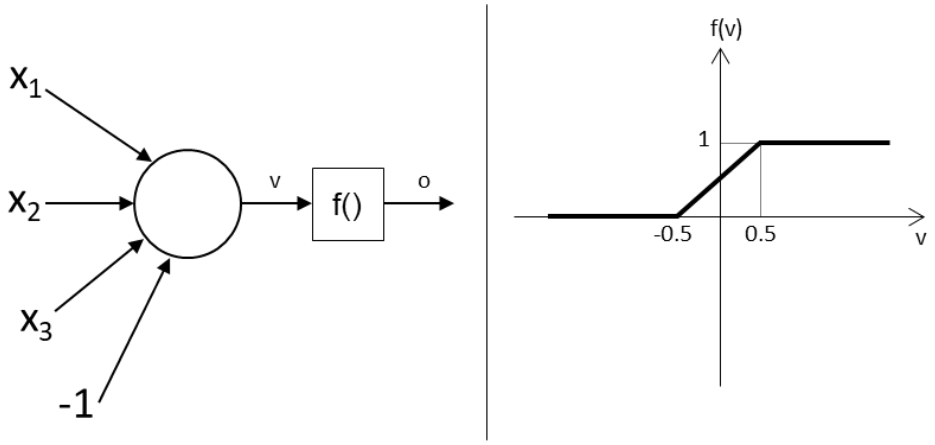
ME 466 Introduction to AI
Fall 2021
Programming Assignment 3
Due: 30 December 2021 @23:59

The solutions of this assignment should be prepared according to the guidelines in the course syllabus. Please read the syllabus first. Submit all evidence of your work; i.e., code, algorithms, flowcharts, MATLAB Command Window/command prompts, inputs, outputs, plots, results, error messages, etc. as an appendix or in the main body of your submission, with proper explanations. Also submit your code and a text file with instructions to run it. **Please fill in the page at the end of this assignment, sign it, and use it as the cover page of your assignment report.**

---

1. (15 pts, Sample Final Question) As we discussed in class, early works on neural networks focused on implementing logic functions with interconnected neurons. Particularly, we discussed the McCulloch-Pitts neuron in which the weights $w_i = \pm 1$, the inputs x_i are either 1 or 0, and activation function is the unit step function. Using hand calculations only, design a network of McCulloch-Pitts neurons that calculates the logic function (x_1 AND x_2) OR x_3 for every possible set of inputs.



2. (35 pts) Consider the neuron on the left with three inputs. The plot of the activation function of the neuron is given on the right. More precisely,

$$f(v) = \begin{cases} 0, & v < -0.5 \\ v + 0.5, & -0.5 \leq v \leq 0.5 \\ 1, & v > 0.5 \end{cases}$$

(a) Suppose the error at the output is defined as $E = \frac{1}{2}(t-o)^2$ where t is the target output. Derive the weight update equations for this neuron using the gradient descent method.

(b) Write a program to train this neuron such that it evaluates the function in Problem 1 above. In your program, you should

i. initialize the weights randomly,

ii. use the weight update equations you derived in part (a),

iii. stop the iterations when the error drops below the "machine epsilon" (in MATLAB, it is denoted by the constant `eps`.).

Report the resulting values of the weights. How does the learning rate affect the convergence? Try different values and discuss.

(c) Since there are three inputs, they can be visualized in 3D space. Plot the input points and the discriminant corresponding to the weights you found in part (b), and explain how this problem can be interpreted as a linear discriminant problem separating two sets of points.

3. (50 pts) In this problem you are going to implement an artificial neural network for a real data set. The problem is to recognize daily activities of a person using the sensors on a smartphone. The data were acquired from 30 volunteers while they performed 6 different activities. The experiments were conducted using a smartphone worn on the waist, and the embedded accelerometer and gyroscope data were recorded. Detailed information about the dataset can be found in [1].
The MATLAB data file `uci_har.mat` contains the data after feature extraction. The `features` variable is a matrix with 10299 columns and 561 rows. Each column of the matrix is a 561-dimensional feature vector, which is a sample corresponding to one of the activities performed by one of the experiment participants. There are 6 activities performed by 30 different participants in this dataset. The activity labels (classes) for each column is given in the variable `classes`, and the participant who performed the activity is given in the variable `participants`. These data are sufficient to solve this problem. However, if you want more information, check the other files provided, or download original files from the repository [1]. The names of the activities can be found in the file `activity_labels.txt`. The files `features.txt` and `features_info.txt` contain more information on how the 561 features are calculated, but you are not going to use that information in this problem.

(a) Implement a multilayer perceptron with 561 input neurons, 6 output neurons (one for each activity) and one hidden layer. Use hyperbolic tangent function as the activation function. In the output layer, the neuron corresponding to the performed activity should output 1, while others output -1. For example, if the correct activity is # 4, the target output of the network should be $[-1 \quad -1 \quad -1 \quad +1 \quad -1 \quad -1]^T$.

(b) Train the network and evaluate its performance by trying different values for the number of hidden layer neurons and the learning rate. Use an appropriate criterion to stop the training iterations. Report the confusion matrices. Use the following cross-validation schemes:

i. **10-fold cross validation:** Randomly split the data into 10 sets, use 9 of the sets for training, 1 set for testing, and calculate the performance. Train the network 10 times, using a different set for testing each time (and the remaining for training) and average the results.

ii. **Leave-one-participant-out cross validation:** There are data from 30 participants in this dataset. Train the network 30 times, train with 29 participants' data and test with the remaining 1 participant, each time using a different participant's data for testing. Then average the results. Note that this represents the case where the activity data of a person is not available to the algorithm beforehand and it tries to determine the activity by learning from other people's data.

Report your results in a concise and understandable format.

(c) Use Principal Components Analysis (PCA) to reduce the number of features to 10. Then repeat part (b) for a network with 10 input neurons. Comment on any improvement or degradation in the recognition performance.

References

[1] J.L.Reyes-Ortiz et al., Human Activity Recognition Using Smartphones Dataset, UCI Machine Learning Repository, University of California, Irvine, CA. URL: `https://archive.ics.uci.edu/ml/datasets/human+activity+recognition+using+smartphones` (2012)

ME 466 Introduction to AI
Fall 2021
Programming Assignment 3
Submitted on: 30 December 2021

Name:

Student ID:

Grade:

1	
2	
3	
Σ	

I hereby declare that the paper I am submitting under this cover is product of my own efforts only. Even if I worked on some of the problems together with my classmates, I prepared this paper on my own, without looking at any other classmate's paper. I am knowledgeable about everything that is written under this cover, and I am prepared to explain any scientific/technical content written here if a short oral examination about this paper is conducted by the instructor. I am aware of the serious consequences of cheating.

Signature: _____