Assignment09

November 29, 2018

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2 2018210031

3 Assignment 09

Github Link: https://github.com/farhan-93/assignment09.git ## Binary- Least Square Classification on MNIST data by random vectors Classifies digit 0 among digit 1-9

Import required libraries for the work.

```
In [1]: import numpy as np
        import matplotlib.pyplot as plt
        import sklearn.metrics as metrics
```

Below function will load training and testing data from CSV files available

```
In [2]: def data_load():
            file_data_train = "mnist_train.csv"
            file_data_test  = "mnist_test.csv"

            h_data_train    = open(file_data_train, "r")
            h_data_test     = open(file_data_test, "r")

            data_train      = h_data_train.readlines()
            data_test       = h_data_test.readlines()

            h_data_train.close()
            h_data_test.close()

            size_row    = 28    # height of the image
            size_col    = 28    # width of the image

            num_train   = len(data_train)    # number of training images
            num_test    = len(data_test)     # number of testing images

            #
            # normalize the values of the input data to be [0, 1]
```

```
#
def normalize(data):

    data_normalized = (data - min(data)) / (max(data) - min(data))

    return(data_normalized)

#
# example of distance function between two vectors x and y
#
def distance(x, y):

    d = (x - y) ** 2
    s = np.sum(d)
    # r = np.sqrt(s)

    return(s)

#
# make a matrix each column of which represents an images in a vector form
#
list_image_train    = np.empty((size_row * size_col, num_train), dtype=float)
list_label_train    = np.empty(num_train, dtype=int)

list_image_test     = np.empty((size_row * size_col, num_test), dtype=float)
list_label_test     = np.empty(num_test, dtype=int)

count = 0

for line in data_train:

    line_data   = line.split(',')
    label       = line_data[0]
    im_vector   = np.asfarray(line_data[1:])
    im_vector   = normalize(im_vector)

    list_label_train[count]     = label
    list_image_train[:, count]  = im_vector

    count += 1

count = 0

for line in data_test:

    line_data   = line.split(',')
    label       = line_data[0]
    im_vector   = np.asfarray(line_data[1:])
    im_vector   = normalize(im_vector)

    list_label_test[count]      = label
    list_image_test[:, count]   = im_vector

    count += 1

#
# plot first 150 images out of 10,000 with their labels
#
f1 = plt.figure(1)

for i in range(150):

    label       = list_label_train[i]
    im_vector   = list_image_train[:, i]
    im_matrix   = im_vector.reshape((size_row, size_col))

    plt.subplot(10, 15, i+1)
    plt.title(label)
    plt.imshow(im_matrix, cmap='Greys', interpolation='None')

    frame   = plt.gca()
    frame.axes.get_xaxis().set_visible(False)
    frame.axes.get_yaxis().set_visible(False)

#plt.show()

#
# plot the average image of all the images for each digit
#
f2 = plt.figure(2)

im_average  = np.zeros((size_row * size_col, 10), dtype=float)
im_count    = np.zeros(10, dtype=int)

for i in range(num_train):

    im_average[:, list_label_train[i]] += list_image_train[:, i]
    im_count[list_label_train[i]] += 1

for i in range(10):

    im_average[:, i] /= im_count[i]

    plt.subplot(2, 5, i+1)
    plt.title(i)
    plt.imshow(im_average[:,i].reshape((size_row, size_col)), cmap='Greys', interpo
    frame    = plt.gca()
    frame.axes.get_xaxis().set_visible(False)
    frame.axes.get_yaxis().set_visible(False)

plt.show()
return list_image_train.T, list_label_train, list_image_test.T, list_label_test
```

Function performs least square fitting with random generated vectors. And returns the model parameters.

```
In [3]: def leastSquarefit(r,x,p,y):
            #indices = np.random.choice(np.arange(r.size), replace=False, size=int(p*0.36))
            #r[indices]=0
            A=np.dot(r[0],x.T)

            for i in range(1,len(r)):
                f=np.dot(r[i],x.T)
                A = np.c_[A,f]

            theta=np.empty([0, 784])
            theta=np.linalg.inv(A.T.dot(A)).dot(A.T).dot(y)
            return theta
```

Below function performms the binary classification by trained model parameters and returns the predicted labels

```
In [4]: def predict(model, X,a):
            ''' From model and data points, output prediction vectors '''
            #print(X.shape)
            results = np.zeros(X.shape[0])
            #results1 = np.zeros(X.shape[0])
            for i in range(X.shape[0]):
                results[i] = np.sign((np.dot(model.T, X[i].T))-a)

            return results
```

Below function Calculates the tp,FP,FN and TN. Aso calculate the Accuracy, Recall and F1 Scores

```
In [5]: def evaluation_metrics(pred,labels):
            #pred= predict(t, X_train)
            TP=0
            for j in range(len(labels)):
                if labels[j]==1 and pred[j]==1:
                    TP+=1
            print("TP = ", TP)
            FN=0
            for j in range(len(labels)):
                if labels[j]==1 and pred[j]==-1:
                    FN+=1
            print("FN = ", FN)
            FP=0
            for j in range(len(labels)):
                if labels[j]!=1 and pred[j]==1:
                    FP+=1
            print("FP = ", FP)
            TN=0
            for j in range(len(labels)):
                if labels[j]!=1 and pred[j]==-1:
                    TN+=1
            print("TN = ", TN)
            Accuracy = (TP + TN) / (TP + TN + FP + FN)
            print("Accuracy = ", Accuracy)
            recall = TP/(TP+FN)
            print("Recall = ", recall)
            Precision = TP / (TP+FP)
            print("Precision = ", Precision)
            F1= 2*((Precision * recall)/(Precision + recall))
            print("F1 Score = ", F1)
            return F1,TP,FN,FP,TN
```

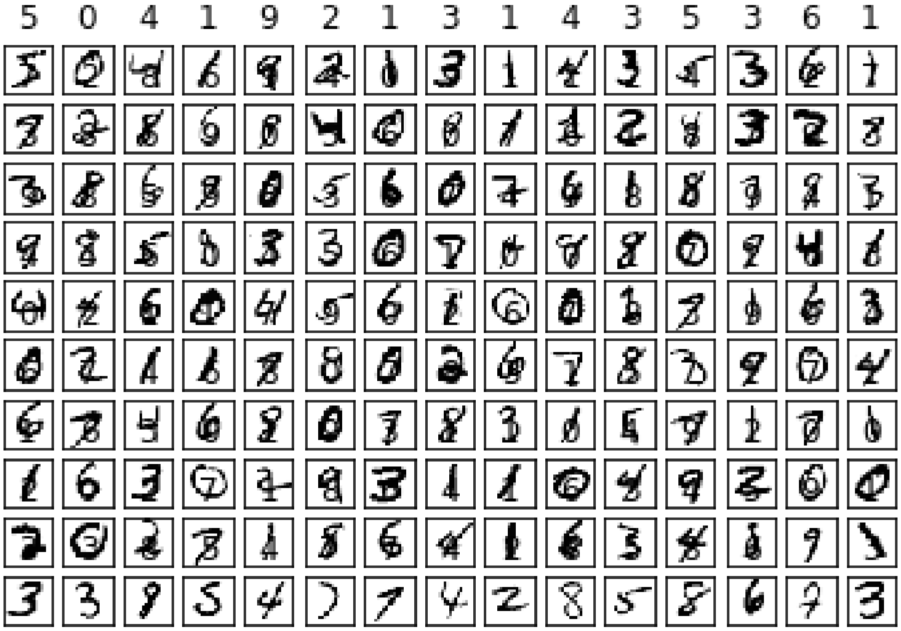
Below function predict the training and testing data with different numbers of model parameters by setting them to zero.

