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ECE 8720

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Takehome #1

Balancing Data sets:

->Before Balancing the datasets we need to clean the data given.

That is,

1.Add target value for each input in AEP and Non-AEP data sets.

Target value for AEP is 0, Non-AEP is 1.

2.Convert it to .csv format for easier access.

->Fetching the data from jupyter notebook:

I used read_csv() defined in the pandas library for fetching the data into the notebook

->Divide the data into training and test datasets

Before we balance data we first divide them into training and testing data sets.

Here I used 80% of the data as training data and 20% of the data as testing data.

Used function test_train_split to split the data sets

->Balancing Datasets

Majority of the dataitems in the given data belong to Non-AEP class, because of which overfiitting may happen.

Balancing the data can be done using: Over-sampling and undersampling methods.

After dividing the data as training and testing there are approximately 60 dataitems in AEP data set in training data set. So, if we choose under-sampling for balancing the training set, we might end up with only 120 dataitems for training, which is insufficient. Hence over-sampling is choosen to balance the training dataitems.

Also choose over-sampling for balancing the test dataset.

Training set dataitems-4962

Testing set dataitems-168

Over-sampling is done using resample() from sklearn.utils

Case 1:

Network contains no bias, no momentum.

Input nuerons=27

Hidden nuerons=55 (2d+1)

Output neurons=2

Step1:

All the weights are randomized using random() function

After returning the network containing all these weights,

Step 2:

We enter the first epoch and forward propogate the network.

After computing the activation function we compute outputs. Then Backpropogation error is calculated and weights are updated using learning rate.

Learning rate=0.1

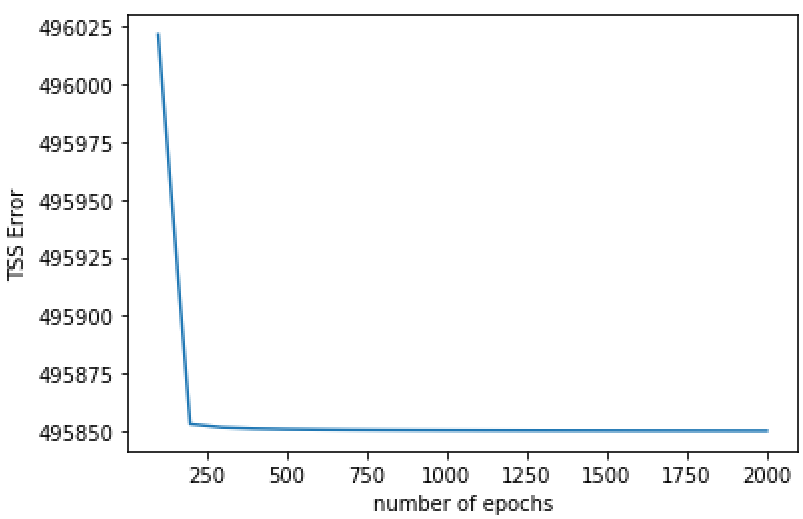
Epochs=2000

Output: TP=85, FN=83, FP=0, TN=0

Sensitivity=0.5059

E(TSS)=495850.145

Graph between TSS Error vs number of epochs



Case 2:

Network contains bias, no momentum.

Input nuerons=27

Hidden nuerons=55 (2d+1)

Output neurons=2

Learning rate=0.1

Epochs=1600

Bias Weights used in code:

- Here there are n+1 weights, one of them is the bias.
- Bias generated is added when calculating net weights to the activation function.
- It is a special weight which does not contain any input to multiply with.
- After calculating the back propogation error bias weight updation is important.

