

## ME 639 - Introduction to Robotics

IIT Gandhinagar

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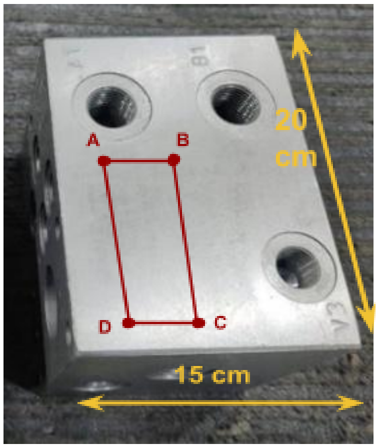
**Assigned:** 9 November, 2023
**Due: 11:59pm** on **Wednesday, 15th November, 2023** on GitHub
**Collaboration Policy:** Discussion with all classmates (including phone calls and WhatsApp messages) and TA are permitted, however no exchange of (or showing) equations, or lines or sections of code are permitted with members outside your group.

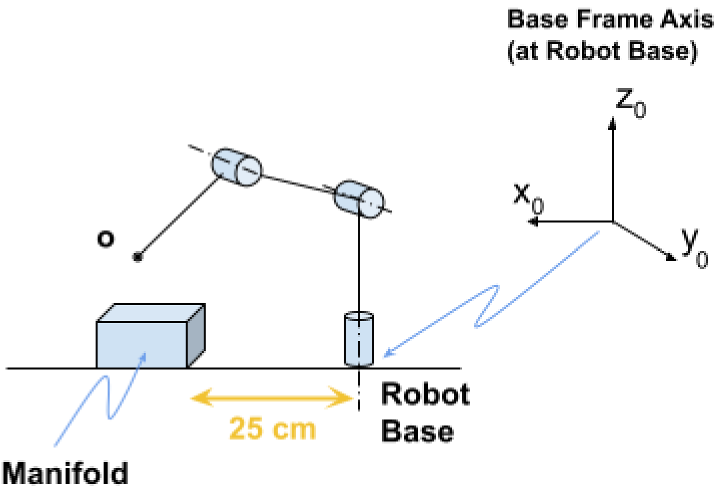
**Tasks:**

1. Consider a planar 3R manipulator with link lengths 1 m each. Using the method that Shail discussed in class last week, write an inverse kinematics code to solve for the joint angles required to trace a circle of radius 1.5 m centred at the base of the manipulator. Verify your results by plotting the results and observing if it indeed traces the desired circle.

2. Consider a manifold block inspection project in which surface roughness on the top surface of the manifold shown in the image is to be checked by a robot. The following subtasks are to develop and execute a trajectory to be followed by an inspection robot such that the robot makes contact with the top surface of the manifold at point A and then traces out a path A-B-C-D-A while in contact with the surface.




   Let us assume that the manifold block is 20 cm by 15 cm with 10cm height (as shown in the image). As illustrated in the schematic below showing a robot (with an PUMA-style RRR configuration), the manifold block is situated 25 cm away from the robot base and is on the same horizontal surface as the robot. The base frame axis ($o_0x_0y_0z_0$) directions are indicated in the schematic (shown separately for



simplicity). Point **o** shown in the figure is the wrist centre. The manifold block's longest side is aligned with the $x_0$ direction in the base frame and the shorter side is aligned with the $y_0$ direction in the base frame.

Please note that the maximum possible range of the (x,y,z) coordinates (in metres) of points A, B, C and D are (0.45, 0.075, 0.1), (0.45, -0.075, 0.1), (0.25, -0.075, 0.1), and (0.25, 0.075, 0.1) respectively, as these are the coordinates of the corners of the top surface of the manifold block. Also note that the z-coordinate on the top surface of the manifold block is always 0.1.

Consider any one 3DOF robot configuration of your choice from the ones used in the previous assignments (could be Stanford-type, PUMA, or SCARA) for the following tasks. Assume all link lengths to be 0.25m and masses of all links to be 0.8kg and moment of inertia to be 0.005 kg-m$^2$. Feel free to either assume any other values that may be needed or change the values of the above parameters if necessary (stating any such assumptions or changes clearly in your solution file). Assume only three links (no wrist).

a. Verify that the entire top surface of the manifold lies within the robot workspace by ensuring that all four corners lie within its workspace, by using inverse kinematics to compute joint parameters and then substituting these joint parameters in the forward kinematics to ensure that the same coordinates are obtained back. If any of the points are outside the workspace, accordingly change the link lengths (and state the new link lengths) to ensure they come within the workspace. Submit both the code and the output from the code showing computed joint variables and the verification.

b. Choose A = (0.40, 0.06, 0.1), B = (0.40, 0.01, 0.1), C = (0.35, 0.01, 0.1), and D = (0.35, 0.06, 0.1) such that these coordinates trace out a 5cm X 5cm square. Generate a trajectory (using your choice of approach) to be used as the desired trajectory for the computation of the control inputs to trace the square ABCD will be traced by the robot. Submit both the explanation of the approach used and the code and its output showing computed joint variables and cartesian variables as functions of time.

c. Synthesize a multivariable control scheme (including feedforward inputs, and ensuring errors will decay with critically-damped behaviour). Explain your approach/key steps, and demonstrate the method in a dynamic simulations (with small amounts of disturbances added to the joint torques as additional external disturbances that are not accounted for in the control algorithms). Submit codes and results and plots from the simulations.