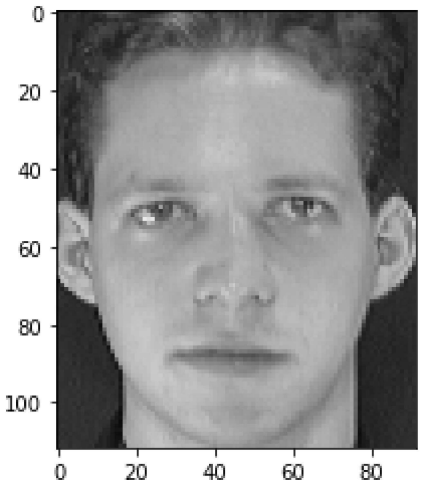
In [1]:

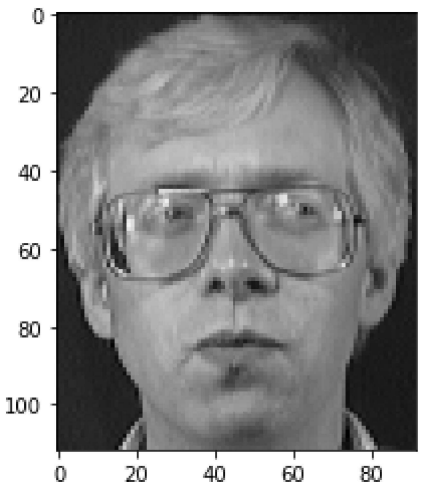
```
# importing libraries

import numpy as np
from PIL import Image
%pylab inline
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
import cv2
```

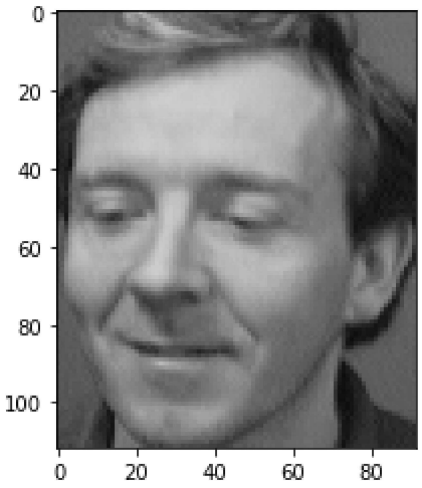
```
Populating the interactive namespace from numpy and matplotlib
```

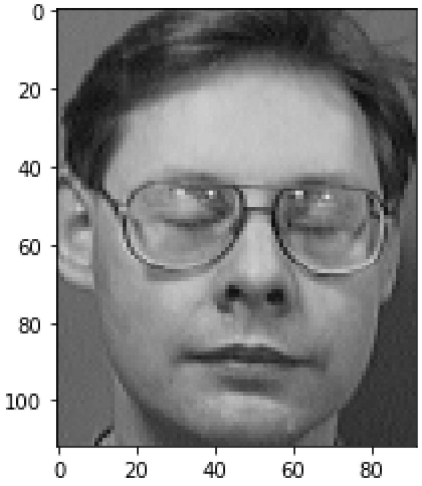
In [2]:

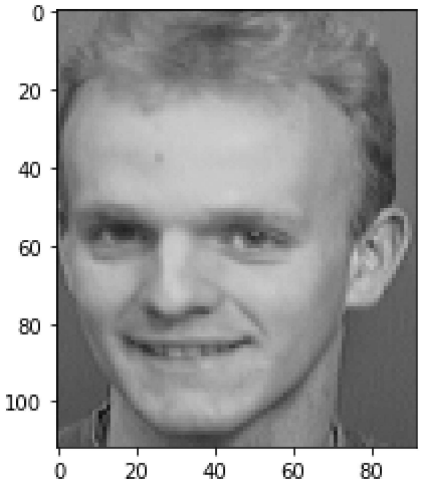
```
# displaying some sample images from random folders

base_path = 'facial_data/Datasets/att_faces_combined/'

img=cv2.imread(base_path + 's1/1.pgm')
imgplot = plt.imshow(img)
plt.show()

img=cv2.imread(base_path + 's2/3.pgm')
imgplot = plt.imshow(img)
plt.show()

img=cv2.imread(base_path + 's3/5.pgm')
imgplot = plt.imshow(img)
plt.show()

img=cv2.imread(base_path + 's4/9.pgm')
imgplot = plt.imshow(img)
plt.show()

img=cv2.imread(base_path + 's5/6.pgm')
imgplot = plt.imshow(img)
plt.show()

leny, lenx, z = img.shape
```






