22AIE304 Deep Learning Lab Sheet 5

Fifth Semester BTech CSE(AI)

Department of Computer Science and Engineering

Amrita School of Computing

Training a Feedforward Neural Network on the MNIST Dataset Using PyTorch

Exercise 1: Use this sample ipynb file for training and do the following:

- Part 1: Setting Up the Environment
  - Installing Required Libraries
  - Loading the MNIST Dataset
- Part 2: Defining the Feedforward Neural Network
  - Input layer (784 units)
  - 1 or 2 hidden layers (try different configurations like 128, 256, 512 units)
  - Output layer (10 units corresponding to the 10 classes in MNIST)
- Part 3: Training the Model - Use sigmoid activation

```python
import torch
import torch.nn as nn
import torch.optim as optim
import torchvision
import torchvision.transforms as transforms
```

```python
trainset = torchvision.datasets.MNIST(root='./data', train=True, download=True, transform=transforms.ToTensor())
trainloader = torch.utils.data.DataLoader(trainset, batch_size=64, shuffle=True)

testset = torchvision.datasets.MNIST(root='./data', train=False, download=True, transform=transforms.ToTensor())
testloader = torch.utils.data.DataLoader(testset, batch_size=64, shuffle=False)
```

```
Downloading http://yann.lecun.com/exdb/mnist/train-images-idx3-ubyte.gz
Failed to download (trying next):
<urlopen error [SSL: CERTIFICATE_VERIFY_FAILED] certificate verify failed: certificate has expired (_ssl.c:1007)>

Downloading https://ossci-datasets.s3.amazonaws.com/mnist/train-images-idx3-ubyte.gz
Downloading https://ossci-datasets.s3.amazonaws.com/mnist/train-images-idx3-ubyte.gz to ./data/MNIST/raw/train-images-idx3-ubyte.gz
100%|██████████| 9912422/9912422 [00:00<00:00, 16118377.72it/s]
Extracting ./data/MNIST/raw/train-images-idx3-ubyte.gz to ./data/MNIST/raw

Downloading http://yann.lecun.com/exdb/mnist/train-labels-idx1-ubyte.gz
Failed to download (trying next):
<urlopen error [SSL: CERTIFICATE_VERIFY_FAILED] certificate verify failed: certificate has expired (_ssl.c:1007)>

Downloading https://ossci-datasets.s3.amazonaws.com/mnist/train-labels-idx1-ubyte.gz
Downloading https://ossci-datasets.s3.amazonaws.com/mnist/train-labels-idx1-ubyte.gz to ./data/MNIST/raw/train-labels-idx1-ubyte.gz
100%|██████████| 28881/28881 [00:00<00:00, 485601.39it/s]
Extracting ./data/MNIST/raw/train-labels-idx1-ubyte.gz to ./data/MNIST/raw

Downloading http://yann.lecun.com/exdb/mnist/t10k-images-idx3-ubyte.gz
Failed to download (trying next):
<urlopen error [SSL: CERTIFICATE_VERIFY_FAILED] certificate verify failed: certificate has expired (_ssl.c:1007)>

Downloading https://ossci-datasets.s3.amazonaws.com/mnist/t10k-images-idx3-ubyte.gz
Downloading https://ossci-datasets.s3.amazonaws.com/mnist/t10k-images-idx3-ubyte.gz to ./data/MNIST/raw/t10k-images-idx3-ubyte.gz
100%|██████████| 1648877/1648877 [00:00<00:00, 4377589.75it/s]
Extracting ./data/MNIST/raw/t10k-images-idx3-ubyte.gz to ./data/MNIST/raw

Downloading http://yann.lecun.com/exdb/mnist/t10k-labels-idx1-ubyte.gz
Failed to download (trying next):
<urlopen error [SSL: CERTIFICATE_VERIFY_FAILED] certificate verify failed: certificate has expired (_ssl.c:1007)>

Downloading https://ossci-datasets.s3.amazonaws.com/mnist/t10k-labels-idx1-ubyte.gz
Downloading https://ossci-datasets.s3.amazonaws.com/mnist/t10k-labels-idx1-ubyte.gz to ./data/MNIST/raw/t10k-labels-idx1-ubyte.gz
100%|██████████| 4542/4542 [00:00<00:00, 7632423.38it/s]Extracting ./data/MNIST/raw/t10k-labels-idx1-ubyte.gz to ./data/MNIST/raw
```

```
class FeedforwardNN(nn.Module):
    def __init__(self, input_size=784, hidden_size=128, output_size=10):
        super(FeedforwardNN, self).__init__()

        self.fc1 = nn.Linear(input_size, hidden_size)
        self.fc2 = nn.Linear(hidden_size, output_size)
        self.sigmoid = nn.Sigmoid()

    def forward(self, x):
        x = x.view(-1, 28*28)
        x = self.sigmoid(self.fc1(x))
        x = self.fc2(x)
        return x

model = FeedforwardNN(hidden_size=128)


criterion = nn.CrossEntropyLoss()
optimizer = optim.SGD(model.parameters(), lr=0.001)

n_epochs = 5
for epoch in range(n_epochs):
    running_loss = 0
    for images, labels in trainloader:
        optimizer.zero_grad()

        outputs = model(images)
        loss = criterion(outputs, labels)

        loss.backward()
        optimizer.step()

        running_loss += loss.item()
    print(f'Epoch [{epoch+1}/{n_epochs}], Loss: {running_loss/len(trainloader):.4f}')
```

```
Epoch [1/5], Loss: 0.1062
Epoch [2/5], Loss: 0.1047
Epoch [3/5], Loss: 0.1040
Epoch [4/5], Loss: 0.1035
Epoch [5/5], Loss: 0.1032
```

```
correct = 0
total = 0
with torch.no_grad():
    for images, labels in testloader:
        outputs = model(images)
        _, predicted = torch.max(outputs.data, 1)
        total += labels.size(0)
        correct += (predicted == labels).sum().item()

print(f'Accuracy for 10,000 data ppoints: {100 * correct / total} %')
```

```
Accuracy for 10,000 data ppoints: 96.31 %
```

