

University of Bath

**DEPARTMENT OF COMPUTER SCIENCE
EXAMINATION**

CM50263: ARTIFICIAL INTELLIGENCE

Assessment Available from: 13:30, 19/05/2022

Latest Submission Time: 16:30, 19/05/2022

All timings are given in British Summer Time (BST)

Please read the (Guidance for Students) before attempting this exam. The Guidance contains information about submitting your exam attempt.

This is an open book exam. You may refer to your own course and revision notes and look up information in offline or online resources, for example textbooks or online journals.

This exam starts at: **13:30** on **19/05/2022**.

This exam is designed to take approximately **2 hours** to complete.

You will have an additional **60 minutes** of submission time for checking your work, collating your answers and uploading files. You are advised to allow sufficient time for minor technical issues when submitting your work.

The exam will close at the end of the submission time, after which you will not be able to submit an attempt.

Which questions should be answered: Answer all questions.

Filenames: If you are required to upload a file as part of your exam attempt, to maintain anonymity please use the following naming convention for your file:

CandidateNumberUnitCodeQuestionNumber.pdf (e.g. 01234AR10001Q2a.pdf). If the exam only requires one file to be submitted, you do not need to include the question number(s).

Additional materials needed to complete the assessment: a phone with a camera/scanner.

Further instructions: Please use the .csv template on moodle for MCQ answers, and submit your working, as well as your answer to the essay question, as a single pdf.

If you have any technical difficulties submitting your answers by the deadline you should contact the Exams Helpline.

Academic Integrity for Remote Exams

Academic misconduct is defined by the University as “**the use of unfair means in any examination or assessment procedure**”. This includes (but is not limited to) cheating, collusion, plagiarism, fabrication, or falsification. The University’s Quality Assurance Code of Practice, <https://www.bath.ac.uk/publications/qa53-examination-and-assessment-offences/>, sets out the consequences of committing an offence and the penalties that might be applied.

By submitting your remote assessment, you confirm that:

1. You have read and understood the University’s guidance about the undertaking of your examinations and about academic misconduct.
2. You have not, and will not, communicate with anyone concerning the content of this assessment before the submission deadline unless it is expressly permitted by the exam instructions.
3. This assessment is your original work and no part of it has been copied from another source without due acknowledgement.
4. No part of this work has been produced for or communicated to you by any other person or organisation.
5. You have not impersonated, or allowed yourself to be impersonated, by any person or organisation for the purposes of this assessment.
6. You understand that presenting the work, idea(s) or creation(s) of another person as though they were your own is plagiarism.
7. You have not previously submitted this work for any other unit/course.
8. You give permission for your submission to be reproduced, communicated, compared, and archived for plagiarism detection, benchmarking, or educational purposes.

Instructions

This exam consists of 15 multiple choice questions and 1 essay question. Some multiple choice questions are worth 3 marks, some are worth 6 marks. The essay question is worth 34 marks. The total amount of marks available is 100. Please note that for the multiple choice questions, there may be more than one correct choice. An example question is below (this question will not count).

Which of the following is an even number? (Mark all choices that could apply).

- (a) 0
- (b) 1
- (c) 2
- (d) 3
- (e) 10
- (f) None of the above.

Notice that there is more than one correct choice in this question and that the question asks you to *mark all choices that could apply*.

To receive credit for a question, you need to mark all correct choices and none of the incorrect choices. For example, to receive credit on the sample question above, you would need to mark (a), (c), (e), and nothing else. Partial credit is not available.

If the question explicitly asks you to *choose only one answer*, please do so. In such cases, if you mark more than one choice, you will receive zero marks for the question.

It is to your advantage to answer all questions because it is not possible to get negative marks for a question. For example, in the above question, if you choose (f), you would receive zero marks for this question but you would not lose any of the marks you have gained from other questions.

Please enter your answers into the template CSV file provided. At the end of the exam, upload a ZIP file containing two files:

1. The completed answer sheet. (1 CSV file)
2. Your working for all questions, and your submission for the essay question. (1 PDF file)

Do not forget to enter your candidate number.

