9/09/2025 Lab 6: Implement Gradient Descent & Backpropagation in Deep Neural Network

Aim: To implement gradient descent and backpropagation algorithm in a deep neural network and study their role in training

Objective:

1) To understand the working of gradient optimization
2) To implement backpropagation for updating neural network weights.
3) To observe the effect of iterations (epochs) on loss reduction.

Pseudocode

1) Initialize weights and bias randomly
2) for each epoch:
   a. Forward Pass:
      - compute weighted sum
        (Z = w*x + b)
      - Apply activation function
        (A = f(Z))

b. Compute Loss

L = difference bw predicted & actual

c. Backward pass :

- Compute gradients of loss w.r.t weights & biases
- update weights : $w = w - \eta * dL/dw$
- update biases : $b = b - \eta * dL/db$

3. Repeat until Converges.

Formula Used

$$z = w \cdot x + b$$

$$L = 1/n \sum (y - \hat{y})^2$$

$$w = w - \eta \frac{dL}{dw}$$

Observation

1) Initially, the model started with random weights leading to high loss and low accuracy

2) with each epoch, gradient descent gradually reduced the loss, showing effect of iterative weight update

3) Backpropagation efficiently adjusted weights layer by layer, improving model accuracy

4) The choice of learning rate and number of epochs strongly influenced convergence speed and final accuracy.

Sample.

Epoch	Training Loss	Accuracy	Remark
1	0.95	65.0	High error, random limit
5	0.48	82.3	Loss decreasing
10	0.25	90.1	Faster convergence
20	0.12	95.5	Model stabilized

Result

Implemented Gradient Descent & Backpropagation in DNN

Epoch 0 - Loss : 0.0134

Epoch 800 - Loss : 0.0107

Epoch 1000 - Loss : 0.0088

Epoch 1800 - Loss : 0.0075

Epoch 2000 - Loss : 0.0065

Epoch 2500 - Loss : 0.0057

Epoch 3000 - Loss : 0.0051

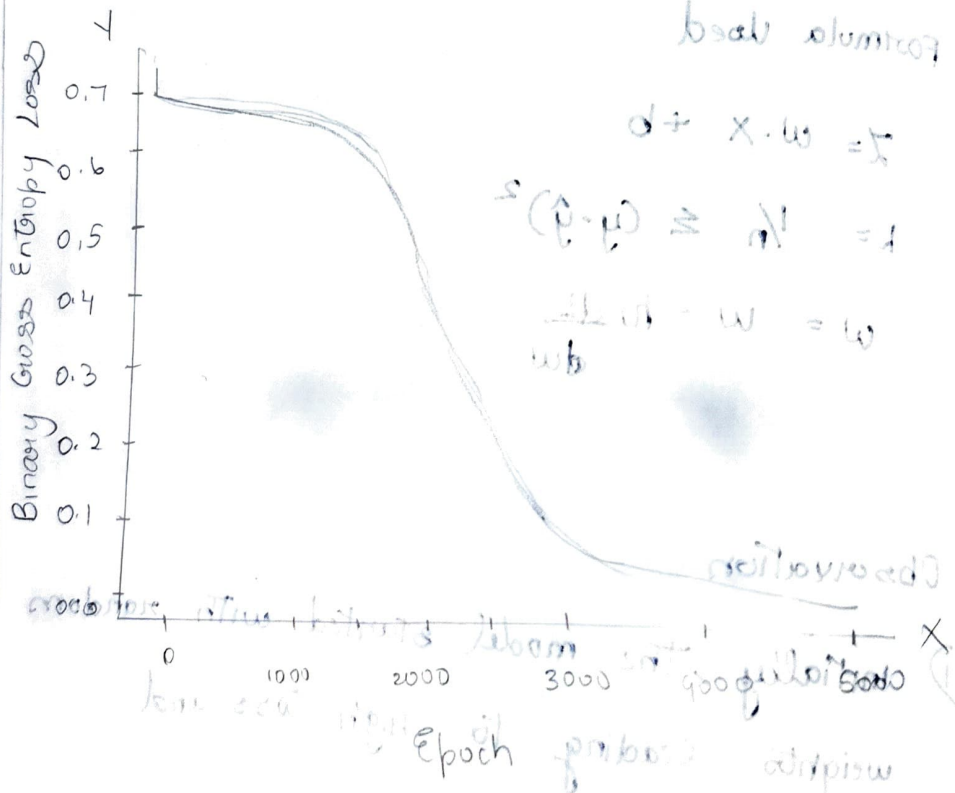
Epoch 3500 - Loss : 0.0046

Epoch 4000 - Loss : 0.0042

Epoch 4500 - Loss : 0.0038

~~Epoch 5000 - Loss :~~

Loss over Epochs



Kernel Tabs Settings Help

L6.ipynb

Code

Notebook Python 3 (ipykernel)

