Iran University of Science & Technology

School of Computer Engineering

Assignment #1

Neural Networks

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Due: Monday, Aban 15, 1402

Contents

Problem 1

As presented in the classroom material where we've explored logic functions such as AND and OR, let's now delve into the NOR logic function using the following data.

Consider the NOR logic function described in the following table:

X1	X2	Y
0	0	1
0	1	0
1	0	0
1	1	0

Attempt to design a single artificial neuron that uses a threshold of -0.5 to solve the NOR logic function. Utilize the neuron's weight values in conjunction with the specified threshold to achieve correct predictions.

(10 points)

Problem 2

a.

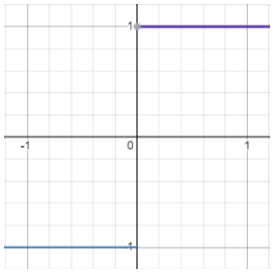
Your challenge involves constructing an ADALINE[1] capable of precisely solving the OR logic function. In the context of this task, the learning rate is specified as 0.1 and a bias of 1 is established and also the initial weights are: b=0.2, w1=0.3, w2=0.1

Your primary goal is to lay out, in comprehensive detail, the sequential steps necessary to craft an ADALINE neuron that effectively learns, refines its weights, and reliably predicts the behavior of the OR logic function. Emphasize the iterative nature of the training process across a span of three steps. Calculate the weights considering following activation functions.

1- Step function (hard limiter)

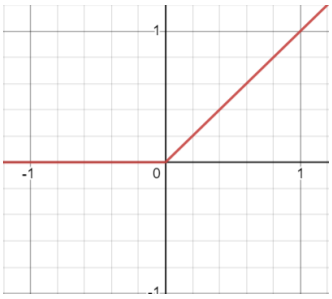
$$out = \begin{cases} 1 \; if \; y >= 0 \\ -1 \; if \; y <= 0 \end{cases}$$

[1] Adaptive Linear Neuron



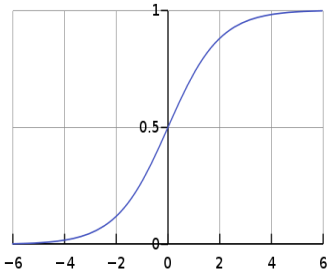
2- ReLU

$$out = \max(0, x)$$



3- Sigmoid

$$out = \frac{1}{1 + e^{-x}}$$



Calculate Gradient Decent and Stochastic Gradient Decent for section 1. Explain and compare the two methods (SGD and GD). Write down your calculations.

X1	X2	Y
0	0	0
0	1	1
1	0	1
1	1	1

(20 points)

b.

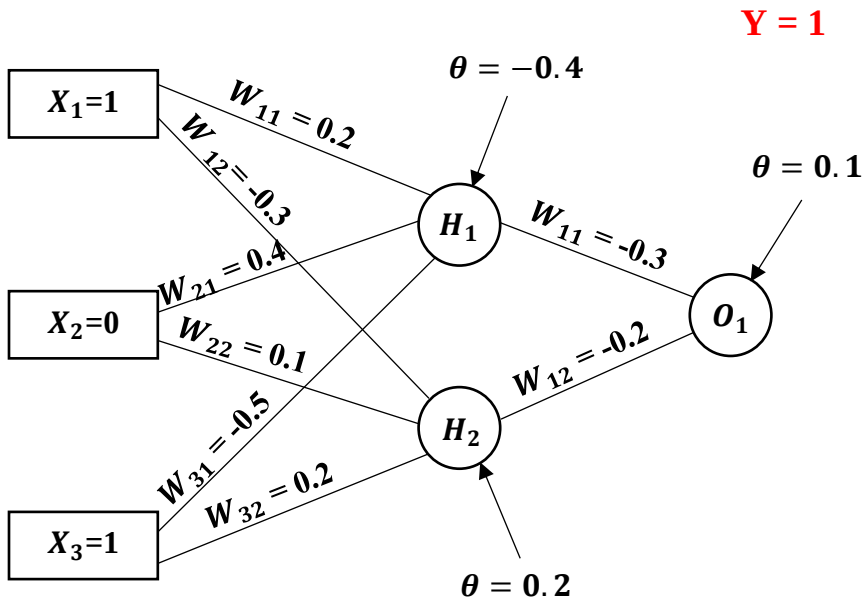
Refer to Problem2.ipynb in the assignment folder. Complete parts A and B to implement an Adaline and Madaline for classifying mentioned dataset. Explain and compare the results.

(20 points)

Problem 3

Consider the following MLP. Calculate the forward pass and backpropagation in this MLP.

- All calculations should be written for two epochs.

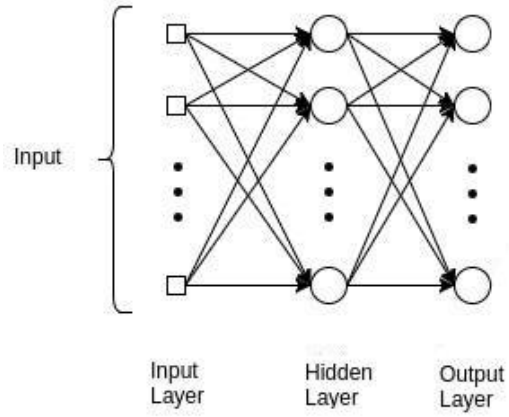


(20 points)

Problem 4

a.

Implement a Multi-Layer Perceptron (MLP) neural network from scratch based on the following structure. Train and test the MLP using the MNIST dataset.



- Input layer:
  - Number of Neurons: 784 (28*28)
- Hidden layer:
  - Number of Neurons: 800
  - Activation Function: Sigmoid
- Output layer:
  - Number of Neurons: 10
  - Activation Function: Softmax

(15 points)

b.

Design and implement a Dynamic Multi-Layer Perceptron (MLP) neural network from scratch. Keep in mind that your design must take inputs such as the number of layers, the number of neurons in each layer, the activation function, the number of epochs and input samples. Then, train the network on some data and finally test it.

Notice: Your MLP will be tested using random data by the TA.

(20 points)

Problem 5

Discuss the potential issue (overfitting or underfitting) in the following scenarios and propose solutions for each one of them.

- Your team is working on a financial fraud detection system using machine learning. The model seems to have poor detection performance on new transactions.

- In the field of natural language processing, your text summarization model produces summaries that are overly generic and fail to capture important details from the source text.

- You are developing a deep learning model for image denoising, aiming to remove noise from medical X-ray images. While the model performs exceptionally well on the training dataset, it fails to generalize to new X-ray images from different hospitals and machines.

(15 points)

Notes:

- Write your implementations in python code and use Jupyter (Notebooks) to show your results. All of your solutions should be explained and reported in a PDF file. Submit your assignment with all necessary components in a compressed folder as HW#_StudentID.zip format.
- Solve the problems on your own, consultation is not allowed.
- You can ask to clarify any ambiguity about problems on the Telegram group.
- You have a total of 144 hours (6 days) allowed delay time in submitting your assignments. Each assignment would have 48 hours open time in addition to its mentioned deadline. If you exceed your allowed submission time, you will lose points.