

challenge_assignment

October 28, 2023

Importing modules

```
[ ]: import torch
import torch.nn as nn
import torch.optim as optim
import torchvision
import torchvision.transforms as transforms
from torchvision import datasets
from torch.utils.data import DataLoader
from pathlib import Path
import numpy as np
import matplotlib.pyplot as plt
import multiprocessing
```

Creating the NN object

```
[ ]: layer_sizes = [784, 512, 256, 10]

# Define a simple neural network model
class Net(nn.Module):
    """
    This is a class Neural network implemented in pytorch.
    It inherits from nn.Module and thereby makes sure that fancy
    ↪ functionalities
    of Pytorch will be available for your neural network architecture.
    """
    def __init__(self):
        super(Net, self).__init__()
        # Define your layers. Usually one defines linear layers and uses the
        ↪ relu function around these layers.
        # A Linear layer is define via lin = nn.Linear(input_dim, output_dim)
        self.layers = nn.Sequential(
            nn.Linear(layer_sizes[0], layer_sizes[1]),
            nn.ReLU(),
            nn.Linear(layer_sizes[1], layer_sizes[2]),
            nn.ReLU(),
            nn.Linear(layer_sizes[2], layer_sizes[3])
        )
```

```

def forward(self, x):
    # Define your evaluate function. You can use the pytorch relu function,
    ↪ via torch.relu
    # You can call your linear layer at a given input x via self.lin(x)
    x = x.view(-1, 28 * 28) # Flatten the input such that we have a vector
    x = self.layers(x) # Pass through the defined layers
    return x

# Initialize the neural network model
net = Net()

```

Network training

```

[ ]: criterion = nn.CrossEntropyLoss()
optimizer = optim.SGD(net.parameters(), lr=0.001, momentum=0.9)

# Define data transformations and load the MNIST dataset
transform = transforms.Compose([transforms.ToTensor(), transforms.Normalize((0.
    ↪ 5,)), (0.5,))])

train_dataset = datasets.MNIST(root='./data', train=True, transform=transform,
    ↪ download=True)
train_loader = DataLoader(train_dataset, batch_size=64, shuffle=True)

# Use DataParallel to utilize multiple CPU cores
if torch.cuda.device_count() > 1:
    print(f"Using {torch.cuda.device_count()} GPUs!")
    net = nn.DataParallel(net)
else:
    print("Using CPU!")

# Training loop
for epoch in range(100): # You can adjust the number of epochs
    running_loss = 0.0
    for i, data in enumerate(train_loader, 0):
        inputs, labels = data
        optimizer.zero_grad()
        outputs = net(inputs)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()
        running_loss += loss.item()
    if i % 100 == 99: # Print every 100 mini-batches
        print(f'Epoch {epoch + 1}, Mini-Batch {i + 1}, Loss: {running_loss /
    ↪ 100:.3f}')
    running_loss = 0.0

```

```
print("Training finished")

# Save the trained model
torch.save(net.state_dict(), 'mnist_model.pth')
```

