Assingment1

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0.1 Assignment 1

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```
In [1]: import scipy.io
        import numpy as np
        from numpy import linalg as LA
        import matplotlib.pyplot as plt
        from sklearn import datasets
        from sklearn import metrics
        from sklearn.neighbors import KNeighborsClassifier
        from sklearn.metrics import accuracy_score
```

```
In [2]: directory = '/Users/Vivek/Dropbox/Spring17/ML/Assingments/Assignment1' # Please put the
```

```
In [3]: images = scipy.io.loadmat('digits.mat')
```

```
In [4]: images.keys()
```

```
Out[4]: dict_keys(['trainLabels', 'testImages', '__globals__', '__version__', 'testLabels', 'tra
```

```
In [5]: trainImages = images['trainImages']
        trainLabels = images['trainLabels']
        testImages = images['testImages']
        testLabels = images['testLabels']
```

```
In [6]: trainImages.shape, trainLabels.shape
```

```
Out[6]: ((28, 28, 1, 60000), (1, 60000))
```

```
In [7]: trainImages.shape
```

```
Out[7]: (28, 28, 1, 60000)
```

```
In [8]: testImages.shape, testLabels.shape
```

```
Out[8]: ((28, 28, 1, 10000), (1, 10000))
```

```
In [9]: trainImages = trainImages.reshape(784, 60000)
        testImages = testImages.reshape(784, 10000)
```

```
In [10]: trainImages.shape, testImages.shape
```

```
Out[10]: ((784, 60000), (784, 10000))
```

```
In [11]: # Let's define a variable size, size of training dataset we want to use
         size = 200
```

```
In [12]: train = trainImages[:,:size] #Taking differnt no of Images for analysis
         # train = trainImages[:,:]
```

```
In [13]: train.shape # Now, we have a train ndarray with 200 Images and each with 784 pixels
```

```
Out[13]: (784, 200)
```

```
In [14]: # Let's get the Similarity Matrix for these 20 Images
         train_ave = train.mean(1)
         train_ave = train_ave.reshape(train_ave.size,1)
         train_ave.shape
```

```
Out[14]: (784, 1)
```

```
In [15]: train_final = train - train_ave
         test_final = testImages - train_ave
         train_final.shape, test_final.shape # Now, we have a training matrix without the simila
```

```
Out[15]: ((784, 200), (784, 10000))
```

```
In [16]: train.shape, train_ave.shape, train_final.shape
```

```
Out[16]: ((784, 200), (784, 1), (784, 200))
```

```
In [17]: B = np.matmul(train_final.T, train_final)
         B.shape, B.max()
```

```
Out[17]: ((200, 200), 7381816.2950000027)
```

```
In [18]: # Let's find eigen vector for B matrix, we will pre multiply it's eigen vector
         # to train_final to get eigen vector matrix of cov-variance matrix
         val, vec = LA.eig(B)
```

```
In [19]: val.shape, vec.shape
```

```
Out[19]: ((200,), (200, 200))
```

```
In [20]: val_sorted = np.sort(val)
         vec_sorted = vec[:, val.argsort()[::-1]]
         #vec_sorted[:] = vec_sorted[::-1]
         #val_sorted[::-1],vec_sorted
```

```
In [21]: # now, to get Eigen vector of Co-variance matrix, premultiply with train_final
         # Eigen Values of co-variance Matrix remains the same
         eig_cov = np.dot(train_final,vec_sorted)  #train_size X 784 #matmul and dot does the sa
         eig_cov.shape

Out[21]: (784, 200)
```

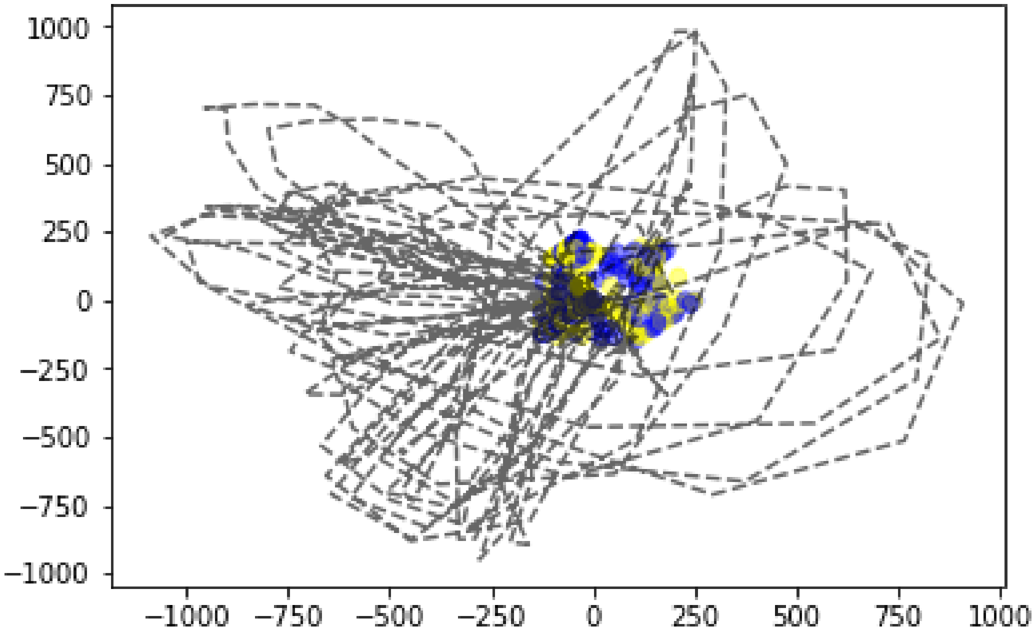
```
In [22]: eig_cov = eig_cov[:,0:15]
```

```
In [23]: eig_cov_t = eig_cov.T
```

```
In [24]: train_proj = np.dot(eig_cov_t, train_final)
         test_proj = np.dot(eig_cov_t, test_final)
```

```
In [25]: train_proj.shape, test_proj.shape

Out[25]: ((15, 200), (15, 10000))
```

```
In [26]: # First two images
         plt.scatter(train_final[:,0], train_final[:,1], alpha = 0.45,  c=('yellow', 'blue'))
         plt.plot(eig_cov[:,0],eig_cov[:,1],'--', alpha = .6, c = ('black'))
         #plt.plot([0,eig[:,0]], [0,eig[:,1]], 'y-', lw = 2)
         plt.show()
```



```
In [27]: train_proj_labels = trainLabels.flatten()[:size]
         train_proj_labels.shape
```

```
Out[27]: (200,)
```

```
In [28]: test_proj_labels = testLabels.flatten()
```

```
In [29]: xtrain, ytrain, xtest, ytest = train_proj.T, train_proj_labels, test_proj.T, test_proj_
```

```
In [30]: xtrain.shape, ytrain.shape, xtest.shape, ytest.shape
```

```
Out[30]: ((200, 15), (200,), (10000, 15), (10000,))
```

```
In [31]: ## Let's make a K nearest Neighbor Classifier
         model = KNeighborsClassifier()
```

```
In [32]: # Let's fit training data to the model
         model.fit(xtrain,ytrain)
         print(model)
```

```
KNeighborsClassifier(algorithm='auto', leaf_size=30, metric='minkowski',
           metric_params=None, n_jobs=1, n_neighbors=5, p=2,
           weights='uniform')
```

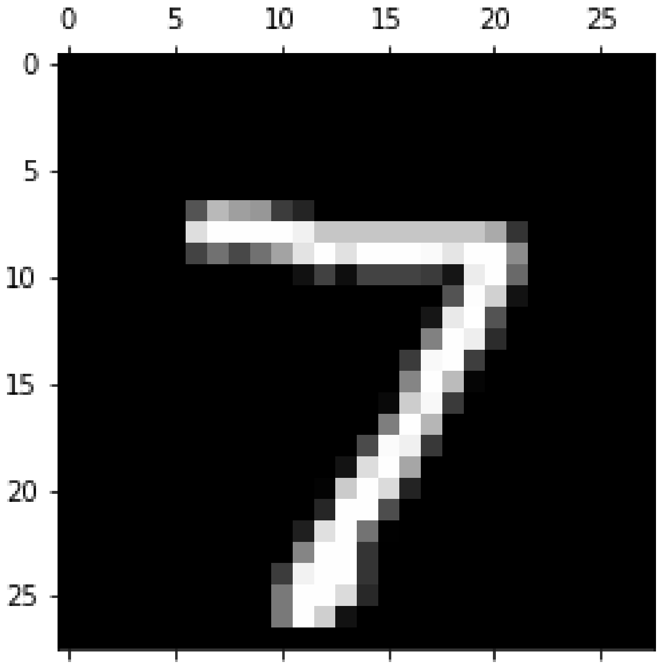
```
In [33]: expected = ytest
```

