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My Code:

HW2.py

```
#!/usr/bin/python
import os, struct
from array import array as pyarray
from numpy import append, array, int8, uint8, zeros
import numpy as np
from pylab import *
import random
import matplotlib.pyplot as plt
def load_mnist(dataset="training", digits=np.arange(10)):
    if dataset == "training":
        fname_img = os.path.join('/Users/ou/Dropbox/course/559 neural
networks/HW/hw2/train-images-idx3-ubyte')
        fname_lbl = os.path.join('/Users/ou/Dropbox/course/559 neural
networks/HW/hw2/train-labels-idx1-ubyte')
    elif dataset == "testing":
        fname_img = os.path.join('/Users/ou/Dropbox/course/559 neural
networks/HW/hw2/t10k-images-idx3-ubyte')
        fname_lbl = os.path.join('/Users/ou/Dropbox/course/559 neural
networks/HW/hw2/t10k-labels-idx1-ubyte')
    else:
        raise ValueError("dataset must be 'testing' or 'training'")
    flbl = open(fname_lbl, 'rb')
    magic_nr, size = struct.unpack(">II", flbl.read(8))
    lbl = pyarray("b", flbl.read())
    flbl.close()
    fimg = open(fname_img, 'rb')
    magic_nr, size, rows, cols = struct.unpack(">IIII", fimg.read(16))
    img = pyarray("B", fimg.read())
    fimg.close()
    ind = [ k for k in range(size) if lbl[k] in digits ]
    N = len(ind)
    images = zeros((N, rows, cols), dtype=uint8)
    labels = zeros((N, 1), dtype=int8)
    for i in range(len(ind)):
        images[i] = array(img[ ind[i]*rows*cols : (ind[i]+1)*rows*cols ]).reshape((rows, cols))
        labels[i] = lbl[ind[i]]
    return images, labels
#imshow(images.mean(axis=0), cmap=cm.gray)
```

```
#show()
#print images[1]
#images /= 255.0
def get_weights(m,n):
	list_x=[0]*784
	list_w=[[ 0 for i in range(10)] for j in range(784)]
	for i in range(1,784):
		for j in range(1,10):
			list_w[i][j]=random.uniform(m,n)
	return	list_w
def get_x(image):
	list_x=[]
	for i in range(28):
		for j in range(28):
			list_x.append(image[i][j])
	return list_x
###################### initalize all global variable ########################
vout=[]
x=[]
######################## all functions ############################
def sample(condition):
	images=[]
	labels=[]
	if condition=='training':
		for n in range(10):
			image,label =load_mnist('training',digits=[n])#the label n
			images.append(image)
			labels.append(label)
	elif condition=='testing':
		for n in range(10):
			image,label =load_mnist('testing',digits=[n])#the label n
			images.append(image)
			labels.append(label)
	else:
		print'the condition is wrong'
	return images,labels
def equals(i,j,w):
	dout=[0]*10
	x=get_x(images[i][j])
	v = np.dot(x,w)
	v = v.tolist()
	max_index=v.index(max(v))
	#desired_output
```

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        dout[i]=1
        if max_index==i:
                return 1,x,v,dout
        else:
                return 0,x,v,dout
# current_output
def current_output(vout):
        cout=[]
        for i in range(len(vout)):
                cout.append(1 if vout[i] >= 0 else 0)
        return cout
def pta(u,dout,cout,x,w):
        for i in range(784):
                for j in range(10):
                        w[i][j]=w[i][j]+u*(dout[j]-cout[j])*x[i]
        return w
def train(w,u,n,minmum):
        error_epoch=[]
        epoch = 0
        while True:
                # step 1 count errors
                error = 0
                for j in range(n/10):
                        for i in range(10):
                                (m,x,v,d)=equals(i,j,w)
                                #print m
                                c=current_output(v)
                                if (m==0):
                                        error = error + 1
                                elif (m==1):
                                        error = error + 0
                error_epoch.append(error)
                print "@epoch", epoch, "# errors = ", error
                # step 2 add epoch
                epoch = epoch + 1
                # step 3 update W
                for j in range(n/10):
                        for i in range(10):
