Watson Studio democratizes machine learning and deep learning to accelerate infusion of AI in your business to drive innovation. Watson Studio provides a suite of tools and a collaborative environment for data scientists, developers and domain experts.

(http://cocl.us/pytorch_link_top)

Neural Networks with Momentum

Table of Contents

In this lab, you will see how different values for the momentum parameters affect the convergence rate of a neural network.

Estimated Time Needed: **25 min**

Preparation

We'll need the following libraries:

In [1]:

```
# Import the libraries 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)
np.random.seed(1)
```

Functions used to plot:

In [2]:

```
# Define a function for plot the decision region

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.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 the dataset class

In [3]:

```
# Create the dataset 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_data(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

Create Neural Network Module using `ModuleList()`

In [4]:

```
# Create dataset object

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
```

Create the function for training the model.

In [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))

    results ={"Loss":LOSS, "Accuracy":ACC}
    fig, ax1 = plt.subplots()
    color = 'tab:red'
    ax1.plot(LOSS,color=color)
    ax1.set_xlabel('epoch', 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 results
```

Define a function used to calculate accuracy.

In [6]:

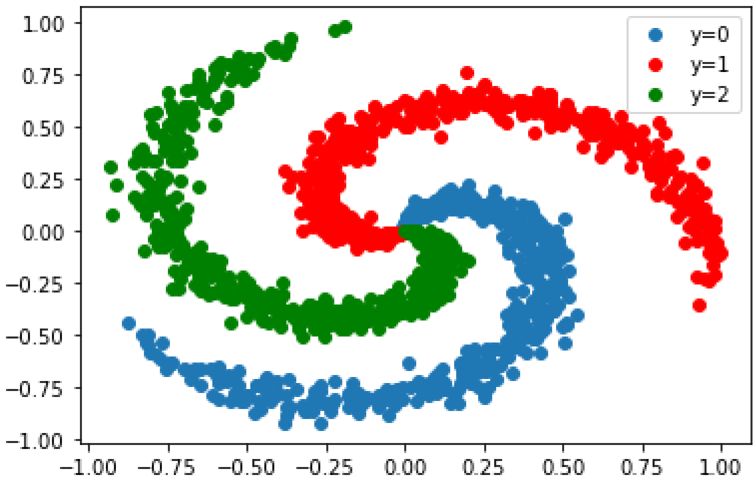
```
# Define a function for calculating accuracy

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

Train Different Networks Model different values for the Momentum Parameter

Crate a dataset object using `Data`

In [7]:

```
# Create the dataset and plot it

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



Dictionary to contain different cost and accuracy values for each epoch for different values of the momentum parameter.

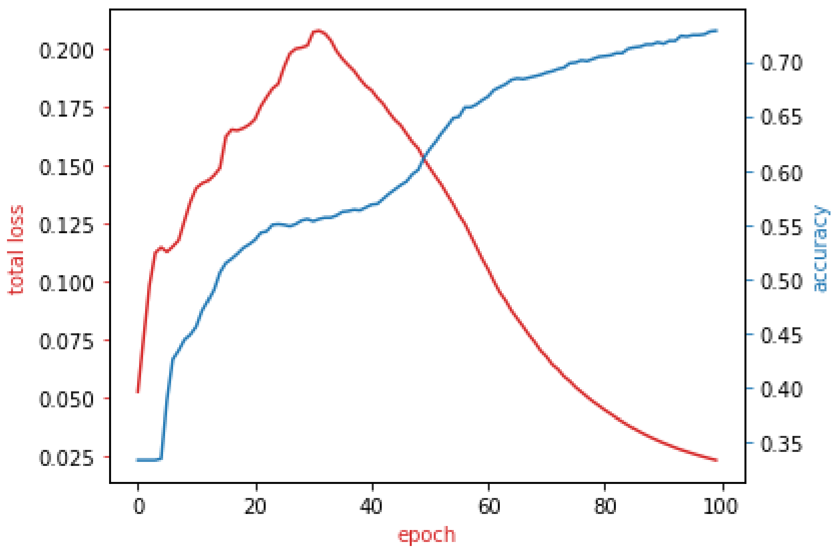
In [8]:

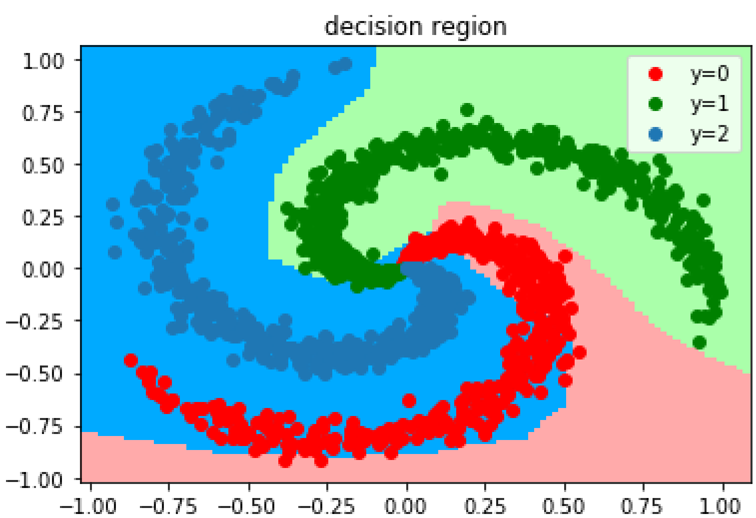
```
# Initialize a dictionary to contain the cost and accuracy

