Data Mining
Minería de Datos

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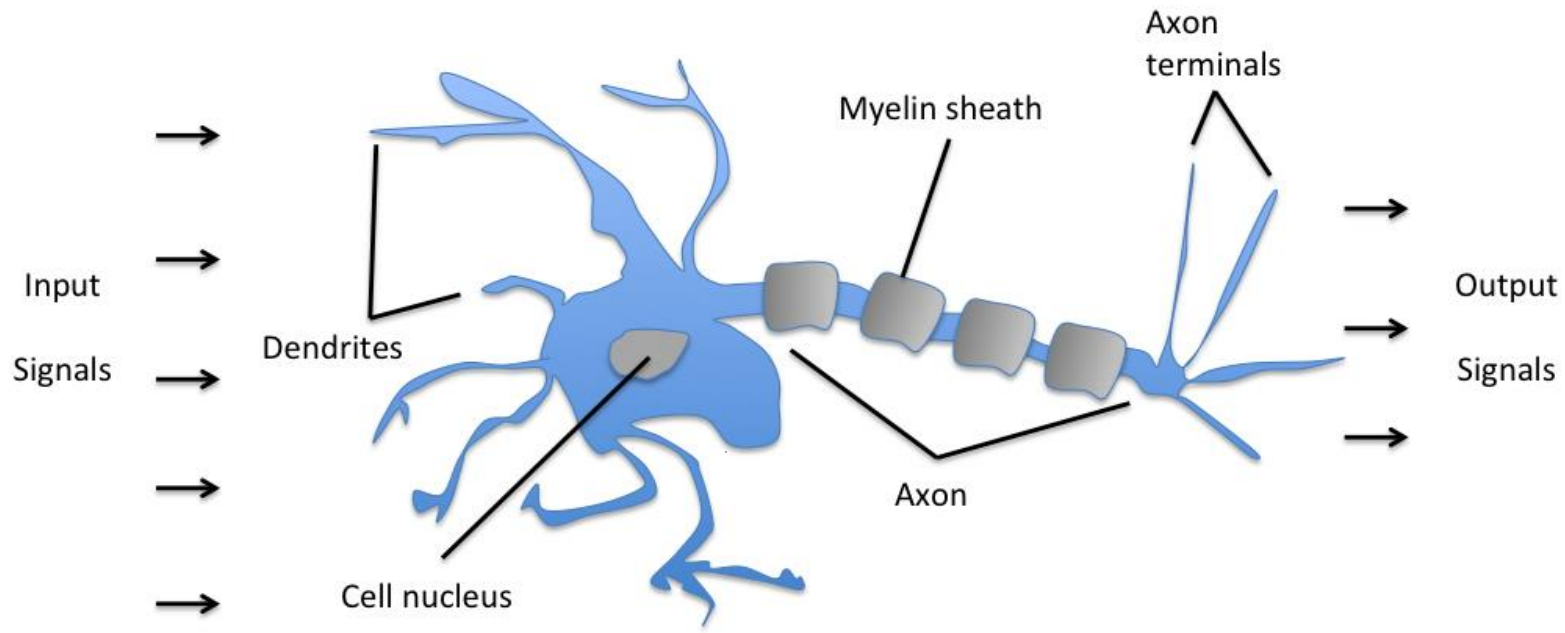
Topics

- Background
- Statistical Concepts
- Markov Chain Monte Carlo
- Parametric Classification
- Non-Parametric Classification
- Clustering
- Decision Trees
- **Artificial Neural Networks**

Artificial Neurons and the McCulloch-Pitts Model



Schematic of a biological neuron.