0
20
40
60
80
100
0
20
40
60
80


0
20
40
60
80
100
0
20
40
60
80


0
20
40
60
80
100
0
20
40
60
80

In [3]:

```
# creating feature vector for images from training

def create_feature_vec(num_train) :

    feature_vector = []
    for i in range(1, 41) : # for each folder
        folder_path = base_path + 's' + str(i) + '/'
        for j in range(1, num_train + 1) : # for each image inside the folder si
            img_path = folder_path + str(j) + '.pgm'
            im = Image.open(img_path)
            pix = im.load()

            img_row = []
            for x in range(lenx) :
                for y in range(leny) :
                    img_row.append(pix[x, y])

            feature_vector.append(img_row)

    feature_vector = np.array(feature_vector)
    feature_vector_T = np.transpose(feature_vector)
    print("feature vector = ", feature_vector)
    print("shape of feature vector = ", feature_vector.shape)
    print("\n")

    return feature_vector
```

In [4]:

```
# mean vector

def create_mean_vec(feature_vector) :

    mean = np.mean(feature_vector, axis = 0)
    mean_T = np.transpose(mean)
    print("mean vector = ", mean)
    print("shape of mean vector = ", mean.shape)
    print("\n")
    return mean, mean_T
```

In [5]:

```
# deviation matrix

def create_dev_mat(feature_vector, mean) :

    dev_mat = feature_vector - mean
    dev_mat_T = np.transpose(dev_mat)
    print("deviation matrix = ", dev_mat)
    print("shape of deviation matrix = ", dev_mat.shape)
    print("\n")
    return dev_mat, dev_mat_T
```

In [6]:

```
# covariance matrix

def create_cov_matrix(dev_mat, dev_mat_T) :

    cov_mat = np.dot(dev_mat, dev_mat_T)
    print("covariance matrix = ", cov_mat)
    print("shape of covariance matrix = ", cov_mat.shape)
    print("\n")
    return cov_mat
```

In [7]:

```
# eigenvalues and eigenvectors

def create_eig_val_vec(cov_mat) :

    eigen_val, eigen_vec = np.linalg.eig(cov_mat)

    eigen_val_s = np.sort(eigen_val)
    eigen_vec_s = eigen_vec[:, eigen_val.argsort()]
    eigen_vec_s = np.fliplr(eigen_vec_s)

    eigen_vec = eigen_vec_s
    eigen_val = eigen_val_s

    print("shape of eigen values vector -->",eigen_val.shape)
    print("shape of eigen vector matrix -->",eigen_vec.shape)
    print("\n")

    return eigen_val, eigen_vec
```

In [8]:

```
def select_k_eigenvectors(eigen_vec, k) :
    return eigen_vec[:, :k]
```

In [9]:

```
def create_eigen_faces(dec_feature_vec, dev_mat) :
    eig_face = np.dot(np.transpose(dec_feature_vec), dev_mat)
    return eig_face
```

In [10]:

```
def signature_each_face(eig_face, dev_mat_T) :
    sig_face = np.dot(eig_face, dev_mat_T)
    return sig_face
```

In [11]:

```
def prediction_vec(proj_test_face, sig_face, k, num_test, num_train) :
    min_idx_each_img = []

    for i in range(num_test * 40) : # for each test image
        test_img_proj = proj_test_face[:, i]
        test_img_proj = np.reshape(test_img_proj, (k, 1))

        dist_vec = []

        for j in range(num_train * 40) : # for each signature of training images
            sig_each_face = sig_face[:, j]
            sig_each_face = np.reshape(sig_each_face, (k, 1))
            dist_vec.append(euclidean_dist(test_img_proj, sig_each_face))

        dist_vec = np.array(dist_vec)
        #print(dist_vec)
        min_dist = dist_vec[0]
        min_idx = 0

        for j in range(len(dist_vec)) :
            if dist_vec[j] < min_dist :
                min_dist = dist_vec[j]
                min_idx = j
        min_idx_each_img.append(min_idx // num_train + 1)
    return min_idx_each_img
```

