E3.16
ISE3.23

IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2003

EEE/ISE PART III/IV: M.Eng., B.Eng. and ACGI

ARTIFICIAL INTELLIGENCE

Friday, 9 May 10:00 am

Time allowed: 3:00 hours

There are SIX questions on this paper.

Answer FOUR questions.

Corrected Copy

Any special instructions for invigilators and information for candidates are on page 1.

Examiners responsible	First Marker(s) :	J.V. Pitt
	Second Marker(s) :	M.P. Shanahan

1. (a) Briefly compare and contrast uniform cost, best first and A* search algorithms.

[6]

(b) Consider the problem illustrated in Figure 1.1. Tiles can slide one space left or right into the empty space, or can hop over one tile into the empty space. The problem is to change the initial state into the goal state by moving one tile at a time.

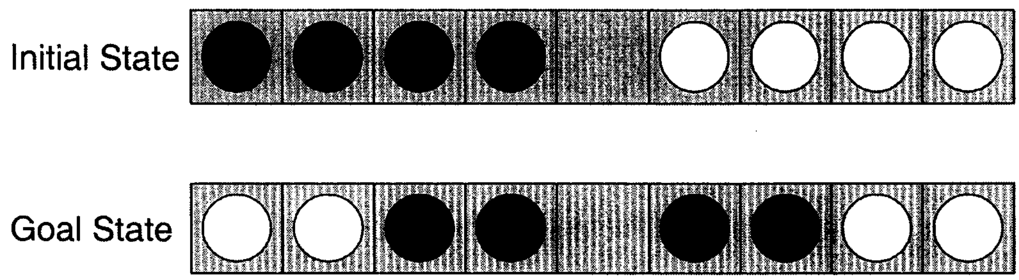


Figure 1.1

Give two heuristics for informed search for this problem, and explain why they would be appropriate for A* search.

[6]

(c) One heuristic is said to be more informed than another if it explores less of a search space in finding a solution to a problem. Explain how one heuristic can be more informed than another in terms of path cost function g, and heuristic cost function h. Illustrate your explanation with reference to the two heuristics given in part (b).

[6]

(d) Briefly comment on ways to make heuristics 'more informed' for A* search.

[2]

2. (a) Define, using Prolog or other appropriate declarative notation, relations for the following list processing functions:

   (i) `sublist/2, sublist( +Li, -Lo )`
   which is true if `Lo` is a sublist of `Li`;

   (ii) `monotonic/1, monotonic( +Li )`
   which is true if all the elements of `Li` are in ascending or descending order;

   (iii) `length/2, length( +Li, -N )`
   which is true if the number of elements in `Li` is `N`;

   (iv) `reverse/2, reverse( +Li, -Lo )`
   which is true if `Lo` contains all the elements of `Li` in reverse order.

[8]

(b) Consider the problem illustrated in Figure 2.1 below. The problem is to arrange all the disks in increasing order of size. The only operation allowed is to 'flip' (reverse) any sequence of disks that are in (increasing or decreasing) order.

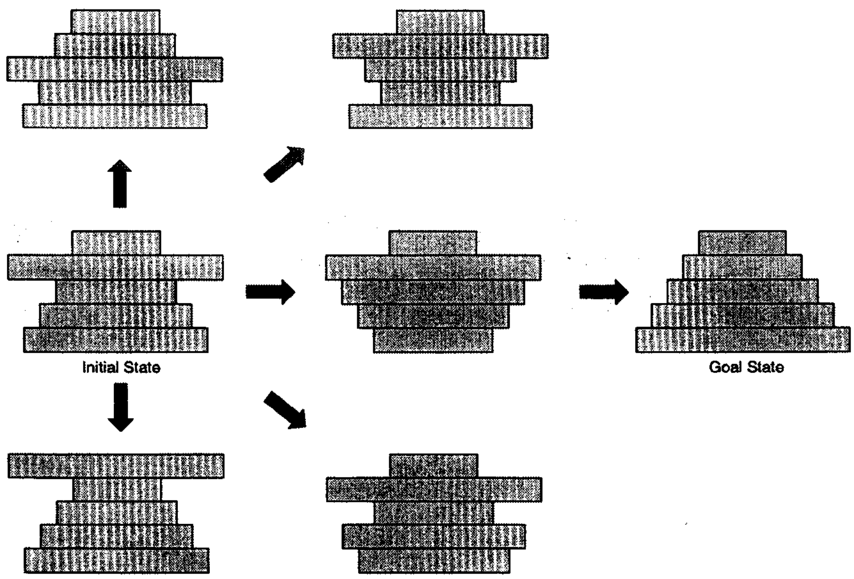


Figure 2.1

Formulate the search space for this problem so that it could be used with the General Graph Search Algorithm. Explain your state space representation and comment the steps in the state-change rule(s).

[8]

(c) Explain how the formulation of part (b) is an implicit definition of a graph rooted on the initial state, and explain how an uninformed search algorithm constructs the graph from this definition.

