Problem2_Code

February 16, 2019

```
In [0]: import numpy as np
        import matplotlib.pyplot as plt

        import torch
        import torch.nn as nn
        import torch.nn.functional as F
        import torch.optim as optim

        import torchvision
        from torchvision import transforms

        torch.backends.cudnn.deterministic=True
        device = torch.device("cuda")
```

```
In [2]: from google.colab import drive
        drive.mount('/content/gdrive')
```

```
Go to this URL in a browser: https://accounts.google.com/o/oauth2/auth?client_id=947318989803-

Enter your authorization code:
ůůůůůůůůůů
Mounted at /content/gdrive
```

```
In [0]: # ~~ MNIST ~~

        transform = transforms.Compose([transforms.ToTensor()])

        train_set = torchvision.datasets.MNIST(root='/content/gdrive/My Drive/Datasets/MNIST',
        test_set = torchvision.datasets.MNIST(root='/content/gdrive/My Drive/Datasets/MNIST',
```

```
In [0]: # MNIST

        train_loader = torch.utils.data.DataLoader(train_set, batch_size=100, shuffle=True)
        test_loader = torch.utils.data.DataLoader(test_set, batch_size=100, shuffle=False)
```

```
In [0]: class ConvolutionalNeuralNetwork(nn.Module):
```

```
def __init__(self):

    super().__init__()

    m = 10

    # ~~ SmallVGGNET ~~ #

    # Block #1

    self.conv1 = nn.Conv2d(1, 16, 3, padding=3)
    self.conv2 = nn.Conv2d(16, 16, 3, padding=1)


    # Block #2

    self.conv3 = nn.Conv2d(16, 32, 3, padding=1)
    self.conv4 = nn.Conv2d(32, 32, 3, padding=1)


    # Block #3

    self.conv5 = nn.Conv2d(32, 64, 3, padding=1)
    self.conv6 = nn.Conv2d(64, 64, 3, padding=1)


    # Block #4

    self.fc1 = nn.Linear(64*4*4, 500)
    self.fc2 = nn.Linear(500, 500)
    self.fc3 = nn.Linear(500, m)

    # Xavier Initialization

    nn.init.xavier_uniform_(self.conv1.weight)
    nn.init.xavier_uniform_(self.conv2.weight)
    nn.init.xavier_uniform_(self.conv3.weight)
    nn.init.xavier_uniform_(self.conv4.weight)
    nn.init.xavier_uniform_(self.conv5.weight)
    nn.init.xavier_uniform_(self.conv6.weight)

    nn.init.xavier_uniform_(self.fc1.weight)
    nn.init.xavier_uniform_(self.fc2.weight)
    nn.init.xavier_uniform_(self.fc3.weight)

def forward(self, x):
```

```
                out = F.relu( self.conv1(x) )
                out = F.relu( self.conv2(out) )
                out = F.max_pool2d(out, 2)

                out = F.relu( self.conv3(out) )
                out = F.relu( self.conv4(out) )
                out = F.max_pool2d(out, 2)

                out = F.relu( self.conv5(out) )
                out = F.relu( self.conv6(out) )
                out = F.max_pool2d(out, 2)

                out = out.view(out.size(0), -1)

                out = F.relu( self.fc1(out) )
                out = F.relu( self.fc2(out) )
                out = self.fc3(out)

