Python and Neural Networks

An introduction

Python's Strengths

Expressibility.

Widely used, huge community.

Very wide set of open source libraries.

Easily extensible using C.

Highly portable across platforms.

Stability (Python is older than Java).

Free of cost.

Python’s Weaknesses

Performance can be an issue.

Not used for mobile or web development.

Need for extensive unit tests.

Lack of true multiprocessor support.

Installing the required software for ms-windows.

Python

Point your browser to https://www.python.org/downloads/windows/

Select the Windows x86-64 executable installer for Python 3.6.1 - 2017-03-21

Install it by double clicking of the downloaded file.

Add python and pip to path.

Open Control Panel\All Control Panel Items\System | advanced system settings | Environment Variables

Append the following to the path environment variable: ;C:\Python34;C:\Python34\Scripts

Install nosetests by running: pip install nose from the command line.
Install git from the following link: https://git-scm.com/download/win
Install the sample code from the command line:
git clone https://github.com/jpazarzis/perceptrons

Download source code

```
cd /

mkdir neural_networks

cd neural_networks

git clone https://github.com/jpazarzis/perceptrons
```

Verify installation

```
cd C:\neural_networks\perceptrons

nosetests
```

Conventional Programming

The input defines deterministically the output.

Applies to problems that can be solved by a sequence of steps that are independent from the data.

Artificial Intelligence

The output is not always known in advance.

The computer has the ability to learn from data.

Provides answers to problems that cannot be analyzed using a deterministic algorithm.

Applications of Artificial Intelligence

- Game playing.
- Speech recognition.
- Handwriting recognition.
- Understanding natural language.
- Computer vision.
- Stock market trading.
- Intelligent Robots.

How a human worker relates to the AI

Ability to use intelligent machines.

Are the worker skills a complement to the computer or the computer can do a better without the intervention of the human?

Is the worker competing against the computer?

How AI compares with human intelligence.

AI increases the ability of machines to substitute human labor and automate working procedures.

In the near future all activities that require human expertise will be assisted by AI.

AI is not a replacement for human knowledge and skill but a support tool.

AI will not supplant humans, instead it will boost their productivity and creativity.

Example of Applications of AI to Business

Improving CRM: Collect and analyze the massive client's interaction data (emails, e-chat, phone calls)

Virtual Assistance: Automate customer service using AI to answer phone calls, build chatbots etc.

Marketing: Improve understanding of customer profile and habits and individualize promotional campaigns.

Automation of manual processes: Labor saving machines, robots.

Expert Systems: Assist human experts based on AI techniques that analyze huge databases containing related

Types of AI Learning

Supervised learning is the machine learning task of inferring a function from labeled training data.The training data consist of a set of training examples. In supervised learning, each example is a pair consisting of an input object (typically a vector) and a desired output value (also called the supervisory signal). A supervised learning algorithm analyzes the training data and produces an inferred function, which can be used for mapping new examples. An optimal scenario will allow for the algorithm to correctly determine the class labels for unseen instances. This requires the learning algorithm to generalize from the training data to unseen situations in a "reasonable" way (see inductive bias).

Unsupervised machine learning is the machine learning task of inferring a function to describe hidden structure from "unlabeled" data (a classification or categorization is not included in the observations). Since the examples given to the learner are unlabeled, there is no evaluation of the accuracy of the structure that is output by the relevant algorithm—which is one way of distinguishing unsupervised learning from supervised learning and reinforcement learning.

Reinforcement learning is an area of machine learning inspired by behaviorist psychology, concerned with how software agents ought to take actions in an environment so as to maximize some notion of cumulative reward. The problem, due to its generality, is studied in many other disciplines, such as game theory, control theory, operations research, information theory, simulation-based optimization, multi-agent systems, swarm intelligence, statistics, and genetic algorithms.

Problems solvable by Neural Networks

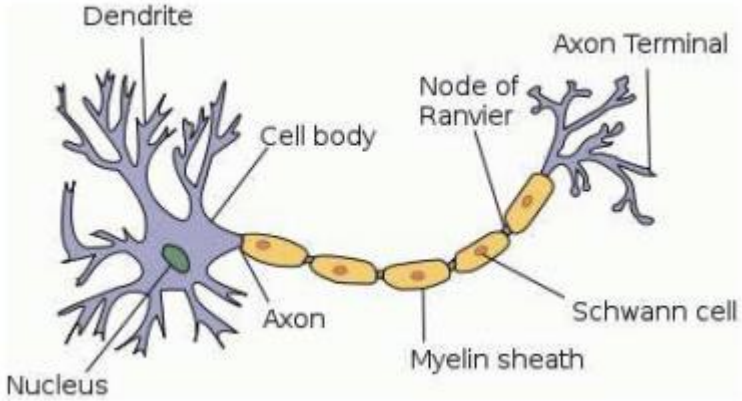
Classification: Models the data into classes

Pattern Recognition: Recognizes regularities or patterns in data

Prediction: Predicts a continued value.

