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(http://cocl.us/pytorch_link_top)

In [1]:

```
#by Christopher Harrison
```

Objective

- How to classify handwritten digits using Neural Network.

Table of Contents

In this lab, you will use a single layer neural network to classify handwritten digits from the MNIST database.

Estimated Time Needed: **25 min**

Preparation

We'll need the following libraries

In [2]:

```
# Import the libraries we need for this lab

# Using the following line code to install the torchvision library
# !conda install -y torchvision

import torch
import torch.nn as nn
import torchvision.transforms as transforms
import torchvision.datasets as dsets
import torch.nn.functional as F
import matplotlib.pylab as plt
import numpy as np
```

Use the following helper functions for plotting the loss:

In [3]:

```
# Define a function to plot accuracy and loss

def plot_accuracy_loss(training_results):
    plt.subplot(2, 1, 1)
    plt.plot(training_results['training_loss'], 'r')
    plt.ylabel('loss')
    plt.title('training loss iterations')
    plt.subplot(2, 1, 2)
    plt.plot(training_results['validation_accuracy'])
    plt.ylabel('accuracy')
    plt.xlabel('epochs')
    plt.show()
```

Use the following function for printing the model parameters:

In [4]:

```
# Define a function to plot model parameters

def print_model_parameters(model):
    count = 0
    for ele in model.state_dict():
        count += 1
        if count % 2 != 0:
            print ("The following are the parameters for the layer ", count // 2 +
1)
        if ele.find("bias") != -1:
            print("The size of bias: ", model.state_dict()[ele].size())
        else:
            print("The size of weights: ", model.state_dict()[ele].size())
```

Define the neural network module or class:

In [5]:

```
# Define a function to display data

def show_data(data_sample):
    plt.imshow(data_sample.numpy().reshape(28, 28), cmap='gray')
    plt.show()
```

Neural Network Module and Training Function

Define the neural network module or class:

In [6]:

```
# Define a Neural Network class

class Net(nn.Module):

    # Constructor
    def __init__(self, D_in, H, D_out):
        super(Net, self).__init__()
        self.linear1 = nn.Linear(D_in, H)
        self.linear2 = nn.Linear(H, D_out)

    # Prediction
    def forward(self, x):
        x = torch.sigmoid(self.linear1(x))
        x = self.linear2(x)
        return x
```

Define a function to train the model. In this case, the function returns a Python dictionary to store the training loss and accuracy on the validation data.

In [7]:

```
# Define a training function to train the model

def train(model, criterion, train_loader, validation_loader, optimizer, epochs=100
):
    i = 0
    useful_stuff = {'training_loss': [],'validation_accuracy': []}
    for epoch in range(epochs):
        for i, (x, y) in enumerate(train_loader):
            optimizer.zero_grad()
            z = model(x.view(-1, 28 * 28))
            loss = criterion(z, y)
            loss.backward()
            optimizer.step()
             #loss for every iteration
            useful_stuff['training_loss'].append(loss.data.item())
        correct = 0
        for x, y in validation_loader:
            #validation
            z = model(x.view(-1, 28 * 28))
            _, label = torch.max(z, 1)
            correct += (label == y).sum().item()
        accuracy = 100 * (correct / len(validation_dataset))
        useful_stuff['validation_accuracy'].append(accuracy)
    return useful_stuff
```

Make Some Data

Load the training dataset by setting the parameters `train` to `True` and convert it to a tensor by placing a transform object in the argument `transform`.

In [8]:

```
# Create training dataset

train_dataset = dsets.MNIST(root='./data', train=True, download=True, transform=tra
nsforms.ToTensor())
```

Load the testing dataset by setting the parameters `train` to `False` and convert it to a tensor by placing a transform object in the argument `transform`:

In [9]:

```
# Create validating dataset

validation_dataset = dsets.MNIST(root='./data', train=False, download=True, transfo
rm=transforms.ToTensor())
```

Create the criterion function:

In [10]:

```
# Create criterion function

criterion = nn.CrossEntropyLoss()
```

Create the training-data loader and the validation-data loader objects:

In [11]:

```
# Create data loader for both train dataset and valdiate dataset

train_loader = torch.utils.data.DataLoader(dataset=train_dataset, batch_size=2000,
shuffle=True)
validation_loader = torch.utils.data.DataLoader(dataset=validation_dataset, batch_s
ize=5000, shuffle=False)
```

Define the Neural Network, Optimizer, and Train the Model

Create the model with 100 neurons:

In [12]:

```
# Create the model with 100 neurons

input_dim = 28 * 28
hidden_dim = 100
output_dim = 10

model = Net(input_dim, hidden_dim, output_dim)
```

