UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2003

MSc in Computing Science
BSc Honours Degree in Mathematics and Computer Science Part III
MSci Honours Degree in Mathematics and Computer Science 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 Royal College of Science

PAPER M231

ARTIFICIAL INTELLIGENCE

Wednesday 14 May 2003, 14:00
Duration: 120 minutes

Answer THREE questions

Paper contains 4 questions
Calculators required

Section A *(Use a separate answer book for this Section)*

1a i) Explain the terms *breadth first, depth first* and *iterative deepening search.*

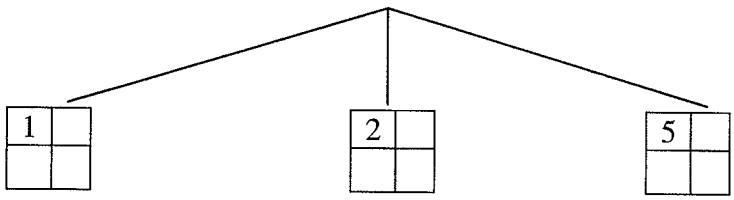
ii) What is the meaning of the word *heuristic* in the context of search strategies. In path finding problems, what is the difference between a uniform path cost search and an A* search? What condition on A* search is required to guarantee completeness and optimality?

b Two agents are playing a game with four coins (1p, 2p, 5p, 5p). Player 1 goes first and they take it in turns to put the coins on this 2x2 black and white board:

Player 1 is only allowed to put a coin on a white square on the board. Player 2 is only allowed to put a coin on a black square on the board. At the end of the game, if the sum of the coins on white squares is more than the sum of the coins on black squares, then player 1 wins all the coins otherwise player 2 wins all the coins.

i) Explain the terms "rational agent" and "minimax principle".

ii) Drawn below is the top of the search tree used in a minimax search to determine player one's first move. What are the states and the operators in this search? What symmetry assumptions have been exploited to reduce the search size?



iii) Copy and complete the above diagram and put the scores for player 1 below the final board states. Caution: leave plenty of space on the RHS of the diagram.

iv) Use the minimax principle to propagate the scores to the top of the diagram. Explain why player 1 can always win, and describe what their first move should be in order to win.

The two parts carry, respectively, 35% and 65% of the marks.

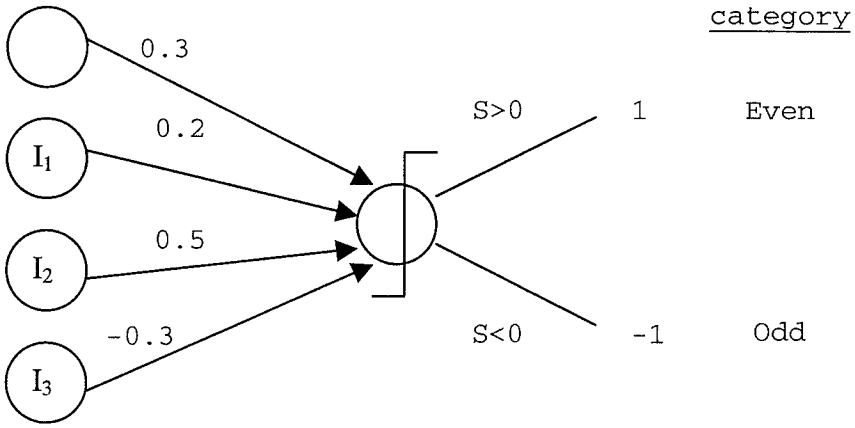
2a The XOR boolean function returns true only if both inputs are different. The NAND boolean function returns the negation of the AND boolean function, which itself returns true only if both inputs are true.

i) Write down one truth table containing the XOR, NAND and AND boolean functions. Use this to determine what the two inputs must be in order for both XOR and NAND to return false.

ii) Which, if any, of these boolean functions can be represented as a perceptron employing a step threshold function. Explain your answer.

iii) For those functions which are representable as a perceptron employing a step function, draw a suitable perceptron.

b A perceptron is being trained for a learning task. The task is to determine when the product of three integers is even and when it is odd. There is an input unit for each integer being multiplied, and the input is +1 if the integer is even, –1 if the integer is odd. The current state of the perceptron is:



i) Why are there four input units?

ii) Would the perceptron predict that the product 2*3*4 is even or odd? (Let I_1 be 2, I_2 be 3 and I_3 be 4).

iii) Using a learning rate of 0.1, and given the input triple (2,3,4), recalculate the weights using the perceptron training rule. Draw the perceptron after training. Does the trained perceptron correctly predict whether 2*3*4 is odd or even?

c i) Give an overview of the backpropagation learning routine for training feed-forward multi-layer ANNs.

ii) What are the two main problems to (try to) avoid when training ANNs? Describe a method for (trying to) avoid each problem.

The three parts carry, respectively, 35%, 35% and 30% of the marks.

3a i) What is a logic program?

ii) When searching through a space of logic programs, what is the generic name for an operator which performs a specialisation step? Give an example of such an operator. What is the generic name for an operator which performs a generalisation step? Give an example of such an operator.

b i) Translate sentences A to E below into first order logic. Use only one logic sentence for each English sentence, and do not include any ground variables. Also, you must use the following predicates:

pm(X) – X is the prime minister.
pres(X) – X is the president.
dw(X) – X has declared war.
isgwb(X) – X is George Bush.

A. Only the president or the prime minister can declare war.
B. The prime minister never declares war.
C. George Bush is president.
D. Someone has declared war.
E. George Bush has declared war.

ii) Translate your first order sentences into conjunctive normal form.

iii) Prove sentence E using sentences A to D as axioms. Do this by using the resolution method to derive a proof by contradiction and draw a resolution diagram showing which sentences have been resolved to give what, and indicating any unification steps required.

iv) For each resolution step in part iii) explain in English what piece of deduction has taken place.

c i) Describe the unit preference strategy for resolution theorem proving.

ii) Describe the set of support strategy for resolution theorem proving.

The three parts carry, respectively, 20%, 50% and 30% of the marks.

4a i) What are the constituents of a constraint satisfaction problem (CSP)? What is the formal definition of a constraint over a set of variables?

ii) Explain what arc-consistency is in binary CSPs and why imposing arc-consistency is an important pre-processing stage in CSP solving.

b In a cryptoarithmetic puzzle, the variables A, B, C, D, E and F can take values 1 to 7. The variables must all be different and, when taken as digits, they must satisfy the following sum:

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  A B
+ C D
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  E F
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In addition, $A + C \leq 7$, $B + D \leq 7$, $A < C$ and $B < D$.

i) Model this problem as a CSP with two constraints: one constraint on the variables (A,C,E) and one constraint on the variables (B,D,F). Write your model as a formal CSP.

ii) In light of the constraints, what variables can you remove from the domains of variables A to F? Write down the domains after the removals.

iii) Suppose the domains were as in ii) and the CSP solving agent was using a variable ordering of {A,C,E,B,D,F} and a value ordering of {1,2,3,4,5,6,7}. Suppose also that the agent was using forward checking. When would the first back-track occur during the search and why?

iv) Given A = 1, find a solution to the puzzle.

c What is n-fold cross validation, what is it attempting to measure and why is it so important in machine learning?

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