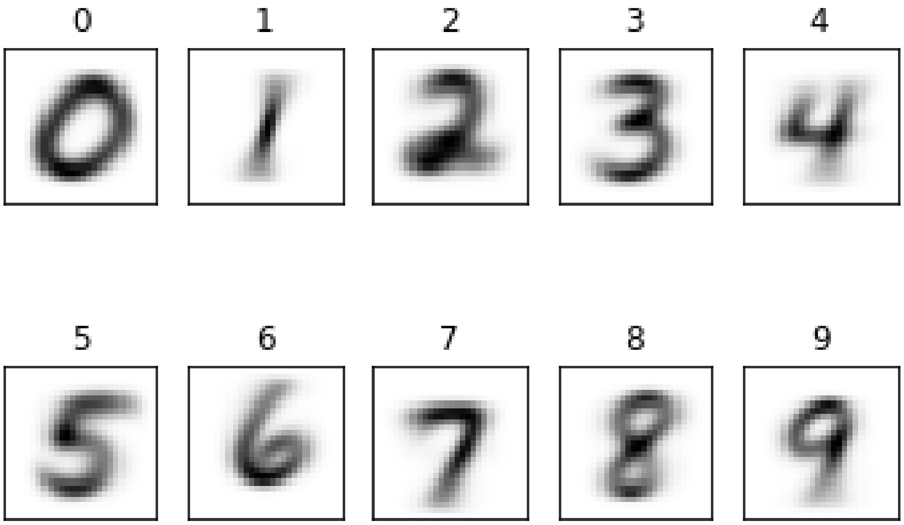
```
In [6]: def diff_p():
            f_train=[]
            f_test=[]
            i=0
            while i<=0.9:
                ##### Makes copy of model parameters
                tt=np.copy(t)
                ##### randomly choice the indices with percentage i
                indices = np.random.choice(np.arange(tt.size), replace=False, size=int(tt.size
                ##### set indices value to zero
                tt[indices] = 0

                print("Training Set Evaluation With paramenters set to zero randomy: ", i*100)
                pred= predict(tt, X_train,0)
                #print(labels_trian)
                f1_t,TP,FN,FP,TN=evaluation_metrics(pred,labels_trian)



                acc=metrics.accuracy_score(labels_trian1,  pred)
                print(acc)
                fpr, tpr, _ = metrics.roc_curve(labels_trian1,  pred)
                auc = metrics.roc_auc_score(labels_trian1, pred)
                plt.figure(i)
                plt.plot(fpr,tpr,label="data 1, auc="+str(auc))
                plt.legend(loc=4)
                plt.show()
                f_train=np.append(f_train,f1_t)
                print("=============")

                print("Testing Set Evaluation With paramenters set to zero randomy in percent:
                pred_test= predict(tt, X_test,0.25)
                f1_tt,TP_t,FN_t,FP_t,TN_t=evaluation_metrics(pred_test,labels_test1)
                acc=metrics.accuracy_score(labels_test1,  pred_test)
                print(acc)
                fpr, tpr, _ = metrics.roc_curve(labels_test1,  pred_test)

                auc = metrics.roc_auc_score(labels_test1, pred_test)
                plt.figure(i*2)
                plt.plot(fpr,tpr,label="data 1, auc="+str(auc))
                plt.legend(loc=4)
                plt.show()
                f_test=np.append(f_test,f1_tt)
                print("======================================================================")
                i+=0.10
            return f_train, f_test
```

This is the main function and execution starts here

```
In [7]: if __name__ == "__main__":
            X_train, labels_trian, X_test, labels_test=data_load()
            #print("Hello")
            mean = 0
            std = 1
            p= 494
            r=np.random.normal(mean, std, (784,784))
            t=leastSquarefit(r,X_train,p,labels_trian)

            #### Convert labels of training data in 1 and -1. (1 for digit zero and -1 for non
            labels_trian1 = labels_trian
            for j in range(len(labels_trian1)):
                if labels_trian1[j] <=0:
                    labels_trian1[j]=1
                else:
                    labels_trian1[j]=-1
            #### Convert labels of testing data in 1 and -1. (1 for digit zero and -1 for non
            labels_test1 = labels_test
            for j in range(len(labels_test1)):
                if labels_test1[j] <=0:
```

```
        labels_test1[j]=1
    else:
        labels_test1[j]=-1
```





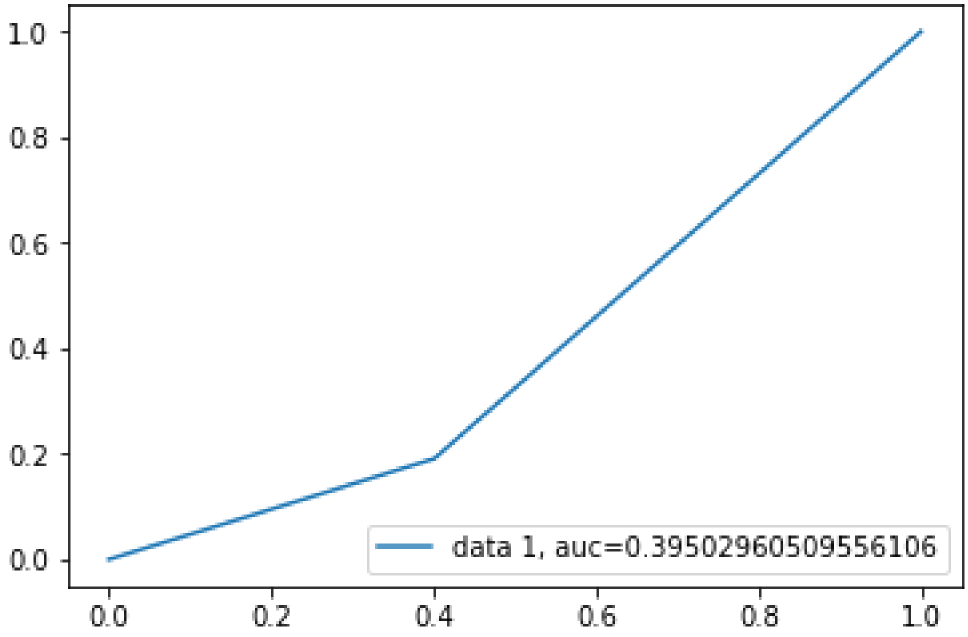
In [8]:
```
#### predict the training data with all 784 parameters
pred= predict(t, X_train,0)
```

```
print("Training Set Evaluation With paramenters 784")
f_t,TP,FN,FP,TN =evaluation_metrics(pred,labels_trian1)
#### predict the testing data with all 784 parameters
pred_test= predict(t, X_test,0)
print("Training Set Evaluation With paramenters 784")
f_tt,TP_t,FN_t,FP_t,TN_t=evaluation_metrics(pred_test,labels_test1)
```

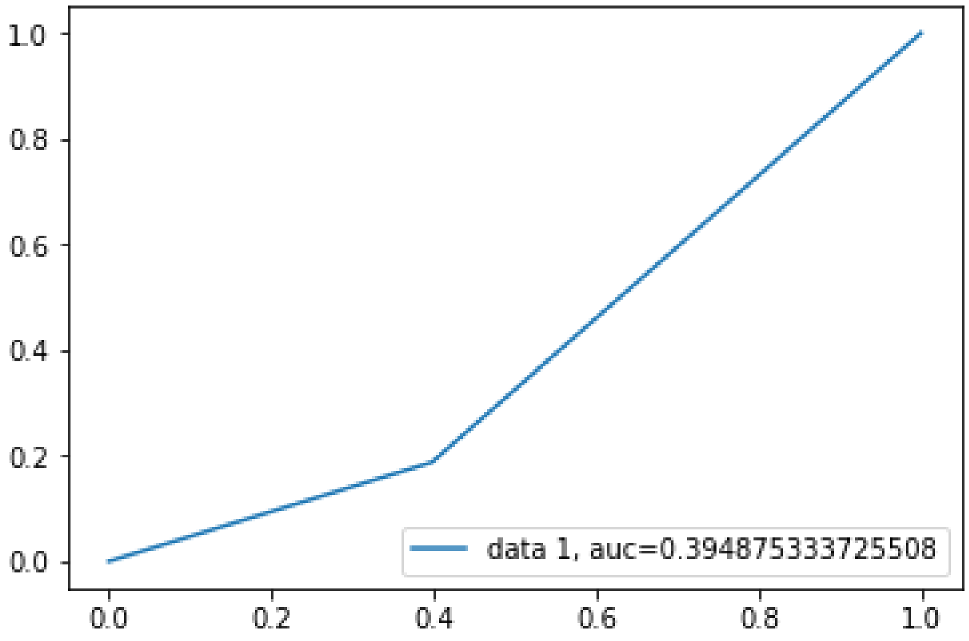
```
Training Set Evaluation With paramenters 784
TP =  1131
FN =  4792
FP =  21679
TN =  32398
Accuracy =  0.5588166666666666
Recall =  0.19095053182508864
Precision =  0.04958351600175362
F1 Score =  0.07872481119270525
Training Set Evaluation With paramenters 784
TP =  185
FN =  795
FP =  3594
TN =  5426
Accuracy =  0.5611
Recall =  0.18877551020408162
Precision =  0.04895474993384493
F1 Score =  0.07774742592981719
```

```
In [16]:  #### Below function predict the training and testing data with different
          #### numbers of model parameters by setting them to zero.
          f_train, f_test= diff_p()
```

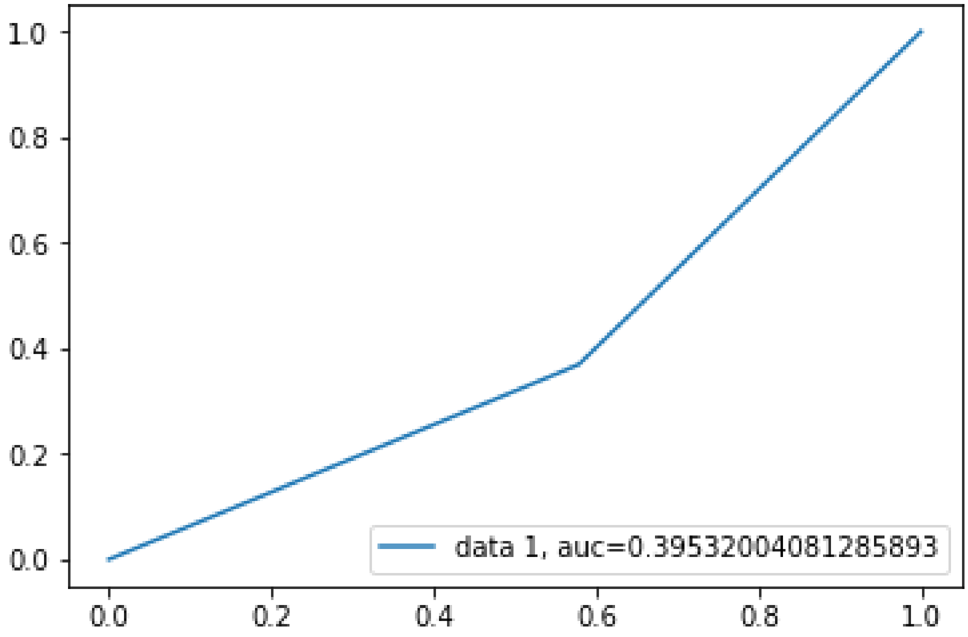
```
Training Set Evaluation With paramenters set to zero randomy:  0
TP =  1131
FN =  4792
FP =  21679
TN =  32398
Accuracy =  0.5588166666666666
Recall =  0.19095053182508864
Precision =  0.04958351600175362
F1 Score =  0.07872481119270525
0.5588166666666666
```



