Course Number: EEL 5840

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Homework 5:

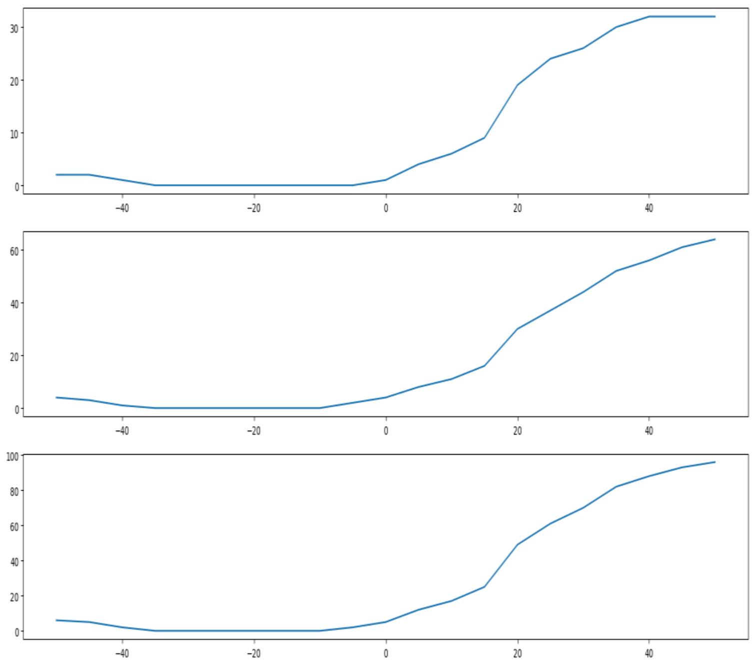
Q1.

Implement the Bayes classifier, under the assumption that your likelihood model p(x | j) is unimodal Gaussian and that the prior probabilities p(j) are dictated by the number of samples n_j belong to R that you have for each class. This classifier is given by the following discriminant function for each class j. (the order of the matrix for the species from up to down and from left to right is 0 and 1)

1) Matrix for test data: $\begin{bmatrix} 28 & 0 \\ 0 & 32 \end{bmatrix}$
2) Matrix for training data: $\begin{bmatrix} 72 & 0 \\ 0 & 68 \end{bmatrix}$
3) Matrix for all the data: $\begin{bmatrix} 100 & 0 \\ 0 & 100 \end{bmatrix}$
4) Processing timer: 0.3445889949798584 seconds

Q2.

Implement a classifier based on linear discriminant analysis. This is a particular case of the Bayes classifier. Here, T belongs to R is a potentially non-zero threshold value that you should choose, in some fashion, on your own. The variables µ0; µ1 2 R7 are the class means for the two classes and Σ0, Σ1 belongs to $R^{7\times7}$ are the class covariances for the two classes. (the order of the matrix for the species from up to down and from left to right is 0 and 1) To make less error I plot a picture of T and sum of error from -50 to 50 as follow and found that the threshold around -20 can cause no error.



The picture of the sum of error and threshold T

1) Matrix for test data: $\begin{bmatrix} 28 & 0 \\ 0 & 32 \end{bmatrix}$

2) Matrix for training data: $\begin{bmatrix} 72 & 0 \\ 0 & 68 \end{bmatrix}$

3) Matrix for all the data: $\begin{bmatrix} 100 & 0 \\ 0 & 100 \end{bmatrix}$

4) Processing time: 0.1093592643737793 seconds

While I did this question, I found that the right of the g(x) is too big, when T is closed to zero. Afterwards, I check out the data and found that the last two dimensions are ‘male’ and ‘female’. These two-opposite phenomena cause the covariance of the two class to be very big. So I add the regularized term lambda to adjust the problem (If I drop one of the last two dimension, the problem can also be solved). I choose the lambda equals to 0.01. To get the threshold, I set the different threshold T, and I got the answers above.

Code 1:

```
import numpy as np
import matplotlib.pyplot as plt
import math
import time
start_time = time.time()

#initial parameters and load data
data = np.loadtxt("dataset.txt")
alldata = data[:,1:8]
training = data[0:140,1:8]
test = data[140:200,1:8]
validate_training = data[0:140,0]
validate_test = data[140:200,0]
validate_data = data[:,0]

count = 0
for i in range(140):
    if validate_training[i] == 1:
        count = count + 1
p_prior1 = count/140
p_prior0 = 1 - (count/140)
```

```
tr_1 = np.zeros([count,7])
tr_0 = np.zeros([140-count,7])

ind1 = 0
ind0 = 0
for i in range(140):
    if validate_training[i] == 1:
        tr_1[ind1] = training[i,:]
        ind1 = ind1 + 1
    if validate_training[i] == 0:
        tr_0[ind0] = training[i,:]
        ind0 = ind0 + 1

mean_1 = np.zeros(7)
mean_0 = np.zeros(7)

for i in range(7):
    mean_1[i] = sum(tr_1[:,i])/count
    M1 = mean_1[i]*np.ones([count,1])

    mean_0[i] = sum(tr_0[:,i])/(140-count)
```

```
	M0 = mean_0[i]*np.ones([(140-count),1])

sig_1 = 0
sig_0 = 0
for i in range(count):
	sig_1 = sig_1 + (tr_1[i,:]-np.asmatrix(mean_1)).T@(tr_1[i,:]-np.asmatrix(mean_1))/count
for i in range(140-count):
	sig_0 = sig_0 + (tr_0[i,:]-np.asmatrix(mean_0)).T@(tr_0[i,:]-np.asmatrix(mean_0))/(140-count)
#sig_1 = np.cov(tr_1.T)
#sig_0 = np.cov(tr_0.T)

count1 = 0
count0 = 0

for i in range(60):
	g1 = -0.5*((np.asmatrix(test[i,:]) - np.asmatrix(mean_1))@np.linalg.inv(sig_1)@(np.asmatrix(test[i,:]) - np.asmatrix(mean_1)).T) - 3.5*math.log1p(2*math.pi) - 0.5*math.log1p(np.linalg.det(sig_1)) + math.log1p(p_prior1)
	g0 = -0.5*((np.asmatrix(test[i,:]) -
```

```
np.asmatrix(mean_0))@np.linalg.inv(sig_0)@(np.asmatrix(test[
i,:]) - np.asmatrix(mean_0)).T) - 3.5*math.log1p(2*math.pi) -
0.5*math.log1p(np.linalg.det(sig_0)) + math.log1p(p_prior0)
    if g1 >= g0:
        if validate_test[i] == 1:
            count1 = count1 + 1
    else:
        if g0 > g1:
            if validate_test[i] == 0:
                count0 = count0 + 1

c = 0
for i in range(60):
    if validate_test[i] == 1:
        c = c + 1

error1 = c - count1
error0 = 60 - c - count0

Matrix1 = np.ones([2,2])
Matrix1[0,0] = count0
Matrix1[1,0] = error0
```

```
Matrix1[0,1] = error1
Matrix1[1,1] = count1



count1 = 0
count0 = 0

for i in range(140):
    g1 = -0.5*((np.asmatrix(training[i,:]) - np.asmatrix(mean_1))@np.linalg.inv(sig_1)@(np.asmatrix(training[i,:]) - np.asmatrix(mean_1)).T) - 3.5*math.log1p(2*math.pi) - 0.5*math.log1p(np.linalg.det(sig_1)) + math.log1p(p_prior1)
    g0 = -0.5*((np.asmatrix(training[i,:]) - np.asmatrix(mean_0))@np.linalg.inv(sig_0)@(np.asmatrix(training[i,:]) - np.asmatrix(mean_0)).T) - 3.5*math.log1p(2*math.pi) - 0.5*math.log1p(np.linalg.det(sig_0)) + math.log1p(p_prior0)
    if g1 >= g0:
        if validate_training[i] == 1:
            count1 = count1 + 1
    else:
        if g0 > g1:
            if validate_training[i] == 0:
```

```
                count0 = count0 + 1

c = 0
for i in range(140):
    if validate_training[i] == 1:
        c = c + 1

error1 = c - count1
error0 = 140 - c - count0

Matrix2 = np.ones([2,2])
Matrix2[0,0] = count0
Matrix2[1,0] = error0
Matrix2[0,1] = error1
Matrix2[1,1] = count1

count1 = 0
count0 = 0

for i in range(200):
    g1 = -0.5*((np.asmatrix(alldata[i,:]) -
np.asmatrix(mean_1))@np.linalg.inv(sig_1)@(np.asmatrix(allda
```

```
ta[i,:]) - np.asmatrix(mean_1)).T) - 3.5*math.log1p(2*math.pi) -
0.5*math.log1p(np.linalg.det(sig_1)) + math.log1p(p_prior1)
    g0 = -0.5*((np.asmatrix(alldata[i,:]) -
np.asmatrix(mean_0))@np.linalg.inv(sig_0)@(np.asmatrix(allda
ta[i,:]) - np.asmatrix(mean_0)).T) - 3.5*math.log1p(2*math.pi) -
0.5*math.log1p(np.linalg.det(sig_0)) + math.log1p(p_prior0)
    if g1 >= g0:
        if validate_data[i] == 1:
            count1 = count1 + 1
    else:
        if g0 > g1:
            if validate_data[i] == 0:
                count0 = count0 + 1

c = 0
for i in range(200):
    if validate_data[i] == 1:
        c = c + 1

error1 = c - count1
error0 = 200 - c - count0
```

```
Matrix3 = np.ones([2,2])
Matrix3[0,0] = count0
Matrix3[1,0] = error0
Matrix3[0,1] = error1
Matrix3[1,1] = count1

print(Matrix1)#test
print(Matrix2)#training
print(Matrix3)#all
print("--- %s seconds ---" % (time.time() - start_time))#processing time
```

Code 2:

```
import numpy as np
import matplotlib.pyplot as plt
import math
import time
start_time = time.time()

#initial parameters and load data
data = np.loadtxt("dataset.txt")
alldata = data[:,1:8]
training = data[0:140,1:8]
test = data[140:200,1:8]
validate_training = data[0:140,0]
validate_test = data[140:200,0]
validate_data = data[:,0]

count = 0
for i in range(140):
    if validate_training[i] == 1:
        count = count + 1
p_prior1 = count/140
p_prior0 = 1 - (count/140)
```

```
tr_1 = np.zeros([count,7])
tr_0 = np.zeros([140-count,7])

ind1 = 0
ind0 = 0
for i in range(140):
    if validate_training[i] == 1:
        tr_1[ind1] = training[i,:]
        ind1 = ind1 + 1
    if validate_training[i] == 0:
        tr_0[ind0] = training[i,:]
        ind0 = ind0 + 1

mean_1 = np.zeros(7)
mean_0 = np.zeros(7)

for i in range(7):
    mean_1[i] = sum(tr_1[:,i])/count
    M1 = mean_1[i]*np.ones([count,1])

    mean_0[i] = sum(tr_0[:,i])/(140-count)
```

```
    M0 = mean_0[i]*np.ones([(140-count),1])

sig_1 = 0
sig_0 = 0
for i in range(count):
    sig_1 = sig_1 + (tr_1[i,:]-np.asmatrix(mean_1)).T@(tr_1[i,:]-
np.asmatrix(mean_1))/count
for i in range(140-count):
    sig_0 = sig_0 + (tr_0[i,:]-np.asmatrix(mean_0)).T@(tr_0[i,:]-
np.asmatrix(mean_0))/(140-count)
#sig_1 = np.cov(tr_1.T)
#sig_0 = np.cov(tr_0.T)

lambda_0 = 0.01
lambda_1 = 0.01

sig_0 = sig_0 + lambda_0*np.eye(7)
sig_1 = sig_1 + lambda_1*np.eye(7)

count1 = 0
count0 = 0
```

```
T = -5
for i in range(60):
    g1 = np.asmatrix(test[i,:])@np.linalg.inv(0.5*(sig_1+sig_0))@(np.asmatrix(mean_1)-np.asmatrix(mean_0)).T
    g0 = 0.25*(np.asmatrix(mean_0)@np.linalg.inv(sig_0)@np.asmatrix(mean_0).T - np.asmatrix(mean_1)@np.linalg.inv(sig_1)@np.asmatrix(mean_1).T + T)
    if g1 >= g0:
        if validate_test[i] == 1:
            count1 = count1 + 1
    else:
        if g1 < g0:
            if validate_test[i] == 0:
                count0 = count0 + 1
print(g0)

c = 0
for i in range(60):
    if validate_test[i] == 1:
```

```
        c = c + 1

error1 = c - count1
error0 = 60 - c - count0

Matrix1 = np.ones([2,2])
Matrix1[0,0] = count0
Matrix1[1,0] = error0
Matrix1[0,1] = error1
Matrix1[1,1] = count1




count1 = 0
count0 = 0

T = -10

for i in range(140):
    g1                                                    =
np.asmatrix(training[i,:])@np.linalg.inv(0.5*(sig_1+sig_0))@(np
.asmatrix(mean_1)-np.asmatrix(mean_0)).T
```

```
    g0 = 0.25*(np.asmatrix(mean_0)@np.linalg.inv(sig_0)@np.asmatrix(mean_0).T - np.asmatrix(mean_1)@np.linalg.inv(sig_1)@np.asmatrix(mean_1).T + T)
    if g1 >= g0:
        if validate_training[i] == 1:
            count1 = count1 + 1
    else:
        if g1 < g0:
            if validate_training[i] == 0:
                count0 = count0 + 1


c = 0
for i in range(140):
    if validate_training[i] == 1:
        c = c + 1


error1 = c - count1
error0 = 140 - c - count0


Matrix2 = np.ones([2,2])
```

```
Matrix2[0,0] = count0
Matrix2[1,0] = error0
Matrix2[0,1] = error1
Matrix2[1,1] = count1



count1 = 0
count0 = 0

T = -10

for i in range(200):
    g1                                                            =
np.asmatrix(alldata[i,:])@np.linalg.inv(0.5*(sig_1+sig_0))@(np.
asmatrix(mean_1)-np.asmatrix(mean_0)).T
    g0                                                            =
0.25*(np.asmatrix(mean_0)@np.linalg.inv(sig_0)@np.asmatrix(
mean_0).T                                                          -
np.asmatrix(mean_1)@np.linalg.inv(sig_1)@np.asmatrix(mean
_1).T + T)
    if g1 >= g0:
```

```
        if validate_data[i] == 1:
            count1 = count1 + 1
    else:
        if g1 < g0:
            if validate_data[i] == 0:
                count0 = count0 + 1
print(g0)

c = 0
for i in range(200):
    if validate_data[i] == 1:
        c = c + 1

error1 = c - count1
error0 = 200 - c - count0

Matrix3 = np.ones([2,2])
Matrix3[0,0] = count0
Matrix3[1,0] = error0
Matrix3[0,1] = error1
Matrix3[1,1] = count1
```

```
print(Matrix1)#test
print(Matrix2)#training
print(Matrix3)#all
print("--- %s seconds ---" % (time.time() - start_time))#processing time
```

Code 3:

```
import numpy as np
import matplotlib.pyplot as plt
import math
import time
start_time = time.time()
fig = plt.figure(figsize=(30,10))

#initial parameters and load data
data = np.loadtxt("dataset.txt")
alldata = data[:,1:8]
training = data[0:140,1:8]
test = data[140:200,1:8]
validate_training = data[0:140,0]
validate_test = data[140:200,0]
validate_data = data[:,0]

count = 0
for i in range(140):
    if validate_training[i] == 1:
        count = count + 1
p_prior1 = count/140
```

```
p_prior0 = 1 - (count/140)

tr_1 = np.zeros([count,7])
tr_0 = np.zeros([140-count,7])

ind1 = 0
ind0 = 0
for i in range(140):
    if validate_training[i] == 1:
        tr_1[ind1] = training[i,:]
        ind1 = ind1 + 1
    if validate_training[i] == 0:
        tr_0[ind0] = training[i,:]
        ind0 = ind0 + 1

mean_1 = np.zeros(7)
mean_0 = np.zeros(7)

for i in range(7):
    mean_1[i] = sum(tr_1[:,i])/count
    M1 = mean_1[i]*np.ones([count,1])
```

```
        mean_0[i] = sum(tr_0[:,i])/(140-count)
        M0 = mean_0[i]*np.ones([(140-count),1])

sig_1 = 0
sig_0 = 0
for i in range(count):
        sig_1 = sig_1 + (tr_1[i,:]-np.asmatrix(mean_1)).T@(tr_1[i,:]-
np.asmatrix(mean_1))/count
for i in range(140-count):
        sig_0 = sig_0 + (tr_0[i,:]-np.asmatrix(mean_0)).T@(tr_0[i,:]-
np.asmatrix(mean_0))/(140-count)
#sig_1 = np.cov(tr_1.T)
#sig_0 = np.cov(tr_0.T)

lambda_0 = 0.01
lambda_1 = 0.01

sig_0 = sig_0 + lambda_0*np.eye(7)
sig_1 = sig_1 + lambda_1*np.eye(7)

count1 = 0
count0 = 0
```

```
error = np.zeros(21)
d = np.arange(-50,55,5)

for t in range(0,21,1):
    T = t*5 - 50
    for i in range(60):
        g1 = np.asmatrix(test[i,:])@np.linalg.inv(0.5*(sig_1+sig_0))@(np.asmatrix(mean_1)-np.asmatrix(mean_0)).T
        g0 = 0.25*(np.asmatrix(mean_0)@np.linalg.inv(sig_0)@np.asmatrix(mean_0).T - np.asmatrix(mean_1)@np.linalg.inv(sig_1)@np.asmatrix(mean_1).T + T)
        if g1 >= g0:
            if validate_test[i] == 1:
                count1 = count1 + 1
        else:
            if g1 < g0:
                if validate_test[i] == 0:
                    count0 = count0 + 1
    c = 0
```

```
    for i in range(60):
        if validate_test[i] == 1:
            c = c + 1
    error1 = c - count1
    error0 = 60 - c - count0
    error[t] = error1 + error0
    count1 = 0
    count0 = 0
p1 = fig.add_subplot(*[3,1,1])
p1.plot(d,error)

for t in range(0,21,1):
    T = t*5 - 50
    for i in range(140):
        g1 = np.asmatrix(training[i,:])@np.linalg.inv(0.5*(sig_1+sig_0))@(np.asmatrix(mean_1)-np.asmatrix(mean_0)).T
        g0 = 0.25*(np.asmatrix(mean_0)@np.linalg.inv(sig_0)@np.asmatrix(mean_0).T - np.asmatrix(mean_1)@np.linalg.inv(sig_1)@np.asmatrix(mean_1).T + T)
```

```
        if g1 >= g0:
            if validate_training[i] == 1:
                count1 = count1 + 1
        else:
            if g1 < g0:
                if validate_training[i] == 0:
                    count0 = count0 + 1
    c = 0
    for i in range(140):
        if validate_training[i] == 1:
            c = c + 1
    error1 = c - count1
    error0 = 140 - c - count0
    error[t] = error1 + error0
    count1 = 0
    count0 = 0
p2 = fig.add_subplot(*[3,1,2])
p2.plot(d,error)

for t in range(0,21,1):
    T = t*5 - 50
    for i in range(200):
```

```
        g1                                                    =
np.asmatrix(alldata[i,:])@np.linalg.inv(0.5*(sig_1+sig_0))@(np.
asmatrix(mean_1)-np.asmatrix(mean_0)).T
        g0                                                    =
0.25*(np.asmatrix(mean_0)@np.linalg.inv(sig_0)@np.asmatrix(
mean_0).T                                                     -
np.asmatrix(mean_1)@np.linalg.inv(sig_1)@np.asmatrix(mean
_1).T + T)
        if g1 >= g0:
            if validate_data[i] == 1:
                count1 = count1 + 1
        else:
            if g1 < g0:
                if validate_data[i] == 0:
                    count0 = count0 + 1
    c = 0
    for i in range(200):
        if validate_data[i] == 1:
            c = c + 1
    error1 = c - count1
    error0 = 200 - c - count0
    error[t] = error1 + error0
```

```
    count1 = 0
    count0 = 0
p3 = fig.add_subplot(*[3,1,3])
p3.plot(d,error)
```