Source: https://sebastianraschka.com/Articles/2015_singlelayer_neurons.html

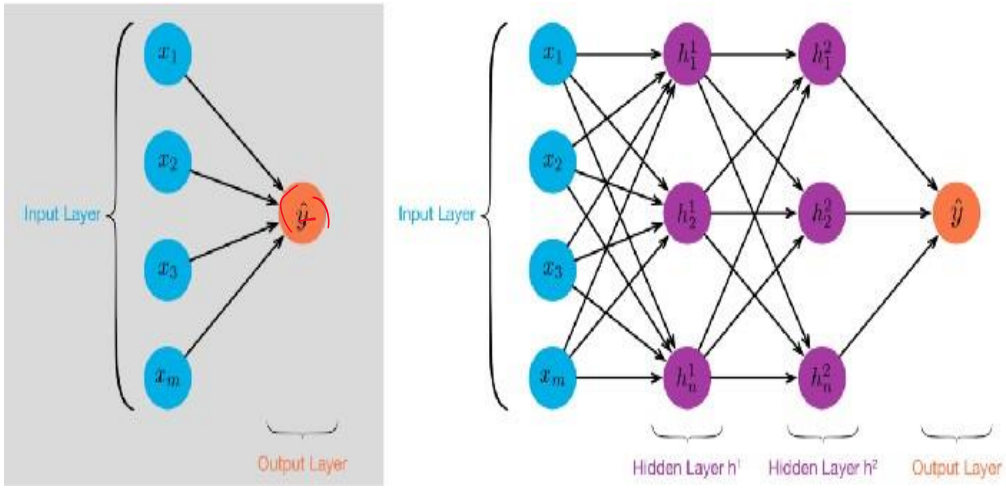
W. S. McCulloch and W. Pitts. A logical calculus of the ideas immanent in nervous activity. The bulletin of mathematical biophysics, 5(4):115–133, 1943.

Perceptron Model

- Developed at Cornell Aeronautical Laboratory, United States, in 1957 for machine-implemented image recognition
- Automatically learn the optimal weight coefficients that are then multiplied with the input features in order to make decision of whether a neuron fires or not.

1. Single-layered perceptron model
   - includes a feed-forward network
   - depends on a threshold transfer function
   - analyze only linearly separable objects with binary outcomes
   - doesn't have previous information
   - weights are allocated inconstantly
   - added weighted inputs are compare to a threshold
   - activated and delivered output as +1.
   - weights are updated to minimize errors.

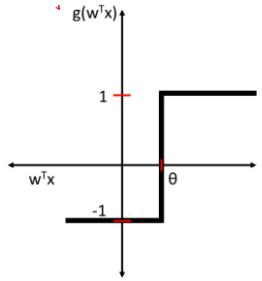
2. Multi-layered perceptron model
   - Similar to SLP but with more number of hidden layers
   - Also called Backpropagation algorithm
   - It is executed in two stages; the **forward stages** and the **backward stages**.
   - the activation function is no longer linear but non-linear



Source: https://towardsdatascience.com/multi-layer-neural-networks-with-sigmoid-function-deep-learning-for-rookies-2-bf464f09eb7f

Single Layer Perceptron Model

- We can pose this problem as a binary classification task
- Two classes: 1 (positive class) and -1 (negative class)
- An activation function $\phi(z)$ takes a linear combination of certain input values x and a corresponding weight vector w
- Where z is the so-called net input ($z=w_1x_1 + \dots + w_mx_m$):
- $$w = \begin{bmatrix} w_1 \\ \cdot \\ \cdot \\ \cdot \\ w_m \end{bmatrix}, x = \begin{bmatrix} x_1 \\ \cdot \\ \cdot \\ \cdot \\ x_m \end{bmatrix}, z = w^T x + b$$
- If the activation of a sample $x^{(i)}$ is greater than a define threshold θ, predict class 1 or class -1
- The activation function is a simple unit step function, also called the Heaviside step function
- $$\phi(z) = \begin{cases} 1 \; if \; z \geq \theta \\ -1 \; otherwise \end{cases}$$



Unit step function.

