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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	: 2015/2016
Date	: 22nd November 2016
Time	: 1.30pm – 4.30pm
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) State and give a brief description of the basic components of a robot.

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.

c) Vision system are being used increasingly with robot automation to perform many tasks. Describe briefly of these tasks.

d) Briefly describe the main types of power source used to power a robot and automation work-cell.

(Q2)

a) "Safety is an important issue to be considered when planning and integrating an industrial robot in a manufacturing work-cell. To avoid accidents, the Industry must consider and emphasize certain procedures/safety issues". Discuss.

b) "The robot gripper plays an important role in industrial part handling operations". Briefly discuss about types of gripper with its working principal.

c) For all industrial jobs below, suggest most suitable robot geometry for each job. Support your answer with a sketch of work envelop.

   i. Painting

   ii. Pick and place in assembly line

   iii. Palletizing

(Q3)

A robot workstation has been set up with a TV camera, as shown in the Figure 1. 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

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

a) Unfortunately, after the equipment has been set up 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.

b) After you have calculated answer for the question (Q3-a), the same person rotated the object about the $x-axis$ of the object and translated it 4 units of distance along the rotated y axis. Determine the position/orientation of the object with respect to the robot's base coordinate system. Also, determine the position/orientation of the object with respect to the rotated camera coordinate system.

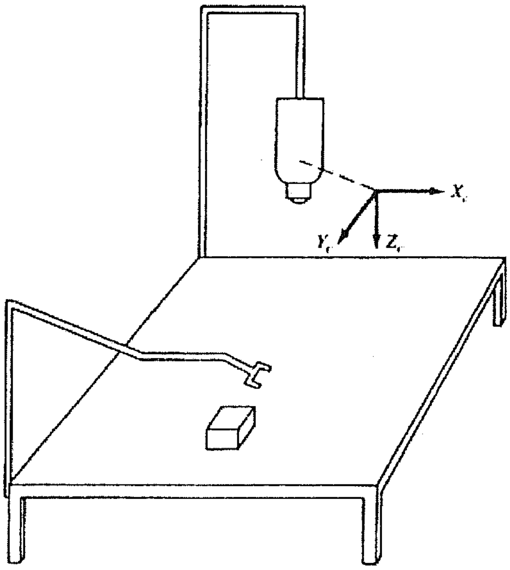

Figure 1

(Q4)

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

b) For the Figure 2 is shown below, find the homogeneous transformation matrices ${}^{i-1}T_i$ and ${}^{0}T_i$ for $i = 1, 2, 3, 4, 5$.

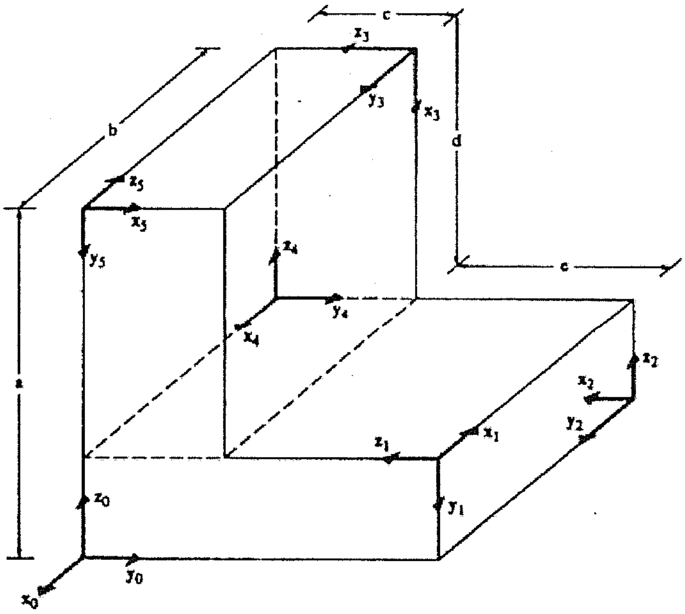

Figure 2

(Q5)

a) What are fundamental rotation matrices? Obtain the three fundamental rotation matrices for rotations about axes x, y, and z from the rotation matrix for rotation about an arbitrary axis k.