```
In [34]: predicted = model.predict(xtest)
```

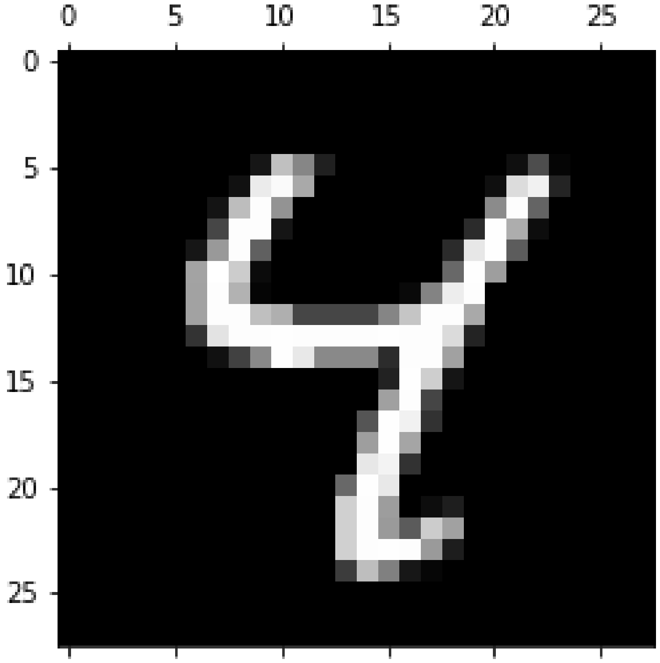
```
In [35]: expected[1],predicted[1]
```

```
Out[35]: (2, 2)
```

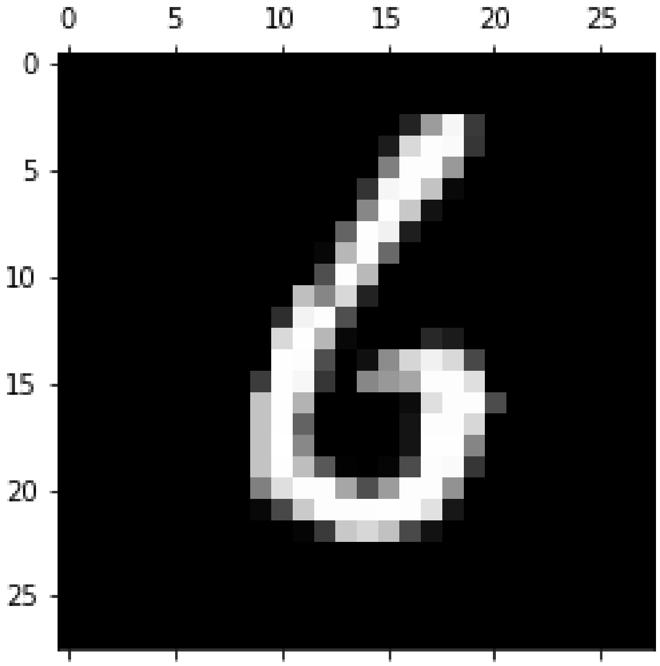
```
In [36]: # Construction of the test digit in the projected eigen space
         pl1=plt.matshow(testImages[:,0].reshape(28,28), cmap=plt.cm.gray)
         plt.show()
```



```
In [37]: p22=plt.matshow(testImages[:,6].reshape(28,28), cmap=plt.cm.gray)
         plt.show()
```



```
In [38]: p66=plt.matshow(testImages[:,50].reshape(28,28), cmap=plt.cm.gray)
         plt.show()
```



```
In [39]: print(metrics.classification_report(expected, predicted))
```

```
             precision    recall  f1-score   support

          0       0.80      0.90      0.85       980
          1       0.78      0.99      0.87      1135
          2       0.74      0.66      0.70      1032
          3       0.65      0.78      0.71      1010
          4       0.65      0.70      0.67       982
          5       0.66      0.33      0.44       892
          6       0.83      0.75      0.79       958
          7       0.80      0.50      0.62      1028
          8       0.63      0.62      0.63       974
          9       0.50      0.68      0.58      1009

avg / total       0.71      0.70      0.69     10000
```

```
In [40]: print(metrics.confusion_matrix(expected, predicted))
```

```
[[ 884    0   17    1    6   35   25    4    5    3]
 [   0 1119    0    4    0    5    1    0    6    0]
 [  22   91  683   43   22   18   27   28   96    2]
 [  23   37   34  791    4   36    3    2   68   12]
 [   1    23    15     1   683     1    24     7     3   224]
 [  61    18    28   222    20   290    39    23   127    64]
 [  46    32    63     0    63    23   719     8     3     1]
 [   1    65    29    14    34     2     1   513    29   340]
 [  54    25    45   132    17    29    20    15   606    31]
 [  12    19     8    16   205     0     3    38    18   690]]
```

```
In [41]: accuracy_score(expected, predicted)
```

```
Out[41]: 0.69779999999999998
```

```
In [ ]:
```

1 Now, I will work on 5 cases: and compare accuracy -

1. changing training sample size from 40 to 700 with steps of 50 and using first 10 eigen vector
2. changing training sample size from 40 to 700 with steps of 50 and using first 50 eigen vector
3. changing training sample size from 40 to 700 with steps of 50 and using all the eigen vector
4. Using 100 Training Images and varying Eigen Vector size from 10 to maximum value
5. Using 200 Training Images and varying Eigen Vector size from 10 to maximum value
6. Using 500 Training Images and varying Eigen Vector size from 10 to maximum value
7. Using 700 Training Images and varying Eigen Vector size from 10 to maximum value

1.1 changing training sample size from 40 to 700 with steps of 50 and using first 10 eigen vector

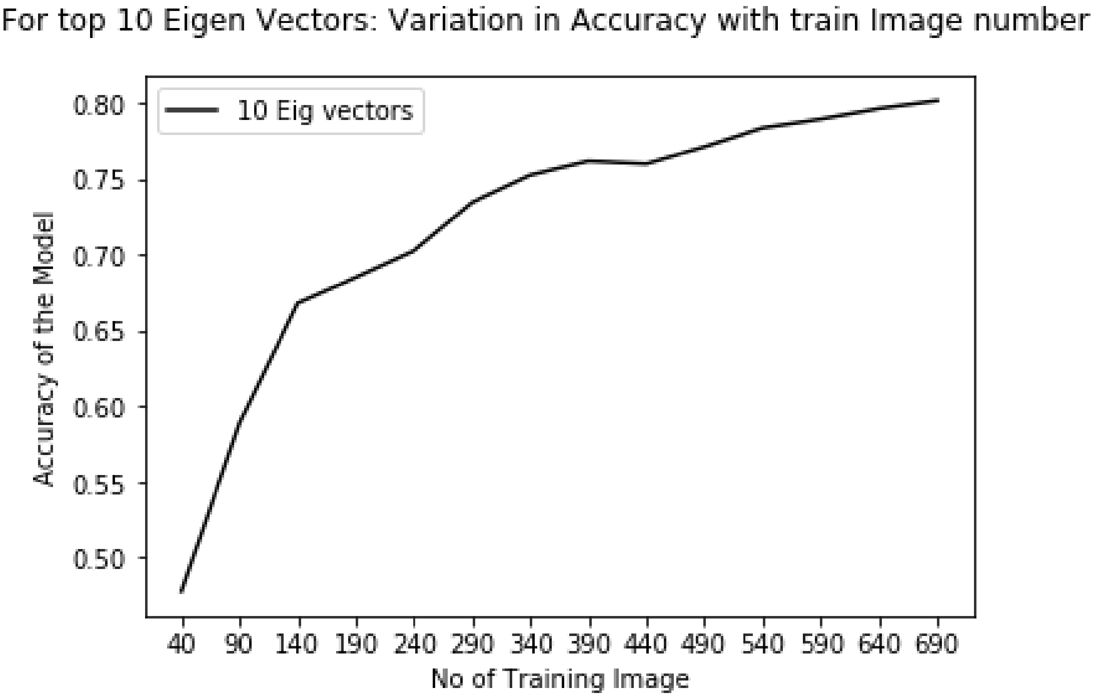
```
In [42]: accuracy_measure1 = []
         train_size1 = []
         for i in range(40,700,50):
             trainImages = images['trainImages']
             trainLabels = images['trainLabels']
             testImages = images['testImages']
             testLabels = images['testLabels']