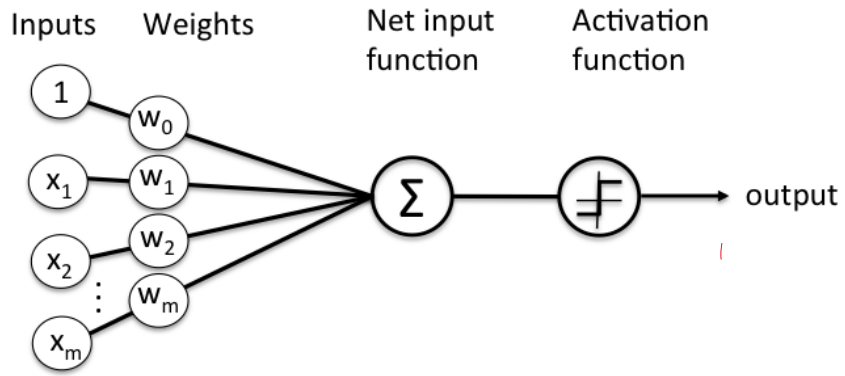
Single Layer Perceptron Model

- The idea is to mimic how a single neuron in the brain works: it either fires or it doesn't
- It can be summarized in the following steps:

    1. Initialize the weights to 0 or small random numbers
    2. For each training sample $x^{(i)}$ perform the following steps:
        1. Compute the output value $\hat{y}$
        2. Update the weights

- The output value is the class label predicted by the unit step function defined earlier
- The simultaneous update of each weight w_j in the weight vector w can be written as
    - $w_j := w_j + \Delta w_j$

- Δw_j is calculated by the perceptron rule
    - $\Delta w_j = \eta\left(y^{(i)} - \hat{y}^{(i)}\right)x_j^{(i)}$
    - Where η is the learning rate



Schematic of Rosenblatt's perceptron.

Supervised Learning – Classification – Artificial Neural networks

Supervised learner by

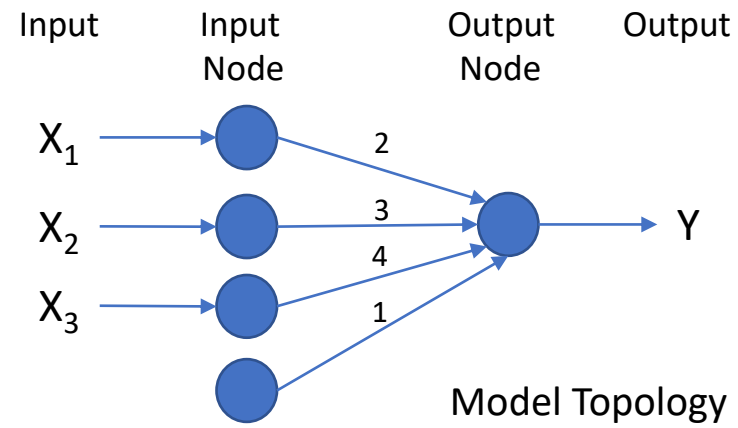
- Developing a functional relationship between input and output variables
- Mimics the architecture of the biological process of a neuron

Foundation

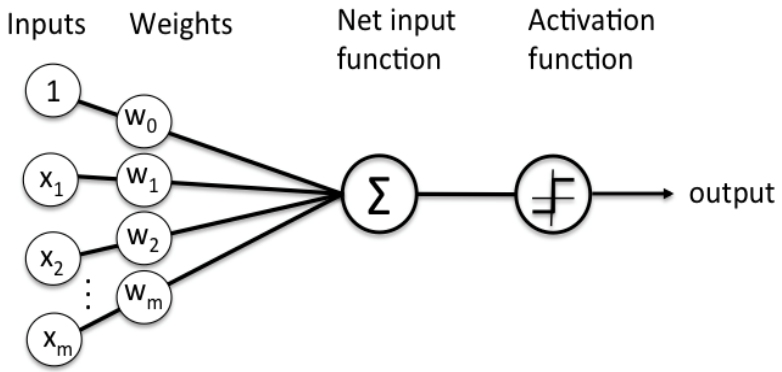
$$Y = 1 + 2X_1 + 3X_2 + 4X_3$$

Where,

Y = calculated output
X_1, X_2, X_3 = input attributes
1 is the intercept
2, 3, and 4 are the scaling factors or coefficients for the input attributes