b) The frame {1} rotate by 90°about the fixed $y - axis$. Then frame {2} translate $3cm$ along the current $z - axis$. Then frame {3} rotate by 45° about the current $y - axis$. Finally frame {4} translate $5cm$ along the fixed $z - axis$.

   i. Write the expression symbolically describing the motions.
   ii. Find the resulting expression by substituting the values of the variables.
   iii. Find the final location of a point $\boldsymbol{P}(\mathbf{1}, \mathbf{2}, \mathbf{3})$ attached to the frame relative to the reference frame.

(Q6)

Consider the diagram of Figure 3. A robot is set up $1m$ from a table. The table top is $1m$ high and $1m^2$. A frame {0} is fixed to the edge of the table as shown. A cube measuring $20cm$ on a side is placed in the center of the table with frame {2} established at the center of the cube as shown. A camera is situated directly above the center of the block $2m$ above the table top with frame {3} attached as shown.

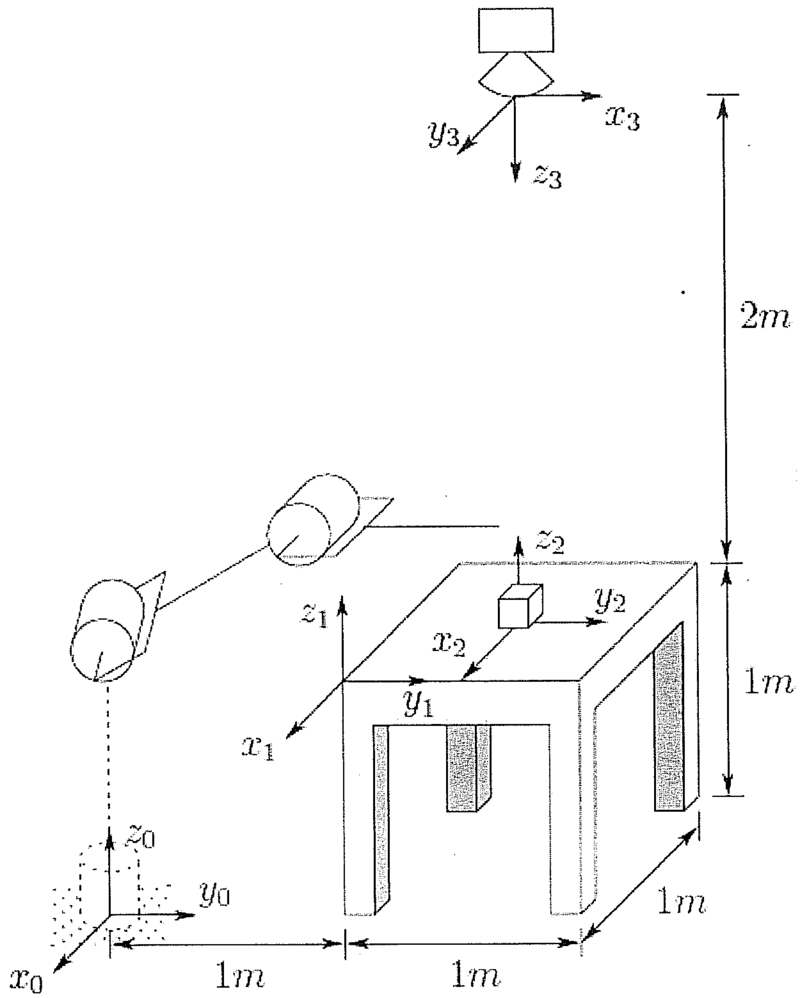

Figure 3

a) Find the homogeneous transformations relating each of these frames to the base frame {0}.

b) Find the homogeneous transformation relating the frame {2} to the camera frame {3}.

(Q7)

Consider the following 2RP2R manipulator is shown in Figure 4.