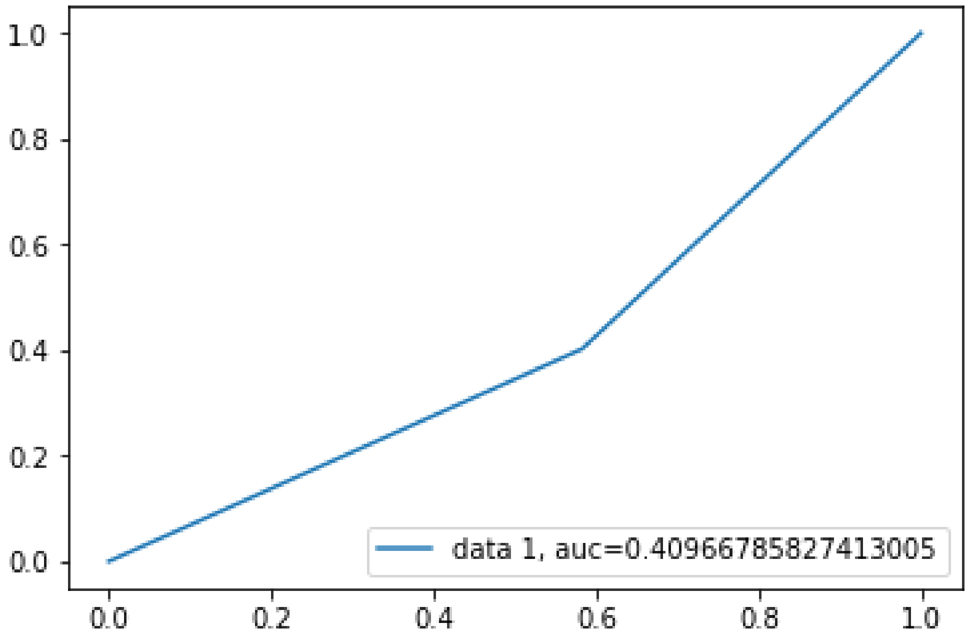
```
=============
Testing Set Evaluation With paramenters set to zero randomy in percent:  0
TP =  184
FN =  796
FP =  3590
TN =  5430
Accuracy =  0.5614
Recall =  0.18775510204081633
Precision =  0.048754636989931106
F1 Score =  0.07740849810685739
0.5614
```



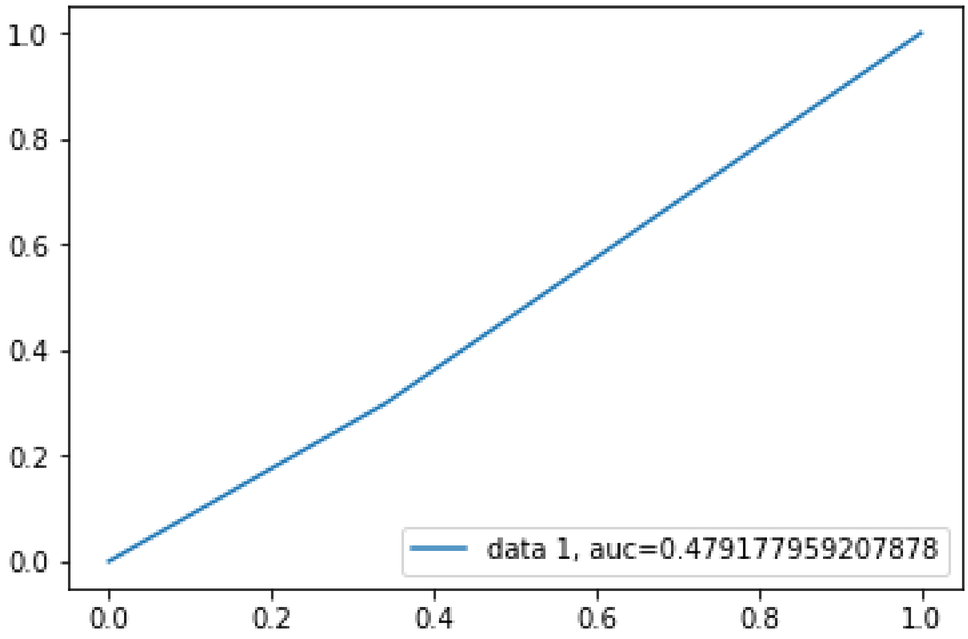
```
======================================================================
Training Set Evaluation With paramenters set to zero randomy:  10.0
TP =  2188
FN =  3735
FP =  31298
TN =  22779
Accuracy =  0.4161166666666667
Recall =  0.3694073949012325
Precision =  0.06534073941348623
F1 Score =  0.11104062523788982
0.4161166666666667
```



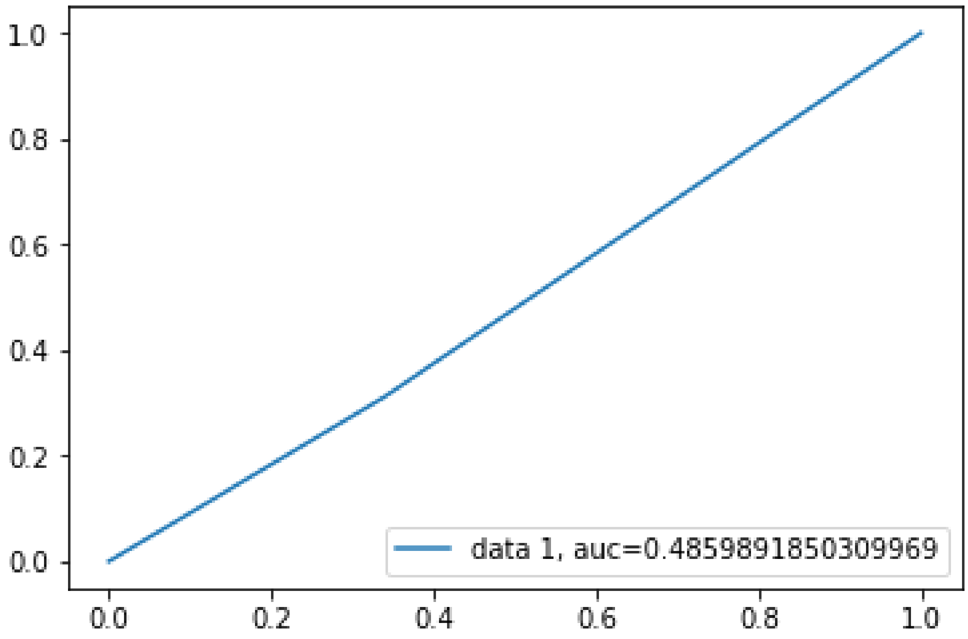
```
=============
Testing Set Evaluation With paramenters set to zero randomy in percent:  10.0
TP =  394
FN =  586
FP =  5256
TN =  3764
Accuracy =  0.4158
Recall =  0.4020408163265306
Precision =  0.06973451327433629
F1 Score =  0.11885369532428357
0.4158
```



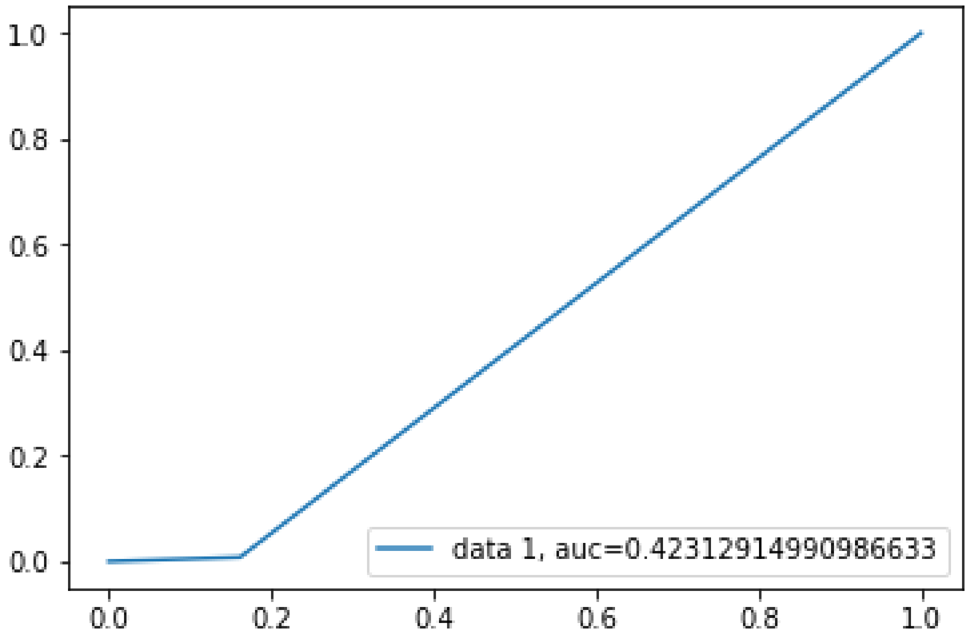
```
======================================================================
Training Set Evaluation With paramenters set to zero randomy:  20.0
TP =  1777
FN =  4146
FP =  18476
TN =  35601
Accuracy =  0.6229666666666667
Recall =  0.30001688333614723
Precision =  0.0877400878882141
F1 Score =  0.13577322738386308
0.6229666666666667
```



