A36932

Calculators may be used in this examination provided they are not capable of being used to store alphabetical information other than hexadecimal numbers



UNIVERSITY OF BIRMINGHAM

School of Computer Science

Second Year Undergraduate

06-34255

LI Artificial Intelligence 2

Main Summer Examinations 2025

Time allowed: 2 hours

[Answer all questions]

Note

Answer ALL questions.

Question 1

(a) A hospital is building a predictive model to determine whether a patient is likely to have pneumonia (Y), based on two features:

- X_1 (Age in years)
- X_2 (Has fever: 1 if fever, 0 otherwise)

A **logistic regression** model is trained, and the estimated parameters are:

$$\log\left(\frac{P(Y=1 \mid X_1, X_2)}{1-P(Y=1 \mid X_1, X_2)}\right) = -3.0 + 0.05X_1 + 1.2X_2$$

where $P(Y=1 \mid X_1, X_2)$ is the probability that a patient has pneumonia given their age and fever status.

(i) A 60-year-old patient with a fever ($X_1 = 60, X_2 = 1$) visits the hospital. Estimate their probability of having pneumonia. Show your working. **[8 marks]**

(ii) Explain the meaning of the model's parameter values in terms of the estimated risk of pneumonia: -3.0 (Intercept), 0.05 (Effect of Age), and 1.2 (Effect of Fever). **[9 marks]**

(b) The hospital also considers using a **Bayesian Network** for diagnosis. Suppose we have the following Bayesian Network representing the relationships between variables:

$$A \to B \to C$$

where A = Smoking (1 if yes, 0 otherwise) affects the probability of B, B = Cholesterol (1 if high, 0 otherwise) affects the probability of C, and C = Heart disease (1 if yes, 0 otherwise) depends only on B.

(i) Using the d-separation criterion, list the conditional independencies implied by the structure of the network. **[6 marks]**

(ii) The following estimates are given:

$$P(A=0) = 0.3, \quad P(B=1 \mid A=0) = 0.4, \quad P(B=1 \mid A=1) = 0.8,$$

$$P(C=1 \mid B=0) = 0.7, \quad P(C=1 \mid B=1) = 0.4.$$

You are given the evidence that $C = 1$. Compute $P(A=1 \mid C=1)$ and interpret what the result means in the given context. **[10 marks]**

Question 2

Autonomous robots rely on computer vision to navigate their environments safely. To improve obstacle detection, a robotics research lab collected a dataset containing sensor features from 800 autonomous robot runs, where 320 resulted in a collision ('Unsafe') and 480 were successful ('Safe'). The dataset consists of 20 features that describe image-based and sensor-derived obstacle features. The table below lists 5 key real-valued independent variables.

i	Features
θ_1	Edge sharpness
θ_2	Object density
θ_3	Distance to nearest object
θ_4	Optical flow variance
θ_5	Motion blur magnitude

You will use this dataset to train a decision tree model to predict whether a new environment is likely to result in a collision.

(a) Explain why decision trees are naturally resistant to highly correlated independent variables. How does feature importance ranking in decision trees help select the most relevant features? **[8 marks]**

(b) Suppose a decision tree is trained using two independent variables: Edge sharpness (θ_1) and Object density (θ_2). The following dataset is given. Answer the following questions, using base 2 logarithms throughout.

Edge sharpness (θ_1)	Object density (θ_2)	Collision (Yes=1, No=0)
3	7	1
8	4	0
6	9	1
5	3	0
7	6	1
4	5	0

