National University of Singapore
Faculty of Engineering

Drill Problem Set 2: ME4245/EE4304: Robotics Term 1, 1997/1998

1. Figure 1 shows the schematic diagram of the Intelledex Robot Model 605T. This robot is a six-axis manipulator consisting of all rotational joints with axes 0, 1, and 2 always co-intersecting at a common point. (Axis 5 intersects at the same co-intersection point only at the configuration shown in Fig. 1.)

a. Assign coordinate frames to each link according to the Denavit-Hartenberg convention *and* the following rules:
   - The base frame (frame 0) should be as indicated in the figure. Its origin should coincide with the co-intersection point of axes 0, 1, and 2.
   - The end-effector frame should be as shown in the figure.
   - To the maximum extent possible, make r_i and d_i be equal to zero

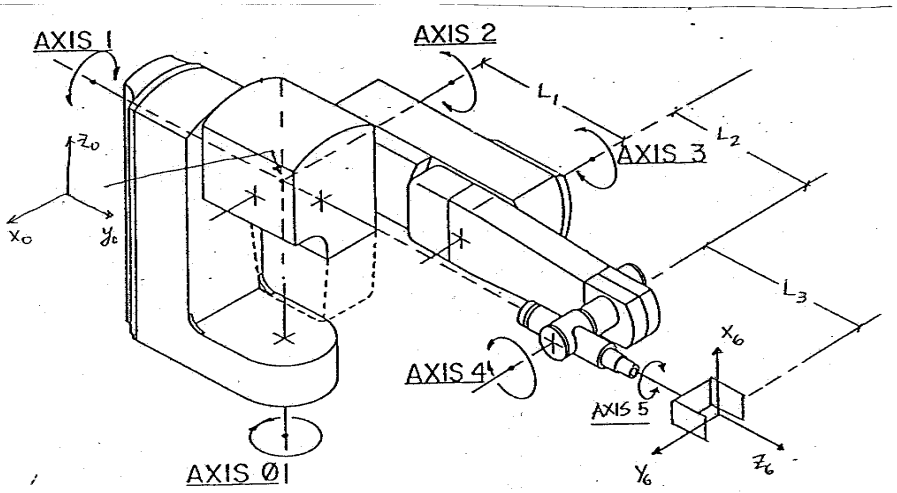
b. Identify the kinematic parameters of the robot by filling in the table in Figure 2.

c. If at the configuration shown in Figure 1, axis 1 has a joint motion range of ± 115°, determine the joint motion range in terms of q_2 (joint variable for 2nd joint, assigned according to the Denavit-Hartenberg convention, item a above.).

d. What are the values of the six joint coordinates for the robot at the configuration shown in Figure 1?

e. Identify the decoupled subsystem, if any, i.e., determine the subset of the task and the subset of joint coordinates responsible for the task.

f. Derive the complete inverse kinematic solution for the intelledex robot.



Link	θ	r	d	α
1				
2				
3				
4				
5				
6				

Figure 1

2. Figure 2 shows a 3-joint robot with one translational joint. It is a cylindrical robot whose first two joints are analogous to polar coordinates when viewed from above. The last joint provides "roll" for the hand.

a) Assign a coordinate frame to each link according to the Denavit-Hartenberg convention (given in class).
b) Identify and tabulate the Denavit-Hartenberg parameters.
c) Compute ${}^0T_3$.
d) Describe the three degrees-of-freedom of the robot in Cartesian space.
e) Derive the complete inverse kinematic equations for the robot.

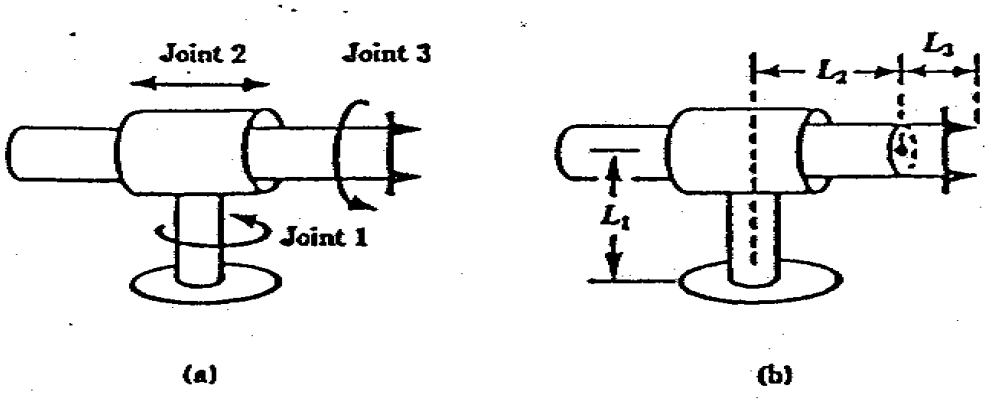


Figure 2

3. Coordinate frame *N* is attached to an end-effector as shown in Figure 3. It is desired to design an *N*-joint robot that can provide the following position and orientation of the end-effector:

$$ {}^0T_N = \begin{pmatrix} n_x & o_x & 0 & p_x \\ n_y & o_y & 0 & p_y \\ 0 & 0 & -1 & p_z \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

where n_x, n_y, o_x, o_y, p_x, p_y, and p_z are functions of the robot joint coordinates.

a) What is the minimum number of degrees-of-freedom required of the robot? (That is, what is the minimum number of joints?)
b) Suggest a robot structure/configuration that can satisfy the task ${}^0T_N$. That is, identify the number and type of joints, draw the base frame 0 and provide a schematic diagram of the robot including the end-effector and its frame *N*.

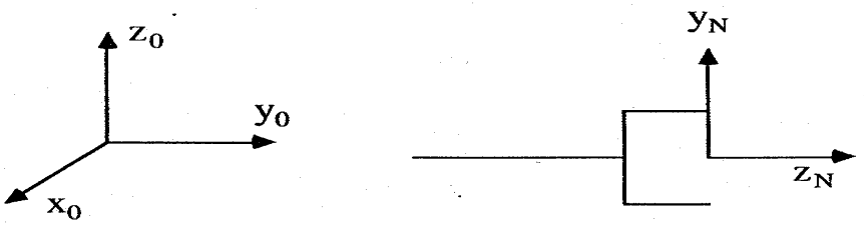


Figure 3