Problem3

May 14, 2018

1 Load Data

```
In [1]: import copy
        import numpy as np
        import pandas as pd
        import matplotlib.pyplot as plt
        from sklearn import preprocessing

        # load iris_train.data and iris_test.data
        pd_train = pd.read_csv("iris/iris_train.data", names=["sepal_length", "sepal_width", "
        pd_test = pd.read_csv("iris/iris_test.data", names=["sepal_length", "sepal_width", "pe

        # parse the features and labels as numpy arrays.
        X_train = pd_train.as_matrix(columns=["sepal_length", "sepal_width", "petal_length", "
        y_train = pd_train.as_matrix(columns=["label"]).ravel()
        X_test = pd_test.as_matrix(columns=["sepal_length", "sepal_width", "petal_length", "pe
        y_test = pd_test.as_matrix(columns=["label"]).ravel()

        # Encode labels
        le = preprocessing.LabelEncoder()
        le.fit(y_train)
        print(le.classes_)
        y_train = le.transform(y_train)
        y_test = le.transform(y_test)
```

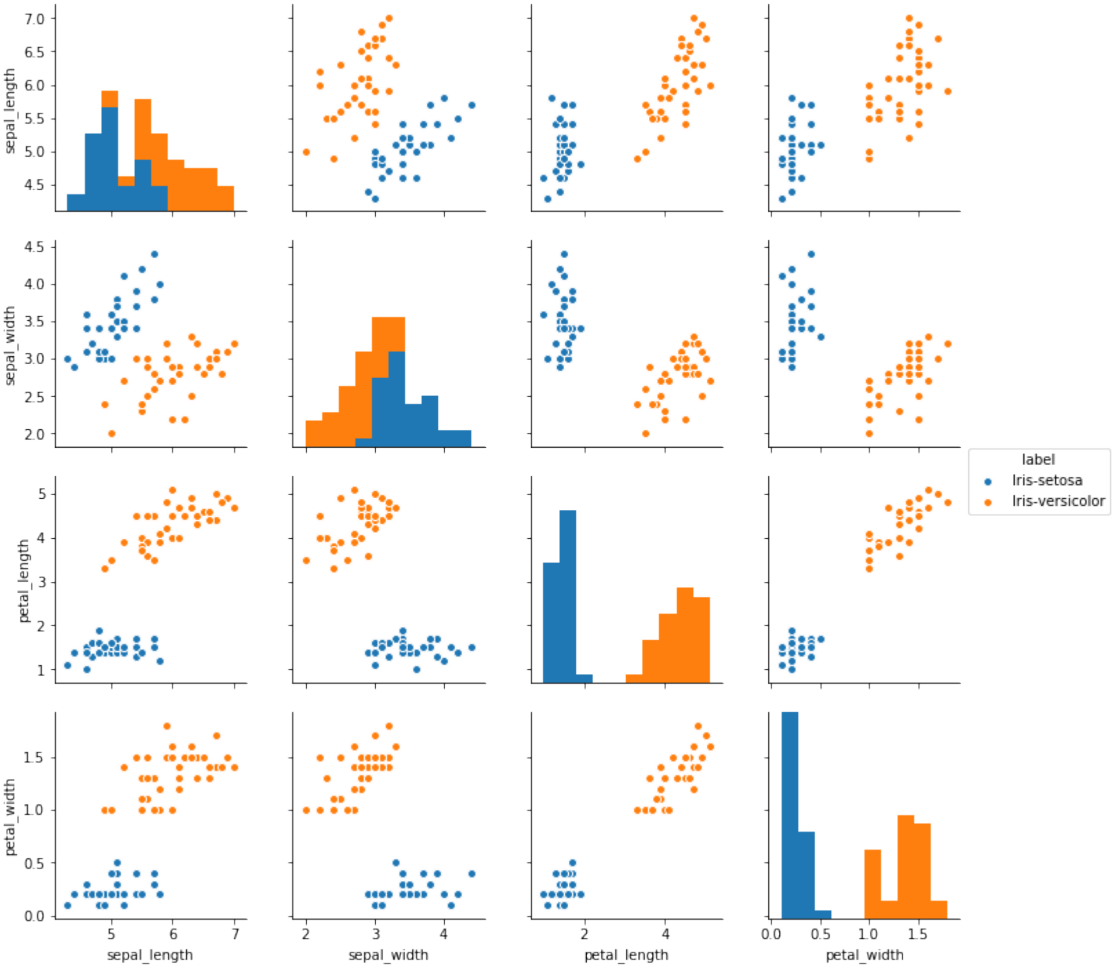
```
['Iris-setosa' 'Iris-versicolor']
```

```
In [2]: saved_y_train = copy.deepcopy(y_train)
        saved_y_test = copy.deepcopy(y_test)
```

2 Pre-Analysis Dataset

```
In [3]: from seaborn import pairplot
        pairplot(pd_train,hue="label")
```

```
Out[3]: <seaborn.axisgrid.PairGrid at 0x27110ed7828>
```



3 Training Programming

```
In [4]: MAX_ITERATION = 100000
        LEARNING_RATE = 1e-3
```

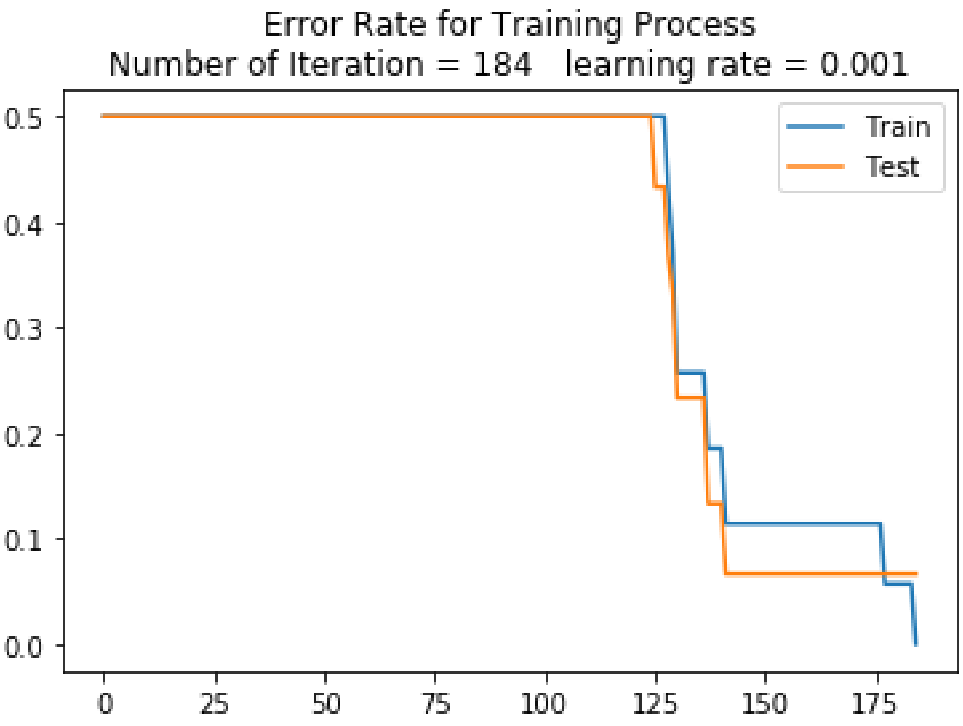
```
In [5]: np.random.seed(233)

        W = np.random.random((1,4))
        b = np.random.random(1)
        y_train = (copy.deepcopy(saved_y_train) - 0.5)*2
        y_test = (copy.deepcopy(saved_y_test) - 0.5)*2
        train_accuracy_list = []
        test_accuracy_list = []

        for count in range(MAX_ITERATION):
            #Check Accuracy
            train_correct = np.sum(np.sign(X_train.dot(W.T) + b) == y_train.reshape(len(X_trai
            test_correct = np.sum(np.sign(X_test.dot(W.T) + b) == y_test.reshape(len(X_test),1
            train_accuracy_list.append(train_correct/len(X_train))
            test_accuracy_list.append(test_correct/len(X_test))
            print("Epoch = "+str(count)+"\tTrain Accuracy = "+
                str(train_correct/len(X_train))+"\tTest Accuracy = "+
                str(test_correct/len(X_test)))
            if train_correct == len(X_train): break
            #Train
            random_id = np.random.randint(0,len(X_train))
            X_tmp = X_train[random_id]
            y_tmp = y_train[random_id]
            prediction =  X_tmp.dot(W.T) + b
            pred_label = 1 if (prediction>=0) else -1
            if prediction!=y_tmp:
                W += LEARNING_RATE*(y_tmp-pred_label)*X_tmp
                b += LEARNING_RATE*(y_tmp-pred_label)
```

```
Epoch = 0        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 1        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 2        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 3        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 4        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 5        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 6        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 7        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 8        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 9        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 10        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 11        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 12        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 13        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 14        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 15        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 16        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 17        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 18        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 19        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 20        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 21        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 22        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 23        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 24        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 25        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 26        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 27        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 28        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 