Advantage seen:

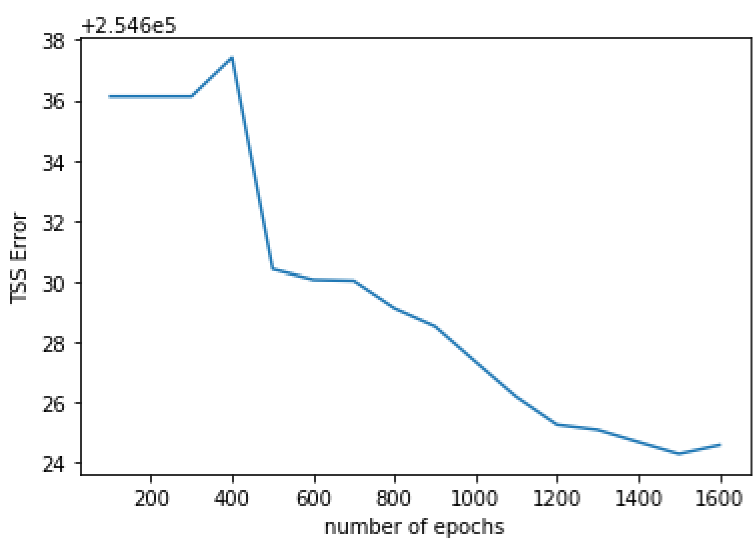
- E(TSS) error has dropped drastically
- Contolled learning rate
- Can perform like the case 1 network with learning rate of 0.04
- Reaches the possible minima
- Adjusts the output better

Output: TP=85, FN=83, FP=0, TN=0

Sensitivity=0.5059

E(TSS)= 254624.298

Graph between TSS Error vs number of epochs



Case 3:

Network contains no bias, but contains momentum.

Input nuerons=27

Hidden nuerons=55 (2d+1)

Output neurons=2

Learning rate=0.1

Momentum=0.5

Epochs=2000

momentum used in code:

- This case takes the initial weights of case 1.
- Momentum is included when we update the weights in the network

Advantage seen:

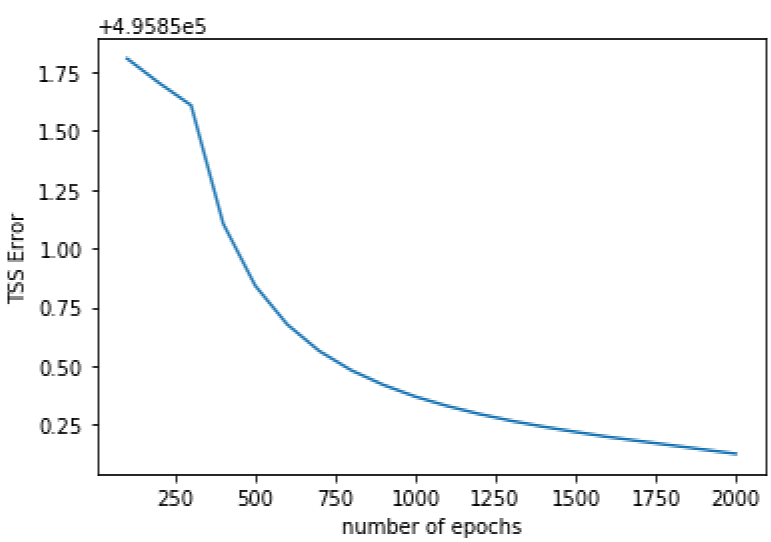
- Weights are adjusted smoothely
- Doesn't have sharp accelerations
- Helps reaching local minima

Output: TP=0, FN=0, FP=84, TN=84

Specificity=0.5000

E(TSS)= 495850.126

Graph between TSS Error vs number of epochs



Case 4:

Network contains bias and momentum.