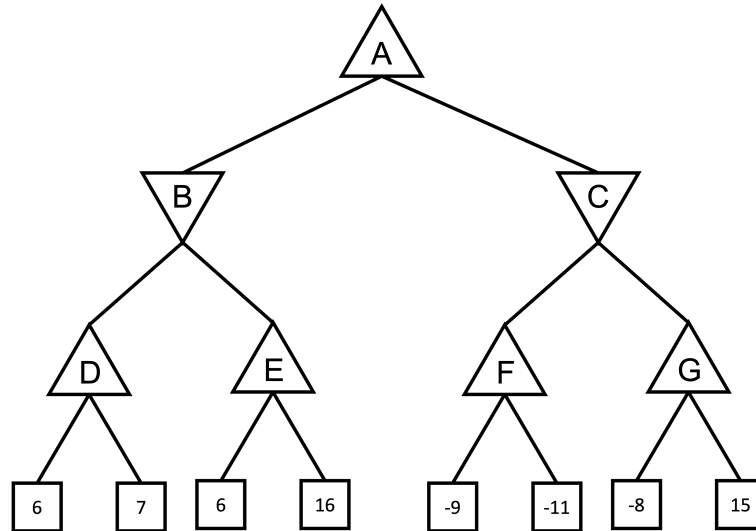
1. A* search uses a heuristic function $h(n)$ to estimate the minimum cost between the current node n and the goal. One important property the heuristic function $h(n)$ can have is **consistency**. For the heuristic function $h(n)$ to be consistent, which of the following must be true for every node, n , and every successor node n' , given a cost c of getting from n to n' ?
 - (a) $h(n) = c + h(n')$
 - (b) $h(n) > c + h(n')$
 - (c) $h(n) \geq c + h(n')$
 - (d) $h(n) < c + h(n')$
 - (e) $h(n) \leq c + h(n')$
 - (f) None of the above.

[3 marks]

2. Which of the following statements about the A* algorithm are true? Pick as many as you think apply.
 - (a) If the heuristic function is consistent and admissible, then an A* search is optimally efficient.
 - (b) If the heuristic function is admissible but not consistent, then an A* search is optimally efficient.
 - (c) If the heuristic function is consistent and admissible, then an A* search is guaranteed to find the optimal solution.
 - (d) If the heuristic function is admissible but not consistent, then an A* is guaranteed to find the optimal solution.
 - (e) If it is not known whether the heuristic function is consistent or admissible, it is possible that a non-optimal solution might be found by an A* search.
 - (f) None of the above

[3 marks]

This part is related to the Questions 3 and 4. Consider the following zero-sum minimax game tree where \triangle are the maximising (Max) nodes, ∇ are the minimising (Min) nodes, and the numbers inside the boxes indicate Maximizers utility at the terminal nodes.



3. What is the value of this game?

- (a) 6 (b) 16 (c) 15 (d) 9 (e) -11 (f) 7

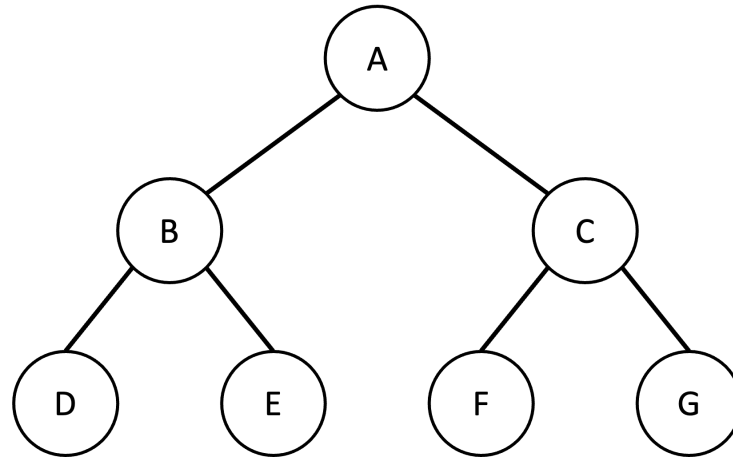
[3 marks]

4. One way to improve minimax is to use alpha-beta pruning. By applying alpha-beta pruning to the tree above from left-to-right, what would be the respective values of α (the upper bound) and β (the lower bound) at node **C** once the value of the game is found?

- (a) $\alpha = \infty$ $\beta = -9$ (b) $\alpha = -9$ $\beta = -\infty$ (c) $\alpha = 16$ $\beta = -9$
 (d) $\alpha = 7$ $\beta = -11$ (e) $\alpha = \infty$ $\beta = 7$ (f) $\alpha = 7$ $\beta = -\infty$

[6 marks]

5. Using the figure provided below, what are possible orders that the nodes could be visited using a **depth-first search**, assuming that if there is a choice of nodes, a possible node is selected randomly?