In [12]:

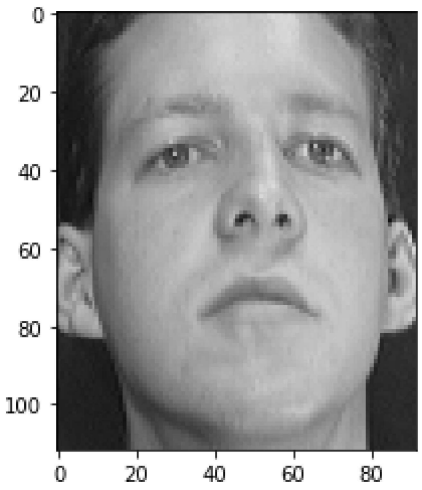
```
def euclidean_dist(a, b) :
    dist = a - b
    sq_dist = np.dot(np.transpose(dist), dist)
    sq_dist = np.sqrt(sq_dist)
    return sq_dist
```

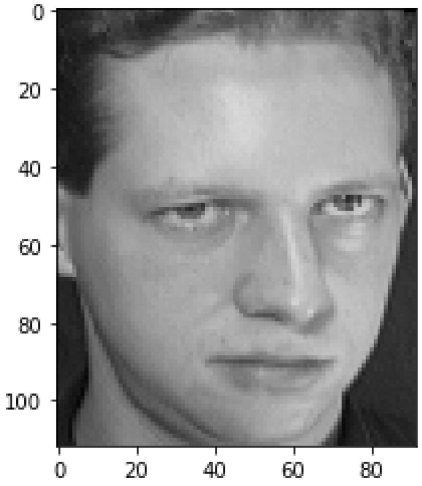
In [13]:

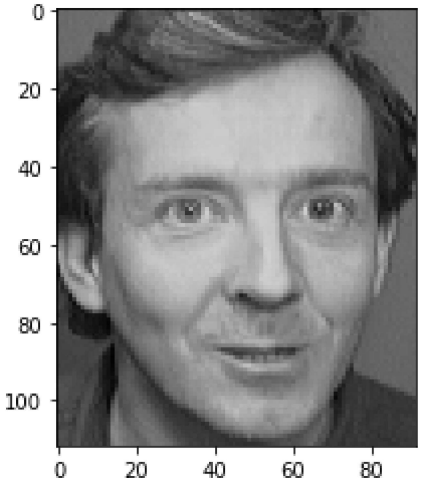
```
# creating testing vector
def create_test_vec(num_test) :

    test_vec = list(range(1, 41))
    test_vec =  [ele for ele in test_vec for i in range(num_test)]

    print("expected values = ",test_vec)
    print("\n")

    return test_vec
```

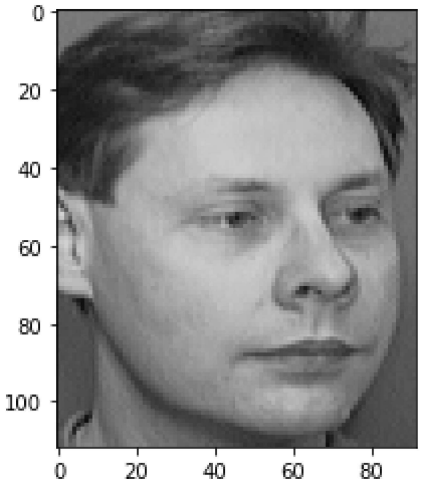
In [14]:

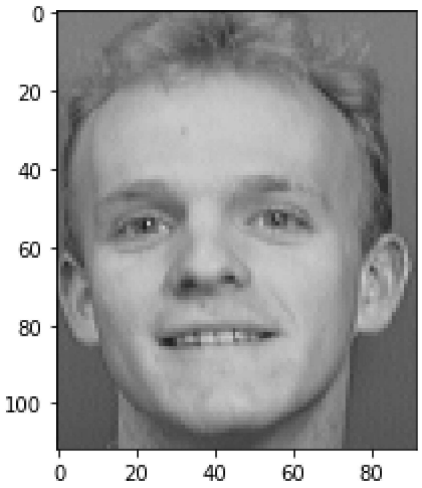
```
# displaying some sample images from random folders

img=cv2.imread(base_path + 's1/9.pgm')
imgplot = plt.imshow(img)
plt.show()

img=cv2.imread(base_path + 's1/10.pgm')
imgplot = plt.imshow(img)
plt.show()

img=cv2.imread(base_path + 's3/10.pgm')
imgplot = plt.imshow(img)
plt.show()

img=cv2.imread(base_path + 's4/10.pgm')
imgplot = plt.imshow(img)
plt.show()

img=cv2.imread(base_path + 's5/10.pgm')
imgplot = plt.imshow(img)
plt.show()
```




0
20
40
60
80
100
0
20
40
60
80


0
20
40
60
80
100
0
20
40
60
80


0
20
40
60
80
100
0
20
40
60
80



In [15]:

```
# create the test matrix

def create_test_matrix(num_train) :

    test_mat = []
    for i in range(1, 41) : # for each folder
        folder_path = base_path + 's' + str(i) + '/'
        for j in range(num_train + 1, 11) :

            img_path = folder_path + str(j) + '.pgm'
            im = Image.open(img_path)
            pix = im.load()

            img_row = []
            for x in range(lenx) :
                for y in range(leny) :
                    img_row.append(pix[x, y])

            test_mat.append(img_row)

    test_mat = np.array(test_mat)
    print("test matrix = ", test_mat)
    print("shape of test matrix = ", test_mat.shape)
    print("\n")
    return test_mat
```

In [16]:

```
# mean zero

def create_mean_zero_test(test_mat, mean) :

    dev_test_mat = test_mat - mean
    dev_test_mat_T = np.transpose(dev_test_mat)
    print("mean zero test matrix = ", dev_test_mat)
    print("shape of mean zero test matrix = ", dev_test_mat.shape)
    print("\n")
    return dev_test_mat, dev_test_mat_T
```

In [17]:

```
# final testing

def testing_for_k(k, eigen_vec, dev_mat, dev_mat_T, dev_test_mat_T, num_test, num_train) :

    dec_feature_vec = select_k_eigenvectors(eigen_vec, k)

    eig_face = create_eigen_faces(dec_feature_vec, dev_mat)

    sig_face = signature_each_face(eig_face, dev_mat_T)

    proj_test_face = np.dot(eig_face, dev_test_mat_T)

    min_idx_each_img = prediction_vec(proj_test_face, sig_face, k, num_test, num_train)

    return min_idx_each_img
```

In [18]:

```
# calculating accuracy

def accuracy(min_idx_each_img, test_vec, num_test) :
    count = 0
    for i in range(num_test * 40) :
        if min_idx_each_img[i] == test_vec[i] :
            count = count + 1
    return (count / (num_test * 40)) * 100
```

In [19]:

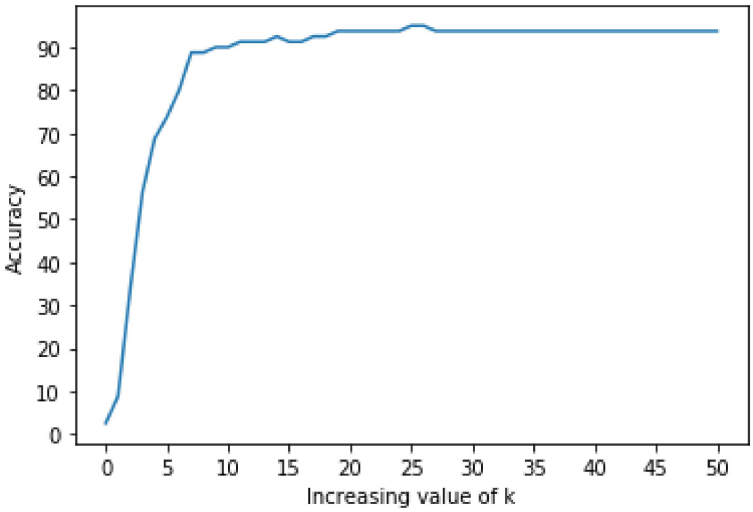
```
# output for various train-test split cases

def diff_cases(num_train, num_test) :

    # getting feature vector
    feature_vector = create_feature_vec(num_train)

    # getting mean
    mean, mean_T = create_mean_vec(feature_vector)

    # getting deaviation matrix
    dev_mat, dev_mat_T = create_dev_mat(feature_vector, mean)

    # getting covariance matrix
    cov_mat = create_cov_matrix(dev_mat, dev_mat_T)

    # getting eigen values and eigen vectors
    eigen_val, eigen_vec = create_eig_val_vec(cov_mat)

    # getting test matrix
    test_mat = create_test_matrix(num_train)

    # getting deviation test matrix
    dev_test_mat, dev_test_mat_T = create_mean_zero_test(test_mat, mean)

    # getting actual test values
    test_vec = create_test_vec(num_test)

    # accuracy for k values

    k_val = []
    acc_val = []
    for k in range(51) :
        min_idx_each_img = testing_for_k(k, eigen_vec, dev_mat, dev_mat_T, dev_test_mat_T,

        k_val.append(k)
        acc_val.append(accuracy(min_idx_each_img, test_vec, num_test))

    print("Plotting accuracy vs k")
    plt.plot(k_val, acc_val)
    plt.xlabel('Increasing value of k')
    plt.ylabel('Accuracy')

    plt.xticks(np.arange(min(k_val), max(k_val) + 1, 5.0))
    plt.yticks(np.arange(0, 100, 10.0))

    plt.show()

    print("maximum accuracy for {}-{} split = {}".format(num_train * 10, num_test * 10, max
```

In [20]:

```
diff_cases(8, 2)
```

```
feature vector =  [[ 48  45  45 ...  46  47  46]
 [ 60  58  68 ...  33  31  34]
 [ 39  44  59 ...  28  27  29]
 ...
 [123 128 126 ...  44  39  42]
 [129 130 127 ...  95  92  93]
 [125 121 122 ...  43  35  40]]
shape of feature vector =  (320, 10304)


mean vector =  [85.503125 85.6      85.771875 ... 70.875    72.559375 73.562
5  ]
shape of mean vector =  (10304,)


deviation matrix =  [[-37.503125 -40.6      -40.771875 ... -24.875    -25.55
9375 -27.5625  ]
 [-25.503125 -27.6      -17.771875 ... -37.875    -41.559375 -39.5625  ]
 [-46.503125 -41.6      -26.771875 ... -42.875    -45.559375 -44.5625  ]
 ...
 [ 37.496875  42.4       40.228125 ... -26.875    -33.559375 -31.5625  ]
 [ 43.496875  44.4       41.228125 ...  24.125     19.440625  19.4375  ]
 [ 39.496875  35.4       36.228125 ... -27.875    -37.559375 -33.5625  ]]
shape of deviation matrix =  (320, 10304)


covariance matrix =  [[14520940.71233399  6843978.97170899  9707034.00920898
...
    294706.07795898  1300224.36233398    99196.94670898]
 [ 6843978.97170899 26651908.23108398 11024794.26858399 ...
   3346732.33733398  4259243.62170898  3341186.20608398]
 [ 9707034.00920898 11024794.26858399 19872676.30608398 ...
   2931904.37483398  2508087.65920898  2494977.24358399]
 ...
 [  294706.07795898  3346732.33733398  2931904.37483398 ...
  12580208.44358398  2599509.72795898  9276486.31233398]
 [ 1300224.36233398  4259243.62170898  2508087.65920898 ...
   2599509.72795898 11376294.01233399  2887470.59670898]
 [   99196.94670898  3341186.20608398  2494977.24358399 ...
   9276486.31233398  2887470.59670898 12637611.18108399]]
shape of covariance matrix =  (320, 320)


shape of eigen values vector --> (320,)
shape of eigen vector matrix --> (320, 320)


test matrix =  [[ 42  41  54 ...  40  39  41]
 [ 34  35  34 ...  41  39  33]
 [ 43  38  39 ...  28  31 141]
 ...
 [ 89  87  87 ... 107 107 109]
 [119 118 120 ...  88  92  85]
 [125 124 121 ...  35  32  34]]
shape of test matrix =  (80, 10304)
```

```
mean zero test matrix =  [[-43.503125 -44.6      -31.771875 ... -30.875    -
33.559375 -32.5625  ]
 [-51.503125 -50.6      -51.771875 ... -29.875    -33.559375 -40.5625  ]
 [-42.503125 -47.6      -46.771875 ... -42.875    -41.559375  67.4375  ]
 ...
 [  3.496875   1.4        1.228125 ...  36.125     34.440625  35.4375  ]
 [ 33.496875  32.4       34.228125 ...  17.125     19.440625  11.4375  ]
 [ 39.496875  38.4       35.228125 ... -35.875    -40.559375 -39.5625  ]]
shape of mean zero test matrix =  (80, 10304)


expected values =  [1, 1, 2, 2, 3, 3, 4, 4, 5, 5, 6, 6, 7, 7, 8, 8, 9, 9, 1
0, 10, 11, 11, 12, 12, 13, 13, 14, 14, 15, 15, 16, 16, 17, 17, 18, 18, 19, 1
9, 20, 20, 21, 21, 22, 22, 23, 23, 24, 24, 25, 25, 26, 26, 27, 27, 28, 28, 2
9, 29, 30, 30, 31, 31, 32, 32, 33, 33, 34, 34, 35, 35, 36, 36, 37, 37, 38, 3
8, 39, 39, 40, 40]


Plotting accuracy vs k
```



