

perceptronClassifier_implementation

May 8, 2021

1 2 Implement a Perceptron

1.0.1 2.1 Weight Update Function

```
In [1]: import perceptron
import datasets
import runClassifier
import numpy as np
import matplotlib.pyplot as plt
```

```
In [13]: def nextExample(self, X, Y):
        """
        X is a vector training example and Y is its associated class.
        We're guaranteed that Y is either +1 or -1. We should update
        our weight vector and bias according to the perceptron rule.
        """

        # check to see if we've made an error
        if Y * self.predict(X) <= 0:    ### SOLUTION-AFTER-IF
            self.numUpd = self.numUpd + 1

            # perform an update
            self.weights = self.weights + Y * X    ### TODO: YOUR CODE HERE

            self.bias = self.bias + Y    ### TODO: YOUR CODE HERE
```

```
In [2]: runClassifier.trainTestSet(perceptron.Perceptron({'numEpoch': 1}), datasets.TennisData)
```

Training accuracy 0.6428571428571429, Test accuracy 0.6666666666666666

```
In [3]: runClassifier.trainTestSet(perceptron.Perceptron({'numEpoch': 2}), datasets.TennisData)
```

Training accuracy 0.8571428571428571, Test accuracy 1.0

1.0.2 2.2 Permuting Training Samples

```
In [4]: runClassifier.trainTestSet(perceptron.PermutedPerceptron({'numEpoch': 1}), datasets.Tenn
Training accuracy 0.7857142857142857, Test accuracy 0.8333333333333334
```

```
In [5]: runClassifier.trainTestSet(perceptron.PermutedPerceptron({'numEpoch': 1}), datasets.Tenn
Training accuracy 0.6428571428571429, Test accuracy 0.5
```

```
In [6]: runClassifier.trainTestSet(perceptron.PermutedPerceptron({'numEpoch': 1}), datasets.Tenn
Training accuracy 0.5, Test accuracy 0.6666666666666666
```

Plotting the mean train and test accuracy of both non-permuted and permuted perceptron classifiers

```
In [7]: data1 = [runClassifier.hyperparamCurveSet(perceptron.Perceptron({}),
                                                    'numEpoch', range(1, 15),
                                                    datasets.SentimentData) for _ in range(10)]
        data2 = [runClassifier.hyperparamCurveSet(perceptron.PermutedPerceptron({}),
                                                    'numEpoch', range(1, 15),
                                                    datasets.SentimentData) for _ in range(10)]
```

```
Training classifier with numEpoch=1...
Training accuracy 0.8358333333333333, Test accuracy 0.755
Training classifier with numEpoch=2...
Training accuracy 0.955, Test accuracy 0.7975
Training classifier with numEpoch=3...
Training accuracy 0.9366666666666666, Test accuracy 0.755
Training classifier with numEpoch=4...
Training accuracy 0.995, Test accuracy 0.8125
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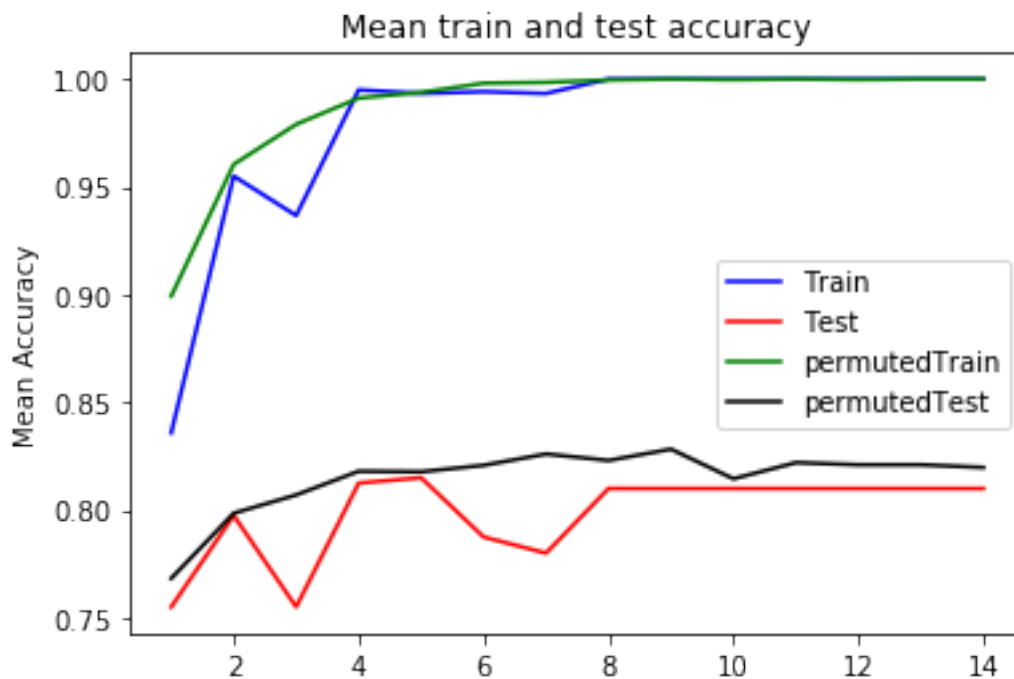
In [8]: def plotCurve2(titleString, data1, data2):
        plt.plot(data1[0], data1[1], 'b-',
                 data1[0], data1[2], 'r-',
                 data2[0], data2[1], 'g-',
                 data2[0], data2[2], 'k-')
        plt.legend( ('Train', 'Test', 'permutedTrain', 'permutedTest') )
        #xlabel('# of training points')
        plt.ylabel('Mean Accuracy')
        plt.title(titleString)
        plt.show()

