Index No. 190696U

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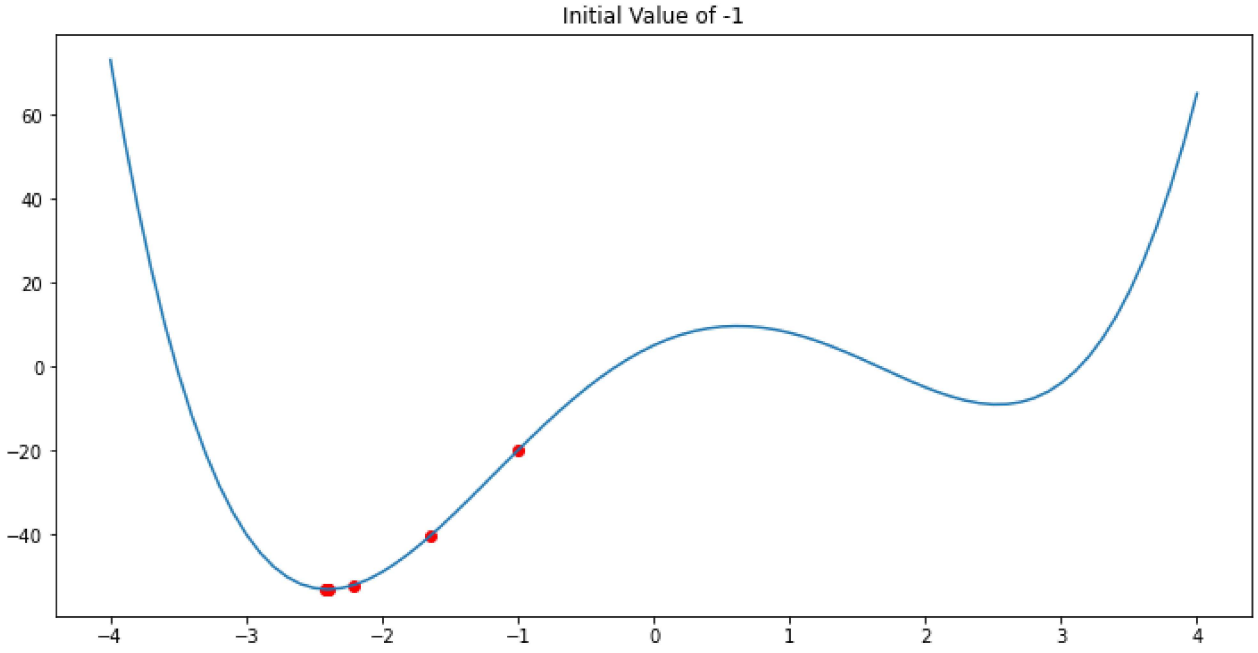
In [ ]:

```
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)

alpha = 0.02
x = -1
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))

fig = plt.figure(figsize = (12,6))
ax = plt.subplot(1,1,1)
delta = 0.1
x_ = np.arange(-4,4+delta,delta)
ax.plot(x_,f(x_))
ax.scatter(x_hist,fx_hist, c='r')
ax.set_title("Initial Value of -1")
```

Out[ ]:

```
x=  -2.4004031389712477 f(x) =  -53.11840483801492
Text(0.5, 1.0, 'Initial Value of -1')
```



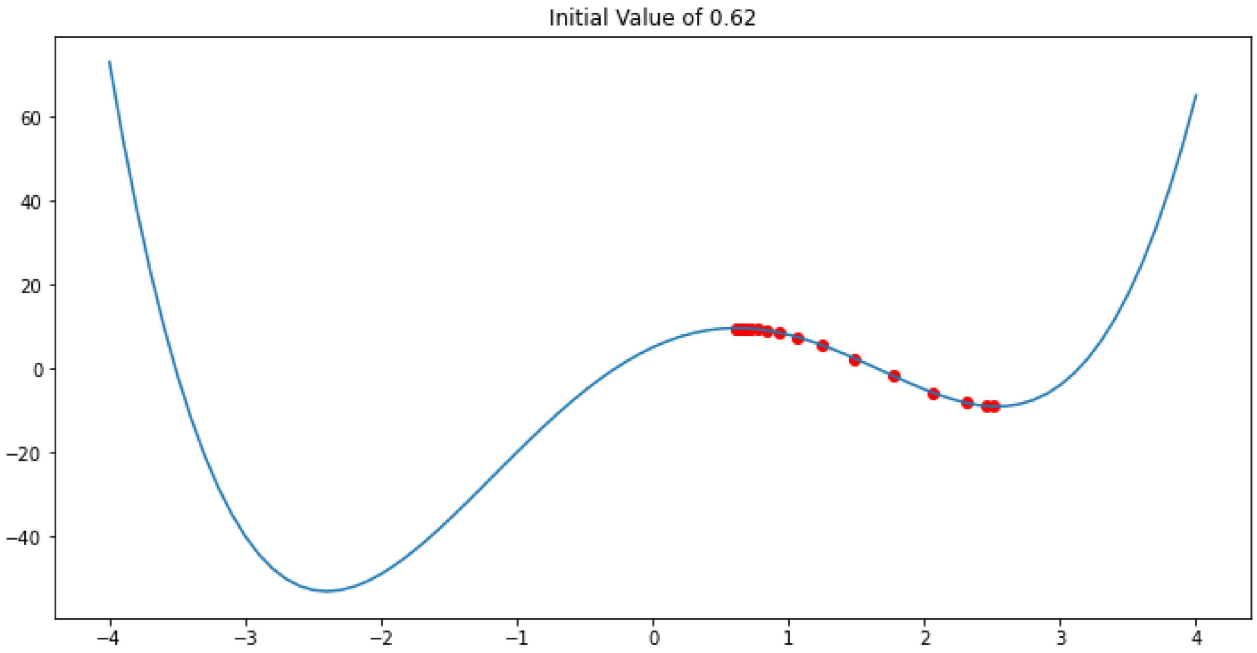
In [ ]:

```
alpha = 0.02
x = 0.62
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))

fig = plt.figure(figsize = (12,6))
ax = plt.subplot(1,1,1)
delta = 0.1
x_ = np.arange(-4,4+delta,delta)
ax.plot(x_,f(x_))
ax.scatter(x_hist,fx_hist, c='r')
ax.set_title("Initial Value of 0.62")
```

```
x=  2.5104174088324025 f(x) =  -9.073558171240812
```