29        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 30        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 31        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 32        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 33        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 34        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 35        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 36        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 37        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 38        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 39        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 40        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 41        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 42        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 43        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 44        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 45        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 46        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 47        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 48        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 49        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 50        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 51        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 52        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 53        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 54        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 55        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 56        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 57        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 58        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 59        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 60        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 61        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 62        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 63        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 64        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 65        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 66        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 67        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 68        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 69        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 70        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 71        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 72        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 73        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 74        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 75        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 76        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 77        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 78        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 79        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 80        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 81        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 82        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 83        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 84        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 85        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 86        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 87        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 88        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 89        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 90        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 91        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 92        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 93        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 94        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 95        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 96        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 97        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 98        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 99        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 100        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 101        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 102        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 103        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 104        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 105        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 106        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 107        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 108        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 109        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 110        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 111        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 112        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 113        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 114        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 115        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 116        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 117        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 118        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 119        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 120        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 121        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 122        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 123        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 124        Train Accuracy = 0.5        Test Accuracy = 0.5
Epoch = 125        Train Accuracy = 0.5        Test Accuracy = 0.5666666666666667
Epoch = 126        Train Accuracy = 0.5       Test Accuracy = 0.5666666666666667
Epoch = 127        Train Accuracy = 0.5       Test Accuracy = 0.5666666666666667
Epoch = 128        Train Accuracy = 0.5714285714285714        Test Accuracy = 0.63333333333333
Epoch = 129        Train Accuracy = 0.6285714285714286        Test Accuracy = 0.66666666666666
Epoch = 130        Train Accuracy = 0.7428571428571429        Test Accuracy = 0.76666666666666
Epoch = 131        Train Accuracy = 0.7428571428571429        Test Accuracy = 0.76666666666666
Epoch = 132        Train Accuracy = 0.7428571428571429        Test Accuracy = 0.76666666666666
Epoch = 133        Train Accuracy = 0.7428571428571429        Test Accuracy = 0.76666666666666
Epoch = 134        Train Accuracy = 0.7428571428571429        Test Accuracy = 0.76666666666666
Epoch = 135        Train Accuracy = 0.7428571428571429        Test Accuracy = 0.76666666666666
Epoch = 136        Train Accuracy = 0.7428571428571429        Test Accuracy = 0.76666666666666
Epoch = 137        Train Accuracy = 0.8142857142857143        Test Accuracy = 0.86666666666666
Epoch = 138        Train Accuracy = 0.8142857142857143        Test Accuracy = 0.86666666666666
Epoch = 139        Train Accuracy = 0.8142857142857143        Test Accuracy = 0.86666666666666
Epoch = 140        Train Accuracy = 0.8142857142857143        Test Accuracy = 0.86666666666666
Epoch = 141        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 142        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 143        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 144        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 145        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 146        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 147        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 148        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 149        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 150        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 151        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 152        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 153        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 154        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 155        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 156        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 157        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 158        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 159        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 160        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 161        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 162        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 163        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 164        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 165        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 166        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 167        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 168        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 169        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 170        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 171        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 172        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 173        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.93333333333333
