M.E. ELECTRONICS AND TELE-COMMUNICATION ENGINEERING FIRST YEAR SECOND SEMESTER – 2024

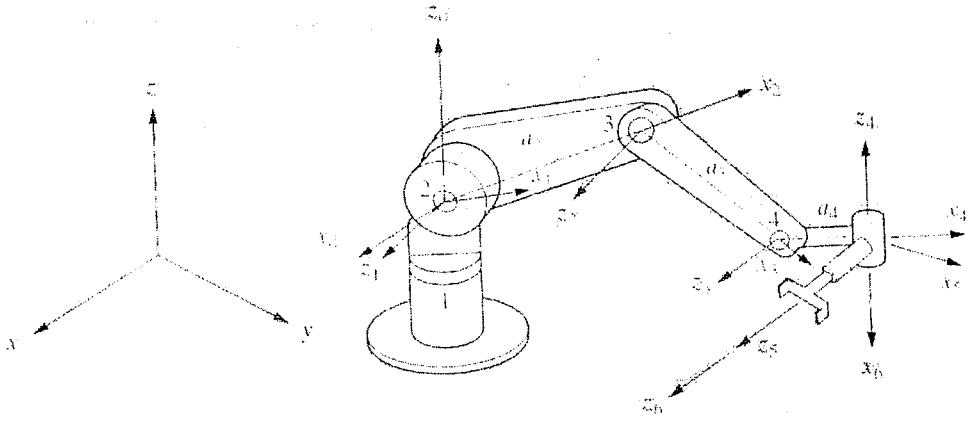
Subject: **ROBOTICS & COMPUTER VISION** Time: 3 Hours Full Marks: 100

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

Part A: Answer any FOUR

1. Find the decoupled expressions of roll, pitch and yaw angles to control the orientation of a robot with the pre-defined destination. 15

2. Find the transformation matrices between the base and the hand of the following robot using D-H scheme. 15



3. (a) Justify why differential operator is not a transformation matrix. 5

(b) The hand frame of a robot with five degrees of freedom, its numerical Jacobian for this instant, and a set of differential motions are given below. Find the new location of the hand after the differential motion. 10

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

4. Prove that 15

$$K = \frac{1}{2}\sum_{i=1}^{n}\sum_{p=1}^{i}\sum_{r=1}^{i} \text{Trace}(U_{ip} J_i U_{ir}^T)\dot{q}_p \dot{q}_r + 1/2 \sum_{i=1}^{n} I_{i(act)} \dot{q}_i^2$$

where symbols carry their usual meanings.

5. (a) Derive the expression of the necessary blending time and hence the maximum permissible linear velocity for joint space trajectory planning with linear segments with parabolic blends. 10

[Turn over

(b) Joint 1 of a 6-axis robot is to go from initial angle of 30^0 to a final angle of 70^0 in 5 seconds with a cruising velocity of 10 degrees/second. Find the necessary time for blending and plot the joint positions, velocities and acceleration. 5

6. Prove that 15

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

and hence derive $\frac{d^2\vec{r}}{dt^2}$ where parameters have their usual meanings.

Part B: Answer any TWO

7. (a) Define a binary image. What type of information can be extracted from a binary image? 2+2

(b) How can you define the orientation of an object? Find an expression for the axis of elongation of an object in a binary image. 1+5

(c) Define connected component in a (binary) image. Suggest two applications where connected component analysis can be useful. 2+2

(d) Find the number of components and their sizes (in terms of number of pixels), and shapes (in terms of polygons) in the following 5 x 5 binary image based on 4-connectivity. Show your steps. 6

1	1	0	0	0
1	1	0	0	1
1	1	0	1	1
0	0	1	1	1
0	0	1	1	1

Here, a '1' denotes a foreground pixel and a '0' denotes a background pixel.

8. (a) What do you mean by image segmentation? Explain the concepts of exhaustive partitioning and exclusive partitioning in this context. 2+4

(b) Define histogram of an image. Consider an 8-bit image of size 32 x 32 pixels. Suppose, this image contains 4 equal sized uniform regions, having minimum intensity +1; maximum intensity; arithmetic mean of minimum intensity + 1, and maximum intensity; and geometric mean of minimum intensity + 1, and maximum intensity values respectively. Draw the histogram of this image. 2+4

(c) State one limitation of histogram based segmentation. Suggest an alternative segmentation strategy, which does not consider histogram information, with an example. 2+4

(d) Name two segmentation algorithms which use energy-based formulations. 2

9. (a) What is salt-and-pepper noise? Discuss, with example, how an effective filter can remove such noise from an image. Analyze whether the above filter is linear and spatially varying. 1+4+2

(b) How can you mathematically represent an edge in an image? Derive the coefficients of a discrete Laplacian filter, which can be used for edge detection. Comment on the sum of coefficients of that filter. 1+4+1

(c) What is Hough Transform? Consider the following set of edge points: (0, 1), (1, 0), (2, 1), (1, 2), (2, 4). Apply Hough Transform to find a (linear) edge passing through these points. You can quantize the parameter space to [-3, 3] for the edge parameters. 2+5