University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

Spring, 23/24 TRIMESTER EXAMINATIONS

COMP47590

Advanced Machine Learning

Module Coordinator: Assoc Professor Brian Mac Namee

Student Number

Seat Number

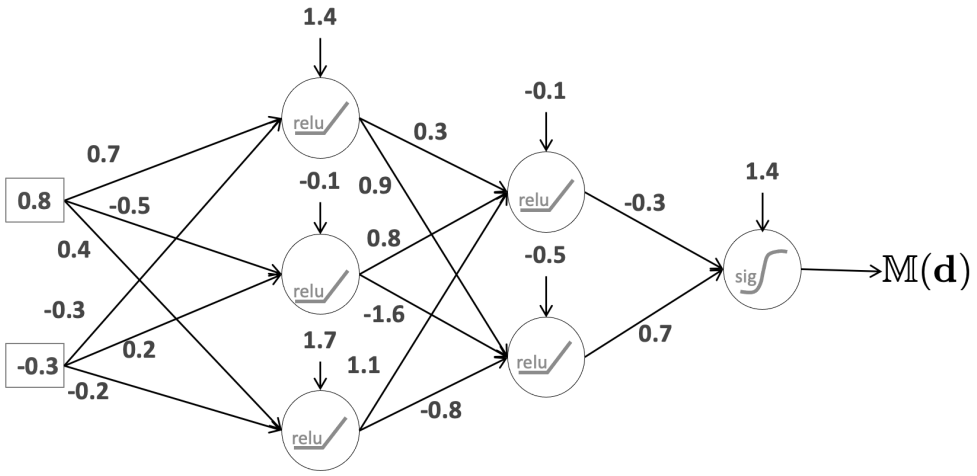
Time Allowed: 120 minutes

Materials Permitted in the Exam Venue:
Non-programmable or scientific calculator
Programmable calculator

Materials to be Supplied to Students:
8 Page Answer Booklets
New Cambridge Statistical Tables

Instructions to Students:
Answer any three out of four questions. All questions carry equal marks. Total marks available 90. The value of each part of each question is shown in brackets next to it.

1. **(a)** The image below shows a *feed forward artificial network*. The computational units in the two hidden layers use *rectified linear* (*relu*) activation functions and the output layer unit uses a *sigmoid* activation function. The *weights* and *biases* are shown along the links in the network.



(i) Perform a **forward propagation** through the network using an input feature vector of [0.8, -0.3]. Show your workings.

[12 marks]

(ii) If the target feature value for the current input vector is 1.0, calculate the **loss** associated with this training instance using **cross entropy loss**.

[2 marks]

(b) The **adam** approach to optimisation during gradient descent has now become the de-facto standard for training deep learning models. Explain how the adam approach improves upon basic gradient descent.

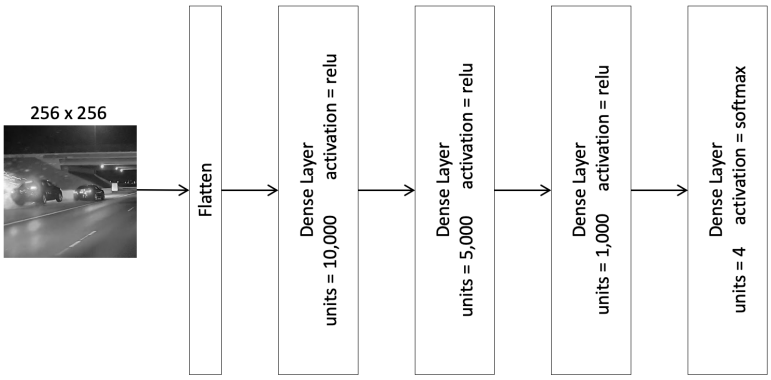
[8 marks]

(c) **Transfer learning** takes advantage of **embeddings** learned in one situation in other situations and can allow us bring the power of deep learning to scenarios where only small amounts of data are available. For transfer learning to be effective embeddings must be **disentangled** from the tasks used to learn them. Describe an approach that can be used to learn disentangled embeddings of images.