Exercise 2: Visualizing the Training Process

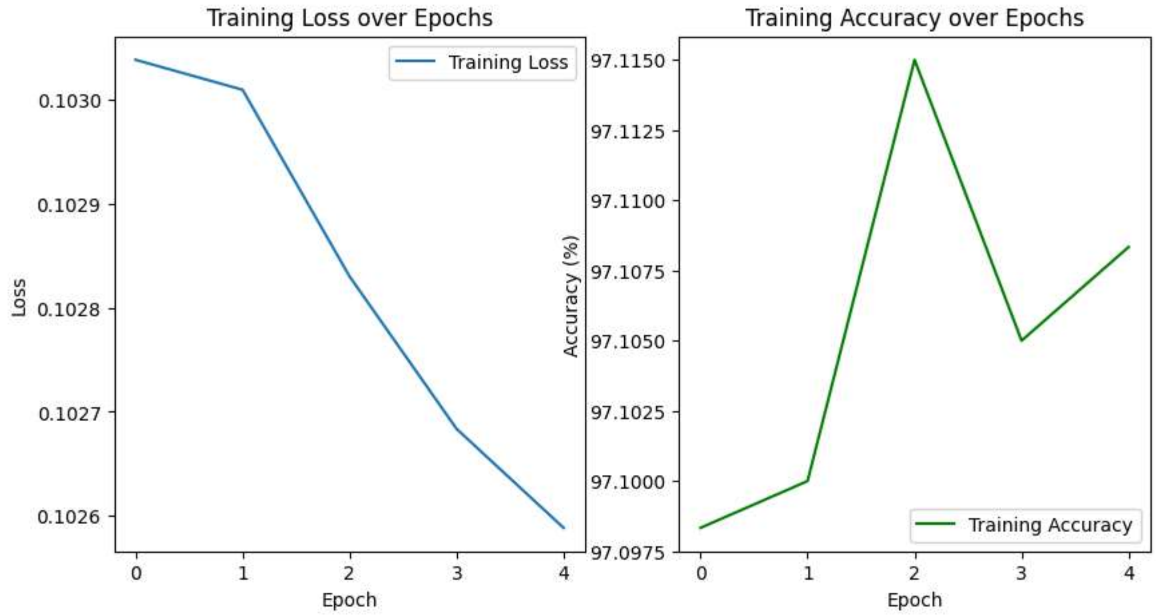
- Plot the Training Loss Curve: Modify your code to store the training loss at each epoch and plot a curve that shows how the loss decreases over time. How does the loss change as the model trains? Does the loss converge as the number of epochs increases?
- Plot the Accuracy Curve: Track the training accuracy after each epoch and plot a graph showing how accuracy improves over time (comparing predictions with true labels). How does training accuracy change during training? Does the accuracy saturate after a certain number of epochs?
- Visualize Weight Updates: Visualize the changes in the weights of the hidden layer during training. After each epoch, store the values of the weights and plot them. How do weights evolve throughout training? Are there any patterns in the weight changes?

```
import matplotlib.pyplot as plt
```

```python
# Lists to store loss and accuracy values for visualization
train_loss_history = []
train_accuracy_history = []

# Modify the training loop
n_epochs = 5  # Adjust the number of epochs as needed
for epoch in range(n_epochs):
    running_loss = 0.0
    correct = 0
    total = 0
    for images, labels in trainloader:
        # Zero the parameter gradients
        optimizer.zero_grad()

        # Forward pass
        outputs = model(images)
        loss = criterion(outputs, labels)

        # Backward pass and optimization
        loss.backward()
        optimizer.step()

        # Track loss
        running_loss += loss.item()

        # Calculate accuracy
        _, predicted = torch.max(outputs.data, 1)
        total += labels.size(0)
        correct += (predicted == labels).sum().item()

    # Store average loss and accuracy for each epoch
    avg_loss = running_loss / len(trainloader)
    accuracy = 100 * correct / total
    train_loss_history.append(avg_loss)
    train_accuracy_history.append(accuracy)

    print(f'Epoch [{epoch+1}/{n_epochs}], Loss: {avg_loss:.4f}, Accuracy: {accuracy:.2f}%')
```