Input nuerons=27

Hidden nuerons=55 (2d+1)

Output neurons=2

Learning rate=0.1

Momentum=0.5

Epochs=1600

Momentum, bias used in code:

- This case takes the initial weights of case 2.
- Momentum is included when we update the weights in the network
- Bias used near weights as an additional weight

Advantage seen:

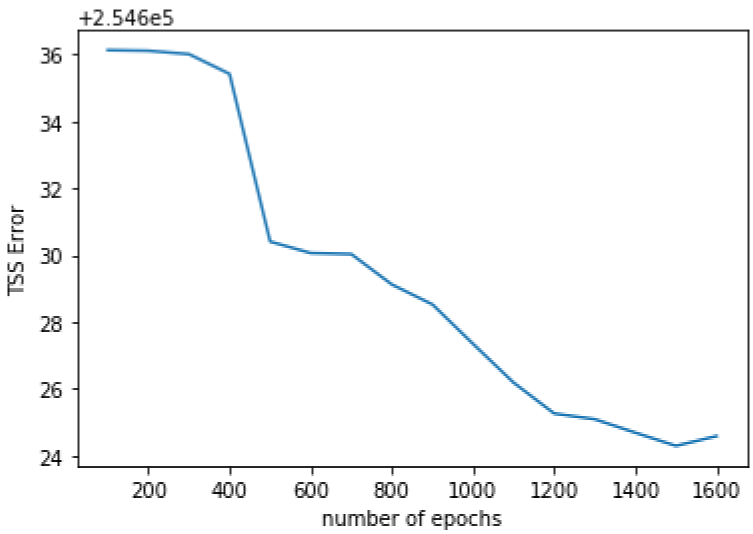
- Weights are adjusted smoothely and faster
- Faster and smoother graphs
- Helps reaching local minima
- Shows a guassian curve in the graph

Output: TP=0, FN=0, FP=84, TN=84

Specificity=0.5000

E(TSS)= 495850.126

Graph between TSS Error vs number of epochs



Problems Faced:

- Time for training is too long
- Takes lots of epochs to train the data
- Learning rates are bigger than thought would be
- Total sum of squares Error is really big
- Since I used jupyter notebook, the server always shuts down when I try to run all the four cases at the same time.

Overall Assessment:

If taken more epochs, I thinks I would have seen more better specificity and sensitivity measures.

Appendix

Programs:

Importing CSV file:

```
import numpy as np

import pandas as pd

 df_train = pd.read_csv('C:/Users/Rajitha Bhavani/Documents/EEGdata.csv')

target_count = df_train.target.value_counts()

print('Class 0:', target_count[0])

print('Class 1:', target_count[1])

print('Proportion:', round(target_count[0] / target_count[1], 2), ': 1')

 target_count.plot(kind='bar', title='Count (target)');
```

Dividing into training and testing:

```
from sklearn.model_selection import train_test_split

labels = df_train.columns[1:]


X = df_train[labels]

y = df_train['target']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.33, random_state=1)
```

Resampling:

```
from sklearn.utils import resample

pos_upsampled = resample(positive,

replace=True, # sample with replacement

n_samples=len(negative), # match number in majority class

random_state=27) # reproducible results

# combine majority and upsampled minority

upsampled = pd.concat([negative, pos_upsampled])
```

check new class counts

upsampled.target.value_counts()

upsampled.to_csv('C:/Users/Rajitha Bhavani/Documents/upsampled12.csv',index=False)

Case 3:

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

# Initialize a network
def initialize_network(n_inputs, n_hidden, n_outputs):
    network = list()
    hidden_layer = [{'weights':[random() for i in range(n_inputs)]} for i in range(n_hidden)]
    network.append(hidden_layer)
    output_layer = [{'weights':[random() for i in range(n_hidden)]} for i in range(n_outputs)]
    network.append(output_layer)
    print(network)
    return network

# Calculate neuron activation for an input
def activate(weights, inputs):
    activation = 0
    for i in range(len(weights)):
        activation += weights[i] * inputs[i]
    return activation
```