Optimization: Fits data to a distribution minimizing errors.

Biological Neuron

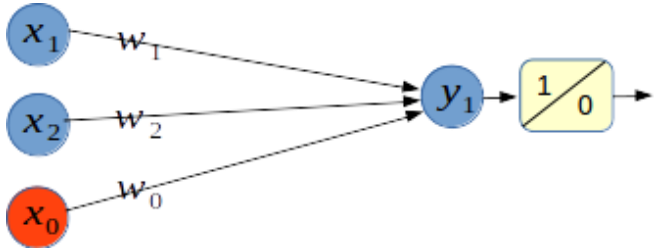


Perceptron: The simplest neural network

Perceptron is an algorithm for learning a binary classifier

Maps an input that consists of a vector x to a function f(x)
returning a single binary value.

High Level view of a perceptron



A perceptron can be expressed mathematically as a function that receives a vector x and returns either a 0 or a 1 as it can be seen in the following expression:

$$f(x) = \begin{cases} 1 \\ 0 \end{cases}$$

where x is a vector of real numbers: $(x_1, \ x_2, \ x_3, \ \cdots)$

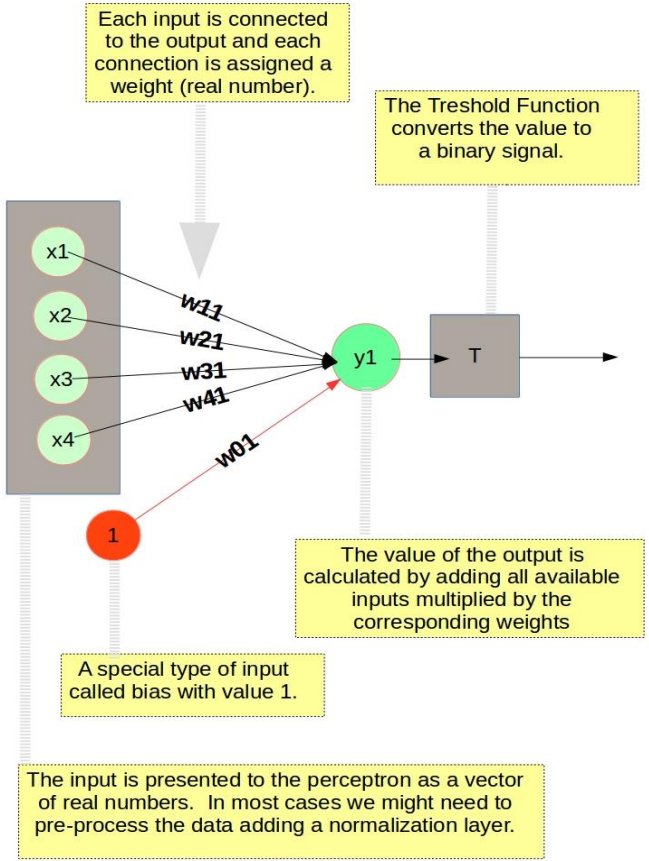
A Single Layer Perceptron (SLP) connects each value of the input layer directly to the unique output value.

An SLP is only capable of learning linearly separable patterns.

Single-layer Neural Networks: The simpler Perceptron possible

The components of a Single Layer Perceptron (SLP).

- The input layer which consists of data that were collected and prepared for processing.
- The output layer which consists of a single node.
- A set of synapses assigned a weight as a real value connecting each input node to the output.
- A special type of input having the value of 1 which is called bias.
- The threshold function which converts the value of the output neural to a binary value.


Each input is connected to the output and each connection is assigned a weight (real number).
The Treshold Function converts the value to a binary signal.
x1
x2
x3
x4
w11
w21
w31
w41
w01
y1
T
1
The value of the output is calculated by adding all available inputs multiplied by the corresponding weights
A special type of input called bias with value 1.
The input is presented to the perceptron as a vector of real numbers. In most cases we might need to pre-process the data adding a normalization layer.