Using CPU!

```
Epoch 1, Mini-Batch 100, Loss: 0.498
Epoch 1, Mini-Batch 200, Loss: 0.460
Epoch 1, Mini-Batch 300, Loss: 0.427
Epoch 1, Mini-Batch 400, Loss: 0.403
Epoch 1, Mini-Batch 500, Loss: 0.390
Epoch 1, Mini-Batch 600, Loss: 0.362
Epoch 1, Mini-Batch 700, Loss: 0.357
Epoch 1, Mini-Batch 800, Loss: 0.365
Epoch 1, Mini-Batch 900, Loss: 0.359
Epoch 2, Mini-Batch 100, Loss: 0.328
Epoch 2, Mini-Batch 200, Loss: 0.355
Epoch 2, Mini-Batch 300, Loss: 0.330
Epoch 2, Mini-Batch 400, Loss: 0.327
Epoch 2, Mini-Batch 500, Loss: 0.322
Epoch 2, Mini-Batch 600, Loss: 0.314
Epoch 2, Mini-Batch 700, Loss: 0.317
Epoch 2, Mini-Batch 800, Loss: 0.303
Epoch 2, Mini-Batch 900, Loss: 0.315
Epoch 3, Mini-Batch 100, Loss: 0.304
Epoch 3, Mini-Batch 200, Loss: 0.291
Epoch 3, Mini-Batch 300, Loss: 0.315
Epoch 3, Mini-Batch 400, Loss: 0.298
Epoch 3, Mini-Batch 500, Loss: 0.275
Epoch 3, Mini-Batch 600, Loss: 0.286
Epoch 3, Mini-Batch 700, Loss: 0.277
Epoch 3, Mini-Batch 800, Loss: 0.269
Epoch 3, Mini-Batch 900, Loss: 0.269
Epoch 4, Mini-Batch 100, Loss: 0.264
Epoch 4, Mini-Batch 200, Loss: 0.271
Epoch 4, Mini-Batch 300, Loss: 0.260
Epoch 4, Mini-Batch 400, Loss: 0.260
Epoch 4, Mini-Batch 500, Loss: 0.272
Epoch 4, Mini-Batch 600, Loss: 0.255
Epoch 4, Mini-Batch 700, Loss: 0.261
Epoch 4, Mini-Batch 800, Loss: 0.237
Epoch 4, Mini-Batch 900, Loss: 0.253
Epoch 5, Mini-Batch 100, Loss: 0.257
Epoch 5, Mini-Batch 200, Loss: 0.258
Epoch 5, Mini-Batch 300, Loss: 0.237
Epoch 5, Mini-Batch 400, Loss: 0.258
Epoch 5, Mini-Batch 500, Loss: 0.219
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Epoch 5, Mini-Batch 600, Loss: 0.227
Epoch 5, Mini-Batch 700, Loss: 0.216
Epoch 5, Mini-Batch 800, Loss: 0.234
Epoch 5, Mini-Batch 900, Loss: 0.223
Epoch 6, Mini-Batch 100, Loss: 0.216
Epoch 6, Mini-Batch 200, Loss: 0.212
Epoch 6, Mini-Batch 300, Loss: 0.222
Epoch 6, Mini-Batch 400, Loss: 0.211
Epoch 6, Mini-Batch 500, Loss: 0.234
Epoch 6, Mini-Batch 600, Loss: 0.215
Epoch 6, Mini-Batch 700, Loss: 0.208
Epoch 6, Mini-Batch 800, Loss: 0.215
Epoch 6, Mini-Batch 900, Loss: 0.207
Epoch 7, Mini-Batch 100, Loss: 0.202
Epoch 7, Mini-Batch 200, Loss: 0.206
Epoch 7, Mini-Batch 300, Loss: 0.201
Epoch 7, Mini-Batch 400, Loss: 0.202
Epoch 7, Mini-Batch 500, Loss: 0.195
Epoch 7, Mini-Batch 600, Loss: 0.183
Epoch 7, Mini-Batch 700, Loss: 0.201
Epoch 7, Mini-Batch 800, Loss: 0.193
Epoch 7, Mini-Batch 900, Loss: 0.189
Epoch 8, Mini-Batch 100, Loss: 0.170
Epoch 8, Mini-Batch 200, Loss: 0.193
Epoch 8, Mini-Batch 300, Loss: 0.185
Epoch 8, Mini-Batch 400, Loss: 0.190
Epoch 8, Mini-Batch 500, Loss: 0.177
Epoch 8, Mini-Batch 600, Loss: 0.191
Epoch 8, Mini-Batch 700, Loss: 0.172
Epoch 8, Mini-Batch 800, Loss: 0.184
Epoch 8, Mini-Batch 900, Loss: 0.163
Epoch 9, Mini-Batch 100, Loss: 0.173
Epoch 9, Mini-Batch 200, Loss: 0.167
Epoch 9, Mini-Batch 300, Loss: 0.171
Epoch 9, Mini-Batch 400, Loss: 0.176
Epoch 9, Mini-Batch 500, Loss: 0.167
Epoch 9, Mini-Batch 600, Loss: 0.157
Epoch 9, Mini-Batch 700, Loss: 0.177
