Image_Classifier

February 7, 2023

[ ]:
```
import numpy as np
import matplotlib.pyplot as plt


def load_data(path):
    def one_hot(y):
        table = np.zeros((y.shape[0], 10))
        for i in range(y.shape[0]):
            table[i][int(y[i][0])] = 1
        return table

    def normalize(x):
        x = x / 255
        return x

    data = np.loadtxt('{}'.format(path), delimiter = ',', skiprows=1)
    return normalize(data[:,1:]),one_hot(data[:,:1])

X_train, y_train = load_data('mnist_train.csv')
X_test, y_test = load_data('mnist_test.csv')
```

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X_train.shape[1]
```

[ ]: 784

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```
class NeuralNetwork:
    def __init__(self, X, y, batch = 64, lr = 1e-3,  epochs = 10):
        self.input = X
        self.target = y
        self.batch = batch
        self.epochs = epochs
        self.lr = lr
        self.momentum = 0.7

        self.x = self.input[:self.batch] # batch input
        self.y = self.target[:self.batch] # batch target value
        self.loss = []
        self.acc = []
```

```
        self.init_weights()
        self.init_momentum()

    def init_weights(self):
        self.W1 = np.random.randn(self.input.shape[1],256)
        self.W2 = np.random.randn(self.W1.shape[1],128)
        self.W3 = np.random.randn(self.W2.shape[1],self.y.shape[1])

        self.b1 = np.random.randn(self.W1.shape[1],)
        self.b2 = np.random.randn(self.W2.shape[1],)
        self.b3 = np.random.randn(self.W3.shape[1],)

    def init_momentum(self):
        self.changeW3 = 0
        self.changeW2 = 0
        self.changeW1 = 0
        self.changeb3 = 0
        self.changeb2 = 0
        self.changeb1 = 0

    def ReLU(self, x):
        return np.maximum(0,x)

    def dReLU(self,x):
        return 1 * (x > 0)

    def softmax(self, z):
        z = z - np.max(z, axis = 1).reshape(z.shape[0],1)
        return np.exp(z) / np.sum(np.exp(z), axis = 1).reshape(z.shape[0],1)

    def shuffle(self):
        idx = [i for i in range(self.input.shape[0])]
        np.random.shuffle(idx)
        self.input = self.input[idx]
        self.target = self.target[idx]

    def feedforward(self):
        assert self.x.shape[1] == self.W1.shape[0]
        self.z1 = self.x.dot(self.W1) + self.b1
        self.a1 = self.ReLU(self.z1)

        assert self.a1.shape[1] == self.W2.shape[0]
        self.z2 = self.a1.dot(self.W2) + self.b2
        self.a2 = self.ReLU(self.z2)

        assert self.a2.shape[1] == self.W3.shape[0]
```

```
        self.z3 = self.a2.dot(self.W3) + self.b3
        self.a3 = self.softmax(self.z3)
        self.error = self.a3 - self.y
        # self.error = self.y * np.log(self.a3)


    def backprop(self):
        dcost = (1/self.batch)*self.error

        DW3 = np.dot(dcost.T,self.a2).T
        DW2 = np.dot((np.dot((dcost),self.W3.T) * self.dReLU(self.z2)).T,self.
↪a1).T
        DW1 = np.dot((np.dot(np.dot((dcost),self.W3.T)*self.dReLU(self.z2),self.
↪W2.T)*self.dReLU(self.z1)).T,self.x).T

        db3 = np.sum(dcost,axis = 0)
        db2 = np.sum(np.dot((dcost),self.W3.T) * self.dReLU(self.z2),axis = 0)
        db1 = np.sum((np.dot(np.dot((dcost),self.W3.T)*self.dReLU(self.z2),self.
↪W2.T)*self.dReLU(self.z1)),axis = 0)

