assignment1

November 22, 2023

A1.1

[ ]:
```
import torchvision.datasets as datasets
import torchvision.transforms as transforms
from torch.utils.data import DataLoader
import torch as th  # MNIST images have dimension ( 1, 28, 28)
import numpy as np
from matplotlib import pyplot as plt
```

[ ]:
```
train_data = datasets.MNIST(root='./data', train=True, download=True, transform=transforms.ToTensor())
train_set = DataLoader(train_data, batch_size=1024, shuffle=True)
test_data = datasets.MNIST(root='./data', train=False, download=True, transform=transforms.ToTensor())
test_set = DataLoader(test_data, batch_size=1024, shuffle=True)
```

a)

[ ]:
```
model = th.nn.Sequential(
    th.nn.Conv2d(1, 8, 5),  # ( 8, 24, 24)
    th.nn.ReLU(),  # ( 8, 24, 24)
    th.nn.MaxPool2d(2, 2),  # ( 8, 12, 12)
    th.nn.Conv2d(8, 16, 5),  # (16, 8, 8)
    th.nn.ReLU(),  # (16, 8, 8)
    th.nn.MaxPool2d(2, 2),  # (16, 4, 4)
    th.nn.Flatten(),  # (16 * 4 * 4)
    th.nn.Linear(256, 128),  # (128)
    th.nn.ReLU(),  # (128)
    th.nn.Linear(128, 32),  # ( 32)
    th.nn.ReLU(),  # ( 32)
    th.nn.Linear(32, 10),
)
criterion = th.nn.CrossEntropyLoss()
optimizer = th.optim.RMSprop(model.parameters(), lr=0.0005)
```

[ ]:
```
def train_test_model(model, optimizer, criterion, n_epochs, train_set, test_set, label_mod, acc_function, output_transform = lambda x: x):
    train_loss, train_acc = [], []
    test_loss, test_acc = [], []
    for e in range(n_epochs):
        print(f"Epoch {e}")
        losses, accuracies = [], []
        for x, y in train_set:
            pred_y = output_transform(model(x))
            optimizer.zero_grad()
            loss = criterion(pred_y, label_mod(y))
            loss.backward()
            optimizer.step()
            losses.append(loss.item())
            acc = acc_function(pred_y, y)
            accuracies.append(acc)
        print(f"Train loss: {np.mean(losses)}")
        print(f"Train acc: {np.mean(accuracies)}")
        train_loss.append(np.mean(losses))
        train_acc.append(np.mean(accuracies))

        # model.eval()
        losses, accuracies = [], []
        with th.no_grad():
            for x, y in test_set:
                pred_y = output_transform(model(x))
                loss = criterion(pred_y, label_mod(y))
                losses.append(loss.item())
                acc = acc_function(pred_y, y)
                accuracies.append(acc)
            print(f"Test loss: {np.mean(losses)}")
            print(f"Test acc: {np.mean(accuracies)}")
            test_loss.append(np.mean(losses))
            test_acc.append(np.mean(accuracies))
        # model.train()
    return train_loss, train_acc, test_loss, test_acc
```

[ ]:

