**Student Number:** 

**The University of Melbourne**

**Semester 1 Assessment 2016**

**Department of Computing and Information Systems**

# COMP30024 Artificial Intelligence

**Reading Time:** 15 minutes.

**Writing Time:** 3 hours.

**This paper has 12 pages including this cover page.**

**Common Content Papers:** None

**Authorised Materials:** None.

**Instructions to Invigilators:**
Each student should initially receive one standard script book.
Students must hand in **both** their **exam paper** and their **script book(s)**.
Students may **not** remove any part of the examination paper from the exam room.

**Instructions to Students:**

- This paper counts for 70% of your final grade, and is worth 70 marks in total.
- There are 7 questions, with marks as indicated. Attempt all questions.
- Answer questions 1, 2 and 3 **on the exam paper**, and answer questions 4, 5, 6, and 7 on the lined pages in your **script book**. If you need more space for questions 1, 2, or 3, then use the spare page at the end of the exam paper.
- You must hand in **both** your **exam paper** and your **script book(s)**.
- Start your answer to each question in the script book on a new page.
- Answer the questions as clearly and precisely as you can.
- Your writing should be clear. Unreadable answers will be deemed wrong. Excessively long answers or irrelevant information may be penalised.
- For numerical methods, marks will be given for applying the correct method. Students will not be heavily penalised for arithmetic errors.

**Question 1 (10 marks) [Write your answers on this page]**

Pick the most appropriate answer to each of the following questions. Please write your answer to each question in the boxes below.

| Question | (a) | (b) | (c) | (d) | (e) |
|---|---|---|---|---|---|
| Answer | | | | | |

(a) Which of the following statements is true in general:

1. both minimax and expectiminimax give perfect play
2. minimax gives perfect play, but expectiminimax does not
3. expectiminimax gives perfect play, but minimax does not
4. none of the above

(b) Breadth first search in a finite search tree is in general:

1. complete and optimal
2. incomplete and optimal
3. complete and not optimal
4. incomplete and not optimal

(c) If two heuristics $h_1$ and $h_2$ are admissible, which one of the following is *not* guaranteed to be admissible:

1. $\alpha * h_1 + (1 - \alpha) * h_2$, for $\alpha \in [0, 1]$
2. $h_1 * h_2$
3. $max(h_1, h_2)$
4. $min(h_1, h_2)$

(d) Which one of the following is true in general:

1. first-price sealed-bid auctions help overcome the winner's curse
2. first-price sealed-bid auctions have more complicated communication than English auctions
3. first-price sealed-bid auctions may not be efficient
4. first-price sealed-bid auctions have a clear dominant strategy

**Question 1 (continued) [Write your answers on the previous page]**

(e) Figure 1-1 shows a robot arm that is made up of two sections $Arm_1$ and $Arm_2$. $Arm_1$ can rotate around the shoulder joint $A$, while $Arm_2$ is connected to $Arm_1$ at the elbow joint $B$, and can rotate around the joint $B$. The configuration of the robot arm can be specified by the angle $\theta_1$ between the horizontal axis and $Arm_1$, and the angle $\theta_2$ between $Arm_1$ and $Arm_2$. Both angles are measured in radians. There are also 2 fixed obstacles shown, which restrict the movement of the robot arm.

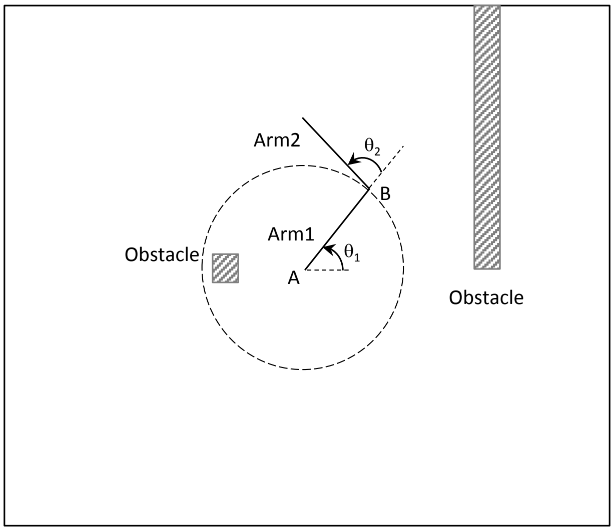



Figure 1-1

Which of the following four figures best represents the *configuration space* for this robot? The figures are labelled (1) to (4).

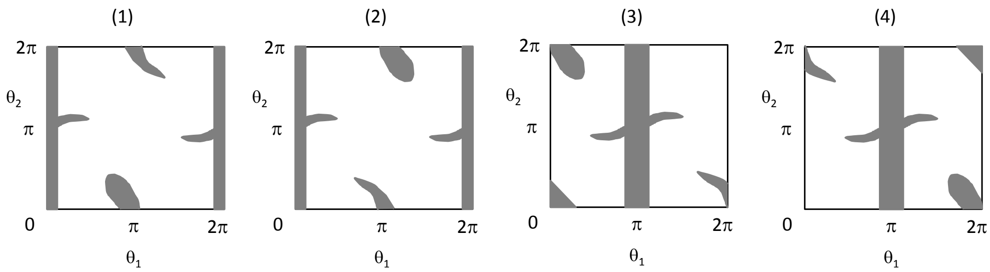



Figure 1-2

**Question 2 (10 marks) [Write your answers on this page]**

For each part of the following question you should write a brief answer in the box provided.

