Programme Code: TU082
Module Code: CMPU 4011

TECHNOLOGICAL UNIVERSITY DUBLIN

City Campus - Grangegorman

TU082 – BSc. (Honours) in Information Systems and Information Technology

Year 4

SEMESTER 2 EXAMINATIONS 2024/25

CMPU 4011 Machine Learning for Predictive Analytics

Internal Examiner(s):
Dr. Bojan Božić
Dr. Paul Doyle

External Examiner(s):
Dr. Andrea Kealy

Instructions To Candidates:

Answer ALL questions.
Question 1 carries 40 marks and questions 2 and 3 carry 30 marks each.

Exam Duration: 2 hours

Special Instructions/Handouts: Available on the last page

1)

a) **(5 marks)** Explain what overfitting is in machine learning. Provide an example to illustrate.

b) **(5 marks)** What is the difference between restriction bias and preference bias? Give an example of each.

c) **(5 marks)** Discuss what could go wrong if a machine learning model assumes feature independence when in reality the features are correlated. Give an example to support your answer.

d) The table below is showing a model's predictions on whether an email is "spam" (true) or "ham" (false).

Actual / Predicted	**Spam (True)**	**Ham (False)**
Spam (True)	50	10
Ham (False)	5	35

Based on this table:

i) **(6 marks)** Construct a **confusion matrix**.

ii) **(4 marks)** Calculate **classification accuracy**.

iii) **(15 marks)** Calculate **precision, recall and F1-score**. Explain what each metric means in this context.

2)

a) The following table contains customer satisfaction data for two features: **Service Quality** and **Response Time**, labeled as "Satisfied" or "Unsatisfied."

Service Quality	**Response Time**	**Satisfaction**
5	10	Satisfied
3	20	Unsatisfied
4	15	Satisfied
2	25	Unsatisfied
5	12	Satisfied

Classify the following query using 3-Nearest Neighbour (3-NN) with Euclidean Distance.

Service Quality	**Response Time**
4	18

i) **(8 marks)** Predict the **Satisfaction** label for the query using 3-NN. Show calculations and justification

ii) **(4 marks)** Normalize **Service Quality** and **Response Time** using **range normalization** (4 decimal places). Explain why normalization is important in k-NN.

iii) **(8 marks)** Repeat part (i) using the **normalized dataset**. Explain if and how the result changes.

b) The next table shows decisions of a bank on whether to grant loans based on four features.

Credit Score	**Income Level**	**Previous Loan**	**Age Group**	**Loan Granted**
High	High	No	Adult	Yes
Medium	Medium	Yes	Senior	No
Low	Low	No	Young	No
High	Medium	Yes	Adult	Yes

i) **(5 marks)** Calculate the **entropy** of the dataset. Explain what the value tells you.

ii) **(5 marks)** Explain what **entropy** indicates about a dataset and provide 2 real-world examples of datasets with high and low entropy.

3)

a) The following table contains a book purchase dataset.

Genre	**Author known**	**Discounted**	**Purchased**
Fiction	Yes	Yes	Yes
Non-fiction	No	Yes	No
Fiction	Yes	No	Yes
Poetry	No	No	No
Fiction	No	Yes	Yes

i) **(18 marks)** Calculate Naïve Bayes probabilities for each feature given target values (4 decimals). Explain why Naïve Bayes is appropriate.

b) **(10 marks)** Given a new book with:

Genre	**Author Known**	**Discounted**
Fiction	Yes	No

Calculate P(Purchased=yes) and P(Purchased=No).

c) **(2 marks)** What would Naïve Bayes predict for this book? Explain how to interpret these probabilities.

Supplemental Material

Useful Formulae

The entropy of a dataset of examples with labels $\boxed{t_1, t_2, \ldots, t_l}$

$$H(D) = -\sum_{i=1}^{l} \left(P(t_i) \times log_2(P(t_i))\right)$$

Information Gain for descriptive feature $\boxed{d}$ that splits $\boxed{D}$ into partitions $\boxed{D_1, D_2, \ldots, D_k}$.

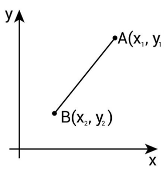
$$IG(d, D) = H(D) - \sum_{i}^{k} \frac{|\mathcal{D}_i|}{|\mathcal{D}|} \times H(D_i)$$

Table of base 2 log for different fractions

$\log_2(a/b)$		a													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
b	1	0.00													
	2	-1.00	0.00												
	3	-1.58	-0.58	0.00											
	4	-2.00	-1.00	-0.42	0.00										
	5	-2.32	-1.32	-0.74	-0.32	0.00									
	6	-2.58	-1.58	-1.00	-0.58	-0.26	0.00								
	7	-2.81	-1.81	-1.22	-0.81	-0.49	-0.22	0.00							
	8	-3.00	-2.00	-1.42	-1.00	-0.68	-0.42	-0.19	0.00						
	9	-3.17	-2.17	-1.58	-1.17	-0.85	-0.58	-0.36	-0.17	0.00					
	10	-3.32	-2.32	-1.74	-1.32	-1.00	-0.74	-0.51	-0.32	-0.15	0.00				
	11	-3.46	-2.46	-1.87	-1.46	-1.14	-0.87	-0.65	-0.46	-0.29	-0.14	0.00			
	12	-3.58	-2.58	-2.00	-1.58	-1.26	-1.00	-0.78	-0.58	-0.42	-0.26	-0.13	0.00		
	13	-3.70	-2.70	-2.12	-1.70	-1.38	-1.12	-0.89	-0.70	-0.53	-0.38	-0.24	-0.12	0.00	
	14	-3.81	-2.81	-2.22	-1.81	-1.49	-1.22	-1.00	-0.81	-0.64	-0.49	-0.35	-0.22	-0.11	0.00

Euclidean distance:

Distance Formula



$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Bayes Theorem:

$$P(A|B) = \frac{P(B|A)\,P(A)}{P(B)}$$