Epoch 9, Mini-Batch 800, Loss: 0.161
Epoch 9, Mini-Batch 900, Loss: 0.144
Epoch 10, Mini-Batch 100, Loss: 0.156
Epoch 10, Mini-Batch 200, Loss: 0.154
Epoch 10, Mini-Batch 300, Loss: 0.151
Epoch 10, Mini-Batch 400, Loss: 0.155
Epoch 10, Mini-Batch 500, Loss: 0.141
Epoch 10, Mini-Batch 600, Loss: 0.160
Epoch 10, Mini-Batch 700, Loss: 0.151
Epoch 10, Mini-Batch 800, Loss: 0.144

Epoch 10, Mini-Batch 900, Loss: 0.162
Epoch 11, Mini-Batch 100, Loss: 0.155
Epoch 11, Mini-Batch 200, Loss: 0.146
Epoch 11, Mini-Batch 300, Loss: 0.144
Epoch 11, Mini-Batch 400, Loss: 0.134
Epoch 11, Mini-Batch 500, Loss: 0.138
Epoch 11, Mini-Batch 600, Loss: 0.155
Epoch 11, Mini-Batch 700, Loss: 0.135
Epoch 11, Mini-Batch 800, Loss: 0.133
Epoch 11, Mini-Batch 900, Loss: 0.139
Epoch 12, Mini-Batch 100, Loss: 0.140
Epoch 12, Mini-Batch 200, Loss: 0.147
Epoch 12, Mini-Batch 300, Loss: 0.123
Epoch 12, Mini-Batch 400, Loss: 0.139
Epoch 12, Mini-Batch 500, Loss: 0.130
Epoch 12, Mini-Batch 600, Loss: 0.129
Epoch 12, Mini-Batch 700, Loss: 0.128
Epoch 12, Mini-Batch 800, Loss: 0.127
Epoch 12, Mini-Batch 900, Loss: 0.124
Epoch 13, Mini-Batch 100, Loss: 0.121
Epoch 13, Mini-Batch 200, Loss: 0.127
Epoch 13, Mini-Batch 300, Loss: 0.126
Epoch 13, Mini-Batch 400, Loss: 0.125
Epoch 13, Mini-Batch 500, Loss: 0.122
Epoch 13, Mini-Batch 600, Loss: 0.128
Epoch 13, Mini-Batch 700, Loss: 0.116
Epoch 13, Mini-Batch 800, Loss: 0.129
Epoch 13, Mini-Batch 900, Loss: 0.115
Epoch 14, Mini-Batch 100, Loss: 0.118
Epoch 14, Mini-Batch 200, Loss: 0.113
Epoch 14, Mini-Batch 300, Loss: 0.109
Epoch 14, Mini-Batch 400, Loss: 0.123
Epoch 14, Mini-Batch 500, Loss: 0.111
Epoch 14, Mini-Batch 600, Loss: 0.113
Epoch 14, Mini-Batch 700, Loss: 0.123
Epoch 14, Mini-Batch 800, Loss: 0.112
Epoch 14, Mini-Batch 900, Loss: 0.112
Epoch 15, Mini-Batch 100, Loss: 0.103
Epoch 15, Mini-Batch 200, Loss: 0.103
Epoch 15, Mini-Batch 300, Loss: 0.107
Epoch 15, Mini-Batch 400, Loss: 0.114
Epoch 15, Mini-Batch 500, Loss: 0.105
Epoch 15, Mini-Batch 600, Loss: 0.102
Epoch 15, Mini-Batch 700, Loss: 0.106
Epoch 15, Mini-Batch 800, Loss: 0.116
Epoch 15, Mini-Batch 900, Loss: 0.114
Epoch 16, Mini-Batch 100, Loss: 0.106
Epoch 16, Mini-Batch 200, Loss: 0.101

Epoch 16, Mini-Batch 300, Loss: 0.091
Epoch 16, Mini-Batch 400, Loss: 0.101
Epoch 16, Mini-Batch 500, Loss: 0.111
Epoch 16, Mini-Batch 600, Loss: 0.100
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Epoch 16, Mini-Batch 800, Loss: 0.104
Epoch 16, Mini-Batch 900, Loss: 0.093
Epoch 17, Mini-Batch 100, Loss: 0.097
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Epoch 44, Mini-Batch 100, Loss: 0.024
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Epoch 48, Mini-Batch 900, Loss: 0.023
Epoch 49, Mini-Batch 100, Loss: 0.022
Epoch 49, Mini-Batch 200, Loss: 0.020
Epoch 49, Mini-Batch 300, Loss: 0.019
Epoch 49, Mini-Batch 400, Loss: 0.025
Epoch 49, Mini-Batch 500, Loss: 0.023
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Training finished

Get the images

