EXAMINATION PAPER: 2323T

SHEFFIELD HALLAM UNIVERSITY

SCHOOL OF ENGINEERING

Full Course Title: **BENG (HONS) ELECTRONIC SYSTEMS ENGINEERING (TARC)**

Level: **3**

Unit Title: **Robotics**

Date: **Friday, 7 September 2001** **Time allowed: 2 hours**
From: 14.00 to 16.10
(including 10 mins reading time)

INSTRUCTIONS TO CANDIDATES:

1. **The normal University examination regulations apply (see script answer book)**
2. **Do not start writing until instructed to do so by the Invigilator**
3. **Answer any THREE questions**
4. **All questions carry equal marks.**

REQUIRED	PLEASE TICK	PLEASE SPECIFY TYPE/NUMBER
TABLES ATTACHED		
DIAGRAMS ATTACHED	✓	WORKSHEET FOR QUESTION 4
FORMULAE BOOKS REQUIRED		
16 - PAGE BOOKLETS	✓	
8 - PAGE BOOKLETS		
SUPPLEMENTARY BOOKS	✓	
GRAPH PAPER REQUIRED	✓	LINEAR

UNIT TUTOR(S): Stuart Birchall

1. **(a)** Several different types of robot exist and there are many methods of classification. Briefly describe one method of classification and give an example for each category of robot within this classification method. **[5 marks]**

(b) Comment on the typical applications of the types of robots in part a) and mention any advantages or disadvantages. **[6 marks]**

(c) Briefly compare humans and robots with regard to performance of "pick and place" tasks. **[6 marks]**

(d) Figure Q1 shows the PUMA robot in its home position. Determine the A matrix for joint J3. **[8 marks]**

(e) The position of the end effector of the PUMA robot arm is given by (400i+300j+200k). Determine the new position of the end effector when it is rotated by 30 degrees about joint 2 followed by a further rotation of 45 degrees around joint 3. Assume $L_2 = 500$ (all dimensions are in millimetres). **[8 marks]**

The following may be of use:

$$\text{tran}(a, b, c) = \begin{bmatrix} 1 & 0 & 0 & a \\ 0 & 1 & 0 & b \\ 0 & 0 & 1 & c \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Rot}(x, \theta) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Rot}(y, \theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Rot}(z, \theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

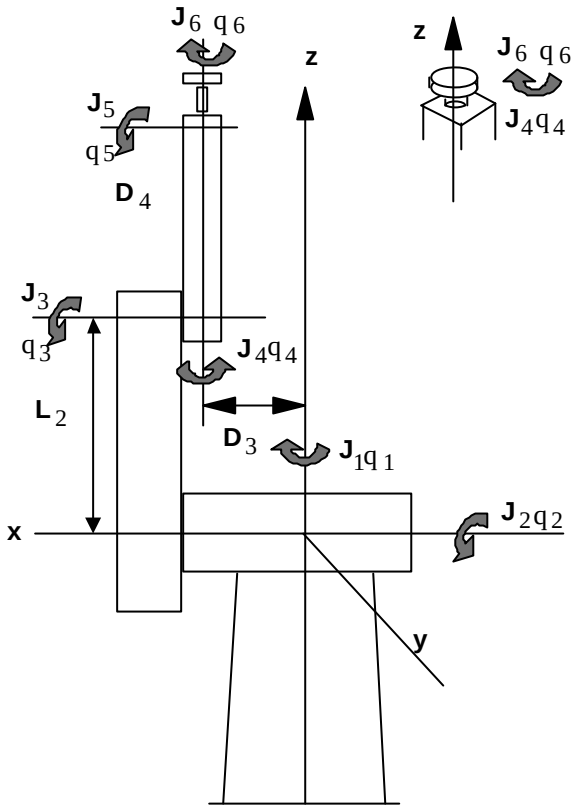


Figure Q1

2. **(a)** Briefly comment on the use, advantages and disadvantages of electrical, hydraulic and pneumatic actuators as used in robots. Full marks can be obtained for 6 areas of comparison **[6 marks]**

(b) Briefly describe the two types of joint known as prismatic and revolute and give an example application of each. **[3 marks]**

(c) Briefly comment on the differences of construction and use of a brushless permanent magnet dc motor and a stepper motor. Mention any advantages and disadvantages. **[6 marks]**

(d) Explain what is meant by the terms holding torque, pull-in torque and pullout torque with reference to a stepper motor. **[3 marks]**

(e) A prismatic joint on a Cartesian robot is driven by a linear drive that comprises a DC motor and lead screw. A linear movement of 1.0 metre requires 200 turns of the lead screw. The motor produces a maximum torque of 0. 5 Nm at a speed of 1200 r.p.m. and has a rotor Moment of Inertia of 0.005 Kg m^2. The mass of the linear moving parts of the joint combined with the payload is equal to 50 Kg.