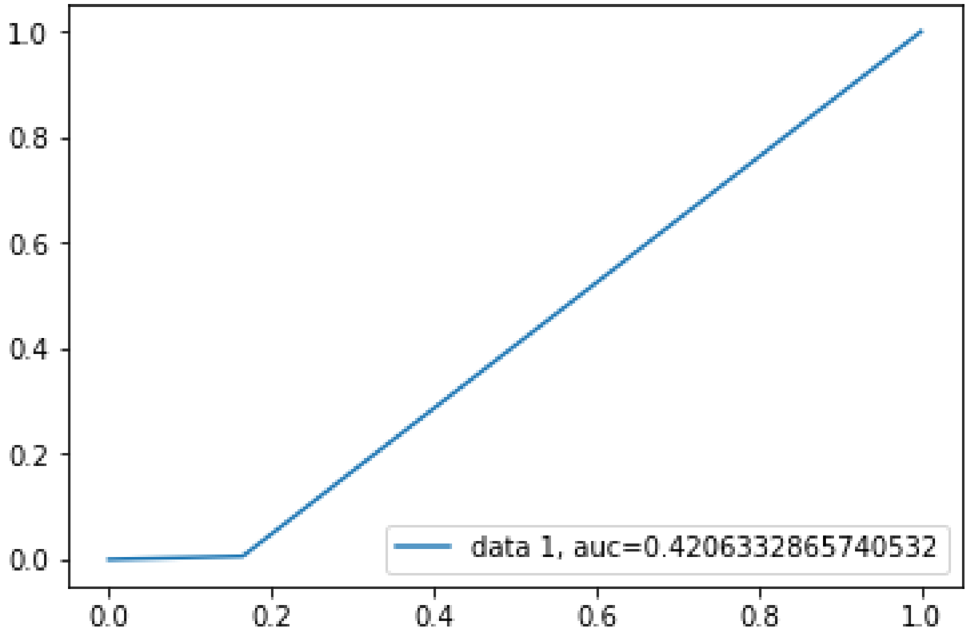
```
=============
Testing Set Evaluation With paramenters set to zero randomy in percent:  20.0
TP =  305
FN =  675
FP =  3060
TN =  5960
Accuracy =  0.6265
Recall =  0.3112244897959184
Precision =  0.09063893016344725
F1 Score =  0.14039125431530494
0.6265
```



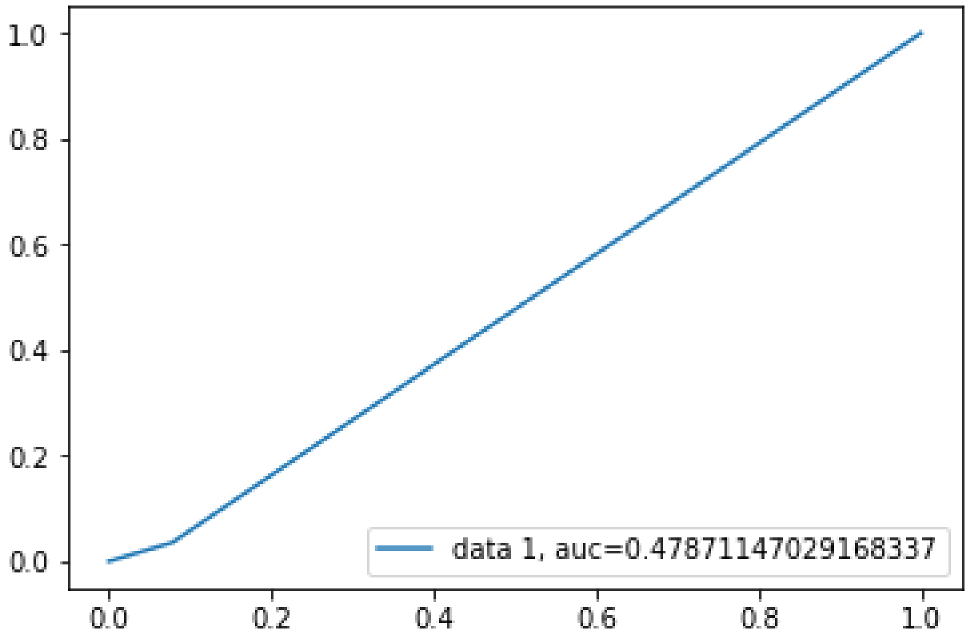
```
======================================================================
Training Set Evaluation With paramenters set to zero randomy:  30.000000000000004
TP =  47
FN =  5876
FP =  8743
TN =  45334
Accuracy =  0.75635
Recall =  0.007935167989194665
Precision =  0.005346985210466439
F1 Score =  0.006388907768639977
0.75635
```



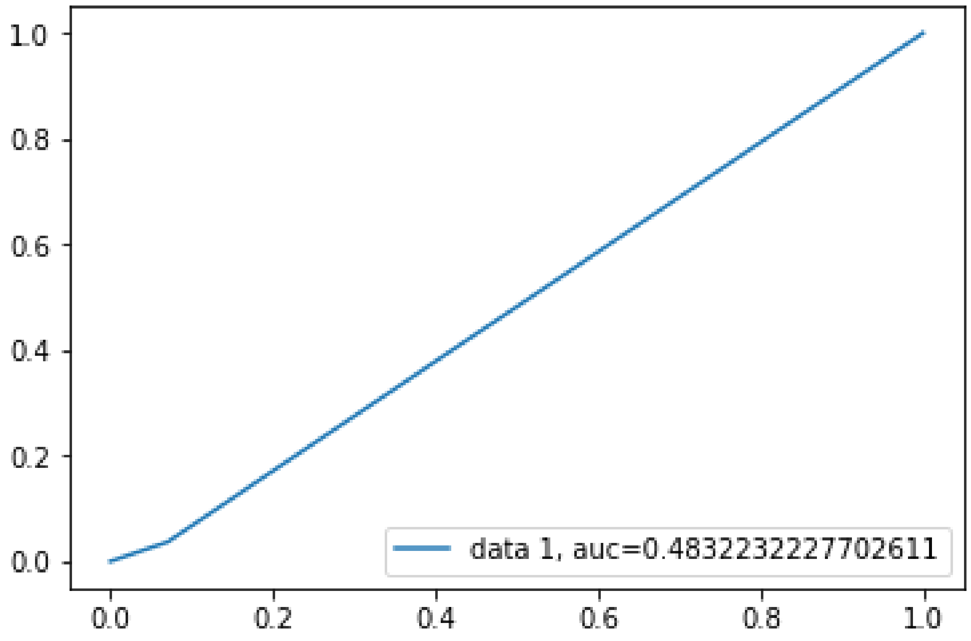
```
=============
Testing Set Evaluation With paramenters set to zero randomy in percent:  30.000000000000004
TP =  6
FN =  974
FP =  1487
TN =  7533
Accuracy =  0.7539
Recall =  0.006122448979591836
Precision =  0.004018754186202277
F1 Score =  0.004852405984634048
0.7539
```



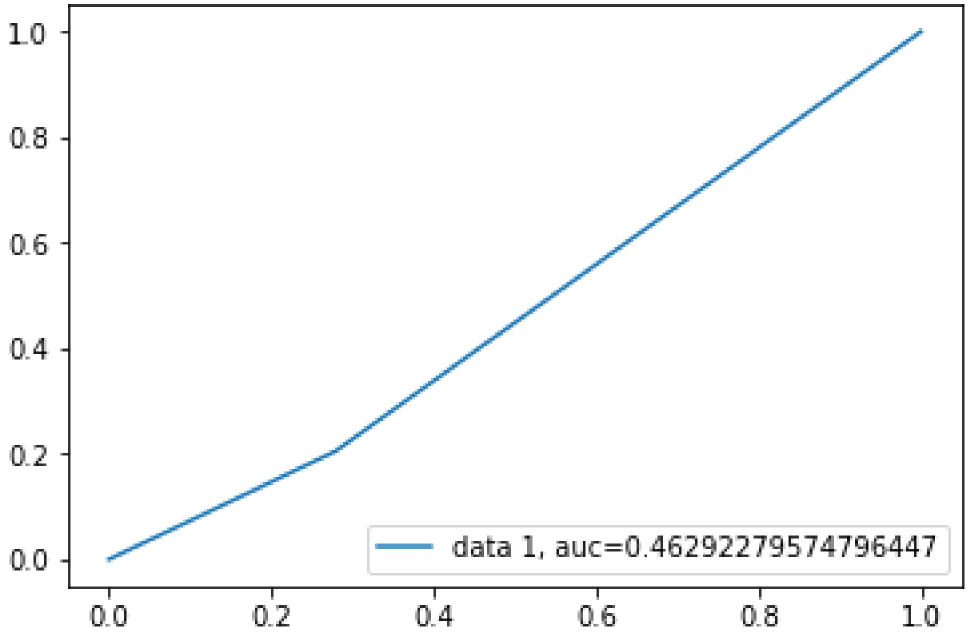
```
======================================================================
Training Set Evaluation With paramenters set to zero randomy:  40.0
TP =  212
FN =  5711
FP =  4238
TN =  49839
Accuracy =  0.8341833333333334
Recall =  0.0357926726321121
Precision =  0.04764044943820225
F1 Score =  0.0408753494649571
0.8341833333333334
```