                                (m,x,v,d)=equals(i,j,w)
                                c=current_output(v)
                                w=pta(u,d,c,x,w)
                # step 4 check if continue
                # 0 should work
```

```
if (error_epoch[epoch-1])<= minmum*n:
                                break
        return w
def test(w,u,n):
                # step 1 count errors
                error = 0
                for j in range(n/10):
                        for i in range(10):
                                (m,x,v,d)=equals(i,j,w)
                                #print m
                                c=current_output(v)
                                if (m==0):
                                        error = error + 1
                                elif (m==1):
                                        error = error + 0
                return error
print'###################### u=1 min=0 ################################'
print'############ Q(f) 50 d #################'
images,labels=sample('training')
w=get_weights(-1,1)
w_f=train(w,1,50,0)
print'########### Q(f) 10000 e ################'
images,labels=sample('testing')
#IndexError: index 892 is out of bounds for axis 0 with size 892
error=test(w_f,1,8920)+test(w_f,1,1080)
print   "# errors of 50    = ", error
print'########### Q(g) 1000 d #################'
images,labels=sample('training')
w=get_weights(-1,1)
w_g=train(w,1,1000,0)
print'########### Q(g) 10000 e ################'
images,labels=sample('testing')
#IndexError: index 892 is out of bounds for axis 0 with size 892
error=test(w_g,1,8920)+test(w_g,1,1080)
print   "# errors of 1000 = ", error
print'########### Q(h) 60000 d ################'
images,labels=sample('training')
w=get_weights(-1,1)
#IndexError: index 5421 is out of bounds for axis 0 with size 5421
w_n=train(w,1,54210,0)
w_h=train(w_n,1,5790,0)
print'########### Q(h) 10000 e ################'
images,labels=sample('testing')
```

```
#IndexError: index 892 is out of bounds for axis 0 with size 892
error=test(w_h,1,8920)+test(w_h,1,1080)
print    "# errors of 60000= ", error
print '########### Repeat the following two subitems three times ##########'
print'########### first time u=10 minimum=0.01 ################'
images,labels=sample('training')
w=get_weights(-1,1)
#IndexError: index 5421 is out of bounds for axis 0 with size 5421
w_n=train(w,10,54210,0.01)
w_h=train(w_n,10,5790,0.01)
images,labels=sample('testing')
#IndexError: index 892 is out of bounds for axis 0 with size 892
error=test(w_h,10,8920)+test(w_h,10,1080)
print    "# errors of 60000= ", error
print'########### second time u=0.1 minimum=0.01    ################'
images,labels=sample('training')
w=get_weights(-1,1)
#IndexError: index 5421 is out of bounds for axis 0 with size 5421
w_n=train(w,0.1,54210,0.01)
w_h=train(w_n,0.1,5790,0.01)
images,labels=sample('testing')
#IndexError: index 892 is out of bounds for axis 0 with size 892
error=test(w_h,0.1,8920)+test(w_h,0.1,1080)
print    "# errors of 60000= ", error
print'########### third time u=10 minimum=0.1 ################'
images,labels=sample('training')
w=get_weights(-1,1)
#IndexError: index 5421 is out of bounds for axis 0 with size 5421
w_n=train(w,10,54210,0.1)
w_h=train(w_n,10,5790,0.1)
images,labels=sample('testing')
#IndexError: index 892 is out of bounds for axis 0 with size 892
error=test(w_h,10,8920)+test(w_h,10,1080)
print    "# errors of 60000= ", error
```

Results:

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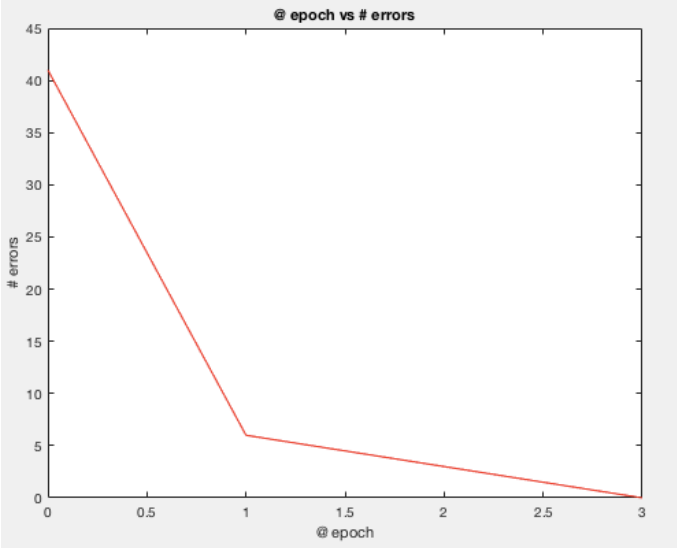
(f) Run Steps (d) and (e) for n=50, η=1,

```
#################### u=1 min=0 ################################
############ Q(f) 50 d ##################
@epoch 0 # errors =    41
@epoch 1 # errors =    6
@epoch 2 # errors =    3
@epoch 3 # errors =    0
########### Q(f) 10000 e ################
```

 # errors of 50 = 4298/10000= 42.98%

the percentages of errors obtained through the training and test samples are different (epoch=0 82% vs 42.98% and finally 0% vs 42.98%), the weights obtained after training present a better result, which means the algorithm works.