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[1]:
```
import torch
import torch.nn.functional as F
import matplotlib.pyplot as plt
```

[4]:
```
X = torch.tensor([[0, 0],
                  [0, 1],
                  [1, 0],
                  [1, 1]], dtype=torch.float32)
y = torch.tensor([[0], [1], [1], [0]], dtype=torch.float32)
```

[5]:
```
torch.manual_seed(42)
input_size = 2
hidden1 = 4
hidden2 = 4
output_size = 1
```

[6]:
```
W1 = torch.randn(input_size, hidden1, requires_grad=True)
b1 = torch.zeros(hidden1, requires_grad=True)
```

[7]:
```
W2 = torch.randn(hidden1, hidden2, requires_grad=True)
b2 = torch.zeros(hidden2, requires_grad=True)
```

[8]:
```
W3 = torch.randn(hidden2, output_size, requires_grad=True)
b3 = torch.zeros(output_size, requires_grad=True)
```

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Code Notebook No Kernel

```
b3 = torch.zeros(output_size, requires_grad=True)

lr = 0.1
epochs = 5000
loss_history = []
```

[13]:
```
for epoch in range(epochs):

    z1 = X @ W1 + b1
    a1 = torch.sigmoid(z1)

    z2 = a1 @ W2 + b2
    a2 = torch.sigmoid(z2)

    z3 = a2 @ W3 + b3
    y_pred = torch.sigmoid(z3)
    loss = F.binary_cross_entropy(y_pred, y)
    loss.backward()
    with torch.no_grad():
        W1 -= lr * W1.grad
        b1 -= lr * b1.grad

        W2 -= lr * W2.grad
        b2 -= lr * b2.grad
```

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Code Notebook No Kernel

```
            W3 -= lr * W3.grad
            b3 -= lr * b3.grad

            # Zero the gradients
            W1.grad.zero_()
            b1.grad.zero_()
            W2.grad.zero_()
            b2.grad.zero_()
            W3.grad.zero_()
            b3.grad.zero_()

        loss_history.append(loss.item())

        if epoch % 500 == 0:
            print(f"Epoch {epoch} - Loss: {loss.item():.4f}")
```

```
Epoch 0 - Loss: 0.0134
Epoch 500 - Loss: 0.0107
Epoch 1000 - Loss: 0.0088
Epoch 1500 - Loss: 0.0075
Epoch 2000 - Loss: 0.0065
Epoch 2500 - Loss: 0.0057
Epoch 3000 - Loss: 0.0051
Epoch 3500 - Loss: 0.0046
Epoch 4000 - Loss: 0.0042
```

Tabs Settings Help

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Code

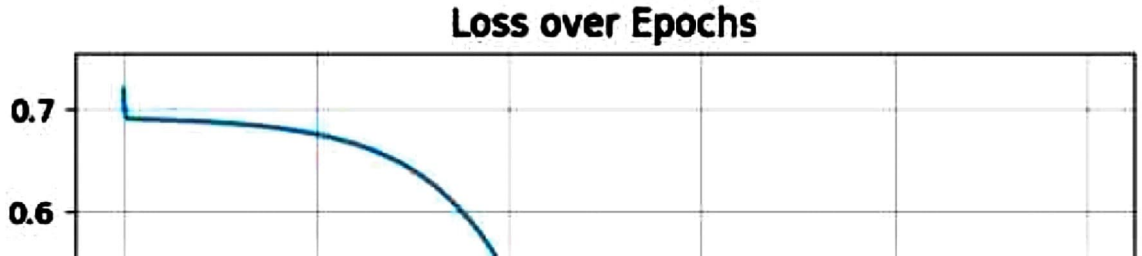
Notebook No Kernel

```
        if epoch % 500 == 0:
            print(f"Epoch {epoch} - Loss: {loss.item():.4f}")
```

```
Epoch 0 - Loss: 0.0134
Epoch 500 - Loss: 0.0107
Epoch 1000 - Loss: 0.0088
Epoch 1500 - Loss: 0.0075
Epoch 2000 - Loss: 0.0065
Epoch 2500 - Loss: 0.0057
Epoch 3000 - Loss: 0.0051
Epoch 3500 - Loss: 0.0046
Epoch 4000 - Loss: 0.0042
Epoch 4500 - Loss: 0.0038
```