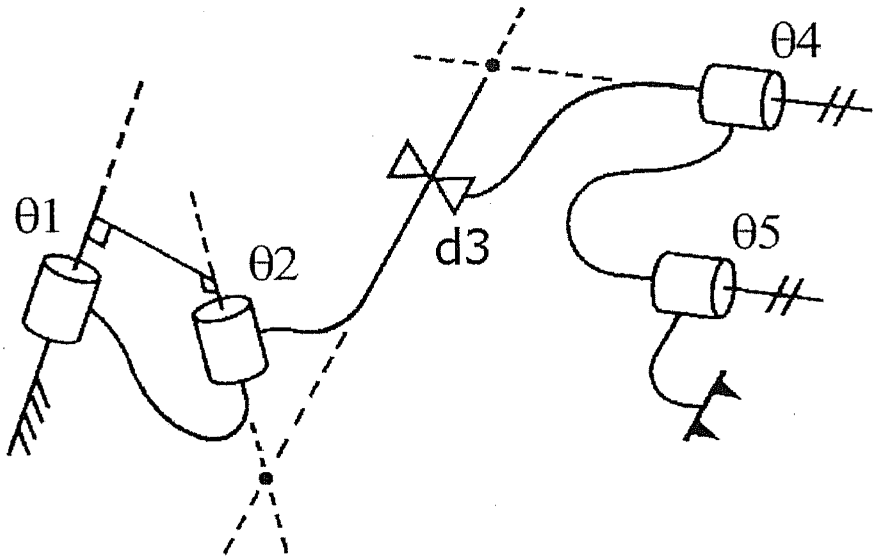

Figure 4

a) Draw a schematic of this manipulator, with the axes of frames {0} through {5} labeled. Include all non-zero DH parameters and the joint variables. Draw your schematic in the position where, as far as possible, the angles θ_i are in their zero positions.

b) Write down the DH parameters for this manipulator.

c) Derive the forward kinematics for this manipulator and find ${}^{0}_{5}T$ (do not perform matrix multiplication).

(Q8)

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

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

c) The coordinate frame assignment is depicted in Figure 5. Derive the inverse kinematics equations for the 2 DOF manipulator.

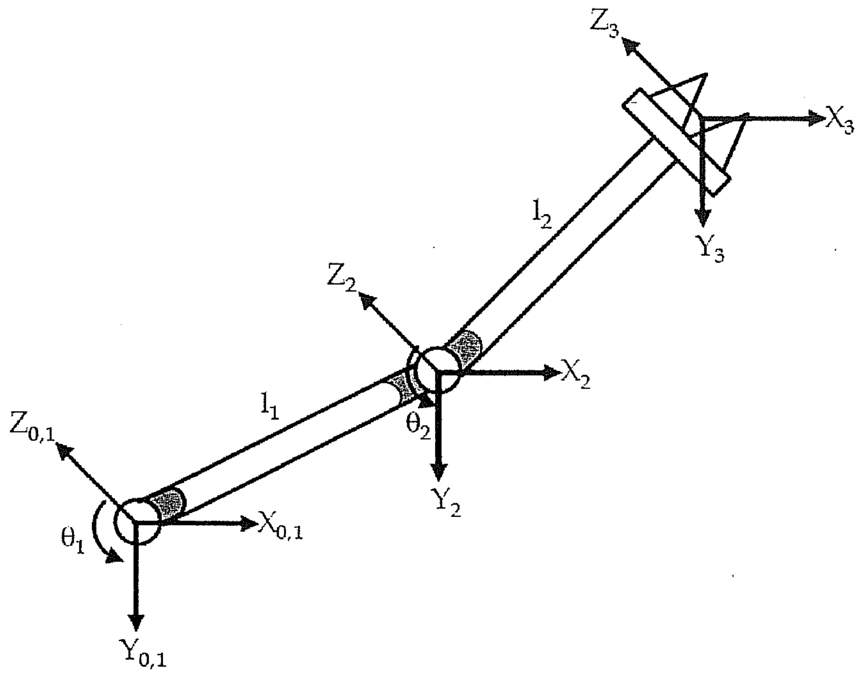

Figure 5

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