- | | | |
|-------------------|-------------------|------------------------|
| (a) A,B,C,D,E,F,G | (b) A,C,G,F,B,E,D | (c) A,C,B,G,F,E,D |
| (d) A,B,D,E,C,F,G | (e) A,B,E,D,C,F,G | (f) None of the above. |

[6 marks]

6. What is the worst-case **time complexity** of the **breadth-first search** algorithm, assuming a branching factor of b , and a depth of the shallowest solution of d ?

- (a) $O(b + d)$
- (b) $O(b \log(d))$
- (c) $O(b^d)$
- (d) $O(b^2 + d^2)$
- (e) $O(b * d)$
- (f) $O(1)$

[3 marks]

This table is used to answer question 7 and 8. Professors X, Y and Z share a kitchen in the department. For a period of time, it is noted when they each make a drink, and whether that drink is coffee, tea, or water. The results are collated into a table:

	Prof. X	Prof. Y	Prof. Z
Coffee	100	12	180
Tea	180	90	15
Water	10	200	102

Table 1: Drinks made in the communal kitchen.

7. What is the probability that a drink made in the kitchen is coffee? Give your answer to 3.d.p.
- (a) 0.900
 - (b) 0.100
 - (c) 0.342
 - (d) 0.5
 - (e) 0.328
 - (f) 0.164

[3 marks]

8. What is the probability that when Prof. Y makes a drink, it is tea? Give your answer to 3.d.p.
- (a) 0.492
 - (b) 0.194
 - (c) 0.342
 - (d) 0.298
 - (e) 0.412
 - (f) 0.101

[3 marks]

9. Scientist are trying to figure out the the accuracy of a test for a rare disease. The disease is so rare that it only affects 1 people out of 1000. There is a test for the disease which is positive in 85% of cases when somebody has the disease. The chance of a test being positive on a random member of the public is 5%. Given this information, what the probability that somebody with a positive test has the disease?
- (a) 0.017
 (b) 0.423
 (c) 0.994
 (d) 0.006
 (e) 0.151
 (f) 0.252

[6 marks]

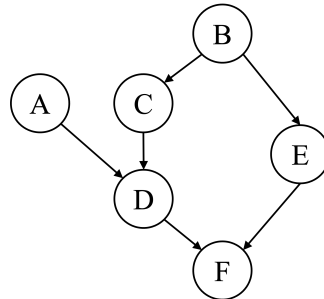
10. The table below shows the surfing conditions over the previous 10 days and whether someone goes surfing on a given day. Given the provided data, and assuming the probability of surfing given one weather condition is conditionally independent of the other two, what is the probability that someone will go surfing on the 11th day given it is windy, raining and cold? Answer to 3.d.p, and without calculating that the probability of it being a windy, rainy and cold day.

	Conditions	Raining	Temperature	Surfing
1	Windy	Yes	Hot	No
2	Windy	Yes	Hot	No
3	Calm	No	Hot	No
4	Windy	No	Cold	Yes
5	Calm	No	Cold	No
6	Calm	No	Cold	Yes
7	Windy	Yes	Cold	No
8	Windy	Yes	Hot	Yes
9	Windy	No	Cold	Yes
10	Calm	Yes	Cold	No

- (a) 0.640 (b) 0.512 (c) 0.126 (d) 0.912 (e) 0.820 (f) 0.360

[6 marks]

11. Consider the following Bayes network. The variables are indicated by the circles containing a letter and the relationships between them are given by the directional arrows between variables. Select all of the statements that apply to the following Bayes network:



- (a) F is dependent on B.
- (b) F is conditionally independent of B given E.
- (c) D is independent of E.
- (d) A is conditionally independent of F given D.
- (e) B is independent of F.
- (f) None of the above.

[6 marks]

12. You use a 1-nearest neighbour classifier that uses euclidean distance to decide the distance between two points. The classes are as follows:

$$\text{Class 1: } \left\{ \begin{bmatrix} 1 \\ 2 \end{bmatrix}, \begin{bmatrix} 4 \\ 3 \end{bmatrix} \right\} \quad \text{Class 2: } \left\{ \begin{bmatrix} -1.5 \\ 3 \end{bmatrix}, \begin{bmatrix} -4 \\ 2 \end{bmatrix} \right\} \quad \text{Class 3: } \left\{ \begin{bmatrix} 5 \\ -3 \end{bmatrix}, \begin{bmatrix} 1 \\ -2 \end{bmatrix} \right\} \quad (1)$$

To which class would the point $\begin{bmatrix} 1 \\ -1 \end{bmatrix}$ belong? Choose as many as you think apply.