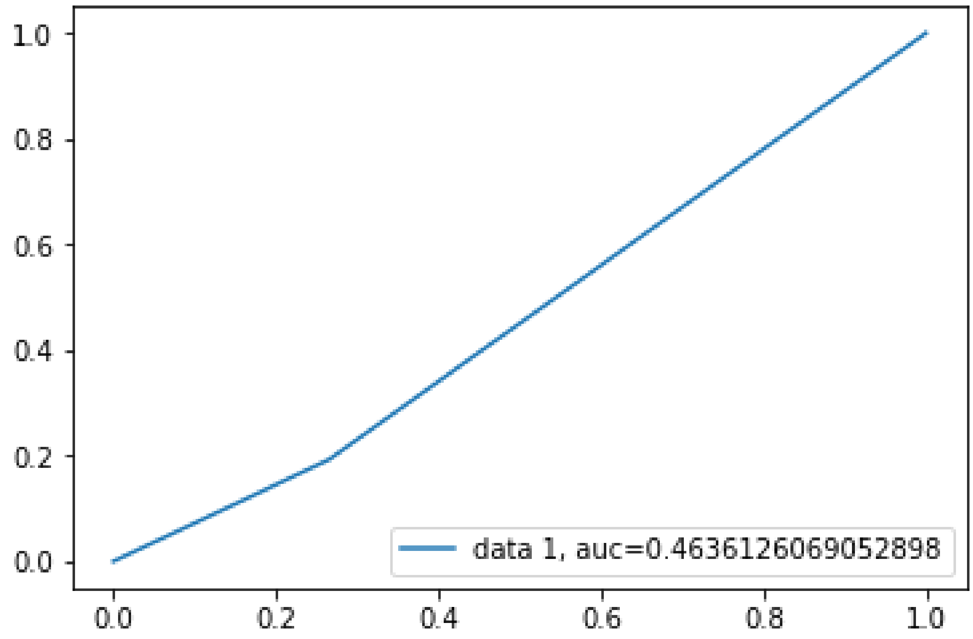
```
=============
Testing Set Evaluation With paramenters set to zero randomy in percent:  40.0
TP =  36
FN =  944
FP =  634
TN =  8386
Accuracy =  0.8422
Recall =  0.036734693877551024
Precision =  0.05373134328358209
F1 Score =  0.04363636363636364
0.8422
```



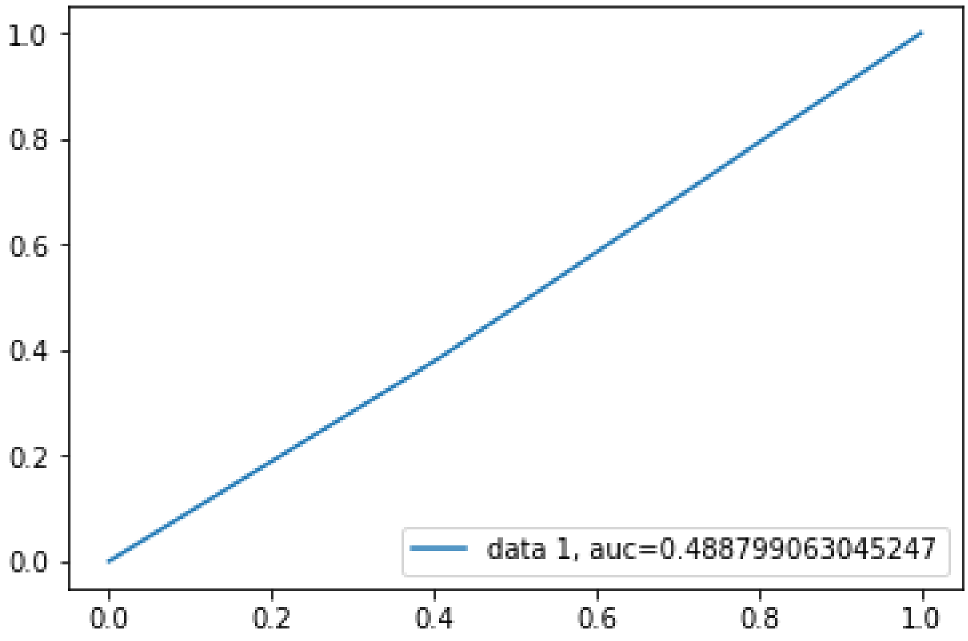
```
======================================================================
Training Set Evaluation With paramenters set to zero randomy:  50.0
TP =  1215
FN =  4708
FP =  15103
TN =  38974
Accuracy =  0.6698166666666666
Recall =  0.2051325341887557
Precision =  0.07445765412427993
F1 Score =  0.10925767726271302
0.6698166666666666
```



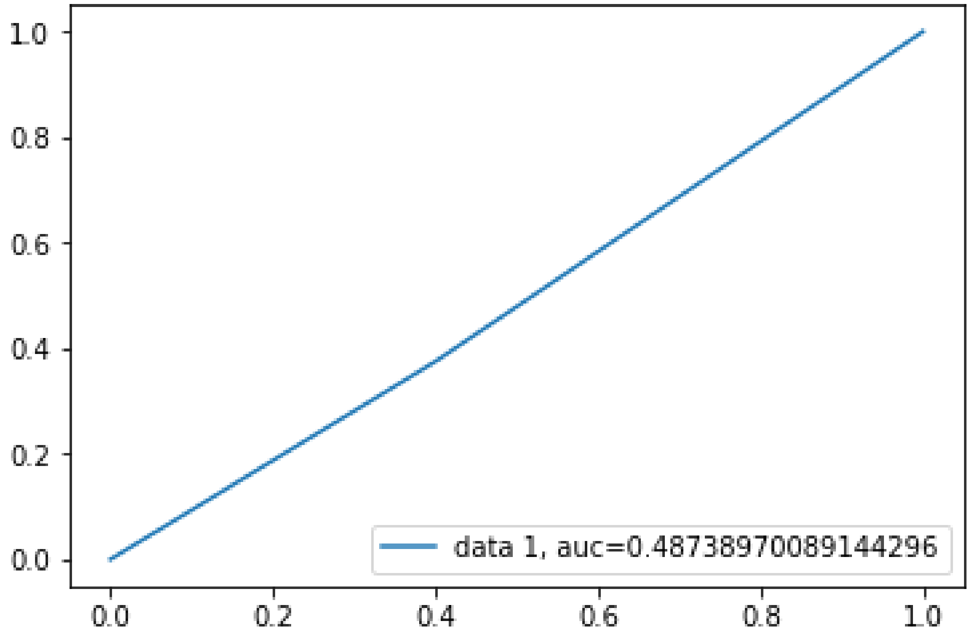
```
=============
Testing Set Evaluation With paramenters set to zero randomy in percent:  50.0
TP =  189
FN =  791
FP =  2396
TN =  6624
Accuracy =  0.6813
Recall =  0.19285714285714287
Precision =  0.07311411992263056
F1 Score =  0.10603085553997194
0.6813
```



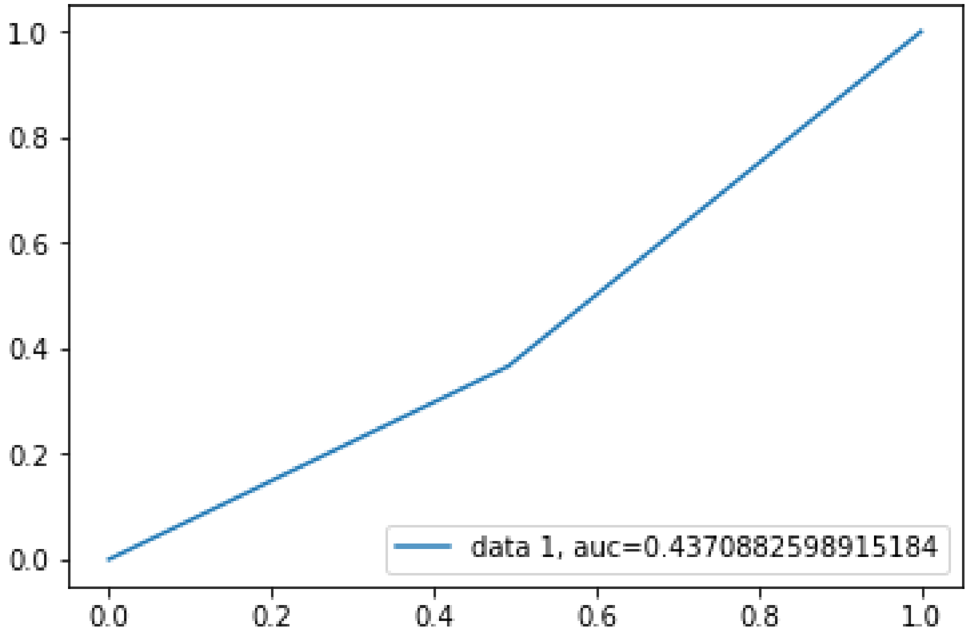
```
======================================================================
Training Set Evaluation With paramenters set to zero randomy:  60.0
TP =  2289
FN =  3634
FP =  22110
TN =  31967
Accuracy =  0.5709333333333333
Recall =  0.3864595644099274
Precision =  0.0938153203000123
F1 Score =  0.15097948684123738
0.5709333333333333
```