Epoch = 174        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.933333333333333
Epoch = 175        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.933333333333333
Epoch = 176        Train Accuracy = 0.8857142857142857        Test Accuracy = 0.933333333333333
Epoch = 177        Train Accuracy = 0.9428571428571428        Test Accuracy = 0.933333333333333
Epoch = 178        Train Accuracy = 0.9428571428571428        Test Accuracy = 0.933333333333333
Epoch = 179        Train Accuracy = 0.9428571428571428        Test Accuracy = 0.933333333333333
Epoch = 180        Train Accuracy = 0.9428571428571428        Test Accuracy = 0.933333333333333
Epoch = 181        Train Accuracy = 0.9428571428571428        Test Accuracy = 0.933333333333333
Epoch = 182        Train Accuracy = 0.9428571428571428        Test Accuracy = 0.933333333333333
Epoch = 183        Train Accuracy = 0.9428571428571428        Test Accuracy = 0.933333333333333
Epoch = 184        Train Accuracy = 1.0        Test Accuracy = 0.9333333333333333
```

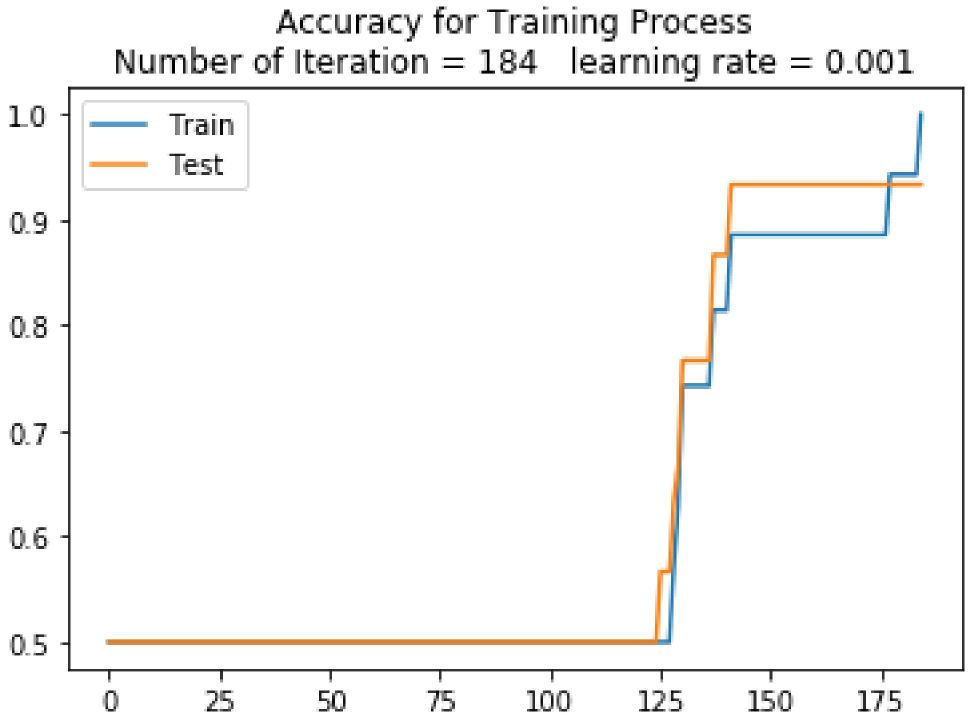
4 Plot

```
In [6]: train_error = [1-a for a in train_accuracy_list]
        test_error = [1-a for a in test_accuracy_list]
```

```
In [7]: plt.plot(train_error)
        plt.plot(test_error)
        plt.title("Error Rate for Training Process\nNumber of Iteration = "+
                  str(count)+"   learning rate = "+str(LEARNING_RATE))
        plt.legend(["Train","Test"])
        plt.show()
```



```
In [8]: plt.plot(train_accuracy_list)
        plt.plot(test_accuracy_list)
        plt.title("Accuracy for Training Process\nNumber of Iteration = "+
                  str(count)+"   learning rate = "+str(LEARNING_RATE))
        plt.legend(["Train","Test"])
        plt.show()
```



```
In [9]: W

Out[9]: array([[-0.54073087,  0.4174156 ,  0.38216564,  0.86654018]])

In [10]: b

Out[10]: array([0.21290549])

In [11]: TP = 0
         FP = 0
         TN = 0
         FN = 0
         for pred, label in  zip(np.sign(X_test.dot(W.T) + b),y_test):
             if pred==1 and label==1: TP+=1
             if pred==1 and label==-1: FP+=1
             if pred==-1 and label==-1: TN+=1
             if pred==-1 and label==1: FN+=1
         Accuracy = (TP+TN)/(TP+FP+TN+FN)
         Precision = TP/(TP+FP)
         Recall = TP/(TP+FN)
         F_value = (2*Precision*Recall) / (Precision+Recall)
         print("Accuracy = "+str(Accuracy)+"\tPrecision = "+str(Precision)+
               "\nRecall = "+str(Recall)+"\tF_value = "+str(F_value))
```

```
Accuracy = 0.9333333333333333        Precision = 0.8823529411764706
Recall = 1.0        F_value = 0.9375
```

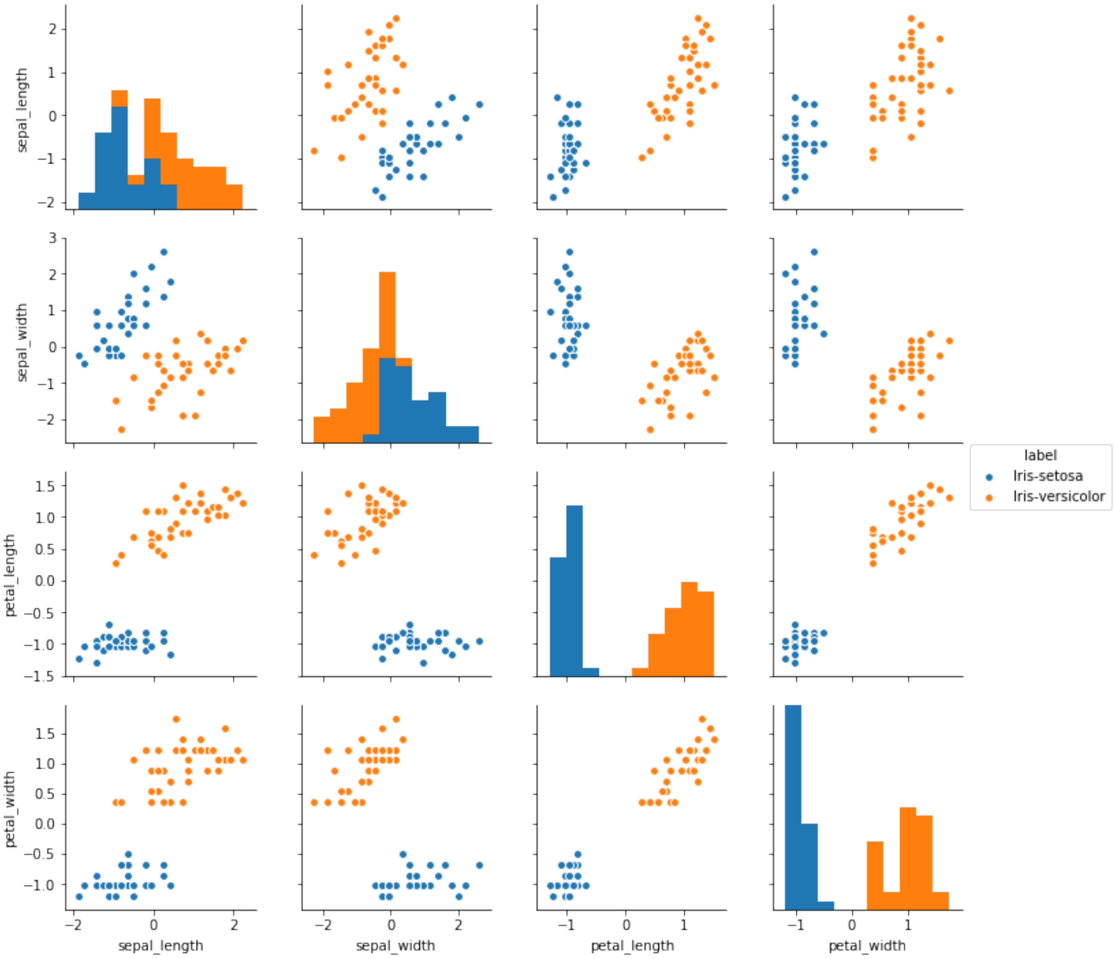
5 Z-score

```
In [12]: X_train_z_score = (X_train-np.mean(X_train,axis=0))/np.std(X_train,axis=0)
         X_test_z_score = (X_test-np.mean(X_train,axis=0))/np.std(X_train,axis=0)
         y_train_z_score = pd_train.as_matrix(columns=["label"])
         y_test_z_score = pd_test.as_matrix(columns=["label"])
```

```
In [13]: pd_train_z_score = pd.DataFrame(np.hstack((X_train_z_score,y_train_z_score.reshape(len
         pd_test_z_score = pd.DataFrame(np.hstack((X_test_z_score,y_test_z_score.reshape(len(X_
```

```
In [14]: pairplot(pd_train_z_score,hue="label")
```

```
Out[14]: <seaborn.axisgrid.PairGrid at 0x27114e7b518>
```



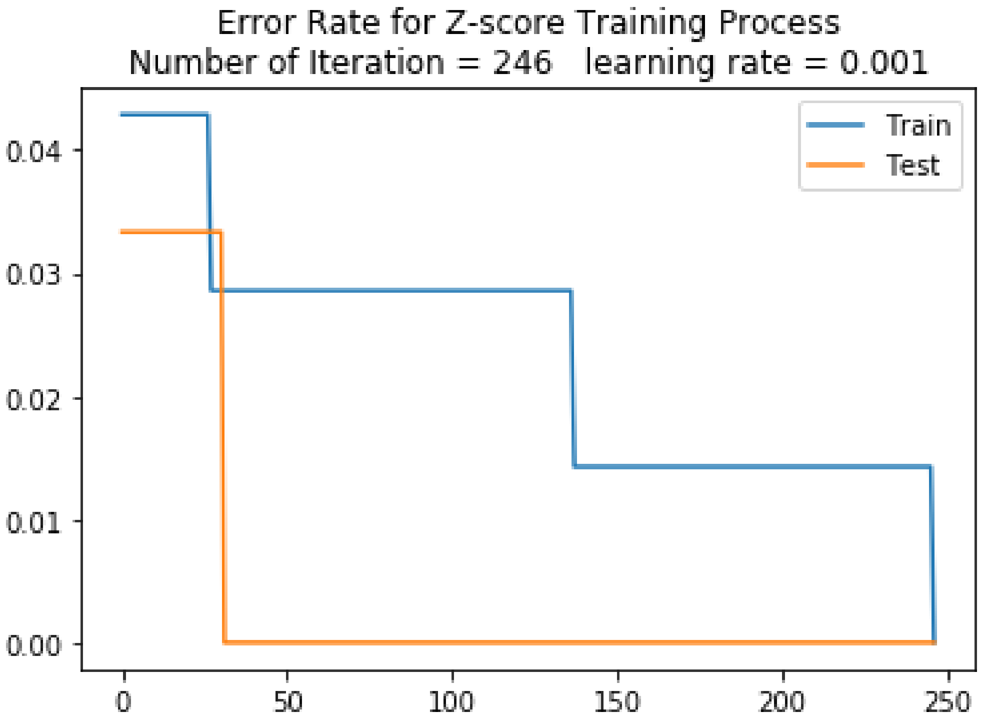
6 Z-score Training

```
In [34]: MAX_ITERATION = 100000
         LEARNING_RATE = 1e-3

In [35]: np.random.seed(233333)

         W = np.random.random((1,4))
         b = np.random.random(1)
         y_train = (copy.deepcopy(saved_y_train) - 0.5)*2
         y_test = (copy.deepcopy(saved_y_test) - 0.5)*2
         train_accuracy_list = []
         test_accuracy_list = []

         for count in range(MAX_ITERATION):
             #Check Accuracy
             train_correct = np.sum(np.sign(X_train_z_score.dot(W.T) + b) == y_train.reshape(le
             test_correct = np.sum(np.sign(X_test_z_score.dot(W.T) + b) == y_test.reshape(len(
             train_accuracy_list.append(train_correct/len(X_train_z_score))
             test_accuracy_list.append(test_correct/len(X_test_z_score))
             print("Epoch = "+str(count)+"\tTrain Accuracy = "+