             trainImages = trainImages.reshape(784, 60000)
             testImages = testImages.reshape(784, 10000)

             train = trainImages[:,:i] #Taking differnt no of Images for analysis

             train_ave = train.mean(1)
             train_ave = train_ave.reshape(train_ave.size,1)

             train_final = train - train_ave
             test_final = testImages - train_ave

             B = np.matmul(train_final.T, train_final)
```

```
        val, vec = LA.eig(B)
        val_sorted = np.sort(val)
        vec_sorted = vec[:, val.argsort()[::-1]]

        eig_cov = np.dot(train_final,vec_sorted)  #train_size X 784 #matmul and dot does th

        eig_cov = eig_cov[:,:10]

        eig_cov_t = eig_cov.T

        train_proj = np.dot(eig_cov_t, train_final)
        test_proj = np.dot(eig_cov_t, test_final)

        train_proj_labels = trainLabels.flatten()[:i]
        test_proj_labels = testLabels.flatten()

        xtrain, ytrain, xtest, ytest = train_proj.T, train_proj_labels, test_proj.T, test_p

        model = KNeighborsClassifier()
        model.fit(xtrain,ytrain)
        expected = ytest
        predicted = model.predict(xtest)
        accuracy = accuracy_score(expected, predicted)

        train_size1.append(i)
        accuracy_measure1.append(accuracy)

    print("For top 10 Eigen Vectors: ")

    print("TrainImages Size:" + str(train_size1))  ,print("Accuracy: "+str(accuracy_measure
```

```
/Library/Frameworks/Python.framework/Versions/3.5/lib/python3.5/site-packages/numpy/core/numeric
  return array(a, dtype, copy=False, order=order)
/Library/Frameworks/Python.framework/Versions/3.5/lib/python3.5/site-packages/sklearn/utils/vali
  array = np.array(array, dtype=dtype, order=order, copy=copy)


For top 10 Eigen Vectors:
TrainImages Size:[40, 90, 140, 190, 240, 290, 340, 390, 440, 490, 540, 590, 640, 690]
Accuracy: [0.47799999999999998, 0.5887, 0.66769999999999996, 0.68469999999999998, 0.702300000000
```

```
Out[42]: (None, None)
```

```
In [43]: #fig1= plt.figure()
         plot1= plt.plot(train_size1, accuracy_measure1, '-', c = ('black'), label = '10 Eig vec
         plt.suptitle('For top 10 Eigen Vectors: Variation in Accuracy with train Image number')
         plt.xlabel('No of Training Image')
         plt.ylabel('Accuracy of the Model')
         plt.xticks(train_size1)
         plt.legend()
         plt.show()
```


For top 10 Eigen Vectors: Variation in Accuracy with train Image number

1.2 changing training sample size from 40 to 700 with steps of 50 and using first 50 eigen vector

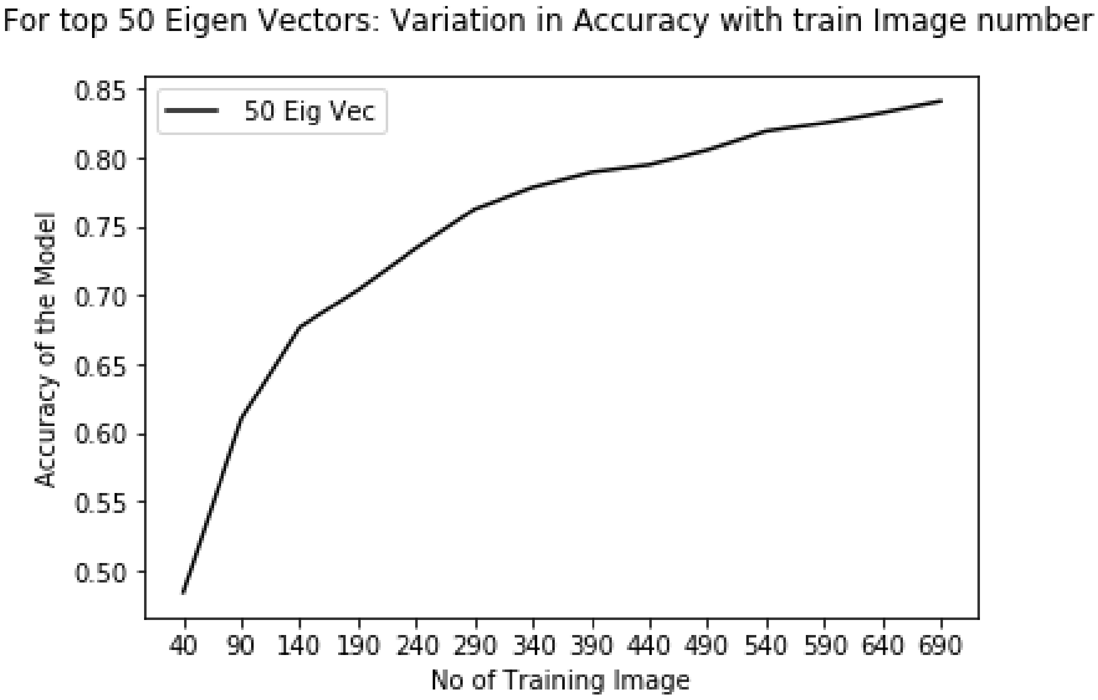
```
In [44]: accuracy_measure2 = []
         train_size2 = []
         for i in range(40,700,50):
             trainImages = images['trainImages']
             trainLabels = images['trainLabels']
             testImages = images['testImages']
             testLabels = images['testLabels']

             trainImages = trainImages.reshape(784, 60000)
             testImages = testImages.reshape(784, 10000)

             train = trainImages[:,:i] #Taking differnt no of Images for analysis

             train_ave = train.mean(1)
             train_ave = train_ave.reshape(train_ave.size,1)
```

```
    train_final = train - train_ave
    test_final = testImages - train_ave

    B = np.matmul(train_final.T, train_final)

    val, vec = LA.eig(B)
    val_sorted = np.sort(val)
    vec_sorted = vec[:, val.argsort()[::-1]]

    eig_cov = np.dot(train_final,vec_sorted)  #train_size X 784 #matmul and dot does th

    eig_cov = eig_cov[:,:50]

    eig_cov_t = eig_cov.T

    train_proj = np.dot(eig_cov_t, train_final)
    test_proj = np.dot(eig_cov_t, test_final)

    train_proj_labels = trainLabels.flatten()[:i]
    test_proj_labels = testLabels.flatten()

    xtrain, ytrain, xtest, ytest = train_proj.T, train_proj_labels, test_proj.T, test_p

    model = KNeighborsClassifier()
    model.fit(xtrain,ytrain)
    expected = ytest
    predicted = model.predict(xtest)
    accuracy = accuracy_score(expected, predicted)

    train_size2.append(i)
    accuracy_measure2.append(accuracy)

print("For top 50 Eigen Vectors: ")
print("TrainImages Size:" + str(train_size2)), print("Accuracy: "+str(accuracy_measure2
```

```
/Library/Frameworks/Python.framework/Versions/3.5/lib/python3.5/site-packages/numpy/core/numeric
  return array(a, dtype, copy=False, order=order)
/Library/Frameworks/Python.framework/Versions/3.5/lib/python3.5/site-packages/sklearn/utils/vali
  array = np.array(array, dtype=dtype, order=order, copy=copy)


For top 50 Eigen Vectors:
TrainImages Size:[40, 90, 140, 190, 240, 290, 340, 390, 440, 490, 540, 590, 640, 690]
Accuracy: [0.48399999999999999, 0.61029999999999995, 0.67659999999999998, 0.70369999999999999, 0
```

