CE213-5-AU

UNIVERSITY OF ESSEX

Undergraduate Examinations 2020

ARTIFICIAL INTELLIGENCE

ANSWERS

Time allowed: **TWO** hours

Candidates are permitted to bring into the examination room:
Calculator – Casio FX-83GT Plus/X or Casio FX-85GT Plus/X ONLY

Candidates must answer **ALL** the questions.

The paper consists of **THREE** questions.

Question 1 is worth 40%.
Questions 2 and 3 are each worth 30%.

The percentages shown in brackets provide an indication of the proportion of the total marks for the **PAPER** that will be allocated for that part of the question.

Please do not leave your seat unless you are given permission by an invigilator.
Do not communicate in any way with any other candidate in the examination room.
Do not open the question paper until told to do so.
All answers must be written in the answer book(s) provided and not on rough paper.
All rough work must be written in the answer book(s) provided. A line should be drawn through any rough work to indicate to the examiner that it is not part of the work to be marked.
At the end of the examination, remain seated until your answer book(s) have been collected and you have been told you may leave.

Question 1

(a) Ben Goertzel proposed the Robot College Student Test in 2012, stating that w*hen a robot can enrol in a human university and take classes in the same way as humans, and get its degree, then we've created artificial [general] intelligence.* Discuss the strengths and weaknesses of the Robot College Student Test according to Alan Turing's definition of AI and by comparing it with the Turing Test. [8%]

Answer:

This is an open-ended question. The Robot College Student Test has not been introduced or discussed in this module's lectures or classes. A typical answer could include the following points:

Alan Turing defined AI as machines that can genuinely think or are of original thought.

The Turing Test is essentially based on behavioural observation and limited to typewritten conversations.

The Robot College Test involves assessment of the robot's abilities to listen, to perceive, to understand, to learn, to answer questions or solve problems.

There are uncertainty and flexibility in the Robot College Student Test, such as choosing the university and the degree course, which may considerably affect the test result.

Some other reasonable arguments can be acceptable.

(b) For game playing, state space search finds an optimal or satisfactory sequence of actions/moves by constructing a game tree. Reinforcement learning finds an optimal or satisfactory sequence of actions/moves by creating a state (game position) – action diagram through learning from data or exploration of the game environment. Discuss two major differences between these two approaches for game playing. [8%]

Answer:

This is a partially open-ended question. A typical answer could include the following points:

State space search often uses heuristics and effective search strategies such as minimax search to construct a game tree, whilst reinforcement learning builds up a state (game position) – action diagram/map with values of game positions and actions accumulatively updated through a large number of iterations without need of heuristics.

In a game tree constructed by state space search game positions are evaluated, whilst in a state-action diagram built up by reinforcement learning the combinations of states and actions are evaluated.

Monte-Carlo tree search and reinforcement learning have something in common in evaluating game positions and/or actions by running simulated games, but the algorithms for updating the values of game positions are very different.

Some other reasonable arguments can be acceptable.

(c) The following upper confidence bound (UCB) is often used as a criterion for the Monte-Carlo tree search method to select a node for the next expansion: [8%]

$$UCB = \frac{w_i}{n_i} + C\sqrt{\frac{\ln(t)}{n_i}}$$

where w_i is the number of wins after visiting node i, n_i is number of times node i has been visited, t is the number of times the parent node of node i has been visited, ln represents natural logarithm, and C is an exploration factor. Explain why the UCB can balance exploitation and exploration in node selection.

