UNIVERSITY EXAMINATIONS

UNIVERSITEITSEKSAMENS

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COS3751

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TECHNIQUES OF ARTIFICIAL INTELLIGENCE

Duration 2 Hours

100 Marks

EXAMINATION PANEL AS APPOINTED BY THE DEPARTMENT

Use of a non-programmable pocket calculator is permissible

Closed book examination

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Examiners :

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Instructions

1 Answer all questions

2 Write neatly and legibly

3 Read each question carefully before answering always make sure you provide an answer to what is being asked

4 This paper consists of 8 pages

[TURN PAGE]

Question 1	State Spaces	**[12]**

(a) Differentiate between an *agent function* and an *agent program* (2)

(b) Define the concept of state-space (3)

(c) In the Francs and Pounds puzzle there is a container with five cells In the initial state of the container the two leftmost cells are occupied by a Franc coin each, while two Pound coins occupy the two rightmost cells The middle cell is empty The game can be illustrated as follows

F	F		P	P

The puzzle involves moving the coins one at a time to reach the goal state In the goal state the Pound and Franc coins are interchanged, as follows

P	P		F	F

There are only four permissible moves

1. A Pound Slide - a Pound coin slides one position to the left into an empty cell
2. A Pound Hop - a Pound coin jumps left across one cell containing a coin into an empty cell
3. A Franc Slide - a Franc coin slides one position to the right into an empty cell
4. A Franc Hop - a Franc coin jumps right across one cell containing a coin into an empty cell.

A cell may never contain more than one coin, all coins must be in the container after every move, and coins cannot jump coins of the same type (that is, a pound coin cannot jump another pound coin).

i Define a state representation for the game Provide the representation using formal mathematical notation – an English description will be awarded 0 Use P to represent pounds, F to represent francs, and Θ to represent an empty square. (2)

ii Using your representation, show the start and goal states (2)

iii Define the applicable actions for the start state (state S_0), be sure to indicate that the action returns a resulting state (3)

Question 2	Searching	[24]

(a) Explain how a uniform cost search differs from a breadth first search Pay attention to the data structure that is used in each (4)

(b) Consider Figure 1 In the four queens problem, we try to place four queens on a 4×4 chess board, so that no queen can capture another queen (i e there is only one queen on any diagonal, row, or column of the board) The placement of a queen is called *legal* if the queen is unable to capture any other queens on the board The start state is the empty board, and goal states are those boards that have four legally placed queens on them (In the figure, children nodes are generated by attempting to place queens in columns from left to right)