```
[ ]: cwd = Path.cwd()
data_dir = cwd.parent / 'data'

def get_mnist():
    return datasets.MNIST(root='./data', train=True, transform=transforms.
        ↳ToTensor(), download=True)

def return_image(image_index, mnist_dataset):
    # Get the image and its corresponding label
    image, label = mnist_dataset[image_index]

    # Now, you have the image as a PyTorch tensor.
    # You can access its data as a matrix using .detach().numpy()
    image_matrix = image[0].detach().numpy() # Grayscale image, so we select
    ↳the first channel (index 0)

    return image_matrix.reshape(image_matrix.size), image_matrix, label

def read_from_file(name=data_dir / "image_19961.txt"):
    x = np.zeros(28 * 28)
    with open(name) as file:
        for i, line in enumerate(file):
            # split and convert values to floats
            x[i * 28 : (i+1)*28] = [float(value) for value in line.
                ↳strip().split()]
```

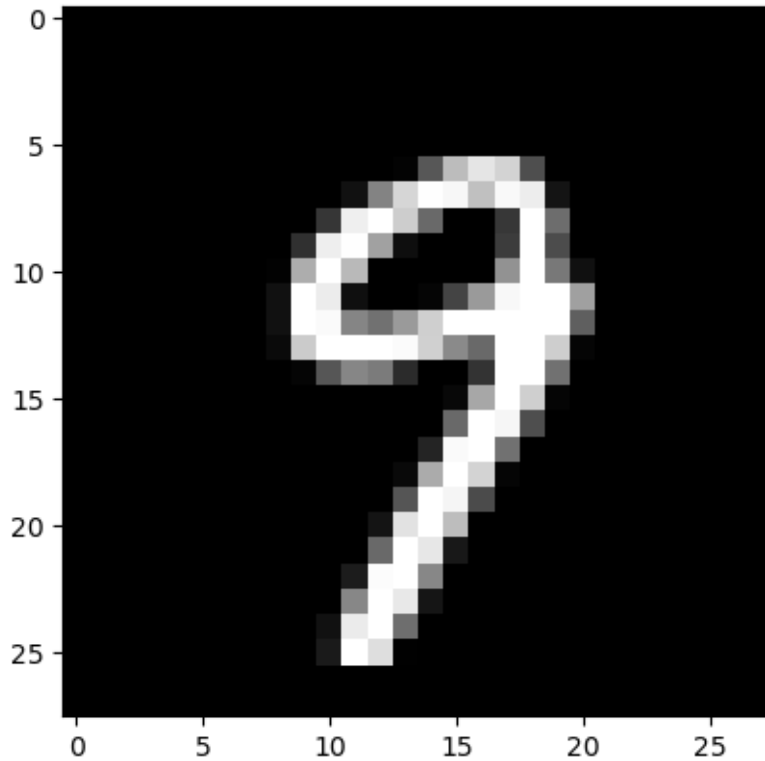
Running the network

```
[ ]: # Choose an index to select one of the images
image_index = 27581
mnist_dataset = get_mnist()
x, image, label = return_image(image_index, mnist_dataset) # This here reads
    ↳image {image_index} from the mnist dataset.
x_file = read_from_file() # In case you were not able to install torchvision,
    ↳you can use this read_from_file function

response_vector = net.forward(torch.tensor(x)).detach().numpy()

plt.imshow(image, cmap='gray')
plt.show()

print(f"The response vector of the network is: {np.argmax(response_vector)}")
print(f"Image {image_index} shows the number {label}")
```



The response vector of the network is: 9
Image 27581 shows the number 9

```
[ ]: # neural network tester

def test_neural_network(net, mnist_dataset):

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

    print(f"Accuracy of the network on the 10000 test images: {100 * correct / total}%")

test_neural_network(net, get_mnist())
```

Accuracy of the network on the 10000 test images: 80.265%