Lab Topic 06 - Linear Classification using Perceptrons
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Background

A **perceptron** is a form of **simple neural network**, consisting of a **single neuron** that takes a **feature vector** with ***n* coordinates**, assigns each coordinate with a **corresponding weight**, and **outputs** the feature vector's **classification** based on a **threshold function**. The perceptron algorithm was conceptualized by Frank Rosenblatt in 1957, and it was one of the first neural networks to be implemented.

Perceptron only works on **linearly separable** data. If the training data is not linearly separable, the perceptron algorithm will not converge.

The Algorithm

Given:

- *m* feature vectors with *n* coordinates and a corresponding target label/classification, *y*, each: $x_0, x_1, \ldots x_n$ -> y
- *n* weights, $w_0, \ldots, w_n$, for each coordinate of a feature vector
- Learning rate, *r*
- Threshold, *t*
- Bias, *b*

The algorithm follows the steps:

1. Choose initial weights (may be random, but are usually initialized to 0)
2. For each individual feature vector (row)
   a. Compute perceptron value, a

   $$a = \sum_{i=0}^{n} (x_i w_i) + b w_b$$

   b. Determine classification, y

   $$y = (a \geq threshold)\,?\,1 : 0$$

   c. Adjust weights

   $$w_a = w_c + r x_p (z - y)$$

   where, w_a is the adjusted weight, w_c is the most recent/current value of the weight, and x_p pertains to the x-value of the previous feature vector
3. If the weights converge, **stop learning**. Else, **repeat step 2** for the next feature vector. The weights have converged **if they stay the same** throughout all feature vectors in the training data set.

Exercise

Create a program that will perform machine learning using the perceptron algorithm.

- Read an input file (**input.txt**) containing the data in the following format:

```
0.1
0.5
1
0 0 1
0 1 1
1 0 1
1 1 0
```

The *first line* is the learning rate, the *second line* is the threshold, and the *third line* is the bias. Always initialize weights to 0. The rest of the lines are the training data. The *last number on each line is the classification/target label*; as with the last exercise, use numbers to denote classifications for simplicity.

**Note that the number of columns for x values should not be restrained to 2 only (can be 2 or more).

- Write the output of your program to a text file (**output.txt**) with the following format:

```
Iteration 1:
    x0   x1   b    w0   w1   wb   a    y   z
    0    0    1.0  0    0    0    0.0  0   0
    0    1    1.0  0.0  0.0  0.0  0.0  0   1
    1    0    1.0  0.0  0.1  0.1  0.1  0   1
    1    1    1.0  0.1  0.1  0.2  0.4  0   1
Iteration 2:
    x0   x1   b    w0   w1   wb   a    y   z
    0    0    1.0  0.2  0.2  0.3  0.3  0   0
    0    1    1.0  0.2  0.2  0.3  0.5  0   1
    1    0    1.0  0.2  0.3  0.4  0.6  1   1
    1    1    1.0  0.2  0.3  0.4  0.9  1   1
Iteration 3:
    x0   x1   b    w0   w1   wb   a    y   z
    0    0    1.0  0.2  0.3  0.4  0.4  0   0
    0    1    1.0  0.2  0.3  0.4  0.7  1   1
    1    0    1.0  0.2  0.3  0.4  0.6  1   1
    1    1    1.0  0.2  0.3  0.4  0.9  1   1
```

- Your score will be computed as follows:

Criteria	**Points**
Read input file correctly	2
Compute a correctly	2
Apply threshold function correctly	2
Adjust weights correctly	2
Write output correctly	2
Total	10

Reference

Stuart Russell and Peter Norvig. 2009. *Artificial Intelligence: A Modern Approach* (3rd ed.). Prentice Hall Press, Upper Saddle River, NJ, USA.