```

```

In [9]: plotCurve2('Mean train and test accuracy', np.mean(data1, axis=0), np.mean(data2, axis=0))

```



1.0.3 2.3 Averaged Perceptron

```
In [10]: data1 = runClassifier.hyperparamCurveSet(perceptron.Perceptron({}),
                                                'numEpoch', range(1, 15),
                                                datasets.SentimentData)
        data2 = runClassifier.hyperparamCurveSet(perceptron.AveragedPerceptron({}),
                                                'numEpoch', range(1, 15),
                                                datasets.SentimentData)
```

```
Training classifier with numEpoch=1...
Training accuracy 0.8358333333333333, Test accuracy 0.755
Training classifier with numEpoch=2...
Training accuracy 0.955, Test accuracy 0.7975
Training classifier with numEpoch=3...
Training accuracy 0.9366666666666666, Test accuracy 0.755
Training classifier with numEpoch=4...
Training accuracy 0.995, Test accuracy 0.8125
Training classifier with numEpoch=5...
Training accuracy 0.9933333333333333, Test accuracy 0.815
Training classifier with numEpoch=6...
Training accuracy 0.9941666666666666, Test accuracy 0.7875
Training classifier with numEpoch=7...
Training accuracy 0.9933333333333333, Test accuracy 0.78
Training classifier with numEpoch=8...
Training accuracy 1.0, Test accuracy 0.81
Training classifier with numEpoch=9...
Training accuracy 1.0, Test accuracy 0.81
Training classifier with numEpoch=10...
Training accuracy 1.0, Test accuracy 0.81
Training classifier with numEpoch=11...
Training accuracy 1.0, Test accuracy 0.81
Training classifier with numEpoch=12...
Training accuracy 1.0, Test accuracy 0.81
Training classifier with numEpoch=13...
Training accuracy 1.0, Test accuracy 0.81
Training classifier with numEpoch=14...
Training accuracy 1.0, Test accuracy 0.81
Training classifier with numEpoch=1...
Training accuracy 0.9275, Test accuracy 0.805
Training classifier with numEpoch=2...
Training accuracy 0.9716666666666667, Test accuracy 0.805
Training classifier with numEpoch=3...
Training accuracy 0.99, Test accuracy 0.82
Training classifier with numEpoch=4...
Training accuracy 0.9966666666666667, Test accuracy 0.8225
Training classifier with numEpoch=5...
Training accuracy 0.9975, Test accuracy 0.8225
Training classifier with numEpoch=6...
Training accuracy 0.9991666666666666, Test accuracy 0.8275
```

```

Training classifier with numEpoch=7...
Training accuracy 1.0, Test accuracy 0.8225
Training classifier with numEpoch=8...
Training accuracy 1.0, Test accuracy 0.82
Training classifier with numEpoch=9...
Training accuracy 1.0, Test accuracy 0.8225
Training classifier with numEpoch=10...
Training accuracy 1.0, Test accuracy 0.8225
Training classifier with numEpoch=11...
Training accuracy 1.0, Test accuracy 0.8225
Training classifier with numEpoch=12...
Training accuracy 1.0, Test accuracy 0.8225
Training classifier with numEpoch=13...
Training accuracy 1.0, Test accuracy 0.8225
Training classifier with numEpoch=14...
Training accuracy 1.0, Test accuracy 0.825