Print the model parameters:

In [13]:

```
# Print the parameters for model

print_model_parameters(model)
```

```
The following are the parameters for the layer  1
The size of weights:  torch.Size([100, 784])
The size of bias:  torch.Size([100])
The following are the parameters for the layer  2
The size of weights:  torch.Size([10, 100])
The size of bias:  torch.Size([10])
```

Define the optimizer object with a learning rate of 0.01:

In [14]:

```
# Set the learning rate and the optimizer

learning_rate = 0.01
optimizer = torch.optim.SGD(model.parameters(), lr=learning_rate)
```

Train the model by using 100 epochs **(this process takes time)**:

In [15]:

```
# Train the model

training_results = train(model, criterion, train_loader, validation_loader, optimiz
er, epochs=30)
```

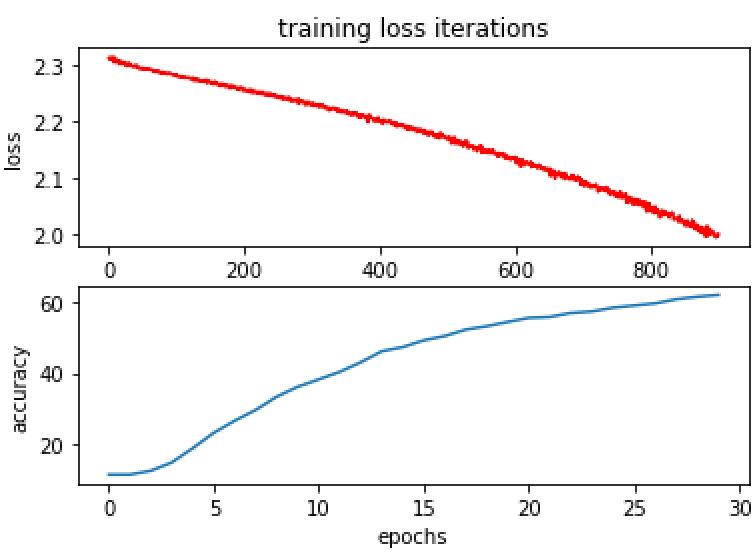
Analyze Results

Plot the training total loss or cost for every iteration and plot the training accuracy for every epoch:

In [16]:

```
# Plot the accuracy and loss

plot_accuracy_loss(training_results)
```

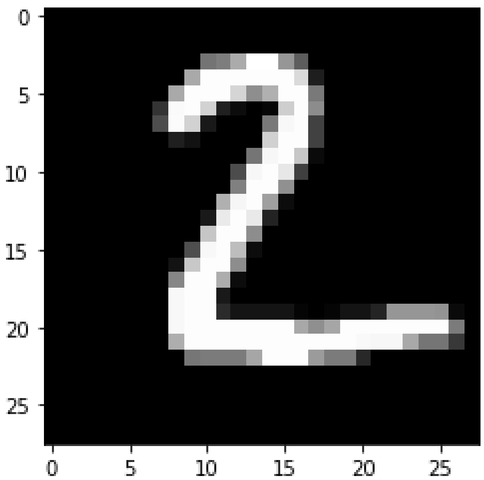


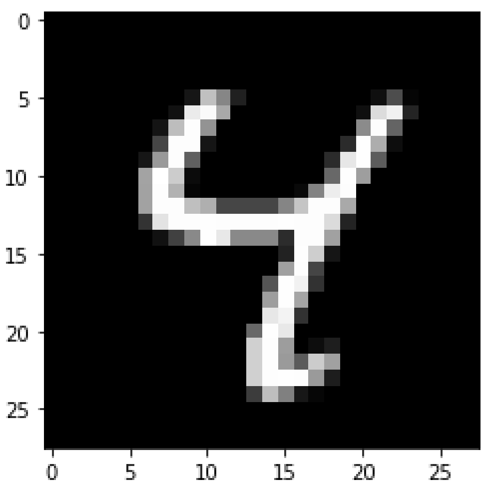
Plot the first five misclassified samples:

In [17]:

```
# Plot the first five misclassified samples

count = 0
for x, y in validation_dataset:
    z = model(x.reshape(-1, 28 * 28))
    _,yhat = torch.max(z, 1)
    if yhat != y:
        show_data(x)
        count += 1
    if count >= 5:
        break
```