[11]:

```
plt.plot(loss_history)
plt.title("Loss over Epochs")
plt.xlabel("Epoch")
plt.ylabel("Binary Cross Entropy Loss")
plt.grid(True)
plt.show()
```



L6.ipynb

Code

Notebook

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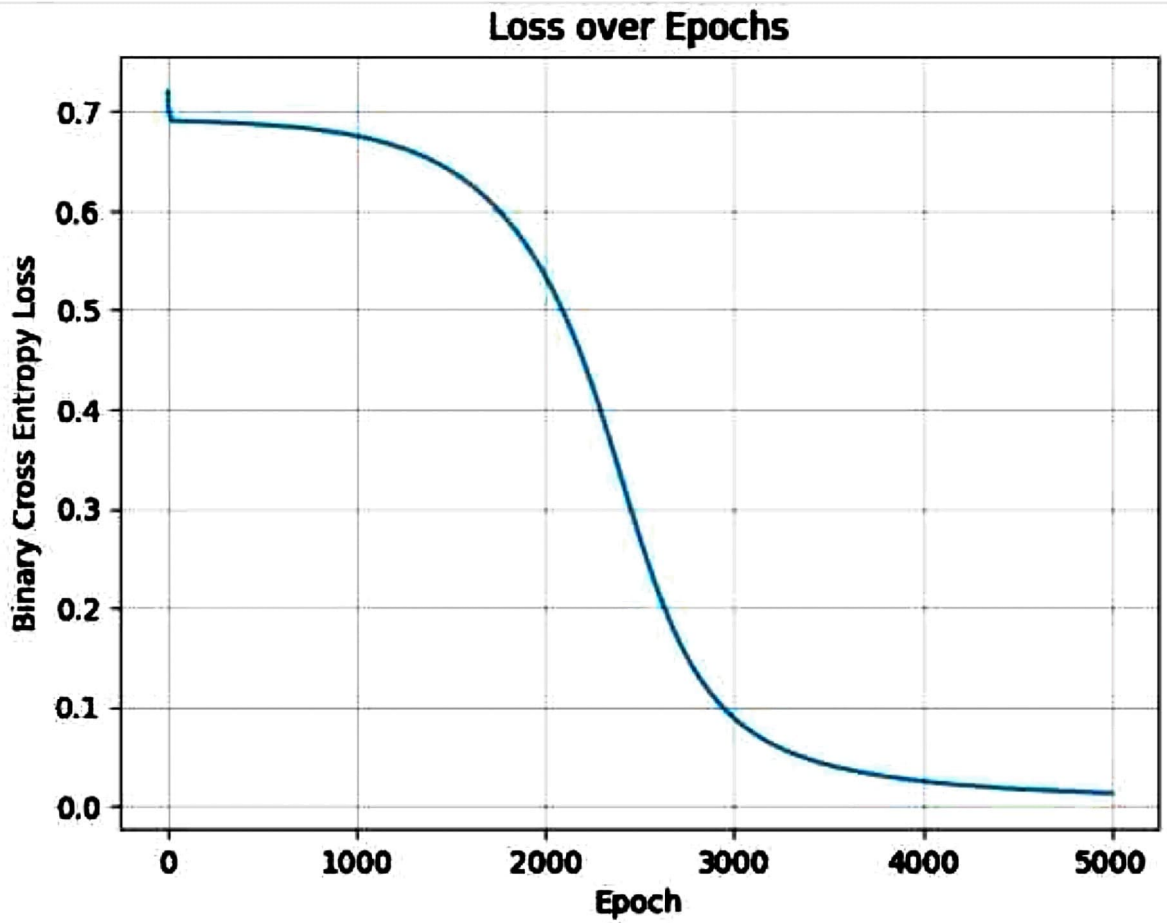

[12]: with torch.no_grad():

L6.ipynb

Code

Notebook

No Kernel

```
        a1 = torch.sigmoid(z1)

        z2 = a1 @ W2 + b2
        a2 = torch.sigmoid(z2)

        z3 = a2 @ W3 + b3
        y_pred = torch.sigmoid(z3)
        predicted = (y_pred > 0.5).float()

print("Predictions:\n", predicted)
print("Ground Truth:\n", y)
```

```
Predictions:
 tensor([[0.],
        [1.],
        [1.],
        [0.]])
Ground Truth:
 tensor([[0.],
        [1.],
        [1.],
        [0.]])
```