PROBLEMS

4-1 Given a desired position of the end-effector, how many solutions are there to the inverse kinematics of the three-link planar arm shown in Figure 4-12? If the orientation of the end-effector is also specified, how many solutions are there? Use the geometric approach to find them.

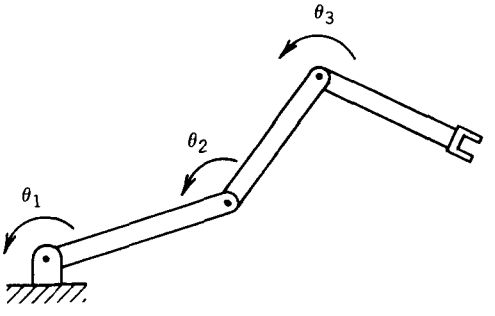

FIGURE 4-12
Three-link planar robot with revolute joints.

4-2 Repeat Problem 4-1 for the three-link planar arm with prismatic joint of Figure 4-13.

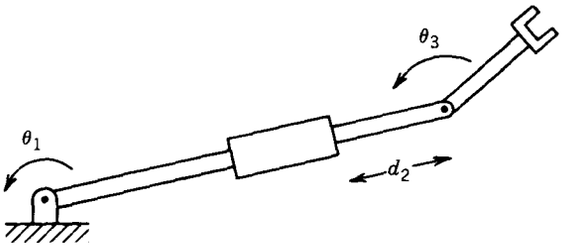

FIGURE 4-13
Three-link planar robot with prismatic joint.

4-3 Solve the inverse position kinematics for the cylindrical manipulator of Figure 4-14.

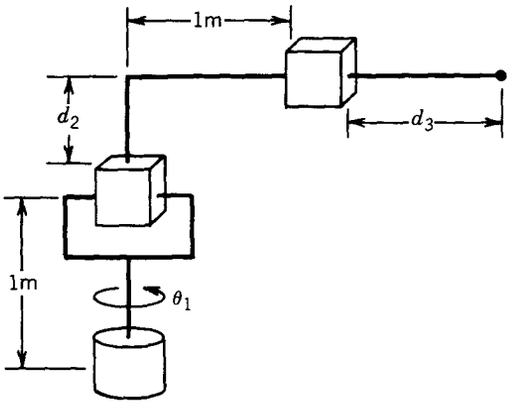

FIGURE 4-14
Cylindrical configuration.

4-4 Solve the inverse position kinematics for the cartesian manipulator of Figure 4-15.

4-5 Add a spherical wrist to the three-link cylindrical arm of Problem 4-3 and write the complete inverse kinematics solution.

4-6 Repeat Problem 4-5 for the cartesian manipulator of Problem 4-4.

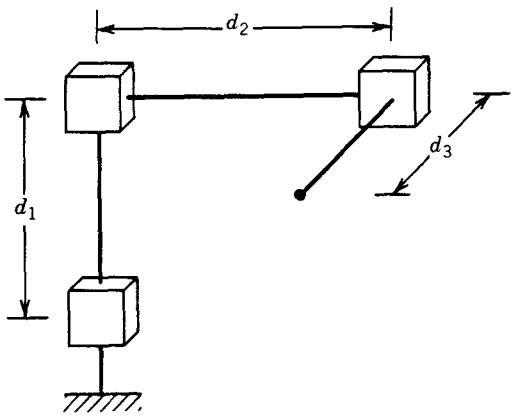

FIGURE 4-15
Cartesian configuration.

4-7 Write a computer program to compute the inverse kinematic equations for the elbow manipulator using Equations 4.4.26–4.4.31. Include procedures for identifying singular configurations and choosing a particular solution when the configuration is singular. Test your routine for various special cases, including singular configurations.

4-8 The Stanford manipulator of Example 3.3.5 has a spherical wrist. Therefore, given a desired position **d** and orientation R of the end-effector,

a) Compute the desired position of the wrist center $\mathbf{p}_c$.

b) Solve the inverse position kinematics, that is, find values of the first three joint variables that will place the wrist center at $\mathbf{p}_c$. Is the solution unique? How many solutions did you find?

c) Compute the rotation matrix R_0^3. Solve the inverse orientation problem for this manipulator by finding a set of Euler angles corresponding to R_3^6 given by (4.4.14).

4-9 Repeat Problem 4-8 for the PUMA 260 manipulator of Problem 3-9, which also has a spherical wrist. How many total solutions did you find?

4-10 Solve the inverse position kinematics for the Rhino robot.

4-11 Find all other solutions to the inverse kinematics of the elbow manipulator of Example 4.4.1.

4-12 Modify the solutions θ_1 and θ_2 for the spherical manipulator given by Equations 4.3.11 and 4.3.12 in the case of a shoulder offset.