Homework 3 **Anirudh Ganesh**
CSE 5523
Prof. Mikhail Belkin
TA: Siyuan Ma Due Date: 04/17/18

Problem 1

Question : Implement gradient descent (Richardson iteration) for the kernel learning problem 2 in previous homework. Observe how the test error changes depending upon the number of iterations on train.

Code :

```
def iterative(n):
    K1=np.zeros([2000,2000],dtype=float)
    for i in range(0,2000):
        for j in range(0,2000):
            K1[i,j]=GaussianKernel(data_scaled_shuffle[i,:],
                data_scaled_shuffle[j,:],final_sigma2)


    learning_rate = 1e-3
    alphast = np.zeros(2000)
    alphast1 = np.zeros(2000)

    for i in range(n):
        alphast = alphast1
        alphast1 = alphast - learning_rate*(np.matmul(K1,alphast) -
            output_shuffle)

    alphas = alphast1

    cnt2=0
    tscore=0
    for i in range(0,2000):
      sum1=0
      for j in range(0,2000):
          sum1=sum1+alphas[j]*GaussianKernel(data_scaled_shuffle[j,:],
              data_test_scaled[i,:],final_sigma2)
      if(sum1<0):
          predict=-1
      else:
          predict=1
      if(predict==y[i]):
          cnt2=cnt2+1
    return cnt2/2000
```

Output :

```
2 iterations, Test Score: 0.9125
5 iterations, Test Score: 0.9265
10 iterations, Test Score: 0.927
20 iterations, Test Score: 0.927
```

Observation : For the given problem, the problem seems to converge to 0.927 in around 5-10 iterations and stabilizes there.

Problem 2

Question : Apply (1) decision trees, (2) bagged, (3) boosted decision trees to the digits dataset from Homework 2. (You may use standard libraries.) Use appropriate cross-validation on the training set. Compare performance.

Decision Trees

Code :

```
mat = sio.loadmat('79.mat')
arr = mat['d79']
arr.reshape(2000,28,28)

y = np.zeros(2000)
for i in range (0,2000):
    if(i<1000):
        y[i] = 7
    else:
        y[i] = 9

mat1 = sio.loadmat('test79.mat')
data_test = mat1['d79']
data_test.reshape(2000,28,28)
clf = tree.DecisionTreeClassifier()
clf.fit(arr,y)

cnt = 0
for i in range(0,2000):
    if(i<1000):
        if(clf.predict(data_test[i].reshape(1, -1))[0] == 7.0):
            cnt+=1
    else:
        if(clf.predict(data_test[i].reshape(1, -1))[0] == 9.0):
            cnt+=1

print('Test Score: {}'.format(cnt/2000))
```

Output :

```
Test Score: 0.943
```

Bagging

Code :

```
mat = sio.loadmat('79.mat')
arr = mat['d79']
arr.reshape(2000,28,28)

y = np.zeros(2000)
for i in range (0,2000):
    if(i<1000):
        y[i] = 7
    else:
        y[i] = 9
```

```
mat1 = sio.loadmat('test79.mat')
data_test = mat1['d79']
data_test.reshape(2000,28,28)
clf2 = BaggingClassifier()
clf2.fit(arr,y)

cnt = 0
for i in range(0,2000):
    if(i<1000):
        if(clf2.predict(data_test[i].reshape(1, -1))[0] == 7.0):
            cnt+=1
    else:
        if(clf2.predict(data_test[i].reshape(1, -1))[0] == 9.0):
            cnt+=1

print('Test Score: {}'.format(cnt/2000))
```

Output :

```
Test Score: 0.956
```

Boosting

Code :

```
mat = sio.loadmat('79.mat')
arr = mat['d79']
arr.reshape(2000,28,28)

y = np.zeros(2000)
for i in range (0,2000):
    if(i<1000):
        y[i] = 7
    else:
        y[i] = 9

mat1 = sio.loadmat('test79.mat')
data_test = mat1['d79']
data_test.reshape(2000,28,28)
clf3 = AdaBoostClassifier(clf)
clf3.fit(arr,y)

cnt = 0
for i in range(0,2000):
    if(i<1000):
        if(clf3.predict(data_test[i].reshape(1, -1))[0] == 7.0):
            cnt+=1
    else:
        if(clf3.predict(data_test[i].reshape(1, -1))[0] == 9.0):
            cnt+=1

print('Test Score: {}'.format(cnt/2000))
```

Output :

```
Test Score: 0.9625
```

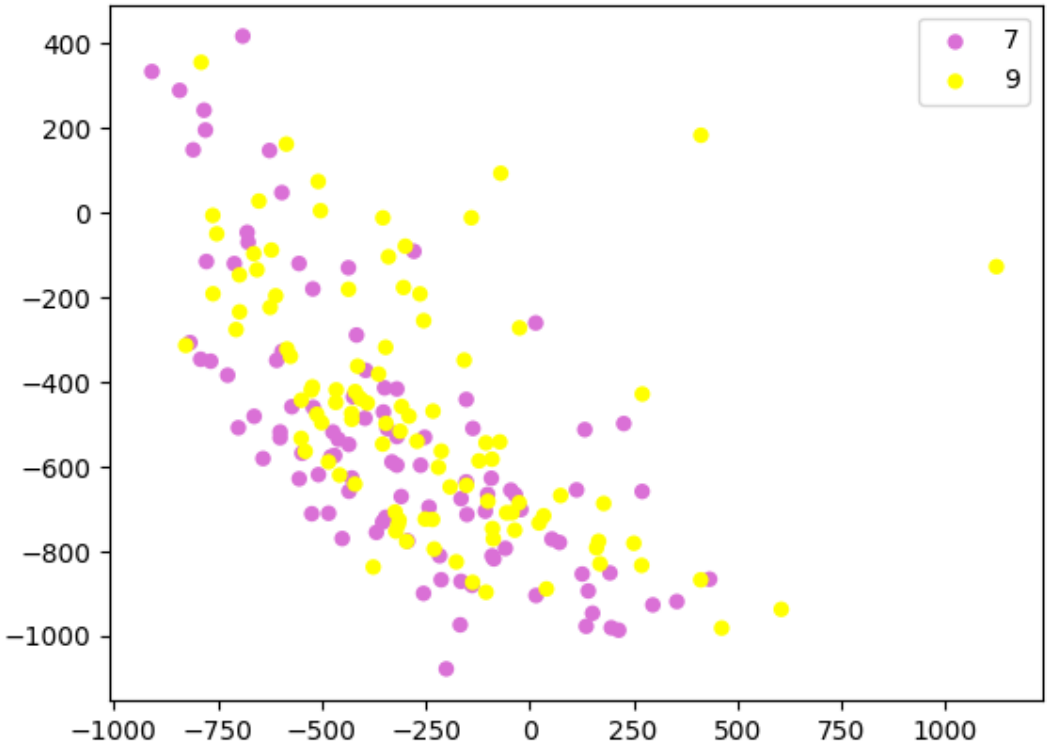
Problem 3

Question : 1. Implement PCA and apply it to the digit data, reducing the dimension to two. Visualize the data after dimensionality reduction using colors for different classes. 2. Produce pictures of "eigendigits" for the dataset combining both classes and for each class separately. Observations?

Code :

```
mat = sio.loadmat('79.mat')
arr = mat['d79']
arr.reshape(2000,784)

y = np.zeros(2000)
for i in range (0,2000):
    if(i<1000):
        y[i] = 7
    else:
        y[i] = 9

cov_mat = np.cov(arr.T)
eig_vals, eig_vecs = np.linalg.eig(cov_mat)
u,s,v = np.linalg.svd(X_std.T)
for ev in eig_vecs:
    np.testing.assert_array_almost_equal(1.0, np.linalg.norm(ev))

eig_pairs = [(np.abs(eig_vals[i]), eig_vecs[:,i]) for i in range(len(
    eig_vals))]

eig_pairs.sort()
eig_pairs.reverse()

Y = X_std.dot(matrix_w)
traces = []

for name in [7,9]:

    trace = Scatter(
        x=Y[y==name,0],
        y=Y[y==name,1],
        mode='markers',
        name=name,
        marker=Marker(
            size=12,
            line=Line(
                color='rgba(217, 217, 217, 0.14)',
                width=0.5),
            opacity=0.8))
    traces.append(trace)


data = Data(traces)

fig = Figure(data=data)
plt.plot(fig)
```

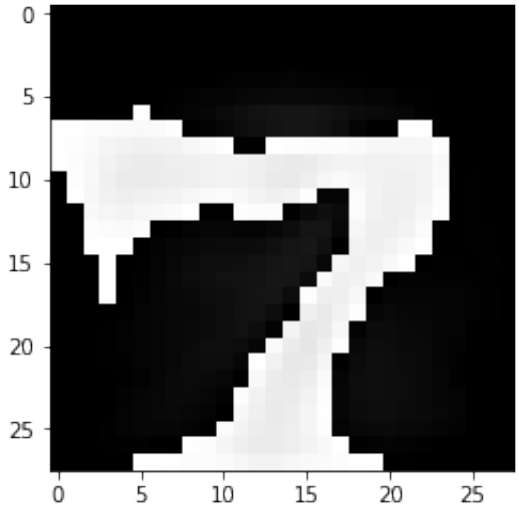
Output :

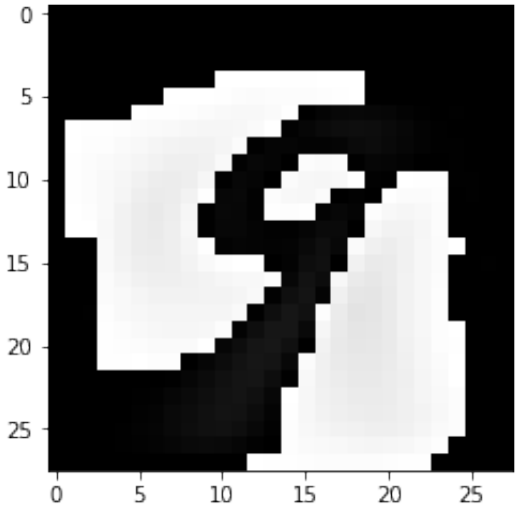


Eigendigits

```
x = eig_vecs[:,0]*255.0
x.reshape(28,28)
x = np.array(x, dtype='uint8').reshape(28,28)
print(x.shape)
plt.imshow(x, cmap='gray')
plt.show()

x = eig_vecs[:,1]*255.0
x.reshape(28,28)
x = np.array(x, dtype='uint8').reshape(28,28)
print(x.shape)
plt.imshow(x, cmap='gray')
plt.show()
```

Output :





Problem 4

Question : Apply k-means clustering to the digits dataset for k= 2, 5, 10, 50. How well does it identify the different digits?

Code :

```
def kmeams(n):
    kmeans = KMeans(n_clusters=n, random_state=0).fit(mat)
    labs=kmeans.labels_
    arr1 = np.zeros((n,2))
    arr2 = np.zeros(n)
    for i in range (0,2000):
        if(i<1000):
            arr1[labs[i]][0]=arr1[labs[i]][0]+1
        else:
            arr1[labs[i]][1]=arr1[labs[i]][1]+1
    for i in range (0,n):
        if(arr1[i][0]>arr1[i][1]):
            arr2[i]=7
        else:
            arr2[i]=9
    predictions = kmeans.predict(t.reshape(2000,-1).astype(float))
    cnt=0
    for i in range (0,2000):
        if(i<1000):
            if(arr2[predictions[i]]==7):
                cnt+=1
        else:
            if(arr2[predictions[i]]==9):
                cnt+=1
    print(cnt/2000)
```

Output :

```
2 clusters, Test Score: 0.5945
5 clusters, Test Score: 0.7280
10 clusters, Test Score: 0.8090
50 clusters, Test Score: 0.9265
```