Ref. No.: **Ex/PG/ETCE/T/128C/2019**

M.E. ELECTRONICS AND TELE-COMMUNICATION ENGINEERING FIRST YEAR
SECQND SEMESTER – 2019

Subject: **ROBOTICS & COMPUTER VISION** Time: 3 Hours Full Marks: 100

Answer ANY FOUR.

All parts of the same question must be answered at one place only.

1. (a) A frame is rotated about the x-axis by 90^0; it is then translated about the current a-axis by 3 inches before being rotated about the z-axis by 90^0. Finally, it is translated about the current o-axis by 5 inches. Find the final location of a point P (1, 5, 4) attached to the frame relative to the reference frame. 8

   (b) Derive the expression of inverse of a homogeneous transformation matrix. 7

   (c) In a robotic setup, a camera is attached to the fifth link of a robot with six degrees of freedom. The camera observes an object and determines its frame relative to the camera's frame. Using the following transformation, determine the necessary motion the end effector has to make to get the object. 10

$$^5\mathbf{T}_{cam} = \begin{bmatrix} 0 & 0 & -1 & 3 \\ 0 & -1 & 0 & 0 \\ -1 & 0 & 0 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad ^{cam}\mathbf{T}_{obj} = \begin{bmatrix} 0 & 0 & 1 & 2 \\ 1 & 0 & 0 & 2 \\ 0 & 1 & 0 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

$$^5\mathbf{T}_H = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad ^H\mathbf{T}_E = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

2. (a) Find out the transformation matrix representing Euler angle orien ation changes. 10

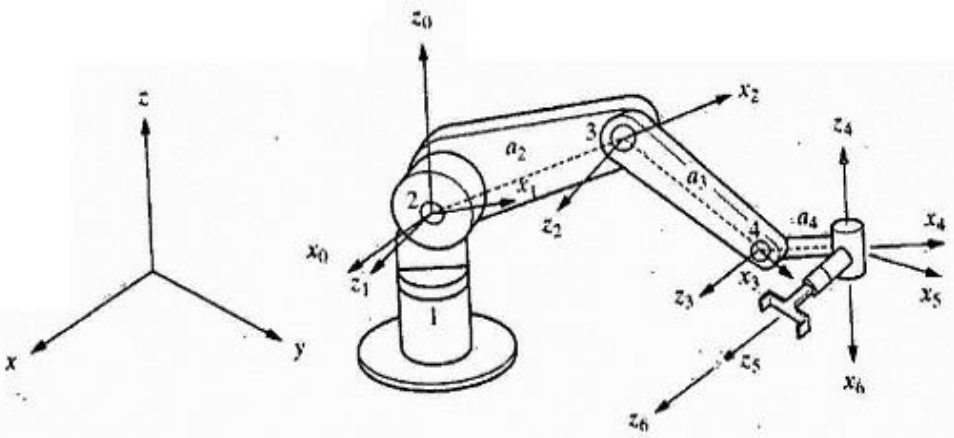
   (b) Derive the decoupled equations of Euler angles for a given final desired orientation. 10

   (c) The desired final position and orientation of the hand of a Cartesian-Euler robot is given below. Find the necessary Euler angles. 5

$$T = \begin{bmatrix} 0.579 & -0.548 & -0.604 & 5 \\ 0.540 & 0.813 & -0.220 & 7 \\ 0.611 & -0.199 & 0.766 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

3. (a) Define the rules for axis selection of the above scheme. 5

   (b) For the following six-degree-of-freedom robot with the body attached frames, determine the transformation matrices $\mathbf{A}_1$ to $\mathbf{A}_6$. 15



