**ROB 537**

**Learning Based Control**

**Fall 2025**

**HW #1: Neural Networks**

**Due: 10/7 at 11:59PM**

Implement in code a one hidden-layer feed forward neural network to classify products into “pass” or “fail” categories. The neural network classifier will assume the role of quality control for a manufacturing plant. We use a simplified dataset for this assignment.

Download train1.csv, test1.csv, and test2.csv from Homework/HW1 on Canvas

Each file is a list of data points, with one data point on each line where the data points have five inputs (x1, x2, x3, x4,x5) and two outputs (y1, y2):

x1, x2, x3, x4, x5, y1, y2

In this case, (x1, x2, x3, x4, x5) are features of products, such as specifications for dimensions, weight, and functionality. These features have been quantified by the values x1 through x5. The values y1 and y2 denote the classification of the product (pass or fail), where (y1 = 0, y2 = 1) indicates the product has passed, and (y1 = 1, y2 = 0) indicates the product has failed.

train1.csv contains 400 training data points (200 pass and 200 fail)

test1.csv contains 50 testing data points (50 pass and 50 fail)

test2.csv contains a different set of 50 testing data points (50 pass and 50 fail)

Use the gradient descent algorithm to train a five input, two output (one for each class) neural network using file train1.csv. Write a report addressing the following questions with experiments supporting your answers. (Run an experiment, tell us the result, and tell us **why** you think you got that result. We are interested in seeing your insight about what is happening at a conceptual level.):

1. Describe the performance of the network using train1.csv and test1.csv:
   1. What happens if you make the learning rate really really big or really really small? Can the neural network still learn? Why or why not? (Hint: How does learning rate affect gradient updates?)
   2. What happens if you set all bias terms to zero? Does it affect the performance? Why or why not? (Hint: Mathematically, what is the bias term doing?)
   3. What happens if you replace all your activation functions with identity functions ie: f(x)=x? Does if affect performance? Why or why not? (Hint: Why is non-linearity beneficial for approximating arbitrary functions?)
   4. What happens if you use a different number of hidden units in the hidden layer? Is there a “correct” number to use? Why or why not? (Hint: Each time we add a hidden unit we are making a tradeoff. What is the benefit and what is the cost?)

(Continue reading to page 2)

Note, this is a classification problem, meaning that each data pattern (x1, x2, x3, x4, x5) belongs to one of two classes (y1 or y2). Consequently, use correct classification percentage (instead of MSE) to report your results. You will still use MSE to train the neural networks; you will simply report the classification percentage (or classification error) to assess the performance of the neural networks.

1. Using the same neural network you trained using train1.csv, answer questions 1.1-1.4 from above for the test2.csv test set. Do you see any differences in your answers when using this test set? If you do, what are they? What do you think may be causing the differences? (Hint: If you plot the xs from test1.csv and test2.csv together, what do you see?)

Submit a pdf of your report with your code attached to the end.

Tips:

You are free to use whatever programming language and libraries you would like. We recommend the python programming language with either the numpy or pytorch library (or both). Numpy provides fast and efficient matrix operations if you want fine-grained control of your neural network implementation. If you instead prefer to work at a more abstract level, then we recommend pytorch, since it provides high-level functions for building networks and computing gradients.

When working with generative AI (ChatGPT, Claude, etc), remember to use with caution. We recommend using simple and precise prompts for productive coding. For example, “Write a python function that takes in a 1D numpy array as an input, applies a sigmoid activation function to the input, and outputs a new array that is the result of the sigmoid activation.” If you start small and work from there, generative AI can be an extremely helpful tool for coding. Just remember that you are responsible for any code you turn in for this class, so do not follow the AI blindly. Check in with yourself as you code to make sure you understand what is going on. Generative AI will lead you down unproductive and frustrating rabbit holes if you are not careful.

Good luck, and don’t forget to ask for help if you are stuck!