Exercise 10

May 18, 2022

0.0.1 Exercise 10

0.0.2 Index Number: 190108X

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Question 1

[19]:

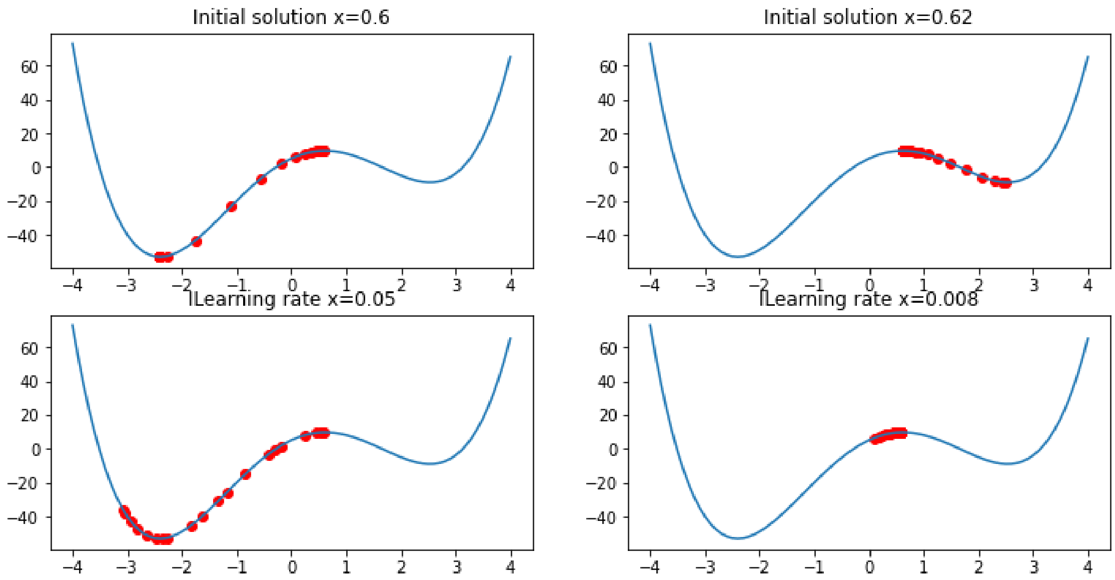
```
import numpy as np
import matplotlib.pyplot as plt

def f(x):
    w = np.array([1,-1,-12,15,5])
    M = np.size(w)-1
    return np.sum([x**i*w[M-i] for i in range(0,M+1)], axis=0)

def g(x):
    w = np.array([1,-1,-12,15,5])
    M = np.size(w)-1
    return np.sum([i*x**(i-1)*w[M-i] for i in range(0,M+1)], axis=0)

def minimum(x,alpha):
    x_hist = np.array(x)
    fx_hist = np.array(f(x))
    for i in range(20):
        x = x - alpha*g(x)
        x_hist= np.append(x_hist, x)
        fx_hist= np.append(fx_hist, f(x))
    print('x= ',x,'f(x) = ',f(x))
    return x_hist,fx_hist

fig,ax = plt.subplots(2,2,figsize=(12,6))
delta = 0.1
x_ = np.arange(-4,4+delta,delta)
ax[0,0].plot(x_,f(x_))

x_hist,fx_hist=minimum(0.6,0.02)
ax[0,0].scatter(x_hist,fx_hist, c='r')
ax[0,0].set_title("Initial solution x=0.6")
delta = 0.1
```

```
x_ = np.arange(-4,4+delta,delta)
ax[0,1].plot(x_,f(x_))
x_hist,fx_hist=minimum(0.62,0.02)
ax[0,1].scatter(x_hist,fx_hist, c='r')
ax[0,1].set_title("Initial solution x=0.62")
delta = 0.1
x_ = np.arange(-4,4+delta,delta)
ax[1,0].plot(x_,f(x_))
x_hist,fx_hist=minimum(0.6,0.05)
ax[1,0].scatter(x_hist,fx_hist, c='r')
ax[1,0].set_title("ILearning rate x=0.05")
delta = 0.1
x_ = np.arange(-4,4+delta,delta)
ax[1,1].plot(x_,f(x_))
x_hist,fx_hist=minimum(0.6,0.008)
ax[1,1].scatter(x_hist,fx_hist, c='r')
ax[1,1].set_title("ILearning rate x=0.008")
```

```
x=  -2.4003994283530288 f(x) =  -53.11840483760499
x=  2.5104174088324025 f(x) =  -9.073558171240812
x=  -0.29497479850285213 f(x) =  -0.43550699945570187
x=  0.09129371545369486 f(x) =  6.2686997952779855
```

