Neural Network from Scratch

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Reference: Online blogs, towardsdatascience.com

Consider Y, X1, X2, X2

A1 i.e. value to input at the first neuron on in the network is

f(X1,X2,X3)=W11*X1 + W12*X2 + W13*X3 + b11

This is further activated by

A1 = g(f(X1,X2,X3))=g(W11*X1 + W12*X2 + W13*X3 + b11)

Similarly

A2 = g(f(X1,X2,X3))=g(W11*X1 + W12*X2 + W13*X3 + b12)

A3 = g(f(X1,X2,X3))=g(W11*X1 + W12*X2 + W13*X3 + b13)

g is an activation function. Here are a few examples of activation functions

If there are two hidden layers, activated valued on the hidden layers are given by A and B.

A = W1 X + b1

B = W2 A + b2

Y_pred = W3 B + b3

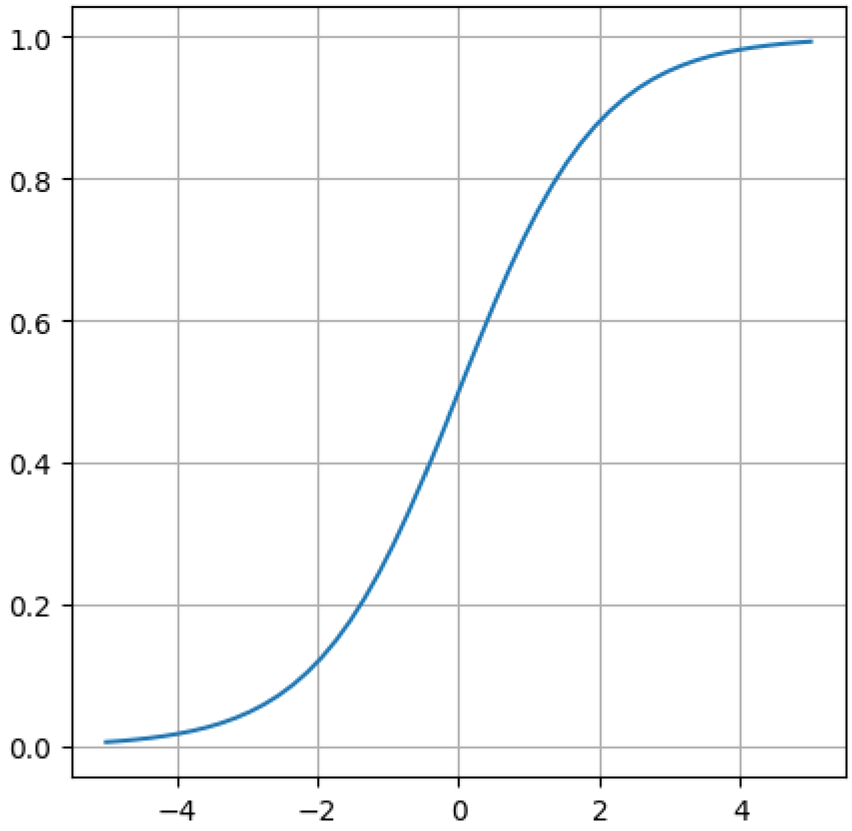
W1, W2, W3 will be matrices of appropriate sizes.

Sigmoid function in Python

In [ ]:
```
import matplotlib.pyplot as plt
import numpy as np
```

In [ ]:
```
x = np.linspace(-5, 5, 50)
z = 1/(1 + np.exp(-x))

plt.subplots(figsize=(5, 5))
plt.plot(x, z)
plt.grid()
plt.show()
```