                 str(train_correct/len(X_train_z_score))+"\tTest Accuracy = "+
                 str(test_correct/len(X_test_z_score)))
             if train_correct == len(X_train_z_score): break
             #Train
             random_id = np.random.randint(0,len(X_train_z_score))
             X_tmp = X_train_z_score[random_id]
             y_tmp = y_train[random_id]
             prediction =  X_tmp.dot(W.T) + b
             pred_label = 1 if (prediction>=0) else -1
             if prediction!=y_tmp:
                 W += LEARNING_RATE*(y_tmp-pred_label)*X_tmp
                 b += LEARNING_RATE*(y_tmp-pred_label)
```

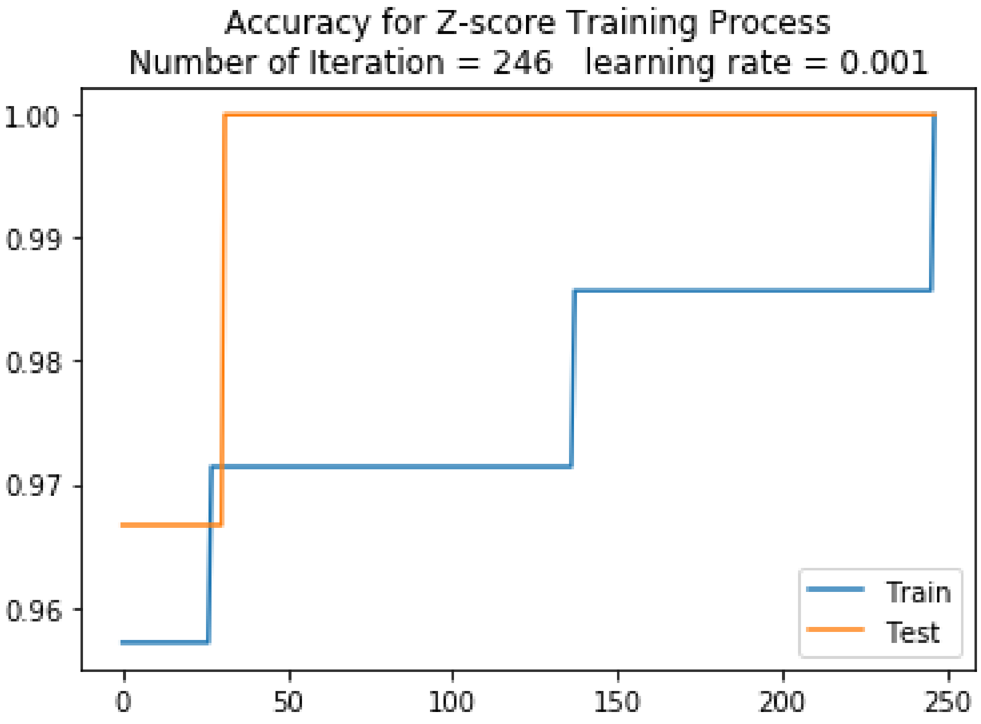
```
Epoch = 0        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.9666666666666667
Epoch = 1        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.9666666666666667
Epoch = 2        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.9666666666666667
Epoch = 3        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.9666666666666667
Epoch = 4        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.9666666666666667
Epoch = 5        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.9666666666666667
Epoch = 6        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.9666666666666667
Epoch = 7        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.9666666666666667
Epoch = 8        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.9666666666666667
Epoch = 9        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.9666666666666667
Epoch = 10        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 11        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 12        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 13        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 14        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 15        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 16        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 17        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 18        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 19        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 20        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 21        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 22        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 23        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 24        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 25        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 26        Train Accuracy = 0.9571428571428572        Test Accuracy = 0.966666666666666
Epoch = 27        Train Accuracy = 0.9714285714285714        Test Accuracy = 0.966666666666666
Epoch = 28        Train Accuracy = 0.9714285714285714        Test Accuracy = 0.966666666666666
Epoch = 29        Train Accuracy = 0.9714285714285714        Test Accuracy = 0.966666666666666
Epoch = 30        Train Accuracy = 0.9714285714285714        Test Accuracy = 0.966666666666666
Epoch = 31        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 32        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 33        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 34        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 35        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 36        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 37        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 38        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 39        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 40        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 41        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 42        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 43        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 44        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 45        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 46        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 47        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 48        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 49        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 50        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 51        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 52        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 53        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 54        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 55        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 