(i) Calculate the maximum load speed **[2 marks]**

(ii) Calculate the effective mass of the motor referred to the linear part of the drive. **[3 marks]**

(iii) Calculate the maximum linear acceleration of the load. **[4 marks]**

(iv) The lead screw can be considered to be a uniform cylinder of diameter 20mm and a length of 1.5 metre. It is made from steel of density 8000 Kg m^{-3}. **[6 marks]**

Calculate :
- the Moment of Inertia of the lead screw
- the effective mass of the screw referred to the linear motion
- the effect on the maximum linear acceleration

The following may be useful :

$$M_{eff} = \frac{4\pi^2 I}{p^2}$$

$$F = \frac{2\pi T}{p}$$ For a uniform cylinder , $$I = \frac{\pi \rho a d^4}{32}$$

3. **(a)** A wire-wound potentiometer consists of resistance wire of diameter 0.25mm close wound on an insulating former of mean diameter 50mm.

(i) What is the angular resolution of this sensor?

(ii) The potentiometer is used as an angular sensor on a 500mm long robot arm. What positional error at the far end of the arm does this resolution correspond to?

[5 marks]

(b) A 10kΩ potentiometer is used to measure angular rotation over a range 0 to 270 degrees. It is fed from a 10V DC excitation supply and its output feeds a buffer amplifier of input resistance equal to 100kΩ. What is the expected error in measurement when the potentiometer is at its mid range position?

[5 marks]

(c) To control the velocity of the arm velocity feedback is required. Describe in detail a device that could be used to provide the required signal.

[8 marks]

(d) By referring to Figure Q3 fully describe the operation (with relevant mathematics) of a resolver to digital tracking converter.

[9 marks]

(e) What is the main advantage of this method of conversion in respect of conversion time?

[3 marks]

(f) How can the same converter be used to give a signal proportional to velocity?

[3 marks]

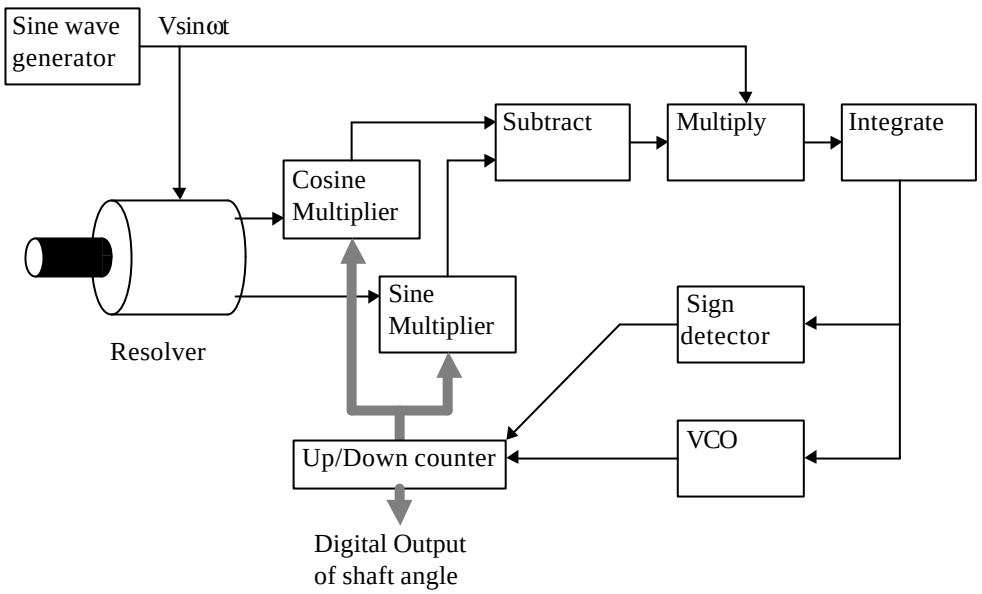


Figure Q3

4. **(a)** Compare the advantages and disadvantages of machine vision against human vision. **[8 marks]**

(b) In a vision system satisfactory illumination of the scene and workpiece is of paramount importance. Briefly discuss the lighting methods commonly used. **[5 marks]**

(c) The general form of a 3 x 3 convolution mask is given by

$$\begin{bmatrix} w_4 & w_3 & w_2 \\ w_5 & w_0 & w_1 \\ w_6 & w_7 & W_8 \end{bmatrix} \frac{1}{N}$$

How is the value of N calculated? **[3 marks]**

(d) A vision system produces a digitised image of an object. The object is solid but some noise is apparent in the digitised image. The white space within the object and the single black pixel are both due to noise. The system has only two grey levels, 0 and 1, and produces an image of 10 pixels by 10 pixels. This image is shown in Figure Q4. The size of each pixel is 1 unit by 1 unit.