```
Out[44]: (None, None)
```

```
In [45]: plot2= plt.plot(train_size2, accuracy_measure2, '-', c = ('black'), label = ' 50 Eig Ve
         plt.suptitle('For top 50 Eigen Vectors: Variation in Accuracy with train Image number')
         plt.xlabel('No of Training Image')
         plt.ylabel('Accuracy of the Model')
         plt.xticks(train_size2)
         plt.legend()
         plt.show()
```



For top 50 Eigen Vectors: Variation in Accuracy with train Image number

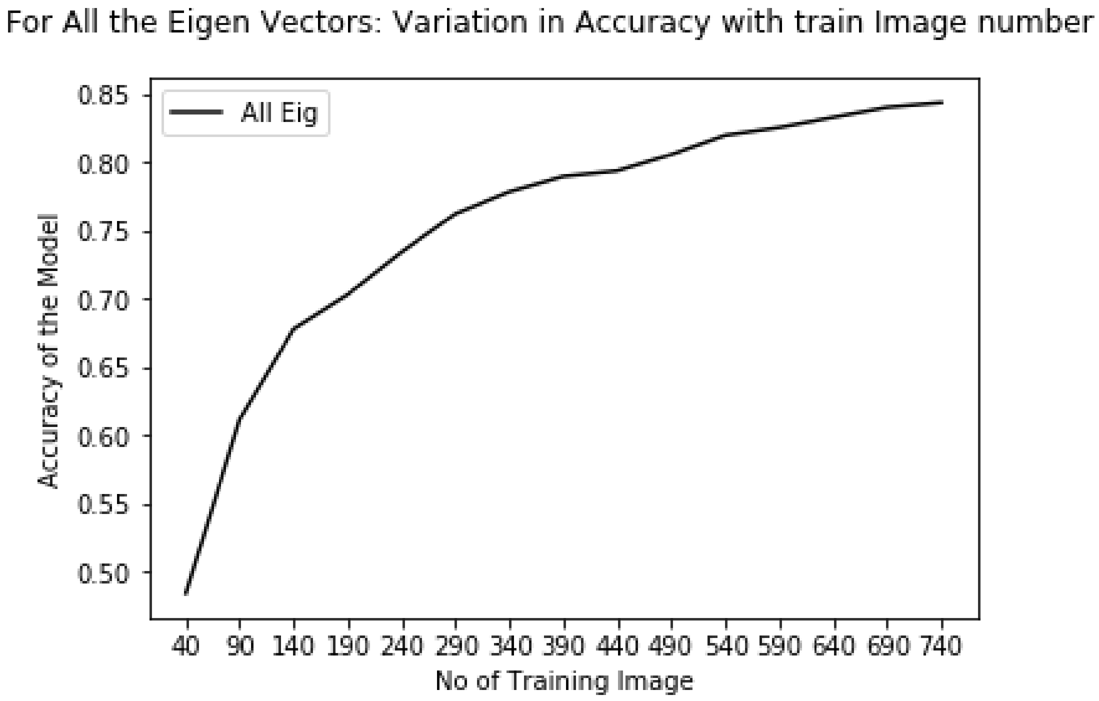
1.3 changing training sample size from 40 to 700 with steps of 50 and using all the eigen vector

```
In [46]: accuracy_measure3 = []
         train_size3 = []
         for i in range(40,780,50):
             trainImages = images['trainImages']
             trainLabels = images['trainLabels']
             testImages = images['testImages']
             testLabels = images['testLabels']

             trainImages = trainImages.reshape(784, 60000)
             testImages = testImages.reshape(784, 10000)

             train = trainImages[:,:i] #Taking differnt no of Images for analysis

             train_ave = train.mean(1)
             train_ave = train_ave.reshape(train_ave.size,1)
```

```
        train_final = train - train_ave
        test_final = testImages - train_ave

        B = np.matmul(train_final.T, train_final)

        val, vec = LA.eig(B)
        val_sorted = np.sort(val)
        vec_sorted = vec[:, val.argsort()[::-1]]

        eig_cov = np.dot(train_final,vec_sorted)  #train_size X 784 #matmul and dot does th

        #eig_cov = eig_cov[:,:]

        eig_cov_t = eig_cov.T

        train_proj = np.dot(eig_cov_t, train_final)
        test_proj = np.dot(eig_cov_t, test_final)

        train_proj_labels = trainLabels.flatten()[:i]
        test_proj_labels = testLabels.flatten()

        xtrain, ytrain, xtest, ytest = train_proj.T, train_proj_labels, test_proj.T, test_p

        model = KNeighborsClassifier()
        model.fit(xtrain,ytrain)
        expected = ytest
        predicted = model.predict(xtest)
        accuracy = accuracy_score(expected, predicted)

        train_size3.append(i)
        accuracy_measure3.append(accuracy)

    print("For all the Eigen Vectors: ")
    print("TrainImages Size:" + str(train_size3)), print("Accuracy: "+str(accuracy_measure3
```

```
/Library/Frameworks/Python.framework/Versions/3.5/lib/python3.5/site-packages/numpy/core/numeric
  return array(a, dtype, copy=False, order=order)
/Library/Frameworks/Python.framework/Versions/3.5/lib/python3.5/site-packages/sklearn/utils/vali
  array = np.array(array, dtype=dtype, order=order, copy=copy)


For all the Eigen Vectors:
TrainImages Size:[40, 90, 140, 190, 240, 290, 340, 390, 440, 490, 540, 590, 640, 690, 740]
Accuracy: [0.48399999999999999, 0.61150000000000004, 0.67769999999999997, 0.70289999999999997, 0


Out[46]: (None, None)
```

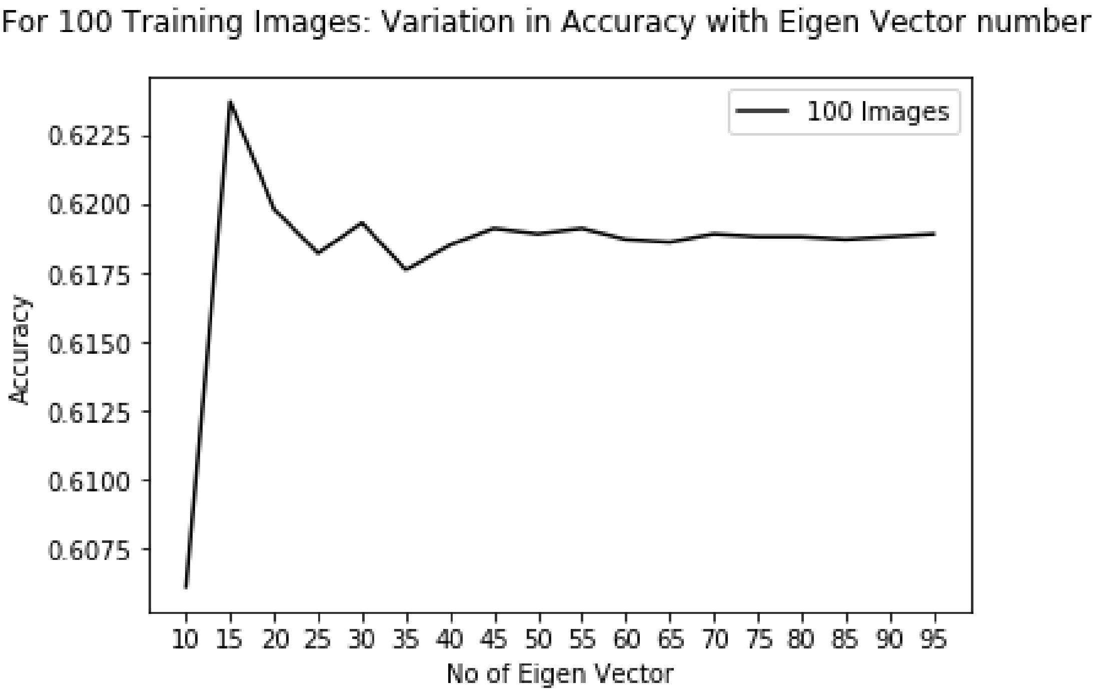
```
In [47]: plot3= plt.plot(train_size3, accuracy_measure3, '-', c = ('black'), label = 'All Eig')
         plt.suptitle('For All the Eigen Vectors: Variation in Accuracy with train Image number'
         plt.xlabel('No of Training Image')
         plt.ylabel('Accuracy of the Model')
         plt.xticks(train_size3)
         plt.legend()
         plt.show()
```



```
In [ ]:
```

1.4 Using 100 Training Images and varying Eigen Vector size from 10 to maximum value

