UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2004

BEng Honours Degree in Computing Part III
for Internal Students of the Imperial College of Science, Technology and Medicine

This paper is also taken for the relevant examinations for the Associateship of the City and Guilds of London Institute

PAPER C333=I3.25

ROBOTICS

Tuesday 27 April 2004, 14:30
Duration: 120 minutes

Answer THREE questions

Paper contains 4 questions
Calculators not required

1a i) Define the work envelope of an industrial robot.

ii) Explain how different combinations of links and joints affect the size and shape of the work envelope.

iii) Give two examples of standard jointed manipulators and calculate the volume of the work envelope in each case, assuming links of length l.

b Six degrees of freedom are required to move a body to any point in space at any orientation.

i) Describe an industrial application where fewer than six degrees of freedom are needed

ii) Describe a situation where more than six degrees of freedom are desirable.

iii) For a walking robot, discuss how many degrees of freedom each leg requires.

c You are commissioned to design a chess-playing robot arm for use with a normal-sized board and standard pieces. Discuss

i) What type of manipulator is appropriate.

ii) What type of end-effector.

iii) What motors and drive system you would use.

iv) What sensors your system would need.

Note: You are not being asked to describe the control program of the robot, only the mechanics involved. Simplicity of control may be a consideration. There is no single correct answer, but you must explain and justify your decisions.

The three parts carry, respectively, 30%, 30%, 40% of the marks.

2a Explain how an encoder can be used to provide

i) Incremental shaft positioning, with direction of movement.

ii) Absolute shaft positioning, using binary code.

Include the techniques used in each method, with any advantages and disadvantages.

iii) Explain what a race condition is and how it can occur with an absolute encoder using binary code. Suggest two solutions.

b Ackerman steering is almost universally used in the car industry.

i) Explain why it is unusual in mobile robots.

ii) Suggest an alternative and explain why it is more appropriate.

iii) Describe a situation in which your answer to ii) would *not* be appropriate and suggest an alternative drive system which would be better.

c A hopper provides a single stream of small LEGO bricks, some blue, some yellow. Describe how you would implement a system to sort the bricks by colour into two separate bins, using the standard LEGO Mindstorms components. Include commented pseudo-code for the control program required.

The three parts carry, respectively, 30%, 30%, 40% of the marks.

3a i) What is a Teleo-Reactive (T-R) program. Give an informal operational semantics.

ii) What is a universal T-R program? What part of the program characterizes the state of the world, as perceived by the robot, that the program is designed to achieve.

b Consider a small round robot in a room containing convex obstacles similar to that depicted below. The gaps between the obstacles are always at least *two* robot diameters wide. You cannot assume anything about their locations but you can assume there is always a path at least two robot diameters wide between any two obstacles and between an obstacle and a wall.

The robot has obstacle detecting sensors. Using these it can detect when an obstacle is directly in front within one robot-diameter and it can detect when an obstacle is within one robot diameter on its left or right side. It can also determine when it is facing north.

Assume that the robot has sensor test routines that return the percepts:

`object_in_front`	there is an object in front
`object_left_side`	there is an object on the left
`facing_north`	true when it is facing due north

Also assume that the robot has actions:

`move_forward`	moves the robot in a straight line in direction it is currently pointing
`swivel_right`	causes the robot to turn right with no forward motion
`swivel_left`	causes the robot to turn left with no forward motion

