Importing all of the essential modules

```
from random import seed
from random import random
from math import exp
import numpy as np
import matplotlib.pyplot as plt
```

Initialize a network

```
def initialize_network(n_inputs, n_hidden, n_outputs):
  network = list()
  hidden_layer = [{'weights':[random() for i in range(n_inputs + 1)]} for i in range(n_hid
  network.append(hidden_layer)
  output_layer = [{'weights':[random() for i in range(n_hidden + 1)]} for i in range(n_out
  network.append(output_layer)
  return network
```

Calculate neuron activation for an input

```
def activate(weights, inputs):
  activation = weights[-1]
  for i in range(len(weights)-1):
    activation += weights[i] * inputs[i]
  return activation
```

Transfer neuron activation

To undo cell deletion use Ctrl+M Z or the Undo option in the Edit menu

```
  return 1.0 / (1.0 + exp(-activation))
```

Forward propagate input to a network output

```
def forward_propagate(network, row):
  inputs = row
  for layer in network:
    new_inputs = []
    for neuron in layer:
      activation = activate(neuron['weights'], inputs)
      neuron['output'] = transfer(activation)
      new_inputs.append(neuron['output'])
    inputs = new_inputs
  return inputs
```

Calculate the derivative of an neuron output

```
def transfer_derivative(output):
  return output * (1.0 - output)
```

Backpropagate error and store in neurons

```
def backward_propagate_error(network, expected):
  for i in reversed(range(len(network))):
    layer = network[i]
    errors = list()
    if i != len(network)-1:
      for j in range(len(layer)):
        error = 0.0
        for neuron in network[i + 1]:
          error += (neuron['weights'][j] * neuron['delta'])
        errors.append(error)
    else:
      for j in range(len(layer)):
        neuron = layer[j]
        errors.append(expected[j] - neuron['output'])
    for j in range(len(layer)):
      neuron = layer[j]
      neuron['delta'] = errors[j] * transfer_derivative(neuron['output'])
```

Update network weights with error

```
def update_weights(network, row, l_rate):
  for i in range(len(network)):
    inputs = row[:-1]
    if i != 0:
```

To undo cell deletion use Ctrl+M Z or the Undo option in the Edit menu

```
      for j in range(len(inputs)):
        neuron['weights'][j] += l_rate * neuron['delta'] * inputs[j]
      neuron['weights'][-1] += l_rate * neuron['delta']
```

Train a network for a fixed number of epochs

```
def train_network(network, train, l_rate, n_epoch, n_outputs):
  for epoch in range(n_epoch):
    sum_error = 0
    if(epoch > 50000):
      l_rate = 1/epoch * 100
    for row in train:
      outputs = forward_propagate(network, row)
      expected = [0 for i in range(n_outputs)]
      expected[int(row[-1])] = 1
      sum_error += sum([(expected[i]-outputs[i])**2 for i in range(len(expected))])
      backward_propagate_error(network, expected)
      update_weights(network, row, l_rate)
```

```
    if(epoch % 100 == 0):
        print('>epoch=%d, lrate=%.3f, error=%.3f' % (epoch, l_rate, sum_error))
```

Make a prediction with a network

```
def predict(network, row):
  outputs = forward_propagate(network, row)
  return outputs.index(max(outputs))
```