```
# Transfer neuron activation
def transfer(activation):
    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:]
        prevval=0
        if i != 0:
            inputs = [neuron['output'] for neuron in network[i - 1]]
        velocity=[None]*len(inputs)
        for neuron in network[i]:
            for j in range(len(inputs)):
                if j==1:
                    velocity[j]=l_rate * neuron['delta'] * inputs[j]
                else:
                    velocity[j]=l_rate * neuron['delta'] * inputs[j] + 0.5 * prevval
                prevval=velocity[j]
```

```
            neuron['weights'][j] += velocity[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):
    sum_errors=0
    errors=list()
    while sum_errors<1:
        for epoch in range(n_epoch):
            sum_error = 0
            for row in train:
                #print(row)
                outputs = forward_propagate(network, row)
                #print(outputs)
                expected = [0 for i in range(n_outputs)]
                expected[row[0]] = 1
                sum_error += sum([(expected[i]-outputs[i])**2 for i in range(len(expected))])/2
                backward_propagate_error(network, expected)
                update_weights(network, row, l_rate)
            if epoch!=0:
                sum_errors+=sum_error
            if epoch!=0 and epoch%100==0:
                errors.append(sum_errors*2)
                ep.append(epoch)
                print('>epoch=%d, lrate=%.3f, error=%.3f' % (epoch, l_rate, sum_errors*2))
                sum_errors=0
    return errors
```

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

# Backpropagation Algorithm With Stochastic Gradient Descent
def back_propagation(train, test, l_rate, n_epoch, n_hidden):
    scores=list()
    n_inputs = 27
    n_outputs = len(set([row[0] for row in train]))
    network = initialize_network(n_inputs, n_hidden, n_outputs)
    sum_errors=train_network(network, train, l_rate, n_epoch, n_outputs)
    predictions = list()
    #for row in test:
    #   prediction = predict(network, row)
    #    predictions.append(prediction)
    #    accuracy=accuracy_metric(row[0],predictions)
    #    scores.append(accuracy)
    #return(scores)
    return sum_errors

def accuracy_metric(actual, predicted):
    correct = 0
    for i in range(actual):
        print(actual)
        print(predict[i])
        if actual == predicted:
```

```
            correct += 1
    return correct / float(actual) * 100.0

# Test training backprop algorithm
#dataset=open('C:/Users/Rajitha Bhavani/Documents/upsampled.txt','r')
#dataset=[[0,5.239742700000001,-6.3819862999999994],[1,9.716892,-9.001553900000001]];
#test=[[0,7.937372200000001,-7.651209599999999],[1,2.7600646,-2.6970943]];
ep=list()
#sum_errors=back_propagation(dataset,test,0.1,1000,55)
scores=list()
n_inputs = 27
n_outputs = len(set([row[0] for row in dataset]))
#network = initialize_network(n_inputs, 55, n_outputs)
sum_errors=train_network(network, dataset, 0.1, 1000, n_outputs)
TN=0
TP=0
FN=0
FP=0
for row in test:
    prediction = predict(network, row)
    if row[0]==0:
        if prediction==row[0]:
            TN+=1
        else:
            FN+=1
    if row[0]==1:
        if prediction==row[0]:
```

```
            TP+=1
        else:
            FP+=1
print(TN,FN,TP,FP)
if TP!=0 or FN!=0:
    SN=TP/TP+FN
    print(SN)
if TN!=0 or FP!=0:
    SP=TN/TN+FP
    print(SP)
plt.plot(ep,sum_errors)
plt.show()
#print('Scores: %s' % scores)
#print('Mean Accuracy: %.3f%%' % (sum(scores)/float(len(scores))))
```

Case 1:

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

# Initialize a network
def initialize_network(n_inputs, n_hidden, n_outputs):
    network = list()
    hidden_layer = [{'weights':[random() for i in range(n_inputs)]} for i in range(n_hidden)]
    network.append(hidden_layer)
```

```
    output_layer = [{'weights':[random() for i in range(n_hidden)]} for i in range(n_outputs)]
    network.append(output_layer)
    print(network)
    return network

