ME 115(a): Final Exam

(Winter Quarter 2001/2002)

Instructions

1. Limit your total time to 5 hours. That is, it is okay to take a break in the middle of the exam if you need to ask me a question, or go to dinner, etc.
2. You may use any class notes, books, or other written material. You may not discuss this final with other class students or other people except me or the T.A..
3. You may use mathematica or any software or computational tools to assist you. However, if you find that your solution approach requires a lot of algebra or a lot of computation, then you are probably taking a less than optimal approach.
4. The final is due by 5:00 p.m. on the last day of finals.
5. The point values are listed for each problem to assist you in allocation of your time.

Problem 1: (35 Points)

Consider the three jointed manipulator shown in Figure 1. This first two joints of this manipulator are revolute joints, while the third joint is a prismatic joint. The joint axes are parallel to each other

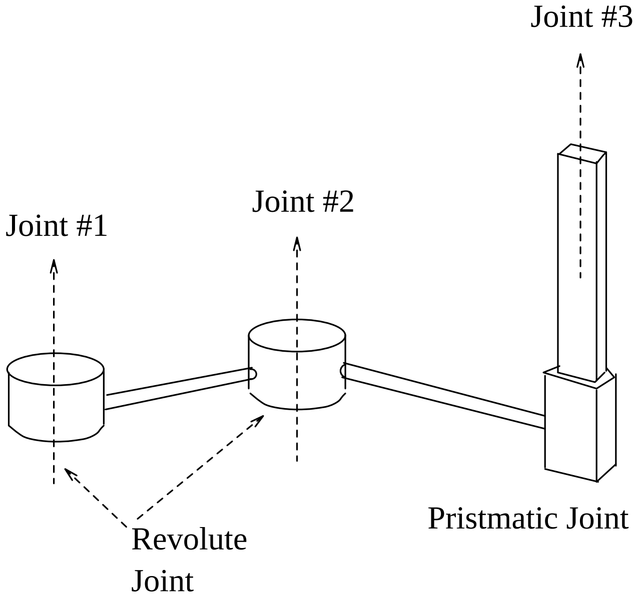

Figure 1: Schematic of RRP Manipulator Geometry

Part (a): (3 points) Determine the Denavit-Hartenberg parameters.

Part (b): (7 points) Using either the Denavit-hartenberg approach or the product-of-exponentials approach, determine the forward kinematics. That is, relate the coordinates of the origin of the tool frame to the joint angles.

Part (c): (15 points) Solve the inverse kinematics of this manipulator, assuming that the goal is to position the origin of the tool frame.

Part (d): (10 points) Find the spatial Jacobian matrix of this manipulator.

Problem 2: (15 points)

Consider the planar object shown in Figure 2 which is grasped by two frictionless fingers. Assume that the contact normals of both finger contacts are collinear. Describe the set of possible planar motions of the object that can not be prevented by any action of the fingers. Use some analysis to back up your discussion.

Problem 3: (17 points)

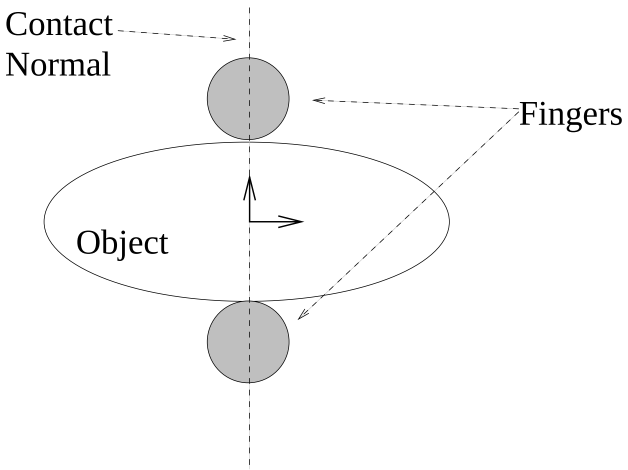

Figure 2: Schematic of two-fingered frictionless grasp

For the rotation matrix given below

$$R = \begin{bmatrix} 0.833333 & -0.186887 & 0.52022 \\ 0.52022 & 0.583333 & -0.623773 \\ -0.186887 & 0.79044 & 0.583333 \end{bmatrix}$$

Part (a): (8 points) Compute the axis of rotation and angle of rotation.

Part (b): (4 points) Determine the unit quaternion that is equivalent to this rotation.

Part (c): (5 points) What are the z-y-z Euler angles of this rotation?

Problem 4: (20 points) Problem 17(a,b) in Chapter 2 of MLS. Part (a) counts for 10 points, and part (b) counts for 10 points.

Problem 5: (13 points)

Assume that the orientation of a rigid body is described by z-y-z Euler angles, where the angles of rotation are respectively ψ, ϕ, and γ. Further assume that the body is spinning with rotation rates of $\dot{\psi}$, $\dot{\phi}$, and $\dot{\gamma}$ about the respective z, y, and z axes. Show that the spatial angular velocity of the body is:

$$\overline{\omega}^s = \begin{bmatrix} -\dot{\phi}\sin\psi + \dot{\gamma}\cos\psi\sin\phi \\ \dot{\phi}\cos\psi + \dot{\gamma}\sin\psi\sin\phi \\ \dot{\psi} + \dot{\gamma}\cos\phi \end{bmatrix}$$