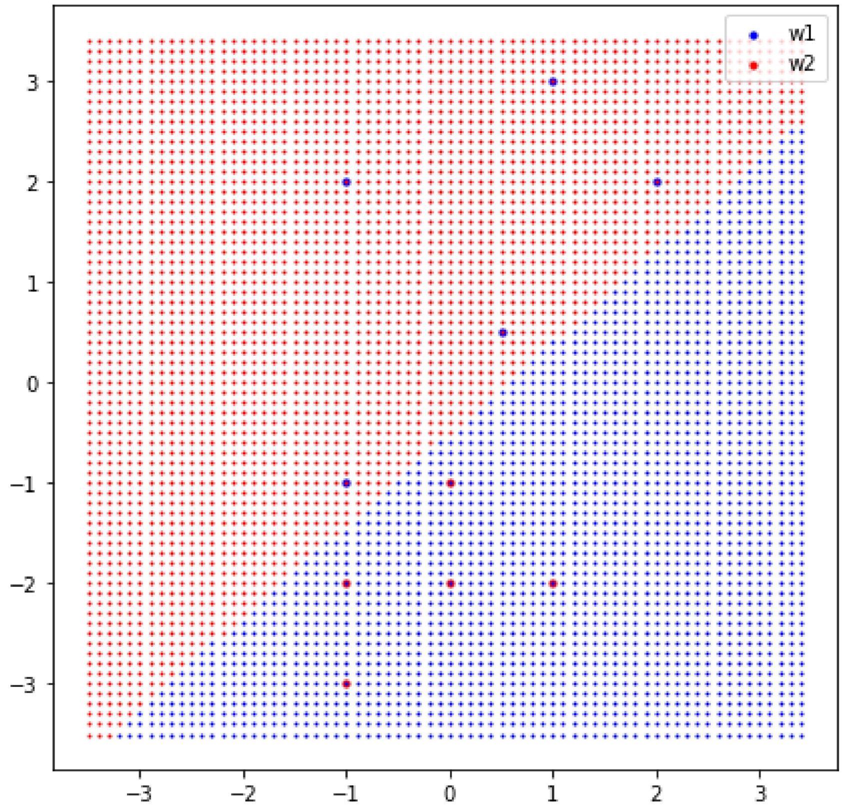
Test training backprop algorithm

```
seed(1)
w1 = np.array([[2, 2, 0], [-1, 2, 0], [1, 3, 0], [-1, -1, 0], [0.5, 0.5, 0]])
w2 = np.array([[-1, -3, 1], [0, -1, 1], [1, -2, 1], [-1, -2, 1], [0, -2, 1]])
dataset = np.concatenate([w1, w2], axis = 0)
w1 = np.array([[2, 2], [-1, 2], [1, 3], [-1, -1], [0.5, 0.5]])
w2 = np.array([[-1, -3], [0, -1], [1, -2], [-1, -2], [0, -2]])
f, ax = plt.subplots(figsize=(7, 7))
c1, c2, c3 = 'b', 'r', 'm'

ax.scatter(*w1.T, c=c1,s = 10, label = "w1")
ax.legend()
ax.scatter(*w2.T, c=c2, s = 10, label = "w2")
ax.legend()

n_inputs = len(dataset[0]) - 1
n_outputs = len(set([row[-1] for row in dataset]))
network = initialize_network(n_inputs, 2, n_outputs)
train_network(network, dataset, 0.5, 1000, n_outputs)
print(network)
```

To undo cell deletion use Ctrl+M Z or the Undo option in the Edit menu

```
  for j in range(len(y)):
    pt = [x[i], y[j]]
    if(predict(network, pt) == 0):
      c = 'r'
    else:
      c = 'b'
    ax.scatter(x[i], y[j], c = c, s = 1)
```

```
>epoch=0, lrate=0.500, error=5.415
>epoch=100, lrate=0.500, error=0.206
>epoch=200, lrate=0.500, error=0.069
>epoch=300, lrate=0.500, error=0.039
>epoch=400, lrate=0.500, error=0.027
>epoch=500, lrate=0.500, error=0.020
>epoch=600, lrate=0.500, error=0.016
>epoch=700, lrate=0.500, error=0.013
>epoch=800, lrate=0.500, error=0.011
>epoch=900, lrate=0.500, error=0.010
[[{'weights': [-4.165736617684192, 4.494165872980581, 2.064357120666933], 'output': 0
```



To undo cell deletion use Ctrl+M Z or the Undo option in the Edit menu