```
In [48]: accuracy_measure4 = []
         eig_size4 = []
         train_size = 100
         for v in range(10,train_size,int(train_size/20)):
             trainImages = images['trainImages']
             trainLabels = images['trainLabels']
             testImages = images['testImages']
             testLabels = images['testLabels']

             trainImages = trainImages.reshape(784, 60000)
             testImages = testImages.reshape(784, 10000)
             train = trainImages[:,:train_size] #Taking differnt no of Images for analysis

             train_ave = train.mean(1)
             train_ave = train_ave.reshape(train_ave.size,1)

             train_final = train - train_ave
             test_final = testImages - train_ave

             B = np.matmul(train_final.T, train_final)

             val, vec = LA.eig(B)
             val_sorted = np.sort(val)
             vec_sorted = vec[:, val.argsort()[::-1]]

             eig_cov = np.dot(train_final,vec_sorted)  #train_size X 784 #matmul and dot does th

             eig_cov = eig_cov[:,:v]

             eig_cov_t = eig_cov.T

             train_proj = np.dot(eig_cov_t, train_final)
             test_proj = np.dot(eig_cov_t, test_final)

             train_proj_labels = trainLabels.flatten()[:train_size]
             test_proj_labels = testLabels.flatten()

             xtrain, ytrain, xtest, ytest = train_proj.T, train_proj_labels, test_proj.T, test_p

             model = KNeighborsClassifier()
             model.fit(xtrain,ytrain)
             expected = ytest
             predicted = model.predict(xtest)
             accuracy = accuracy_score(expected, predicted)

             eig_size4.append(v)
             accuracy_measure4.append(accuracy)

         print("For 100 Training Images :")
         print("eig_size: " + str(eig_size4)), print("accuracy:" + str(accuracy_measure4))

For 100 Training Images :
eig_size: [10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95]
accuracy:[0.6060999999999997, 0.6237000000000003, 0.6198000000000002, 0.6181999999999997, 0.


Out[48]: (None, None)

In [49]: plot4 = plt.plot(eig_size4, accuracy_measure4, '-', c = ('black'), label = '100 Images'
         plt.suptitle('For 100 Training Images: Variation in Accuracy with Eigen Vector number')
         plt.xlabel('No of Eigen Vector')
         plt.ylabel('Accuracy')
         plt.xticks(eig_size4)
         plt.legend()
         plt.savefig('plot1.png', dpi = 100)
         plt.show()
```

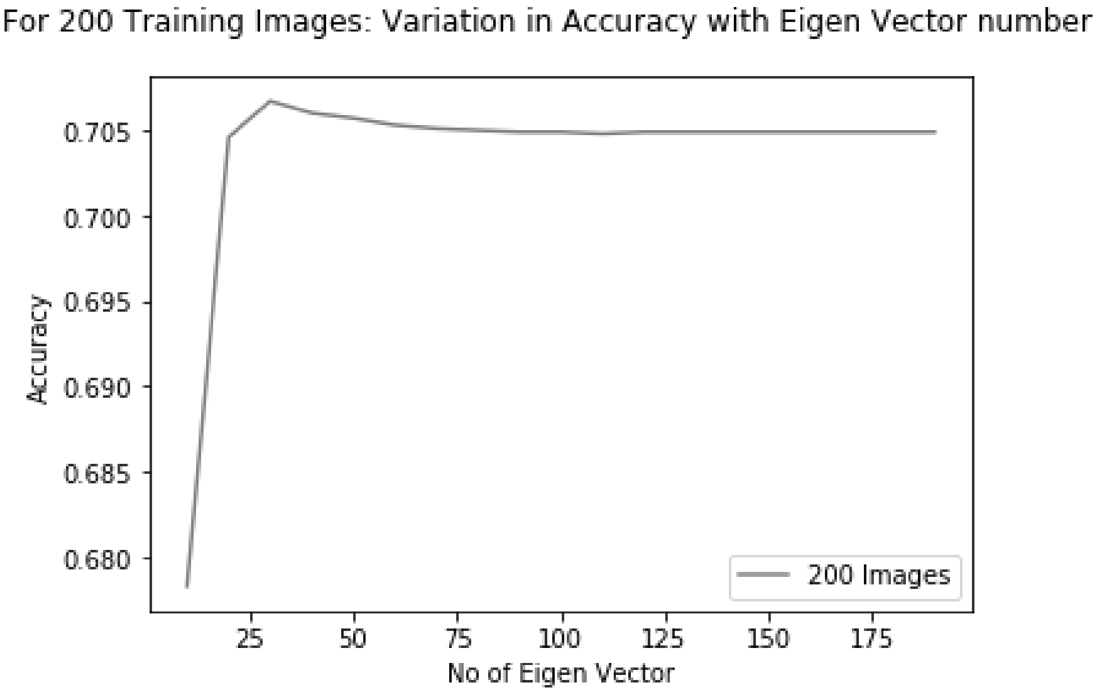


```
In [ ]:
```

1.5 Using 200 Training Images and varying Eigen Vector size from 10 to maximum value

```
In [50]: accuracy_measure5 = []
         eig_size5 = []
         train_size = 200
         for v in range(10,train_size,int(train_size/20)):
             trainImages = images['trainImages']
             trainLabels = images['trainLabels']
             testImages = images['testImages']
             testLabels = images['testLabels']

             trainImages = trainImages.reshape(784, 60000)
             testImages = testImages.reshape(784, 10000)
             train = trainImages[:,:train_size] #Taking differnt no of Images for analysis

             train_ave = train.mean(1)
             train_ave = train_ave.reshape(train_ave.size,1)

             train_final = train - train_ave
             test_final = testImages - train_ave

             B = np.matmul(train_final.T, train_final)

             val, vec = LA.eig(B)
             val_sorted = np.sort(val)
             vec_sorted = vec[:, val.argsort()[::-1]]

             eig_cov = np.dot(train_final,vec_sorted)  #train_size X 784 #matmul and dot does th

             eig_cov = eig_cov[:,:v]

             eig_cov_t = eig_cov.T

             train_proj = np.dot(eig_cov_t, train_final)
             test_proj = np.dot(eig_cov_t, test_final)

             train_proj_labels = trainLabels.flatten()[:train_size]
             test_proj_labels = testLabels.flatten()

             xtrain, ytrain, xtest, ytest = train_proj.T, train_proj_labels, test_proj.T, test_p

             model = KNeighborsClassifier()
             model.fit(xtrain,ytrain)
             expected = ytest
             predicted = model.predict(xtest)
             accuracy = accuracy_score(expected, predicted)

             eig_size5.append(v)
             accuracy_measure5.append(accuracy)

         print("For 200 Training Images :")
         print("eig_size: " + str(eig_size5)), print("accuracy:" + str(accuracy_measure5))

For 200 Training Images :
eig_size: [10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190]
accuracy:[0.6783000000000001, 0.7046, 0.7066999999999999, 0.7059999999999996, 0.7056999999999


Out[50]: (None, None)

In [51]: plot5= plt.plot(eig_size5, accuracy_measure5, '-', c = ('gray'), label = '200 Images')
```

```
plt.suptitle('For 200 Training Images: Variation in Accuracy with Eigen Vector number')
plt.xlabel('No of Eigen Vector')
plt.ylabel('Accuracy')
plt.legend()
plt.savefig('plot2.png', dpi = 100)
plt.show()
```



```
In [ ]:
```

```
In [ ]:
```

1.6 Using 500 Training Images and varying Eigen Vector size from 10 to maximum value

