

HERIOT-WATT UNIVERSITY

**SCHOOL OF MATHEMATICAL
AND COMPUTER SCIENCES**

**COMPUTER
SCIENCE**

ROBOTICS & AUTOMATION

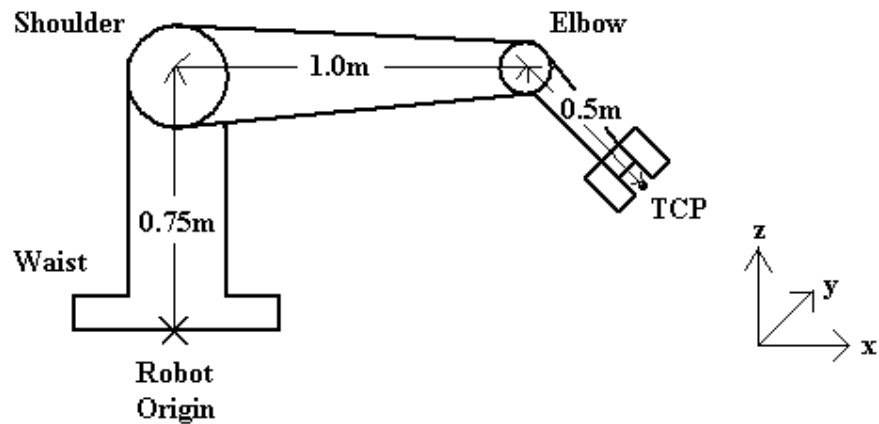
**DECEMBER 2011
2 Hours**

Answer THREE questions

**Candidates may only use a University approved
Calculator**

Q1

Consider the following manipulator geometry with three rotational joints (waist, shoulder, elbow) -



- (a) Derive the inverse kinematic equations for the three joint angles for this manipulator.
[Hint: Geometric intuition can be used here]

(13)

- (b) Solve the inverse kinematic equations for a TCP position, in the robot reference frame, of -

$$\begin{aligned}x &= 1.0\text{m} \\y &= 0.0\text{m} \\z &= 0.75\text{m}\end{aligned}$$

(7)

Q2

- (a) Examine the following VAL-1 program:

```

SHIFT NIB BY 10.0, 10.0, 0.0
MOVE NIB : OFFSET
MOVES NIB
SHIFT NIB BY 80.0, 80.0, 0.0
MOVES NIB
SHIFT NIB BY 80.0, -80.0, 0.0
MOVES NIB
DEPART 20
SHIFT NIB BY -40.0, 40.0, 0.0
MOVE NIB : OFFSET
MOVES NIB
SHIFT NIB BY -80.0, 0.0, 0.0
MOVES NIB
DEPART 20
SHIFT NIB BY -50.0, -50.0, 0.0
MOVES NIB
STOP

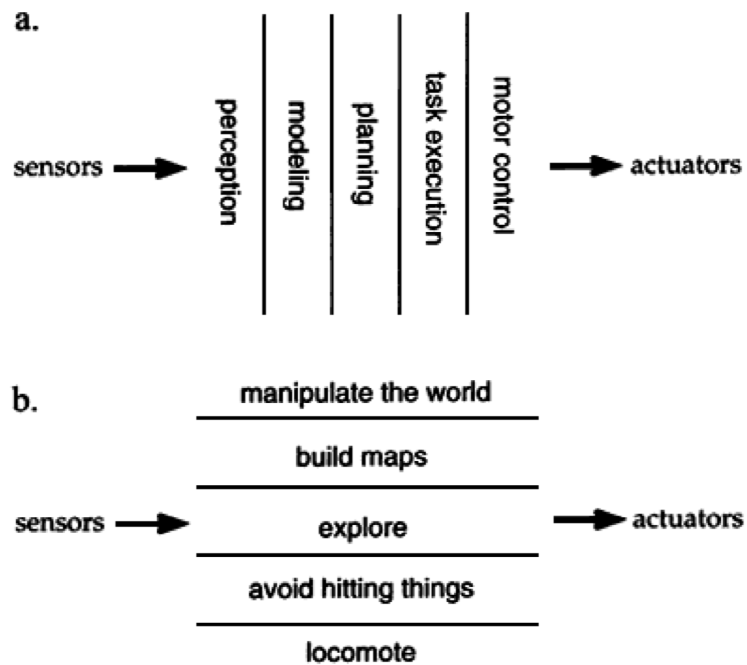
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If a pen is used as the end-effector of a PUMA robot executing this program and a blank piece of paper is supported in the $Z=0$ plane and *NIB* and *OFFSET* are initialised as follows:

$$NIB = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad OFFSET = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 20 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

- (i) Draw a diagram of the shape which will appear on the paper. Give precise co-ordinates for all important points and indicate the direction of travel of the Tool Centre Point. (8)
 - (ii) What would be the likely effects of substituting *MOVE* commands for *MOVES* commands in the program? (2)
 - (iii) Why is the off-line programming of robots in this manner still problematic and unreliable? (4)
- (b) Describe three other methods by which an industrial manipulator could be programmed. (6)

- Q3 (a) What is an “adaptive system”? Differentiate “adaptation” and “learning”. (6)
- (b) Define “adaptive behaviour”. Explain the difference between “behaviour” and “mechanism”. (6)
- (c) Explain the difference between the two architectures a. and b. below of an intelligent control system of a robot.



(8)

- Q4 (a) A robot wishes to go through a door but the door is locked. A robot adopting a cognitive approach has constructed the following plan in its 'head':

Plan for opening the door:

- Go to the place where the key is.
- Take the key.
- Go to the door.
- Open the door with the key.

Suggest some rules that a reactive robot could use to solve the same task. What are the limitations of the approach that the reactive robot uses compared to the cognitive robot?

(7)

- (b) There are four types of adaptation, define "evolutionary adaptation". Explain the "Baldwin Effect".

(6)

- (c) Define "reality-gap" in robotics. Explain one way of "crossing the reality-gap" when designing an intelligent robot controller.

(7)

END OF PAPER