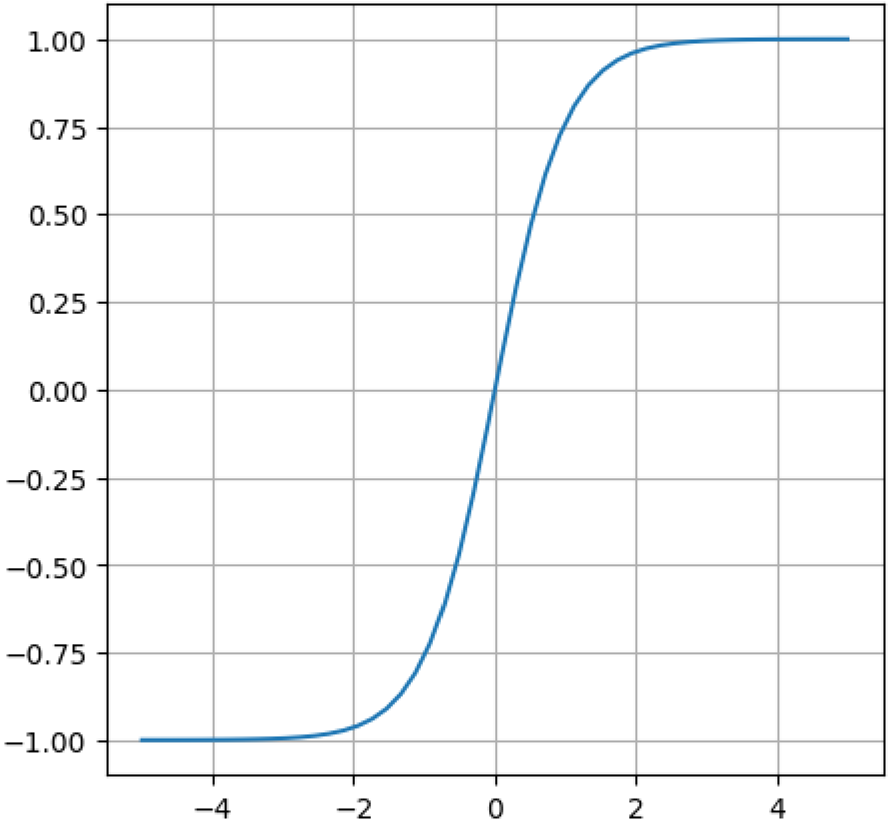
tanh function in Python

In [ ]:

```
# tanh function in Python
import matplotlib.pyplot as plt
import numpy as np

x = np.linspace(-5, 5, 50)
z = np.tanh(x)

plt.subplots(figsize=(5, 5))
plt.plot(x, z)
plt.grid()
plt.show()
```



Softmax function in Python

Softmax is a generalization sigmoid i.e. Softmax is used in multiple dimensions. And is generally used as an activation function in the output layer.

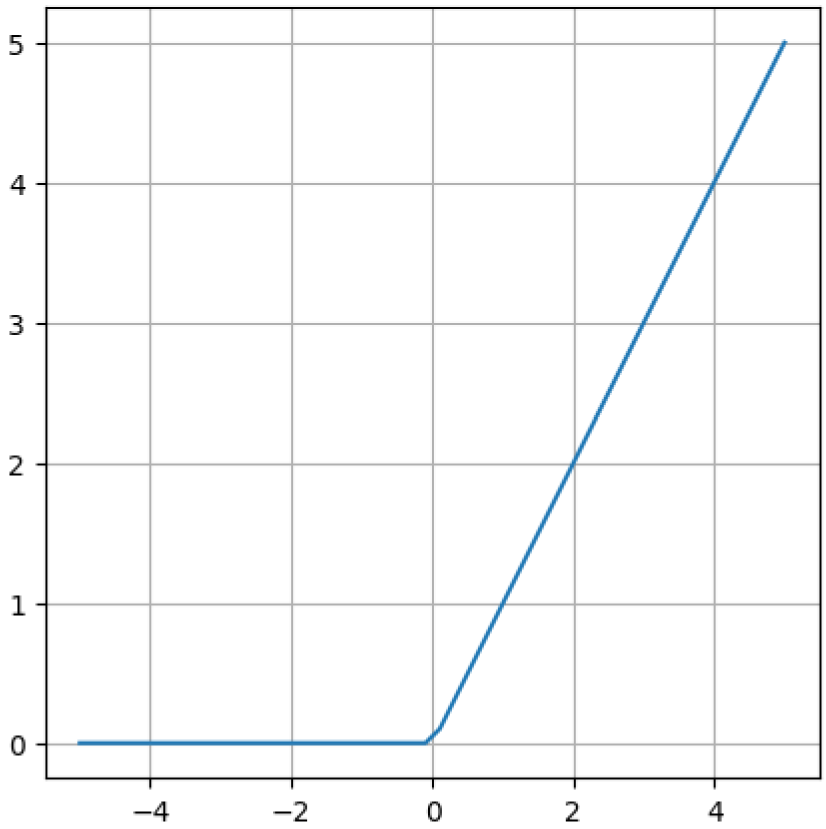
Rectified Linear Unit (ReLU)