Out[ ]:

```
Text(0.5, 1.0, 'Initial Value of 0.62')
```

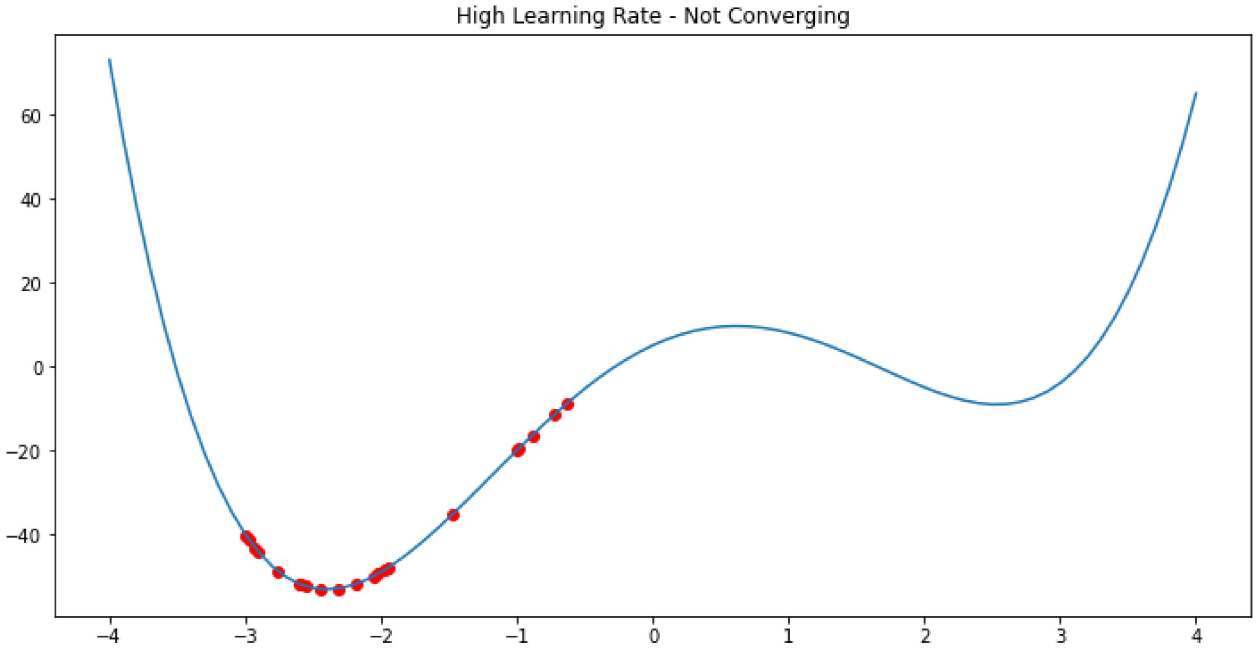


When the initial value changes, the converging minimum value will change between the local and global minimums. In the above image, with a initial value approximately less than 0, the algorithm will converge to the global minimum. However, when the initial value is greater tha approximately 0, it will converge to the local minimum between 2 and 3.

When the learning rate is unnecassarily high, the minimum will be skipped. The estimated point will keep oscillating around the minimum value without converging to it. So, we have tune it by trial and error and with insights about how the learning rate needs to be changed to converge to the minimum within minimum number of iterations.

