EEL 5934 Applied Machine Learning Systems
Spring 2024
Final Exam
May 2, 2024
Time Limit: 130 minutes Name: _____

The exam consists of two parts:

- **Part I:** (60 minutes) a closed-book part, in which you may use one formula sheet and a calculator, no computer.
- **Part II:** (70 minutes) an open book, open notes, open computer part.

Note that some questions are worth more than other questions.
You must sign the honor statement at the end in order to receive any credit.

- **Write your name in the formula sheet**
- **Write legibly**

Answer the questions in the spaces provided on the question sheets. If you run out of room for an answer, continue on the back of the page.

Part I

(60 minutes) **Closed-book, no computer, one-page formulas, calculator**

Grade Table (for teacher use only)

Question:	1	2	3	4	5	6	7	Total
Points:	5	9	4	7	10	9	6	50
Score:								

1. (5 points) In the context of the Curse of Dimensionality, we studied the unit porcupine example (sphere inside cube). We measure the ratio between the volume of the sphere over the volume of a cube as the dimensionality of the feature space increases, i.e., $\lim_{D\to\infty} \frac{V(\text{sphere})}{V(\text{cube})}$. To what value is this ratio going to converge to? Why is this relevant in machine learning?

2. (9 points) Dimensionality reduction techniques are often used to mitigate the Curse of Dimensionality. Amongst these techniques, we studied feature selection with Recursive Feature Elimination (RFE) and feature extraction with Principal Component Analysis (PCA).

   (a) (3 points) Identify at least two advantages of PCA over RFE. Justify your answer.

   (b) (3 points) Provide the pseudo-code for implementing PCA. Be sure to include any necessary preprocessing.

(c) (3 points) What are the limitations of PCA? Can manifold learning algorithms mitigate these limitations? Do they introduce other challenges?

3. (4 points) In class, we studied the standard (or uniform) and weighted K-Nearest Neighbors (KNN) in the context of classification tasks. But KNN can also be used for regression tasks. Provide a pseudo-code for implementing standard KNN for regression tasks.

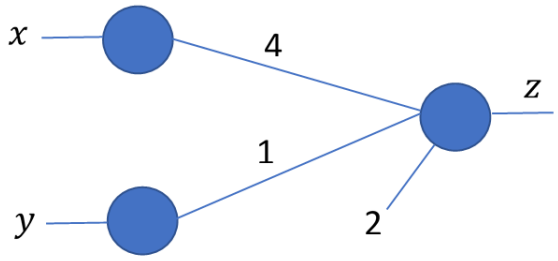
4. (7 points) Answer the following questions:

   (a) (4 points) Describe two techniques (one supervised and one unsupervised) to select the right number of clusters when using K-Means.

   (b) (3 points) For a given dataset, will K-Means converge to the same solution? Why or why not?

5. (10 points) Answer the following questions:

   (a) (5 points) Consider the Perceptron learning algorithm with the initial values listed in the figure below.

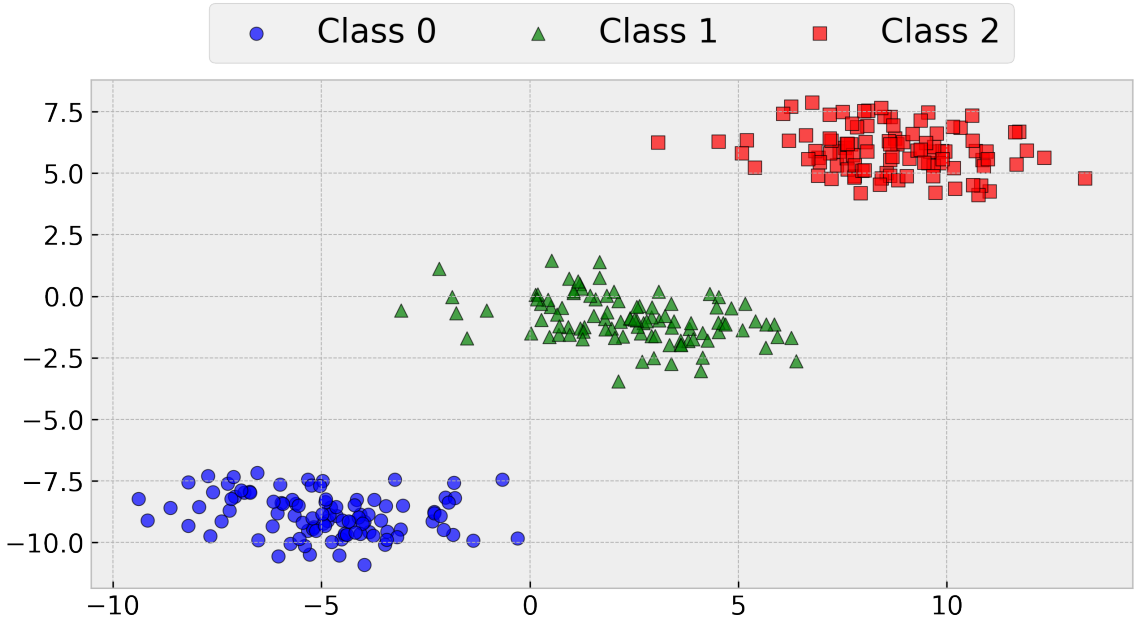


The mapper function is $z = \phi(4x + 1y + 2)$, where $\phi(x) = \begin{cases} 1 & x > 0 \\ -1 & x \leq 0 \end{cases}$. Suppose you have the following 5 data samples (x, y) and their corresponding labels t:

$$\begin{aligned} (x_1, y_1) &= (1, 0) \text{ with } t_1 = 1 \\ (x_2, y_2) &= (4, 2) \text{ with } t_2 = 1 \\ (x_3, y_3) &= (0, -1) \text{ with } t_3 = -1 \\ (x_4, y_4) &= (-1, -1) \text{ with } t_4 = -1 \\ (x_5, y_5) &= (-2, 1) \text{ with } t_5 = -1 \end{aligned}$$

Carry <u>one</u> update for the weights and bias using a learning rate $\eta = 0.5$. Show your work.

(b) (5 points) Consider the following two-dimensional data set with 3 target labels:



Design a multi-layer perceptron (MLP) that can solve this classification problem with zero classification error on this dataset. Pick which activation function you wish. The only constraint is that the output layer should have a single unit.

6. (9 points) This problem covers Multi-Layer Perceptrons (MLPs) and Convolutional Neural Networks (CNNs). Answer the following questions:

   (a) (3 points) Suppose that you are working with a regression task with 10 attributes and 3 target values, $\mathbf{t} = \begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix}$. Suppose that t_1 and t_2 are numerical values greater than 50,000, and t_3 is categorical with values between 0 and 10. What is the shape of input and output layers of a MLP? Which activation function would you use in the output layer?

   (b) (3 points) Suppose that you are working with a classification task with input images of size $100 \times 100 \times 3$ and 10 categorical target labels. What is the shape of input and output layers of this MLP? Which activation function would you use in the output layer?

(c) (3 points) For the classification task described in part (b), suppose that you are instead working with CNNs. What is the shape of input and output layers of a MLP? Which activation function would you use in the output layer?

7. (6 points) Let's explore the auto-encoder architecture. Can you name three (3) applications where auto-encoders are commonly used?

HONOR STATEMENT

I understand that I am bound to uphold the honor code of the University of Florida. I have neither given nor received assistance on this examination. In addition, I did not use any outside materials on this exam other than the one page of formulas that was allowed.

Sign Your Name: _____

Write the Date: _____

Print Your Name: _____

Turn in your formula sheet with your exam!!!