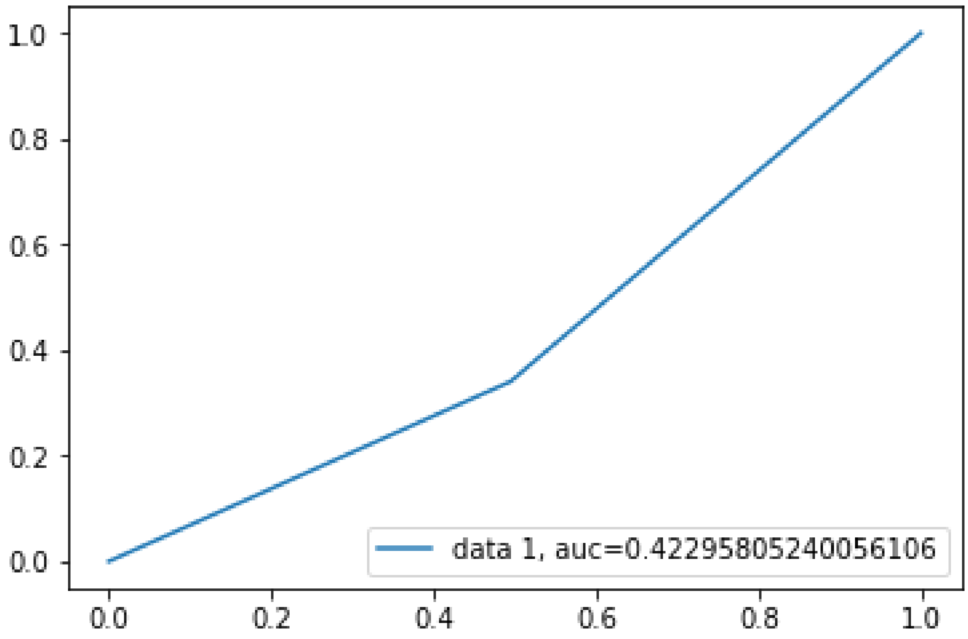
```
=============
Testing Set Evaluation With paramenters set to zero randomy in percent:  60.0
TP =  370
FN =  610
FP =  3633
TN =  5387
Accuracy =  0.5757
Recall =  0.37755102040816324
Precision =  0.09243067699225581
F1 Score =  0.14850491671683722
0.5757
```



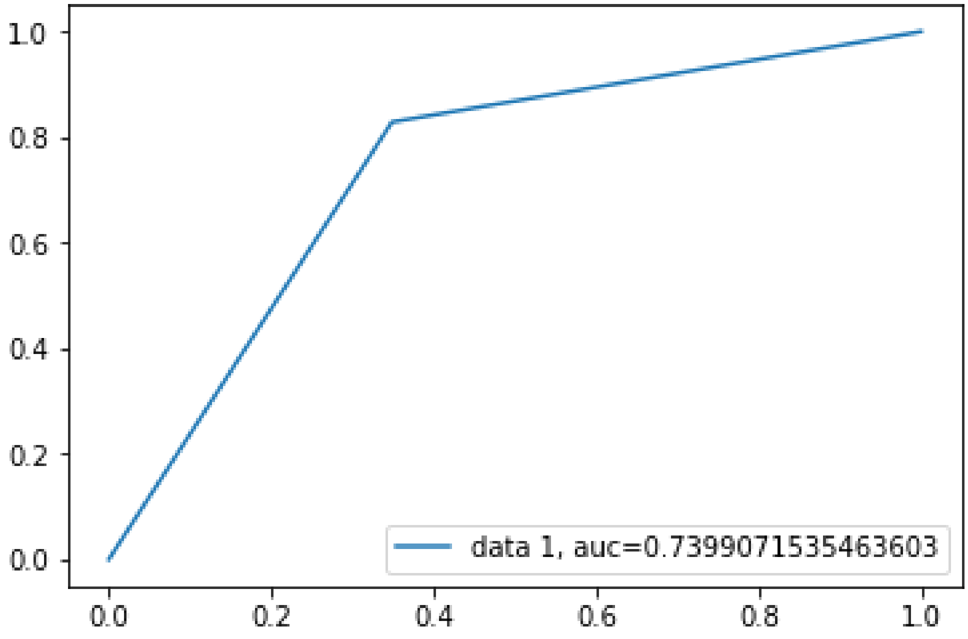
```
=======================================================================
Training Set Evaluation With paramenters set to zero randomy:  70.0
TP =  2168
FN =  3755
FP =  26598
TN =  27479
Accuracy =  0.49411666666666665
Recall =  0.36603072767178796
Precision =  0.07536675241604672
F1 Score =  0.12499639655222115
0.49411666666666665
```



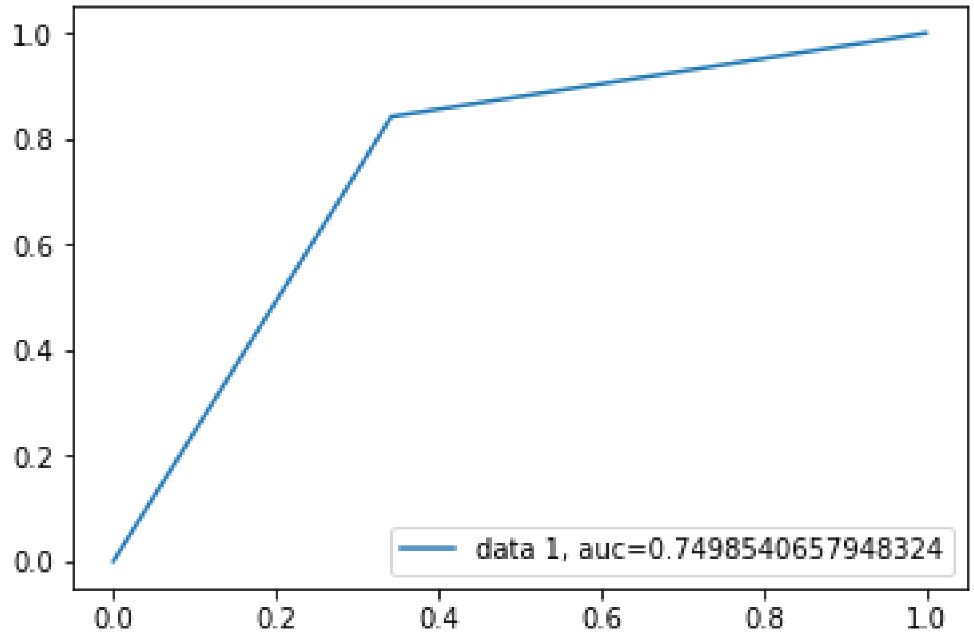
```
=============
Testing Set Evaluation With paramenters set to zero randomy in percent:  70.0
TP =  334
FN =  646
FP =  4464
TN =  4556
Accuracy =  0.489
Recall =  0.3408163265306122
Precision =  0.06961233847436432
F1 Score =  0.11561093804084459
0.489
```



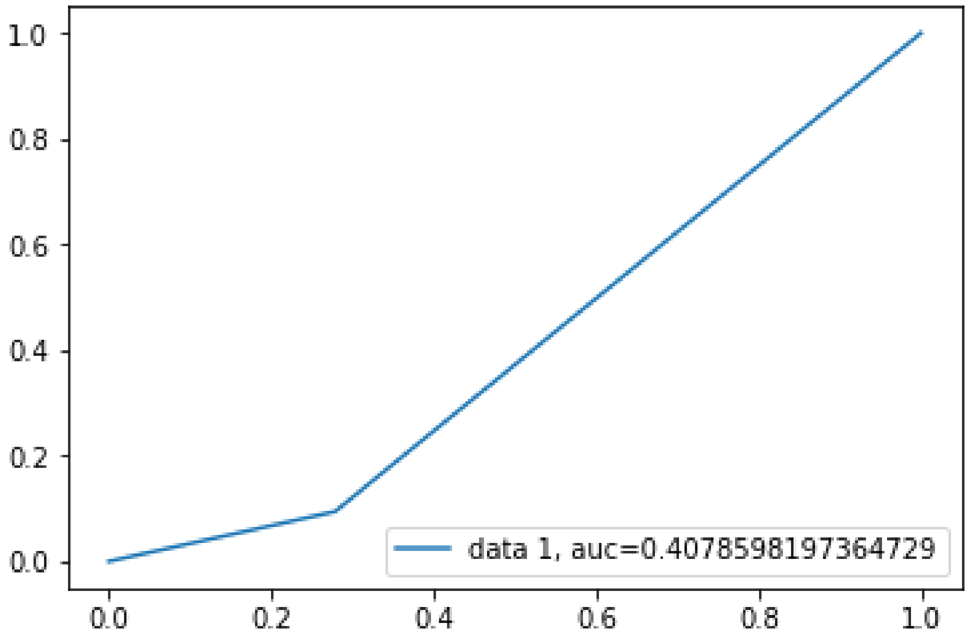
```
======================================================================
Training Set Evaluation With paramenters set to zero randomy:  80.0
TP =  4907
FN =  1016
FP =  18854
TN =  35223
Accuracy =  0.6688333333333333
Recall =  0.8284653047442174
Precision =  0.2065148773199781
F1 Score =  0.33061581997035444
0.6688333333333333
```



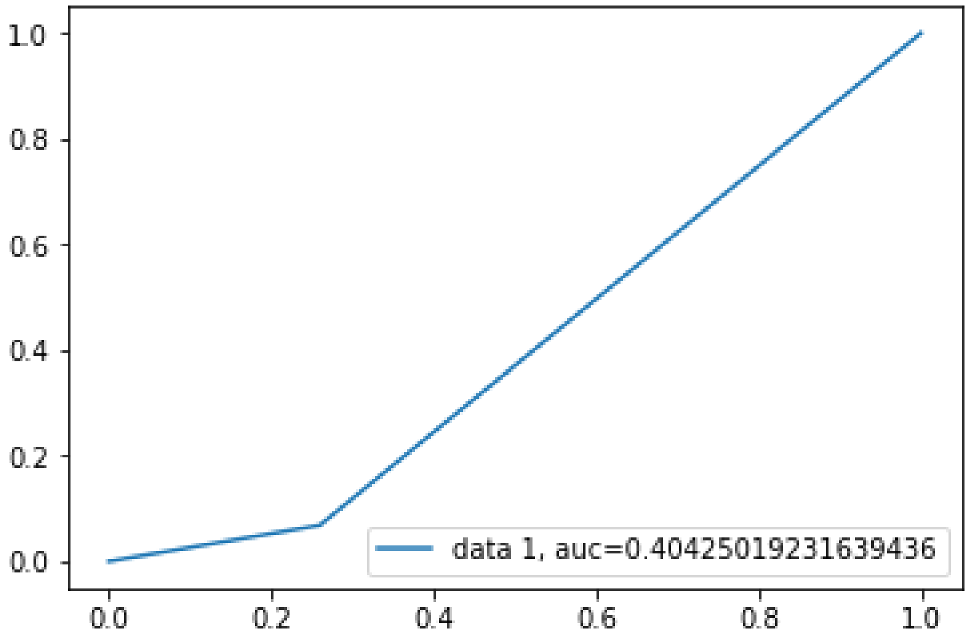
```
=============
Testing Set Evaluation With paramenters set to zero randomy in percent:  80.0
TP =  825
FN =  155
FP =  3086
TN =  5934
Accuracy =  0.6759
Recall =  0.8418367346938775
Precision =  0.21094349271286117
F1 Score =  0.3373543242690657
0.6759
```



```
======================================================================
Training Set Evaluation With paramenters set to zero randomy:  89.99999999999999
TP =  559
FN =  5364
FP =  15069
TN =  39008
Accuracy =  0.65945
Recall =  0.09437784906297485
Precision =  0.035769132326593296
F1 Score =  0.05187694306528699
0.65945
```

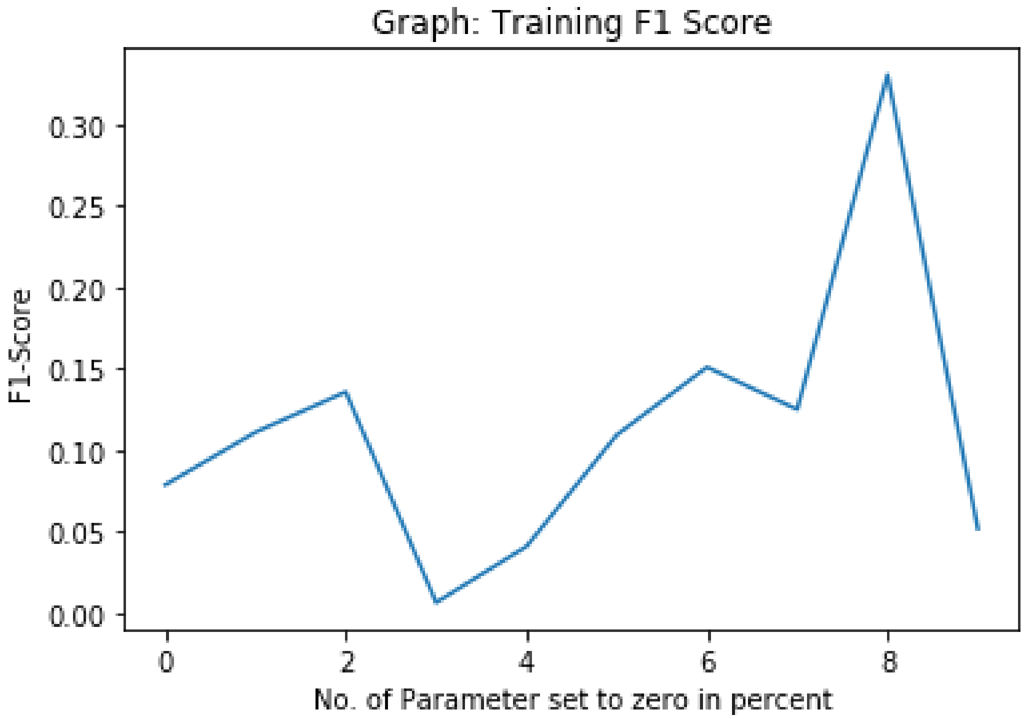


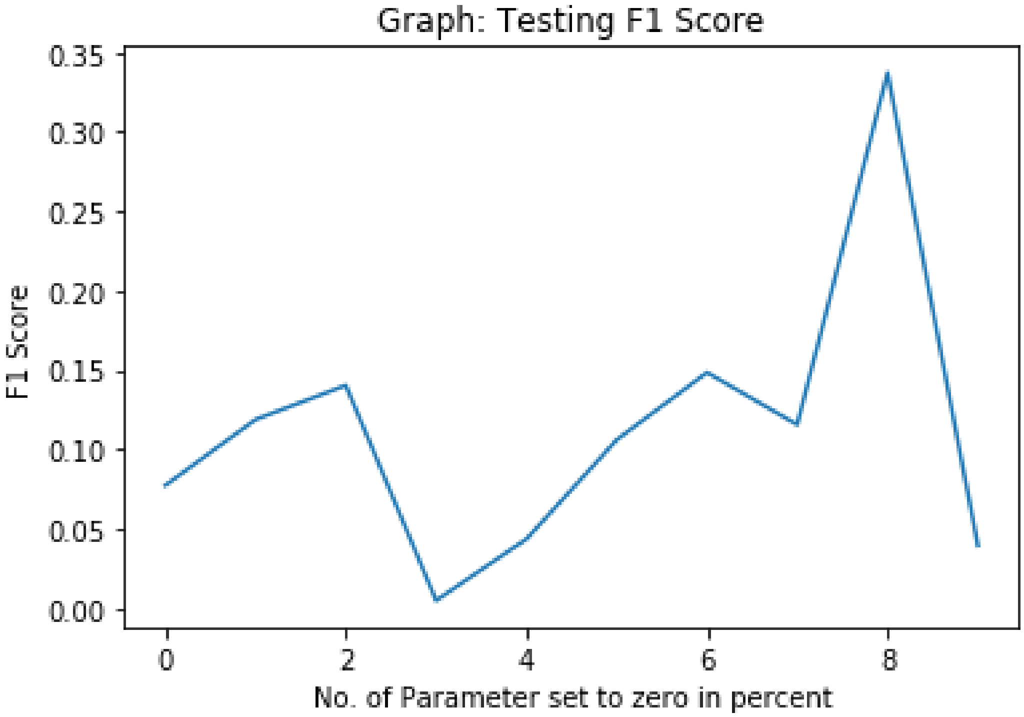
```
=============
Testing Set Evaluation With paramenters set to zero randomy in percent:  89.99999999999999
TP =  67
FN =  913
FP =  2344
TN =  6676
Accuracy =  0.6743
Recall =  0.06836734693877551
Precision =  0.02778929904603899
F1 Score =  0.03951636685343557
0.6743
```



```
======================================================================
```

```
In [17]: plt.figure(100)
         plt.title("Graph: Training F1 Score")
         plt.xlabel("No. of Parameter set to zero in percent")
         plt.ylabel("F1-Score")
         plt.plot(f_train)
         plt.figure(101)
         plt.title("Graph: Testing F1 Score")
         plt.xlabel("No. of Parameter set to zero in percent")
         plt.ylabel("F1 Score")
         plt.plot(f_test)

Out[17]: [<matplotlib.lines.Line2D at 0x2793befe588>]
```


Graph: Training F1 Score
F1-Score
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0
2
4
6
8
No. of Parameter set to zero in percent


Graph: Testing F1 Score
F1 Score
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0
2
4
6
8
No. of Parameter set to zero in percent

Below code Calculated the average images of TP,TN, FP, FN

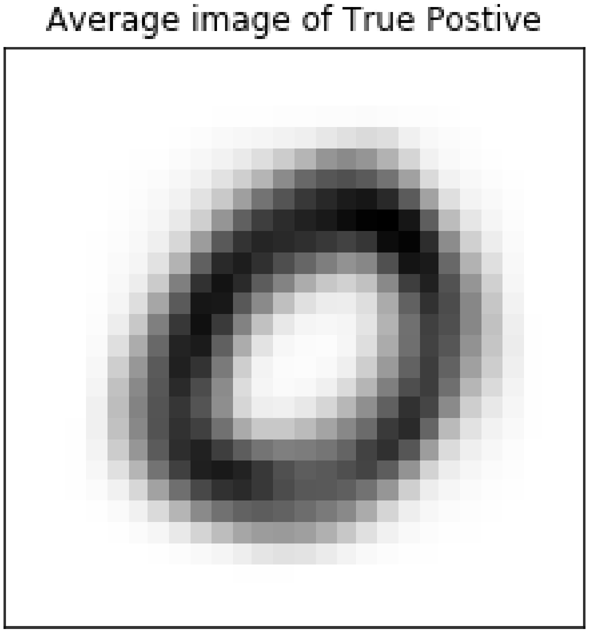
```
In [11]:    labels_train1=labels_trian
            TPl=[]
            TP=0
            for j in range(len(labels_train1)):
                #print(j)
                if labels_train1[j]==1 and pred[j]==1:
                    TP+=1
                    TPl=TPl+[j]
            print("TP = ", TP)
            TN=0
            TNl=[]
            for j in range(len(labels_train1)):
                if labels_train1[j]!=1 and pred[j]==-1:
                    TN+=1
                    TNl=TNl+[j]
            print("TN = ", TN)
            FN=0
            FNl=[]
            for j in range(len(labels_train1)):
                if labels_train1[j]!=1 and pred[j]==-1:
                    FN+=1
                    FNl=FNl+[j]
            print("FN = ", FN)
            FP=0
            FPl=[]
            for j in range(len(labels_train1)):
                if labels_train1[j]!=1 and pred[j]==-1:
                    FP+=1
                    FPl=FPl+[j]
            print("FP = ", FP)
```

```
TP =  1131
TN =  32398
FN =  32398
FP =  32398
```

```
In [12]:    print("Average image of True Postive")
            X_train1=X_train.T
            im_average  = np.zeros((28 * 28), dtype=float)
            #im_count    = np.zeros(10, dtype=int)

            for i in TPl:

                im_average[:] += X_train1[:, i]
                #TP[labels_train1[i]] += 1
```

```
im_average /= TP

plt.plot()
plt.title("Average image of True Postive")
plt.imshow(im_average[:].reshape((28, 28)), cmap='Greys', interpolation='None')

frame   = plt.gca()
frame.axes.get_xaxis().set_visible(False)
frame.axes.get_yaxis().set_visible(False)


plt.show()
```

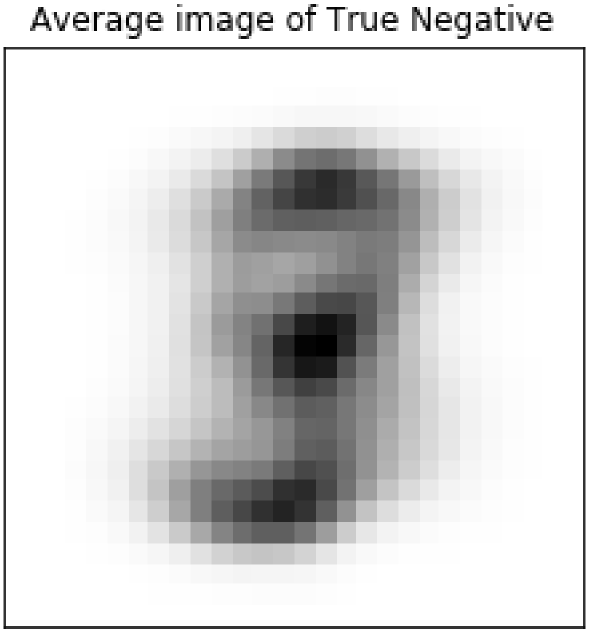
```
Average image of True Postive
```



```
In [13]:    print("Average image of True Negative")
            X_train1=X_train.T
            im_average  = np.zeros((28 * 28), dtype=float)
            #im_count    = np.zeros(10, dtype=int)

            for i in TN1:

                im_average[:] += X_train1[:, i]
                #TP[labels_train1[i]] += 1
```

```
im_average /= TN

plt.plot()
plt.title("Average image of True Negative")
plt.imshow(im_average[:].reshape((28, 28)), cmap='Greys', interpolation='None')

frame   = plt.gca()
frame.axes.get_xaxis().set_visible(False)
frame.axes.get_yaxis().set_visible(False)


plt.show()
```

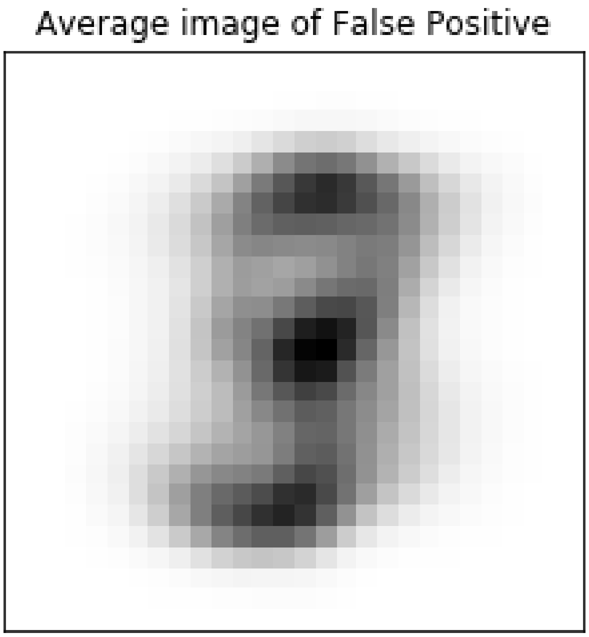
```
Average image of True Negative
```



```
In [14]:    print("Average image of False Positive")
            X_train1=X_train.T
            im_average  = np.zeros((28 * 28), dtype=float)
            #im_count    = np.zeros(10, dtype=int)

            for i in FP1:

                im_average[:] += X_train1[:, i]
                #TP[labels_train1[i]] += 1
```

```
im_average /= FP

plt.plot()
plt.title("Average image of False Positive")
plt.imshow(im_average[:].reshape((28, 28)), cmap='Greys', interpolation='None')

frame   = plt.gca()
frame.axes.get_xaxis().set_visible(False)
frame.axes.get_yaxis().set_visible(False)


plt.show()
```

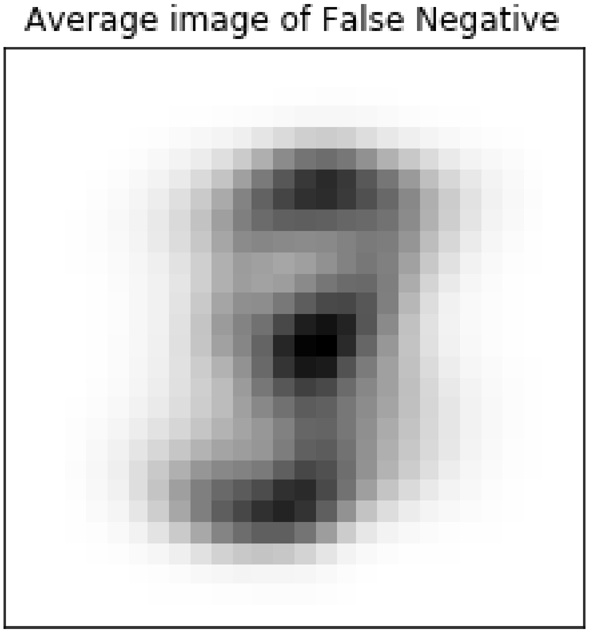
```
Average image of False Positive
```



```
In [15]:  print("Average image of False Negative")
           X_train1=X_train.T
           im_average  = np.zeros((28 * 28), dtype=float)
           #im_count    = np.zeros(10, dtype=int)

           for i in FN1:

               im_average[:] += X_train1[:, i]
               #TP[labels_train1[i]] += 1
```

```
im_average /= FN

plt.plot()
plt.title('Average image of False Negative')
plt.imshow(im_average[:].reshape((28, 28)), cmap='Greys', interpolation='None')

frame    = plt.gca()
frame.axes.get_xaxis().set_visible(False)
frame.axes.get_yaxis().set_visible(False)


plt.show()
```

```
Average image of False Negative
```



The results shows that when 80 % of the parameter are set to zero randomly it shows the best F1 score and highest Area Under Curve (AUC).