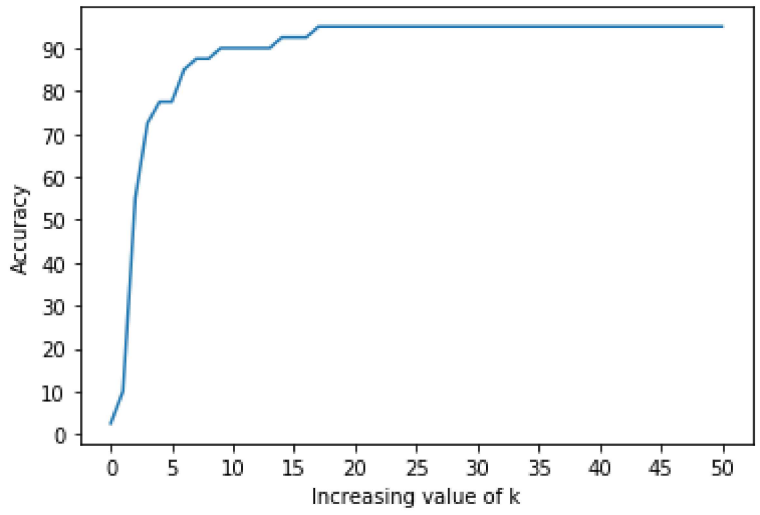

```
maximum accuracy for 80-20 split = 95.0
```