The following is the weight update rule for TDLeaf($\lambda$) learning as described in the lectures

$$w_j \leftarrow w_j + \eta \sum_{i=1}^{N-1} \frac{\partial r(s_i^l, w)}{\partial w_j} [\sum_{m=1}^{N-1} \lambda^{m-i} \, d_m]$$

where $\eta$ is the learning rate, $d_i = r(s_{i+1}^l, w) - r(s_i^l, w)$ is the temporal difference between successive states, and $w$ is the vector of weights in the evaluation function.

(a) [2 marks] What is the role of the learning rate parameter $\eta$?

(b) [3 marks] Why do we use the temporal difference $d_i$ between successive states in this rule?

(c) [2 marks] Under what conditions should we use $\lambda = 0$, and why?

**Question 2 (continued) [Write your answer on this page]**

(d) [3 marks] A rare painting is to be auctioned. Two collectors each attach the same value of \$5million to the painting, and the third possible buyer values the painting at \$4million. Should the auctioneer use a *first-price, sealed-bid auction* or a *second-price sealed-bid auction*? Briefly justify your answer.

**Question 3 (10 marks) [Write your answers on this page]**

Consider the 3-ply game tree shown in Figure 3-1. Each node has an identifier (e.g., the root of the tree is node 1; it has three successor nodes 2, 12 and 22), and each terminal node has an associated value (e.g., the value of node 4 is 7).

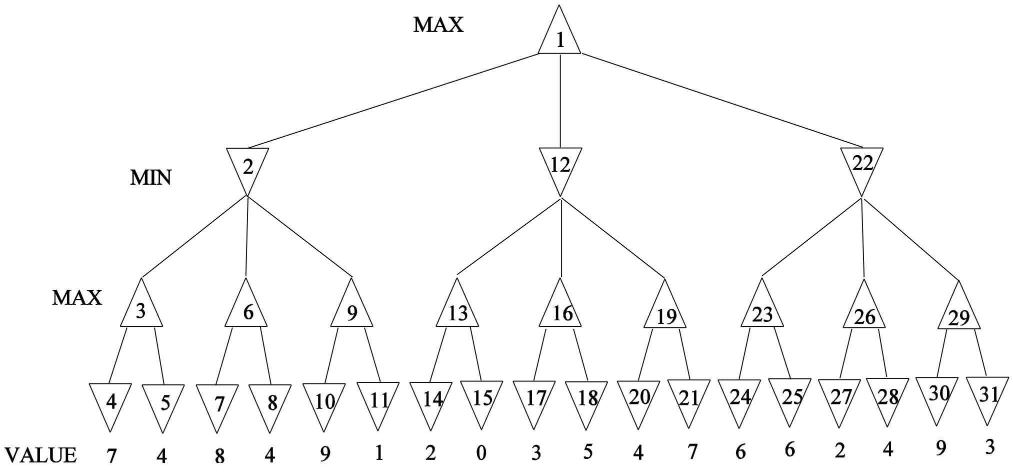



Figure 3-1

In the following questions, you are NOT required to redraw the search tree in your answer.

(a) [2 marks] What is the minimax value at node 1 after applying the minimax algorithm to this search tree?

**Answer:**

(b) [5 marks] If the nodes are examined in the order shown by the identifier in each node in Figure 3-1, which nodes would be pruned if alpha-beta pruning is used? For each node that would be pruned, place a cross in the corresponding box below.

**Answer:**

| Node | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pruned | | | | | | | | | | | | | | | | |

| Node | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pruned | | | | | | | | | | | | | | | |

**Question 3 (continued) [Write your answers on this page]**

(c) [3 marks] Consider a version of minimax search that uses *iterative-deepening* rather than the standard depth-limited search. Briefly give **two** advantages of iterative-deepening minimax search compared to depth-limited minimax search.

Write your answer in the space provided below. If you require more space, please use the last page of the exam paper, and clearly indicate on this page that you have used the last page.

**Answer:**

**Question 4 (10 marks) [Write your answers in your script book]**

For parts (a), (b) and (c), consider the following problem. Two people $B1$ and $B2$ are lost in an $N \times N$ maze, i.e., a square grid of cells. Assume that the co-ordinates of any grid cell can be given by a pair of integers $(x, y)$, where $x$ is the co-ordinate of the column of the cell on the grid, $y$ is the co-ordinate of the row of the cell on the grid, and $1 \leq x \leq N$ and $1 \leq y \leq N$. You can also assume that the cell $(1, 1)$ is in the top-left corner of the grid.

Each person starts in a different cell. Their aim is to find their way through the maze so that they both end up in the same cell - note that they **don't care where** that cell is. At each time step, each person simultaneously moves in one of the following directions: {up, down, left, right, stop} - note that each person can make a different move. The aim of the search is to find a sequence of moves that get $B1$ and $B2$ together, somewhere, in as few moves as possible. Passing each other in adjacent cells does not count as meeting - they must occupy the same cell at the same time. For the purposes of the questions below, you do not need to know where the walls are in the maze.

