H5P3

November 2, 2024

[12]:
```
from torchvision import datasets
from torchvision.transforms import ToTensor
from torch.utils.data import DataLoader
import torch
from torch import nn
import numpy as np
import matplotlib.pyplot as plt
```

[13]:
```
train_data = datasets.USPS(root='usps', download=True, transform=ToTensor(),␣
 ↪train=True)
test_data = datasets.USPS(root='usps', download=True, transform=ToTensor(),␣
 ↪train=False)

# Create DataLoaders for training and testing
train_loader = DataLoader(train_data, batch_size=128, shuffle=True)
test_loader = DataLoader(test_data, batch_size=len(test_data), shuffle=False)
```

[14]:
```
# Define the MLP model with 2 hidden layers, both with 128 units
class MLP(nn.Module):
    def __init__(self):
        super().__init__()
        self.flatten = nn.Flatten()
        self.mlp = nn.Sequential(
            nn.Linear(16 * 16, 128),  # Input layer to first hidden layer
            nn.ReLU(),
            nn.Linear(128, 128),      # First hidden layer to second hidden␣
 ↪layer
            nn.ReLU(),
            nn.Linear(128, 128),      # Second hidden layer
            nn.ReLU(),
            nn.Linear(128, 10)        # Output layer for 10 classes
        )

    def forward(self, X):
        return self.mlp(self.flatten(X))
```

```
model = MLP().to('cuda')
loss_fn = nn.CrossEntropyLoss()
optimizer = torch.optim.SGD(model.parameters(), lr=0.5)
```

[15]:
```
%%time
epochs = 1000
CE = torch.zeros((epochs))
Training = torch.zeros((epochs))
Test = torch.zeros((epochs))
for epoch in range(epochs):
    cumulative_accuracy = 0
    cumulative_loss = 0
    for X, Y in train_loader:
        X, Y = X.to('cuda'), Y.to('cuda')
        out = model(X)
        loss = loss_fn(out, Y)
        optimizer.zero_grad()
        loss.backward()
        optimizer.step()
        cumulative_loss += loss.item()
        cumulative_accuracy += (out.argmax(axis=1) == Y).sum().item()
    CE[epoch] = cumulative_loss / len(train_loader)
    Training[epoch] = cumulative_accuracy / len(train_data)
    with torch.no_grad():
        for Xt, Yt in test_loader:
            Xt, Yt = Xt.to('cuda'), Yt.to('cuda')
            test_out = model(Xt)
            test_accuracy_epoch = (test_out.argmax(axis=1) == Yt).sum().item() /
 ↪ len(test_data)
        Test[epoch] = test_accuracy_epoch
    if (epoch + 1) % 100 == 0:
        print(f"Epoch {epoch + 1}/{epochs} | Loss: {CE[epoch]:.4f} | Training␣
↪Accuracy: {Training[epoch]:.4f} | Test Accuracy: {Test[epoch]:.4f}")
```

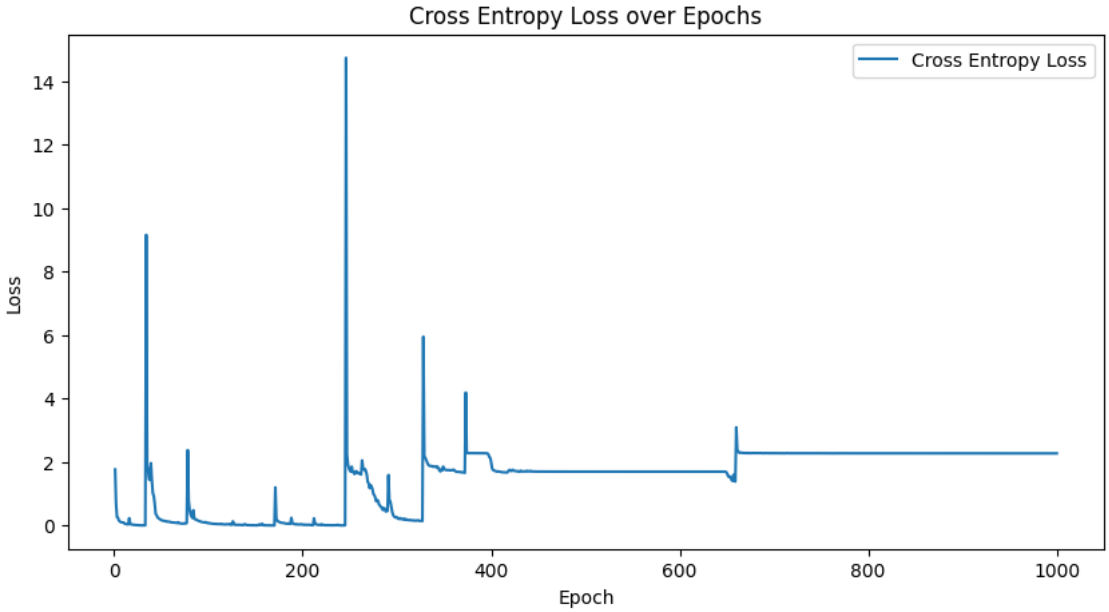
```
Epoch 100/1000 | Loss: 0.0847 | Training Accuracy: 0.9717 | Test Accuracy:
0.9223
Epoch 200/1000 | Loss: 0.0234 | Training Accuracy: 0.9926 | Test Accuracy:
0.9253
Epoch 300/1000 | Loss: 0.2611 | Training Accuracy: 0.9281 | Test Accuracy:
0.8749
Epoch 400/1000 | Loss: 1.9852 | Training Accuracy: 0.2347 | Test Accuracy:
0.3039
Epoch 500/1000 | Loss: 1.6971 | Training Accuracy: 0.3000 | Test Accuracy:
0.3044
Epoch 600/1000 | Loss: 1.6961 | Training Accuracy: 0.2980 | Test Accuracy:
0.3044
Epoch 700/1000 | Loss: 2.2770 | Training Accuracy: 0.1625 | Test Accuracy:
0.1315
```

