Deeper Neural Networks with nn.ModuleList()

Objective for this Notebook

1. Create a Deeper Neural Network with `nn.ModuleList()`

2. Train and Validate the Model.

Table of Contents

In this lab, you will create a Deeper Neural Network with `nn.ModuleList()`

Estimated Time Needed: **25 min**

Preparation

We'll need the following libraries

[1]:
```
# Import the libraries we need for this lab

import matplotlib.pyplot as plt
import numpy as np
import torch
import torch.nn as nn
import torch.nn.functional as F
from matplotlib.colors import ListedColormap
from torch.utils.data import Dataset, DataLoader

torch.manual_seed(1)
```

[1]:
```
<torch._C.Generator at 0x11c408610>
```

Function used to plot:

[2]:
```
# Define the function to plot the diagram

def plot_decision_regions_3class(model, data_set):
    cmap_light = ListedColormap(['#FFAAAA', '#AAFFAA', '#00AAFF'])
    cmap_bold = ListedColormap(['#FF0000', '#00FF00', '#00AAFF'])
    X = data_set.x.numpy()
    y = data_set.y.numpy()
    h = .02
    x_min, x_max = X[:, 0].min() - 0.1, X[:, 0].max() + 0.1
    y_min, y_max = X[:, 1].min() - 0.1, X[:, 1].max() + 0.1
    xx, yy = np.meshgrid(np.arange(x_min, x_max, h), np.arange(y_min, y_max, h))
    XX = torch.Tensor(np.c_[xx.ravel(), yy.ravel()])
    _, yhat = torch.max(model(XX), 1)
    yhat = yhat.numpy().reshape(xx.shape)
    plt.pcolormesh(xx, yy, yhat, cmap=cmap_light)
    plt.plot(X[y[:] == 0, 0], X[y[:] == 0, 1], 'ro', label = 'y=0')
    plt.plot(X[y[:] == 1, 0], X[y[:] == 1, 1], 'go', label = 'y=1')
    plt.plot(X[y[:] == 2, 0], X[y[:] == 2, 1], 'o', label = 'y=2')
    plt.title("decision region")
    plt.legend()
```

Create Dataset `Class`

[3]:
```
# Create Data Class

class Data(Dataset):

------
    #  modified from: http://cs231n.github.io/neural-networks-case-study/
    # Constructor
    def __init__(self, K=3, N=500):
        D = 2
        X = np.zeros((N * K, D)) # data matrix (each row = single example)
        y = np.zeros(N * K, dtype='uint8') # class labels
        for j in range(K):
          ix = range(N * j, N * (j + 1))
          r = np.linspace(0.0, 1, N) # radius
          t = np.linspace(j * 4, (j + 1) * 4, N) + np.random.randn(N) * 0.2 # theta
          X[ix] = np.c_[r * np.sin(t), r*np.cos(t)]
          y[ix] = j
        self.y = torch.from_numpy(y).type(torch.LongTensor)
        self.x = torch.from_numpy(X).type(torch.FloatTensor)
        self.len = y.shape[0]

------
    # Getter
```

```
    def __getitem__(self, index):
        return self.x[index], self.y[index]

    # Get Length
    def __len__(self):
        return self.len

    # Plot the diagram
    def plot_stuff(self):
        plt.plot(self.x[self.y[:] == 0, 0].numpy(), self.x[self.y[:] == 0, 1].numpy(), 'o', label="y = 0")
        plt.plot(self.x[self.y[:] == 1, 0].numpy(), self.x[self.y[:] == 1, 1].numpy(), 'ro', label="y = 1")
        plt.plot(self.x[self.y[:] == 2, 0].numpy(), self.x[self.y[:] == 2, 1].numpy(), 'go', label="y = 2")
        plt.legend()
```

Neural Network Module and Function for Training

Neural Network Module using `ModuleList()`

[4]:
```
# Create Net model class

class Net(nn.Module):

    # Constructor
    def __init__(self, Layers):
        super(Net, self).__init__()
        self.hidden = nn.ModuleList()
        for input_size, output_size in zip(Layers, Layers[1:]):
            self.hidden.append(nn.Linear(input_size, output_size))

    # Prediction
    def forward(self, activation):
        L = len(self.hidden)
        for (l, linear_transform) in zip(range(L), self.hidden):
            if l < L - 1:
                activation = F.relu(linear_transform(activation))
            else:
                activation = linear_transform(activation)
        return activation
```

A function used to train.