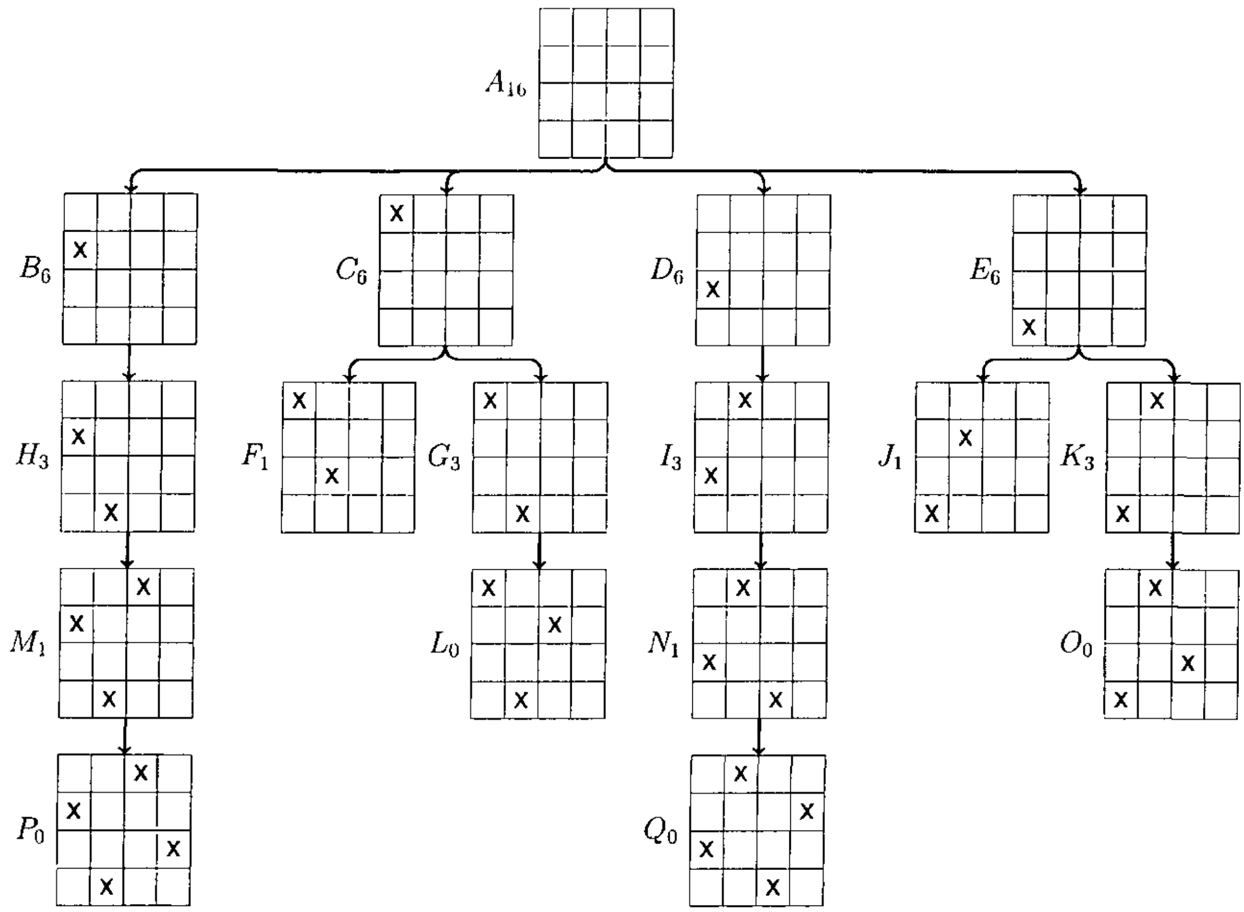

Figure 1 State Space for the Four Queens Problem

Perform an A^* search (on the state space provided in Figure 1) to find a solution path from the start state to a goal state Keep the following in mind when answering this question

1 You only need to show the first 5 steps (step 1 has already been completed for you)

2 In your answer, show the contents of the frontier after each step, as well as the $\hat{g}$, $\hat{h}$ and $\hat{f}$ values for every expanded node The name of each node appears next to it in Figure 1

3 You only need to show the new nodes added to the frontier after each step don't rewrite the entire frontier at each step.
4 Let $\hat{h}(S)$ be the number of squares on the board (for state S) where another queen may be placed legally ($\hat{h}$ provided as a subscript of the node name in the figure)
5 Let $\hat{g}(m)$ be the depth of node m
6 $\hat{g}(A) = 0$
7 When two $\hat{f}$ values are the same, always choose the node with the name that is first alphabetically for expansion.

The following table provides the structure you should use in your answer (the first step has been provided) (12)

Step	Expanded	Frontier $(n(\hat{h}, \hat{g}, \hat{f}))$
1		A(16, 0, 16)
2		

(c) Consider the state-space graph in Figure 2

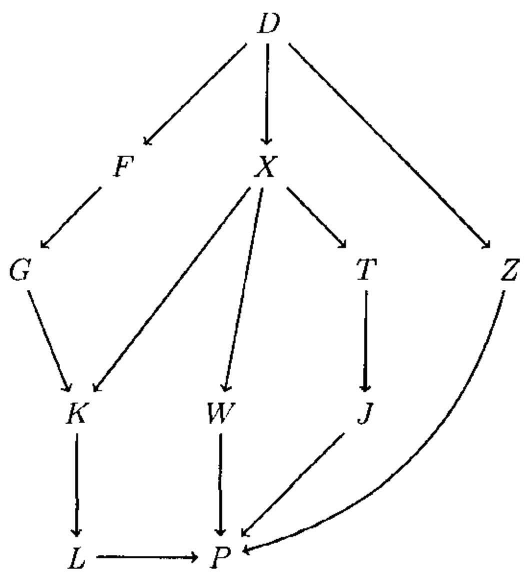

Figure 2 State-space graph

Assume that a breadth first search is employed, and that the start node is D and the goal node is P Write down the content of the frontier once X has been expanded Provide the path from start to goal (include the start and goal nodes) The order of expansion should be from left to right thus F is expanded before X, and so on. (8)