```
In [52]: accuracy_measure6 = []
         eig_size6 = []
         train_size = 500
         for v in range(10,train_size,int(train_size/20)):
             trainImages = images['trainImages']
             trainLabels = images['trainLabels']
             testImages = images['testImages']
             testLabels = images['testLabels']

             trainImages = trainImages.reshape(784, 60000)
             testImages = testImages.reshape(784, 10000)
```

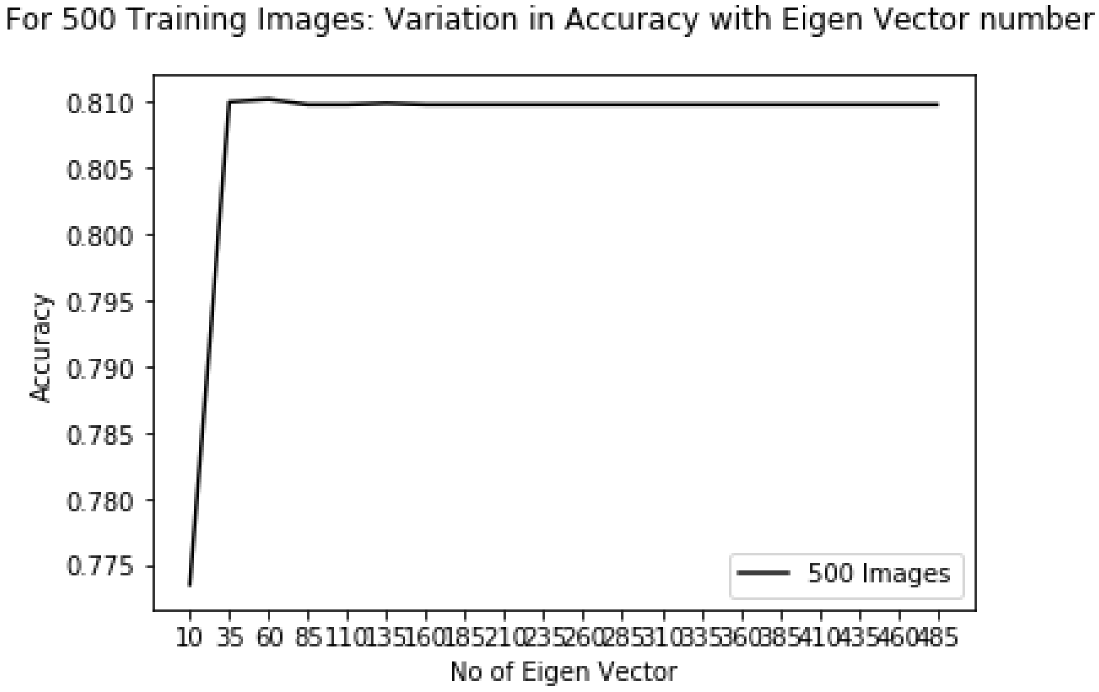
```
    train = trainImages[:,:train_size] #Taking differnt no of Images for analysis

    train_ave = train.mean(1)
    train_ave = train_ave.reshape(train_ave.size,1)

    train_final = train - train_ave
    test_final = testImages - train_ave

    B = np.matmul(train_final.T, train_final)

    val, vec = LA.eig(B)
    val_sorted = np.sort(val)
    vec_sorted = vec[:, val.argsort()[::-1]]

    eig_cov = np.dot(train_final,vec_sorted)  #train_size X 784 #matmul and dot does th

    eig_cov = eig_cov[:,:v]

    eig_cov_t = eig_cov.T

    train_proj = np.dot(eig_cov_t, train_final)
    test_proj = np.dot(eig_cov_t, test_final)

    train_proj_labels = trainLabels.flatten()[:train_size]
    test_proj_labels = testLabels.flatten()

    xtrain, ytrain, xtest, ytest = train_proj.T, train_proj_labels, test_proj.T, test_p

    model = KNeighborsClassifier()
    model.fit(xtrain,ytrain)
    expected = ytest
    predicted = model.predict(xtest)
    accuracy = accuracy_score(expected, predicted)

    eig_size6.append(v)
    accuracy_measure6.append(accuracy)

print("For a Training Images of 500 numbers: ")
print("eig_size: " + str(eig_size6)), print("accuracy:" + str(accuracy_measure6))
```

```
For a Training Images of 500 numbers:
eig_size: [10, 35, 60, 85, 110, 135, 160, 185, 210, 235, 260, 285, 310, 335, 360, 385, 410, 435,
accuracy:[0.77349999999999997, 0.81000000000000005, 0.81020000000000003, 0.80979999999999996, 0.
```

```
Out[52]: (None, None)
```

```
In [53]: plot6= plt.plot(eig_size6, accuracy_measure6, '-', c = ('black'), label = '500 Images')
```

```
plt.suptitle('For 500 Training Images: Variation in Accuracy with Eigen Vector number')
plt.xlabel('No of Eigen Vector')
plt.ylabel('Accuracy')
plt.xticks(eig_size6)
plt.legend()
plt.show()
```



In [ ]:

1.7 Using 700 Training Images and varying Eigen Vector size from 10 to maximum value

In [54]:
```
accuracy_measure7 = []
eig_size7 = []
train_size = 700
for v in range(10,train_size,int(train_size/20)):
    trainImages = images['trainImages']
    trainLabels = images['trainLabels']
    testImages = images['testImages']
    testLabels = images['testLabels']

    trainImages = trainImages.reshape(784, 60000)
    testImages = testImages.reshape(784, 10000)
```

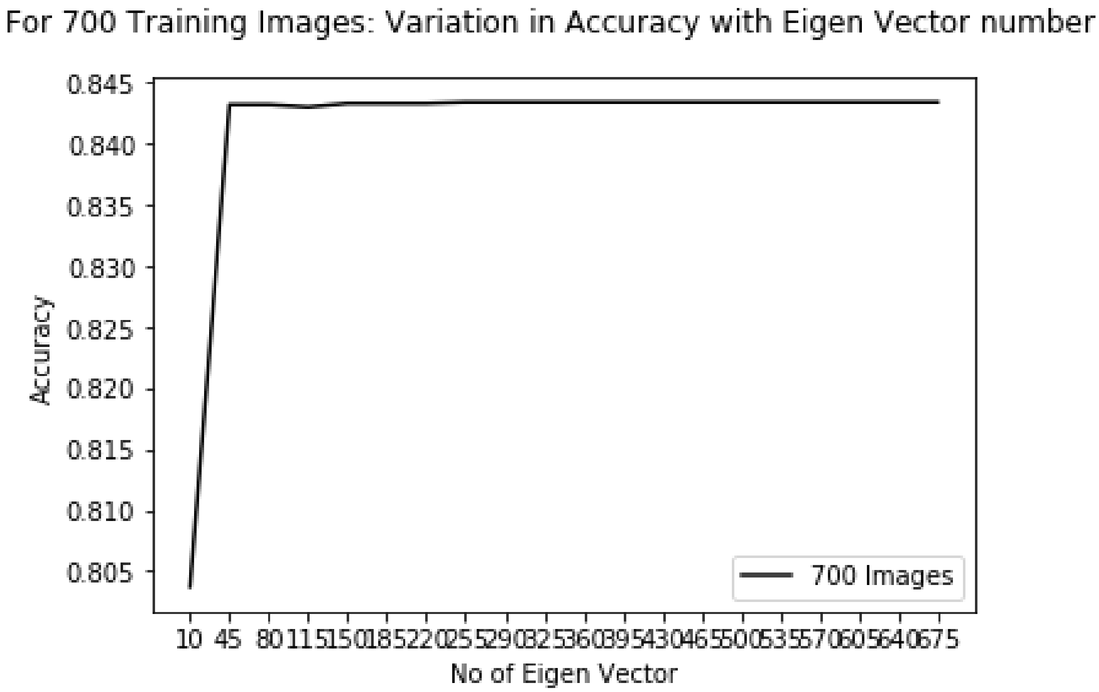
```
            train = trainImages[:,:train_size] #Taking differnt no of Images for analysis

            train_ave = train.mean(1)
            train_ave = train_ave.reshape(train_ave.size,1)

            train_final = train - train_ave
            test_final = testImages - train_ave

            B = np.matmul(train_final.T, train_final)

            val, vec = LA.eig(B)
            val_sorted = np.sort(val)
            vec_sorted = vec[:, val.argsort()[::-1]]

            eig_cov = np.dot(train_final,vec_sorted)  #train_size X 784 #matmul and dot does th

            eig_cov = eig_cov[:,:v]

            eig_cov_t = eig_cov.T

            train_proj = np.dot(eig_cov_t, train_final)
            test_proj = np.dot(eig_cov_t, test_final)

            train_proj_labels = trainLabels.flatten()[:train_size]
            test_proj_labels = testLabels.flatten()

            xtrain, ytrain, xtest, ytest = train_proj.T, train_proj_labels, test_proj.T, test_p

            model = KNeighborsClassifier()
            model.fit(xtrain,ytrain)
            expected = ytest
            predicted = model.predict(xtest)
            accuracy = accuracy_score(expected, predicted)

            eig_size7.append(v)
            accuracy_measure7.append(accuracy)

        print("For 700 Training Images of  : ")
        print("eig_size: " + str(eig_size7)), print("accuracy:" + str(accuracy_measure7))
```