(i) Calculate the entropy of the dataset before any split. **[6 marks]**

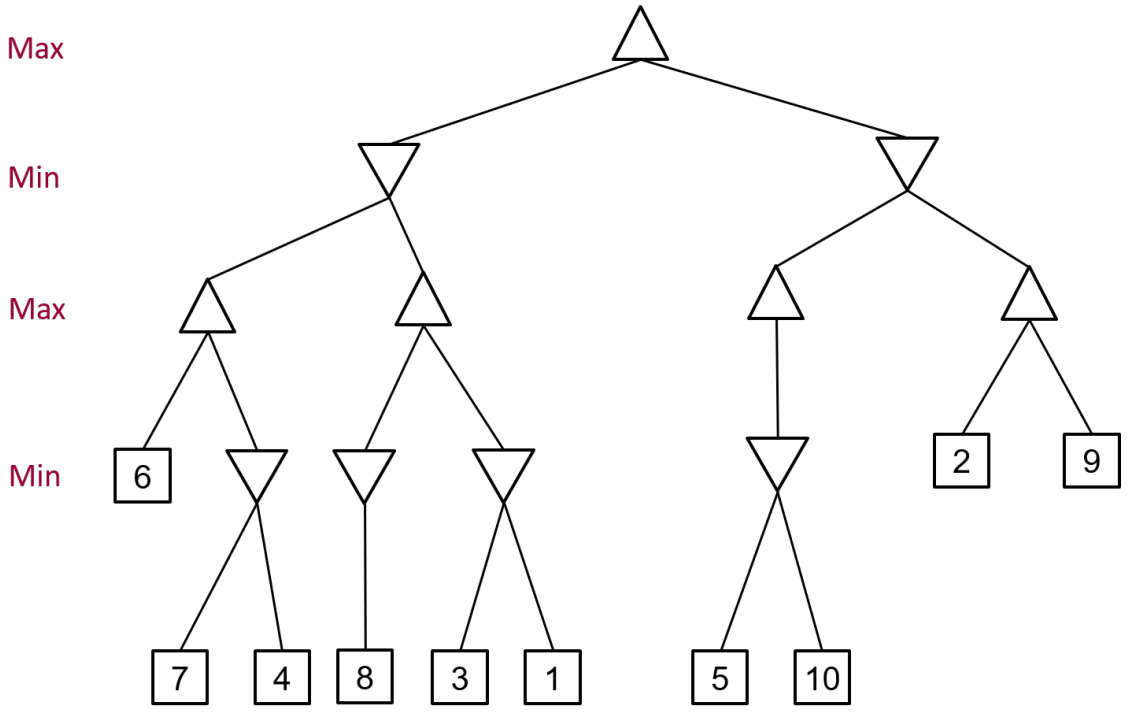
(ii) Compute the information gain if the dataset is split on Edge sharpness (θ_1) at threshold $\theta_1 \leq 6$. **[6 marks]**

(iii) Consider a decision tree having $\theta_1 \leq 6$ at its root node and $\theta_2 \leq 5$ at the next level. Predict the class label for a new environment with Edge sharpness $\theta_1 = 7$ and Object density $\theta_2 = 4$. **[6 marks]**

(c) Discuss the implications of the bias-variance tradeoff in decision trees for robotic vision. How could you use confidence bounds and pruning to help in selecting an optimal model? **[8 marks]**