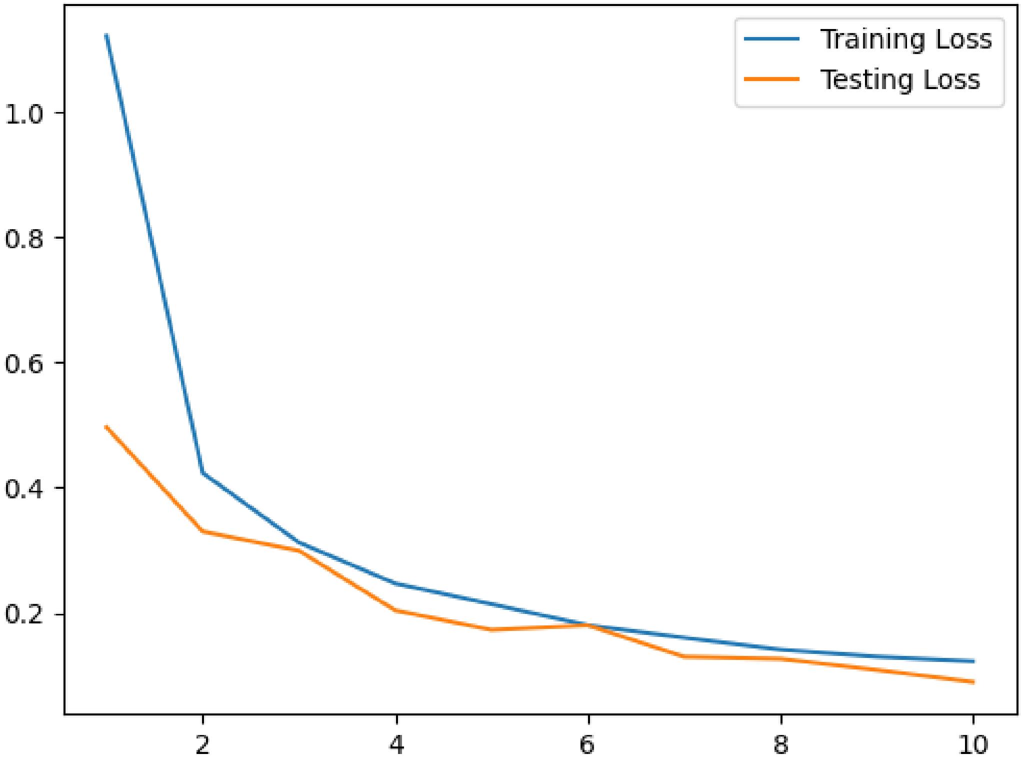
```
acc1 = lambda pred_y, y: (pred_y.max(dim=-1)[1] == y).sum().item() / y.shape[0]
```

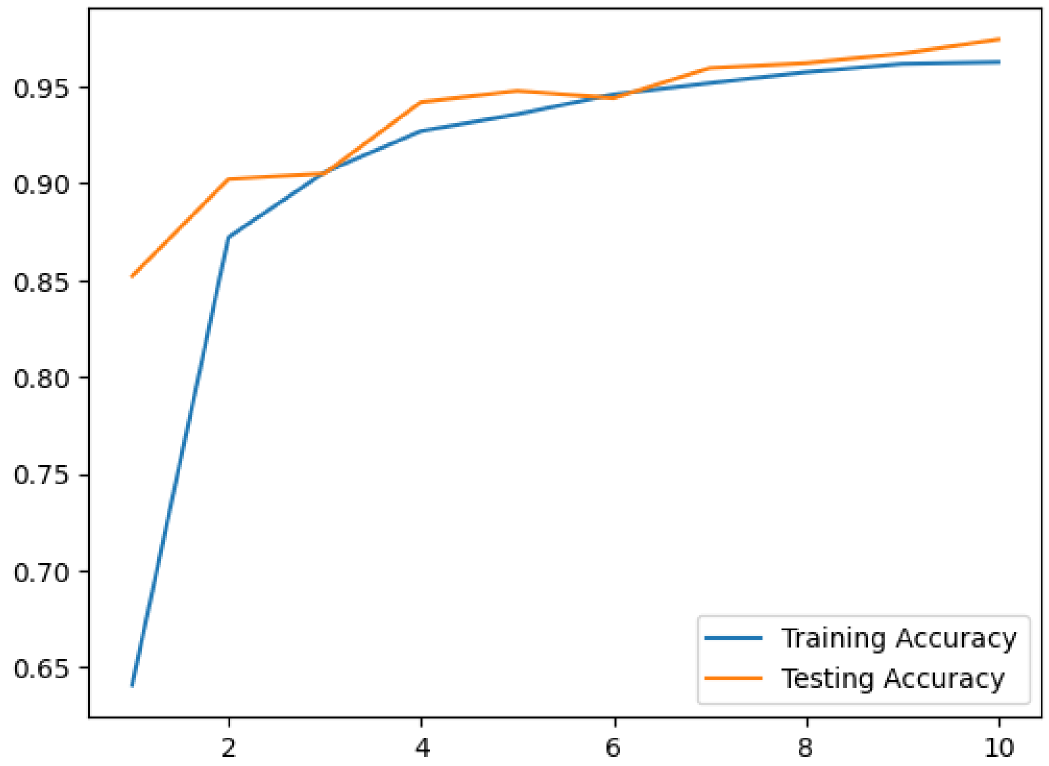
[ ]:

```
tr_l, tr_a, ts_l, ts_a = train_test_model(
    model, optimizer, criterion, 10, train_set, test_set, lambda x: x, acc1
)
```