0
5
10
15
20
25
0 5 10 15 20 25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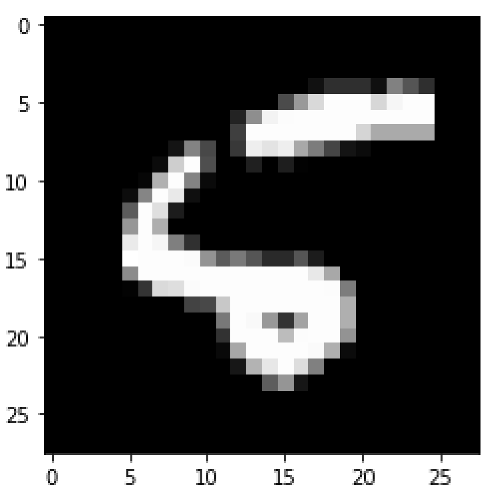
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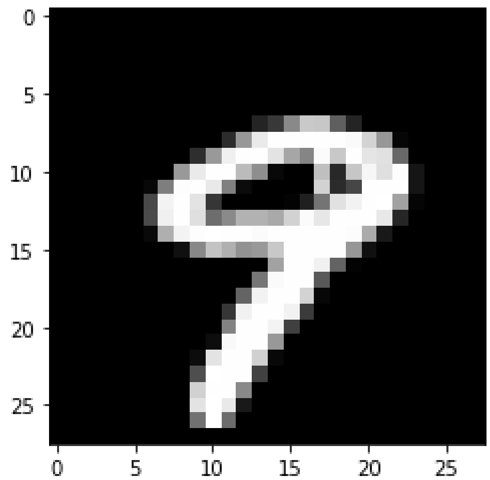
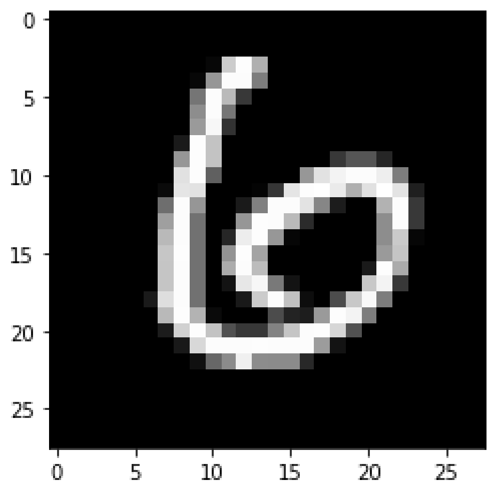




Practice

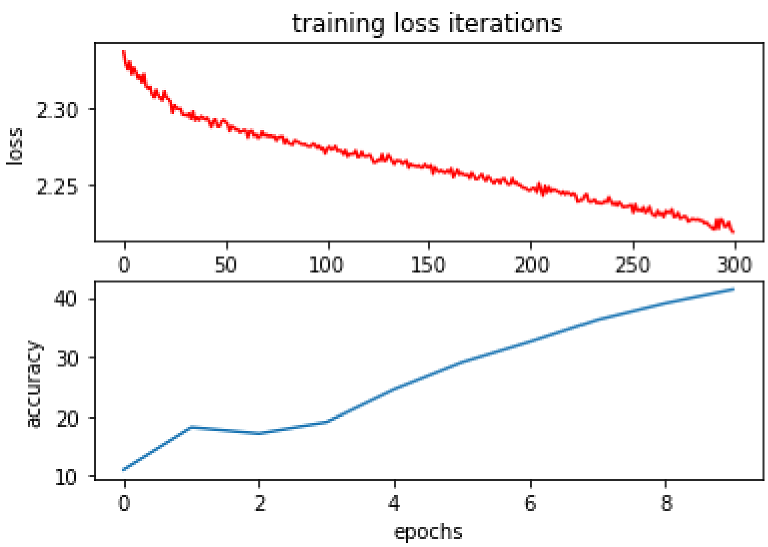
Use `nn.Sequential` to build exactly the same model as you just built. Use the function train to train the model and use the function `plot_accuracy_loss` to see the metrics. Also, try different epoch numbers.

In [18]:

```
# Practice: Use nn.Sequential to build the same model. Use plot_accuracy_loss to pr
int out the accuarcy and loss

# Type your code here
input_dim = 28 * 28
hidden_dim = 100
output_dim = 10

model = torch.nn.Sequential(
    torch.nn.Linear(input_dim, hidden_dim),
    torch.nn.Sigmoid(),
    torch.nn.Linear(hidden_dim, output_dim),
)
learning_rate = 0.01
optimizer = torch.optim.SGD(model.parameters(), lr = learning_rate)
training_results = train(model, criterion, train_loader, validation_loader, optimiz
er, epochs = 10)
plot_accuracy_loss(training_results)
```



About the Authors:

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Change Log

Date (YYYY-MM-DD)	Version	Changed By	Change Description
2020-09-23	2.0	Shubham	Migrated Lab to Markdown and added to course repo in GitLab