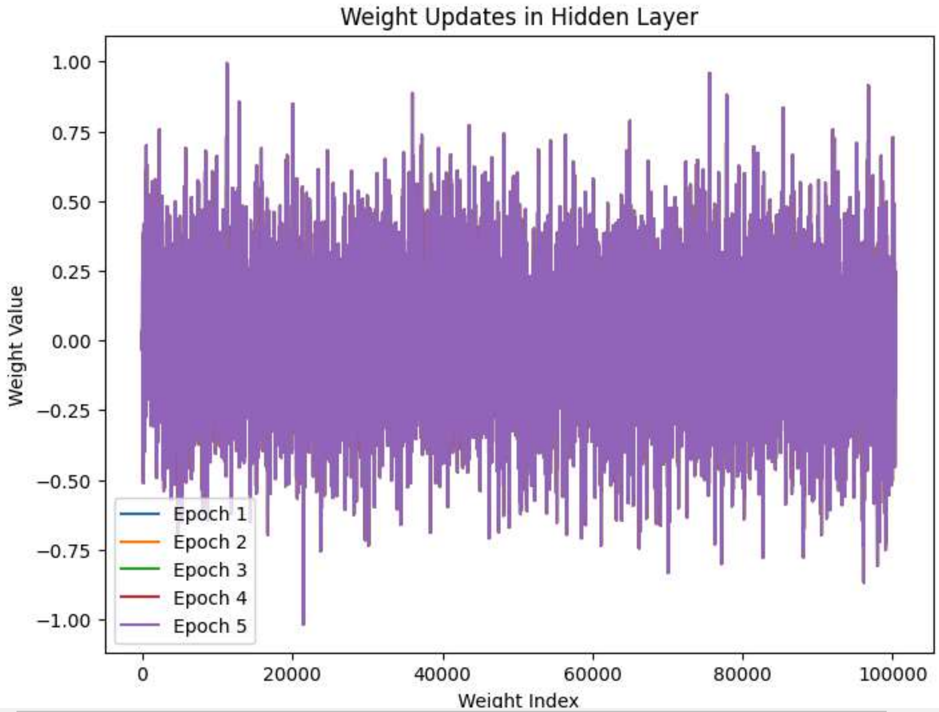
```
Epoch [1/5], Loss: 0.1030, Accuracy: 97.10%
Epoch [2/5], Loss: 0.1030, Accuracy: 97.10%
Epoch [3/5], Loss: 0.1028, Accuracy: 97.11%
Epoch [4/5], Loss: 0.1027, Accuracy: 97.11%
Epoch [5/5], Loss: 0.1026, Accuracy: 97.11%
```

```python
# Plot the training loss curve
plt.figure(figsize=(10, 5))
plt.subplot(1, 2, 1)
plt.plot(train_loss_history, label='Training Loss')
plt.title('Training Loss over Epochs')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()

# Plot the accuracy curve
plt.subplot(1, 2, 2)
plt.plot(train_accuracy_history, label='Training Accuracy', color='green')
plt.title('Training Accuracy over Epochs')
plt.xlabel('Epoch')
plt.ylabel('Accuracy (%)')
plt.legend()

plt.show()
```




```
# Store the weights of the hidden layer after each epoch
hidden_weights_history = []

for epoch in range(n_epochs):
    running_loss = 0.0
    correct = 0
    total = 0
    for images, labels in trainloader:
        optimizer.zero_grad()

        outputs = model(images)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()

        running_loss += loss.item()

        _, predicted = torch.max(outputs.data, 1)
        total += labels.size(0)
        correct += (predicted == labels).sum().item()

    avg_loss = running_loss / len(trainloader)
    accuracy = 100 * correct / total
    train_loss_history.append(avg_loss)
    train_accuracy_history.append(accuracy)

    # Store the hidden layer weights after each epoch
    hidden_weights_history.append(model.fc1.weight.data.clone())

    print(f'Epoch [{epoch+1}/{n_epochs}], Loss: {avg_loss:.4f}, Accuracy: {accuracy:.2f}%')

# Visualize the changes in the weights of the hidden layer
plt.figure(figsize=(8, 6))
for i in range(n_epochs):
    plt.plot(hidden_weights_history[i].view(-1).cpu().numpy(), label=f'Epoch {i+1}')

plt.title('Weight Updates in Hidden Layer')
plt.xlabel('Weight Index')
plt.ylabel('Weight Value')
plt.legend()
plt.show()
```

```
Epoch [1/5], Loss: 0.1025, Accuracy: 97.12%
Epoch [2/5], Loss: 0.1024, Accuracy: 97.11%
Epoch [3/5], Loss: 0.1024, Accuracy: 97.12%
Epoch [4/5], Loss: 0.1023, Accuracy: 97.13%
Epoch [5/5], Loss: 0.1022, Accuracy: 97.14%
```



Start coding or generate with AI.