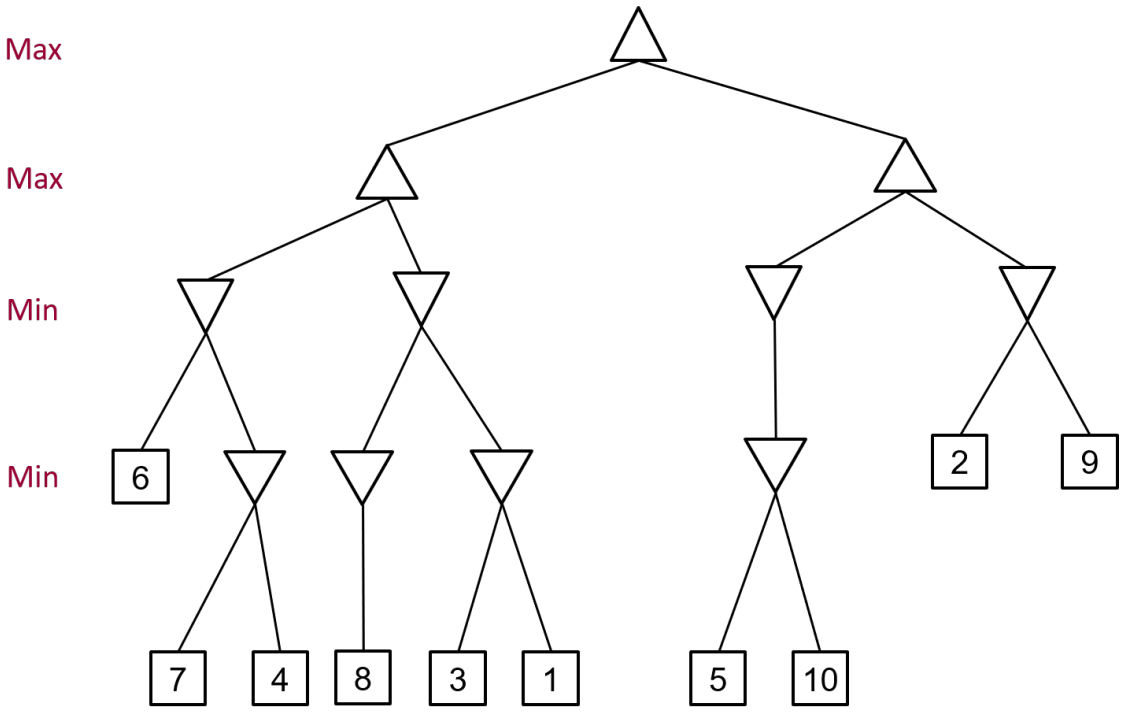
Question 3

(a) Consider the following minimax game tree. There are two players Max and Min; the player Max wants to maximise the utility and the player Min wants to minimise the utility. The tree has five layers and we can use L*m*-*n* to denote the *n*th node from left to right in the layer *m*; for example, the root node can be denoted by L1-1, the first node at the bottom layer (with value 7) can be denoted by L5-1, and the sixth node at the fourth layer (with value 2) can be denoted by L4-6. Give the value of the root node (L1-1) and the values of the two nodes at the second layer (L2-1 and L2-2). **[6 marks]**



(b) We use the alpha-beta pruning algorithm to prune the tree. List all the pruned nodes. Assume that child nodes are visited from left to right. **[12 marks]**

(c) Now suppose that the rule that the two players take the move alternately changed to the each of the players takes 2 moves in a row. That is, first the Max player takes two moves and then the Min player takes two moves (shown in the figure below). Give the value of the root node (L1-1) and the values of the two nodes at the second layer (L2-1 and L2-2). **[6 marks]**



(d) Can this tree get pruned (assume that child nodes are visited from left to right)? If yes, list all the pruned nodes; If no, give your explanation. **[9 marks]**

Do not complete the attendance slip, fill in the front of the answer book or turn over the question paper until you are told to do so

Important Reminders

- Coats/outwear should be placed in the designated area.
- Unauthorised materials (e.g. notes or Tippex) must be placed in the designated area.
- Check that you do not have any unauthorised materials with you (e.g. in your pockets, pencil case).
- Mobile phones and smart watches **must** be switched off and placed in the designated area or under your desk. They must not be left on your person or in your pockets.
- You are not permitted to use a mobile phone as a clock. If you have difficulty seeing a clock, please alert an Invigilator.
- You are not permitted to have writing on your hand, arm or other body part.
- Check that you do not have writing on your hand, arm or other body part – if you do, you must inform an Invigilator immediately
- Alert an Invigilator immediately if you find any unauthorised item upon you during the examination.

Any students found with non-permitted items upon their person during the examination, or who fail to comply with Examination rules may be subject to Student Conduct procedures.