**CS 7267- HW 2**

**Intro. Open file and Set matrix**

|  |
| --- |
| import csv  import numpy as np  import numpy.linalg as lin  import matplotlib.pyplot as plt  #Open file and set matrix  tmpfile = open("MNIST\_training.csv", "rt", encoding='utf-8')  trn = np.array(list(csv.reader(tmpfile)))  trnY = np.transpose(np.matrix(np.array(trn[1:, 0], dtype=int)))  trnX = np.array(trn[1:, :], dtype=int)  trnX[0:, 0] = 1 #set 0-th column value 1 for intercept  tmpfile = open("MNIST\_test.csv", "rt", encoding='utf-8')  tst = np.array(list(csv.reader(tmpfile)))  tstY = np.transpose(np.matrix(np.array(tst[1:, 0], dtype=int)))  tstX = np.array(tst[1:, :], dtype=int)  tstX[0:, 0] = 1 #set 0-th column value 1 for intercept |

To make trnY and tstY vector(column), I applied np.array and np.matrix and then np.transpose.

trnY is labels of training data.

trnX is features of training data.

tstY is labels of test data.

tstX is features of test data.

For intercept, I put 0-th column value 1.

**Task 1. Classifying MNIST data**

1. Train a linear regression model

Here is a function to get optimal coefficient by the equation: b\_opt = (X'X)^(-1)X'y

# Get optimal coefficient

def getOptCoef(X,y) :

Xt = np.transpose(X)

optCoef = np.array(np.dot(np.dot(lin.pinv(np.dot(Xt, X)),Xt),y), dtype=float)

return optCoef

2. Display the optimal coefficients (denoted by b\_opt)

# Display the optimal coefficients (denoted by b\_opt)

b\_opt = getOptCoef(trnX,trnY)

print(b\_opt)

OUTPUT : [Appendix (1) b\_opt](#Appendix1_b_opt)

3. Classify test data (MNIST\_test.csv) with a threshold of 0.5.

def binaryClassification(X, coef, threshold):

y\_pred = np.dot(X, coef)

y\_pred[y\_pred > threshold] = 1

y\_pred[y\_pred <= threshold] = 0

return y\_pred

y\_pred = binaryClassification(tstX, b\_opt, 0.5)

print(y\_pred)

4. Display the accuracy

# Display the accuracy

Accuracy = (np.sum(y\_pred == tstY))/len(tstY)

Accuracy

OUTPUT : 0.97999999999999998

**Task 2. Implementation of Gradient Descent**

1. Set the initial coefficient to zeros

b\_est = np.zeros((len(trnX[0]), 1), dtype=float)

2. Determine hyper-parameters such as learning rate and iteration numbers

iteration = 50

learningRate = 0.000000003

sqError = np.zeros((iteration, 1), dtype=float)

3. Run "gradient descent" algorithm with the hyper-parameters and check "Learning Curve"

Learning curve shows whether it converges or not.

# Get estimated coefficient by Gradient Descend

def getGDcoef(coef, X, y, sqError,iteration, learningRate):

Xt = np.transpose(X)

for i in range(iteration):

coef = coef - learningRate\*(np.dot(np.dot(Xt,X), coef) - np.dot(Xt, y))

sqError[i] = np.dot((np.transpose(y-np.dot(X, coef))), (y-np.dot(X, coef)))

return coef

b\_est = getGDcoef(b\_est, trnX, trnY, sqError,iteration, learningRate)

The equation to get squared error: J(b) = (y-Xb)’(y-Xb)

Its gradient : J’(b) = 2X’Xb – 2X’y

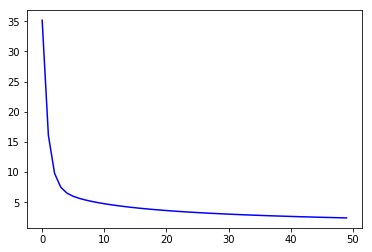
In function getGDcoef(), it iterates { coef = coef – J’(coef) } until sqError(in other words, J(coef)) is small enough.

# Check "Learning Curve"

print(sqError)

plt.plot(sqError, 'b-')

plt.show()



X-axis shows iteration, while y-axis shows cost.

OUTPUT of print(sqError) is on [Appendix (2) sqError](#Appendix2_sqError) .

4. Display the optimal coefficients (denoted by b\_est)

print(b\_est)

OUTPUT : [Appendix (3) b\_est](#Appendix3_b_est) .

5. Classify test data (MNIST\_test.csv) with a threshold of 0.5.

y\_pred = binaryClassification(tstX, b\_est, 0.5)

6. Display the accuracy

Accuracy = (np.sum(y\_pred == tstY))/len(tstY)

print(Accuracy)

OUTPUT : 0.995

7. Display the total differences between b\_opt and b\_est

print(np.sum(np.abs(b\_opt-b\_est)))

OUTPUT : 0.0714927920412

**Appendix**

(1) b\_opt

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