The Open University of Sri Lanka
Faculty of Engineering Technology

Study Programme	: Bachelor of Technology (Engineering)
Name of the Examination	: Final Examination
Course Code and Title	: **MEX6271 - ROBOTICS**
Academic Year	: 2014/2015
Date	: 17th September 2015
Time	: 2.30pm – 5.30pm
Duration	: 3 hours

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of 8 questions. All questions carry equal marks.
3. Answer any 5 questions only.

(Q1)

a) Discuss the reasons using a robot instead of human being to perform a specific task.

b) Describe the methods of teaching robots.

c) "A human arm has 7 DOF". Discuss the advantages of having one extra DOF (with respect to 6 DOF) on a human arm.

d) Discuss possible applications in which the redundant manipulators would be useful.

(Q2)

a) "As technology advances, will the human worker lose jobs to robotic workers"? Explain.

b) Discuss the essential characteristics of **arc-welding robotic manipulators** and **spot welding manipulators**.

c) Explain applicability of Artificial Intelligence with regard to robotics.

d) What are the different types of actuators used in robots? What are the advantages and disadvantages of each?

(Q3)

a) Frame {2} and a frame {1} are initially coincident. Frame {2} is rotated about Y_2 by angle θ, and then rotated about the new Z_2 by an angle $\emptyset$. Determine the 3×3 rotation matrix, ${}^1_2R$, which will transform the coordinate of a position vector from ${}^2P$, its value in frame {2}, into ${}^1P$, its value in frame {1}.

b) We are given a single frame {1} and a position vector ${}^1P$ described in this frame. Then transform ${}^1P$ by first rotating it about Z_1 by an angle $\emptyset$ then rotating about Y_1 by an angle θ. Determine the 3×3 rotation matrix operator, $R(\emptyset, \theta)$, which describes this transform.

c) Given a transformation matrix:

$$ {}^2_1T = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & C\theta & -S\theta & 2 \\ 0 & S\theta & C\theta & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

i. Find ${}^1_2T$

ii. Given $\theta = 45°$ and ${}^2P = [4 \quad 5 \quad 6]^T$, compute ${}^1P$.

(Q4)

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

b) A frame is given two rotations, one about x-axis by $60°$ and one about y-axis by $45°$. Show that $\boldsymbol{R_x R_y \neq R_y R_x}$. Explain.

c) The rotation matrix ${}^1_2R$, relating the orientation of frame {2} with respect to frame {1} is given by

$$ {}^1_2R = \begin{bmatrix} 0.87 & -0.43 & 0.25 \\ 0.5 & 0.75 & -0.43 \\ 0 & 0.5 & 0.87 \end{bmatrix} $$

Determine the corresponding set of ZYX- Euler angles.

(Q5)

a) Obtain a mathematical expression for composite transformation of frames.

b) A frame {2} was rotated about the x-axis by 90°, it was then translated about the current z-axis by 3 units before being rotated about the z-axis by 90°. Finally, it was translated about the current y-axis by 5 units.

i. Write an equation describing the motions.

ii. Find the final location of a point $\boldsymbol{P(1, 5, 4)}$ attached to the frame relative to the reference frame.

c) A frame {3} has been moved 9 units along x-axis, and 5 units along z-axis of the reference frame. Find the new location of the frame.

$$\{3\} = \begin{bmatrix} 0.527 & -0.574 & 0.628 & 5 \\ 0.369 & 0.819 & 0.439 & 3 \\ -0.766 & 0 & 0.643 & 8 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(Q6)

a) Figure 1 and figure 2 show diagrams of industrial robots arms. For each figure:

i. Name type of robot geometry

ii. Identify degree of freedom

iii. Draw work envelop

iv. List of robot applications

b) A robot workstation has been set up with a TV camera, as shown in the Figure 3. The camera can see the origin of the base coordinate system where a six-link robot arm is attached, and also 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

$$T_1 = \begin{bmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 10 \\ 0 & 0 & -1 & 9 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad T_2 = \begin{bmatrix} 1 & 0 & 0 & -10 \\ 0 & -1 & 0 & 20 \\ 0 & 0 & -1 & 10 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Determine the position of the center of the cube with respect to the base coordinate system.