[ ]:

```
epochs = range(1, 11)
plt.plot(epochs, tr_l, label = "Training Loss")
plt.plot(epochs, ts_l, label = "Testing Loss")
plt.legend()
plt.show()
plt.clf()
plt.plot(epochs, tr_a, label = "Training Accuracy")
plt.plot(epochs, ts_a, label = "Testing Accuracy")
plt.legend()
plt.show()
```





b)

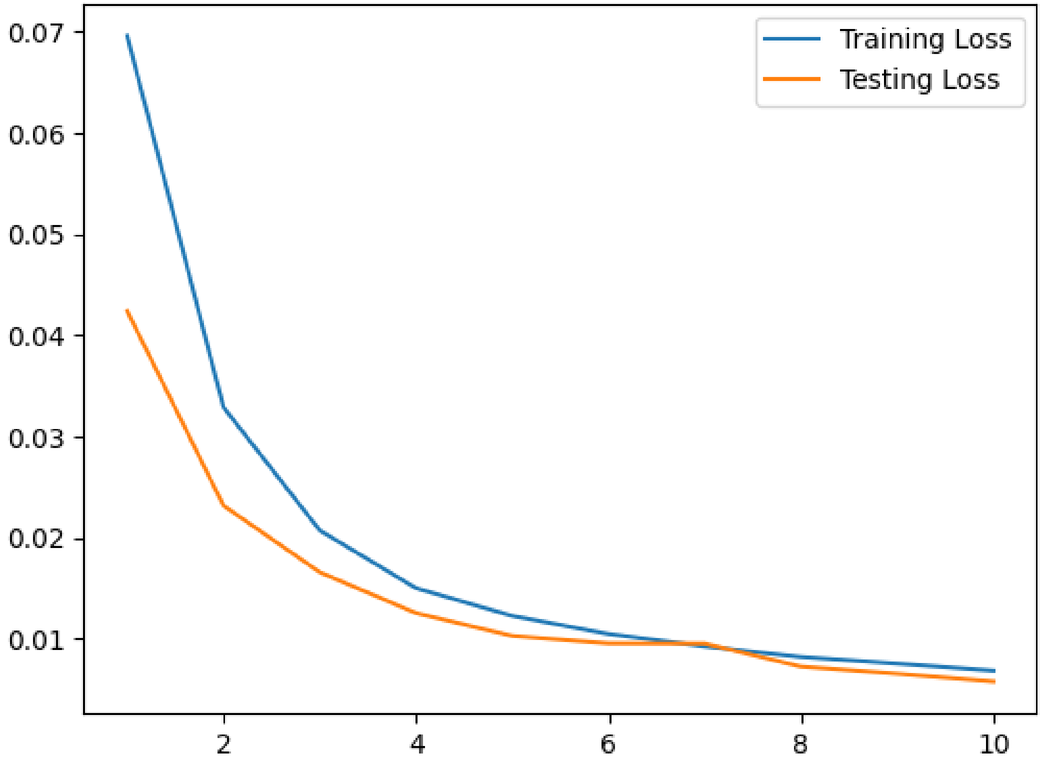
[ ]:
```
criterion2 = th.nn.MSELoss()
```

