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The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX6571/MEX6271 Robotics**
Academic Year	: 2017/18
Date	: 08th February 2019
Time	: 1400 hrs – 1700 hrs
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **four (4)** pages.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Relevant charts/ codes are provided.
6. This is a Closed Book Test (CBT).
7. Answers should be in clear hand writing.
8. Do not use a Red color pen.

Question 01

A food processing plant which produces bottled jam has sought your expertise in robotics in exploring the possibility of employing robots as means of achieving higher productivity.

a) Select a suitable application that a robot will be effective in achieving the above objective and justify the need of assigning a robot to perform this selected application.

b) What geometrical configuration and control scheme best suit your need? Justify.

c) What are the main specifications that should be taken into consideration when selecting the robot for the above application? Justify the reasons why you have

selected the mentioned specifications. You may take numerical values to elaborate on your answer.

d) Discuss the effects on the ability to handle the selected task by the robot, if the above specifications are not correctly chosen.

Question 02

a) In modelling of robotic manipulators, an inverse kinematic problem is not simple and straightforward as a direct kinematic problem. Do you agree with this statement? Justify your answer.

b) Discuss the importance of homogeneous coordinates and transformations in the context of robotic manipulator modelling.

c) Describe the types of reference frames used in jogging a robot.

d) Explain the term 'dexterity' in relation to the movement of a robot manipulator.

Question 03

a) Find the mathematical representation which describes a point P in frame {2} with respect to frame {1}. Assume that frame {2} has been rotated about a fixed origin with respect to frame {1}.

b) Explain mathematically, what is meant by the term 'Rotation matrix' [**R**].

c) Show that, ${}^{2}\mathbf{R}_{1}=\left[{}^{1}\mathbf{R}_{2}\right]^{T}=\left[{}^{1}\mathbf{R}_{2}\right]^{-1}$ for a rotation matrix [**R**]. (You may use the results obtained in 3-a above to deduce your answer).

Question 04

a) Show that the relationship given by the expression (4.a) below holds true for homogenous transformations.

$$ {}^{2}\mathbf{T}_{1}=\left[{}^{1}\mathbf{T}_{2}\right]^{-1}=\left[\begin{array}{ccc:c} & {}^{1}\mathbf{R}_{2}{}^{T} & & -{}^{1}\mathbf{R}_{2}{}^{T}\,{}^{1}\mathbf{D}_{2} \\ \hdashline 0 & 0 & 0 & 1 \end{array}\right] \quad \text{--------} \; (4.a) $$

b) In a robotic manipulator, a frame {2} is rotated with respect to frame {1} about the X-axis by an angle 45^{0}. The position of the frame {2} as seen from frame {1} is given by $[4\ \ 8\ \ 4]^{T}$.

i) Find the homogeneous transformation matrix which describes the position and orientation of frame {2} relative to frame {1}.

ii) Find the homogeneous transformation matrix which describes the position and orientation of frame {1} relative to frame {2}. [Hint: you may use the relationship 4.a in order to answer the question].

Question 05

A RP two link planar manipulator is show in figure 01. The axes Z_0 , Z_1 and Z_2 are pointing perpendicularly outwards of the paper.

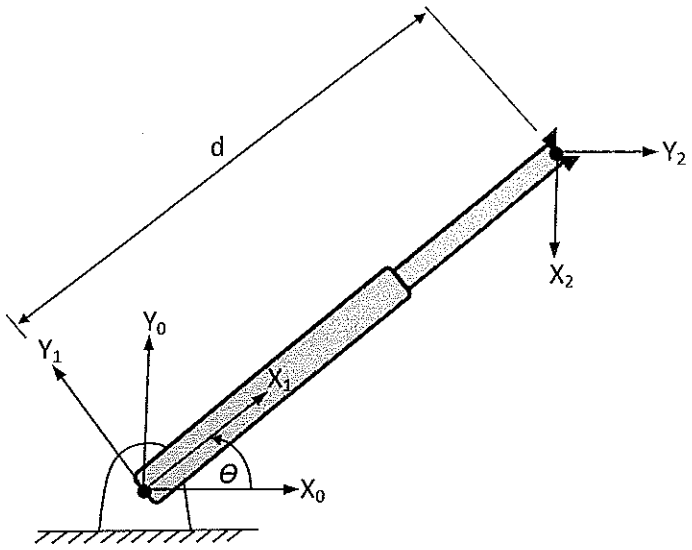

Figure 01

a) How many degrees of freedom does the above RP manipulator possess? What are they?

b) If frame {0} is rotated by an angle $\Theta = 45^0$ about the Z axis, find ${}^0\mathbf{R}_1$.

c) Obtain an expression for the homogeneous transformation matrix ${}^0\mathbf{T}_2$ for the above manipulator.

d) What would be the position vector ${}^1\mathbf{P}$, if the coordinates of a point at the end-effector is **P** = [5 5 8].

Question 06

a) Briefly explain the D-H formulation in determining the forward kinematic equation for a robotic manipulator.

b) Determine the link parameters using D-H convention for the RP planar manipulator given in figure 01. (Assume any missing parameters).

c) Find the homogeneous transformation matrix ${}^0\mathbf{T}_2$ for the RP planar manipulator given in figure 01 using the D-H convention. The general form of the homogeneous transformation matrix in standard notation is;

$$ {}^{i-1}\mathbf{T}_i = \begin{bmatrix} c\theta_i & -s\theta_i & 0 & \alpha_{i-1} \\ s\theta_i c\alpha_{i-1} & c\theta_i c\alpha_{i-1} & -s\alpha_{i-1} & -s\alpha_{i-1}d_i \\ s\theta_i s\alpha_{i-1} & c\theta_i s\alpha_{i-1} & c\alpha_{i-1} & c\alpha_{i-1}d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

Question 07

a) A moving frame {2} is rotated about a fixed origin with respect to a fixed frame {1}. Describe a point P in space, with respect to;.

   i) Fixed frame {1}

   ii) Moving frame {2}

   iii) Show that the rotational transformation matrix R is independent of the point P.

b) What does ZYX Euler angle rotation matrix represent? Show that the order of rotation for ZYX and XYZ are equivalent.

Question 08

a) Briefly explain the trajectory planning procedure employed in robotics.

b) Distinguish between joint space trajectory planning and Cartesian space trajectory planning approaches in robotic trajectory panning.

c) The joint of a robotic manipulator needs to move from 20^0 to 120^0 in 10 seconds in order to achieve a smooth motion from a start point to the goal point in the absence of via points.

   i) What is the minimum degree of the polynomial that will satisfy the above trajectory? Justify your answer.

   ii) Based on the answer given on part (i) of this question, find the polynomial to generate the smooth trajectory for this robotic joint.

   iii) Determine the maximum velocity and acceleration for the above generated trajectory.

END