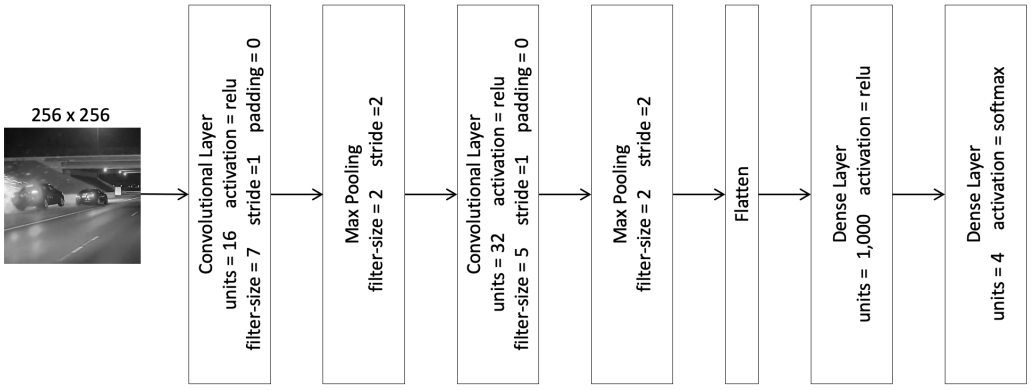
[8 marks]

2. **(a)** You have been tasked with training a neural network to control a self-driving racing car from image input. The model should output one of four control signals - *left, right, brake, or accelerate* - from each input image frame. The only input to the model is a 256 pixel by 256 pixel greyscale image from the front of the car.

Image (a) shows the architecture of a multi-layer perceptron neural network designed for this problem. Image (b) shows the architecture of a convolutional neural network designed for this problem. Both architectures are composed of four layers.



(a) Multi-layer perceptron network architecture

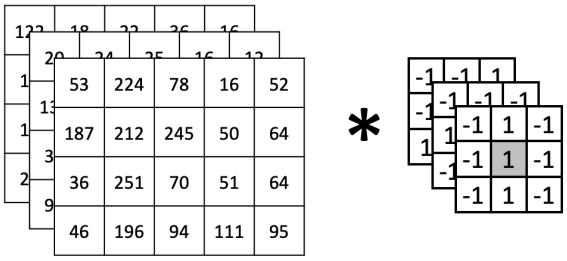


(b) Convolutional neural network architecture

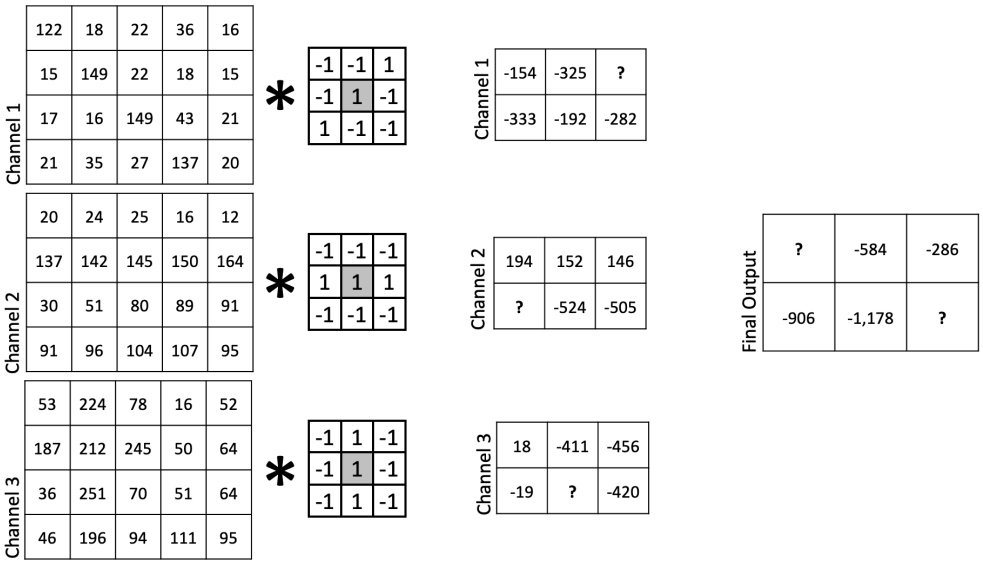
Calculate the number of parameters (weights and biases) that need to be learned for each network architecture.

[12 marks]

(b) The image below shows a 3-channel input that is being convolved (cross correlated) with a 3-channel 3 x 3 kernel.