Answer:

The first term in the UCB formula, w_i/n_i, measures how good node i is in terms of how likely passing through this node will lead to win endgame, and the second term indicates how often node i has been visited so far compared to its siblings. Therefore, the first term represents the value for exploitation of node i, and the second term the value for exploration. {5 marks}

Using a larger value for parameter C, the UCB emphasises more on exploration; Otherwise, it emphasises more on exploitation. Good balance between exploitation and exploration can be achieved by choosing an optimal value for C. {3 marks}

(d) Assume both structural learning and parametric learning are applied to train a neural network described by the following formula: [8%]

$$y_k = f\left(\sum_{i=1}^{n} w_{ki}^{o} \cdot f\left(\sum_{j=1}^{M} w_{ij}^{h} . x_j - \theta_i^h\right) - \theta_k^o\right), \qquad k = 1, 2, \ldots, K$$

where y_k represents the output of the neural network, x_j represents the input, f is the neuronal activation function, K is the number of output neurons, M is the number of input nodes, n is the number of hidden neurons, and other variables in the formula represent connection weights and biases respectively. Explain what in the neural network will be optimised by structural learning and what will be updated during parametric learning.

Answer:

The structure of the neural network is determined by M, n, K. The values for K and M depend on the specific problem to be solved. Therefore the structure of this neural network depends on the number of hidden neuron, n, which will be optimised by structural learning. {4 marks}

The connection weights w_{ki}^{0}, w_{ij}^{h} and biases θ_{i}^{h}, θ_{k}^{o} will be updated during parametric learning. [To answer the question the students need to understand the mathematical model of the neural network] {4 marks}

(e) In both production systems (or expert systems) and reactive agents with subsumption architecture, there are states (or conditions) and actions, and IF-THEN rules can be used to describe relationships among states and actions. Discuss two major differences between a reactive agent with subsumption architecture and a production system from the perspective of IF-THEN rule interpretation and execution. [8%]

Answer:

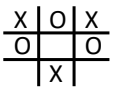
This is a relatively open-ended question. The answer may cover the following aspects:

1) There is no working memory in a reactive agent. Whether a rule's condition part is matched or not depends on the current state only. 2) Assigned priority may be the only conflict resolution strategy available for a reactive agent during rule interpretation, whilst several other conflict resolution strategies can be applied to a production system. 3) Backward chaining has been adopted in many production systems, but it is generally unsuitable for reactive agents.

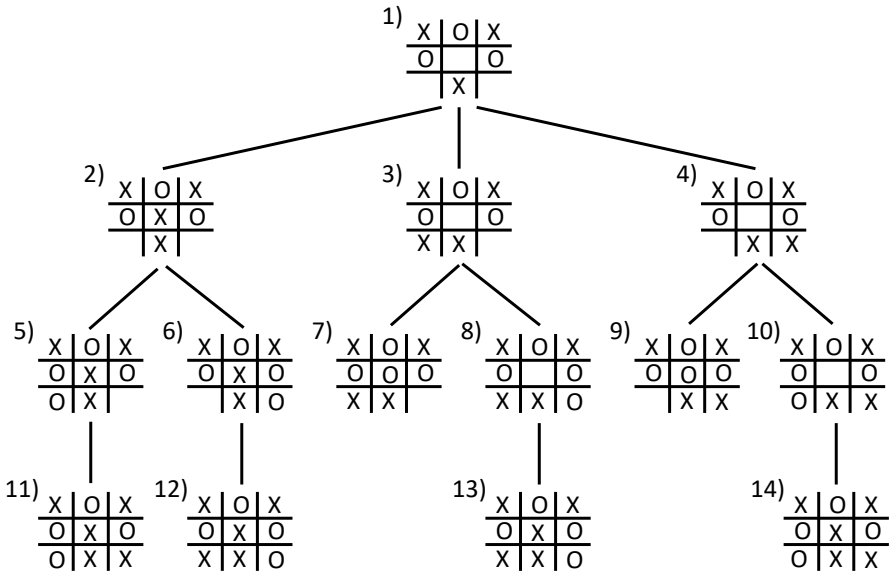
A full mark may be awarded if two of the above aspects have been thoroughly addressed.

Question 2

(a) The following figure shows the current game position or state of a Noughts and Crosses (Tic-Tac-Toe) board game played by two players: Player X and Player O.