Results = {"momentum 0": {"Loss": 0, "Accuracy:": 0}, "momentum 0.1": {"Loss": 0,
"Accuracy:": 0}}
```

Create a network to classify three classes with 1 hidden layer with 50 neurons and a momentum value of zero.

In [9]:

```
# Train a model with 1 hidden layer and 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()
Results["momentum 0"] = train(data_set, model, criterion, train_loader, optimizer,
epochs=100)
plot_decision_regions_3class(model, data_set)
```

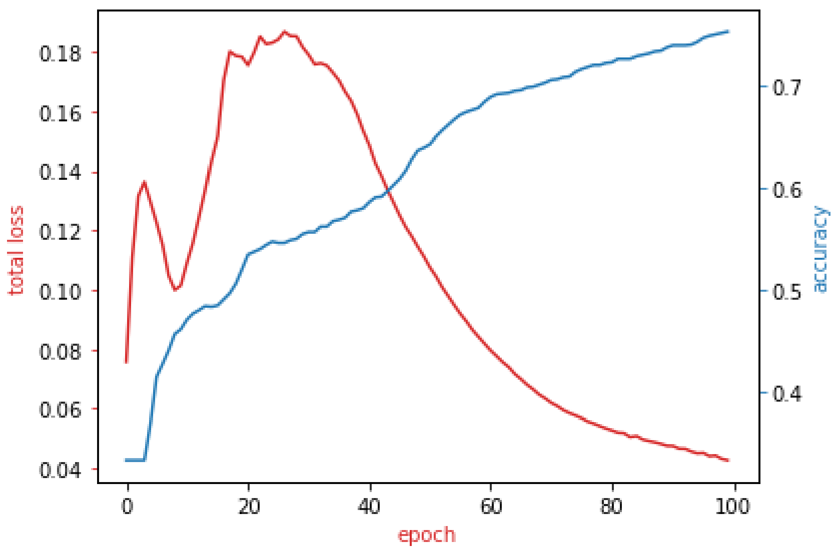


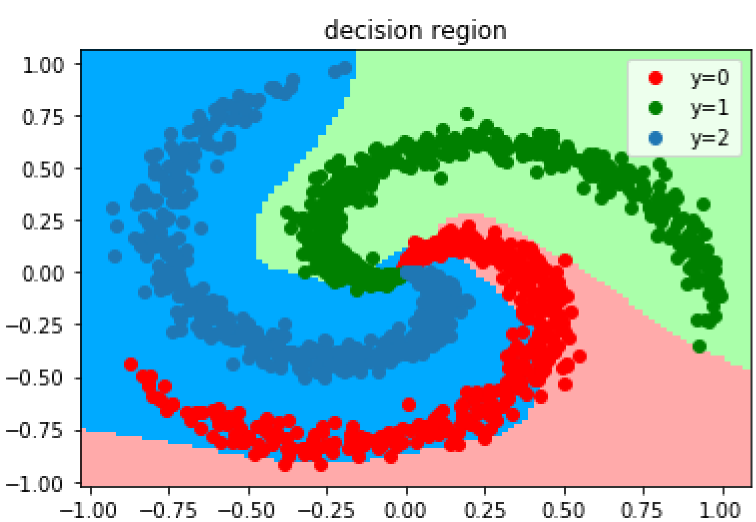


Create a network to classify three classes with 1 hidden layer with 50 neurons and a momentum value of 0.1.

In [10]:

```
# Train a model with 1 hidden layer and 50 neurons with 0.1 momentum

Layers = [2, 50, 3]
model = Net(Layers)
learning_rate = 0.10
optimizer = torch.optim.SGD(model.parameters(), lr=learning_rate, momentum=0.1)
train_loader = DataLoader(dataset=data_set, batch_size=20)
criterion = nn.CrossEntropyLoss()
Results["momentum 0.1"] = train(data_set, model, criterion, train_loader, optimizer
, epochs=100)
plot_decision_regions_3class(model, data_set)
```

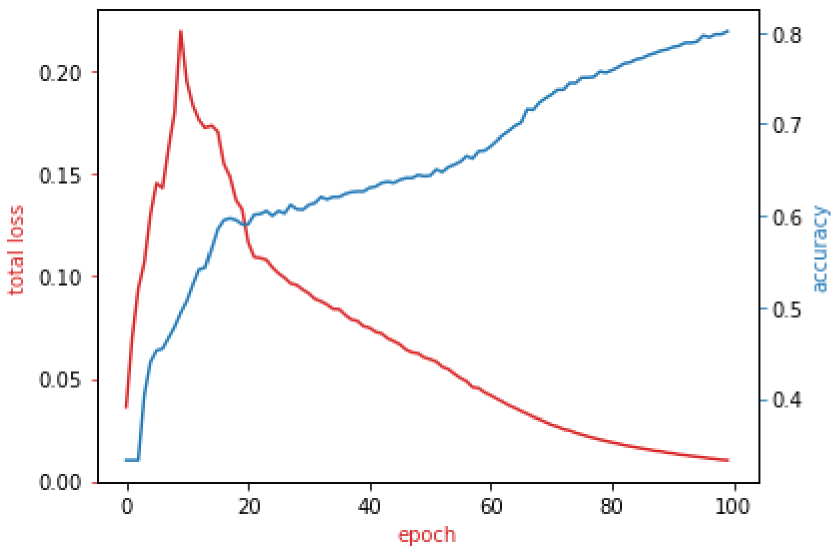


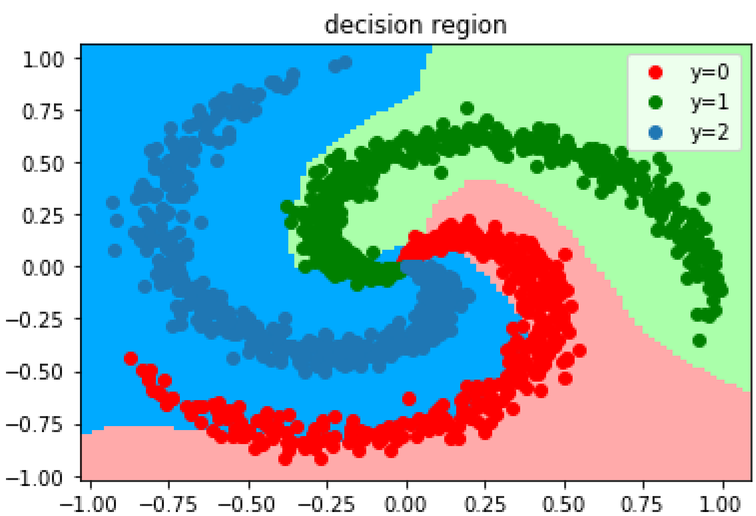


Create a network to classify three classes with 1 hidden layer with 50 neurons and a momentum value of 0.2.

In [11]:

```
# Train a model with 1 hidden layer and 50 neurons with 0.2 momentum

Layers = [2, 50, 3]
model = Net(Layers)
learning_rate = 0.10
optimizer = torch.optim.SGD(model.parameters(), lr=learning_rate, momentum=0.2)
train_loader = DataLoader(dataset=data_set, batch_size=20)
criterion = nn.CrossEntropyLoss()
Results["momentum 0.2"] = 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 1 hidden layer with 50 neurons and a momentum value of 0.4.

In [ ]:

```
# Train a model with 1 hidden layer and 50 neurons with 0.4 momentum

Layers = [2, 50, 3]
model = Net(Layers)
learning_rate = 0.10
optimizer = torch.optim.SGD(model.parameters(), lr=learning_rate, momentum=0.4)
train_loader = DataLoader(dataset=data_set, batch_size=20)
criterion = nn.CrossEntropyLoss()
Results["momentum 0.4"] = 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 1 hidden layer with 50 neurons and a momentum value of 0.5.

In [ ]:

```
# Train a model with 1 hidden layer and 50 neurons with 0.5 momentum

Layers = [2, 50, 3]
model = Net(Layers)
learning_rate = 0.10
optimizer = torch.optim.SGD(model.parameters(), lr=learning_rate, momentum=0.5)
train_loader = DataLoader(dataset=data_set, batch_size=20)
criterion = nn.CrossEntropyLoss()
Results["momentum 0.5"] = train(data_set, model, criterion, train_loader, optimizer
, epochs=100)
plot_decision_regions_3class(model,data_set)
```

Compare Results of Different Momentum Terms

The plot below compares results of different momentum terms. We see that in general. The Cost decreases proportionally to the momentum term, but larger momentum terms lead to larger oscillations. While the momentum term decreases faster, it seems that a momentum term of 0.2 reaches the smallest value for the cost.

In [ ]:

```
# Plot the Loss result for each term

for key, value in Results.items():
    plt.plot(value['Loss'],label=key)
    plt.legend()
    plt.xlabel('epoch')
    plt.ylabel('Total Loss or Cost')
```

The accuracy seems to be proportional to the momentum term.

In [ ]:

```python
# Plot the Accuracy result for each term

for key, value in Results.items():
    plt.plot(value['Accuracy'],label=key)
    plt.legend()
    plt.xlabel('epoch')
    plt.ylabel('Accuracy')
```


About the Authors:

Joseph Santarcangelo (https://www.linkedin.com/in/joseph-s-50398b136/) 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.

Other contributors: Michelle Carey (https://www.linkedin.com/in/michelleccarey/), Mavis Zhou (www.linkedin.com/in/jiahui-mavis-zhou-a4537814a)
