CS486

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THE NATIONAL UNIVERSITY OF IRELAND
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Summer Examinations

B.Sc. Honours in Computer Science 1998

Knowledge Based Systems

Time allowed: **Two hours**

Answer **all** questions.

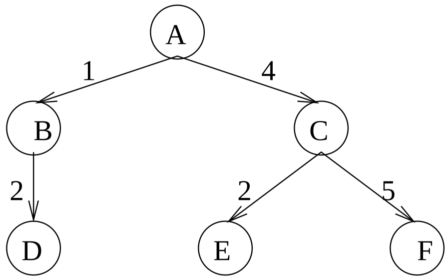
1 (10 marks)

(i) [2 marks]

(a) [1 mark] What does it mean for a search strategy to be *complete*?

(b) [1 mark] What does it mean for a search strategy to be *optimal*?

(ii) [4 marks] Consider the following state space in which the states are shown as nodes labeled A through F. A is the initial state and E is the goal state. The numbers alongside the edges represent the costs of moving between the states.



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 the 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) Iterative-deepening; and

(d) Least-cost search.

(iii) [4 marks] Least-cost search might not be complete and/or optimal in general if costs are allowed to be negative.

Carefully explain why negative costs might result in it not being complete and why they might result in it not being optimal.

2 (10 marks)

In this question you develop a problem representation on which search algorithms could be used. While your answers need not be expressed in logic or in some programming language, you will gain marks for precision (e.g. a mixture of English and logic and/or set-theoretic operators would be suitable).

> Five men and five women have just been married on a tropical island. All now wish to return to the mainland.
>
> A boat, which can carry at most three people, is available to ferry the newly-weds back to the mainland. The boat must be crewed by at least one person, male or female, on every trip it makes.
>
> Libidos are at full stretch and the couples have agreed that no woman should at any point find herself in the company of the other men (even if they are with their wives!) unless her husband is with her.

(i) [3 marks] What representation would you use for the states?

Give the initial state.

Give the goal state.

(ii) [4 marks] Give the operators.

(iii) [3 marks] Would this problem benefit from being solved by a planning system such as STRIPS? Explain your answer.

3 (10 marks)

This question concerns a system which automatically writes computer programs for a machine that has two registers. The question uses the following 'key':

Continued.

Predicate symbols	
MEM(x,y,z)	In state z, the contents of the two registers are x and y respectively.

Function symbols	
load(z)	*load* denotes a function that returns the new state of the machine attained if the machine is in state z and the contents of the second register are loaded into the first register.
add(z)	*add* denotes a function that returns the new state of the machine attained if the machine is in state z and the contents of the second register are added to the first register.
store(z)	*store* denotes a function that returns the new state of the machine attained if the machine is in state z and the contents of the first register are stored in the second register.
$x + y$	$+$ denotes a function, written in infix notation, that returns the sum of its arguments.

Constant symbols	
a	the initial contents of the first register
b	the initial contents of the second register
s_0	the initial state

x, y and z (possibly subscripted) are used for variables.

You will use the following axioms (already in clausal form):

1. $\neg MEM(x_1, y_1, z_1) \vee MEM(y_1, y_1, load(z_1))$
2. $\neg MEM(x_2, y_2, z_2) \vee MEM(x_2 + y_2, y_2, add(z_2))$
3. $\neg MEM(x_3, y_3, z_3) \vee MEM(x_3, x_3, store(z_3))$
4. $MEM(a, b, s_0)$

(i) [8 marks] Use *resolution refutation* theorem-proving to answer the question: what program doubles the contents of the second register, i.e. in first-order predicate calculus:

$$\exists x \exists z MEM(x, b + b, z)$$

Show your working and present your proof in the form of a *refutation tree.*

(**Hint:** Among the changes you will make to the goal is the introduction of a literal $ANS(z)$.)

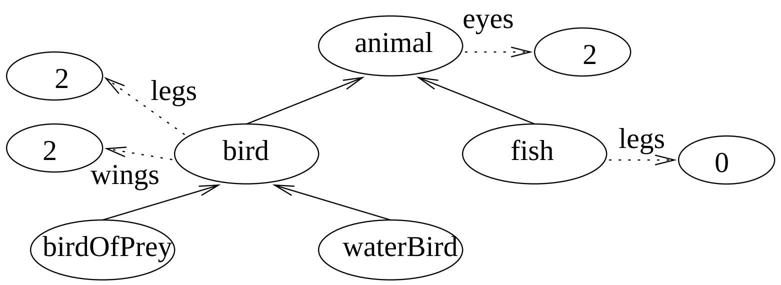
(ii) [2 marks] Part (i) shows that, if instructions and machine states are suitably axiomatised, resolution-refutation theorem-proving can be used for automatic program synthesis. Equally, a planning system such as STRIPS or POP can also be used for (simple) program synthesis.

Using symbols that are *similar* to those used in part (i), translate the four axioms into the STRIPS language.

(**Hint:** States are explicit arguments in part (i) but will be implicit in the STRIPS language representation.)

4 (10 marks)

(i) [4 marks] A zoologist has drawn up the following semantic net in which ovals denote classes, full lines denote subclassing and dotted lines denote a property. (There are no instances of classes in this question.)



Give **two** translations of the net into logic. One translation should use predicate symbols to denote classes and properties; the other should reify classes and properties. You should handle simple inheritance but you can ignore multiple inheritance and over-riding of inheritance.

(ii) [3 marks] On seeing your logical translations, the zoologist realises that s/he had intended the immediate subclasses of a class to be *mutually exclusive*. For the translation in which predicate symbols denote classes and properties, give the extra axioms that would state this mutual exclusiveness.

(iii) [3 marks] Suppose that, instead of storing the net in the computer as a node-and-pointer structure, the reified logical representation is stored, and a standard resolution-refutation theorem-prover is used. Suppose further that this is done for a much larger version of the above net.

If we want to find the value of some property for some class (e.g. the number of eyes that eagles have), which would be more efficient in general: backwards-resolution or forwards-resolution? Explain your answer in detail.

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.

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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?

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