Player X will make the next move to put a cross on one of the three empty grids. Assume a game tree, with 14 game positions numbered as 1) to 14) respectively, is constructed to find the optimal move for Player X, as shown in the following figure.



i) Assume that the value to Player X of an endgame position is 1 if Player X wins, -1 if Player X loses, and 0 if it is a draw. Use minimax search strategy to find the values to Player X of all the game positions in the above game tree. [8%]

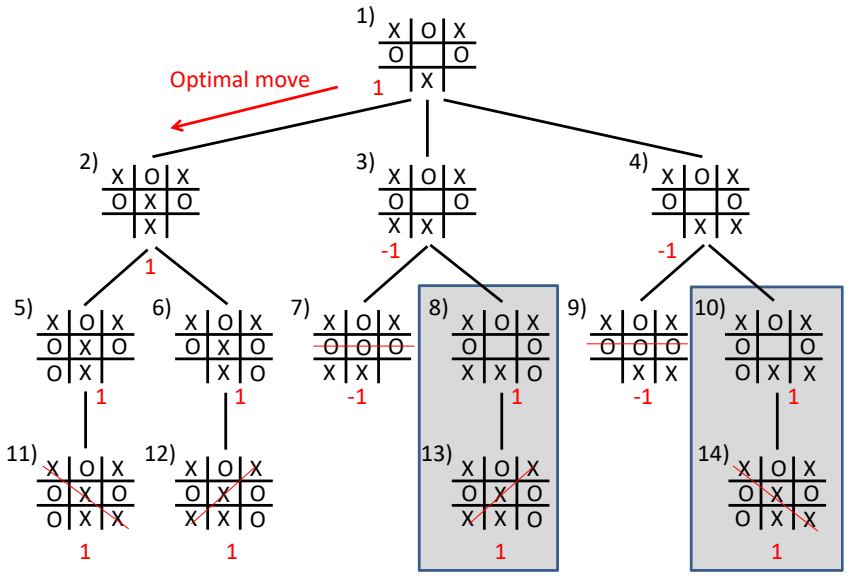
ii) If alpha-beta pruning is used in the minimax search process for the above game tree and the evaluation of game positions is done from left to right, which game positions need not be evaluated? What should be the optimal move of Player X at game position 1)? Justify your answer. [10%]

Answer:

(i) *There are 6 endgame positions in the game tree. Their values to Player X are as follows: -1 for game positions 7) and 9); 1 for game positions 11), 12), 13), and 14). {2 marks}*
By maximising, the values to Player X returned to game positions 5), 6), 8), and 10) are the same, that is, 1. {2 mark}
By minimising, the values to Player X returned to game positions 2), 3), and 4) are 1, -1, -1 respectively. {2 marks}
Finally, by maximising, the value to Player X returned to game position 1) is 1. {2 mark}

(ii) *By applying alpha-beta pruning in the minimax search, firstly game positions 5) and 6) have the value of 1 returned by maximising respectively, and then game position 2) has the value of 1 returned by minimising. {2 marks}*
The next game position to be evaluated is 7), which is a loss endgame having the value of -1. Since its value is smaller than the value returned to game position 2) (its uncle node), there is no need to evaluate game position 8) and thus game position 13,) and the value of -1 is returned to game position 3). {3 marks}
Now game position 9) should be evaluated, which has the value of -1. Since its value is smaller than the value returned to game position 2) (its uncle node), there is no need to evaluate game position 10) and thus game position 14), and the value of -1 is returned to game position 4). {3 marks}
Finally, by maximising the value of 1 is returned to game position 1). Since it is returned from game position 2), the optimal move of Player X at game position 1) is moving to game position 2). {2 mark}

The following figure is to show the minimax search process with alpha-beta pruning. This is not needed in the answers from the students.



Note: If assuming 1 is the maximum value for any game position, then game positions 3), 4), 7), 9) do not need evaluation either. This is acceptable and no mark should be deducted.