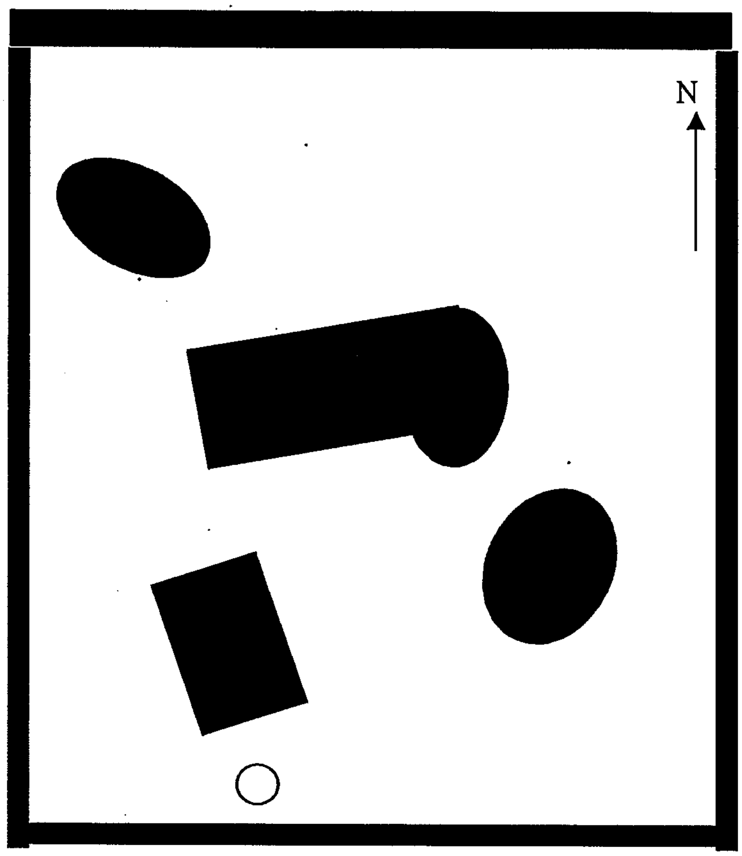
All are persistent actions – they will continue until another action is selected.

i) Give a sequence of T-R rules that will serve as a control program for getting the robot to the north west corner of the room. The robot should not collide with any obstacle. To prevent this it should not continue its forward motion if an obstacle is detected in front but should navigate round the obstacle to the right.

You can assume that if it detects an obstacle in front, and it swivels to the right, then whilst it is swivelling it will continue to perceive that the obstacle is in front until it perceives it to be on its left hand side. It will only simultaneously perceive that there is an obstacle in front and to its left when at the north west corner of the room.

(Hint: You might find it useful to have a state variable, `avoiding`, that starts with value `false` but which has value `true` while the robot is trying to avoid an obstacle by move round it to the right.)

ii) Explain how the robot will behave under control of your program and state any other assumptions you may have made about the environment.



The two parts carry, respectively, 30% and 70% of the marks

4a i) Summarise the vector fields approach to controlling the behaviour of a mobile robot.

ii) Mention one drawback and indicate how it can be overcome.

iii) What important behaviour cannot be represented as a vector?

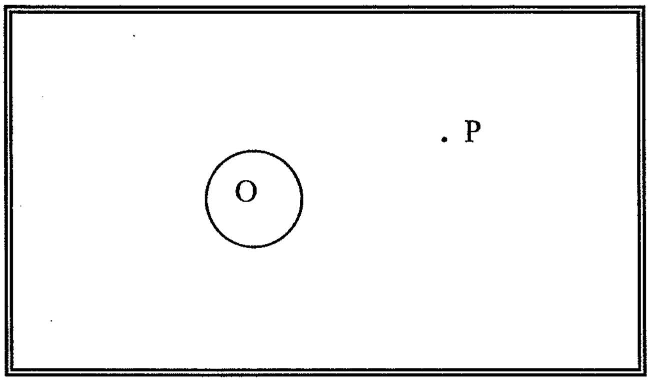
b In the diagram below O is a cylindrical object to be avoided when a robot is within 1 meter of the circumference of the object. The cross section of O is a circle one metre in diameter.

P is a position in the space is to be approached at a uniform speed by the robot from any point in the space

The robot must move away from a wall if it gets within 1 meter.

Copy the diagram and indicate, using an arrow, the *combined* vector force that can be viewed as acting on a robot at *any* non-occupied position.

Also indicate a position in which the combined vector force acting on the robot may be zero.



c When the vector forces that are considered to be acting on a robot need to be computed the robot uses its sensors to sensors to determine the strength and direction of each force. Give functions that the robot might use to compute the force acting upon it from:

i) A position P that lies at an angle A to the right of the current orientation of the robot D meters away and which should be approached at a constant speed until the robot is within 2 meters when the speed should decrease linearly until it at P.

ii) An obstacle O that is to be avoided which lies an an angle of A degrees to the left of its current orientation a distance D away. The robot should move tangentially to the obstacle at a constant speed when it is 1.5 meters away, and it should move away from the obstacle when it is within 1.5 meters of the obstacle. The repulsive force felt by the robot should increase linearly from 0 to 1 as the distance between the obstacle and the robot moves from 1.5 meters to 0 meters.

The three parts carry, respectively, 40%, 30%, 30% of the marks