Question 3	Adversarial Search	**[15]**

(a) Consider the game tree in Figure 3 and then answer the questions that follow (the static utility values for the leaf nodes are provided below each leaf node, and node A is a MAX node)

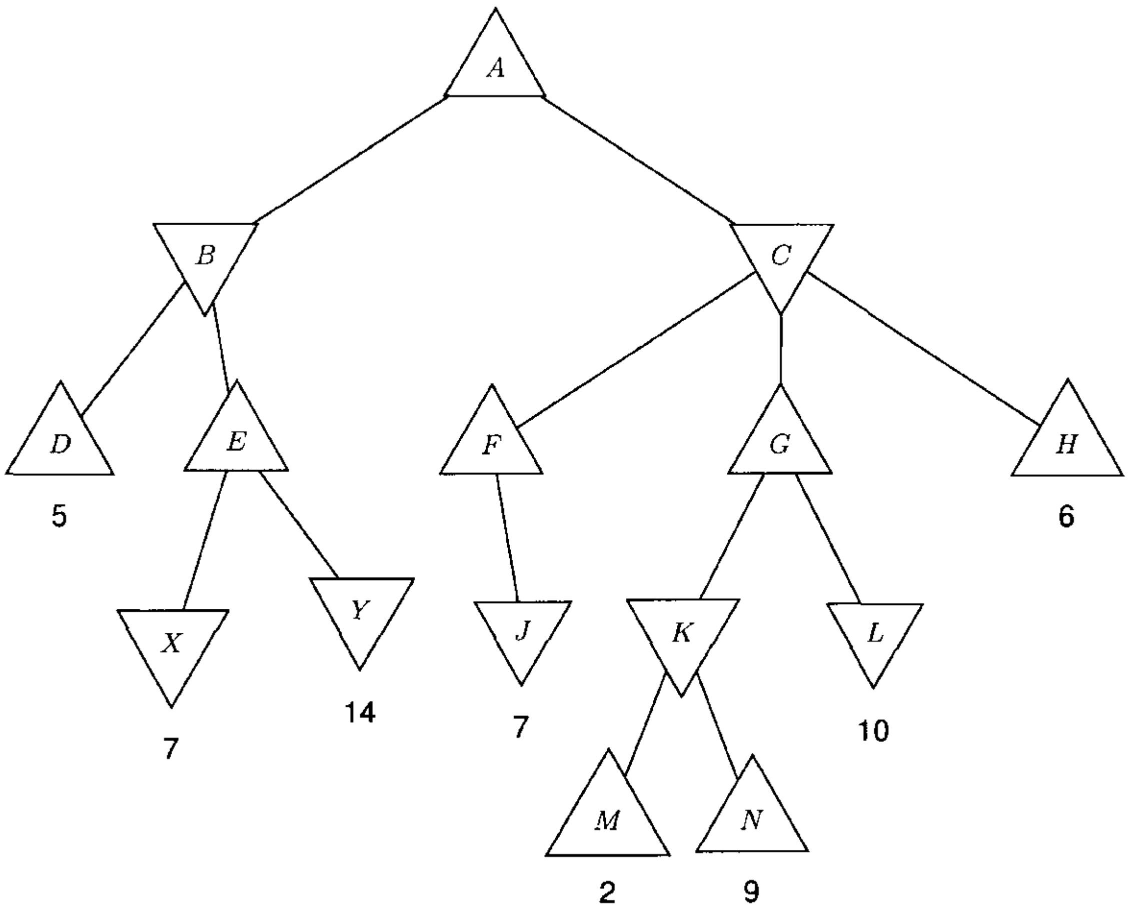

Figure 3 Adversarial Search Tree

i Suppose a Minimax search is performed on the tree Provide the min-max values for nodes A $B, C,$ and G (4)

ii Suppose a Minimax search with Alpha/Beta pruning is done in a left-to-right fashion on the tree Provide the α and β values for nodes A B C, and E which would have been recorded during the search (the values when the search terminates) (8)

