OLLSCOIL NA hÉIREANN
THE NATIONAL UNIVERSITY OF IRELAND
COLÁISTE NA hOLLSCOILLE, CORCAIGH
UNIVERSITY COLLEGE, CORK

RESIT EXAMINATIONS

B.Sc. Honours in Computer Science 1998

Knowledge Based Systems

Time allowed: **Two hours**

Answer **all** questions.

1 (10 marks)

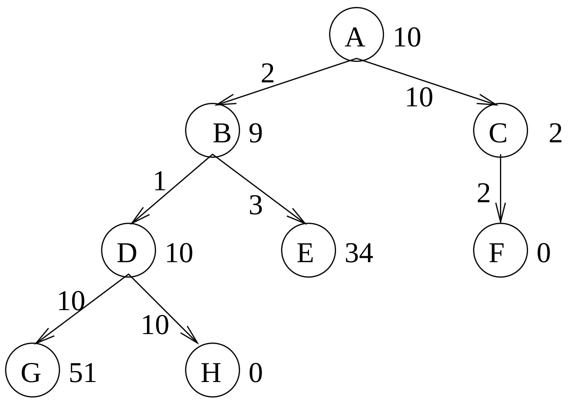
(i) [5 marks]

(a) [1 mark] What is meant by the *branching factor* of a state space?

(b) [4 marks] Let b be the branching factor of a state space, d be the length of the path to the shallowest solution, and m be the maximum of the lengths of the paths in the state space.

Using 'big-oh' notation, give the worst case *time complexity* and *space complexity* of *breadth-first search* and *depth-first search*.

(ii) [5 marks] Consider the following state space in which the states are shown as nodes labeled A through H. A is the initial state, and F and H are the goal states. The numbers alongside the edges represent the costs of moving between the states. To the right of every state is the estimated cost of the path from the state to the nearest goal.



Show how each of the following search strategies finds a solution in this state space by writing down, in order, the names of the nodes removed from the agenda. Assume the search halts when a goal state is removed from the agenda. (In some cases, multiple answers are possible. You need give only one such answer in each case.)

(a) Breadth-first;

(b) Depth-first;

(c) Least-cost search; and

(d) Heuristic search using $f(n) = g(n) + h(n)$ as the heuristic function, where $g(n)$ is the cost of the path to node n, and $h(n)$ is the estimated cost of the path from node n to the nearest goal.

2 (10 marks)

The Towers of Hanoi Problem

There are 3 poles, and there are five disks of different diameters each having a hole in its centre so that it can be slotted onto the poles. The disks are all on the first of the poles and must be moved to the third of the poles. Only one exposed disk may be moved at a time. At all times, the disks on a pole will be in decreasing order of size (smallest on the top).

While there are straightforward (recursive and non-recursive) algorithms to solve this problem, in this question you formulate it as an AI search problem. You must develop the problem representation on which search algorithms could be used. (Examples: the problem representation we used for the Water Jugs Problem used a pair of integers to denote states and 8 operators; the problem representation we used for the 8-tiles Puzzle used a 3×3 array of integers to denote states and 4 operators.)

(a) What representation would you use for the *states* in the Towers of Hanoi Problem?

(b) Give the *initial state*.

(c) Give the *goal state*.

(d) Give the *operators*. (The easiest formulation uses six operators. Showing one of the six and giving a sentence that explains briefly how the rest differ will suffice.)

(Extra marks will be gained for precision.)

3 (10 marks)

This question uses the following 'key' for the unary predicate symbols p and e, the binary predicate symbol f and the constant symbols jr, tc and rp:

$p(x)$	:	x is a pirate ship
$e(x)$	:	x is an enemy ship
$f(x, y)$	:	ship x flies flag y
jr	:	the Jolly Roger flag
tc	:	the Tricolore flag
rp	:	the ship called the Ribald Pirate

(v, x, y and z will be used as variables.)

(i) [3 marks] Convert the following formula of first-order predicate calculus into *clausal form logic*:

$$\forall x(p(x) \rightarrow \exists y f(x, y)) \wedge \exists z\, p(z)$$

(ii) [7 marks] You are given the following clauses:

$\neg p(x) \vee e(x)$	all pirate ships are enemy ships
$\neg p(y) \vee f(y, jr)$	all pirate ships fly the Jolly Roger
$\neg f(z, jr) \vee \neg f(z, tc)$	all ships fly one or other of the flags
$p(rp)$	the Ribald Pirate is a pirate ship

Use *resolution refutation* theorem-proving to show that not all enemy ships fly the Tricolore, i.e. in first-order predicate calculus:

$$\neg\forall v(e(v) \rightarrow f(v, tc))$$

Show your working, presenting your proof in the form of a *refutation tree*.

4 (10 marks)

There are three statements below that describe typical AI planning systems. **Explain** each statement **in detail** (i.e. say *what* it means). **Justify** each statement **in detail** (i.e. say *why* it is advantageous for planners to work in this way).

(a) *"Planners typically work by regression."*

(b) *"Planners exploit the logic-based representation of (sub)goals in their selection of operators."*

(c) *"Planners decompose problems and solve the resulting subproblems as independently as possible."*

5 (10 marks)

The rules below show some of the knowledge that we might find in a rule-based expert system that diagnoses liver disorders.

Qualitative data abstraction rules e.g.

```
IF   bilirubin is 13.2 THEN bilirubin is high
```

Definitional data abstraction rules e.g.

```
IF   bilirubin is high THEN patient has jaundice
```

Hypothesis triggering rules e.g.

```
IF   patient has jaundice THEN cholestasis is suggested
```

Hypothesis refinement rules

e.g. refining cholestasis by its location

```
IF   cholestasis is suggested AND
     there is a history of heart problems
THEN the cholestasis may be extrahepatic
```

e.g. refining cholestasis by its cause

```
IF   cholestasis is suggested AND
     the cholestasis may be extrahepatic AND
     there is extreme tiredness
THEN there is evidence of bile duct cancer
```

There are hence qualitative and definitional relationships in a data space, and a hypothesis space that comprises a hierarchical taxonomy of disorders, along with relationships between the two spaces.

(i) [5 marks] Suppose the inference engine uses backwards-chaining and depth-first search. There would be cases (although none are shown above) where a (sub)goal is matched by the consequents of more than one rule. The inference engine must try the rules in some order. This order can be

- predetermined (e.g. the order the rules appear in the knowledge base);
- determined by numeric measures (e.g. probabilities or certainty factors) that are indicative of a rule's utility; or
- determined by the application of meta-rules.

Compare these three options from the point of view of the effect they might have on *the naturalness of the dialogue.*

(ii) [5 marks] Suppose the diagnostic inference engine is augmented with facilities that enable it to instruct a novice user in liver disease diagnosis.

When working through an example diagnosis with the system, what sorts of questions might the student user want to ask and how well can they be supported by the rule-based knowledge representation? (N.B. Do not confine your answer to the questions that rule-based expert systems have traditionally supported in the past. Consider also what the novice user may *want* to ask.)

$$$$