178 HW1

January 22, 2019

1 CS 178 Homework 1

Problem 2.1 :

```
In [86]: import numpy as np
         import matplotlib.pyplot as plt
         X = np.genfromtxt("iris.txt", delimiter=',', usecols=(0,1,2,3)) # load the feature va
         Y = np.genfromtxt("iris.txt", delimiter=',', usecols=(4), dtype=str) # load the class
         # convert the class labels to numeric seqeunce 0, 1, 2
         for i, c in enumerate(np.unique(Y)):
             mask = np.where(Y==c)[0]
             Y[mask]=i
         Y=Y.astype(int)
         print("The number of features:")
         print(X.shape[1])
         print("The number of data points:")
         print(X.shape[0])
```

```
The number of features:
4
The number of data points:
150
```

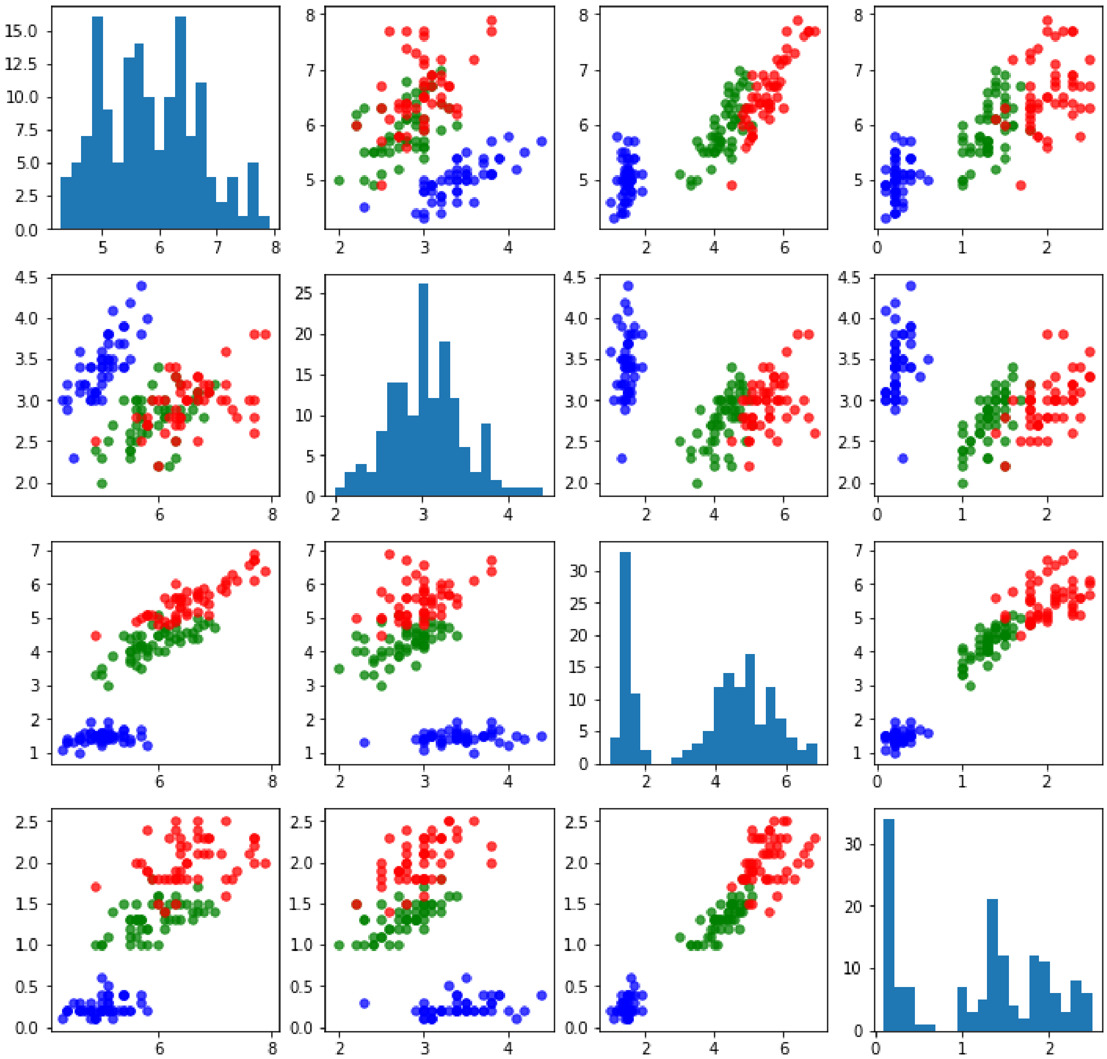
Problem 2.2:

```
In [87]: m, n = X.shape
         ig, ax = plt.subplots(4, 4, figsize=(12, 12))
         colors = ['b','g','r']
         print("The graph below is a '4 x 4' plot gird of scatterplots of all dimension pairs.'
         print("For the same feature, plot the histogram of data values instead:")
         ax[0,0].hist(X[:,0], bins=20) #histogram of feature 0
         ax[1,1].hist(X[:,1], bins=20) #histogram of feature 1
         ax[2,2].hist(X[:,2], bins=20) #histogram of feature 2
         ax[3,3].hist(X[:,3], bins=20) #histogram of feature 3
         # feature 0 vs. feature 1
         for c in range(3):
             mask=np.where(Y==c)[0]
```

```
    ax[0,1].scatter(X[mask,1], X[mask,0], s=30, c=colors[c], alpha=0.75)
# feature 0 va. feature 2
for c in range(3):
    mask=np.where(Y==c)[0]
    ax[0,2].scatter(X[mask,2], X[mask,0], s=30, c=colors[c], alpha=0.75)
# feature 0 va. feature 3
for c in range(3):
    mask=np.where(Y==c)[0]
    ax[0,3].scatter(X[mask,3], X[mask,0], s=30, c=colors[c], alpha=0.75)
# feature 1 vs. feature 0
for c in range(3):
    mask=np.where(Y==c)[0]
    ax[1,0].scatter(X[mask,0], X[mask,1], s=30, c=colors[c], alpha=0.75)
# feature 1 vs. feature 2
for c in range(3):
    mask=np.where(Y==c)[0]
    ax[1,2].scatter(X[mask,2], X[mask,1], s=30, c=colors[c], alpha=0.75)
# feature 1 vs. feature 3
for c in range(3):
    mask=np.where(Y==c)[0]
    ax[1,3].scatter(X[mask,3], X[mask,1], s=30, c=colors[c], alpha=0.75)
# feature 2 vs. feature 0
for c in range(3):
    mask=np.where(Y==c)[0]
    ax[2,0].scatter(X[mask,0], X[mask,2], s=30, c=colors[c], alpha=0.75)
# feature 2 vs. feature 1
for c in range(3):
    mask=np.where(Y==c)[0]
    ax[2,1].scatter(X[mask,1], X[mask,2], s=30, c=colors[c], alpha=0.75)
# feature 2 vs. feature 3
for c in range(3):
    mask=np.where(Y==c)[0]
    ax[2,3].scatter(X[mask,3], X[mask,2], s=30, c=colors[c], alpha=0.75)
# feature 3 vs. feature 0
for c in range(3):
    mask=np.where(Y==c)[0]
    ax[3,0].scatter(X[mask,0], X[mask,3], s=30, c=colors[c], alpha=0.75)
# feature 3 vs. feature 1
for c in range(3):
    mask=np.where(Y==c)[0]
    ax[3,1].scatter(X[mask,1], X[mask,3], s=30, c=colors[c], alpha=0.75)
# feature 3 vs. feature 2
for c in range(3):
    mask=np.where(Y==c)[0]
    ax[3,2].scatter(X[mask,2], X[mask,3], s=30, c=colors[c], alpha=0.75)
plt.show()
```

The graph below is a '4 x 4' plot gird of scatterplots of all dimension pairs.

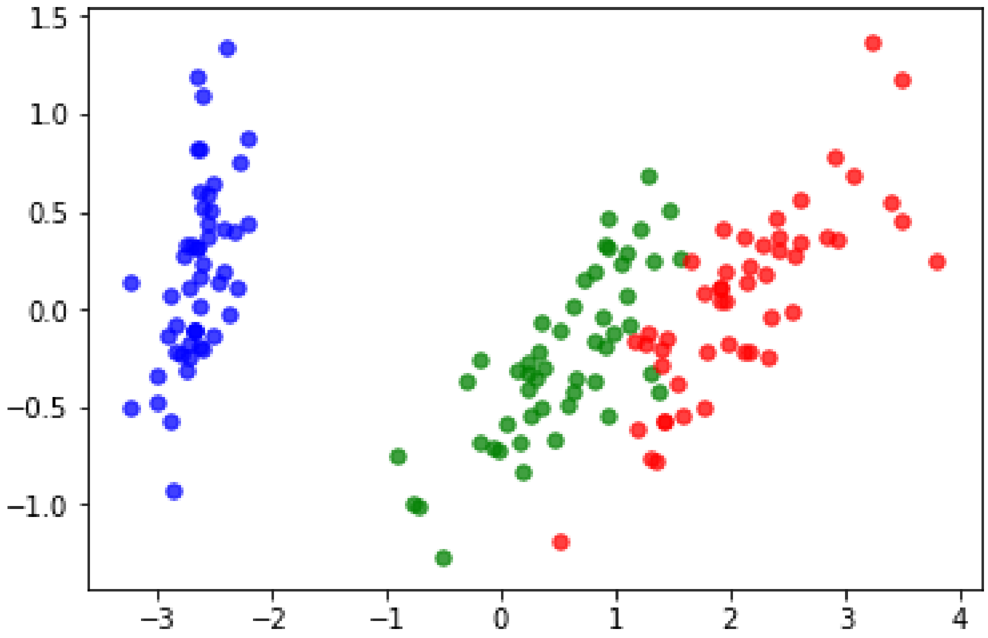
For the same feature, plot the histogram of data values instead:



Problem 2.3:

```
In [88]: from sklearn.decomposition import PCA
         import sklearn
         from sklearn.linear_model import Perceptron
         pca = PCA(n_components=2) # constructor
         Xpca = pca.fit_transform(X) # PCA function to convert X into 2D feature space
         colors=['b', 'g', 'r']
         print("The below is a PCA graph with 2 components:")
         for i, c in enumerate(np.unique(Y)):
             mask=np.where(Y==c)[0]
             plt.scatter(Xpca[mask,0], Xpca[mask,1], s=30, c=colors[i], alpha=0.75)
         plt.show()
```

The below is a PCA graph with 2 components:



Problem 3.1:

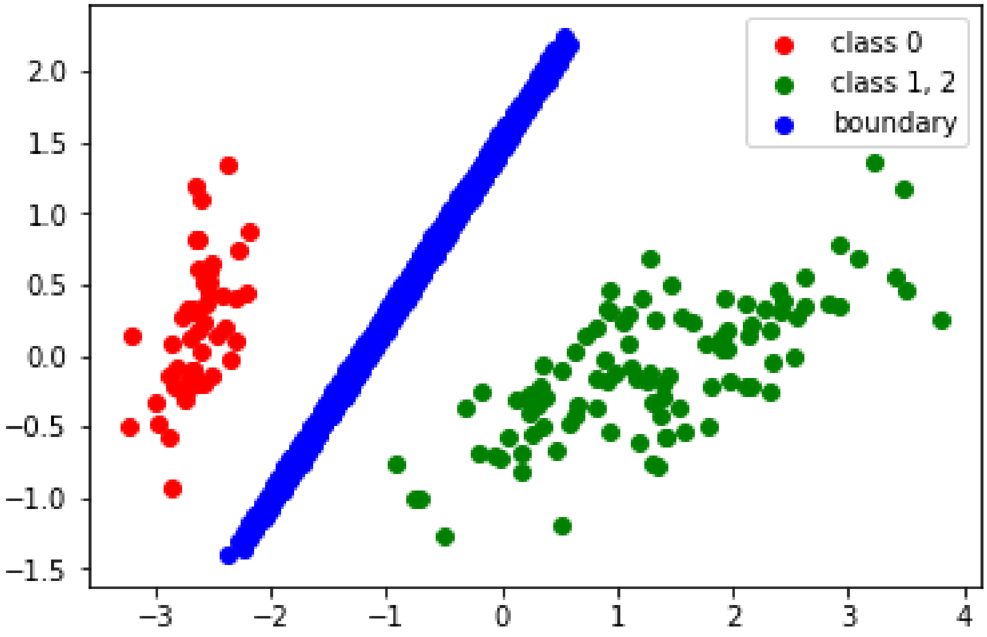
```
In [20]: import sklearn
         from sklearn.linear_model import Perceptron
         # Dataset classes according to 3.1
         XA, YA = X[Y==0,:], Y[Y==0] # Dataset A: class 0
         XB, YB = X[Y!=0,:], Y[Y!=0] # Dataset B: class 1 & 2

         YA[:]=0 # Class 0 as Class 0
         YB[:]=1 # Class 1&2 as Class 1

         Xtr = np.concatenate((XA,XB),axis=0)
         Ytr = np.concatenate((YA,YB),axis=0)

         # Create a sklearn perceptron classifier instance
         clf = Perceptron(random_state=0,tol=1e-3)
         clf.fit(Xtr,Ytr)
         print("The mean accuracy (original space):")
         print(clf.score(Xtr, Ytr))
         print("The error rate: ")
         print(1-clf.score(Xtr, Ytr))
```

```
The mean accuracy (original space):
1.0
```

```
The error rate:
0.0
```

```
In [18]: from sklearn.decomposition import PCA
         import sklearn
         from sklearn.linear_model import Perceptron
         pca = PCA(n_components=2)
         Xpca = pca.fit_transform(X)
         # Plot the data in PCA space
         # mask A: class 0; mask B: class 1 & 2
         maskA, maskB = np.where(Y==0), np.where(Y!=0)
         XApca = Xpca[maskA]
         XBpca = Xpca[maskB]
         plt.scatter(XApca[:,0], XApca[:,1], c='r', label="class 0")
         plt.scatter(XBpca[:,0], XBpca[:,1], c='g', label="class 1, 2")
         # Plot the hyperplane in PCA space
         interNum = 70
         xx0 = np.linspace(X[:,0].min(), X[:,0].max(), interNum)
         xx1 = np.linspace(X[:,1].min(), X[:,1].max(), interNum)
         xx2 = np.linspace(X[:,2].min(), X[:,2].max(), interNum)
         xx3 = np.linspace(X[:,3].min(), X[:,3].max(), interNum)
         gridData = np.array(np.meshgrid(xx0, xx1, xx2, xx3)).T.reshape(-1,4)
         gridPrediction = clf.decision_function(gridData)
         # prediction hyperplane set
         gridDataBound = gridData[np.abs(gridPrediction)<0.0000005, :]
         gridDataBoundPCA = pca.transform(gridDataBound)
         print("The below graph is a 2-dimenional PCA graph which separate 'Iris setosa'")
         print("(class0) from the other two species:")
         plt.scatter(gridDataBoundPCA[:,0], gridDataBoundPCA[:,1], c='b', label="boundary")
         plt.legend()
         plt.show()
```

```
The below graph is a 2-dimenional PCA graph which separate 'Iris setosa'
(class0) from the other two species:
```



Problem 3.2:

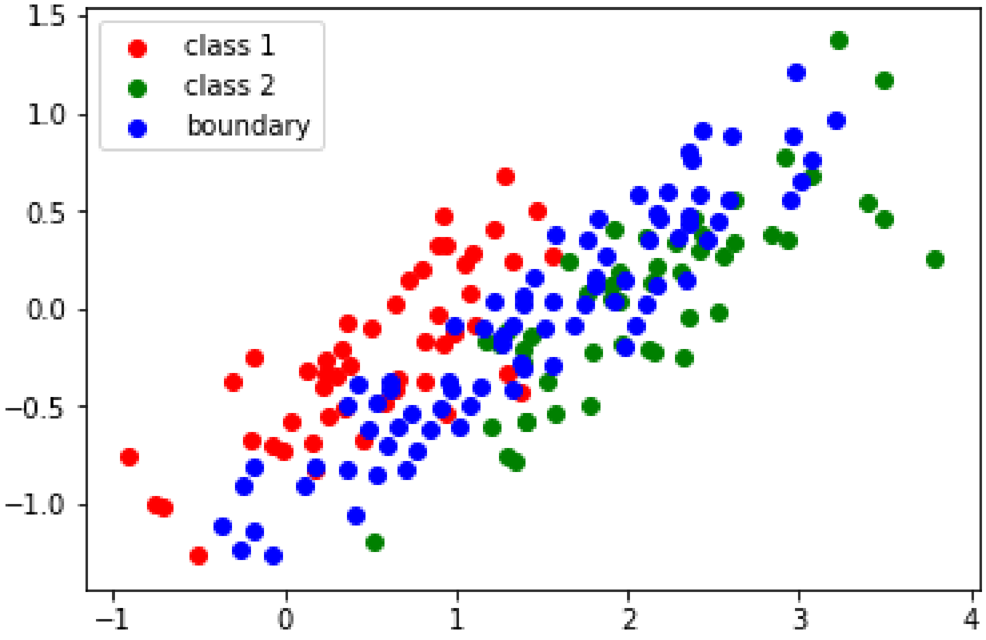
```
In [76]: import sklearn
         from sklearn.linear_model import Perceptron
         # Dataset classes according to 3.1
         XA, YA = X[Y==1,:], Y[Y==1] # Dataset A: class 1
         XB, YB = X[Y==2,:], Y[Y==2] # Dataset B: class 2

         YA[50:]=0 # Class 1 as Class 0
         YB[50:]=1 # Class 2 as Class 1

         Xtr = np.concatenate((XA,XB),axis=0)
         Ytr = np.concatenate((YA,YB),axis=0)

         # Create a sklearn perceptron classifier instance
         clf = Perceptron(random_state=0)
         clf.fit(Xtr,Ytr)
         print("The mean accuracy (original space):")
         print(clf.score(Xtr, Ytr))
         print("The error rate: ")
         print(round(1-clf.score(Xtr, Ytr),3))
```

```
The mean accuracy (original space):
0.98
The error rate:
0.02
```

```
/anaconda3/lib/python3.7/site-packages/sklearn/linear_model/stochastic_gradient.py:166: FutureW
  FutureWarning)
```

```
In [23]: pca = PCA(n_components=2)
         Xpca = pca.fit_transform(X)
         # Plot the data in PCA space
         # mask A: class 1; mask B: class 2
         maskA, maskB = np.where(Y==1), np.where(Y==2)
         XApca = Xpca[maskA]
         XBpca = Xpca[maskB]
         plt.scatter(XApca[:,0], XApca[:,1], c='r', label="class 1")
         plt.scatter(XBpca[:,0], XBpca[:,1], c='g', label="class 2")
         # Plot the hyperplane in PCA space
         interNum = 70
         xx0 = np.linspace(X[50:,0].min(), X[50:,0].max(), interNum)
         xx1 = np.linspace(X[50:,1].min(), X[50:,1].max(), interNum)
         xx2 = np.linspace(X[50:,2].min(), X[50:,2].max(), interNum)
         xx3 = np.linspace(X[50:,3].min(), X[50:,3].max(), interNum)
         gridData = np.array(np.meshgrid(xx0, xx1, xx2, xx3)).T.reshape(-1,4)
         gridPrediction = clf.decision_function(gridData)
         # prediction hyperplane set
         gridDataBound = gridData[np.abs(gridPrediction)<0.000000000000005, :]
         gridDataBoundPCA = pca.transform(gridDataBound)
         print("The below graph is a 2-dimenional PCA graph which separate the other two specie
         plt.scatter(gridDataBoundPCA[:,0], gridDataBoundPCA[:,1], c='b', label="boundary")
         plt.legend()
         plt.show()
```

```
The below graph is a 2-dimenional PCA graph which separate the other two species (class 1 & 2)
```

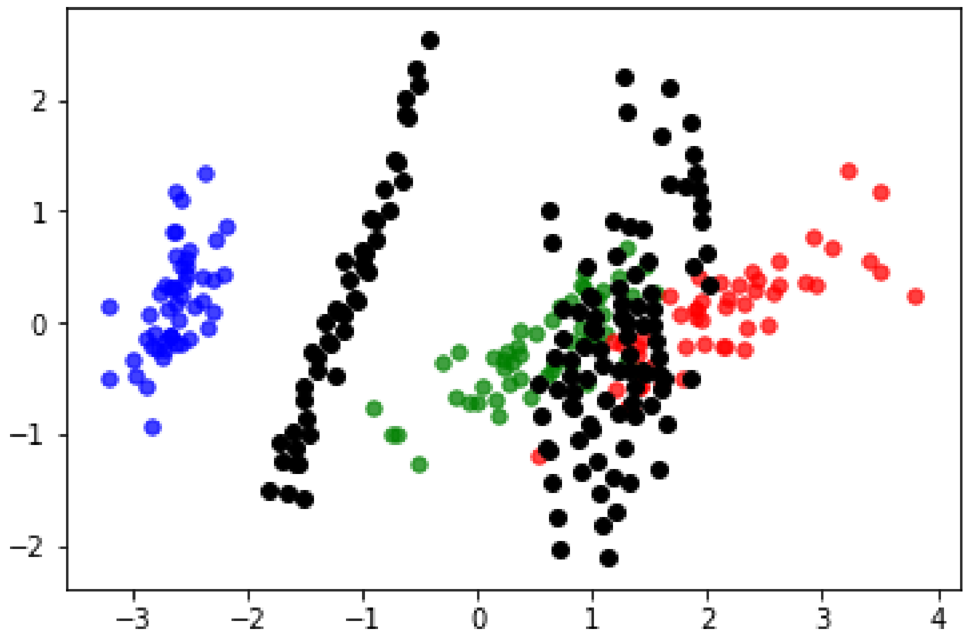


Problem 4:

```
In [85]: from sklearn.decomposition import PCA
         import sklearn
         from sklearn.linear_model import Perceptron
         from sklearn.svm.libsvm import predict_proba
         from sklearn import neighbors
         pca = PCA(n_components=2) # constructor
         Xpca = pca.fit_transform(X) # PCA function to convert X into 2D feature space
         colors=['b', 'g', 'r']
         for i, c in enumerate(np.unique(Y)):
             mask=np.where(Y==c)[0]              #mask is the list of index
             plt.scatter(Xpca[mask,0], Xpca[mask,1], s=30, c=colors[i], alpha=0.75)
         #scatter(x_dataposition, y_dataposition, s = scalar of array, alpha = 0-1:transparent
         interNum = 7
         xx4 = np.linspace(X[:,0].min(), X[:,0].max(), interNum)
         xx5 = np.linspace(X[:,1].min(), X[:,1].max(), interNum)
         xx6 = np.linspace(X[:,2].min(), X[:,2].max(), interNum)
         xx7 = np.linspace(X[:,3].min(), X[:,3].max(), interNum)
         gridData = np.array(np.meshgrid(xx4, xx5, xx6, xx7)).T.reshape(-1,4)

         clf = neighbors.KNeighborsClassifier(n_neighbors = 9)
         clf.fit(X,Y)
         print("The numerical error rate is:")
         print(1-clf.score(X,Y))
         arrPro = clf.predict_proba(gridData)
```

```
newGrid = []
for i, c in enumerate(arrPro):
    alist = c;
    alist.sort()
    if (alist[2] - alist[1]) < 0.12:
        newGrid.append(i)
newGridData = gridData[newGrid, :]

Xpca = pca.transform(newGridData)

plt.scatter(Xpca[:,0],Xpca[:,1], c = 'black', label = "boundary")
print("The below graph shows that the separation plane in 2-dimensional PCA for iris
plt.show()
```

```
The numerical error rate is:
0.020000000000000018
The below graph shows that the separation plane in 2-dimensional PCA for iris data set:
```



Problem 5: When I am doing this homework, I search for same functions online. There are some useful websites such as "https://scikit-learn.org" which is a package of skikit learn. It's very useful in Python. TA inspires me alot during the discussion section. He gave us a detailed talk about how our homework 1 should look like. Also, I go to a study group with Jiaxiang Wang, Wanjing Zhang. On the problem 4, for the confidence function, I get ideas from Jiaxiang Wang.