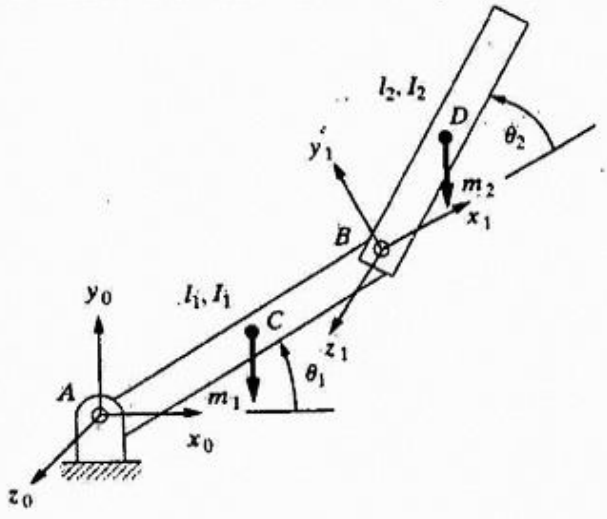
(c) Hence determine the total transformation matrix for the above problem. 5

4. (a) The differential operator is not a transformation matrix. Justify. 5

(b) The hand frame of a five-degree-of-freedom robot with 2RP2R configuration, its numerical Jacobian at that instant and the set of differential motions are given below. Find the new location of the hand frame after the differential motion. 8

$$\mathbf{T}_6 = \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 0 & -1 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad \mathbf{J} = \begin{bmatrix} 3 & 0 & 0 & 0 & 0 \\ -2 & 0 & 1 & 0 & 0 \\ 0 & 4 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ -1 & 0 & 0 & 0 & 1 \end{bmatrix}, \quad \begin{bmatrix} d\theta_1 \\ d\theta_2 \\ d\theta_3 \\ d\theta_4 \\ d\theta_5 \end{bmatrix} = \begin{bmatrix} 0.1 \\ -0.1 \\ 0.05 \\ 0.1 \\ 0 \end{bmatrix}$$

(c) Using Lagrangian method, derive the equations of motion for the two-degree-of-freedom robot-arm. The centre of mass for each link is concentrated at the centre of the link. The moments of inertia of the links are I_1 and I_2 respectively. 12



5. (a) Prove that 12

$$\frac{d\bar{r}}{dt} = \frac{d^*\bar{r}}{dt} + \bar{\omega} \times \bar{r}$$

and hence derive $\frac{d^2\bar{r}}{dt^2}$ where the parameters have their usual meaning.

(b) For a two-link robot determine $\dot{\bar{v}}_i$ and $\dot{\bar{\omega}}_i$ for link i. 6

(c) The end-point gripper of a six-link robot needs to be moved from an initial angle of 30^0 to a final angle of 70^0 on a plane in 5 seconds with a cruising velocity of 10^0/sec. Find the necessary time for blending and calculate the joint angle, velocity, and acceleration at 1, 2, 3 and 4 seconds. 7

6. (a) For a binary image, establish the relationship between its

(i) Area, center of area and projection 3

(ii) Area and run-length code 2

(b) What is a connected component? 2

(c) Explain the sequential algorithm for labeling connected components of an image. 7

(d) What is the significance of a size filter? 2

(e) Define the distance transform and the medial axis of a binary image. 2+2

(f) Find out the distance transform of the following image after the second iteration. 4

1 1 1 1 1 1
1 1 1 1 1 1
1 1 1 1 1 1
1 1 1 1 1 1
1 1 1 1 1 1

(g) When expansion is used followed by shrinking? 1

7. (a) How peaks and valleys are detected in a histogram to facilitate selection of threshold in mode-based thresholding technique? 6

(b) Explain the principle of adaptive thresholding to handle images of uneven illumination. 3

(c) What is primary limitation of histogram based approaches for thresholding? 2

(d) An 8×8 image $f[i, j]$ has grey levels given by $f[i, j] = |i - j|$ for $i, j = 0, 1, \ldots, 7$. Find out the output image obtained by applying a 3×3 median filter on the image $f[i, j]$. The border pixels are to be kept unchanged. 7

(e) Derive the expression of the Laplacian operator. 4

(f) Give an example to show how Laplacian operator could be used to detect ramp edge in an image. 3