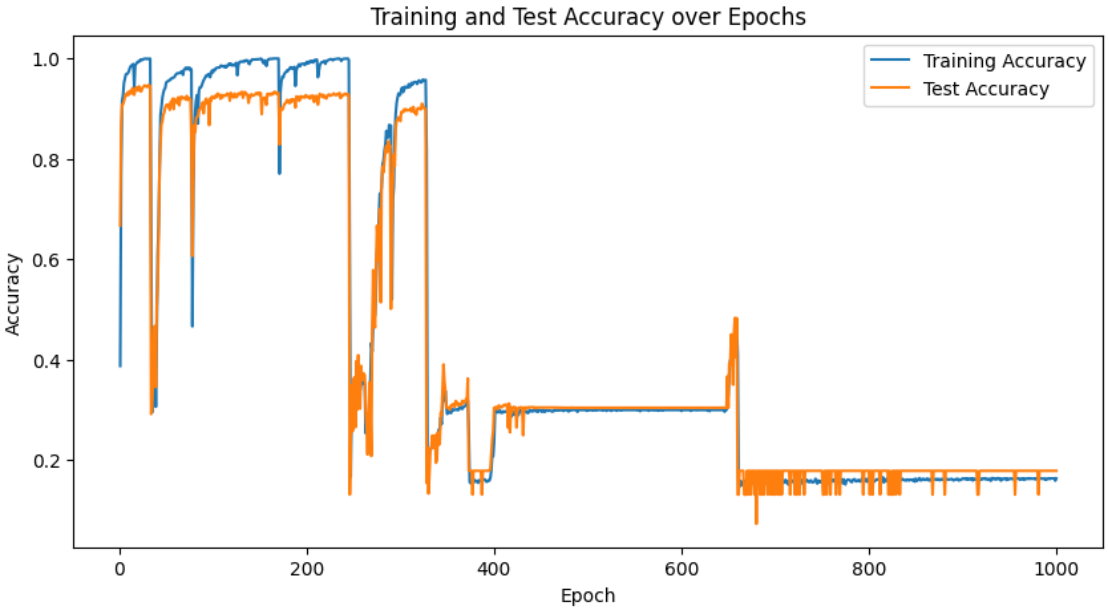
```
Epoch 800/1000 | Loss: 2.2732 | Training Accuracy: 0.1643 | Test Accuracy:
0.1789
Epoch 900/1000 | Loss: 2.2735 | Training Accuracy: 0.1638 | Test Accuracy:
0.1789
Epoch 1000/1000 | Loss: 2.2716 | Training Accuracy: 0.1638 | Test Accuracy:
0.1789
CPU times: user 13min 34s, sys: 2.98 s, total: 13min 37s
Wall time: 13min 42s
```

[16]:
```python
epochs_range = np.arange(1, epochs + 1)
CE_np = CE.cpu().numpy()
Training_np = Training.cpu().numpy()
Test_np = Test.cpu().numpy()

plt.figure(figsize=(10, 5))
plt.plot(epochs_range, CE_np, label="Cross Entropy Loss")
plt.xlabel("Epoch")
plt.ylabel("Loss")
plt.title("Cross Entropy Loss over Epochs")
plt.legend()
plt.show()

plt.figure(figsize=(10, 5))
plt.plot(epochs_range, Training_np, label="Training Accuracy")
plt.plot(epochs_range, Test_np, label="Test Accuracy")
plt.xlabel("Epoch")
plt.ylabel("Accuracy")
plt.title("Training and Test Accuracy over Epochs")
plt.legend()
plt.show()
```


Cross Entropy Loss over Epochs
Cross Entropy Loss
Loss
Epoch
0
2
4
6
8
10
12
14
0
200
400
600
800
1000


Training and Test Accuracy over Epochs
Training Accuracy
Test Accuracy
Accuracy
Epoch
0.2
0.4
0.6
0.8
1.0
0
200
400
600
800
1000