In [21]:

```
diff_cases(9, 1)
```

```
feature vector =  [[ 48  45  45 ...  46  47  46]
 [ 60  58  68 ...  33  31  34]
 [ 39  44  59 ...  28  27  29]
 ...
 [129 130 127 ...  95  92  93]
 [125 121 122 ...  43  35  40]
 [119 118 120 ...  88  92  85]]
shape of feature vector =  (360, 10304)


mean vector =  [85.45555556 85.55833333 85.78611111 ... 71.525      73.33055
556
 74.66944444]
shape of mean vector =  (10304,)


deviation matrix =  [[-37.45555556 -40.55833333 -40.78611111 ... -25.525
-26.33055556
  -28.66944444]
 [-25.45555556 -27.55833333 -17.78611111 ... -38.525      -42.33055556
  -40.66944444]
 [-46.45555556 -41.55833333 -26.78611111 ... -43.525      -46.33055556
  -45.66944444]
 ...
 [ 43.54444444  44.44166667  41.21388889 ...  23.475       18.66944444
   18.33055556]
 [ 39.54444444  35.44166667  36.21388889 ... -28.525      -38.33055556
  -34.66944444]
 [ 33.54444444  32.44166667  34.21388889 ...  16.475       18.66944444
   10.33055556]]
shape of deviation matrix =  (360, 10304)


covariance matrix =  [[14464163.56341821  6924880.48286266  9712023.39397376
...
   1253466.38841821    87144.9273071   2243818.38841821]
 [ 6924880.48286266 26870488.4023071  11167462.31341821 ...
   4350164.30786266  3466812.84675154  4504342.30786265]
 [ 9712023.39397376 11167462.31341821 19939432.22452931 ...
   2523096.21897377  2544691.75786265  3510941.21897377]
 ...
 [ 1253466.38841821  4350164.30786266  2523096.21897377 ...
  11339555.21341821  2885437.7523071   7321640.21341821]
 [   87144.9273071   3466812.84675154  2544691.75786265 ...
   2885437.7523071  12670284.29119598  1790997.7523071 ]
 [ 2243818.38841821  4504342.30786265  3510941.21897377 ...
   7321640.21341821  1790997.7523071  14044364.21341821]]
shape of covariance matrix =  (360, 360)


shape of eigen values vector --> (360,)
shape of eigen vector matrix --> (360, 360)


test matrix =  [[ 34  35  34 ...  41  39  33]
 [ 37  31  34 ...  27  67 133]
 [104 102 107 ...  57  56  59]
```

```
 ...
 [108 102 105 ...  46  80  48]
 [ 89  87  87 ... 107 107 109]
 [125 124 121 ...  35  32  34]]
shape of test matrix =  (40, 10304)


mean zero test matrix =  [[-51.45555556 -50.55833333 -51.78611111 ... -30.52
5      -34.33055556
  -41.66944444]
 [-48.45555556 -54.55833333 -51.78611111 ... -44.525       -6.33055556
   58.33055556]
 [ 18.54444444  16.44166667  21.21388889 ... -14.525      -17.33055556
  -15.66944444]
 ...
 [ 22.54444444  16.44166667  19.21388889 ... -25.525        6.66944444
  -26.66944444]
 [  3.54444444   1.44166667   1.21388889 ...  35.475       33.66944444
   34.33055556]
 [ 39.54444444  38.44166667  35.21388889 ... -36.525      -41.33055556
  -40.66944444]]
shape of mean zero test matrix =  (40, 10304)


expected values =  [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 1
7, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 3
6, 37, 38, 39, 40]


Plotting accuracy vs k
```



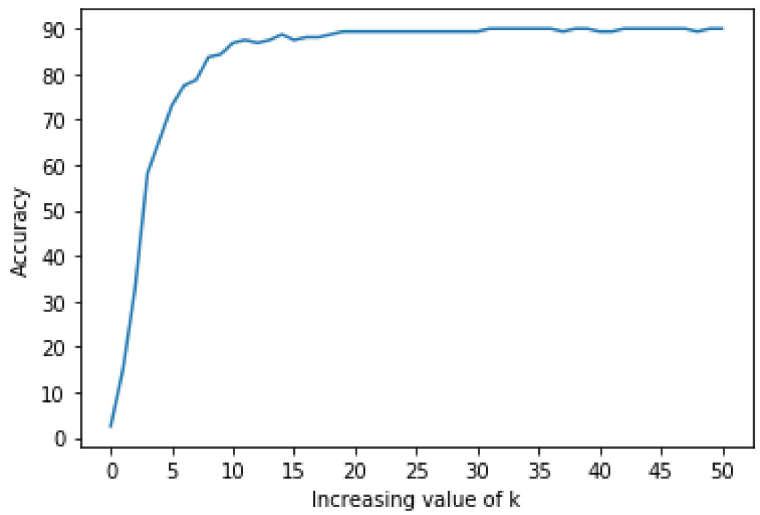
```
maximum accuracy for 90-10 split = 95.0
```