The image below expands the three-channel input and three-channel kernel so that all values can be seen and shows the intermediate convolution result for each channel as well as the final output. Calculate the values marked with a **?** in the intermediate convolution results and the final output.



[8 marks]

(c) The 2017 paper "*Attention is all you need*" by Vaswani et al is now one of the most cited papers in machine learning research. Explain what **attention** is and how the **transformer** architecture utilises it.

[10 marks]

3. **(a)** Describe the concept of **discounted return** that is frequently used in reinforcement learning.

[4 marks]

(b) An intelligent agent trained to play a video game completes an episode and receives the following sequence of rewards over six timesteps:

$$\{r_0 = 77, r_1 = 105, r_2 = -57, r_3 = -86, r_4 = -112\}$$

Compare the **discounted returns** calculated at time $t = 0$ based on this reward sequence when discounting factors of 0.9 and 0.1 are used.

[6 marks]

(c) To try to better understand the behaviour of their chef, a restaurant manager monitored the chef's activities over a period of time, recording the chef's activity at 1-minute intervals. The activity stream looked like this (with time flowing down through the columns):

0	PREPPING	12	PREPPING	24	PREPPING	36	COOKING
1	COOKING	13	PREPPING	25	PLATING	37	COOKING
2	COOKING	14	PREPPING	26	COOKING	38	PLATING
3	PREPPING	15	COOKING	27	PREPPING	39	PLATING
4	PREPPING	16	COOKING	28	PREPPING	40	PLATING
5	COOKING	17	PREPPING	29	PREPPING	41	PLATING
6	PLATING	18	PREPPING	30	PLATING	42	PLATING
7	PLATING	19	PLATING	31	PLATING	43	PREPPING
8	PREPPING	20	PREPPING	32	PLATING	44	PREPPING
9	PREPPING	21	PLATING	33	PLATING	45	PREPPING
10	PREPPING	22	PLATING	34	COOKING	46	PREPPING
11	PREPPING	23	COOKING	35	COOKING	47	PLATING

The restaurant noticed that the chef could occupy one of three states - PREPPING, COOKING, or PLATING - and moved quite freely between them.

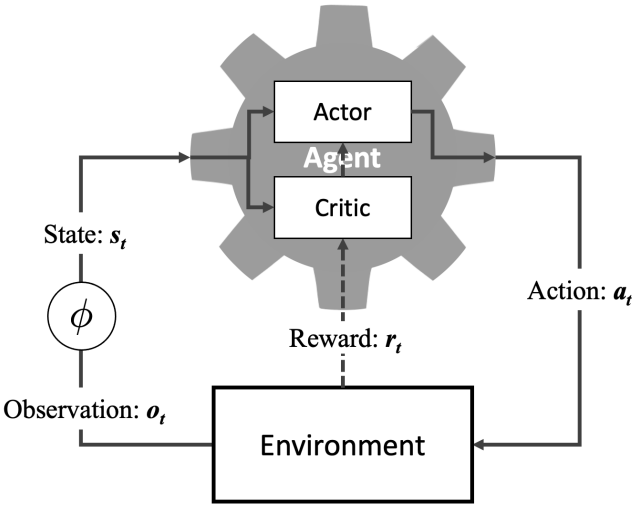
(i) Based on the sequence of states given above calculate a transition matrix that gives the probability of moving between each of the three states.

[10 marks]

(ii) Draw a Markov process diagram to capture the behaviour of a chef as described above.

[5 marks]

(d) The image below shows an illustration of reinforcement learning using **actor-critic** method.



Describe the role of the actor and critic models in this approach.

[5 marks]

4. **(a)** Describe *three* different motivations for using **ensemble methods** in machine learning.

[10 marks]

(b) When developing a machine learning model that will be deployed to perform a task for a user, we can describe three different goals of evaluation:

1. to determine which model is the most suitable for a task
2. to estimate how the model will perform after deployment
3. to convince users that the model will meet their needs

Describe the differences between these goals, and how the evaluation methods used to achieve each of them can be different.

[10 marks]

(c) The **EU AI Act** will probably come into effect in 2025. The act is expected to enforce different obligations for providers of artificial intelligence solutions with different level of risk. Four levels of risk, as illustrated below, are expected.

Discuss these levels of risk, giving examples of solutions likely to be considered at each, and the obligations that are likely to be enforced.

[10 marks]

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