(b) As part of the analysis of post-Brexit UK economy, EcoAI uses an exhaustive backward chaining expert system to analyse the impact of the Brexit on UK economy. The expert system uses the uncertainty representation system developed for MYCIN and includes the following rules: [12%]

R1: IF Brexit deal excludes EU customs union
THEN CONCLUDE UK will sign a free trade agreement with US within 2 years
WITH CERTAINTY 0.8

R2: IF UK will sign a free trade agreement with US within 2 years
THEN CONCLUDE UK economy will grow by 2.5% in 2025

WITH CERTAINTY 0.6

R3: IF Brexit deal excludes EU customs union
THEN CONCLUDE UK will sign a free trade agreement with China within 3 years
WITH CERTAINTY 0.5

R4: IF UK will sign a free trade agreement with Chine within 3 years
THEN CONCLUDE UK economy will grow by 2.5% in 2025
WITH CERTAINTY 0.7

Suppose that the Brexit deal definitely excludes EU customs union. Based on the above 4 rules only, calculate the certainty factor of drawing the conclusion that UK economy will grow by 2.5% in 2025. Your answer should show your working.

Answer:

Initial hypothesis: UK economy will grow by 2.5% in 2025.
The RHS of Rule 2 and Rule 4 match the initial hypothesis.
{2 marks}
Rule 2: LHS not sure
Sub-hypothesis: UK will sign a free trade agreement with US within a year.
Only Rule 1's RHS matches the sub-hypothesis.
Rule 1: LHS satisfied with certainty 1
Conclude UK will sign a free trade agreement with US within 2 years with certainty 0.8
Now LHS of Rule 2 satisfied with certainty 0.8
*Conclude UK economy will grow by 2.5% in 2025 with certainty 0.8*0.6=0.48*
{4 marks}
Rule 4: LHS not sure
Sub-hypothesis: UK will sign a free trade agreement with China within 3 years.
Only Rule 3's RHS matches the sub-hypothesis.
Rule 3: LHS satisfied with certainty 1
Conclude UK will sign a free trade agreement with China within 3 years with certainty 0.5
Now LHS of Rule 4 satisfied with certainty 0.5
*Conclude UK economy will grow by 2.5% in 2025 with certainty 0.5*0.7=0.35*
{4 marks}
Combining conclusions from Rule 2 and Rule 4:
*Certainty of drawing the conclusion that UK economy will grow by 2.5% in 2025 is 0.48+(1-0.48)*0.35=0.35+(1-0.35)*0.48=0.662*
{2 marks}

Question 3

(a) A social understanding project has produced a large Excel data spreadsheet through interviewing tens of thousands of adults in the UK. The first column of the data spreadsheet contains the ID numbers of the interviewees, and the other columns of the data spreadsheet includes values of attributes of each interviewee, such as age, gender, race, education, income, etc.. You are asked to divide these interviewees into a reasonable number of groups using a machine learning approach according to certain separability criteria, and then to identify an attribute that is most informative for distinguishing these groups from each other. Choose and justify two machine learning methods, which you have learnt from this module, for fulfilling the two given tasks. [8%]

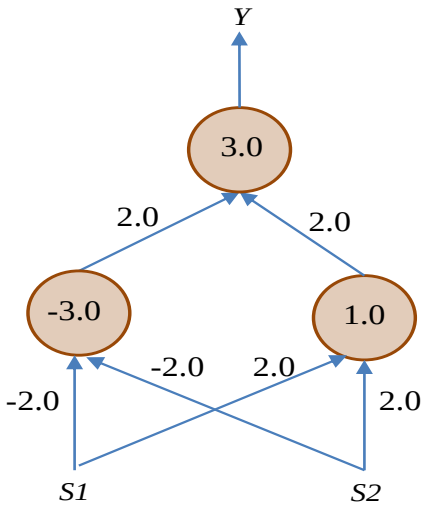
Answer:

This is a partly open-ended question. What follows is a typical answer, but other answers with appropriate justification can be acceptable.

