The Open University of Sri Lanka
Faculty of Engineering Technology

Study Programme	:	Diploma in Technology/Bachelor of Technology (Engineering)
Name of the Examination	:	Final Examination
Course Code and Title	:	**MEX6271 - ROBOTICS**
Academic Year	:	2012/13
Date	:	24th July 2013
Time	:	0930 – 1230 Hrs
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 the definition for an 'Industrial robot'.

(b) Briefly discuss the evolutionary stages in robotics, emphasizing on their characteristics, control capabilities and applications.

(c) What are the types of robots classified according to tasks? Elaborate on your answer by giving suitable examples.

(d) Elaborate on the importance of 'joints' with respect to robotic manipulators.

Q2. (a) Differentiate between a spatial manipulator and a planer manipulator in relation to robotic manipulators.

(b) Explain the term 'degree of freedom'. Describe the degree of freedom in a spatial and a planer manipulator in terms of position and orientation.

(c) Redundant manipulators would typically have enhanced dexterity. Explain.

(d) What are the types of robots used in industry based on the utilized control system? Give applications of each of the types of robots based on the above classification.

Q3. (a) State and elaborate on robot specifications with regard to;

(i) Speed
(ii) Precision of movement.

(b) A robot's accuracy is often defined as one-half of its control resolution. Explain by taking a suitable example.

(c) A robot's link is actuated by a geared stepper motor. The gear connected to the stepper motor has 15 teeth while the gear connected to the link of the robot has 60 teeth. The controller dives the motor at 1.5^0 per pulse. Determine the link resolution.

(d) Explain the term 'dexterous workspace' in relation to robot workspace.

Q4. (a) Briefly explain the concept of 'equivalent angle axis representation' with respect to fundamental rotation of frames. Using standard notations, obtain an expression for the rotational matrix between two frames for equivalent angle axis representation.

(b) Two coordinate frames {1} and {2} are initially coincident. If frame {2} is rotated by 60^0 about a vector $\mathbf{a} = [0.5 \quad 0.866 \quad 0]^T$ passing through the origin, describe frame {2} with respect to frame {1}. [You may use the expressions obtained in (a) above to arrive at your answer.]

Q5. (a) Show that a vector transformation which rotates a vector by an angle θ and translates it by ${}^1\mathbf{D}$ is same as the homogeneous transformation $\mathbf{T}$ that describes a frame rotated by an angle θ and translated by ${}^1\mathbf{D}$ relative to the reference frame.

(b) In a robotic work cell, a point P is described with respect to the robot's base frame. Determine the new location of this point, if it is rotated by an angle of 45^0 about the z-axis in anti-clock wise direction and then translate it by -2 units along the x-axis and -5 units along the z-axis. Depict the vector transformation pictorially.

(c) What would be the equivalent frame transformation for the vector transformation described in (b) above. Represent this frame transformation in a neat diagram.

Q6. (a) Using basic principles of coordinate transformations and standard notations derive an expression for inverting a homogeneous transformation matrix.

(b) A camera is attached to the fifth link of a six degree of freedom robotic manipulator. The camera observes an object and determines its frame relative to the camera's frame. Determine the necessary motion the end effector has to make to get to the object. The following information given below is known.

$${}^5\mathbf{T}_{camera} = \begin{bmatrix} 0 & 0 & -1 & 3 \\ 0 & -1 & 0 & 0 \\ -1 & 0 & 0 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad {}^5\mathbf{T}_{Hand} = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$^{Camera}\mathbf{T}_{object} = \begin{bmatrix} 0 & 0 & 1 & 2 \\ 1 & 0 & 0 & 2 \\ 0 & 1 & 0 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad ^{Hand}\mathbf{T}_{End-effector} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

[Hint: Use the knowledge of composite transformations and inverse transformations for solving the above problem]

Q7. (a) Distinguish between Joint space and Cartesian space methods in relation to robot trajectory planning.

(b) Using first principles, solve for the coefficients of a cubic polynomial trajectory in joint space trajectory scheme.

(c) A particular joint of a manipulator is to move from an initial position of 20^0 to a final position of 80^0 in 4 seconds. Assuming that the joint starts and finishes at zero velocity, find the cubic polynomial that satisfies this motion. Also determine the position, velocity and acceleration of this joint at intervals of 1 second and plot these against time.

Q8. Figure 01 shows a robot arm having two degrees of freedom. The center of mass for each link is at the center of the respective links. The moments of inertia, masses and lengths of links 1 and 2 are I_1,I_2, m_1, m_2, and l_1, l_2 respectively. Using Lagrangian method, derive the equations of motion for the robot arm. (Assume any missing parameters)

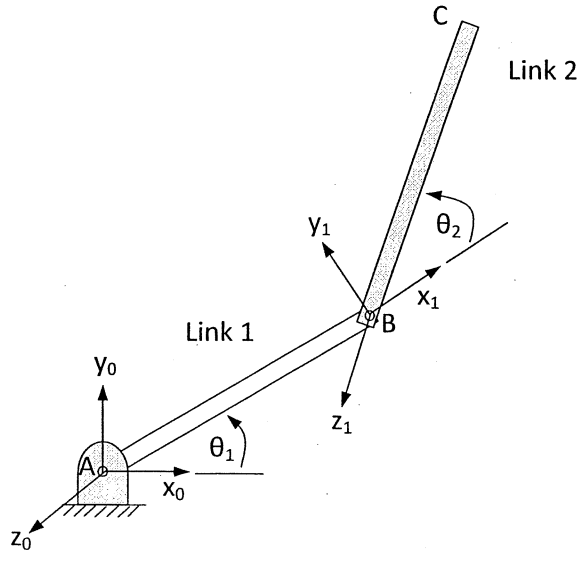


Figure 01

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