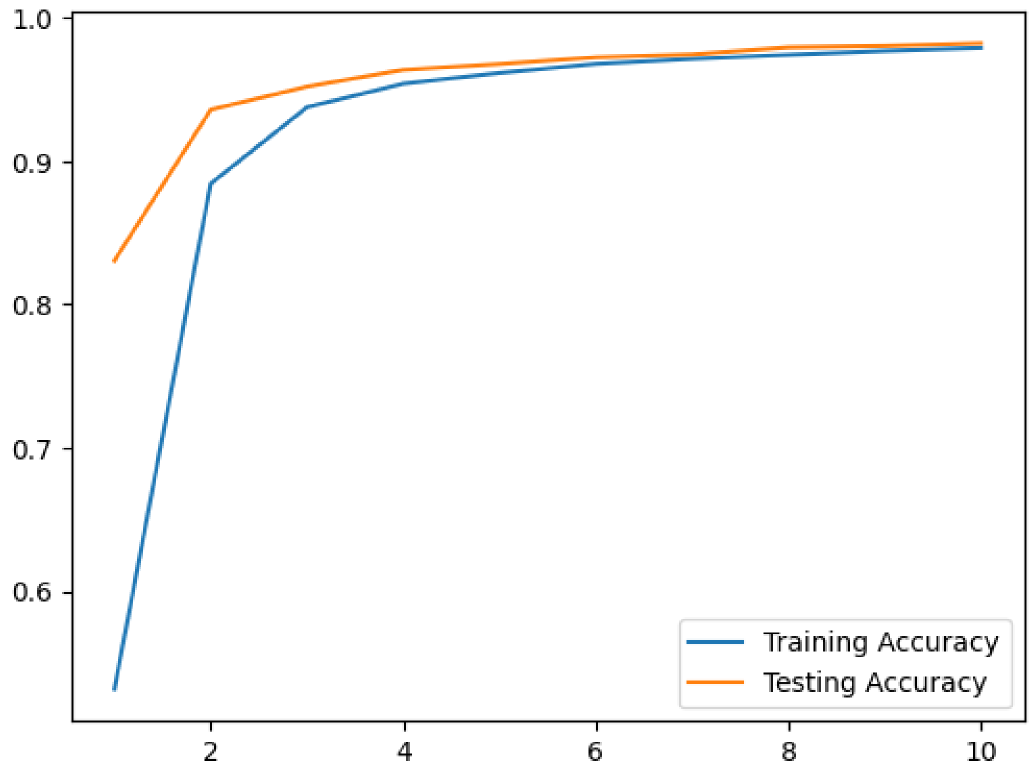
[ ]:
```
model2 = th.nn.Sequential(
    th.nn.Conv2d(1, 8, 5),  # ( 8, 24, 24)
    th.nn.ReLU(),  # ( 8, 24, 24)
    th.nn.MaxPool2d(2, 2),  # ( 8, 12, 12)
    th.nn.Conv2d(8, 16, 5),  # (16, 8, 8)
    th.nn.ReLU(),  # (16, 8, 8)
    th.nn.MaxPool2d(2, 2),  # (16, 4, 4)
    th.nn.Flatten(),  # (16 * 4 * 4)
    th.nn.Linear(256, 128),  # (128)
    th.nn.ReLU(),  # (128)
    th.nn.Linear(128, 32),  # ( 32)
    th.nn.ReLU(),  # ( 32)
    th.nn.Linear(32, 10),
)
optimizer2 = th.optim.RMSprop(model2.parameters(), lr=0.0005)
```

[ ]:
```
tr_l2, tr_a2, ts_l2, ts_a2 = train_test_model(
    model2,
    optimizer2,
    criterion2,
    10,
    train_set,
    test_set,
    lambda x: th.nn.functional.one_hot(x).float(),
    acc1
)
```

[ ]:

```
epochs = range(1, 11)
plt.plot(epochs, tr_l2, label = "Training Loss")
plt.plot(epochs, ts_l2, label = "Testing Loss")
plt.legend()
plt.show()
plt.clf()
plt.plot(epochs, tr_a2, label = "Training Accuracy")
plt.plot(epochs, ts_a2, label = "Testing Accuracy")
plt.legend()
plt.show()
```





c)