(b) Analysis of chess games in which white has a King, a Queen, and a Knight, and black has a King, and two Rooks (for example a board position such as provided in Figure 4) revealed that 17% of such games end in a draw, 78% end in a win for white, and 5% end in a win for black

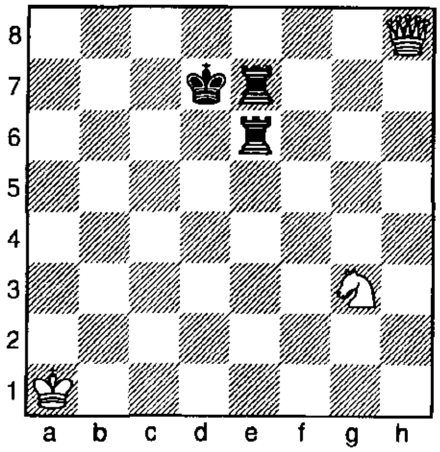

Figure 4 KQN/KRR Combination (white to move)

Calculate the expected value for boards as described above for white. Provide any detail you feel is necessary in order to calculate the value (Show your calculations.) (3)

Question 4	Constraint Satisfaction Problems	**[19]**

(a) Define *forward checking*. (2)

(b) A company offering airport shuttle services has a limited number of shuttles with which to transport clients to the airport. They have the following clients booked for the same day, and need to figure out how to accommodate all of them

Client Name	Shuttle departure	Travel time (total)
Derren	09 00	00:35
Ibrahim	09 30	00:45
Tholo	09 45	00:15
Dudu	10 10	01·30
Yared	10 45	00 20

Assume that the *travel time* indicated provides enough time for any shuttle to travel to a client, and to transport them to the airport, and that the departure time indicated provides the time at which the shuttle will depart to pick the client up

i Define the variables for this CSP (3)

ii Define the domain for each variable in the CSP (2)

iii Provide the constraints for this problem (4)

iv Draw a constraint graph for this problem (5)

v How many shuttles are needed at minimum to ensure everybody gets to their flights on time? Show how you arrived at this answer (3)

Question 5	Predicate Logic	[10]

(a) Define the *ground resolution theorem* (2)

(b) Provide an example which illustrates the *unit resolution inference rule*. (3)

(c) Show that the following sentence is not *valid* $(Big \wedge Dumb) \vee \neg Dumb$ (5)

Question 6	Learning from Examples	[20]

Consider the following data set (Table 1) which represents a function comprised of three binary input attributes (A_1, A_2, and A_3), and one binary output y:

Example	A_1	A_2	A_3	y
x_1	0	1	0	0
x_2	0	1	1	0
x_3	1	0	0	0
x_4	1	1	1	1
x_5	1	1	0	1

Table 1 Data set

(a) Using the principles of Information Gain build a decision tree for the data Show the computations made to determine the attribute to split at each node. Use the table on page 8 for the entropy calculations Also show the decision tree· branch and leaf nodes, as well as edges and appropriate labels for the edges

Total: 100

A Entropy Table (Boolean valued variables)

p Ratio of positive examples
E Corresponding entropy $(-(plog_2p + (1-p)log_2(1-p)))$

p	E
0 00	0 00
0 10	0 47
0 15	0 61
0.20	0 72
0 25	0 81
0 29	0 87
0.30	0 88
0 33	0 91
0.35	0.93
0 38	0 96
0 40	0 97
0 45	0 99
0 50	1 00
0.55	0 99
0 60	0.97
0 63	0 95
0 65	0 93
0 67	0 91
0 70	0 88
0 75	0 81
0 80	0 72
0.85	0 61
0 90	0 47
0 95	0 29
1 00	0 00

Example. For a set of 4 positive examples, and 1 negative example (written $E[4,1]$), the ratio $p = \frac{4}{5}$, or $0\ 80$ The corresponding entropy value is given by the table as $0\ 72$

Round to the closest value on the table above, and always round to the closest $\frac{1}{100}$· for example $0\ 375 \sim 0\ 38$, but $0\ 374 \simeq 0\ 37$