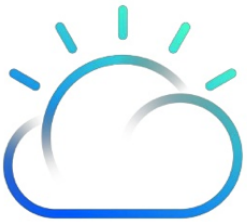

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(http://cocl.us/pytorch_link_top)

Practice: Neural Networks with One Hidden Layer: Noisy XOR

Table of Contents

In this lab, you will see how many neurons it takes to classify noisy XOR data with one hidden layer neural network.

Estimated Time Needed: **25 min**

Preparation

We'll need the following libraries

In [1]:

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



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

Use the following function to plot the data:

In [2]:

```
# Plot the data

def plot_decision_regions_2class(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 = np.logical_not((model(XX)[:, 0] > 0.5).numpy()).reshape(xx.shape)
    plt.pcolormesh(xx, yy, yhat, cmap=cmap_light)
    plt.plot(X[y[:, 0] == 0, 0], X[y[:, 0] == 0, 1], 'o', label='y=0')
    plt.plot(X[y[:, 0] == 1, 0], X[y[:, 0] == 1, 1], 'ro', label='y=1')
    plt.title("decision region")
    plt.legend()
```

Use the following function to calculate accuracy:

In [3]:

```
# Calculate the accuracy

def accuracy(model, data_set):
    return np.mean(data_set.y.view(-1).numpy() == (model(data_set.x)[:, 0] > 0.5).n
umpy())
```

Neural Network Module and Training Function

Define the neural network module or class:

In [4]:

```
# Define the class Net with one hidden layer

class Net(nn.Module):

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

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

Define a function to train the model:

In [5]:

```
# Define the train model

def train(data_set, model, criterion, train_loader, optimizer, epochs=5):
    COST = []
    ACC = []
    for epoch in range(epochs):
        total=0
        for x, y in train_loader:
            optimizer.zero_grad()
            yhat = model(x)
            loss = criterion(yhat, y)
            optimizer.zero_grad()
            loss.backward()
            optimizer.step()
            #cumulative loss
            total+=loss.item()
        ACC.append(accuracy(model, data_set))
        COST.append(total)

    fig, ax1 = plt.subplots()
    color = 'tab:red'
    ax1.plot(COST, 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 COST
```

Make Some Data

Dataset class:

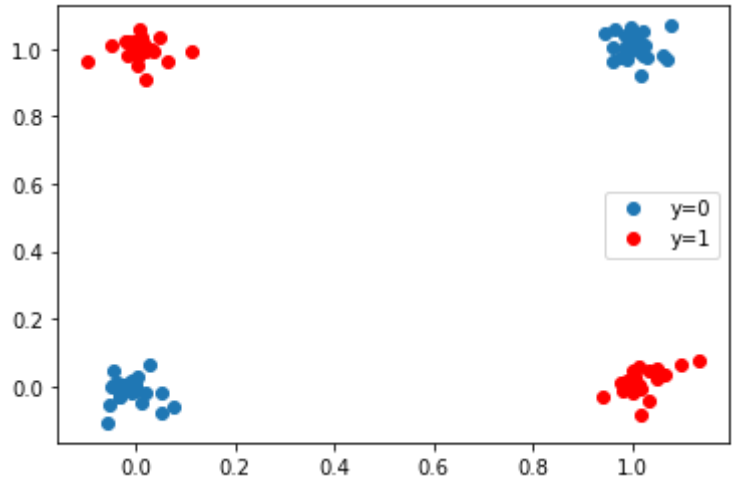
In [6]:

```
# Define the class XOR_Data

class XOR_Data(Dataset):

    # Constructor
    def __init__(self, N_s=100):
        self.x = torch.zeros((N_s, 2))
        self.y = torch.zeros((N_s, 1))
        for i in range(N_s // 4):
            self.x[i, :] = torch.Tensor([0.0, 0.0])
            self.y[i, 0] = torch.Tensor([0.0])

            self.x[i + N_s // 4, :] = torch.Tensor([0.0, 1.0])
            self.y[i + N_s // 4, 0] = torch.Tensor([1.0])

            self.x[i + N_s // 2, :] = torch.Tensor([1.0, 0.0])
            self.y[i + N_s // 2, 0] = torch.Tensor([1.0])

            self.x[i + 3 * N_s // 4, :] = torch.Tensor([1.0, 1.0])
            self.y[i + 3 * N_s // 4, 0] = torch.Tensor([0.0])

            self.x = self.x + 0.01 * torch.randn((N_s, 2))
        self.len = N_s

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

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

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

Dataset object:

In [7]:

```
# Create dataset object

data_set = XOR_Data()
data_set.plot_stuff()
```



One Neuron

Try

Create a neural network `model` with one neuron. Then, use the following code to train it:

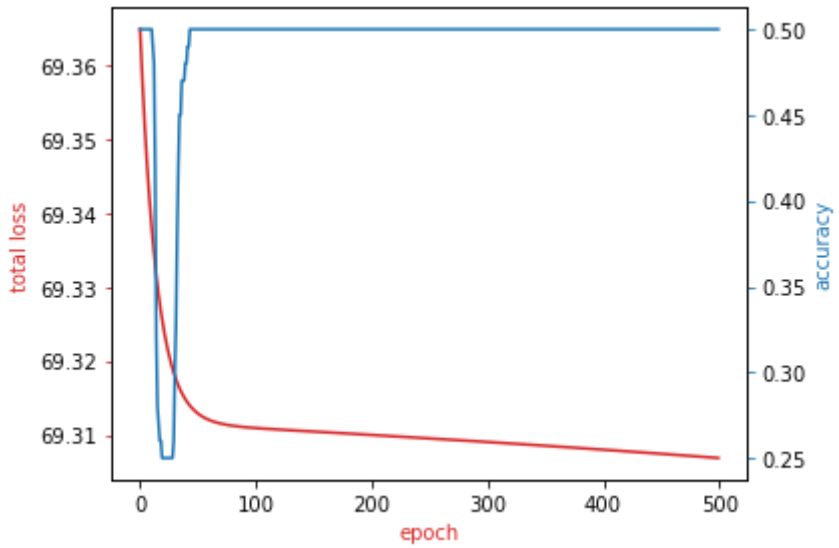
In [8]:

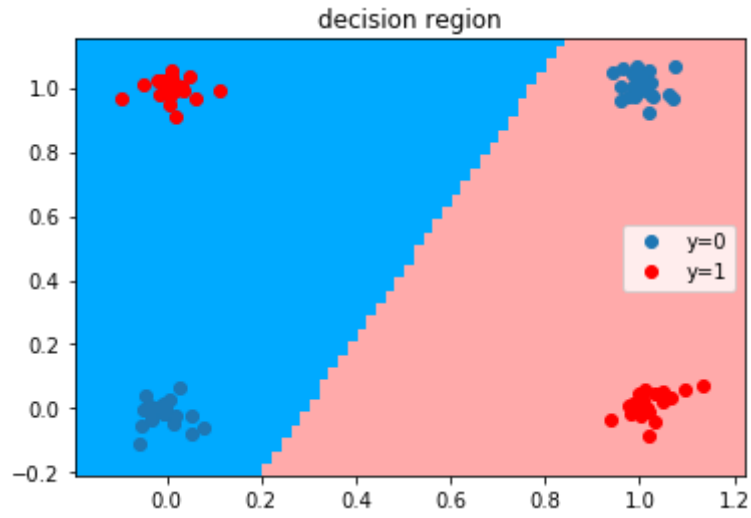
```
# Practice: create a model with one neuron
model = Net(2, 1, 1)
```

Double-click **here** for the solution.

In [9]:

```
# Train the model

learning_rate = 0.001
criterion = nn.BCELoss()
optimizer = torch.optim.SGD(model.parameters(), lr=learning_rate)
train_loader = DataLoader(dataset=data_set, batch_size=1)
LOSS12 = train(data_set, model, criterion, train_loader, optimizer, epochs=500)
plot_decision_regions_2class(model, data_set)
```





Two Neurons

Try

Create a neural network `model` with two neurons. Then, use the following code to train it:

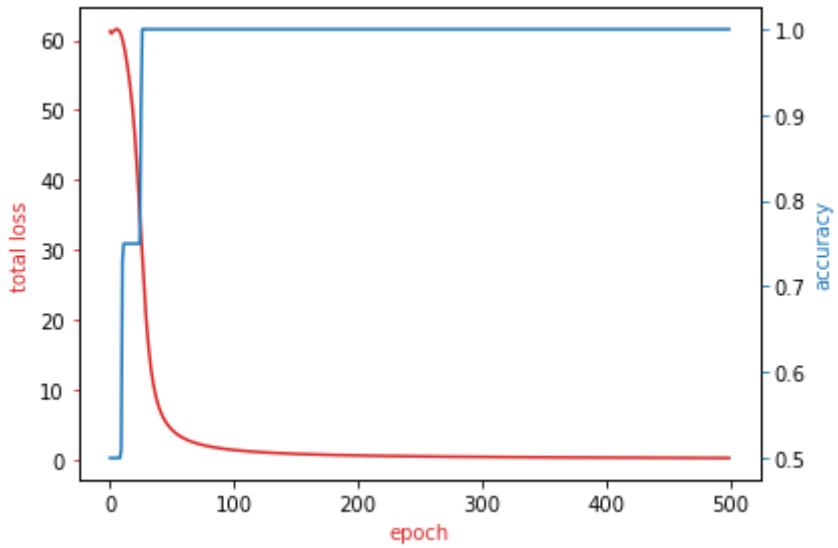
In [10]:

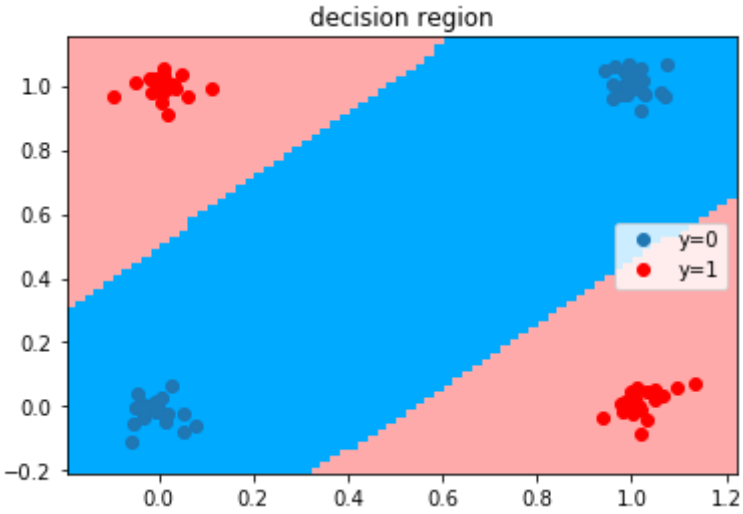
```
# Practice: create a model with two neuron
model = Net(2, 2, 1)
```

Double-click **here** for the solution.

In [11]:

```
# Train the model

learning_rate = 0.1
criterion = nn.BCELoss()
optimizer = torch.optim.SGD(model.parameters(), lr=learning_rate)
train_loader = DataLoader(dataset=data_set, batch_size=1)
LOSS12 = train(data_set, model, criterion, train_loader, optimizer, epochs=500)
plot_decision_regions_2class(model, data_set)
```





Three Neurons

Try

Create a neural network `model` with three neurons. Then, use the following code to train it:

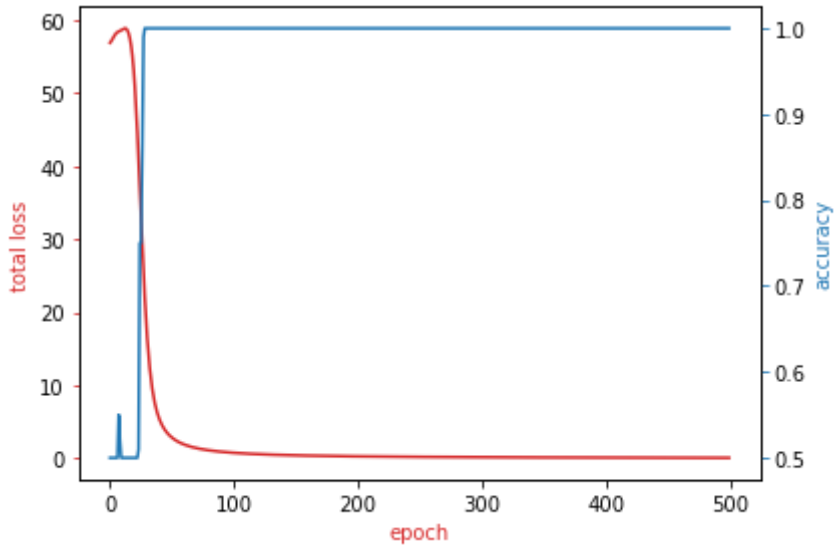
In [12]:

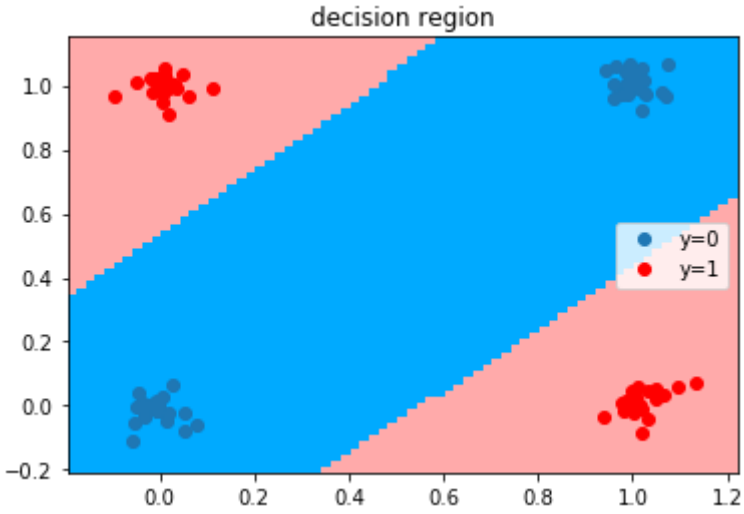
```
# Practice: create a model with two neuron
model = Net(2, 4, 1)
```

Double-click **here** for the solution.

In [13]:

```
# Train the model

learning_rate = 0.1
criterion = nn.BCELoss()
optimizer = torch.optim.SGD(model.parameters(), lr=learning_rate)
train_loader = DataLoader(dataset=data_set, batch_size=1)
LOSS12 = train(data_set, model, criterion, train_loader, optimizer, epochs=500)
plot_decision_regions_2class(model, data_set)
```


total loss
accuracy
epoch
60
50
40
30
20
10
0
1.0
0.9
0.8
0.7
0.6
0.5
0
100
200
300
400
500


decision region
y=0
y=1
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2

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.

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