```

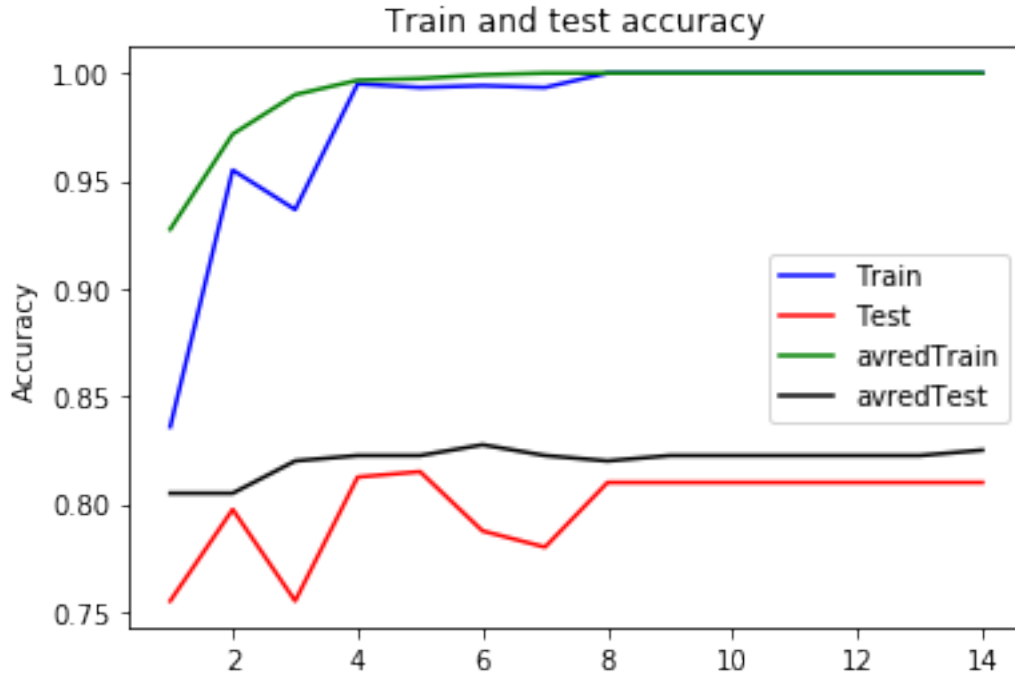
Plotting the train and test accuracy of both averaged and original perceptron classifiers

```

In [11]: def plotCurve3(titleString, data1, data2):
            plt.plot(data1[0], data1[1], 'b-',
                     data1[0], data1[2], 'r-',
                     data2[0], data2[1], 'g-',
                     data2[0], data2[2], 'k-')
            plt.legend( ('Train', 'Test', 'avredTrain', 'avredTest') )
            #xlabel('# of training points')
            plt.ylabel('Accuracy')
            plt.title(titleString)
            plt.show()

In [12]: plotCurve3('Train and test accuracy', data1, data2)

```

1.0.4 Let's re-work the analysis in equations 4.3 to 4.6 of the textbook to show that the perceptron also performs better on negative examples ($y = -1$) after a weight update.

So we have a negative example: $y = -1$. We compute an activation a , and make an error: $ya \leq 0 \Rightarrow a \geq 0$. We now update our weights and bias. Let's call the new weights w'_1, \dots, w'_D, b' . Suppose we observe the same example again and need to compute a new activation a' :

$$\begin{aligned}
 a' &= \sum_{d=1}^D w'_d x_d + b' \\
 &= \sum_{d=1}^D (w_d - x_d) x_d + b - 1 \\
 &= \sum_{d=1}^D w_d x_d + b - \sum_{d=1}^D x_d^2 - 1 \\
 &= a - \left(\sum_{d=1}^D x_d^2 + 1 \right) < a
 \end{aligned}$$

Thus, the new activation is always at least the old activation minus one. Since this was a negative example, we have successfully moved the activation in the proper direction.

Let's modify section 4.5's convergence proof in the textbook to find the bound if x has a norm of at most R instead of 1. In the perceptron convergence proof, the use of the assumption that

all x have a norm of at most 1 is done by going from line 4.14 to line 4.15. This becomes with the new assumption:

$$\|w^{(k)}\|^2 = \|w^{(k-1)} + yx\|^2 \quad \text{def. of } w^{(k)} \text{ (4.13)}$$

$$= \|w^{(k-1)}\|^2 + y^2 \|x\|^2 + 2yw^{(k-1)}.x \quad \text{quadratic rule (4.14)}$$

$$\leq \|w^{(k-1)}\|^2 + R^2 + 0 \quad \text{assumption and } a < 0 \text{ (4.15)}$$

Thus, the squared norm of $w^{(k)}$ increases by at most R^2 every update. Therefore: $\|w^{(k)}\|^2 \leq kR^2$.

Now putting this together with the fact that $w^*.w^{(k)} \geq k\gamma$ and because w^* being a unit vector implies $\|w^{(k)}\| \geq w^*.w^{(k)}$, we have for $\gamma > 0$:

$$R\sqrt{k} \geq \|w^{(k)}\| \geq w^*.w^{(k)} \geq k\gamma \Rightarrow R^2k \geq k^2\gamma^2 \Rightarrow \frac{R^2}{\gamma^2} \geq k$$

The bound is then $k \leq \frac{R^2}{\gamma^2}$.