[5]:
```
# Define the function for training the model

def train(data_set, model, criterion, train_loader, optimizer, epochs=100):
    LOSS = []
    ACC = []
    for epoch in range(epochs):
        for x, y in train_loader:
            optimizer.zero_grad()
            yhat = model(x)
            loss = criterion(yhat, y)
            optimizer.zero_grad()
            loss.backward()
            optimizer.step()
            LOSS.append(loss.item())
        ACC.append(accuracy(model, data_set))

    fig, ax1 = plt.subplots()
    color = 'tab:red'
    ax1.plot(LOSS, color = color)
    ax1.set_xlabel('Iteration', color = color)
    ax1.set_ylabel('total loss', color = color)
    ax1.tick_params(axis = 'y', color = color)

    ax2 = ax1.twinx()
    color = 'tab:blue'
    ax2.set_ylabel('accuracy', color = color)  # we already handled the x-label with ax1
    ax2.plot(ACC, color = color)
    ax2.tick_params(axis = 'y', color = color)
    fig.tight_layout()  # otherwise the right y-label is slightly clipped

    plt.show()
    return LOSS
```

A function used to calculate accuracy

[6]:
```
# The function to calculate the accuracy

def accuracy(model, data_set):
    _, yhat = torch.max(model(data_set.x), 1)
    return (yhat == data_set.y).numpy().mean()
```

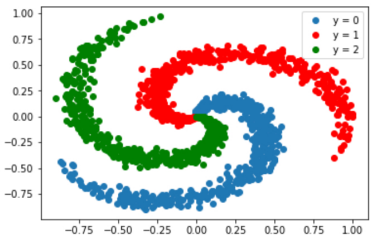
Train and Validate the Model

Did you know? IBM Watson Studio lets you build and deploy an AI solution, using the best of open source and IBM software and giving your team a single environment to work in. Learn more here.

Crate a dataset object:

[7]:
```
# Create a Dataset object

data_set = Data()
data_set.plot_stuff()
data_set.y = data_set.y.view(-1)
```

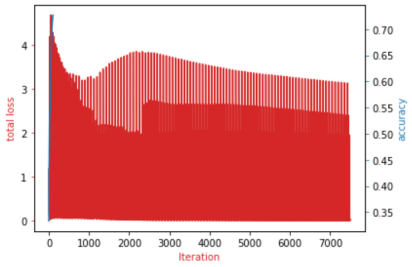


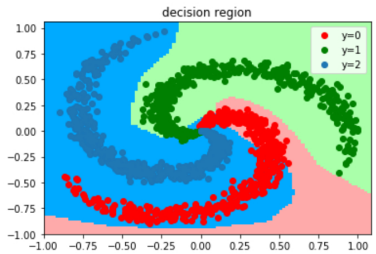
Create a network to classify three classes with 1 hidden layer with 50 neurons

[8]:
```
# Train the model with 1 hidden layer with 50 neurons

Layers = [2, 50, 3]
model = Net(Layers)
learning_rate = 0.10
optimizer = torch.optim.SGD(model.parameters(), lr=learning_rate)
train_loader = DataLoader(dataset=data_set, batch_size=20)
criterion = nn.CrossEntropyLoss()
LOSS = train(data_set, model, criterion, train_loader, optimizer, epochs=100)

plot_decision_regions_3class(model, data_set)
```





Create a network to classify three classes with 2 hidden layers with 20 neurons in total

[15]:
```
Net([3,3,4,3]).parameters
```

[15]:
```
<bound method Module.parameters of Net(
  (hidden): ModuleList(
    (0): Linear(in_features=3, out_features=3, bias=True)
    (1): Linear(in_features=3, out_features=4, bias=True)
    (2): Linear(in_features=4, out_features=3, bias=True)
  )
)>
```

[ ]:
```
# Train the model with 2 hidden layers with 20 neurons

Layers = [2, 10, 10, 3]
model = Net(Layers)
learning_rate = 0.01
optimizer = torch.optim.SGD(model.parameters(), lr=learning_rate)
train_loader = DataLoader(dataset=data_set, batch_size=20)
criterion = nn.CrossEntropyLoss()
LOSS = train(data_set, model, criterion, train_loader, optimizer, epochs=1000)

plot_decision_regions_3class(model, data_set)
```

Practice

Create a network with three hidden layers each with ten neurons, then train the network using the same process as above

[ ]:
```
# Practice: Create a network with three hidden layers each with ten neurons.

# Type your code here
```

Double-click here for the solution.

About the Authors:

Joseph Santarcangelo has a PhD in Electrical Engineering, his research focused on using machine learning, signal processing, and computer vision to determine how videos impact human cognition. Joseph has been working for IBM since he completed his PhD.

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Change Log

Date (YYYY-MM-DD)	Version	Changed By	Change Description
2020-09-21	2.0	Srishti	Migrated Lab to Markdown and added to course repo in GitLab