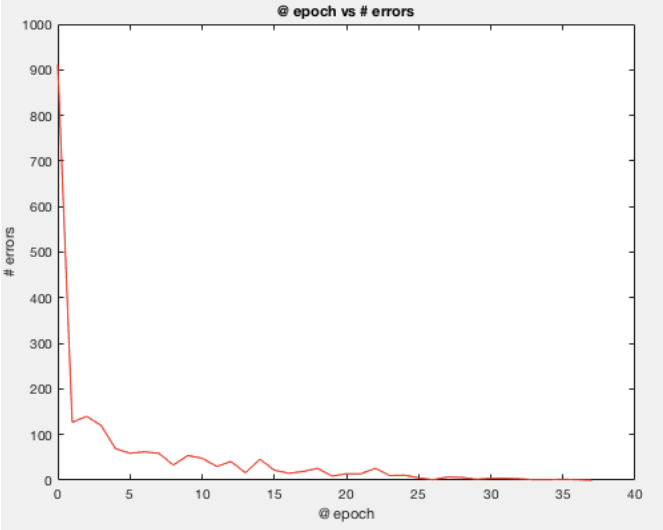
(g) Run Steps (d) and (e) for n=1000, η=1,

########### Q(g) 1000 d ##################
@epoch 0 # errors = 911
@epoch 1 # errors = 127
@epoch 2 # errors = 140
@epoch 3 # errors = 120
@epoch 4 # errors = 69
@epoch 5 # errors = 59
@epoch 6 # errors = 62
@epoch 7 # errors = 59
@epoch 8 # errors = 33
@epoch 9 # errors = 54
@epoch 10 # errors = 48
@epoch 11 # errors = 30
@epoch 12 # errors = 41
@epoch 13 # errors = 16
@epoch 14 # errors = 46
@epoch 15 # errors = 22
@epoch 16 # errors = 15
@epoch 17 # errors = 19
@epoch 18 # errors = 26
@epoch 19 # errors = 9
@epoch 20 # errors = 14
@epoch 21 # errors = 14
@epoch 22 # errors =
@epoch 23 # errors = 10
@epoch 24 # errors = 11
@epoch 25 # errors = 5
@epoch 26 # errors = 1
@epoch 27 # errors = 7
@epoch 28 # errors = 6
@epoch 29 # errors = 2
@epoch 30 # errors = 4
@epoch 31 # errors = 4
@epoch 32 # errors = 3
@epoch 33 # errors = 1
@epoch 34 # errors = 1

@epoch 35 # errors = 2
@epoch 36 # errors = 1
@epoch 37 # errors = 0
########### Q(g) 10000 e #################

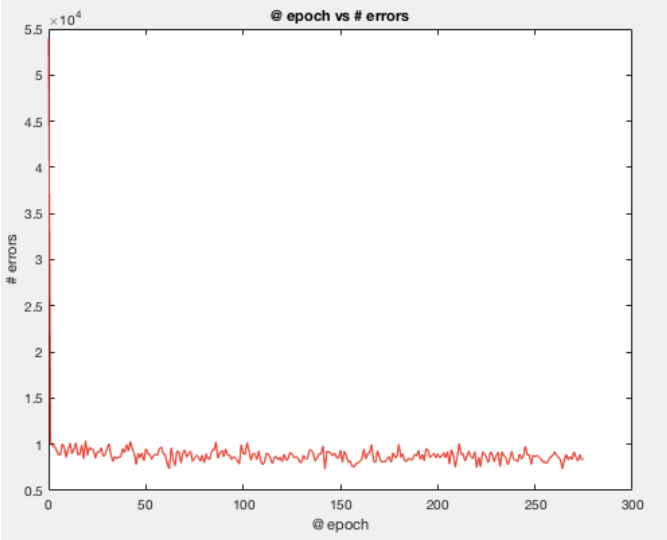
 # errors of 1000 = 1787/10000= 17.87%

the percentages of errors obtained through the training and test samples are different (epoch=0 91.1% vs 17.87% and finally 0% vs 17.87%) and after comparing the weights obtained in 50 samples training and in 1000 samples, I found more samples could train a better and more idealized weight.