                return out
```

```
In [0]: class Model:

            def __init__(self, architecture):

                self.net = architecture

            def train(self, train_loader, test_loader, nb_epochs=10):

                self.net.train()

                criterion = nn.CrossEntropyLoss()
                optimizer = optim.SGD(self.net.parameters(), lr=0.03)

                train_accuracy = []
                train_er = []

                test_accuracy = []
                test_er = []

                # Record train values
                train_accuracy_epoch, train_er_epoch = self.test(train_loader)

                print(train_er_epoch)
                print(train_accuracy_epoch)

                train_accuracy.append(train_accuracy_epoch)
                train_er.append(train_er_epoch)
```

```
# Record test values
test_accuracy_epoch, test_er_epoch = self.test(test_loader)

test_accuracy.append(test_accuracy_epoch)
test_er.append(test_er_epoch)

print(test_er_epoch)
print(test_accuracy_epoch)

# Start training

for epoch in range(nb_epochs):

    print('\nEpoch', epoch+1)

    for i, (X_batch, y_batch) in enumerate(train_loader):

        # Send the batch to the GPU
        X_batch, y_batch = X_batch.to(device), y_batch.to(device)

        # Reset the gradients to zero
        optimizer.zero_grad()

        # Forward propagation
        y_hat_batch = self.net(X_batch)

        # Compute loss
        loss = criterion(y_hat_batch, y_batch)

        # Backward propagation
        loss.backward()

        # Update weights
        optimizer.step()

    # Record train values
    train_accuracy_epoch, train_er_epoch = self.test(train_loader)

    print(train_er_epoch)
    print(train_accuracy_epoch)

    train_accuracy.append(train_accuracy_epoch)
    train_er.append(train_er_epoch)

    # Record test values
    test_accuracy_epoch, test_er_epoch = self.test(test_loader)

    test_accuracy.append(test_accuracy_epoch)
```

```
            test_er.append(test_er_epoch)

            print(test_er_epoch)
            print(test_accuracy_epoch)

        return train_accuracy, train_er, test_accuracy, test_er

    def test(self, data_loader):

        self.net.eval()

        criterion = nn.CrossEntropyLoss()

        with torch.no_grad():

            accuracy = 0
            correct_predictions = 0
            empirical_risk = 0

            for X_batch, y_batch in data_loader:

                # Send the batch to the GPU
                X_batch, y_batch = X_batch.to(device), y_batch.to(device)

                # Forward propagation
                y_hat_batch = self.net(X_batch)

                # Compute loss
                loss = criterion(y_hat_batch, y_batch)

                # Pick up most predicted class
                _, predictions = torch.max(y_hat_batch.data, 1)