        assert DW3.shape == self.W3.shape
        assert DW2.shape == self.W2.shape
        assert DW1.shape == self.W1.shape

        assert db3.shape == self.b3.shape
        assert db2.shape == self.b2.shape
        assert db1.shape == self.b1.shape


        self.update_weight_with_momentum(DW3, DW2, DW1, db3, db2, db1)
        # self.W3 = self.W3 - self.lr * DW3
        # self.W2 = self.W2 - self.lr * DW2
        # self.W1 = self.W1 - self.lr * DW1

        # self.b3 = self.b3 - self.lr * db3
        # self.b2 = self.b2 - self.lr * db2
        # self.b1 = self.b1 - self.lr * db1

    def update_weight_with_momentum(self, DW3, DW2, DW1, db3, db2, db1):
        new_changeW3 = self.lr * DW3 + self.momentum * self.changeW3
        self.W3 = self.W3 - new_changeW3
        self.changeW3 = new_changeW3

        new_changeW2 = self.lr * DW2 + self.momentum * self.changeW2
        self.W2 = self.W2 - new_changeW2
        self.changeW2 = new_changeW2
```

```
        new_changeW1 = self.lr * DW1 + self.momentum * self.changeW1
        self.W1 = self.W1 - new_changeW1
        self.changeW1 = new_changeW1

        new_changeb3 = self.lr * db3 + self.momentum * self.changeb3
        self.b3 = self.b3 - new_changeb3
        self.changeb3 = new_changeb3

        new_changeb2 = self.lr * db2 + self.momentum * self.changeb2
        self.b2 = self.b2 - new_changeb2
        self.changeb2 = new_changeb2

        new_changeb1 = self.lr * db1 + self.momentum * self.changeb1
        self.b1 = self.b1 - new_changeb1
        self.changeb1 = new_changeb1

        # print("changeb1", self.changeb1[:2])


    def train(self):
        for epoch in tqdm(range(self.epochs)):
            l = 0
            acc = 0
            self.shuffle()

            for batch in range(self.input.shape[0]//self.batch-1):
                start = batch*self.batch
                end = (batch+1)*self.batch
                self.x = self.input[start:end]
                self.y = self.target[start:end]
                self.feedforward()
                self.backprop()
                l+= self.cross_entropy_loss()
                acc+= np.count_nonzero(np.argmax(self.a3,axis=1) == np.
↪argmax(self.y,axis=1)) / self.batch

            self.loss.append(l/(self.input.shape[0]//self.batch))
            self.acc.append(acc*100/(self.input.shape[0]//self.batch))

    def cross_entropy_loss(self):

        epsilon = 1e-15 # to avoid division by zero
        self.a3 = np.clip(self.a3, epsilon, 1 - epsilon)
        loss = -np.mean(np.sum(self.y * np.log(self.a3), axis=-1))
        return loss

    def plot(self):
```

```
        plt.figure(dpi = 125)
        plt.plot(self.loss)
        plt.xlabel("Epochs")
        plt.ylabel("Loss")

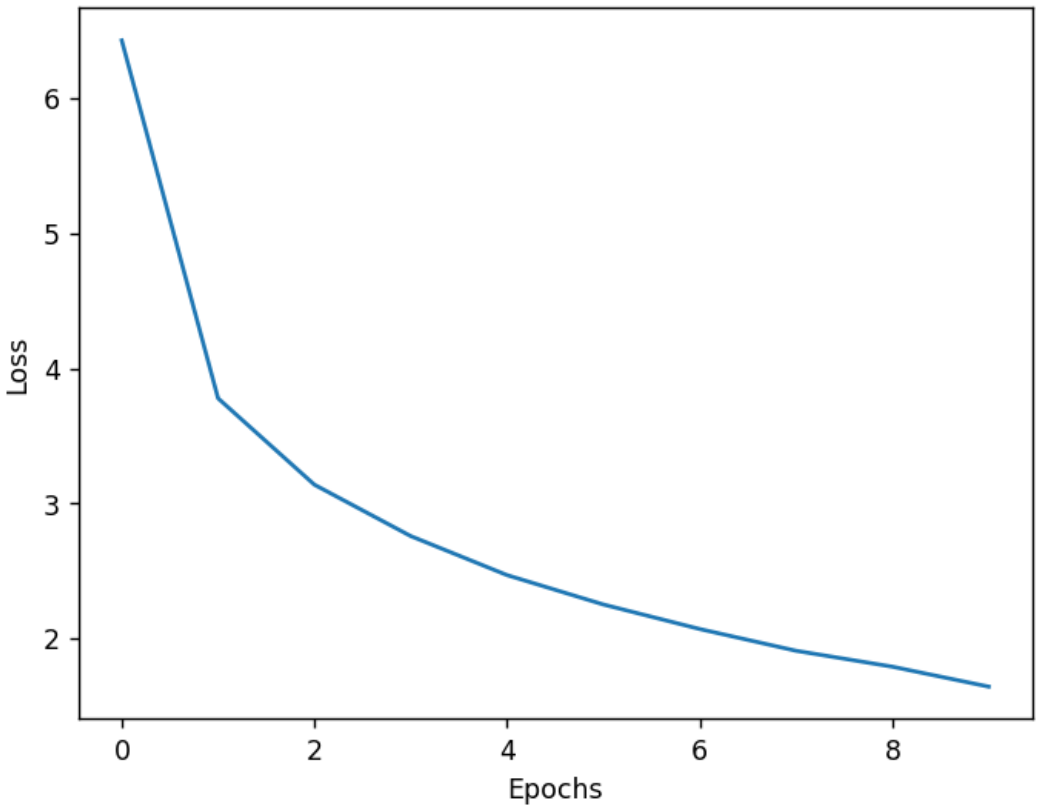
    def acc_plot(self):
        plt.figure(dpi = 125)
        plt.plot(self.acc)
        plt.xlabel("Epochs")
        plt.ylabel("Accuracy")

    def test(self,xtest,ytest):
        self.x = xtest
        self.y = ytest
        self.feedforward()
        acc = np.count_nonzero(np.argmax(self.a3,axis=1) == np.argmax(self.
 ↪y,axis=1)) / self.x.shape[0]
        print("Accuracy:", 100 * acc, "%")



NN = NeuralNetwork(X_train, y_train)
NN.train()
NN.plot()
NN.test(X_test,y_test)
```