In [ ]:
```
alpha = 0.05
x = -1
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))

fig = plt.figure(figsize = (12,6))
ax = plt.subplot(1,1,1)
delta = 0.1
x_ = np.arange(-4,4+delta,delta)
ax.plot(x_,f(x_))
ax.scatter(x_hist,fx_hist, c='r')
ax.set_title("High Learning Rate - Not Converging")
```

Out[ ]:
```
x=  -1.4753808162865225 f(x) =  -35.30192756074364
Text(0.5, 1.0, 'High Learning Rate - Not Converging')
```



In [ ]:

```
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_tes t ) = 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 ) ]

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.
```

```
x_train =>  (50000, 32, 32, 3)
```

In [ ]:

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

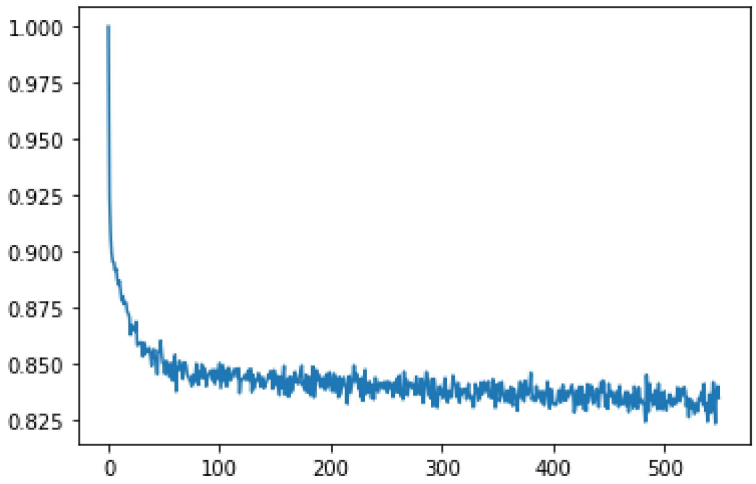
```
    # For diapaying the weights matrix w as an image. 32*32*3 assumption is there
    if showim:
        f, axarr = plt.subplots(2, 5)
        f.set_size_inches(16, 6)
        for i in range(10):
            img = w[:, i].reshape(32, 32, 3)# CIFAR10
            # img = w1[:, i].reshape(28, 28)# MNIST
            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, ax
    print("train_acc = ", train_acc)

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

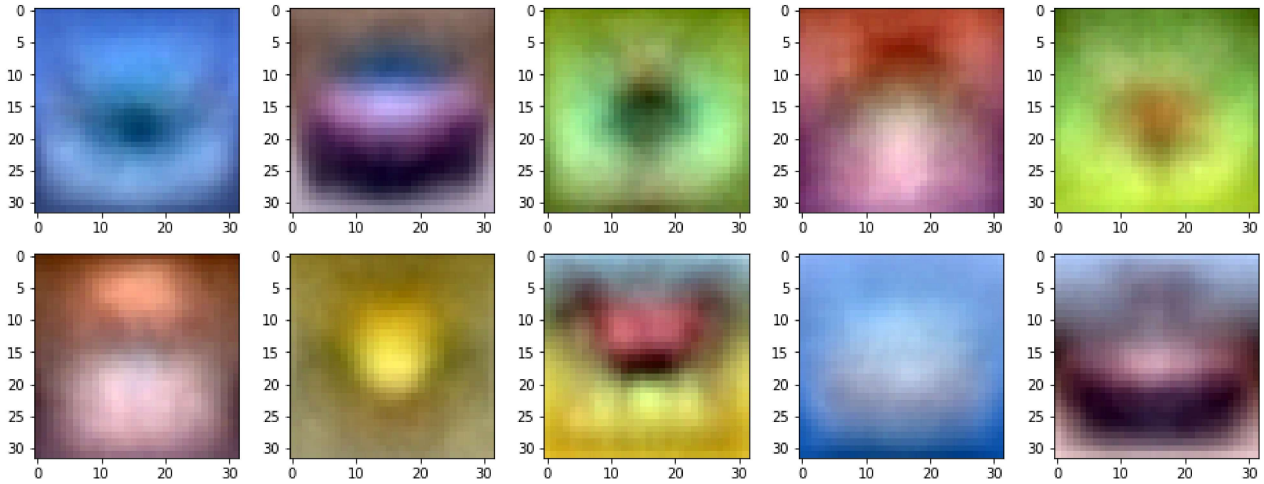
In [ ]:

```
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_hist = []
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]
        y = y_train[batch_indices]

        #forward pass
        y_pred = x@w + b
        loss = 1./batch_size*np.square(y_pred-y).sum()
        loss_hist.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 #dw is daba L/daba w
        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 0.850458
Iteration 5 / 11: loss 0.836765
Iteration 10 / 11: loss 0.834906
```

In [ ]:
```
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_hist, w, showim = True)
```





```
train_acc =  0.33576
test_acc =  0.3354
```