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	**: MEX6271/DMX6571 Robotics**
Academic Year	: 2019/20
Date	: 11th August 2020
Time	: 1330-1630hrs
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **Six (6)** 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. This is a Closed Book Test (CBT).
6. Answers should be in clear handwriting.
7. Do not use Red colour pen.

Question 01

a) State and give a brief description of the basic components of a typical industrial robot manipulator. [*5 marks*]

b) Robot programming language can be classified into several categories according to the level at which the programmer must interact with the system during the programming process. Describe these robot programming classifications. [*5 marks*]

c) Vision systems are being used increasingly with robots to perform many automated tasks in the industry. Describe briefly of these tasks. [*5 marks*]

d) Briefly describe the main types of power sources used to power a robot and an automation work-cell. [5 marks]

Question 02

a) Write down a definition for a Robot. What makes a Robot different from other forms of automated devices? [5 marks]

b) Explain types of robots. What distinguishes anthropomorphic robots from other forms of robots? Give examples and applications of the above-mentioned type of robots. [5 marks]

c) "The technical features are the prime considerations in the selection of a robot". Briefly describe the technical features that must be considered before selecting a robot. [5 marks]

d) Explain types of joints in a robot in relation to its nature of motion. [5 marks]

Question 03

a) The coordinates of point P in frame $\{1\}$ are $[3 \quad 2 \quad 1]^T$. The position vector P is rotated about the $z - axis$ by $45°$. Find the coordinates of point Q, the new position of P. (Elaborate with an appropriate figure). [5 marks]

b) Frame $\{2\}$ is rotated with respect to frame $\{1\}$ about the x-axis by an angle of 60°. The position of the origin of the frame $\{2\}$ as seen from frame $\{1\}$ is ${}^1_2D = [7 \quad 5 \quad 7]^T$. Obtain the transformation matrix ${}^1_2T$, which describes frame $\{2\}$ relative to frame $\{1\}$. Also, find the description of point P in frame $\{1\}$ if ${}^2P = [2 \quad 4 \quad 6]^T$. [7 marks]

c) Consider a point P in space. Determine the new location of this point after rotating it by an angle of $45°$ about z-axis and then translating it by –1 unit along x-axis and –2 units along z-axis. Distinguish and pictorially show the transformation of the vector. What will be the equivalent frame transformation for this vector transformation? Show the transformation frames graphically. [8 marks]

Question 04

a) Discuss the difference of the arm configurations between polar and articulated arms. [5 marks]

b) Two points $a_{uvw} = [4 \quad 3 \quad 2]^T$ and $b_{uvw} = [6 \quad 2 \quad 4]^T$ are to be translated a distance $+5$ units along the OX axis and $+3$ units along the OZ axis. Using the appropriate homogeneous transformation matrix, determine the new points of a_{xyz} and b_{xyz}. [5 marks]

c) Find a homogeneous transformation matrix $\boldsymbol{T}$ that represents a rotation of $\boldsymbol{\alpha}$ angle about the OX axis, followed by a translation of $\boldsymbol{a}$ units of distance along the OX axis, followed by a translation of $\boldsymbol{d}$ units of distance along the OZ axis, followed by a rotation through an angle $\boldsymbol{\theta}$ about the OZ axis. [5 marks]

d) Explaining basic requirements for a rotation matrix, show that given 3×3 matrix R is a rotation matrix. [5 marks]

$$\mathbf{R} = \begin{bmatrix} 1/\sqrt{2} & 0 & 1/\sqrt{2} \\ -1/2 & 1/\sqrt{2} & 1/2 \\ -1/2 & -1/\sqrt{2} & 1/2 \end{bmatrix}$$

Question 05

A robot workstation has been setup with a TV camera, as shown in the following Figure Q5. The camera can see the origin of the base coordinate system where a six-link robot arm is attached and the center of a cube to be manipulated by the robot. If a local coordinate system has been established at the center of the cube, then this object, as seen by the camera, can be represented by a homogeneous transformation matrix T_1. Also, origin of the base coordinate system as seen by the camera can be expressed by a homogeneous transformation matrix T_2, where,

$$\mathbf{T}_1 = \begin{bmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 10 \\ 0 & 0 & -1 & 9 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad \mathbf{T}_2 = \begin{bmatrix} 1 & 0 & 0 & -10 \\ 0 & -1 & 0 & 20 \\ 0 & 0 & -1 & 10 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

a) Unfortunately, after the equipment has been setup and these coordinate systems have been taken, someone rotates the camera 90° about z-axis of the camera. Determine

the position/orientation of the camera with respect to the robot's base coordinate system. [*10 marks*]

b) After you have calculated answer for the Q5(a), the same person rotated the object (cube) 90° about the x-axis of the object and translated it 4 units of distance along the rotated y-axis.

Determine

(i) the position/orientation of the object with respect to the robot's base coordinate system. [*5 marks*]

(ii) the position/orientation of the object with respect to the rotated camera coordinate system. [*5 marks*]

