

S228/419C

DUBLIN INSTITUTE OF TECHNOLOGY  
KEVIN STREET, DUBLIN 8

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**BSc. (Honours)**  
**Degree in Computer Science**

**Year 4**

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**SUMMER EXAMINATIONS 2015**

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**ARTIFICIAL INTELLIGENCE II [CMPU4011]**

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Monday 11<sup>th</sup> May 2015  
4:00 p.m to 6:00 p.m

Question 1 is **compulsory**

Answer Question 1 (40 marks) **and**  
any 2 Other Questions (30 marks each).

1. (a) Explain what is meant by **inductive learning**.

(5 marks)

- (b) Explain what can go wrong when a machine learning classifier uses the wrong inductive bias.

(5 marks)

- (c) Table 1 shows the predictions made for a categorical target feature by a model for a test dataset.

- (i) Create the **confusion matrix** for the results listed in Table 1.

(5 marks)

- (ii) Calculate the **classification accuracy** for the results listed in Table 1.

$$\text{classification accuracy} = \frac{(TP + TN)}{(TP + TN + FP + FN)}$$

(5 marks)

- (iii) Calculate the **average class accuracy (harmonic mean)** for the results listed in Table 1. (During this calculation you should round all long floats to 4 places of decimal.)

$$\text{average class accuracy}_{HM} = \frac{1}{\frac{1}{|levels(t)|} \sum_{l \in levels(t)} \frac{1}{recall_l}}$$

(8 marks)

- (iv) Which of these performance metrics (**misclassification rate** or **average class accuracy (harmonic mean)**) is the most appropriate metric to use in this scenario? Provide an explanation for your answer.

(12 marks)

Table 1: The predictions made by a model for a categorical target on a test set of 20 instances

ID	Target	Prediction	ID	Target	Prediction
1	false	false	11	false	false
2	false	false	12	false	true
3	false	false	13	false	false
4	false	false	14	false	false
5	false	true	15	false	false
6	false	false	16	false	false
7	false	false	17	true	false
8	false	false	18	true	false
9	false	false	19	true	false
10	false	false	20	true	true

2. (a) Table 3, on the next page, lists a dataset containing examples described by two descriptive features, **Feature 1** and **Feature 2**, and labelled with a target class **Target**. Table 4, also on the next page, lists the details of a query for which we want to predict the target label. We have decided to use a **3-Nearest Neighbor** model for this prediction and we will use Euclidean distance as our distance metric:

$$d(x_1, x_2) = \sqrt{\sum_{i=1}^n ((x_1.f_i - x_2.f_i)^2)}$$

- (i) With which target class (**C1** or **C2**) will our **3-Nearest Neighbor** model label the query? Provide an explanation for your answer.

(8 marks)

- (ii) There is a large variation in range between **Feature 1** and **Feature 2**. To account for this we decide to normalize the data. Compute the normalized versions of Feature 1 and Feature 2 to four decimal places of precision using range normalization

$$x_i.f' = \frac{x_i.f - \min(f)}{\max(f) - \min(f)}$$

(4 marks)

- (iii) Assuming we use the normalized dataset as input, with which target class (**C1** or **C2**) will our **3-Nearest Neighbor** model label the query? Provide an explanation for your answer.

(8 marks)

- (b) Table 5, on the next page, lists a classification dataset. Each instance in the dataset has two descriptive features (Feature A and Feature B) and is classified as either a positive (+) or a negative(-) example. Note that Table 2, below, lists some equations that you may find useful for this question.

Table 2: Equations from information theory.

$$H(\mathbf{f}, \mathcal{D}) = - \sum_{l \in \text{levels}(f)} P(f = l) \times \log_2(P(f = l))$$

$$\text{rem}(\mathbf{f}, \mathcal{D}) = \sum_{l \in \text{levels}(f)} \frac{|\mathcal{D}_{f=l}|}{|\mathcal{D}|} \times H(\mathbf{t}, \mathcal{D})$$

$$IG(\mathbf{d}, \mathcal{D}) = H(\mathbf{t}, \mathcal{D}) - \text{rem}(\mathbf{d}, \mathcal{D})$$

- (i) Calculate the classification **entropy** for this dataset.

(5 marks)

- (ii) Calculate the **information gain** for Feature A and Feature B.

(5 marks)

Table 3: Dataset for the 3-Nearest Neighbor question

ID	Feature 1	Feature 2	Target
101	4	180000	C1
102	3	120000	C2
103	7	360000	C2
104	5	420000	C1
105	8	480000	C2

Table 4: Query instance for the 3-Nearest Neighbor question.

ID	Feature 1	Feature 2	Target
250	4	240000	?

Table 5: Classification dataset for information question.

Feature A	Feature B	Classification
True	True	+
True	False	-
True	False	+
True	True	+
False	True	-

3. Table 6 lists a dataset of the previous decision made by a couple regarding whether or not they would wait for a table at a restaurant (i.e., the feature WAITED is the target feature in this domain).
- (a) Calculate the probabilities (to four places of decimal) that a **naive Bayes** classifier would use to represent this domain.
- (18 marks)
- (b) Assuming conditional independence between features given the target feature value, calculate the **probability** of each outcome (WAITED=Yes, and WAITED=No) for the following restaurant for this couple (marks will be deducted if workings are not shown, round your results to four places of decimal)

BAR=False, PATRONS=None, PRICE=Expensive

(10 marks)

- (c) What prediction would a **naive Bayes** classifier return for the above restaurant?

(2 marks)

Table 6: A dataset describing the previous decisions made by an individual about whether to wait for a table at a restaurant.

ID	BAR	PATRONS	PRICE	WAITED
1	False	Some	Expensive	Yes
2	False	Full	Cheap	No
3	True	Some	Cheap	Yes
4	False	Full	Cheap	Yes
5	False	Full	Expensive	No
6	True	Some	Reasonable	No
7	True	None	Cheap	No
8	False	Some	Reasonable	No
9	True	Full	Cheap	No
10	True	None	Reasonable	Yes

4. (a) The following model is commonly used for continuous prediction tasks:

$$y(x) = w_0 + w_1x_1 + \cdots + w_Dx_D$$

- (i) Provide the name for this model and explain all of the terms that it contains. (4 marks)

- (ii) Explain how the following model can overcome some of the limitations of the model given above. (8 marks)

$$y(x) = \sum_{j=0}^{M-1} w_j \phi_j(x)$$

- (b) A multivariate logistic regression model has been built to predict the propensity of shoppers to perform a repeat purchase of a free gift that they are given. The descriptive features used by the model are the age of the customer, the average amount of money the customer spends on each visit to the shop, and the average number of visits the customer makes to the shop per week. This model is being used by the marketing department to determine who should be given the free gift. The trained model is

$$\begin{aligned} \text{REPEAT PURCHASE} = & -3.82398 - 0.02990 \times \text{AGE} \\ & + 0.74572 \times \text{SHOP FREQUENCY} \\ & + 0.02999 \times \text{SHOP VALUE} \end{aligned}$$

And, the logistic function is defined as:

$$\text{logistic}(x) = \frac{1}{1 + e^{-x}}$$

Assuming that the *yes* level is the positive level and the classification threshold is 0.5, use this model to make predictions for each of the query instances shown in Table 7 below.

(18 marks)

Table 7: The queries for the multivariate logistic regression question

ID	AGE	SHOP FREQUENCY	SHOP VALUE
1	56	1.60	109.32
2	21	4.92	11.28
3	48	1.21	161.19