A36941

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

Fourth Year Undergraduate/Postgraduate

06-36404

LM Artificial Intelligence and Machine Learning

Main Summer Examinations 2025

Time allowed: 2 hours

[Answer all questions]

Turn Over

Note

Answer ALL questions.

Question 1

(a) Define what a combinatorial optimization problem is and give an example. **[5 marks]**

(b) In the context of solving a combinatorial optimization problem, what is the difference between an exact algorithm and an approximate algorithm? Cite one algorithm for each type. **[5 marks]**

(c) Explain the concept of exhaustive search and discuss why, for some kinds of combinatorial optimization problem, it becomes impractical for problems of large size. **[5 marks]**

(d) Consider a set of N activities, each with a start time s_i and finish time f_i. The goal is to select the maximum number of non-overlapping activities. Assume the activities are sorted by finish time.

(i) List the steps of a greedy sequential decision process algorithm to solve this problem. **[5 marks]**

(ii) Apply your algorithm to the activities provided in Table 1. Clearly show the configuration set at each iteration and the final optimal solution. **[10 marks]**

(iii) Is the greedy SDP algorithm implemented above exact? Justify your answer. **[5 marks]**

Activity	A	B	C	D
Start Time	1	3	0	5
Finish Time	4	5	6	7

Table 1: Table for Question 1(d).

Question 2

(a) List the key differences between supervised and unsupervised learning techniques in machine learning. Provide an example of a problem that is best suited to each technique. **[5 marks]**

(b) Consider a linear regression model with two input features.

(i) Write the mathematical equation for the linear regression model that represents this problem. Define all the terms in the equation. **[3 marks]**

(ii) Define the square loss function that can be optimized to evaluate the error when using the linear regression model to predict new unseen data. Explain the role of this loss function in training the model. **[5 marks]**

(iii) Describe the steps of the sequential gradient descent algorithm for solving the linear regression problem. **[10 marks]**

(c) Considering the dataset for house price prediction provided in Table 2, estimate the updated set of weights after **one iteration** of the gradient descent algorithm. Initialize the weights for size and bedrooms as 0.1 and 1, respectively, the bias term as 0, and the learning rate as $\alpha = 0.001$. Show all calculations. **[12 marks]**

Size (sq. ft)	bedrooms	Price (£)
1000	2	350
1500	3	450
2000	4	600

Table 2: Dataset for Question 2(c).

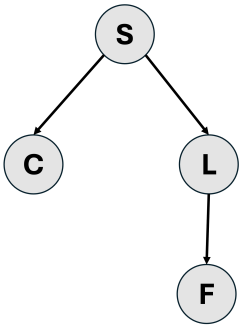


Figure 1: PGM for Question 3.

Question 3

(a) Probability provides a mathematical framework for reasoning about random events.

(i) Define what a random event is and provide three examples of random events in real-world situations. **[4 marks]**

(ii) Define a probabilistic graphical model (PGM) and describe how it can be used in machine learning. **[4 marks]**

(b) Consider the PGM shown in Figure 1, which represents a medical diagnosis system. The random variables S, L, C, and F represent the probabilities of smoking, lung cancer, cough, and fatigue, respectively.

(i) Identify at least one conditional independence relationship implied by this PGM. **[2 marks]**

(ii) Write the Markov factorization of this PGM, given the topological ordering $[S, C, L, F]$. **[5 marks]**

(c) Ignore fatigue (F) in the PGM from Figure 1 and focus only on the relationships between S, C, and L.

(i) Explain how a naïve Bayes classifier could be used to predict the probability of smoking given observations of cough and lung cancer. **[5 marks]**

(ii) Given the following probabilities:

- prior probability of smoking: 25%
- probability of cough given smoking: 50%
- probability of cough without smoking: 30%
- probability of lung cancer given smoking: 90%
- probability of lung cancer without smoking: 20%

Compute the probability of smoking for a patient who is diagnosed with lung cancer and is coughing. Show all steps. **[10 marks]**

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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.