56        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 57        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 58        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 59        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 60        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 61        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 62        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 63        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 64        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 65        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 66        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 67        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 68        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 69        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 70        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 71        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 72        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 73        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 74        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 75        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 76        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 77        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 78        Train Accuracy = 0.9714285714285714       Test Accuracy = 1.0
Epoch = 79        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 80        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 81        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 82        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 83        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 84        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 85        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 86        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 87        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 88        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 89        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 90        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 91        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 92        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 93        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 94        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 95        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 96        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 97        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 98        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 99        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 100        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 101        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 102        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 103        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 104        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 105        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 106        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 107        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 108        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 109        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 110        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 111        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 112        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 113        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 114        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 115        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 116        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 117        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 118        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 119        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 120        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 121        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 122        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 123        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 124        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 125        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 126        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 127        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 128        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 129        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 130        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 131        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 132        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 133        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 134        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 135        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 136        Train Accuracy = 0.9714285714285714        Test Accuracy = 1.0
Epoch = 137        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 138        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 139        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 140        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 141        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 142        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 143        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 144        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 145        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 146        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 147        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 148        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 149        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 150        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 151        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 152        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 153        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 154        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 155        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 156        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 157        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 158        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 159        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 160        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 161        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 162        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 163        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 164        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 165        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 166        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 167        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 168        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 169        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 170        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 171        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 172        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 173        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 174        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 175        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 176        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 177        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 178        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 179        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 180        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 181        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 182        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 183        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 184        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 185        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 186        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 187        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 188        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 189        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 190        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 191        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 192        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 193        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 194        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 195        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 196        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 197        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 198        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 199        