```
/Library/Frameworks/Python.framework/Versions/3.5/lib/python3.5/site-packages/numpy/core/numeric
  return array(a, dtype, copy=False, order=order)
/Library/Frameworks/Python.framework/Versions/3.5/lib/python3.5/site-packages/sklearn/utils/vali
  array = np.array(array, dtype=dtype, order=order, copy=copy)


For 700 Training Images of  :
eig_size: [10, 45, 80, 115, 150, 185, 220, 255, 290, 325, 360, 395, 430, 465, 500, 535, 570, 605
```

```
accuracy:[0.80369999999999997, 0.84319999999999995, 0.84319999999999995, 0.84299999999999997, 0.
```

```
Out[54]: (None, None)
```

```
In [55]: plot7= plt.plot(eig_size7, accuracy_measure7, '-', c = ('black'), label = '700 Images')
         plt.suptitle('For 700 Training Images: Variation in Accuracy with Eigen Vector number')
         plt.xlabel('No of Eigen Vector')
         plt.ylabel('Accuracy')
         plt.xticks(eig_size7)
         plt.legend()
         plt.show()
```

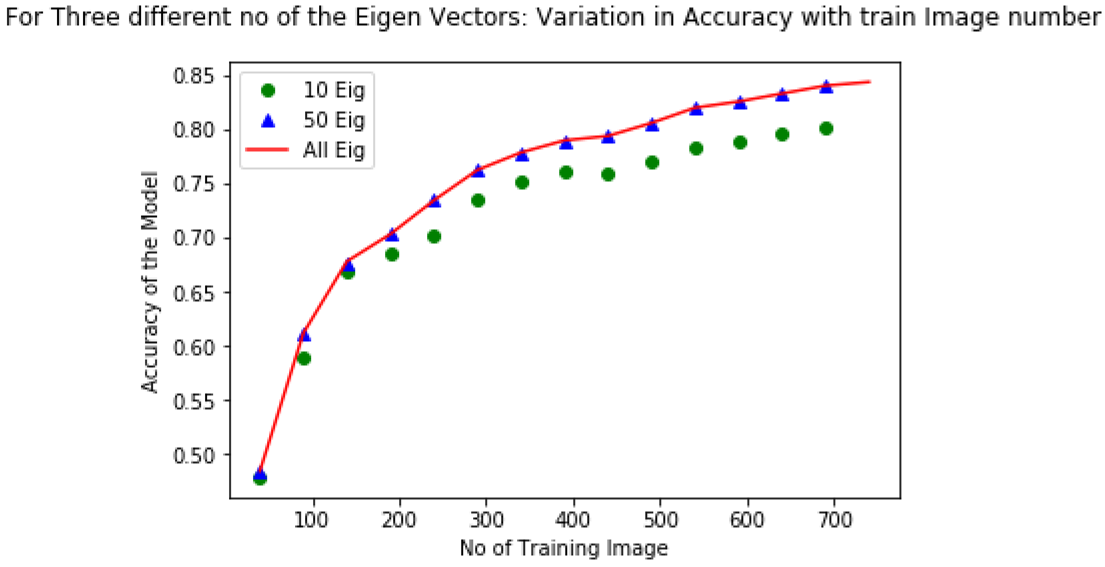


```
In [ ]:
```

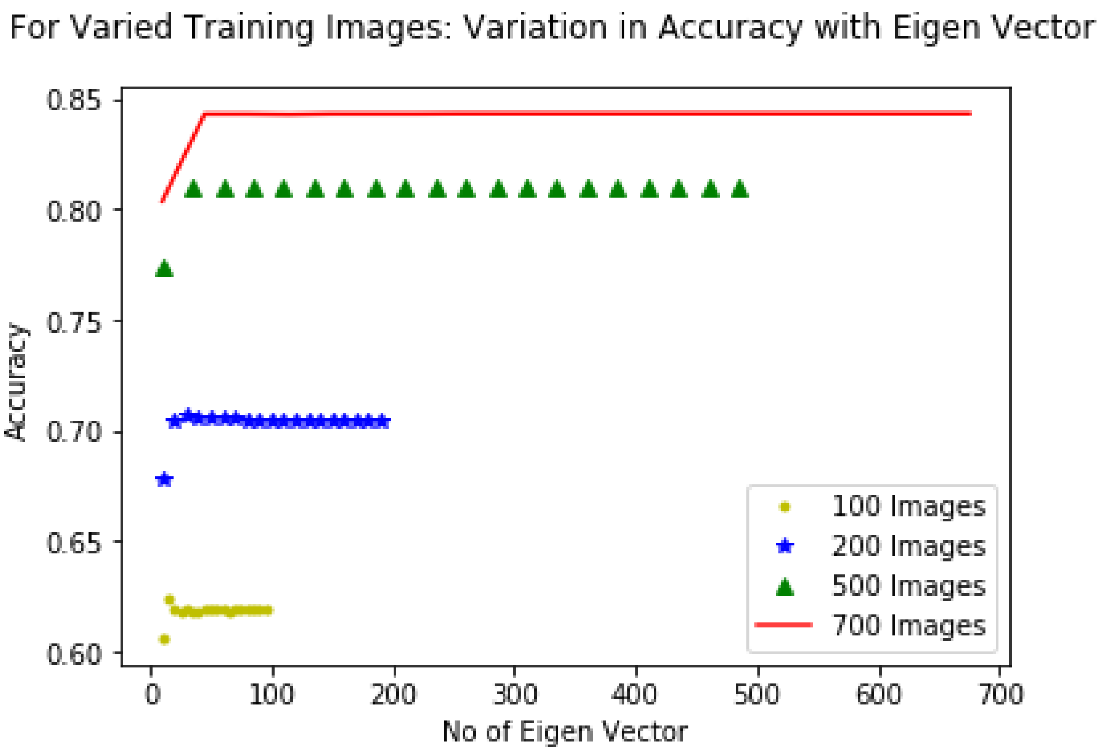
```
In [56]: ## Let's have a comparative plot of various training size with fix no of eigen vectors
```

```
In [57]: plt.plot(train_size1, accuracy_measure1, 'go', label = '10 Eig')
         plt.plot(train_size2, accuracy_measure2, 'b^', label = '50 Eig')
         plt.plot(train_size3, accuracy_measure3, 'r-', label = 'All Eig' )

         plt.suptitle('For Three different no of the Eigen Vectors: Variation in Accuracy with t
         plt.xlabel('No of Training Image')
         plt.ylabel('Accuracy of the Model')
         plt.legend()
```

```
        plt.savefig('plot3.png', dpi = 100)