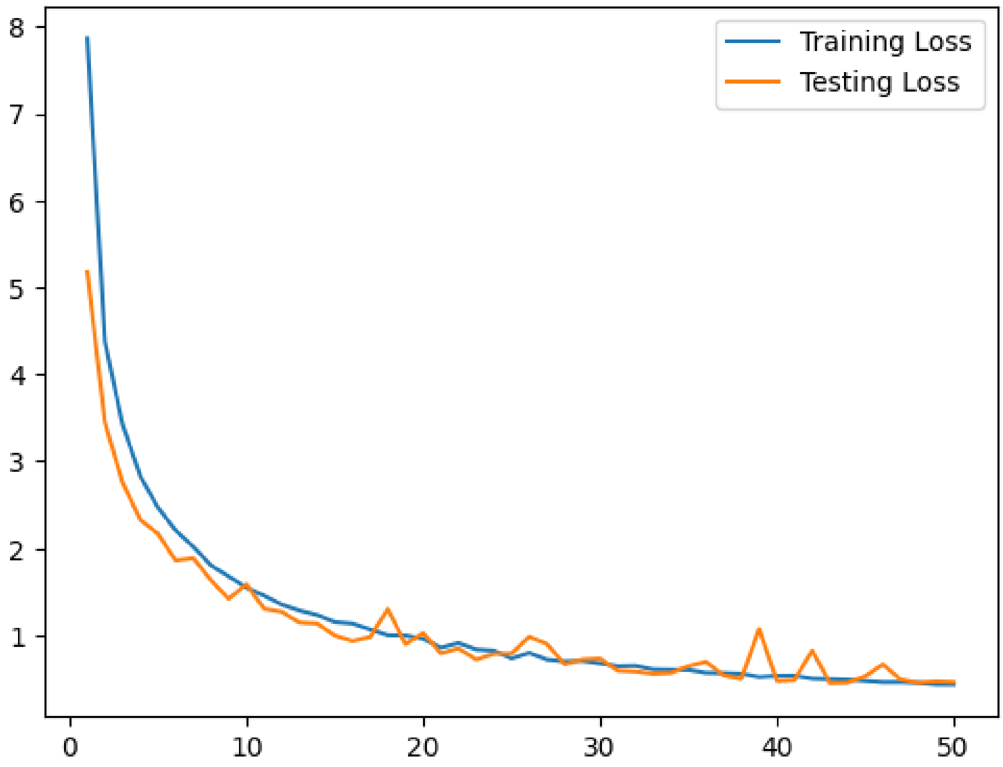
[ ]:
```
model3 = th.nn.Sequential(
    th.nn.Conv2d(1, 8, 5),  # ( 8, 24, 24)
    th.nn.ReLU(),  # ( 8, 24, 24)
    th.nn.MaxPool2d(2, 2),  # ( 8, 12, 12)
    th.nn.Conv2d(8, 16, 5),  # (16, 8, 8)
    th.nn.ReLU(),  # (16, 8, 8)
    th.nn.MaxPool2d(2, 2),  # (16, 4, 4)
    th.nn.Flatten(),  # (16 * 4 * 4)
    th.nn.Linear(256, 128),  # (128)
    th.nn.ReLU(),  # (128)
    th.nn.Linear(128, 32),  # ( 32)
    th.nn.ReLU(),  # ( 32)
    th.nn.Linear(32, 1),
)
optimizer3 = th.optim.RMSprop(model3.parameters(), lr=0.0005)
```

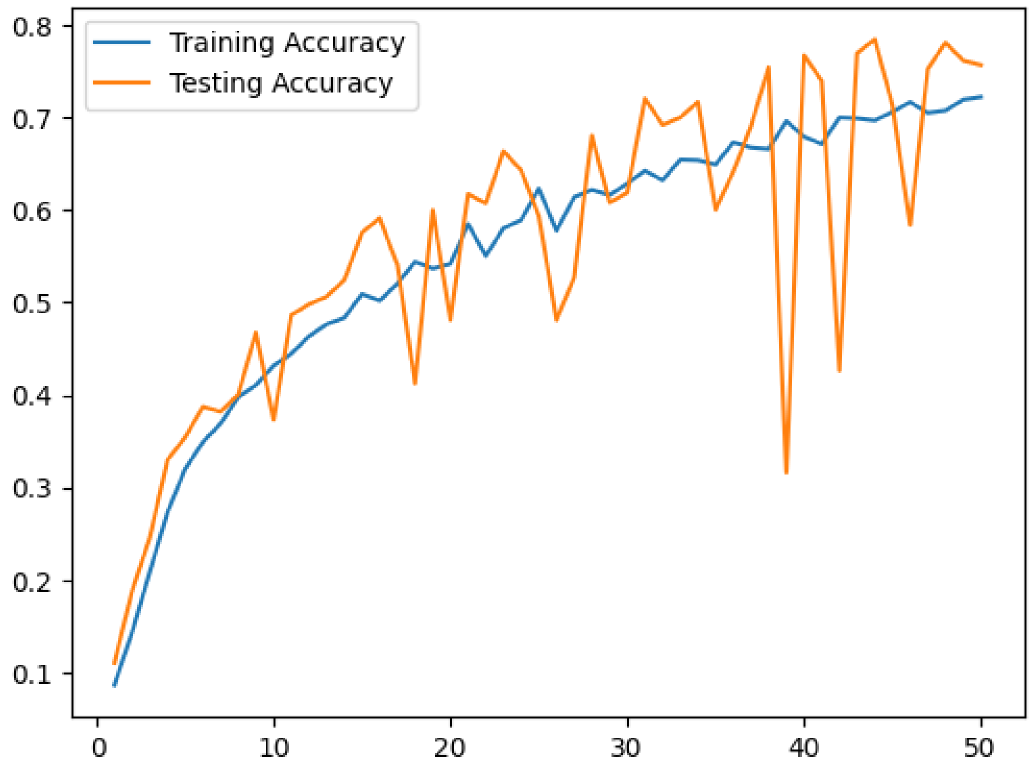
[ ]:
```
acc2 = lambda pred_y, y: (th.round(pred_y[:,0]) == y).sum().item() / y.shape[0]
```