# Calculate neuron activation for an input
def activate(weights, inputs):
    activation = 0
    for i in range(len(weights)):
        activation += weights[i] * inputs[i]
    return activation

# Transfer neuron activation
def transfer(activation):
    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:
            inputs = [neuron['output'] for neuron in network[i - 1]]
        for neuron in network[i]:
            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):
    sum_errors=0
    errors=list()
    while sum_errors<1:
        for epoch in range(n_epoch):
            sum_error = 0
            for row in train:
                #print(row)
                outputs = forward_propagate(network, row)
                #print(outputs)
                expected = [0 for i in range(n_outputs)]
                expected[row[0]] = 1
                sum_error += sum([(expected[i]-outputs[i])**2 for i in range(len(expected))])/2
                backward_propagate_error(network, expected)
                update_weights(network, row, l_rate)
            if epoch!=0:
                sum_errors+=sum_error
            if epoch!=0 and epoch%100==0:
```

```
            errors.append(sum_errors*2)
            ep.append(epoch)
            print('>epoch=%d, lrate=%.3f, error=%.3f' % (epoch, l_rate, sum_errors*2))
            sum_errors=0
    return errors

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

# Backpropagation Algorithm With Stochastic Gradient Descent
def back_propagation(train, test, l_rate, n_epoch, n_hidden):
    scores=list()
    n_inputs = 27
    n_outputs = len(set([row[0] for row in train]))
    network = initialize_network(n_inputs, n_hidden, n_outputs)
    sum_errors=train_network(network, train, l_rate, n_epoch, n_outputs)
    predictions = list()
    #for row in test:
    #   prediction = predict(network, row)
    #    predictions.append(prediction)
    #    accuracy=accuracy_metric(row[0],predictions)
    #    scores.append(accuracy)
    #return(scores)
    return sum_errors

def accuracy_metric(actual, predicted):
```

```
    correct = 0
    for i in range(actual):
        print(actual)
        print(predict[i])
        if actual == predicted:
            correct += 1
    return correct / float(actual) * 100.0

# Test training backprop algorithm
#dataset=open('C:/Users/Rajitha Bhavani/Documents/upsampled.txt','r')
#dataset=[[0,5.239742700000001,-6.381986299999994],[1,9.716892,-9.001553900000001]];
#test=[[0,7.937372200000001,-7.651209599999999],[1,2.7600646,-2.6970943]];
ep=list()
#sum_errors=back_propagation(dataset,test,0.1,1000,55)
scores=list()
n_inputs = 27
n_outputs = len(set([row[0] for row in dataset]))
network = initialize_network(n_inputs, 55, n_outputs)
sum_errors=train_network(network, dataset, 0.1, 4000, n_outputs)
TN=0
TP=0
FN=0
FP=0
for row in test:
    prediction = predict(network, row)
    if row[0]==0:
        if prediction==row[0]:
```