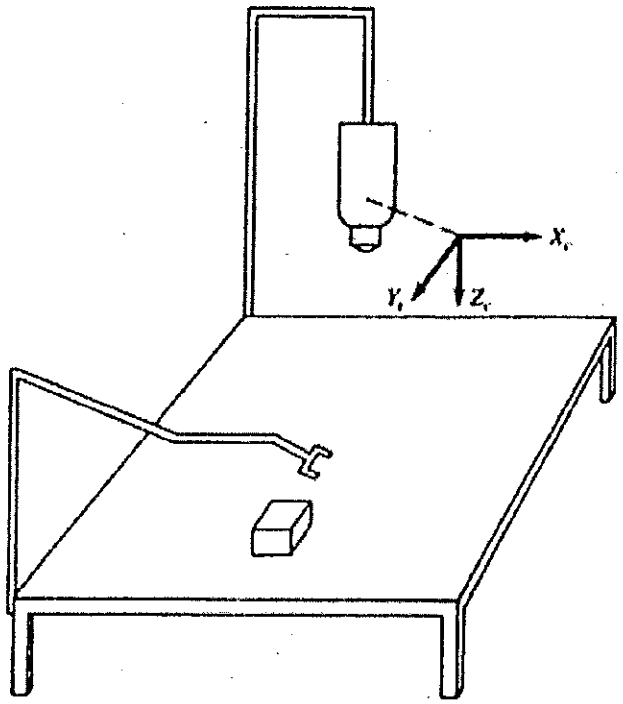

Figure Q5

Question 06

a) What does ZYX Euler angle rotation matrix represent? Show that the order of rotation for ZYX and XYZ are equivalent. [*8 marks*]

b) The rotation matrix ${}^{1}R_{2}$, relating the orientation of frame {2} with respect to frame {1} is given by

$$ {}^{1}R_{2} = \begin{bmatrix} 0.87 & 0.43 & 0.25 \\ 0.5 & 0.75 & -0.43 \\ 0 & 0.5 & 0.87 \end{bmatrix} $$

Determine the corresponding set of ZYX Euler angles. [*4 marks*]

c) Find the homogeneous transformation matrix for rotation of 30° about the OZ-axis, followed by a rotation of 60° about the OX-axis, followed by a rotation of 90° about the OY-axis. [*8 marks*]

Question 07

a) "Why does DH convention does not give a unique frame assignment for a given manipulator". Explain. [*4 marks*]

b) Consider coordinate frame assignment for planer manipulator as shown in Figure Q7. Find the DH parameters. [*8 marks*]

c) Find homogeneous transformation matrix for planer manipulator in Q7(b). [*8 marks*]

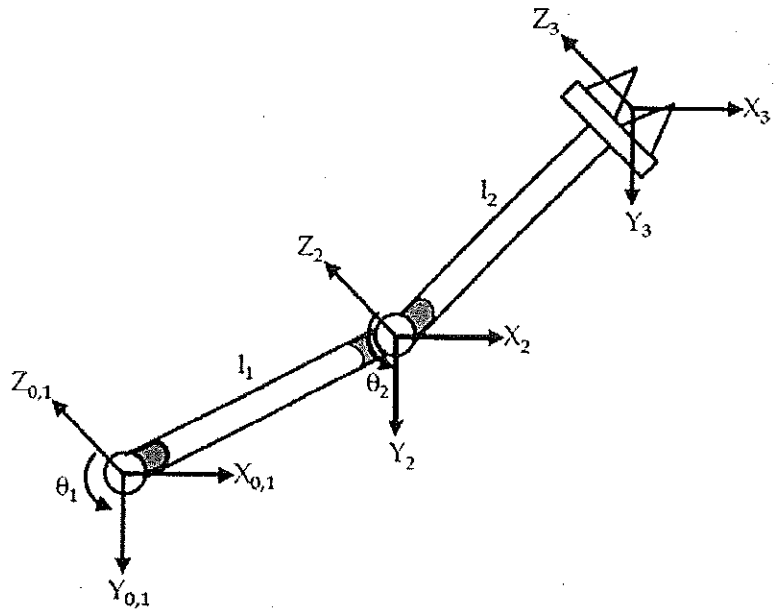

Figure Q7

Question 08

In the 3×RPR planar parallel mechanism of Figure Q8, the prismatic joints are actuated. Define $\boldsymbol{a_1 \epsilon R^2}$ to be the vector from the fixed frame origin O to joint $A_i, i = 1,2,3,$ expressed in fixed frame coordinates. Define $\boldsymbol{b_1 \epsilon R^2}$ to be the vector from the moving platform frame origin P to joint $B_i, i = 1,2,3$ defined in terms of the moving platform frame coordinates.

a) Solve the inverse kinematics. [*8 marks*]

b) Derive a procedure to solve the forward kinematics. [*8 marks*]

c) Is the configuration shown an end-effector singularity? Explain your answer by examining the inverse kinematics Jacobian. Is this also an actuator singularity? [*4 marks*]

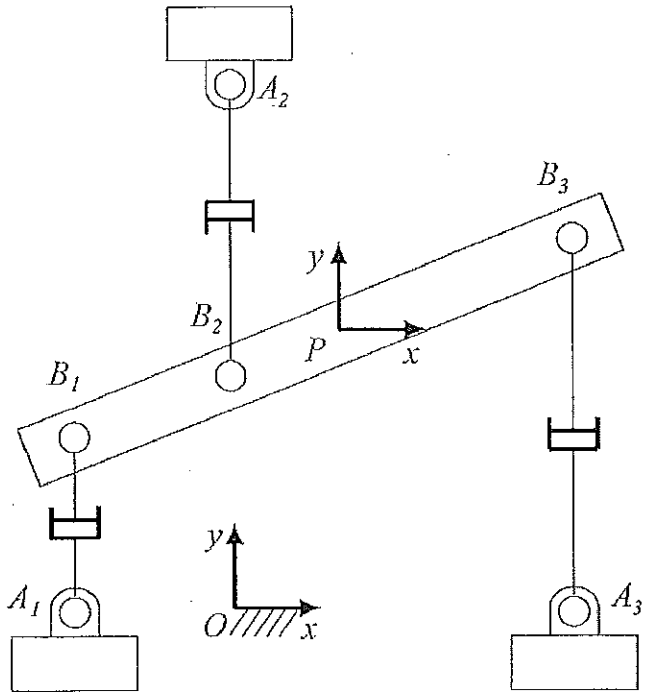

Figure Q8

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