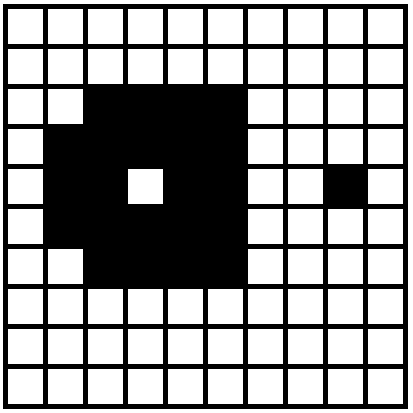


Figure Q4

(i) Suggest a 3 x 3 convolution mask that could be used to low pass filter the image. Use this mask and obtain the processed image. Fill in the pixel values on the worksheet provided. **[7 marks]**

(ii) Calculate the co-ordinates of the Centroid of the processed image of part d (i). Clearly show the origin of your co-ordinate system on the worksheet provided. **[5 marks]**

(iii) Determine an algorithm suitable for finding the perimeter of an object from its digitised image, assuming that there is no more than one image segment on any line. **[5 marks]**

5. **(a)** The PUMA robot can be controlled in three possible manual modes, known as world mode, tool mode and joint mode. Explain the meaning of these terms making reference to the co-ordinate system used in each case. **[6 marks]**

(b) By considering two separate applications explain why trajectory adhesion is more important in some applications than in others. **[3 marks]**

(c) Imagine that you have now left University, having successfully passed your degree. You have recently started a new job with a company and your manager has noticed from your CV that you have studied Robotics. He sets you the following task. **[12 marks]**
It is required to move various parts from one part of the factory to another. This is presently undertaken manually by operatives either carrying or using a forklift to transport the parts. Your manager wants you to write a report evaluating the options for using some type of mobile robot. He does not have an understanding of the potential technical problems, health and safety issues, or the information that he needs to make available for you to make the evaluation.

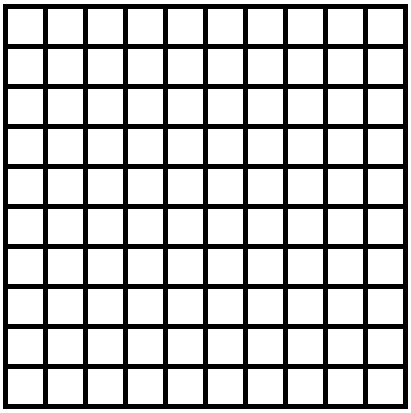
He has arranged a staff meeting for you to gather the information from staff.

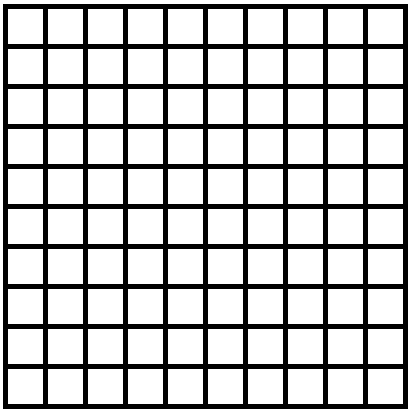
Write a short report explaining the information that you would request and what bearing this would have on the evaluation. Discuss the types of mobile robot that you could use dependant on the information you might receive.

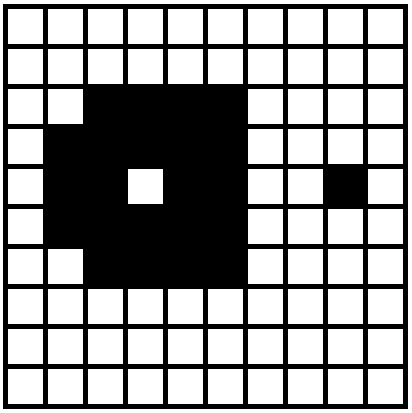
(d) A robot joint is to move from 15 degrees to 75 degrees in 3 seconds. The joint has an initial angular velocity of 20 degrees per second and the final angular velocity is to be zero.

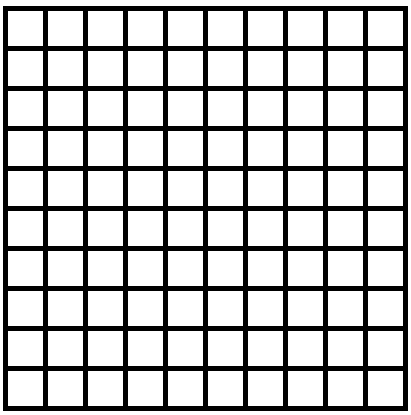
(i) Deduce three separate expressions for the joint position, velocity and acceleration as a function of time. **[7 marks]**

(ii) Sketch graphs of the joint position, velocity and acceleration as a function of time. **[5 marks]**









Worksheet for Question Q4