SCHOOL OF MATHEMATICAL AND COMPUTER SCIENCES

Computer Science

F21RO

INTELLIGENT ROBOTICS

Semester 2 2016/17

Duration: Two Hours

ANSWER THREE QUESTIONS

Answer each question in a <u>separate</u> script book

Q1 (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
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
```

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:

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

(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)

Q2 (a) What is an Euler angle set and what are the advantages of using such a set to specify an orientation in 3-Dimensional space? (4)

(b) (i) Determine the general Euler angle matrix for a Z-Y-Z set of ϕ, θ, ψ. (4)

(ii) Derive robust formulae for the three Z-Y-Z Euler angles which describe the orientation contained in a homogeneous transformation of the form –

$$\begin{pmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

(4)

(iii) In what sense are the formulae you derived in (ii) robust? (2)

(c) Calculate the Z-Y-Z Euler angle set that would produce a re-orientation of a manipulator's TCP of 180° about its local *x*-axis followed by -90° about its local *y*-axis. (6)

Q3 The I-Spy game is a game that is played with young children. It requires a player to find an object within the environment, based on the description of the other player. Usually they begin with the information about the colour of the object. A player has 5 questions to identify the correct object or his opponent gets a point for this round. The winner of the game is the player who can identify the most objects with the fewest questions.

Assume you have a robotic system that is able to play the I-Spy game with a human. It has two different strategies to win the game, which can be selected before the game is started from the programmer.

Using this robotic system you want to identify the best strategy for the robot to win the game.

S1: One strategy of the robot is to always pick the object of the given colour closest to the human.

S2: The second strategy is to pick a random object of the given colour.

Hypothesis: The robot will win more games when using the first strategy (S1).

(a) Describe a setup for your study using the following equipment – (6)

- A NAO robot equipped with the capability to play the I-Spy game
- Two video cameras
- A Laptop to collect data
- Lab space with table and chairs
- Objects placed on the table to play with the robot

(b) Design the process of a human-robot interaction study given the above hypothesis “The robot will win more games when using the first strategy.”

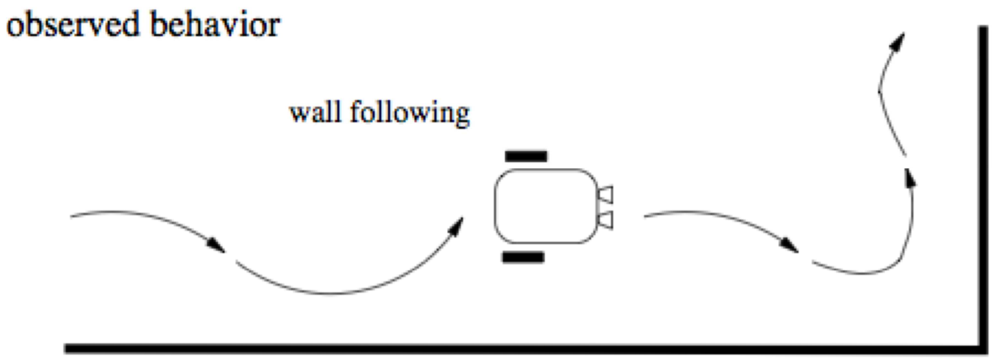
(i) What evaluation metrics would you use and why? (2)

(ii) What participant population would you invite and how many would you invite? (2)

(c) (i) What is the formal definition of “embodiment”? (5)

(ii) How can you change the embodiment of an humanoid robot? (5)

Q4 Given the observed behaviour below, answer the following questions:



(a) Using a Genetic Algorithm, implement an evolutionary robotics approach to design a robot controller to evolve this "wall following" behaviour in a two-wheeled robot with only 3 distance sensors, one at the front and one at each side of the robot.

You must explicitly explain the rationale behind your design choices for:

(i) The genetic encoding (2)

(ii) The initial population size (2)

(iii) The maximum number of generations (2)

(iv) The selection criteria for each generation (2)

(v) The fitness function (2)

(vi) The crossover and mutation rate (2)

(b) Could the mechanism evolved for item (a) generate a different behaviour? Give an example. (3)

(c) What is emergent behaviour? Explain what kind of behaviour could emerge during your experiment if you add another 6 robots in the same arena with the same evolved mechanism of item (a). (5)

END OF PAPER