[19]:

```
Text(0.5, 1.0, 'ILearning rate x=0.008')
```



[22]:

```
# finding a root close to x0
from scipy.optimize import fsolve
from scipy.optimize import minimize
```

```
x0=0.7
root = fsolve(g,x0) #gradient is zero ath this point
print(root)
#Using scipy to find minimum
minimum = minimize(f,x0)
print(minimum)
```

```
[0.61654501]
      fun: -9.083837308515939
 hess_inv: array([[0.02625738]])
      jac: array([-7.62939453e-06])
  message: 'Optimization terminated successfully.'
     nfev: 16
      nit: 3
     njev: 8
   status: 0
  success: True
        x: array([2.53385792])
```

According to the above results, we can see that to get a good final outcome, we need to choose the correct initial solution. Also, the learning rate is important to converge the solution correctly. We need to tune it with the correct value.

Question 2

[8]:

```
# Utility function for displaying
def display(y_train, y_test, y_train_pred, y_test_pred, loss_history, w, showim␣
 ↪= True):
    plt.plot(loss_history)


     # For displaying the weights matrix w as an image. 32*32*3 assumption is␣
 ↪there
    if showim:
        f, axarr = plt.subplots(2, 5)
        f.set_size_inches(16, 6)
        for i in range(10):
            img = w[:, i].reshape(32, 32, 3)# CIFAR10
            # img = w1[:, i].reshape(28, 28)# MNIST
            img = (img - np.amin(img))/(np.amax(img) - np.amin(img))
            axarr[i//5, i%5].imshow(img)
        plt.show()

    train_acc = np.mean(np.abs(np.argmax(y_train, axis=1) == np.
 ↪argmax(y_train_pred, axis=1)))
    print("train_acc = ", train_acc)

    test_acc = np.mean(np.abs(np.argmax(y_test, axis=1) == np.
↪argmax(y_test_pred, axis=1)))
    print("test_acc = ", test_acc)
```

[1]:

```
import ssl
ssl._create_default_https_context = ssl._create_unverified_context
import numpy as np
import tensorflow as tf
from tensorflow import keras
import matplotlib.pyplot as plt
from tensorflow.keras.datasets import cifar10 , mnist

( x_train , y_train ),( x_test , y_test ) = cifar10.load_data ( )
# ( x_train , y_train ) , ( x_test , y_test ) = mnist . load_data ( )
print ( " x_train => " , x_train . shape )

Ntr = x_train . shape [ 0 ]
Nte = x_test . shape [ 0 ]
Din = 3072 # CIFAR10
# Din = 784 # MINIST
x_train = x_train [ range ( Ntr ) , : ]
x_test = x_test [ range ( Nte ) , : ]
y_train = y_train [ range ( Ntr ) ]
y_test = y_test [ range ( Nte ) ]
```

```
A local file was found, but it seems to be incomplete or outdated because the
auto file hash does not match the original value of
6d958be074577803d12ecdefd02955f39262c83c16fe9348329d7fe0b5c001ce so we will re-
download the data.
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170498071/170498071 [==============================] - 164s 1us/step
 x_train =>  (50000, 32, 32, 3)
```

[12]:

```
K = len(np.unique(y_train))

y_train = tf.keras.utils.to_categorical(y_train,num_classes=K)
y_test= tf.keras.utils.to_categorical(y_test,num_classes=K)

x_train = np.reshape(x_train,(Ntr,Din))
x_test= np.reshape(x_test,(Nte,Din))
x_train=x_train.astype(np.float32)
x_test = x_test.astype(np.float32)

x_train /= 255.
x_test /=255.
```