(a) [3 marks] What is the maximum branching factor of this problem?

(b) [4 marks] What is the maximum size of the search space for the problem?

(c) [3 marks] Give a non-trivial admissible heuristic for this problem.

**Question 5 (10 marks) [Write your answers in your script book]**

Consider the map shown in Figure 5-1(a), which shows five countries A, B, C, D and E. The aim is to assign a colour to each country using the three colours red (r), green (g) and blue (b), such that no two countries have the same colour if they share a border, e.g., A and B cannot have the same colour. The corresponding constraint graph for this problem is shown in Figure 5-1(b).

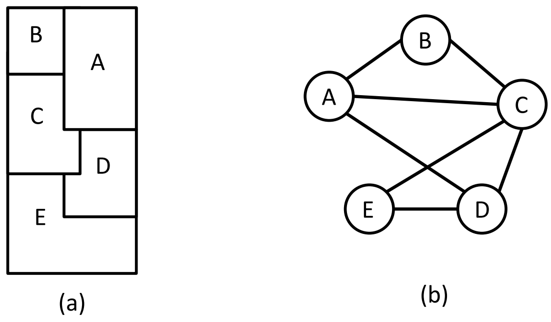



Figure 5-1

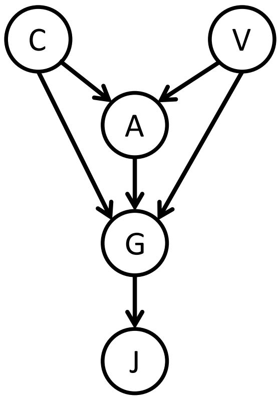
(a) [3 marks] If A = r, E = b, and the domains of B, C and D are each r, b, g, show the results of applying *forward checking* to all the variables in this problem, in terms of the reduced domain of values for each variable.

(b) [3 marks] Which variable(s) would you select as the cutset for cutset conditioning on this constraint satisfaction problem? Briefly justify your answer.

(c) [4 marks] In general, if a constraint graph has no loops, what is the runtime complexity of solving the corresponding constraint satisfaction problem? Use big-O notation, and assume the graph has $n$ variables, and the domain of each variables has $d$ possible values. Briefly justify your answer.

**Question 6 (10 marks) [Write your answers in your script book]**

Consider the Bayes network shown in Figure 6-1, where C = CommitCrime, A = Arrested, G = FoundGuilty, J = SentToJail and V = TelevisedStory are all Boolean random variables, i.e., they take the value either *true (t)* or *false (f)*. Also note that $P(c)$ is shorthand for $P(C = \text{true})$ and $P(\neg c)$ is shorthand for $P(C = \text{false})$.




| P(C) | P(V) |
|---|---|
| 0.9 | 0.1 |

| C | V | P(A\|C,V) |
|---|---|---|
| t | t | 0.9 |
| t | f | 0.5 |
| f | t | 0.5 |
| f | f | 0.1 |

| G | P(J\|G) |
|---|---|
| t | 0.9 |
| f | 0.0 |

| C | A | V | P(G\|C,A,V) |
|---|---|---|---|
| t | t | t | 0.9 |
| t | t | f | 0.8 |
| t | f | t | 0.0 |
| t | f | f | 0.0 |
| f | t | t | 0.2 |
| f | t | f | 0.1 |
| f | f | t | 0.0 |
| f | f | f | 0.0 |

Figure 6-1

(a) [3 marks] Briefly explain whether or not the following relationship is consistent with the given network structure?

$P(C, A, V) = P(C)P(A)P(V)$

(b) [3 marks] Briefly explain whether or not the following relationship is consistent with the given network structure?

$P(J|G) = P(J|G, A)$

(c) [4 marks] Calculate the value of $P(j|c, a, v)$. If you cannot easily calculate the final value, try to simplify the expression as best you can.

**Question 7 (10 marks) [Write your answers in your script book]**

You are given a bag containing $n$ unbiased coins (i.e., either side of a coin can come up with equal probability when tossed). You are told that $n-1$ of these coins are normal (with heads on one side and tails on the other), whereas one coin is a trick coin that has heads on *both* sides.

(a) [5 marks] Suppose you reach into the bag, pick out a coin uniformly at random, flip it, and the result is heads. What is the conditional probability that the coin you chose is a trick coin, given this result?

Justify you answer mathematically and show all your calculations (note: your answer should be an expression in terms of $n$).

(b) [5 marks] Suppose you continue flipping the chosen coin for a total of $k$ times after picking it, and you see $k$ heads. Now what is the conditional probability that the coin you chose is a trick coin, given these $k$ results?

Justify you answer mathematically and show all your calculations (note: your answer should be an expression in terms of $n$ and $k$).

**END OF EXAM QUESTIONS**

**Extra space if needed to answer questions 1, 2 or 3. If you write part of your answer here, please write the question number, and indicate at the corresponding question that you have used this space.**

**LAST PAGE OF EXAM**