In [22]:

```
diff_cases(6, 4)
```

```
feature vector =  [[ 48  45  45 ...  46  47  46]
 [ 60  58  68 ...  33  31  34]
 [ 39  44  59 ...  28  27  29]
 ...
 [130 126 123 ...  39  42  40]
 [128 129 126 ...  90  91  84]
 [123 128 126 ...  44  39  42]]
shape of feature vector =  (240, 10304)


mean vector =  [84.82916667 85.1        85.19583333 ... 70.25833333 71.25833
333
 72.075     ]
shape of mean vector =  (10304,)


deviation matrix =  [[-36.82916667 -40.1        -40.19583333 ... -24.2583333
3 -24.25833333
  -26.075     ]
 [-24.82916667 -27.1        -17.19583333 ... -37.25833333 -40.25833333
  -38.075     ]
 [-45.82916667 -41.1        -26.19583333 ... -42.25833333 -44.25833333
  -43.075     ]
 ...
 [ 45.17083333  40.9         37.80416667 ... -31.25833333 -29.25833333
  -32.075     ]
 [ 43.17083333  43.9         40.80416667 ...  19.74166667  19.74166667
   11.925     ]
 [ 38.17083333  42.9         40.80416667 ... -26.25833333 -32.25833333
  -30.075     ]]
shape of deviation matrix =  (240, 10304)


covariance matrix =  [[14776305.51154514  6797204.43654514  9795830.08654514
...
  -2153240.20512153  1931371.12404514   393609.30737847]
 [ 6797204.43654514 26302994.36154512 10811451.01154514 ...
   3175694.71987847  3152996.04904514  3143496.23237847]
 [ 9795830.08654514 10811451.01154514 19794903.66154513 ...
   1564836.36987847  2627156.69904514  2864238.88237847]
 ...
 [-2153240.20512153  3175694.71987847  1564836.36987847 ...
  14144203.0782118   3198586.40737847  4716683.59071181]
 [ 1931371.12404514  3152996.04904514  2627156.69904514 ...
   3198586.40737847 10773686.73654514  3846877.91987847]
 [  393609.30737847  3143496.23237847  2864238.88237847 ...
   4716683.59071181  3846877.91987847 12522650.10321181]]
shape of covariance matrix =  (240, 240)


shape of eigen values vector --> (240,)
shape of eigen vector matrix --> (240, 240)


test matrix =  [[ 41  44  48 ...  35  33  38]
 [ 44  44  41 ...  37  32  37]
 [ 42  41  54 ...  40  39  41]
```

```
 ...
 [125 121 122 ...  43  35  40]
 [119 118 120 ...  88  92  85]
 [125 124 121 ...  35  32  34]]
shape of test matrix =  (160, 10304)


mean zero test matrix =  [[-43.82916667 -41.1        -37.19583333 ... -35.25
833333 -38.25833333
  -34.075     ]
 [-40.82916667 -41.1        -44.19583333 ... -33.25833333 -39.25833333
  -35.075     ]
 [-42.82916667 -44.1        -31.19583333 ... -30.25833333 -32.25833333
  -31.075     ]
 ...
 [ 40.17083333  35.9         36.80416667 ... -27.25833333 -36.25833333
  -32.075     ]
 [ 34.17083333  32.9         34.80416667 ...  17.74166667  20.74166667
   12.925     ]
 [ 40.17083333  38.9         35.80416667 ... -35.25833333 -39.25833333
  -38.075     ]]
shape of mean zero test matrix =  (160, 10304)


expected values =  [1, 1, 1, 1, 2, 2, 2, 2, 3, 3, 3, 3, 4, 4, 4, 4, 5, 5, 5,
5, 6, 6, 6, 6, 7, 7, 7, 7, 8, 8, 8, 8, 9, 9, 9, 9, 10, 10, 10, 10, 11, 11, 1
1, 11, 12, 12, 12, 12, 13, 13, 13, 13, 14, 14, 14, 14, 15, 15, 15, 15, 16, 1
6, 16, 16, 17, 17, 17, 17, 18, 18, 18, 18, 19, 19, 19, 19, 20, 20, 20, 20, 2
1, 21, 21, 21, 22, 22, 22, 22, 23, 23, 23, 23, 24, 24, 24, 24, 25, 25, 25, 2
5, 26, 26, 26, 26, 27, 27, 27, 27, 28, 28, 28, 28, 29, 29, 29, 29, 30, 30, 3
0, 30, 31, 31, 31, 31, 32, 32, 32, 32, 33, 33, 33, 33, 34, 34, 34, 34, 35, 3
5, 35, 35, 36, 36, 36, 36, 37, 37, 37, 37, 38, 38, 38, 38, 39, 39, 39, 39, 4
0, 40, 40, 40]


Plotting accuracy vs k
```




```
maximum accuracy for 60-40 split = 90.0
```

In [ ]: