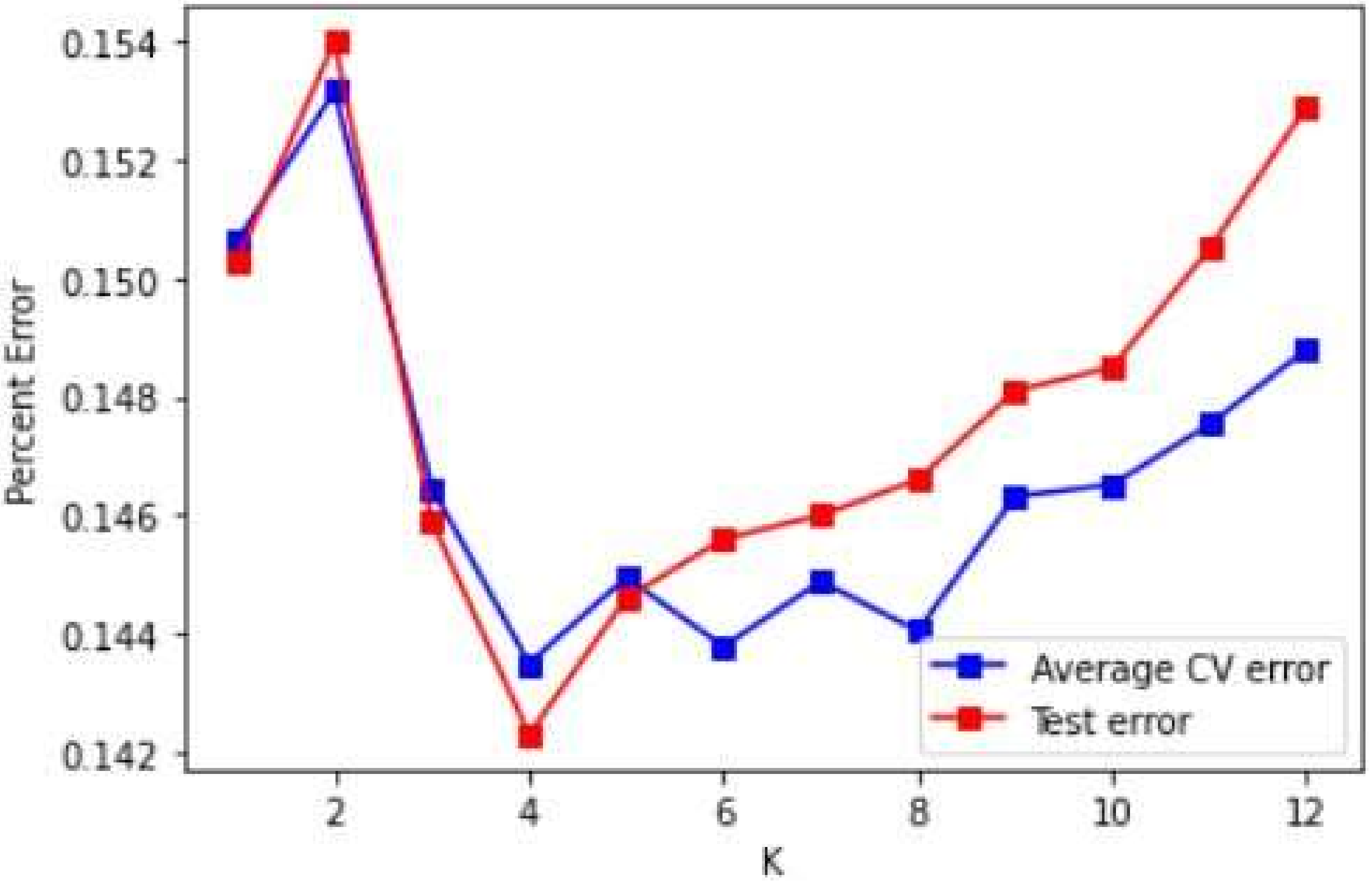
Cory Sweet

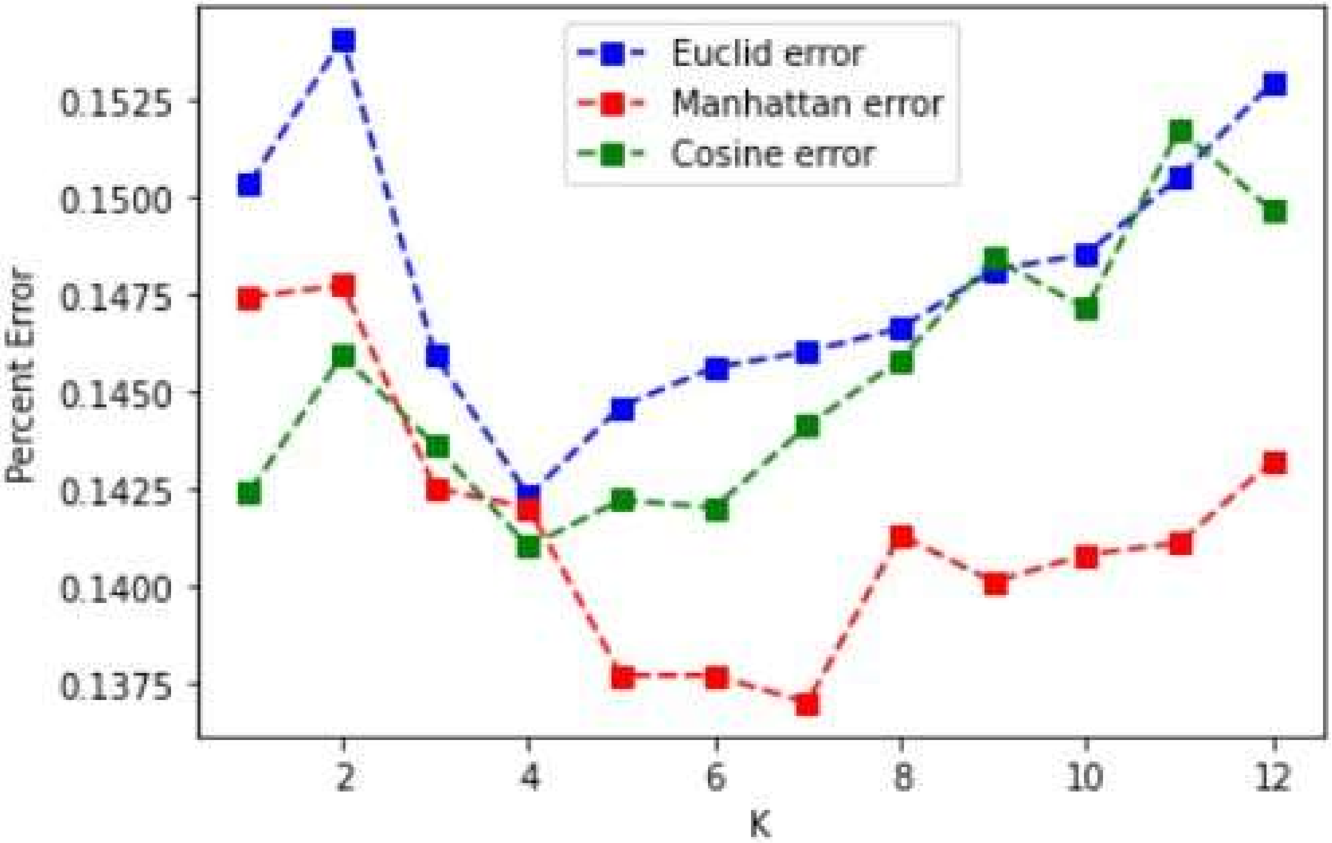
Math 251
Homework 1

Question 1



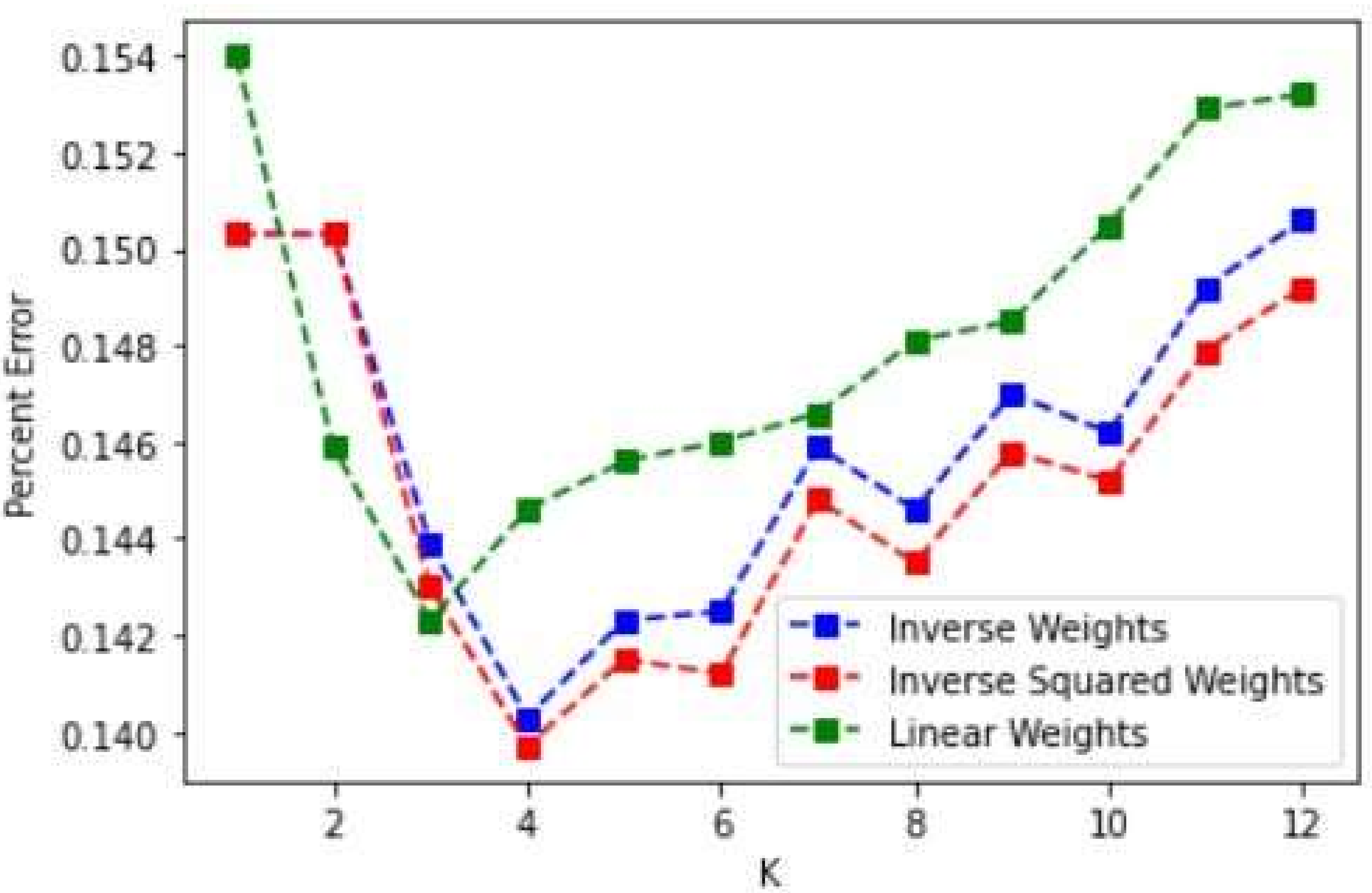
Both curves have the lowest error rate at k=4. The error in terms is consistent on which k is best.
The smallest error rate for the test values was: 0.1423

Question 2



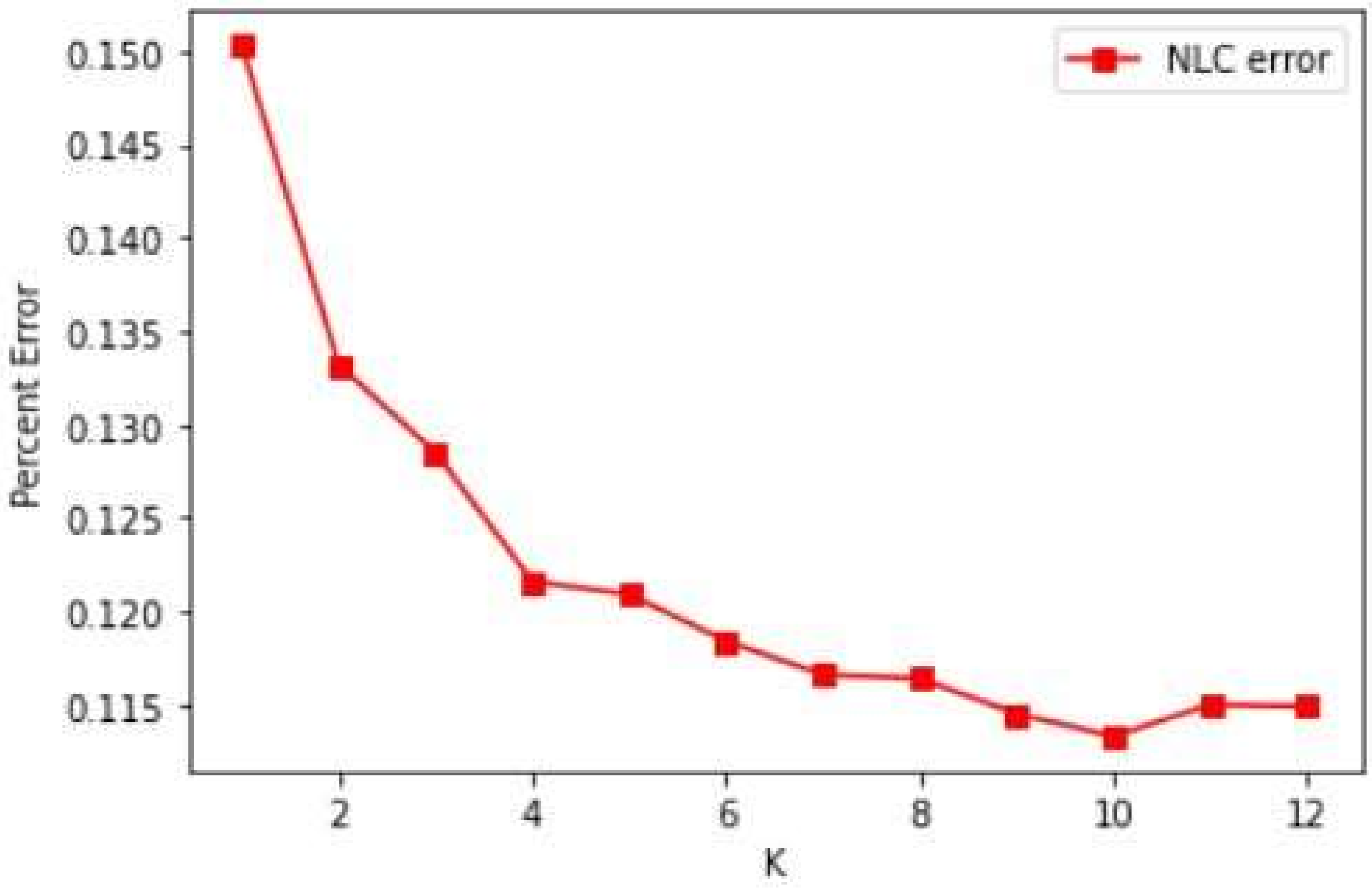
Manhattan distance produced the lowest error rate, and thus is best.
The lowest error rate was: 0.137
The lowest error rate was achieved at k=7.

Question 3



Inverse Squared weights provided the smallest error. The smallest error was 0.1397 at k = 4

Question 4

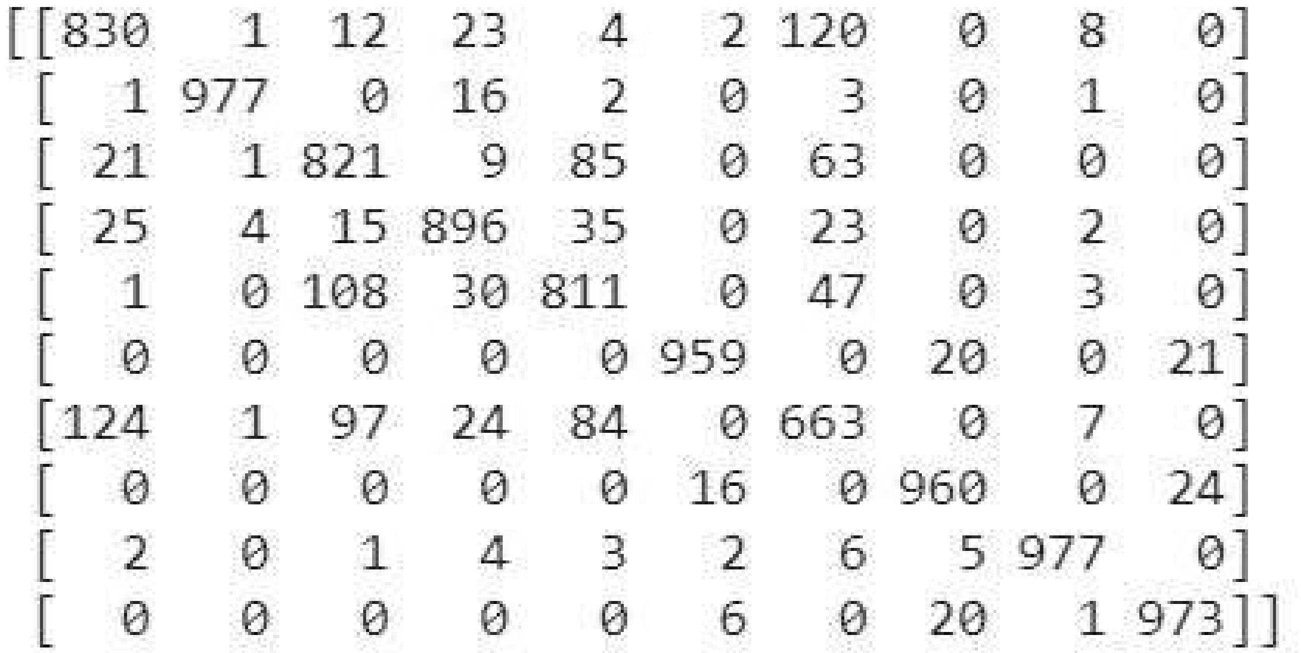


The smallest error was 0.1133 which was achieved at k=10

Question 4 - Confusion Matrix

Predictions

Actual



```
[[830   1  12  23   4   2 120   0   8   0]
 [  1 977   0  16   2   0   3   0   1   0]
 [ 21   1 821   9  85   0  63   0   0   0]
 [ 25   4  15 896  35   0  23   0   2   0]
 [  1   0 108  30 811   0  47   0   3   0]
 [  0   0   0   0   0 959   0  20   0  21]
 [124   1  97  24  84   0 663   0   7   0]
 [  0   0   0   0   0  16   0 960   0  24]
 [  2   0   1   4   3   2   6   5 977   0]
 [  0   0   0   0   0   6   0  20   1 973]]
```

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from tensorflow import keras
from sklearn.neighbors import KNeighborsClassifier
from sklearn.model_selection import cross_val_score
from sklearn.metrics import accuracy_score
from sklearn.metrics import pairwise_distances
from scipy.spatial.distance import cosine

fashion_mnist = keras.datasets.fashion_mnist
(train_images, train_labels), (test_images, test_labels) = fashion_mnist.load_data()
"""
0       T-shirt/top
1       Trouser
2       Pullover
3       Dress
4       Coat
5       Sandal
6       Shirt
7       Sneaker
8       Bag
9       Ankle boot
"""

label_names=['T-shirt/top','Trouser','Pullover','Dress','Coat','Sandal',
            'Shirt','Sneaker','Bag','Ankle boot']

X_train = np.zeros([60000,784])
for i in range(60000):
    img=train_images[i,:,:]
    X_train[i,:] = img.reshape([784])

X_test = np.zeros([10000,784])
for i in range(10000):
    img=test_images[i,:,:]
    X_test[i,:] = img.reshape([784])

X_sub = X_train[:600,:]
y_sub = train_labels[:600]

#############################################1
#cross val

cv_acc=[]
for k in range(1,13):
    model = KNeighborsClassifier(n_neighbors=k)
    scores = cross_val_score(model, X_train, train_labels, scoring='accuracy', cv=6)
    cv_acc.append(scores.mean())
    print('K is',k,'\n acc is:', scores.mean())

#on testing data
test_acc=[]
```

```
for k in range(1,13):
   model = KNeighborsClassifier(n_neighbors=k)
   model.fit(X_train, train_labels)
   y_preds = model.predict(X_test)
   score=accuracy_score(y_true=test_labels, y_pred=y_preds)
   test_acc.append(score)
   print('K is',k,'\n acc is:', score)

#cv_error = 1-np.array(cv_acc)
#test_error = 1-np.array(test_acc)

"""My Kernel would often crash while doing these, so I recorded these
cv_acc = [.8493666666666666, .8468333333333332, .8535333333333334, .8564999999999999,
        .85505, .8562166666666667, .8551166666666666, .85595, .8536833333333335,
        .8534833333333335,.8524666666666666, .8512]

test_acc=[0.8497,0.846,0.8541,0.8577,0.8554,0.8544,
        0.854,0.8534,0.8519,0.8515,0.8495,0.8471]
"""

cv_error = 1-np.array(cv_acc)
test_error = 1-np.array(test_acc)

#plots
plt.plot(range(1,13), cv_error, '-bs', label='Average CV error')
plt.plot(range(1,13), test_error,'-rs', label = 'Test error')
plt.legend()
plt.xlabel('K')
plt.ylabel('Percent Error')

#############################################2
#euclid
euclid_acc=[]
for k in range(1,13):
   model = KNeighborsClassifier(n_neighbors=k,metric='euclidean')
   model.fit(X_train, train_labels)
   y_preds = model.predict(X_test)
   score=accuracy_score(y_true=test_labels, y_pred=y_preds)
   euclid_acc.append(score)
   print('K:',k,'\n Accuracy:', score)

#city-block
man_acc=[] #Manhattan dist
for k in range(1,13):
   model = KNeighborsClassifier(n_neighbors=k, metric='manhattan')
   model.fit(X_train, train_labels)
   y_preds = model.predict(X_test)
   score = accuracy_score(y_true=test_labels, y_pred=y_preds)
   man_acc.append(score)
   print('K:',k,'\n Accuracy:', score)

#cosine
cos_acc=[]
```

```
for k in range(1,13):
    model = KNeighborsClassifier(n_neighbors=k, metric='cosine')
    model.fit(X_train, train_labels)
    y_preds = model.predict(X_test)
    score=accuracy_score(y_true=test_labels, y_pred=y_preds)
    cos_acc.append(accuracy_score(y_true=test_labels, y_pred=y_preds))
    print('K:',k,'\n Accuracy:', score)

"""
euclid_acc=[0.8497, 0.846, 0.8541, 0.8577, 0.8554, 0.8544,
            0.854, 0.8534, 0.8519, 0.8515, 0.8495, 0.8471]

man_acc=[0.8526, 0.8523, 0.8575, 0.858, 0.8623, 0.8623,
         0.863, 0.8587, 0.8599, 0.8592, 0.8589, 0.8568]

cos_acc=[0.8576,0.8541,0.8564,0.859,0.8578,0.858,
        0.8559,0.8542,0.8516,0.8529,0.8483,0.8504]
"""
euclid_error = 1-np.array(euclid_acc)
man_error = 1-np.array(man_acc)
cos_error = 1-np.array(cos_acc)

plt.plot(range(1,13), euclid_error, '--bs', label='Euclid error')
plt.plot(range(1,13), man_error,'--rs', label = 'Manhattan error')
plt.plot(range(1,13), cos_error,'--gs', label = 'Cosine error')

plt.legend()
plt.xlabel('K')
plt.ylabel('Percent Error')

#####################################################3
#Inverse
inv_acc=[]
for k in range(1,13):
    model = KNeighborsClassifier(n_neighbors=k,weights='distance')
    model.fit(X_train, train_labels)
    y_preds = model.predict(X_test)
    score=accuracy_score(y_true=test_labels, y_pred=y_preds)
    inv_acc.append(score)
    print('K:',k,'\n Accuracy:', score)

#inverse squared
def dist_inv_sq(v):
    return 1/(v**2)

inv_sq_acc=[]
for k in range(1,13):
    model = KNeighborsClassifier(n_neighbors=k,weights=dist_inv_sq)
    model.fit(X_train, train_labels)
    y_preds = model.predict(X_test)
    score=accuracy_score(y_true=test_labels, y_pred=y_preds)
    inv_sq_acc.append(score)
    print('K:',k,'\n Accuracy:', score)
```

```
#linear weights
def f2(v):
    dk=v[-1] #dist to k+1 point
    d1=v[0]
    w=(dk-v)/(dk-d1)
    return w

lin_acc=[]
for k in range(1,13):
    model = KNeighborsClassifier(n_neighbors=k)
    model.fit(X_train, train_labels)
    y_preds = model.predict(X_test)
    score=accuracy_score(y_true=test_labels, y_pred=y_preds)
    lin_acc.append(score)
    print('K:',k,'\n Accuracy:', score)

"""
inv_acc=[0.8497,0.8497,0.8561,0.8597,0.8577,0.8575,
        0.8541,0.8554,0.853,0.8538,0.8508,0.8494]
inv_sq_acc = [0.8497,0.8497,0.857,0.8603,0.8585,0.8588,
             0.8552,0.8565,0.8542,0.8548,0.8521,0.8508]
lin_acc=[0.8497,0.846,0.8541,0.8577,0.8554,0.8544,
        0.854,0.8534,0.8519,0.8515,0.8495,0.8471]
"""

inv_error = 1-np.array(inv_acc)
inv_sq_error = 1-np.array(inv_sq_acc)
lin_error = 1-np.array(lin_acc)

plt.plot(range(1,13), inv_error, '--bs', label='Inverse Weights')
plt.plot(range(1,13), inv_sq_error,'--rs', label = 'Inverse Squared Weights')
plt.plot(range(1,13), lin_error,'--gs', label = 'Linear Weights')

plt.legend()
plt.xlabel('K')
plt.ylabel('Percent Error')

##############################################4
G0 = X_train[train_labels==0,:]
G1 = X_train[train_labels==1,:]
G2 = X_train[train_labels==2,:]
G3 = X_train[train_labels==3,:]
G4 = X_train[train_labels==4,:]
G5 = X_train[train_labels==5,:]
G6 = X_train[train_labels==6,:]
G7 = X_train[train_labels==7,:]
G8 = X_train[train_labels==8,:]
G9 = X_train[train_labels==9,:]

#let k=1
#find dist from k to all train points
#find clostsest 1 from each group
```

```
#find centroid
#find dist from k to each centroid
#find smallest distance
#arg min to find prediction

#k=2
#find next closest
#find centroid
#find dist from test point to each centroid
#find smallest distance
#arg min to find prediction
#... repeat for k 3:12

#
k1_preds=[]
k2_preds=[]
k3_preds=[]
k4_preds=[]
k5_preds=[]
k6_preds=[]
k7_preds=[]
k8_preds=[]
k9_preds=[]
k10_preds=[]
k11_preds=[]
k12_preds=[]

for r in range(X_test.shape[0]): #later replace with X_test.shape[0]

    G0_dists, G1_dists, G2_dists, G3_dists, G4_dists = [],[],[],[],[]
    G5_dists, G6_dists, G7_dists, G8_dists, G9_dists = [],[],[],[],[]
    closest_img_index_G0, closest_img_index_G1, closest_img_index_G2 = [],[],[]
    closest_img_index_G3, closest_img_index_G4, closest_img_index_G5= [],[],[]
    closest_img_index_G6, closest_img_index_G7, closest_img_index_G8  = [],[],[]
    closest_img_index_G9 = []

    test_point = X_test[r,:]

    #finds all distances, only run once
    for i in range(G0.shape[0]):
        G0_dists.append( np.sqrt(np.sum((  test_point - G0[i,:]  )**2)) )
        G1_dists.append( np.sqrt(np.sum((  test_point - G1[i,:]  )**2)) )
        G2_dists.append( np.sqrt(np.sum((  test_point - G2[i,:]  )**2)) )
        G3_dists.append( np.sqrt(np.sum((  test_point - G3[i,:]  )**2)) )
        G4_dists.append( np.sqrt(np.sum((  test_point - G4[i,:]  )**2)) )
        G5_dists.append( np.sqrt(np.sum((  test_point - G5[i,:]  )**2)) )
        G6_dists.append( np.sqrt(np.sum((  test_point - G6[i,:]  )**2)) )
        G7_dists.append( np.sqrt(np.sum((  test_point - G7[i,:]  )**2)) )
        G8_dists.append( np.sqrt(np.sum((  test_point - G8[i,:]  )**2)) )
        G9_dists.append( np.sqrt(np.sum((  test_point - G9[i,:]  )**2)) )

    #k=1##########################################
    #find index of shortest dist
```

```
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)


closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#find centroid but doesn't matter for k=1
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)


#find dist from test point to each centroid
test_to_centroids_dists = []
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )
#actually finds the prediction
k1_preds.append(np.argmin(test_to_centroids_dists))


#k=2##########################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#find centroids
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
```

```
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)

#find dist from test point to each centroid
test_to_centroids_dists = []
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )

#actually finds the prediction
k2_preds.append(np.argmin(test_to_centroids_dists))

#k=3########################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
```

```
G9_dists[i9] = np.Inf

#find centroids
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)

#find dist from test point to each centroid
test_to_centroids_dists = []
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )

#actually finds the prediction
k3_preds.append(np.argmin(test_to_centroids_dists))

#k=4
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
```

```
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#find centroids
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)

#find dist from test point to each centroid
test_to_centroids_dists = []
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )

#actually finds the prediction
k4_preds.append(np.argmin(test_to_centroids_dists))

#k=5#################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)
```

```
closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#find centroids
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)

#find dist from test point to each centroid
test_to_centroids_dists = []
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )

#actually finds the prediction
k5_preds.append(np.argmin(test_to_centroids_dists))

#k=6#####################################################
#find next index
i0=np.argmin(G0_dists)
```

```
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#find centroids
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)

#find dist from test point to each centroid
test_to_centroids_dists = []
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )

#actually finds the prediction
k6_preds.append(np.argmin(test_to_centroids_dists))

#k=7#################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#find centroids
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)
```

```
#find dist from test point to each centroid
test_to_centroids_dists = []
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )

#actually finds the prediction
k7_preds.append(np.argmin(test_to_centroids_dists))

#k=8#####################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#find centroids
```

```
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)

#find dist from test point to each centroid
test_to_centroids_dists = []
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )

#actually finds the prediction
k8_preds.append(np.argmin(test_to_centroids_dists))

#k=9#####################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
```

```
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#find centroids
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)

#find dist from test point to each centroid
test_to_centroids_dists = []
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )

#actually finds the prediction
k9_preds.append(np.argmin(test_to_centroids_dists))

#k=10#################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
```

```
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#find centroids
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)

#find dist from test point to each centroid
test_to_centroids_dists = []
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )

#actually finds the prediction
k10_preds.append(np.argmin(test_to_centroids_dists))

#k=11#################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
```

```
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#find centroids
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)

#find dist from test point to each centroid
test_to_centroids_dists = []
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )
```

```
#actually finds the prediction
k11_preds.append(np.argmin(test_to_centroids_dists))

#k=12#################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#find centroids
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)

#find dist from test point to each centroid
test_to_centroids_dists = []
```

```
    test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
    test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
    test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
    test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
    test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
    test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
    test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
    test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
    test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
    test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )

    #actually finds the prediction
    k12_preds.append(np.argmin(test_to_centroids_dists))

scorek1=accuracy_score(y_true=test_labels, y_pred=k1_preds)
scorek2=accuracy_score(y_true=test_labels, y_pred=k2_preds)
scorek3=accuracy_score(y_true=test_labels, y_pred=k3_preds)
scorek4=accuracy_score(y_true=test_labels, y_pred=k4_preds)
scorek5=accuracy_score(y_true=test_labels, y_pred=k5_preds)
scorek6=accuracy_score(y_true=test_labels, y_pred=k6_preds)
scorek7=accuracy_score(y_true=test_labels, y_pred=k7_preds)
scorek8=accuracy_score(y_true=test_labels, y_pred=k8_preds)
scorek9=accuracy_score(y_true=test_labels, y_pred=k9_preds)
scorek10=accuracy_score(y_true=test_labels, y_pred=k10_preds)
scorek11=accuracy_score(y_true=test_labels, y_pred=k11_preds)
scorek12=accuracy_score(y_true=test_labels, y_pred=k12_preds)

"""
NLC_acc=[0.8497,0.8668,0.8715,0.8784,0.8791,0.8816,
        0.8834,0.8836,0.8855,0.8867,0.885,0.8851]
"""

np.argmax(NLC_acc) #9 is the best

NLC_error = 1-np.array(NLC_acc)


plt.plot(range(1,13), NLC_error,'-rs', label = 'NLC error')
plt.legend()
plt.xlabel('K')
plt.ylabel('Percent Error')


##################################4 confusion matrix


#let k=1
#find dist from k to all train points
#find clostsest 1 from each group
#find centroid
#find dist from k to each centroid
#find smallest distance
#arg min to find prediction
```

```
#k=2
#find next closest
#find centroid
#find dist from test point to each centroid

#
k1_preds=[]
k2_preds=[]
k3_preds=[]
k4_preds=[]
k5_preds=[]
k6_preds=[]
k7_preds=[]
k8_preds=[]
k9_preds=[]
k10_preds=[]
k11_preds=[]
k12_preds=[]

for r in range(X_test.shape[0]):

    G0_dists, G1_dists, G2_dists, G3_dists, G4_dists = [],[],[],[],[]
    G5_dists, G6_dists, G7_dists, G8_dists, G9_dists = [],[],[],[],[]
    closest_img_index_G0, closest_img_index_G1, closest_img_index_G2 = [],[],[]
    closest_img_index_G3, closest_img_index_G4, closest_img_index_G5= [],[],[]
    closest_img_index_G6, closest_img_index_G7, closest_img_index_G8  = [],[],[]
    closest_img_index_G9 = []

    test_point = X_test[r,:]

    #finds all distances, only run once
    for i in range(G0.shape[0]):
        G0_dists.append( np.sqrt(np.sum((  test_point - G0[i,:]  )**2)) )
        G1_dists.append( np.sqrt(np.sum((  test_point - G1[i,:]  )**2)) )
        G2_dists.append( np.sqrt(np.sum((  test_point - G2[i,:]  )**2)) )
        G3_dists.append( np.sqrt(np.sum((  test_point - G3[i,:]  )**2)) )
        G4_dists.append( np.sqrt(np.sum((  test_point - G4[i,:]  )**2)) )
        G5_dists.append( np.sqrt(np.sum((  test_point - G5[i,:]  )**2)) )
        G6_dists.append( np.sqrt(np.sum((  test_point - G6[i,:]  )**2)) )
        G7_dists.append( np.sqrt(np.sum((  test_point - G7[i,:]  )**2)) )
        G8_dists.append( np.sqrt(np.sum((  test_point - G8[i,:]  )**2)) )
        G9_dists.append( np.sqrt(np.sum((  test_point - G9[i,:]  )**2)) )

    #k=1###########################################
    #find index of shortest dist
    i0=np.argmin(G0_dists)
    i1=np.argmin(G1_dists)
    i2=np.argmin(G2_dists)
    i3=np.argmin(G3_dists)
    i4=np.argmin(G4_dists)
    i5=np.argmin(G5_dists)
    i6=np.argmin(G6_dists)
```

```
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)


closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#k=2######################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
```

```
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf
#k=3##########################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf


#k=4
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
```

```
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#k=5#######################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
```

```
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#k=6######################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#k=7######################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
```

```
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#k=8#################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
```

```
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#k=9####################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf


#k=10####################################################
#find next index
i0=np.argmin(G0_dists)
i1=np.argmin(G1_dists)
i2=np.argmin(G2_dists)
i3=np.argmin(G3_dists)
i4=np.argmin(G4_dists)
i5=np.argmin(G5_dists)
i6=np.argmin(G6_dists)
i7=np.argmin(G7_dists)
```

```
i8=np.argmin(G8_dists)
i9=np.argmin(G9_dists)

closest_img_index_G0.append(i0)
closest_img_index_G1.append(i1)
closest_img_index_G2.append(i2)
closest_img_index_G3.append(i3)
closest_img_index_G4.append(i4)
closest_img_index_G5.append(i5)
closest_img_index_G6.append(i6)
closest_img_index_G7.append(i7)
closest_img_index_G8.append(i8)
closest_img_index_G9.append(i9)
#set that dist to inf so it's not found on next loop
G0_dists[i0] = np.Inf
G1_dists[i1] = np.Inf
G2_dists[i2] = np.Inf
G3_dists[i3] = np.Inf
G4_dists[i4] = np.Inf
G5_dists[i5] = np.Inf
G6_dists[i6] = np.Inf
G7_dists[i7] = np.Inf
G8_dists[i8] = np.Inf
G9_dists[i9] = np.Inf

#find centroids
c0 = np.mean(G0[closest_img_index_G0,:],axis=0)
c1 = np.mean(G1[closest_img_index_G1,:],axis=0)
c2 = np.mean(G2[closest_img_index_G2,:],axis=0)
c3 = np.mean(G3[closest_img_index_G3,:],axis=0)
c4 = np.mean(G4[closest_img_index_G4,:],axis=0)
c5 = np.mean(G5[closest_img_index_G5,:],axis=0)
c6 = np.mean(G6[closest_img_index_G6,:],axis=0)
c7 = np.mean(G7[closest_img_index_G7,:],axis=0)
c8 = np.mean(G8[closest_img_index_G8,:],axis=0)
c9 = np.mean(G9[closest_img_index_G9,:],axis=0)

#find dist from test point to each centroid
test_to_centroids_dists = []
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c0)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c1)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c2)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c3)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c4)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c5)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c6)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c7)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c8)**2) ) )
test_to_centroids_dists.append(np.sqrt( np.sum( (test_point - c9)**2) ) )

#actually finds the prediction
k10_preds.append(np.argmin(test_to_centroids_dists))
```

```
from sklearn.metrics import confusion_matrix

print(confusion_matrix(test_labels, k10_preds, labels=[0,1,2,3,4,5,6,7,8,9]))

""" for k=10
[[830   1  12  23   4   2 120   0   8   0]
 [  1 977   0  16   2   0   3   0   1   0]
 [ 21   1 821   9  85   0  63   0   0   0]
 [ 25   4  15 896  35   0  23   0   2   0]
 [  1   0 108  30 811   0  47   0   3   0]
 [  0   0   0   0   0 959   0  20   0  21]
 [124   1  97  24  84   0 663   0   7   0]
 [  0   0   0   0   0  16   0 960   0  24]
 [  2   0   1   4   3   2   6   5 977   0]
 [  0   0   0   0   0   6   0  20   1 973]]
 """
```