        plt.show()
```

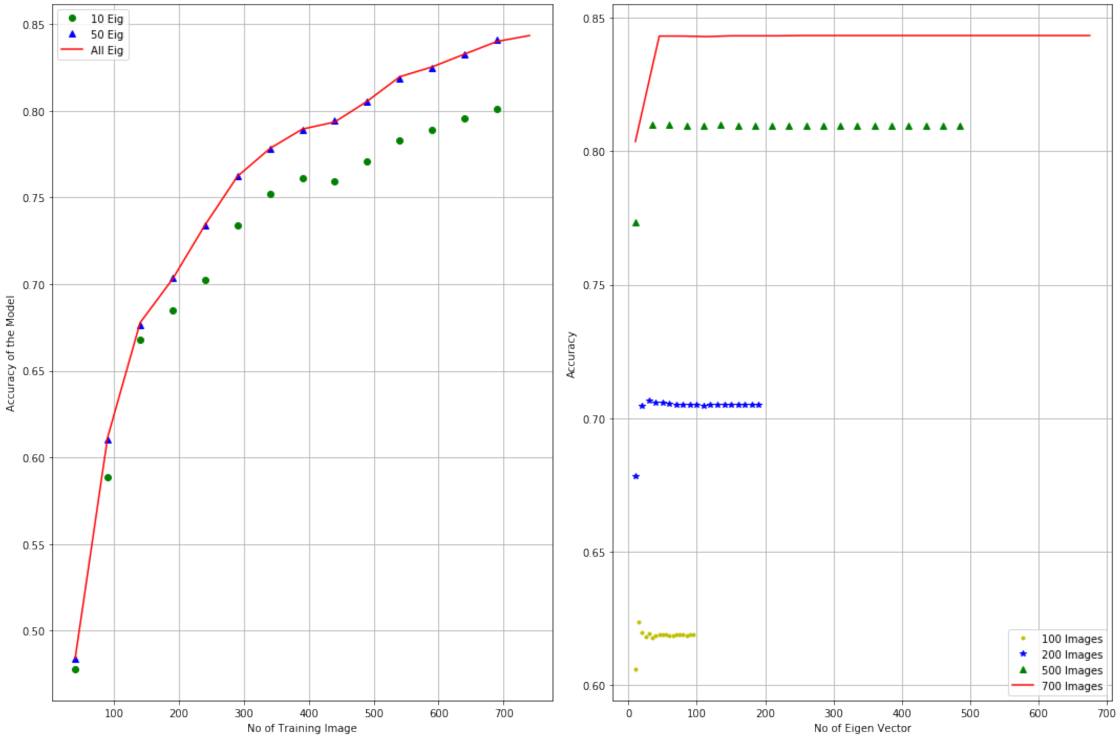


```
In [58]: plt.plot(eig_size4, accuracy_measure4, 'y.', label = '100 Images')
         plt.plot(eig_size5, accuracy_measure5, 'b*', label = '200 Images')
         plt.plot(eig_size6, accuracy_measure6, 'g^', label = '500 Images')
         plt.plot(eig_size7, accuracy_measure7, 'r-', label = '700 Images')

         plt.suptitle('For Varied Training Images: Variation in Accuracy with Eigen Vector')
         plt.xlabel('No of Eigen Vector')
         plt.ylabel('Accuracy')

         plt.legend()
         plt.savefig('plot4.png', dpi = 100)
         plt.show()
```



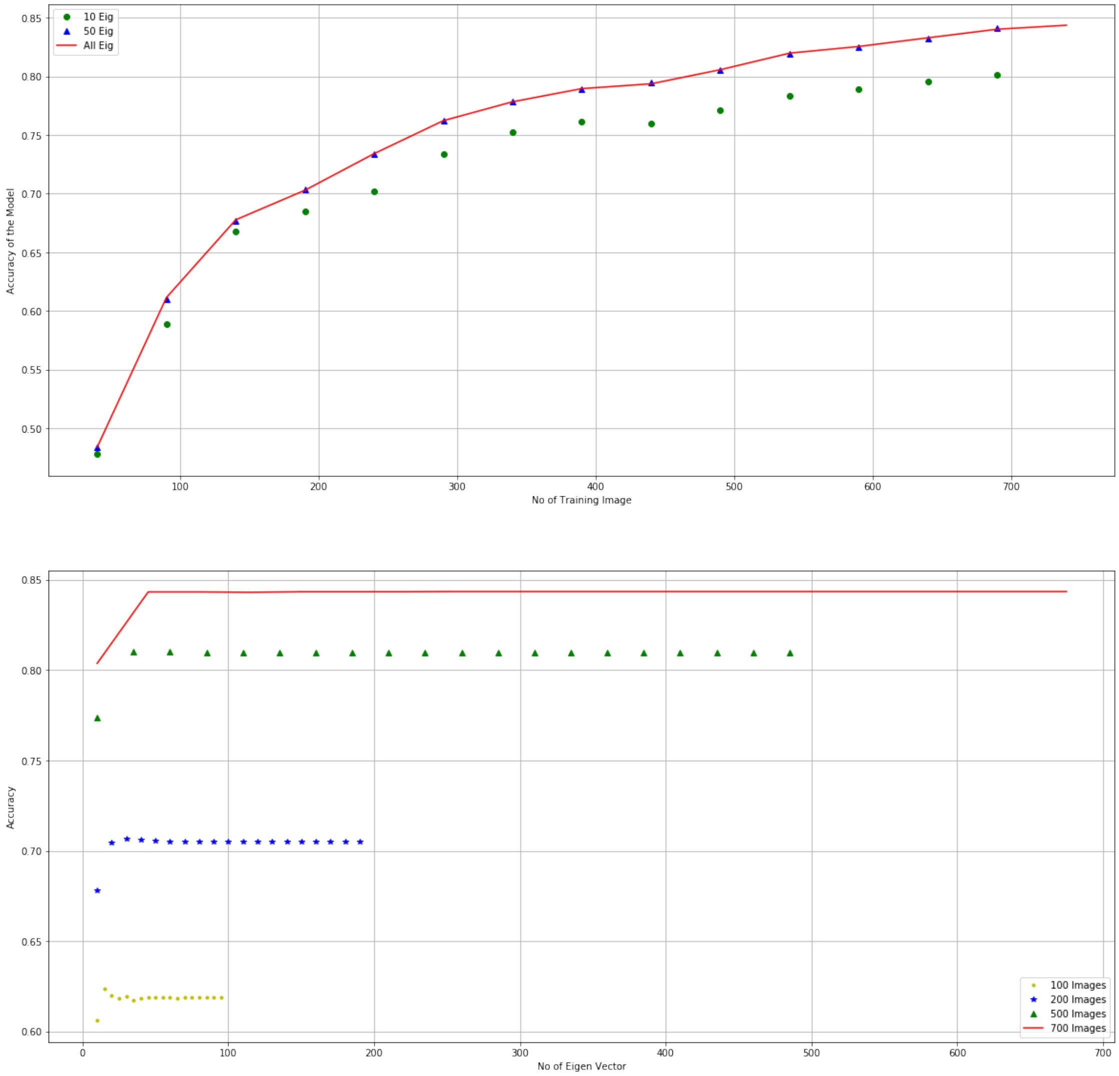
```
In [59]: fig1 = plt.figure(figsize=(15,10))
         #plt.subplots(1,2)
         plt.subplot(121)

         plt.plot(train_size1, accuracy_measure1, 'go', label = '10 Eig')
         plt.plot(train_size2, accuracy_measure2, 'b^', label = '50 Eig')
         plt.plot(train_size3, accuracy_measure3, 'r-', label = 'All Eig' )

         #plt.suptitle('For Three different no of the Eigen Vectors: Variation in Accuracy with
         plt.xlabel('No of Training Image')
         plt.ylabel('Accuracy of the Model')
         plt.legend()
         plt.grid(True)


         plt.subplot(122)

         plt.plot(eig_size4, accuracy_measure4, 'y.', label = '100 Images')
         plt.plot(eig_size5, accuracy_measure5, 'b*', label = '200 Images')
         plt.plot(eig_size6, accuracy_measure6, 'g^', label = '500 Images')
         plt.plot(eig_size7, accuracy_measure7, 'r-', label = '700 Images')

         #plt.suptitle('For Varied Training Images: Variation in Accuracy with Eigen Vector')
```

```
plt.xlabel('No of Eigen Vector')
plt.ylabel('Accuracy')

plt.tight_layout()
plt.grid(True)
plt.legend()
plt.savefig('plot5.png', dpi = 100)
plt.show()
```



```
In [60]: fig1 = plt.figure(figsize=(20,20))
         #plt.subplots(1,2)
         ax1=plt.subplot(211)

         ax1.plot(train_size1, accuracy_measure1, 'go', label = '10 Eig')
         ax1.plot(train_size2, accuracy_measure2, 'b^', label = '50 Eig')
         ax1.plot(train_size3, accuracy_measure3, 'r-', label = 'All Eig')
         #ax1.set_xlim(train_size3)



         plt.suptitle('For Three different no of the Eigen Vectors: Variation in Accuracy with t
         plt.xlabel('No of Training Image')
         plt.ylabel('Accuracy of the Model')
         plt.legend()
         plt.grid(True)


         ax2=plt.subplot(212)

         ax2.plot(eig_size4, accuracy_measure4, 'y.', label = '100 Images')
         ax2.plot(eig_size5, accuracy_measure5, 'b*', label = '200 Images')
         ax2.plot(eig_size6, accuracy_measure6, 'g^', label = '500 Images')
         ax2.plot(eig_size7, accuracy_measure7, 'r-', label = '700 Images')
         #plt.set_xlim(eig_size7)



         plt.suptitle('For Varied Training Images: Variation in Accuracy with Eigen Vector')
         plt.xlabel('No of Eigen Vector')
         plt.ylabel('Accuracy')

         #plt.tight_layout
         plt.legend()
         plt.grid(True)
         plt.show()
```

For Varied Training Images: Variation in Accuracy with Eigen Vector



```
In [ ]:
```