[ENG87]

UNIVERSITY OF GREATER MANCHESTER

SCHOOL OF ENGINEERING

MSc ROBOTICS, AUTONOMOUS SYSTEMS AND TELECOMMUNICATIONS

SEMESTER 2 EXAMINATIONS

2024/2025

ROBOTICS

MODULE NO: ROB7006

Date: Wednesday 14 MAY 2025 **Time: 14:00 – 16:00**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions.

Answer any FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

This examination paper carries a total of ONE HUNDRED marks.

All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.

Question 1

(a) Define robotics and explain its importance in modern industries, provide examples in the roles that it is commonly used in. **(8 marks)**

(b) Name and briefly describe five common types of serial robotic joints. **(10 marks)**

(c) Illustrate and label a schematic diagram of a PRR (Prismatic-Revolute-Revolute) robotic manipulator, including its joints, links, and end effector. **(7 marks)**

Total Marks: 25

Question 2:

(a) Identify and briefly explain the key components of a robotic vision system **(10 marks)**

(b) Explain the key differences between edge detection and feature matching in computer vision, including their purposes, methods, and common applications . **(8 marks)**

(c) What are the differences between monocular, stereo, and depth cameras? **(7 marks)**

Total Marks: 25

Please turn the page

Question 3:

(a) You are designing a robotic arm with the aim of maximising strength while minimising weight.

i) What are the key factors to considerate in selecting a suitable motor? Briefly explain why they are an important factor. **(10 marks)**

ii) Which motor would you select for a small medical robotic arm, justify your choice. **(3 marks)**

(b) A motor you selected for the shoulder joint of a robotic arm is too weak and stalls under load. Assuming power is provided uninterrupted, what will eventually lead to permanent damage? **(8 marks)**

(c) Discuss the safety of a "soft" robotic arm's end-effector hitting an object at 3 m/s compared to a conventional robotic arm. **(4 marks)**

Total Marks: 25

Question 4

A. Consider a 2-DOF planar robot arm with two links of lengths L1 = 10cm and L2 = 8cm. The base of the arm is at origin (0,0).
- The first (shoulder) joint rotates by θ_1(measured from the positive x-axis).
- The second (elbow) joint rotates by θ_2 relative to the first link.

a) Write the equations for the x and y coordinates of the end-effector in terms of θ_1 and θ_2.

(8 marks)

b) If $\theta_1 = 30^0$ and $\theta_2 = 45^0$, calculate the (x, y) position of the end-effector.

(7 marks)

B. A vector is described as P = 3i + 5j + 2k. Express the vector in matrix form:

a) With a scale factor of 2.

(5 marks)

b) If it were to describe a direction as a unit vector.

(5 marks)

Total: 25 Marks

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Question 5

A. Discuss the challenges and considerations involved in implementing inverse kinematics for a 2-DOF planar robotic arm in embedded systems. In your response, explain the role of inverse kinematics, the factors that affect the feasibility of solutions, and how workspace limitations impact motion planning.

(12 marks)

B. A vector **p =** $\begin{bmatrix} \mathbf{0.371} \\ \mathbf{0.557} \\ \boldsymbol{q_z} \\ \mathbf{0} \end{bmatrix}$ is 5 units long and is in the direction off a unit vector q.

Express the vector in matrix form.

(8 marks)

C. Define Transformations and list its different forms.

(5 marks)

Total: 25 Marks

End of Questions.

Turn over for the Formula Sheet.

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Formula Sheet

To determine the end-effector position (x, y) given joint angles

$$x = L_1 cos\theta_1 + L_2 \cos(\theta_1 + \theta_2)$$
$$y = L_1 sin\theta_1 + L_2 \sin(\theta_1 + \theta_2)$$

To determine joint angles from a given end-effector position:

$$cos\theta_2 = \frac{x^2 + y^2 - L_1^2 - L_2^2}{2L_1L_2}$$

$$\theta_2 = cos^{-1}\left(\frac{x^2 + y^2 - L_1^2 - L_2^2}{2L_1L_2}\right)$$

$$\theta_1 = tan^{-1}\left(\frac{y}{x}\right) - tan^{-1}\left(\frac{L_2 sin\theta_2}{L_1 + L_2 cos\theta_2}\right)$$

For a 2D rotation by angle theta:

$$R(\theta) = \begin{bmatrix} cos\theta & -sin\theta \\ sin\theta & cos\theta \end{bmatrix}$$

For joint rotation and translation:

$$T = \begin{bmatrix} cos\theta & -sin\theta & x \\ sin\theta & cos\theta & y \\ 0 & 0 & 1 \end{bmatrix}$$

To find the final position in homogeneous coordinates**:**

$$P_{final} = T_1 \, x \, T_2 \, x \, P_{base}$$

Where, $P_{base} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$

Dot Product.
A = (A_x, A_y)
B = (B_x, B_y)

$$cos\theta = \frac{A.B}{|A||B|}$$

$$\theta = cos^{-1}\left(\frac{A_xB_x + A_y B_y}{\sqrt{A_x^2 + A_y^2}.\sqrt{B_x^2 + B_y^2}}\right)$$

Cross Product for 3D Robotics

$$AxB = \begin{bmatrix} A_yB_z - A_zB_y \\ A_zB_x - A_xB_z \\ A_xB_y - A_yB_x \end{bmatrix}$$

END OF EXAM