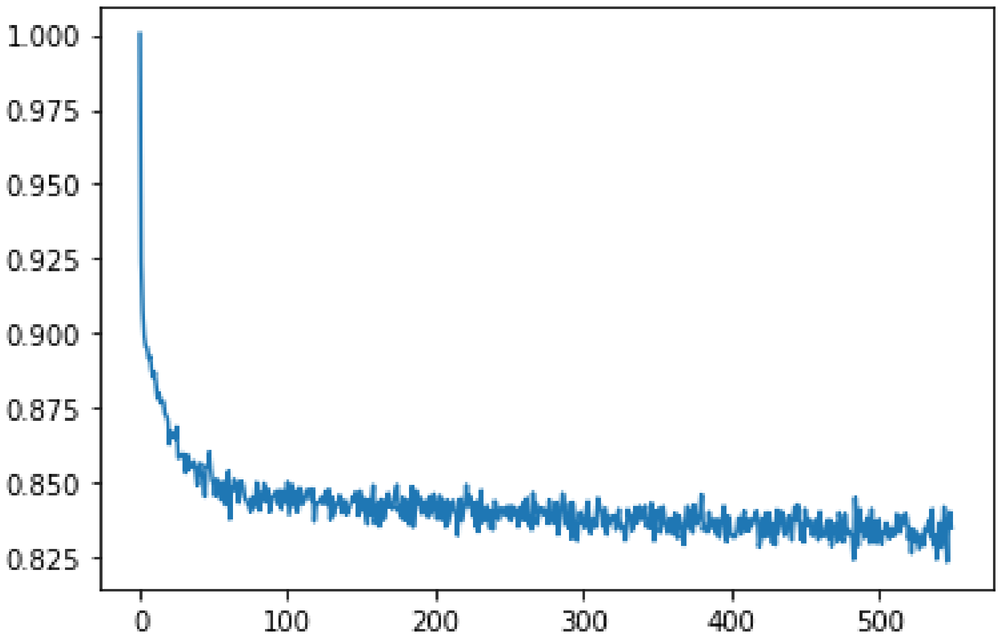
[15]:

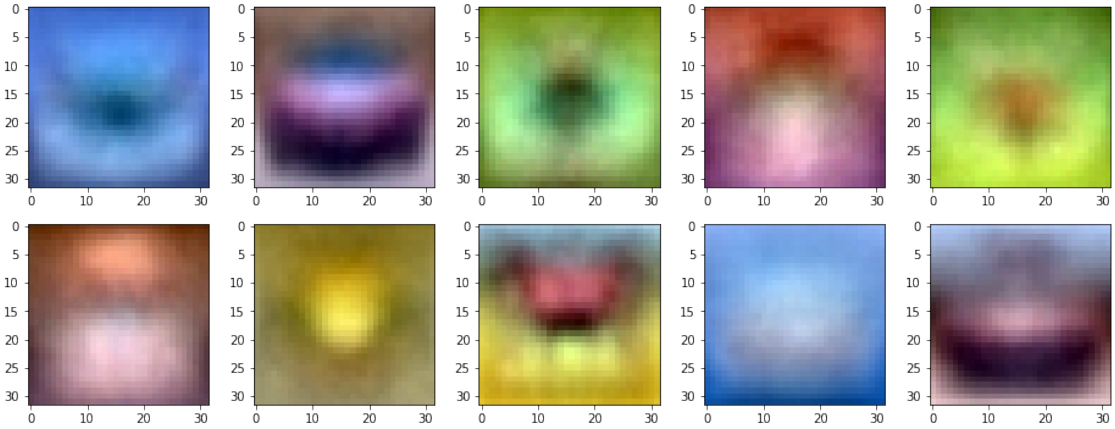
```python
std =1e-5
w = std*np.random.randn(Din,K)
b = np.zeros(K)
lr = 1e-3
lr_decay=0.1
epochs =11
batch_size=1000
loss_history = []
rng = np.random.default_rng(seed=0)

for e in range(epochs):
    indices = np.arange(Ntr)
    rng.shuffle(indices)
    for batch in range(Ntr//batch_size):
        batch_indices = indices[batch*batch_size:(batch+1)*batch_size]
        x =x_train[batch_indices]#Extract a batch of 100
        y = y_train[batch_indices]

        #Forward pass
        y_pred = x@w+b
        loss=1./batch_size*np.square(y_pred-y).sum()
        loss_history.append(loss)

        #backward pass
        dy_pred =1./batch_size*2.0*(y_pred-y)
        dw = x.T @ dy_pred
        db = dy_pred.sum(axis=0)*1
        w=w-lr*dw
        b = b-lr*db

    if e % 5==0:
        print("Iteration %d / %d: loss %f"%(e,epochs,loss))

    if e % 10==0:
        lr *= lr_decay
```

```
Iteration 0 / 11: loss 0.850461
Iteration 5 / 11: loss 0.836753
Iteration 10 / 11: loss 0.834915
```

[16]:

```python
y_train_pred = x_train.dot(w)+b
y_test_pred = x_test.dot(w)+b
display(y_train,y_test,y_train_pred,y_test_pred,loss_history,w,showim=True)
```





```
train_acc =  0.33568
test_acc =  0.3356
```