Description of the Single layer perceptron

In the previous image we can see the following variables:

x1, x2, ..: The inputs to the network

w11, w21 ..: The weight of each connection (synapse) between an input and the output.

y1: The (unique) output of the network.

Calculating the output of the network

The value of the y1 (which is the output of the perceptron) is given by the following formula:

$$y_1 = x_1 * w_{11} + x_2 * w_{21} + .. + x_n * w_{n1}$$

or in a more generic way:

$$y_j = \sum_{i=1}^{n} x_i * w_{ij}$$

Interpretation of perceptron output.

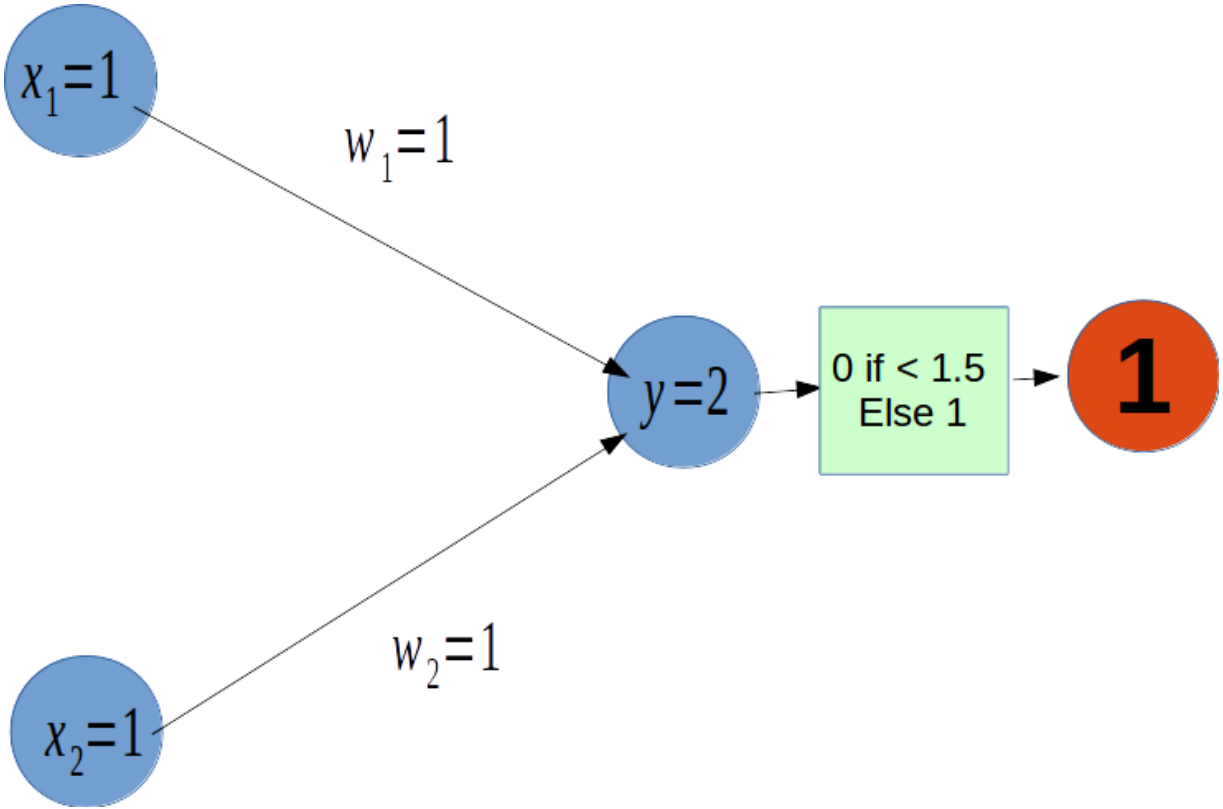
The output of the perceptron is a real number that needs a threshold which will transform it to a binary value. This means that if the output is more than the threshold it will become 1 and in the other case it will become 0.