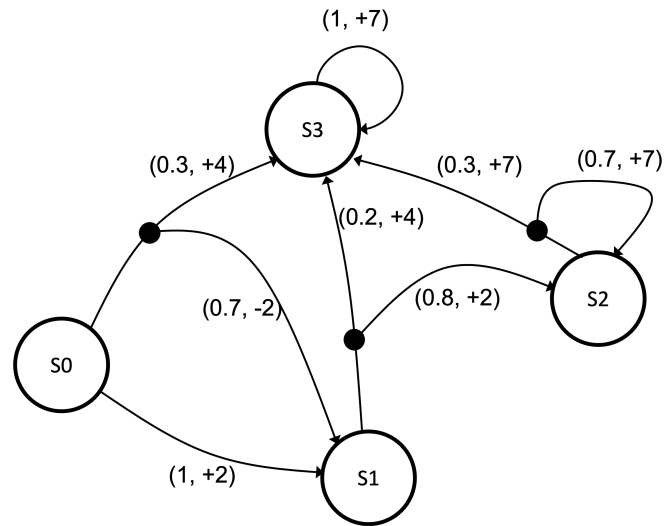
- (a) Class 1
- (b) Class 2
- (c) Class 3
- (d) Class 1 & 2
- (e) Class 1 & 3
- (f) Class 2 & 3

[6 marks]

13. Pick all of the following statements that are true about Markov Decision Processes.
- (a) All state transitions in an MDP must obey the Markov Property.
 - (b) MDP's can be used to model continuous time decision making processes.
 - (c) An MDP defines a policy $\pi(a|s)$ that maps the appropriate action to take in a given state.
 - (d) The formal definition of an MDP consists of 4 components: the set of states, the set of actions, the transition probabilities and the reward function.
 - (e) The probabilities of future states and rewards depend only on the current state and action, and not on any past values.
 - (f) The reward function of an MDP must sum to 0 in a given state.

[3 marks]

This part is related to the Questions 14 and 15. Consider the following Markov Decision Process (MDP). Actions are represented by the black dots on the lines. A split from the action indicates a stochastic transition with the numbers next to each line indicating the transition probability (left) and the reward for that transition (right). The states are indicated by the large circles, identified by the number within them, e.g. S2 indicates state 2. Assume a discount factor $\gamma = 0.9$ for the following two questions.



14. What is the value of state S3 under the optimal policy? Select exactly one answer.

- (a) 1 (b) 4 (c) 7 (d) 19 (e) 70 (f) 85

[3 marks]

15. What is the utility of the optimal policy at state S1? Select exactly one answer.

- (a) 54 (b) 4 (c) 65.4 (d) 6 (e) 69.68 (f) 2.8

[6 marks]

The essay question: critical evaluation of an AI application

16. You were asked to read the following 3 papers in advance of coming to this exam:

Papers

Berner, C., Brockman, G., Chan, B., Cheung, V., Debiak, P., Dennison, C., Farhi, D., Fischer, Q., Hashme, S., Hesse, C., et al., 2019. Dota 2 with large scale deep reinforcement learning. *Arxiv preprint arxiv:1912.06680*.

Davies, A., Veličković, P., Buesing, L., Blackwell, S., Zheng, D., Tomašev, N., Tanburn, R., Battaglia, P., Blundell, C., Juhász, A., et al., 2021. Advancing mathematics by guiding human intuition with ai. *Nature*, 600(7887), pp.70–74.

Ramesh, A., Pavlov, M., Goh, G., Gray, S., Voss, C., Radford, A., Chen, M., and Sutskever, I., 2021. Zero-shot text-to-image generation. *International conference on machine learning*. PMLR, pp.8821–8831.

Select one of these papers, indicate its title in your answer and write an essay of about one page comprising:

- one paragraph summarising the paper’s contributions and motivations,
- one paragraph giving a high-level overview of the methodology or techniques covered in the paper
- one or two paragraphs giving your critical assessment of the research contributions and AI applications discussed, informed by aspects such as the related work and conclusions.

The following marking criteria are applied: The essay is worth 34 marks with an in-principle distribution of 9/9/16 for the three parts.

Your essay will be assessed based on the accuracy and clarity of your statements. In addition, your essay will be assessed based on the breadth and depth of your evaluation, and how well you support your arguments.

Note: ‘Breadth’ relates to the variety of issues that you touch upon. ‘Depth’ relates to how thoughtful and penetrating your comments are. [34 marks]