(h) Run Steps (d) and (e) for n=60000, η=1,

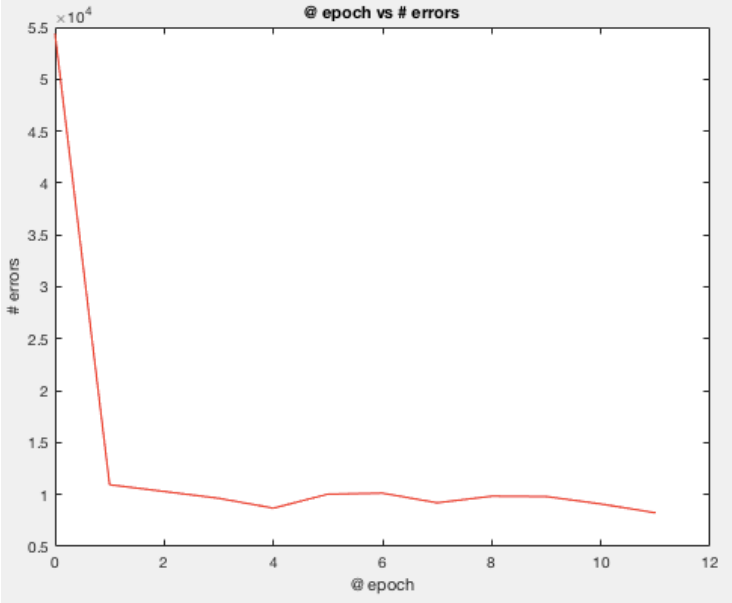
the number of epoch is too big; I will just show pictures below.



the algorithm does not converge because the training samples are not linearly separable. The error number begins to oscillate.

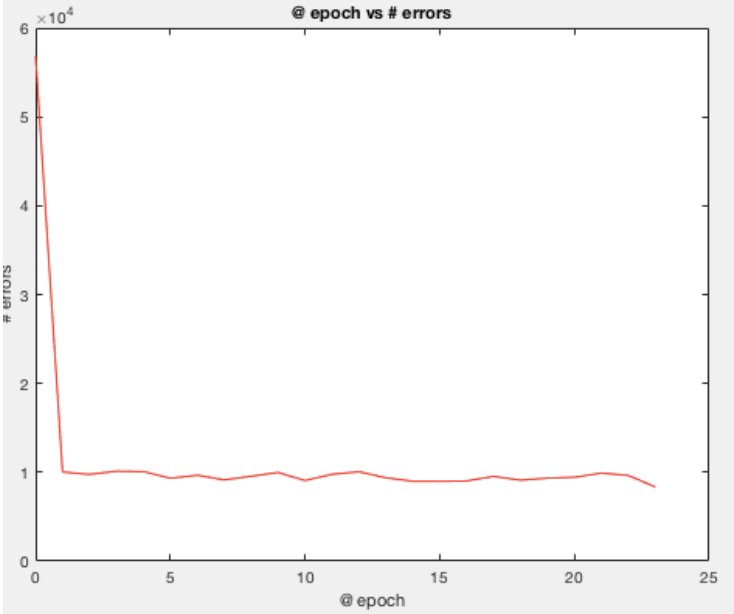
(I)Repeat the following two sub items three times with different initial weights and comment on the results:

η=1, $\varepsilon = 0.14$



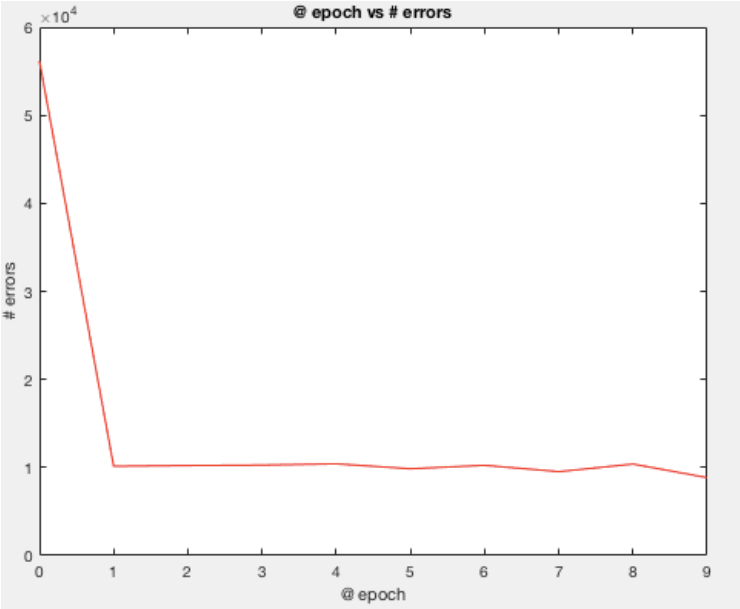
The percentage of errors number is 1630/10000 = 16.30%

η=10, $\varepsilon = 0.14$



The percentage of errors number is 1580/10000 = 15.80%

η=1, $\varepsilon = 0.15$



The percentage of errors number is 1918/10000 = 19.18%

After three experiences, the most obvious conclusion I can draw is that when $\boldsymbol{\varepsilon}$ becomes bigger, the epoch for convergence decrease significantly. And the final error percentage is nearly 10%. However, after training 1000 samples, we can also get the similar result. Moreover, no matter how much $\boldsymbol{\eta}$ is, there is no obvious difference in final result, maybe epoch becomes bigger or maybe it will be smaller than prior one. Therefore, I need more experiences to verify these uncertain aspects.