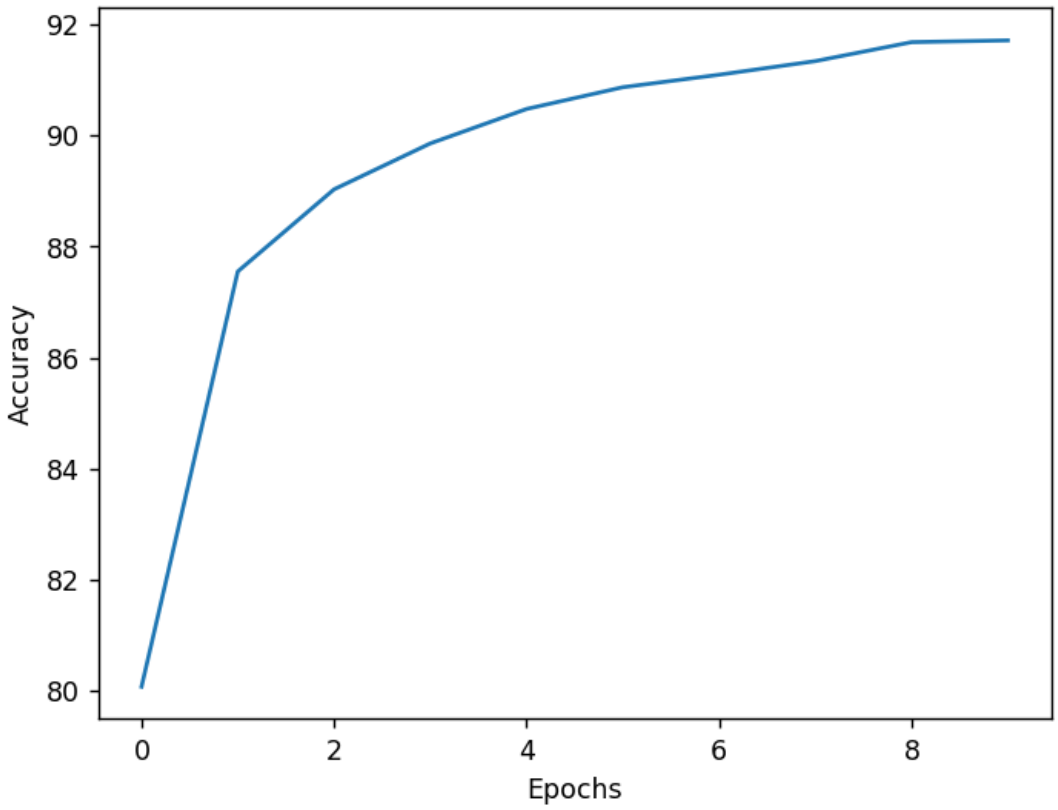
```
100%|      | 10/10 [00:40<00:00,  4.04s/it]
Accuracy: 90.34 %
```



Observation 4: -inf issue in categorical cross entropy loss: in the beggining, we have lots of 0 in the matrix. Since the log(0) isn't defined, we cannot calculate cross entropy loss. We resolve the problem through setting the min and max in the code: `np.clip(self.a3, epsilon, 1 - epsilon)`.

Observation 5: Setting momentum can both increase or decrease the accuracy for our model, but it always decreases the loss. In a good case, it can increase or decrease our accruacy by 2%. (ranging from 88% to 91 % accuracy). It might because since our model weight and bias is initialized randomly, the momentum can either drive our model to a good or bad diretion based on the initial setting. From our experiments momentum = 0.7 is the best for our model.

[ ]:
```
NN.acc_plot()
```



[ ]:
```
NN.test(X_test,y_test)
```

```
Accuracy: 90.34 %
```

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```