For dividing the interviewees into a reasonable number of groups, unsupervised learning algorithms should be used as there is no label information about the given data. The k-means clustering can be used with the number of clusters determined adaptively/automatically. Agglomerative hierarchical clustering can also be used to create a dendrogram tree and then find the most reasonable number of groups by analysing the dendrogram. For both clustering methods, certain similarity measure should be adopted. {4 marks}

After the grouping is done, the interviewees can be labelled based on the groups they belong to. With the label information, the information gain of each attribute about the group classification can be calculated and ranked, in a similar way as that for best attribute selection in decision tree induction. The attribute with the largest information gain can be regarded as the most informative for distinguishing these groups from each other. [Other criteria about the relevance between an attribute and the group labels can be adopted as well, e.g., some correlation or similarity measures.] {4 marks}

(b) The figure below shows a neural network consisting of three McCulloch-Pitts neurons with binary output (0 or 1), where the numbers inside the circles are thresholds of the neurons respectively and the numbers alongside the arrows are weights of the corresponding inputs. [10%]



This neural network is applied for fault detection. It will report a fault when its output Y=1 or no fault when Y=0. Obviously, the neural network's output Y depends on its inputs $S1$ and $S2$. Will this neural network report a fault when its inputs are $S1$=1 and $S2$=1? Justify your answer by showing your working.

Answer:

When S1=1 and S2=1:

The weighted sum of inputs to the neuron with a threshold of -3.0 is -4, less than -3.0. Thus, this neuron's output is 0. {3 marks}

The weighted sum of inputs to the neuron with a threshold of 1.0 is 4, greater than 1.0. Thus, this neuron's output is 1. {3 marks}

Therefore, the weighted sum of inputs to the neuron with a threshold of 3.0 is 2, less than 3.0. Thus, this neuron's output is 0.

Because when S1=1 and S2=1 this neural network's output Y=0, it will not report fault.

{4 marks}

(c) Assume the data in the following table are used to induce a decision tree that serves as a simple medical diagnostic system: [12%]

Blood Pressure	Pulse	Temperature	Diagnosis
High	High	High	A
Normal	High	High	B
Normal	Normal	High	C
High	Normal	Normal	A
Normal	Normal	Normal	C
Normal	High	Normal	B
High	Normal	High	A
High	High	Normal	A

If information gain is used as the criterion to select best attributes and the information gain from *Temperature* has been found to be 0. Which of the remaining attributes, *Blood Pressure* or *Pulse*, should be in the root node of the induced decision tree? Justify your answer by showing your working.

[$I \equiv -\sum_{i=1}^{n} p_i \log_2 p_i$, $0\times\log_2(0)=0$, $\log_2(1)=0$, $\log_2(1/2)=-1$, $\log_2(1/4)=-2$, $\log_2(1/8)=-3$]

Answer:

Initial information about Diagnosis class:

$-0.5*\log_2(0.5)-0.25*\log_2(0.25)-0.25*\log_2(0.25)=1.5$ bits {2 marks}

Information about Diagnosis class given Blood Pressure:

$0.5[-1*\log_2(1)-0*\log_2(0)-0*\log_2(0)]+0.5[(-0*\log_2(0)-0.5*\log_2(0.5)-0.5*\log_2(0.5)]=0.5$

Hence information gain from Blood Pressure is 1.5-0.5=1 bit

{5 marks}

Information about Diagnosis class given Pulse:

$0.5[-0.5*\log_2(0.5)-0.5*\log_2(0.5)-0*\log_2(0)]+0.5[(-0.5*\log_2(0.5)-0*\log_2(0)-0.5*\log_2(0.5)]$ =1 bit

Hence information gain from Pulse is 1.5-1=0.5 bits

Blood Pressure has the largest information gain about Diagnosis class and should be the root node of the induced decision tree.

{5 marks}

END OF PAPER CE213-5-AU