```
            TN+=1
        else:
            FN+=1
    if row[0]==1:
        if prediction==row[0]:
            TP+=1
        else:
            FP+=1
print(TN,FN,TP,FP)
if TP!=0 or FN!=0:
    SN=TP/TP+FN
    print(SN)
if TN!=0 or FP!=0:
    SP=TN/TN+FP
    print(SP)
plt.plot(ep,sum_errors)
plt.show()
#print('Scores: %s' % scores)
#print('Mean Accuracy: %.3f%%' % (sum(scores)/float(len(scores))))
```

Case 4:

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

# 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_hidden)]
    network.append(hidden_layer)
    output_layer = [{'weights':[random() for i in range(n_hidden+1)]} for i in range(n_outputs)]
    network.append(output_layer)
    print(network)
    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
def transfer(activation):
    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:]
        prevval=0
        if i != 0:
            inputs = [neuron['output'] for neuron in network[i - 1]]
        velocity=[None]*len(inputs)
        for neuron in network[i]:
            for j in range(len(inputs)):
                if j==1:
                    velocity[j]=l_rate * neuron['delta'] * inputs[j]
                else:
                    velocity[j]=l_rate * neuron['delta'] * inputs[j] + 0.5 * prevval
                prevval=velocity[j]
                neuron['weights'][j] += velocity[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):
    sum_errors=0
    errors=list()
    while sum_errors<1:
        for epoch in range(n_epoch):
            sum_error = 0
            for row in train:
```

```
            #print(row)
            outputs = forward_propagate(network, row)
            #print(outputs)
            expected = [0 for i in range(n_outputs)]
            expected[row[0]] = 1
            sum_error += sum([(expected[i]-outputs[i])**2 for i in range(len(expected))])/2
            backward_propagate_error(network, expected)
            update_weights(network, row, l_rate)
        if epoch!=0:
            sum_errors+=sum_error
        if epoch!=0 and epoch%100==0:
            errors.append(sum_errors*2)
            ep.append(epoch)
            print('>epoch=%d, lrate=%.3f, error=%.3f' % (epoch, l_rate, sum_errors*2))
            sum_errors=0
    return errors

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

# Backpropagation Algorithm With Stochastic Gradient Descent
def back_propagation(train, test, l_rate, n_epoch, n_hidden):
    scores=list()
    n_inputs = 27
    n_outputs = len(set([row[0] for row in train]))
    network = initialize_network(n_inputs, n_hidden, n_outputs)
```

```
    sum_errors=train_network(network, train, l_rate, n_epoch, n_outputs)
    predictions = list()
    #for row in test:
    #   prediction = predict(network, row)
    #    predictions.append(prediction)
    #    accuracy=accuracy_metric(row[0],predictions)
    #    scores.append(accuracy)
    #return(scores)
    return sum_errors

def accuracy_metric(actual, predicted):
    correct = 0
    for i in range(actual):
        print(actual)
        print(predict[i])
        if actual == predicted:
            correct += 1
    return correct / float(actual) * 100.0

# Test training backprop algorithm
#dataset=open('C:/Users/Rajitha Bhavani/Documents/upsampled.txt','r')
#dataset=[[0,5.239742700000001,-6.3819862999999994],[1,9.716892,-9.001553900000001]];
#test=[[0,7.937372200000001,-7.651209599999999],[1,2.7600646,-2.6970943]];
ep=list()
#sum_errors=back_propagation(dataset,test,0.1,1000,55)
scores=list()
n_inputs = 27
```

```
n_outputs = len(set([row[0] for row in dataset]))
#network = initialize_network(n_inputs, 55, n_outputs)
sum_errors=train_network(network, dataset, 0.1, 1000, n_outputs)
TN=0
TP=0
FN=0
FP=0
for row in test:
    prediction = predict(network, row)
    if row[0]==0:
        if prediction==row[0]:
            TN+=1
        else:
            FN+=1
    if row[0]==1:
        if prediction==row[0]:
            TP+=1
        else:
            FP+=1
print(TN,FN,TP,FP)
if TP!=0 or FN!=0:
    SN=TP/TP+FN
    print(SN)
if TN!=0 or FP!=0:
    SP=TN/TN+FP
    print(SP)
plt.plot(ep,sum_errors)
```

```
plt.show()
#print('Scores: %s' % scores)
#print('Mean Accuracy: %.3f%%' % (sum(scores)/float(len(scores))))
```

Case 2:

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

# 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_hidden)]
    network.append(hidden_layer)
    output_layer = [{'weights':[random() for i in range(n_hidden+1)]} for i in range(n_outputs)]
    network.append(output_layer)
    print(network)
    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
def transfer(activation):
    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:
            inputs = [neuron['output'] for neuron in network[i - 1]]
        for neuron in network[i]:
            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):
    sum_errors=0
    errors=list()
```

