Due Date:
March 31, 2020
(12 Farvardin 98)

In the name of god

Advanced Robotics

Homework Assignment #4-1

1) Prove each of the following:

I) For a skew-symmetric matrix S(a) of a vector (a) and a rotation matrix R and a vector X

a- $S(\alpha a+\beta b)=\alpha S(a)+\beta S(b)$

b- $S(a)p=a\times p$

c- $RS(a)R^T=S(Ra)$

d- $X^T SX=0$

e- $S(k)^3=-S(k)$

II)Given the euler angle transformation

$$R=R_{z,\psi}R_{y,\theta}R_{z,\varphi}$$

Show that $\frac{d}{dt}R=S(\omega)R$ where

$$\omega=\{c_\psi s_\theta\dot{\phi}-s_\psi\dot{\theta}\}i+\{s_\psi s_\theta\dot{\phi}+c_\psi\dot{\theta}\}j+\{\dot{\psi}+c_\theta\dot{\phi}\}k$$

III) Repeat Problem part (II) this time for the Roll-Pitch-Yaw transformation. In other words find an explicit expression for ω such that $\frac{d}{dt}R=S(\omega)R$

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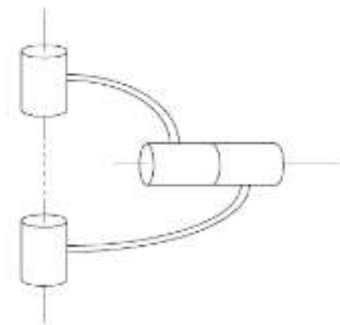
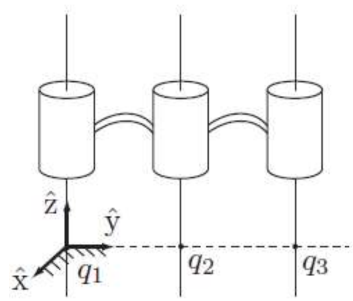
2) some common kinematic singularities that occur in 6-dof manipulator with revolute and prismatic joints are mentioned below. Use Geometric Jacobian and prove singularity existence in each of the following :

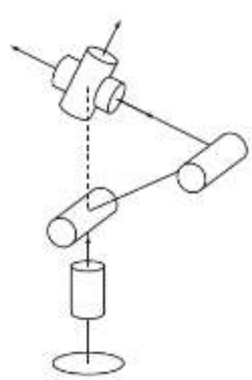
a)Two collinear Revolute joint Axes



b) Three Coplanar and Parallel Revolute Joint Axes



c) Four Revolute Joint Axes Intersecting at a Common Point



d) Four Coplanar Revolute Joints

e) Six Revolute Joints Intersecting a Common Line

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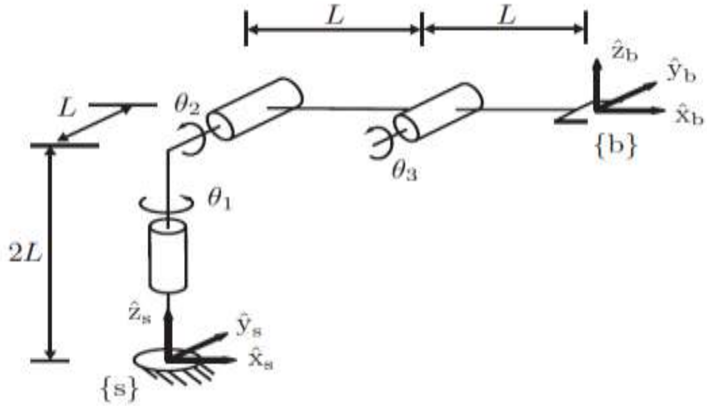
3) The spatial 3R manipulator is shown in its zero position. Let p be the coordinates of the origin of {b} expressed in {s}.



a) Write down the Jacobian (Geometric Jacobian).(use method of Spong's book)

b) In its zero position (configuration shown in figure), suppose we wish to make the end-effector move with linear velocity V= (10; 0; 0) (V is expressed in {s}frame). What are the required input joint velocities ?

c) Suppose that the robot is in the configuration $\theta_1 = 0$, $\theta_2 = 45$, $\theta_3 = -45$
Assuming static equilibrium, suppose that we wish to generate an end-effector force fb = (10; 0; 0), where fb is expressed with respect to the end-effector frame({b} frame). What are the required input joint torques ?

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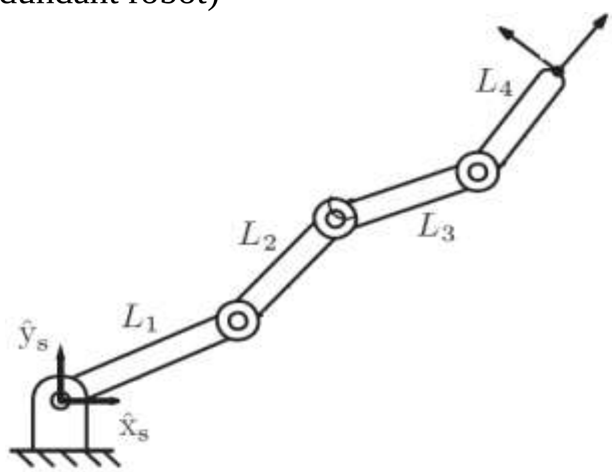
4) Answer the following questions for the 4R planar manipulator (this planer 4-DOF robot is a redundant robot)



a)Write down the Jacobian (Geometric Jacobian).(with **two different method** arbitrary for sure)

b) Suppose that the manipulator is in static equilibrium at the configuration and that a force f = (10; 10; 0) and a moment m = (0; 0; 10) are applied to the tip (both f and m are expressed with respect to the fixed frame{s}). What are the torques experienced at each joint?