ME 192 Exam 1 Solutions

19/24/14

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Score \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. SCARA stands for Selectively Compliant Assembly Robot Arm. Name the non-compliant direction(s).

**(4)** Non-compliant in the (angular) directions of Yaw and Pitch at the wrist joint. (The robot can reach an object in a vertical direction only without additional degrees of freedom added to the end effector.)

The two key **rules in setting up the joint frames that the robots in the lab also follow:**

1. **(3)** Between joints (fixed rotation): Rotate Frame i about its X axis to orient Frame i+1.
2. **(3)** Within joints (variable rotation): Rotate about or translate along Z axis following frame rotation.
3. In the below, frame {1} transforms into {2} by rotating 90° about its X1 and translating to the {2} position. Then frame {2} rotates about its Z2 by -90° to set its X2 orientation. Complete the labeling of the axes below and set up a three-step transformation (rotate-translate-rotate) for frame 2. Also show the inverse of the resulting matrix and the D-H table entries for steps 1 and 2 prior to the Z2 rotation.



y

**(3) (3) (2) (2) (3)**

z

d

1

**(3)**  **(3)** 

2

x

a

y

1. In the below transformation matrix, evaluate or describe what the vectors represent:

= The projection ofof frame {i} onto the three axes of {i+1}. **(2)**

= The projection of  of frame {i} onto the three axes of {i-1}. (**2)**

= The origin of frame {i} relative to that of {i-1}.  **(2)**

**-1 (3)**

 

The (2, 4) element of when P== -r12 - r22 - r32 **(4)**

1. The below V+ commands are written for a SCARA robot. Given the position P = [x, y, z, 0, 180, r], and #Q = [α, β, d, γ] with all parameters predefined, find the new values of P and #Q.

DECOMPSE V[1]= P ; Extract the Cartesian coordinates and the roll angle

SET P=P:TRANS(100, -V[2], -V[3]+300, 0, 0, -V[6]) ; Redefine P via a vector addition.

DECOMPSE W[1]= #Q ; Extract the joint roll angles and displacements.

SET #Q=#PPOINT(-W[1], -W[2]+30, -W[3]+60, -W[4]+90) ; Redefine # Q

**(5)** P = [x+100, 0, 300, 0, 180, 0]

**(5)** #Q = [- α, - β +30, -d+60, -γ +90]

1. In a SCARA robot, the roll angle on the Z axis “r” is given in terms of the base frame. If r needs to be kept constant when the arm moves (e.g. the axes rotate.) how should the wrist angle γ be set?

**(5)** Since roll angle r = α + β + (180 – γ) , keep γ equal to α + β + (180) to counter-rotate by α + β.

What is the values of the 4th column of the transformation matrix of a SCARA robot when the joint values are #Q = [α, β, d, γ] and the link lengths are L1 and L2, and the maximum Z height is D.

**(5)** P = [L1cos α + L2cos (α + β), L1sin α + L2sin (α + β), D-d, 1]

1. What rotation about one of the principal axes will result in the below

**(4)**  Axis: X Axis Angle: 180°

In a matrix form, show that 



**(2.5) (2.5)**

1. Show the transpose of a rotation matrix RT = R-1. Choose an algebraic proof based on the dot product properties of orthonormal matrices. Follow the argument that *because RR-1=I, if RRT = I, then, RT = R-1*.

    **(7)**

**(3)** (The above is due to that all 3x3 elements of RRT are the vector dot products of two rows or two columns of orthonormal matrices which are either 0 or 1.Since RR-1=I and RRT = I, it follows that RT = R-1.

1. Find the transformation matrix

B

C

A

Going either clockwise or counterclockwise

**(6)** 

D

E

1. The linked rotation matrices of a SCARA robot is expressed by, where  is a variable rotation matrix and  is a fixed rotational relationship between Z2 and Z3. If a subscript “0” denotes a zero rotation and θ denotes a non-zero rotation, then find the single joint rotations from a composite rotation. Start by explaining why

**(3)** : Because 

**(3)** 🡨 Express in terms of  and and/or their inverses.

**(3)**  Only one side of is applicable.

**(3)** 

*Note that Program ROTJOINT outputs both  and, and their inverses. The six axis version of the above can be derived fromand *