In [ ]:

```
# ReLU in Python
import matplotlib.pyplot as plt
import numpy as np


x = np.linspace(-5, 5, 50)
z = [max(0, i) for i in x]

plt.subplots(figsize=(5, 5))
plt.plot(x, z)
plt.grid()
plt.show()
```



In [ ]:
```
from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_squared_error
```

Define ReLU function

In [ ]:
```
def relu(z): # takes a numpy array as input and returns activated array
    a = np.maximum(0,z)
    return a
```

Initialize parameters

```python
In [ ]: def initialize_params(layer_sizes): #takes a list of the layer sizes as input and returns initialized parameters
            params = {}
            for i in range(1, len(layer_sizes)):
                params['W' + str(i)] = np.random.randn(layer_sizes[i], layer_sizes[i-1])*0.01
                # rand(d0,d1) will return an array of size d0 x d1.
                params['B' + str(i)] = np.random.randn(layer_sizes[i],1)*0.01
            return params
```

Loss or cost is defined as $J(W,B) = \frac{1}{2m} * \Sigma(Y_{pred} - Y_{true})^2$

W and B represent weight and bias matrices. m is the number of observastion i.e. data points.

```python
In [ ]: def compute_cost(values, Y_train): #takes true values and dictionary having activations of
        # all layers as input and returns cost
            layers = len(values)//2
            Y_pred = values['A' + str(layers)]
            cost = 1/(2*len(Y_train)) * np.sum(np.square(Y_pred - Y_train))
            return cost
```

Define forward propagation

```python
In [ ]: def forward_propagation(X_train, params):
            #takes input training features and parameters as input and returns a dictionary
        # containining the numpy arrays of activations of all layers
            layers = len(params)//2
            values = {}
            for i in range(1, layers+1):
                if i==1: # transformation from input layer
                    values['Z' + str(i)] = np.dot(params['W' + str(i)], X_train) + params['B' + str(i)]
                    values['A' + str(i)] = relu(values['Z' + str(i)])
                else: # transformation from non-input layer
                    values['Z' + str(i)] = np.dot(params['W' + str(i)], values['A' + str(i-1)]) + params['B' + str(i)]
                    if i==layers: # Do not use activation function in the output layer
                        values['A' + str(i)] = values['Z' + str(i)]
                    else: # use activation function for non-output layers
```

```
            values['A' + str(i)] = relu(values['Z' + str(i)])
    return values
```

Define function for backward propagation

In [ ]:
```
def backward_propagation(params, values, X_train, Y_train):
    #takes parameters, activations, training set as input and returns gradients wrt parameters
    layers = len(params)//2
    m = len(Y_train)
    grads = {}
    for i in range(layers,0,-1):
        if i==layers:
            dA = 1/m * (values['A' + str(i)] - Y_train)
            dZ = dA
        else:
            dA = np.dot(params['W' + str(i+1)].T, dZ)
            dZ = np.multiply(dA, np.where(values['A' + str(i)]>=0, 1, 0))
        if i==1:
            grads['W' + str(i)] = 1/m * np.dot(dZ, X_train.T)
            grads['B' + str(i)] = 1/m * np.sum(dZ, axis=1, keepdims=True)
        else:
            grads['W' + str(i)] = 1/m * np.dot(dZ,values['A' + str(i-1)].T)
            grads['B' + str(i)] = 1/m * np.sum(dZ, axis=1, keepdims=True)
    return grads
```

Function for updating paramters (this is done after backpropagation)

In [ ]:
```
def update_params(params, grads, learning_rate):
    #takes parameters, gradients and learning rate as input and returns updated parameters
    layers = len(params)//2
    params_updated = {}
    for i in range(1,layers+1):
        params_updated['W' + str(i)] = params['W' + str(i)] - learning_rate * grads['W' + str(i)]
        params_updated['B' + str(i)] = params['B' + str(i)] - learning_rate * grads['B' + str(i)]
    return params_updated
```