So, we can express the output using the following logic:

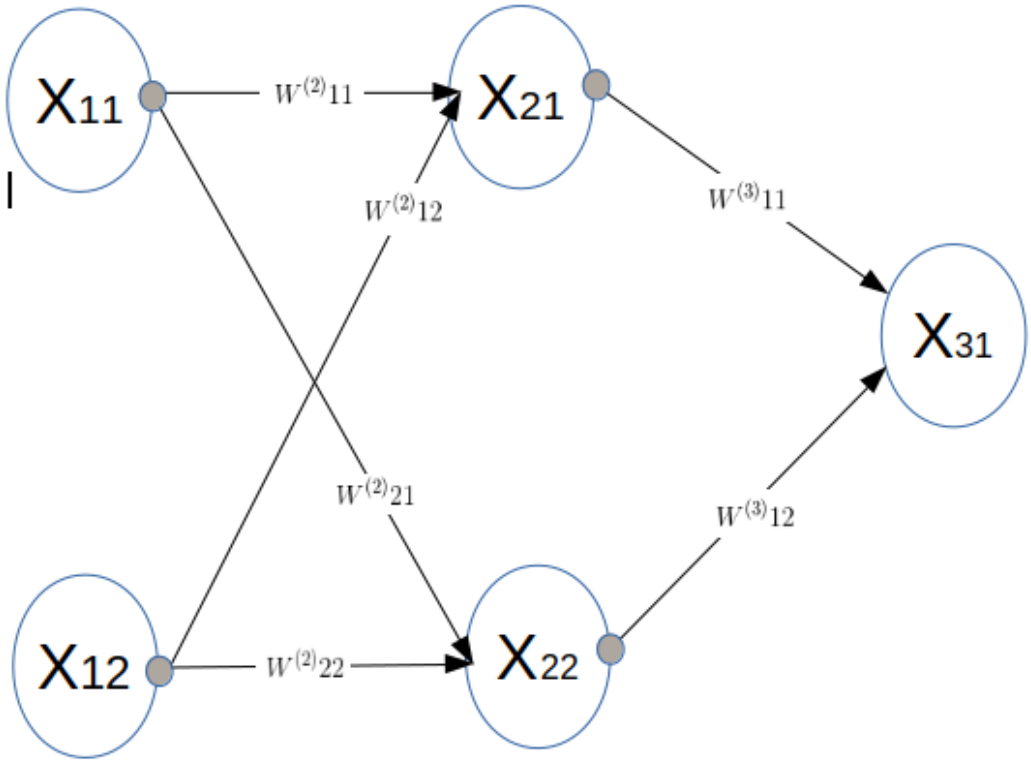
$$\text{if } \sum_i w_i I_i \geq t \text{ then } y = 1$$

$$\text{else } (\text{ if } \sum_i w_i I_i < t \text{ }) \text{ then } y = 0$$

The AND operator using Single layer perceptron



Multi-level neural network



Values for Multi-level neural network

Hidden Layer

$$X_{21} = W_{11}^{(2)} * X_{11} + W_{12}^{(2)} * X_{12}$$

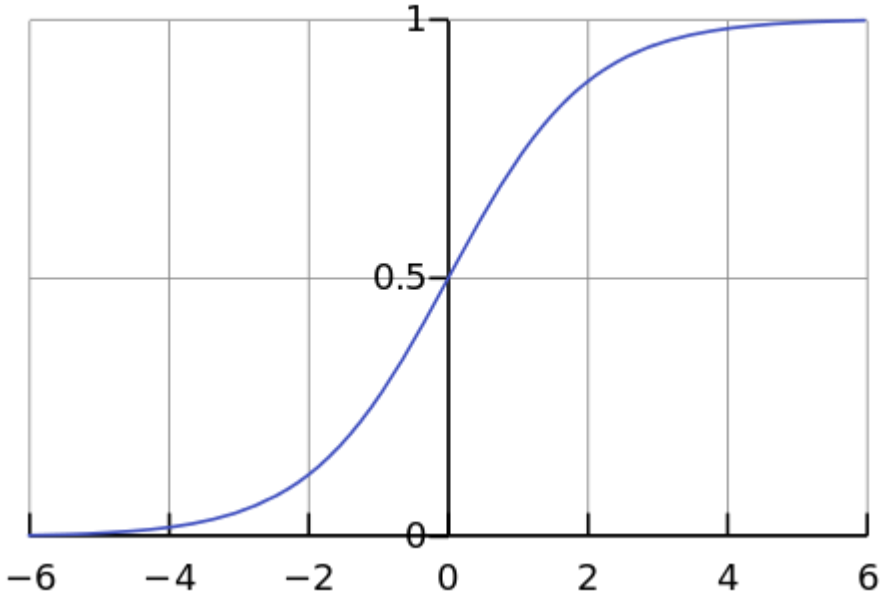
$$X_{22} = W_{21}^{(2)} * X_{11} + W_{22}^{(2)} * X_{12}$$