                # Compare predictions and real label
                correct_predictions += (predictions == y_batch).sum().item()

                # Sum losses
                empirical_risk += loss


        accuracy = (correct_predictions / len(data_loader.dataset)) * 100
        empirical_risk /= len(data_loader)

        return accuracy, empirical_risk
```

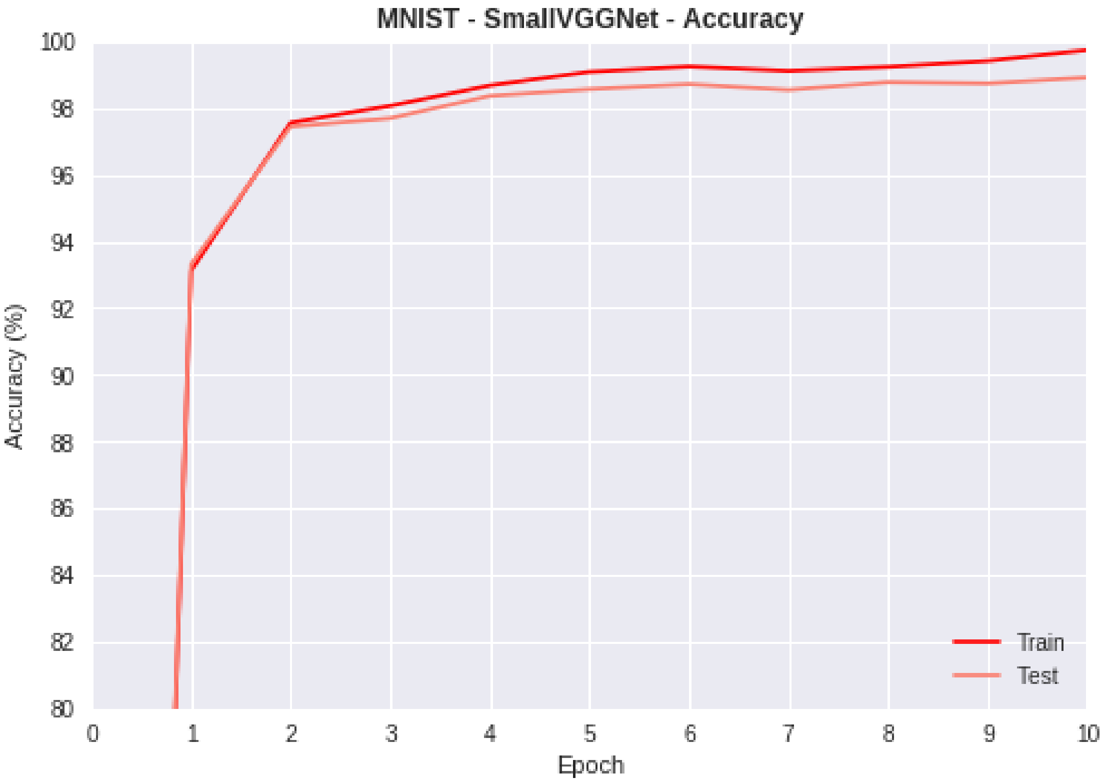
```
In [22]: torch.manual_seed(0)
         torch.cuda.manual_seed(0)
```

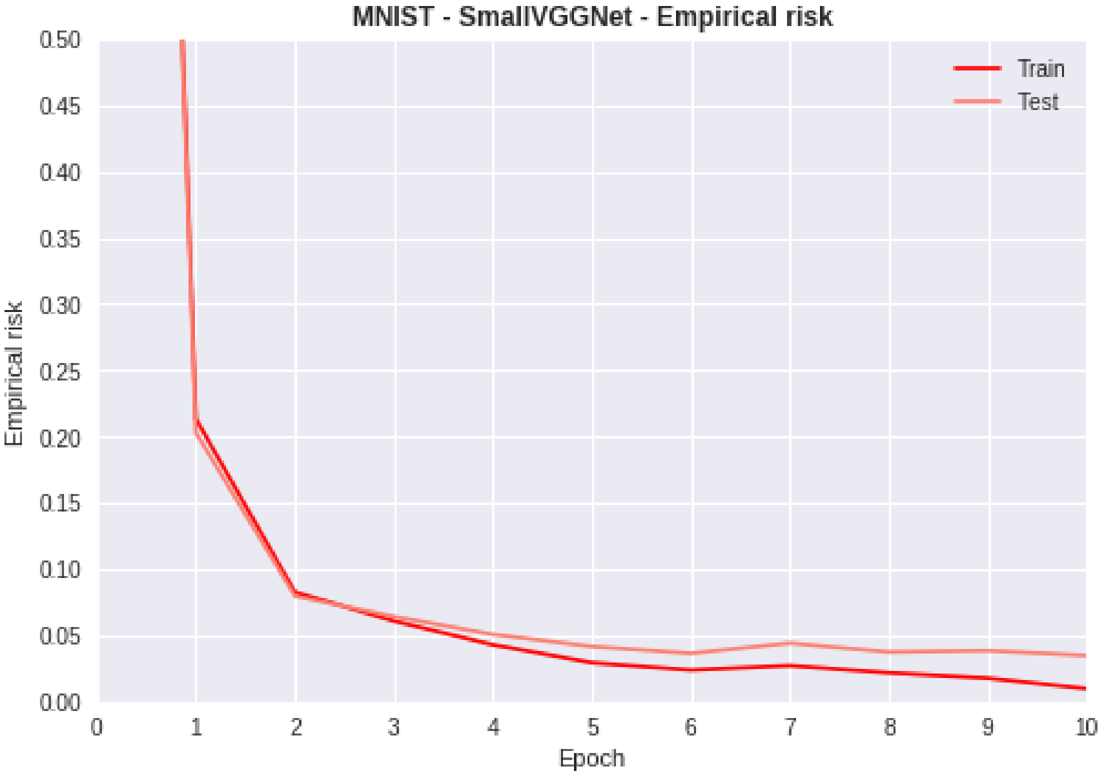
```
cnn = ConvolutionalNeuralNetwork().to(device)

model = Model(cnn)

train_accuracy, train_er, test_accuracy, test_er = model.train(train_loader, test_loa
```

```
tensor(2.3039, device='cuda:0')
9.93
tensor(2.3031, device='cuda:0')
10.32

Epoch 1
tensor(0.2133, device='cuda:0')
93.11833333333334
tensor(0.2029, device='cuda:0')
93.31

Epoch 2
tensor(0.0827, device='cuda:0')
97.55833333333334
tensor(0.0797, device='cuda:0')
97.44

Epoch 3
tensor(0.0609, device='cuda:0')
98.06166666666667
tensor(0.0644, device='cuda:0')
97.69

Epoch 4
tensor(0.0430, device='cuda:0')
98.67166666666667
tensor(0.0508, device='cuda:0')
98.36

Epoch 5
tensor(0.0295, device='cuda:0')
99.08
tensor(0.0417, device='cuda:0')
98.56

Epoch 6
tensor(0.0240, device='cuda:0')
99.24333333333333
tensor(0.0365, device='cuda:0')
98.71

Epoch 7
```

```
tensor(0.0273, device='cuda:0')
99.11166666666666
tensor(0.0443, device='cuda:0')
98.54

Epoch 8
tensor(0.0218, device='cuda:0')
99.23166666666667
tensor(0.0375, device='cuda:0')
98.77

Epoch 9
tensor(0.0178, device='cuda:0')
99.40833333333333
tensor(0.0385, device='cuda:0')
98.72999999999999

Epoch 10
tensor(0.0099, device='cuda:0')
99.72999999999999
tensor(0.0348, device='cuda:0')
98.91
```

```
In [32]: plt.xticks(np.arange(0,11))
         plt.yticks(np.arange(80,101,2))
         plt.ylim(80,100)
         plt.xlim(0,10)

         plt.plot(train_accuracy, label='Train', color='red')
         plt.plot(test_accuracy, label='Test', color='salmon')

         plt.title('MNIST - SmallVGGNet - Accuracy', fontweight='bold')
         plt.xlabel('Epoch')
         plt.ylabel('Accuracy (%)')
         plt.legend(loc=4)
         plt.show()

         plt.clf()

         plt.xticks(np.arange(0,11))
         plt.yticks(np.arange(0,0.51,0.05))
         plt.ylim(0,0.5)
         plt.xlim(0,10)

         plt.plot(train_er, label='Train', color='red')
         plt.plot(test_er, label='Test', color='salmon')
         plt.title('MNIST - SmallVGGNet - Empirical risk', fontweight='bold')
         plt.xlabel('Epoch')
         plt.ylabel('Empirical risk')
         plt.legend(loc=1)
         plt.show()
```




MNIST - SmallVGGNet - Empirical risk
Empirical risk
Epoch
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
1
2
3
4
5
6
7
8
9
10
Train
Test

```
In [0]:
```