Define function for accuracy

In [ ]:
```
def compute_accuracy(X_train, X_test, Y_train, Y_test, params): #compute accuracy on test and training data given learnt param
    values_train = forward_propagation(X_train.T, params)
    values_test = forward_propagation(X_test.T, params)
    train_acc = np.sqrt(mean_squared_error(Y_train, values_train['A' + str(len(layer_sizes)-1)].T))
    test_acc = np.sqrt(mean_squared_error(Y_test, values_test['A' + str(len(layer_sizes)-1)].T))
    return train_acc, test_acc
```

Define function for predicting

In [ ]:
```
def predict(X, params):  #predict on new array X given learnt parameters
    values = forward_propagation(X.T, params)
    predictions = values['A' + str(len(values)//2)].T
    return predictions
```

Assemble the model i.e. create the model i.e. setup the model

In [ ]:
```
def model(X_train, Y_train, layer_sizes, num_iters, learning_rate): #trains the model
    params = initialize_params(layer_sizes)
    for i in range(num_iters):
        values = forward_propagation(X_train.T, params)
        cost = compute_cost(values, Y_train.T)
        grads = backward_propagation(params, values,X_train.T, Y_train.T)
        params = update_params(params, grads, learning_rate)
        # print('Cost at iteration ' + str(i+1) + ' = ' + str(cost) + '\n')
    return params
```

Run the model

In [ ]:
```
# import pandas for importing csv files
import pandas as pd
from sklearn.preprocessing import normalize
# from sklearn.datasets import load_boston
data = np.genfromtxt('dummy_data.csv', delimiter=',')                                        #load dataset
```

```
# X,Y = dataset["data"], dataset["target"]                                  #separate data into input and output
X = data[:, :-1]  # Select all rows, and all columns except the last one
Y = data[:, -1]   # Select all rows, and only the last column
# There are 13 features and 1 target.
```

In [ ]:
```
# print(X)
# print()
# print()
# print(Y)
```

In [ ]:
```
from sklearn.model_selection import train_test_split

# Split the data into training and testing sets with an 80:20 ratio
X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.2, random_state=42)
print(X_train.shape)
print(X_test.shape)
print(Y_train.shape)
print(Y_test.shape)
```

```
(404, 13)
(102, 13)
(404,)
(102,)
```

In [ ]:
```
layer_sizes = [13, 8, 8, 1] #list containing the number of neurons in each layer
params=model(X_train, Y_train, layer_sizes, 1000, 0.01) #train the model
```

In [ ]:
```
# print(params)
```

In [ ]:
```
compute_accuracy(X_train, X_test, Y_train, Y_test, params) #compute accuracy on test and training data given learnt parameters
```

Out[ ]:
```
(8.944903237552355, 8.366294622130322)
```

In [ ]:
```
Y_pred = predict(X_test, params)
Y_pred #predict on test set
```

```
Out[ ]:  array([[24.50206107],
               [25.4650899 ],
               [23.84216973],
               [23.99939487],
               [23.49123198],
               [23.00713332],
               [24.05212072],
               [23.73310161],
               [24.18411732],
               [24.42512452],
               [24.46263972],
               [24.12297963],
               [ 4.80621779],
               [23.71562362],
               [24.16908575],
               [22.85867628],
               [23.42187118],
               [22.51172684],
               [26.26707021],
               [24.19183355],
               [24.91774209],
               [25.40958365],
               [22.16204599],
               [24.23860693],
               [19.53192211],
               [21.48020044],
               [24.29293759],
               [ 0.34837684],
               [24.26975484],
               [24.3973734 ],
               [24.51763909],
               [24.5185254 ],
               [24.18168305],
               [23.34811726],
               [20.16220384],
               [16.12093598],
               [24.37686071],
               [24.51401099],
               [23.46408351],
               [23.12042754],
```

```
[24.30236942],
[25.40407943],
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[24.64472622],
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[22.13814684],
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[24.05500322],
[14.52711591],
[25.05234244],
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[23.80196334],
[24.2490846 ],
[26.53347074],
[24.103149  ],
[20.94132273],
[24.6947842 ],
```

```
[19.05882277],
[26.15599503],
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[24.51270976],
[22.26902811],
[15.57120775],
[24.4920009 ],
[25.04971715],
[24.25516069],
[24.22366574],
[ 7.45088996],
[24.45330603],
[22.4360396 ],
[21.75322013],
[23.7920773 ],
[22.4366876 ],
[ 1.40919585],
[ 1.5780535 ],
[ 2.02043573],
[24.39261524],
[23.53891241]])
```