Output Layer

$$X_{31} = W_{11}^{(3)} * X_{21} + W_{12}^{(3)} * X_{22}$$

Activation Function (Sigmoid)

$$f(x) = \frac{1}{1 + e^{-x}}.$$



Sigmoid's Derivative

$$f(x) = \frac{1}{1 + e^{-x}}.$$

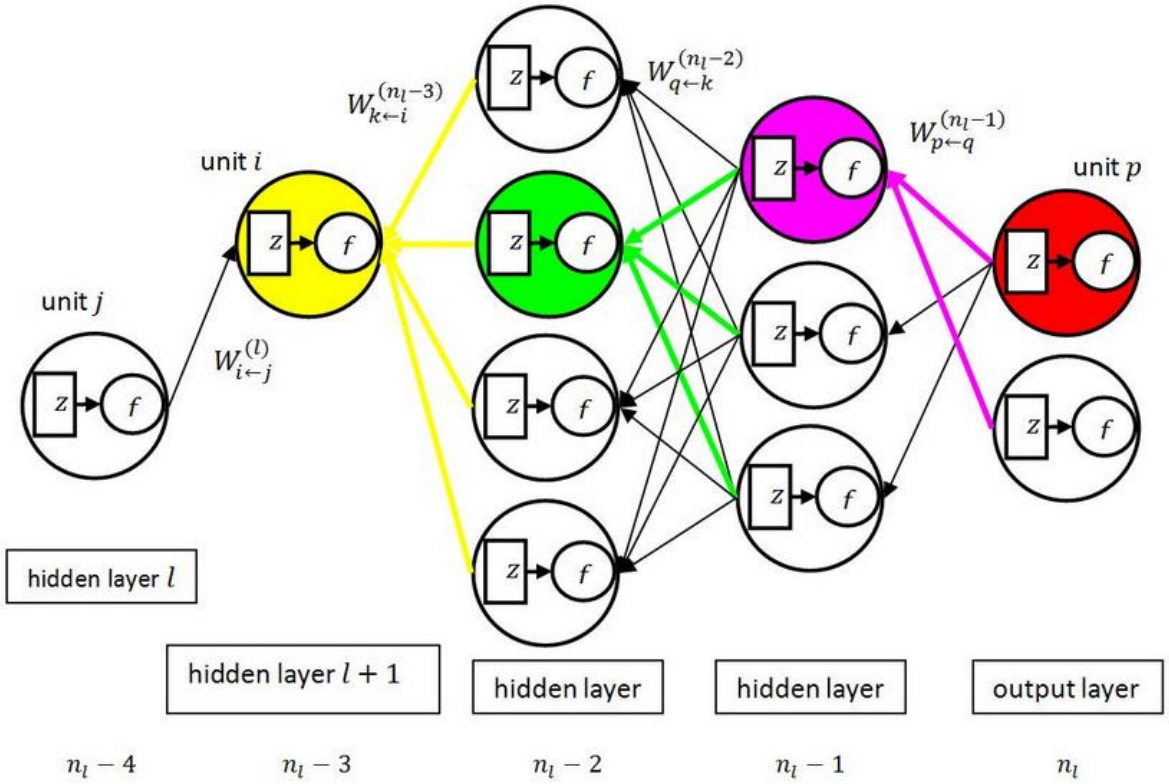
The derivative of the sigmoid function is easy to calculate as can be seen here:

$$f(x) = \frac{1}{1 + e^{-x}} = \frac{e^x}{1 + e^x}$$

$$\frac{d}{dx} f(x) = \frac{e^x * (1 + e^x) - e^x * e^x}{(1 + e^x)^2}$$

$$\frac{d}{dx} f(x) = \frac{e^x}{(1 + e^x)^2} = f(x)(1 - f(x))$$

Back propagation



The iris data set

Versicolor

Setosa

Virginica

The structure of the IRIS database can be seen in following table:

sepal_length	sepal_width	petal_length	petal_width	target
6.5	2.8	4.6	1.5	versicolor
6.6	2.9	4.6	1.3	versicolor
7	3.2	4.7	1.4	versicolor
6.3	2.5	4.9	1.5	versicolor
5.1	3.4	1.5	0.2	setosa
5.6	2.5	3.9	1.1	versicolor
5.5	3.5	1.3	0.2	setosa
4.4	2.9	1.4	0.2	setosa
4.6	3.2	1.4	0.2	setosa