[ ]:
```
tr_l3, tr_a3, ts_l3, ts_a3 = train_test_model(
    model3,
    optimizer3,
    criterion2,
    50,
    train_set,
    test_set,
    lambda x: x.unsqueeze(dim=1).float(),
    acc2,
)
```

[ ]:

```
epochs = range(1, 51)
plt.plot(epochs, tr_l3, label = "Training Loss")
plt.plot(epochs, ts_l3, label = "Testing Loss")
plt.legend()
plt.show()
plt.clf()
plt.plot(epochs, tr_a3, label = "Training Accuracy")
plt.plot(epochs, ts_a3, label = "Testing Accuracy")
plt.legend()
plt.show()
```





d)

[ ]:

```
model4 = th.nn.Sequential(
    th.nn.Conv2d(1, 8, 5),  # ( 8, 24, 24)
    th.nn.ReLU(),  # ( 8, 24, 24)
    th.nn.MaxPool2d(2, 2),  # ( 8, 12, 12)
    th.nn.Conv2d(8, 16, 5),  # (16, 8, 8)
    th.nn.ReLU(),  # (16, 8, 8)
    th.nn.MaxPool2d(2, 2),  # (16, 4, 4)
    th.nn.Flatten(),  # (16 * 4 * 4)
    th.nn.Linear(256, 128),  # (128)
    th.nn.ReLU(),  # (128)
    th.nn.Linear(128, 32),  # ( 32)
    th.nn.ReLU(),  # ( 32)
    th.nn.Linear(32, 1),
)
optimizer4 = th.optim.RMSprop(model4.parameters(), lr=0.0005)
```

[ ]:

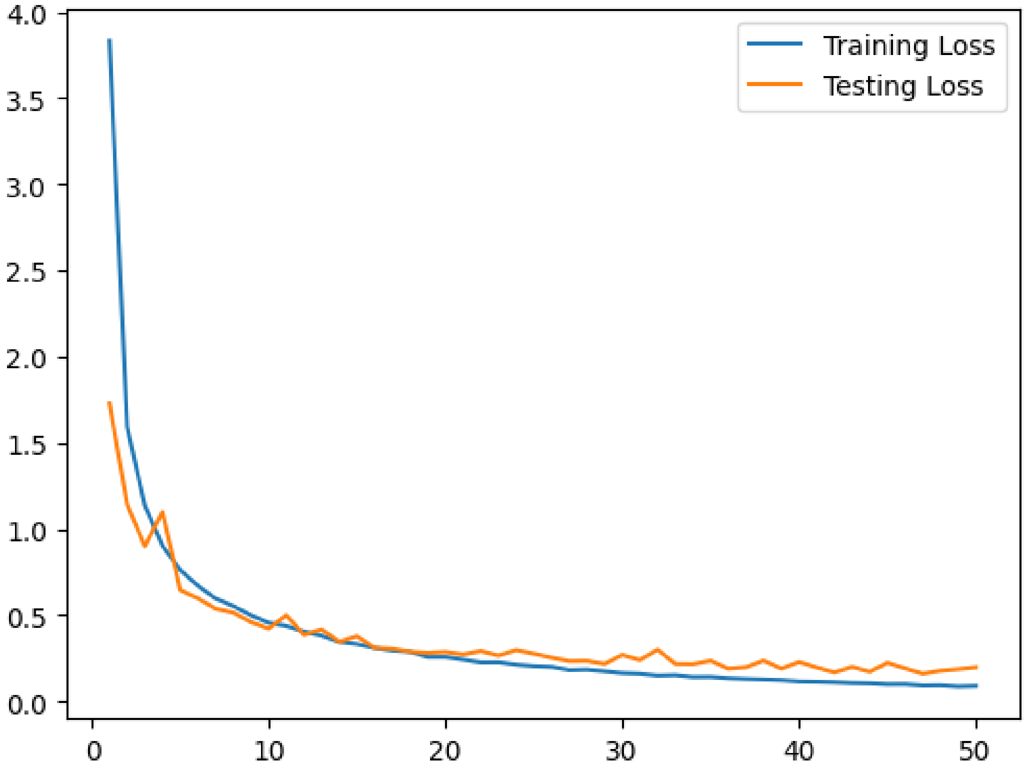
```
output_transform4 = lambda x: th.add(th.multiply(x, 4.5), 4.5)
```

