Ref. No.: Ex/PG/ETCE/T/128C/2017

M.E. ELECTRONICS AND TELECOMMUNICATION ENGINEERING

FIRST YEAR SECOND SEMESTER 2017

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

Answer ANY FIVE.

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

1. (a) 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. 7

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

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

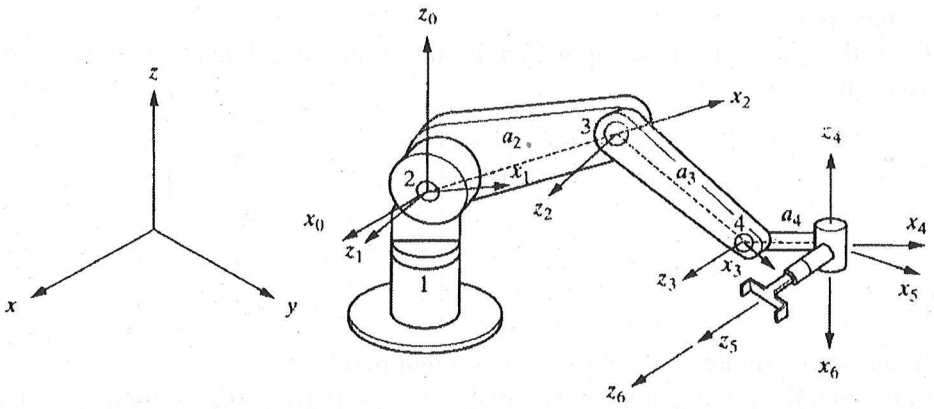
(b) Derive the inverse kinematic solution of the RPY configuration of a robot. **8**

(c) Determine the necessary roll, pitch and yaw angles and displacements for the desired position and orientation of the hand of a Cartesian-RPY robot given as follows. **5**

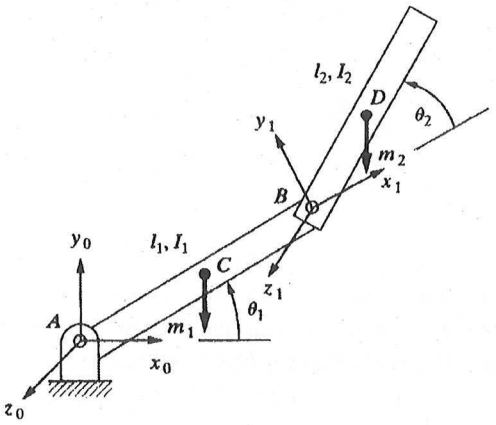
$$ {}^{R}\mathbf{T}_{P} = \begin{bmatrix} 0.354 & -0.674 & 0.649 & 4.33 \\ 0.505 & 0.722 & 0.475 & 2.50 \\ -0.788 & 0.160 & 0.595 & 8 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

2. (a) Define the link parameters used in Denavit-Hartenberg 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**



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



(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**

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

4. (a) 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 75^0 on a plane in 5 seconds. Using a third-order polynomial, calculate the joint angle, velocity, and acceleration at 1, 2, 3 and 4 seconds. **10**

(b) For a general multi-axis robot with n links, derive the expression of Lagrangean. **10**

5. (a) What do you mean by connected component labeling? **3**

(b) State the sequential connected component labeling algorithm based on 4-connectivity. **5**

(c) Find the area of all components in the following binary image using the algorithm in (b). **7**

	*	*		*	*
	*	*	*		
		*			
			*	*	*
				*	*

In the above figure '*' denotes a foreground pixel.

(d) Show that the pixel connectivity satisfies the property of an equivalence relation. **5**

6. (a) Explain what is meant by distance transform. 4
   (b) Obtain a disk of radius 4 for the Euclidean distance. 4
   (c) Discuss the erosion and dilation operations with proper sketches. 3+3
   (d) Consider a rectangular object in a binary image of size 5 x 3 pixels. Show the impacts of erosion and dilation on this object with (i) a vertical line shaped structuring element of length 3 pixels and (ii) a square shaped structuring element of dimension 3x3 pixels. 6

7. (a) What is image segmentation? Name two different image segmentation strategies, one of which uses and the other one does not use the histogram based information. 3+2
   (b) Suppose the pixels in a 8-bit grayscale image of size 64×64 are samples from one of the two Gaussian distributions: $N_1(50,5)$ and $N_2(230,4)$. Draw the image histogram. Assume the proportion of samples from N_1 and N_2 to be 70:30. How can you choose a threshold from the histogram in this case for the purpose of segmentation? 5+2
   (c) Describe an image segmentation strategy which does not use the histogram information. 4
   (d) Discuss an image data structure which is commonly used for the implementation of the strategy in (c). 4

8. (a) Explain why median filters are effective in removing salt and pepper noise. Argue whether a median filter is a linear spatially invariant filter. 4+4
   (b) Obtain the coefficients of the Laplacian mask. State the significance of the fact that the sum of the coefficients of this mask is zero. 5+2
   (c) Explain how the Butterworth low pass filter can remove image noise. 5