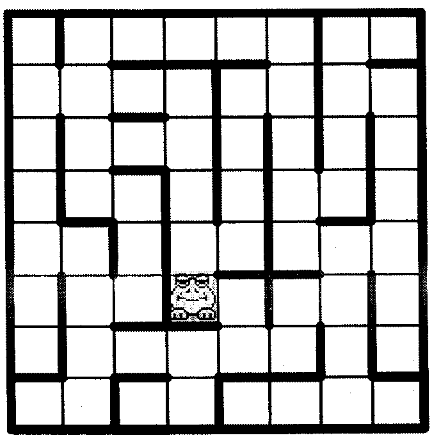
[4]

3. (a) Give a general algorithm for path finding and path following for a robot operating in grid-like mazes, as illustrated in Figure 3.1(a). Explain the data structure used by the robot to represent its environment, the basic steps in the algorithm, and state any assumptions that you make. Illustrate your answer with an example.

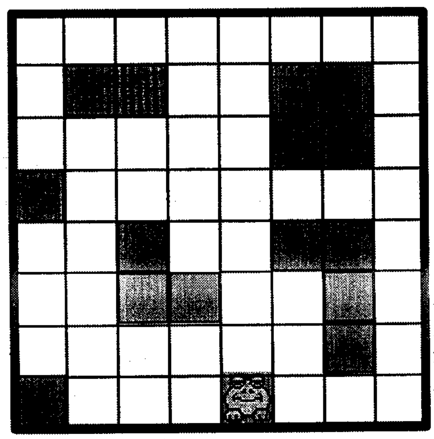
[10]

(b) Give a general algorithm for path finding and path following for a robot operating in an open environment, with obstacles made up of regular polygons and other moving robots, as illustrated in Figure 3.1(b). Explain the steps in constructing a global map of the environment, the steps in determining a path from its current location q to a goal location $qloc$, and how the affects of other moving objects can be accommodated.

[10]



(a) Grid-like Maze



(b) Open Environment

Figure 3.1

4. (a) Prove, using the proof procedure KE, the following equivalences:
   (i) $(p \to q) \leftrightarrow (\neg p \lor q)$
   (ii) $(p \lor q) \leftrightarrow \neg(\neg p \land \neg q)$
   (iii) $((p \land q) \to r) \leftrightarrow (p \to (q \to r))$
   Annotate your proofs to show the KE rule/formula(s) used at each step.

[6]

(b) Consider the following English statements:

Every general is able to issue orders to any captain.
Every captain is able to issue orders to any private.
Being able to issue orders is transitive.
Benjamin is a private.
Scarlet is a captain.
Chaos is a general.

(i) Formalise these statements as sentences of First Order Predicate Logic;
(ii) Convert these sentences to Horn Clauses, using the equivalences of part (a) if required;
(iii) Prove, using resolution, that General Chaos is able to issue orders to Private Benjamin. In particular, show the unifications in each step of the proof.

[12]

(c) Given that, for some steps in the proof of part (b)(iii), there are several possible unifications, explain briefly how this procedure could be automated.

[2]

5. (a) Briefly explain four desirable properties of a proof system for propositional logic.

[4]

(b) Consider the following English statements:

I have a euro.
If I have a euro, then I can buy a coffee.
If I have a euro, then I can buy a doughnut.
Therefore, I can buy a coffee and I can buy a doughnut.

(i) Formalise these statements as sentences of Propositional Logic;
(ii) Prove, using the KE proof procedure, that the argument in sound;
(iii) Account for the unintuitive result;
(iv) Suggest a scheme whereby the KE proof procedure could be modified to produce arguments more in keeping with intuition.

[7]

(c) Show that the axiom schema B, $p \rightarrow \Box\Diamond p$, is not valid in the class of all models.
Show that the axiom schema B is valid in the class of models in which the accessibility relation R is symmetric.

[6]

(d) Given the modal KE proof rules for the modal logic S5 as:

$$\frac{i : \Box p}{j : p} \quad \frac{i : \neg\Diamond p}{j : \neg p} \quad \textit{for any integer } j \qquad \frac{i : \neg\Box p}{j : \neg p} \quad \frac{i : \Diamond p}{j : p} \quad \textit{for } j \textit{ new to the branch}$$

Prove that the axiom schema B is a theorem of S5 using modal KE. Annotate each step in the proof with the rule and formula(s) being used.

[3]

6. (a) Explain how a vector clock can be used to determine *potential causality* between events in a distributed system without a global clock.

[6]

(b) Using a Message Sequence Chart (MSC), indicate the problems of determining the sequence of messages and responses in an English Auction Protocol, from the point of view of the auctioneer and a bidder. Indicate how these problems can be resolved using potential causality, using message pairs on the MSC.

[8]

(c) Describe a scheme for implementing a vector clock in a system of communicating agents participating in an English Auction Protocol.

[6]