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 200        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 201        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 202        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 203        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 204        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 205        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 206        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 207        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 208        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 209        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 210        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 211        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 212        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 213        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 214        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 215        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 216        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 217        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 218        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 219        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 220        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 221        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 222        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 223        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 224        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 225        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 226        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 227        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 228        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 229        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 230        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 231        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 232        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 233        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 234        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 235        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 236        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 237        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 238        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 239        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 240        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 241        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 242        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 243        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 244        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 245        Train Accuracy = 0.9857142857142858        Test Accuracy = 1.0
Epoch = 246        Train Accuracy = 1.0        Test Accuracy = 1.0
```

```
In [36]: train_error = [1-a for a in train_accuracy_list]
         test_error = [1-a for a in test_accuracy_list]
```

```
In [37]: plt.plot(train_error)
         plt.plot(test_error)
         plt.title("Error Rate for Z-score Training Process\nNumber of Iteration = "+
                   str(count)+"   learning rate = "+str(LEARNING_RATE))
         plt.legend(["Train","Test"])
         plt.show()
```



```
In [38]: plt.plot(train_accuracy_list)
         plt.plot(test_accuracy_list)
         plt.title("Accuracy for Z-score Training Process\nNumber of Iteration = "+
                   str(count)+"   learning rate = "+str(LEARNING_RATE))
         plt.legend(["Train","Test"])
         plt.show()
```



```
In [39]: W

Out[39]: array([[0.30657108, 0.25808087, 0.6521715 , 0.70696151]])

In [40]: b

Out[40]: array([0.31247015])

In [41]: TP = 0
         FP = 0
         TN = 0
         FN = 0
         for pred, label in  zip(np.sign(X_test_z_score.dot(W.T) + b),y_test):
             if pred==1 and label==1: TP+=1
             if pred==1 and label==-1: FP+=1
             if pred==-1 and label==-1: TN+=1
             if pred==-1 and label==1: FN+=1

         Accuracy = (TP+TN)/(TP+FP+TN+FN)
         Precision = TP/(TP+FP)
         Recall = TP/(TP+FN)
         F_value = (2*Precision*Recall) / (Precision+Recall)
         print("Accuracy = "+str(Accuracy)+"\tPrecision = "+str(Precision)+
               "\nRecall = "+str(Recall)+"\tF_value = "+str(F_value))
```

```
Accuracy = 1.0        Precision = 1.0
Recall = 1.0        F_value = 1.0
```