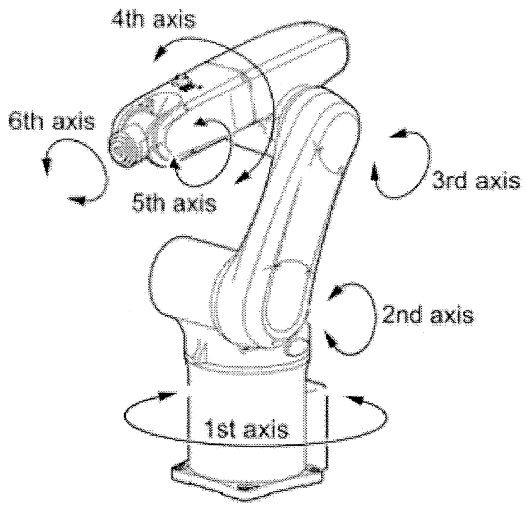


Figure 1

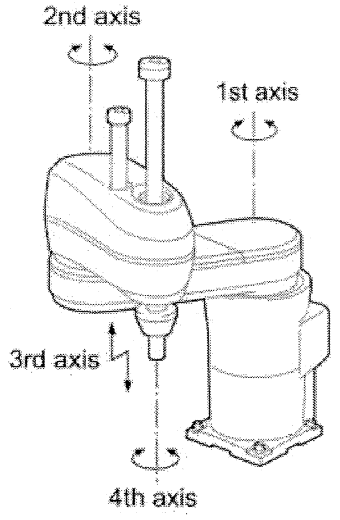


Figure 2

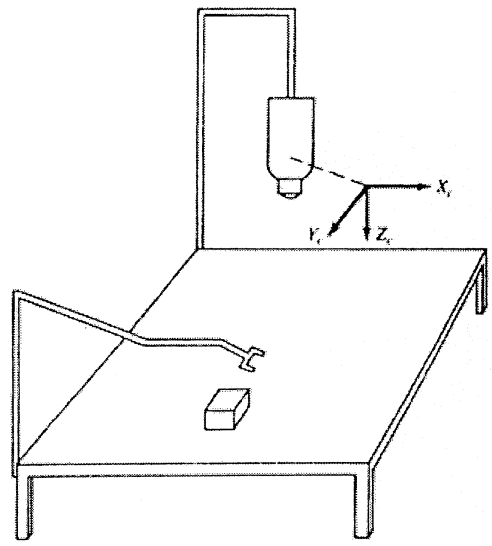


Figure 3

(Q7)

a) Why it is important to choose a frame assignment for an $n\,DOF$ manipulator that gives a maximum number of zero joint-link parameters? Explain.

b) What problems will be encountered if the frames are arbitrary assigned to develop the forward kinematic model of a manipulator? Explain briefly.

c) A $3\,DOF$ articulated arm is shown in figure 4, obtaining the transformation matrix for the end point.

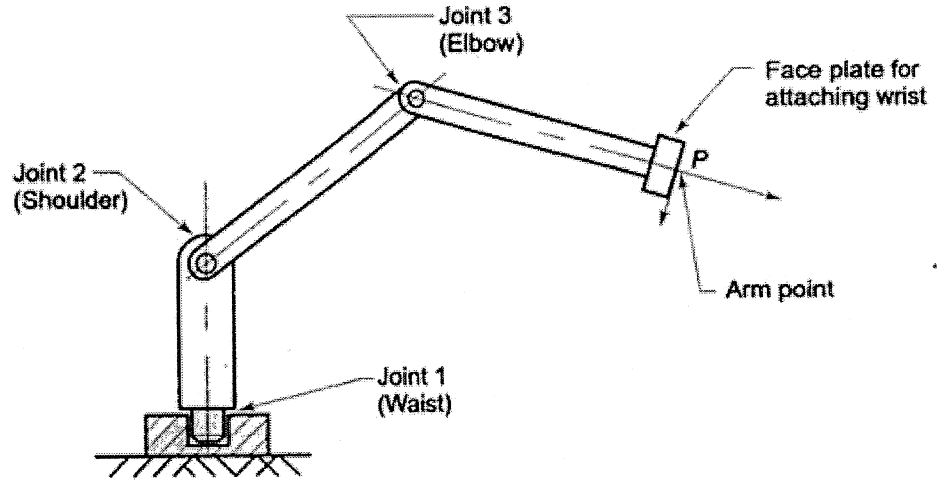


Figure 4

(Q8)

a) Explain the factors which will depend on the number of solutions to a given inverse kinematic model.

b) How are feasible solutions determined to a given inverse kinematic problem? Explain.

c) Explain why closed form analytical solutions are preferred over numerical iterative solutions.

d) For the manipulator arm consisting of 3 DOF shown if figure 4, obtain the inverse kinematic solutions.

END