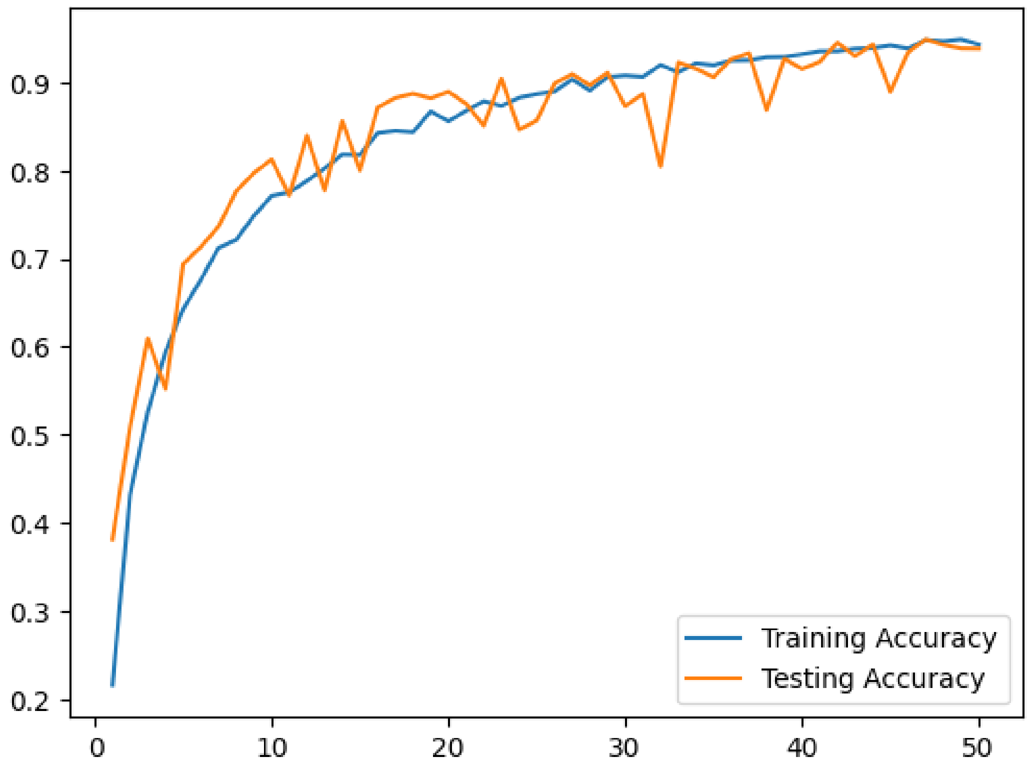
[ ]:

```
tr_l4, tr_a4, ts_l4, ts_a4 = train_test_model(
    model4,
    optimizer4,
    criterion2,
    50,
    train_set,
    test_set,
    lambda x: x.unsqueeze(dim=1).float(),
    acc2,
    output_transform4,
)
```

[ ]:

```
epochs = range(1, 51)
plt.plot(epochs, tr_l4, label = "Training Loss")
plt.plot(epochs, ts_l4, label = "Testing Loss")
plt.legend()
plt.show()
plt.clf()
plt.plot(epochs, tr_a4, label = "Training Accuracy")
plt.plot(epochs, ts_a4, label = "Testing Accuracy")
plt.legend()
plt.show()
```





The model converges much more quickly and the end accuracy is higher. Thanks to linear scaling, the range of accepted answers from the model changes from (0, 9) to (-1, 1). This reduces the required weights in the model and increases stability.