```
    while sum_errors<1:
        for epoch in range(n_epoch):
            sum_error = 0
            for row in train:
                #print(row)
                outputs = forward_propagate(network, row)
                #print(outputs)
                expected = [0 for i in range(n_outputs)]
                expected[row[0]] = 1
                sum_error += sum([(expected[i]-outputs[i])**2 for i in range(len(expected))])/2
                backward_propagate_error(network, expected)
                update_weights(network, row, l_rate)
            if epoch!=0:
                sum_errors+=sum_error
            if epoch!=0 and epoch%100==0:
                errors.append(sum_errors*2)
                ep.append(epoch)
                print('>epoch=%d, lrate=%.3f, error=%.3f' % (epoch, l_rate, sum_errors*2))
                sum_errors=0
    return errors

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

# Backpropagation Algorithm With Stochastic Gradient Descent
def back_propagation(train, test, l_rate, n_epoch, n_hidden):
```

```
    scores=list()
    n_inputs = 27
    n_outputs = len(set([row[0] for row in train]))
    network = initialize_network(n_inputs, n_hidden, n_outputs)
    sum_errors=train_network(network, train, l_rate, n_epoch, n_outputs)
    predictions = list()
    #for row in test:
    #   prediction = predict(network, row)
    #    predictions.append(prediction)
    #    accuracy=accuracy_metric(row[0],predictions)
    #    scores.append(accuracy)
    #return(scores)
    return sum_errors

def accuracy_metric(actual, predicted):
    correct = 0
    for i in range(actual):
        print(actual)
        print(predict[i])
        if actual == predicted:
            correct += 1
    return correct / float(actual) * 100.0

# Test training backprop algorithm
#dataset=open('C:/Users/Rajitha Bhavani/Documents/upsampled.txt','r')
#dataset=[[0,5.239742700000001,-6.3819862999999994],[1,9.716892,-9.001553900000001]];
#test=[[0,7.937372200000001,-7.651209599999999],[1,2.7600646,-2.6970943]];
```

```
ep=list()

#sum_errors=back_propagation(dataset,test,0.1,1000,55)

scores=list()

n_inputs = 27

n_outputs = len(set([row[0] for row in dataset]))

network = initialize_network(n_inputs, 55, n_outputs)

sum_errors=train_network(network, dataset, 0.1, 4000, n_outputs)

TN=0

TP=0

FN=0

FP=0

for row in test:

   prediction = predict(network, row)

   if row[0]==0:

      if prediction==row[0]:

         TN+=1

      else:

         FN+=1

   if row[0]==1:

      if prediction==row[0]:

         TP+=1

      else:

         FP+=1

print(TN,FN,TP,FP)

if TP!=0 or FN!=0:

   SN=TP/TP+FN

   print(SN)
```

```
if TN!=0 or FP!=0:
    SP=TN/TN+FP
    print(SP)
plt.plot(ep,sum_errors)
plt.show()
#print('Scores: %s' % scores)
#print('Mean Accuracy: %.3f%%' % (sum(scores)/float(len(scores))))
```

<u>Weights from Case 1:</u>

[[{'weights': [0.041163081276754054, 0.6377906283355136, 0.4152200353796044,
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<u>Result From Case 1:</u>

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>epoch=200, lrate=0.100, error=495853.103

>epoch=300, lrate=0.100, error=495851.608

>epoch=400, lrate=0.100, error=495851.105

>epoch=500, lrate=0.100, error=495850.841

>epoch=600, lrate=0.100, error=495850.676

>epoch=700, lrate=0.100, error=495850.563

>epoch=800, lrate=0.100, error=495850.481

>epoch=900, lrate=0.100, error=495850.419

>epoch=1000, lrate=0.100, error=495850.369

>epoch=1100, lrate=0.100, error=495850.329

>epoch=1200, lrate=0.100, error=495850.295

>epoch=1300, lrate=0.100, error=495850.266

>epoch=1400, lrate=0.100, error=495850.241

>epoch=1500, lrate=0.100, error=495850.219

>epoch=1600, lrate=0.100, error=495850.198

>epoch=1700, lrate=0.100, error=495850.180

>epoch=1800, lrate=0.100, error=495850.162

>epoch=1900, lrate=0.100, error=495850.144

>epoch=2000, lrate=0.100, error=495850.126

Weights From Case 2:

[[{'weights': [0.712129350102695, 0.18222896613725081, 0.15180959788620207, 0.5551304209805042, 0.9741723945285157, 0.7018220244666719, 0.42395227858487416, 0.07519816734360318, 0.8311876710980036, 0.0692716386836506, 0.26401715296176576, 0.268855869073224, 0.950013325869599, 0.1998334599957199, 0.2160065803560407, 0.9601611450262671, 0.017151410794021715, 0.3143131154186526, 0.6356380099950615, 0.33850902835994146, 0.21874285624883372, 0.33356482659947573, 0.385856291545279, 0.05519115666652774, 0.22379102545184482, 0.5001742594717306, 0.3437503307138857, 0.8439993411342014]}, {'weights': [0.1492105318123229, 0.8079065155706857, 0.4747066181263859, 0.9165594788316784, 0.7969236869996312, 0.34132150505042547, 0.5746677444498021, 0.6583989856512333, 0.09232505094911636, 0.8375983718539503, 0.8037565184590039, 0.48083646036498695, 0.6941428734545818, 0.7646935852585821, 0.3729937765023318, 0.46871965979075325, 0.005361944009864894, 0.3904166105254162, 0.49186490533665794, 0.2929599117347289, 0.9196911449886779, 0.8254929134728102, 0.8672341446987283, 0.14027618991105928, 0.43874671021592115, 0.5114135924252341, 0.7698565311396993, 0.8747222125315471]}, {'weights': [0.865036521673338, 0.8712578082535752, 0.4887627020960674, 0.6117523499401915, 0.4646548800922692, 0.12284840378226003, 0.29735045957635375, 0.21499430442847323, 0.5403097775387812, 0.42807461799719015, 0.7448634280721445, 0.3133704674746385, 0.8270454205862061, 0.9135943272128128, 0.8192210296059225, 0.9941128834110139, 0.47630727310478593, 0.4276108203579235, 0.07536860424573111, 0.07489396463734521, 0.5414339414852639, 0.2922737554358995, 0.8763272173006443, 0.32858124593961757, 0.379278177093217, 0.11005979035505176, 0.9218954284357302, 0.5674077693281032]}, {'weights': [0.7688915518480438, 0.22122030139990856, 0.10315865384853395, 0.8078050734011645, 0.8432302155720174, 0.11024521546759825, 0.6580275521736446, 0.1395779076729271, 0.18319440875414117, 0.9510633340095971, 0.5693606964863518, 0.5993050070635415, 0.04797209936396751, 0.8473257473293264, 0.4225012001769082, 0.15511277756330533,

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<u>Results from Case 2:</u>

>epoch=100, lrate=0.100, error=495977.842

>epoch=200, lrate=0.100, error=439222.687

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>epoch=300, lrate=0.100, error=254636.124
>epoch=400, lrate=0.100, error=254637.414
>epoch=500, lrate=0.100, error=254630.407
>epoch=600, lrate=0.100, error=254630.064
>epoch=700, lrate=0.100, error=254630.033
>epoch=800, lrate=0.100, error=254629.124
>epoch=900, lrate=0.100, error=254628.528
>epoch=1000, lrate=0.100, error=254627.349
>epoch=1100, lrate=0.100, error=254626.189
>epoch=1200, lrate=0.100, error=254625.265
>epoch=1300, lrate=0.100, error=254625.095
>epoch=1400, lrate=0.100, error=254624.692
>epoch=1500, lrate=0.100, error=254624.298
>epoch=1600, lrate=0.100, error=254624.590
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