Model Topology



Schematic of Rosenblatt's perception

Supervised Learning – Classification – Artificial Neural networks

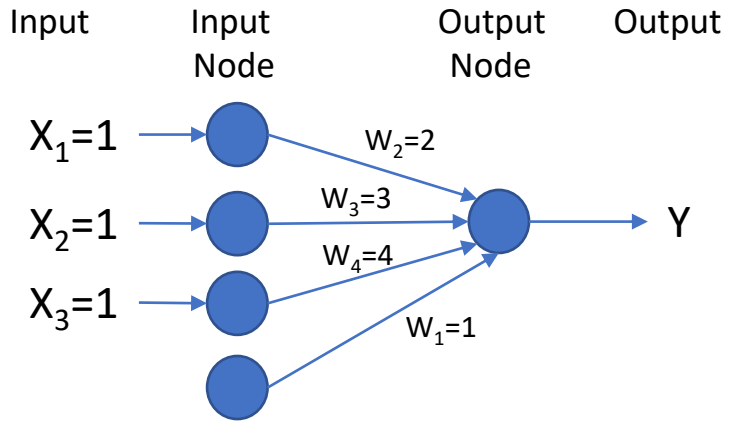
Example:

1. Determine the topology and activation function
   - Dataset with 3 numeric input attributes (X1, X2, X3) and one numeric output (Y)
   - A topology with two layers and a simple aggregation activation function is used
2. Initiation
   - Initial weights for links are 1,2,3, and 4
   - Training record with all inputs as 1 and the output Y=15
3. Calculating Error
   - Calculate the output using the model

     $\bar{y} = 1 + 1 * 2 + 1 * 3 + 1 * 4 = 10$

     $e = y - \bar{y} = 15 - 10 = 5$
4. Weight Adjustment
   - The error is passed back from the output node to all other nodes in the reverse direction
   - The weights of the links are adjusted by a fraction of the error
   - The fraction λ applied to the error is called the learning rate
   - The new weight of the link (w) is the sum of the old weight (w') and the product of the learning rate and proportion of the error (λ*e)

     $w = w' + \lambda * e$
   - Determine the initial value for λ



- The same training example can be repeated until the error rate is less than a threshold

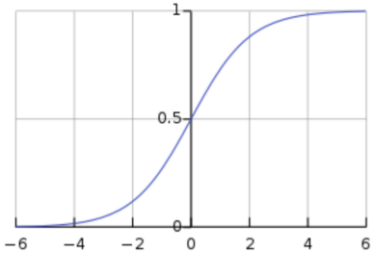
Supervised Learning – Classification – Artificial Neural networks

ANN,

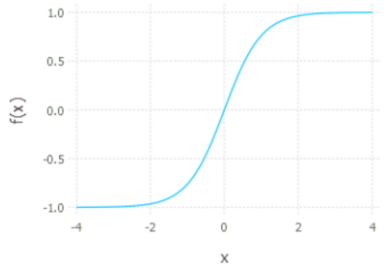
- Is typically used for modeling nonlinear, complicated relationships between input and output variables
- Creates more than one layer in the topology, called hidden layers

The activation function:

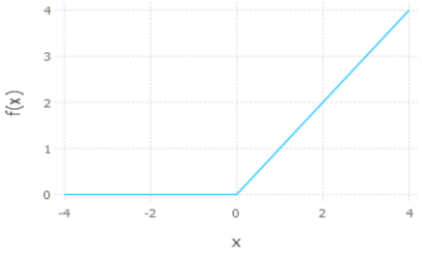
- Consist of a combination of an aggregation function (summarization), and a transfer function (sigmoid, normal bell curve, logistic hyperbolic, or linear functions) for linear and nonlinear transformations



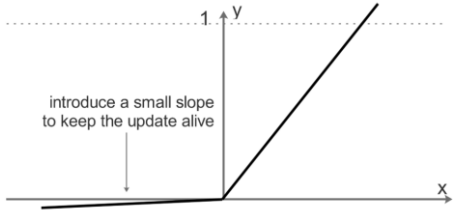
Sigmoid / Logistic



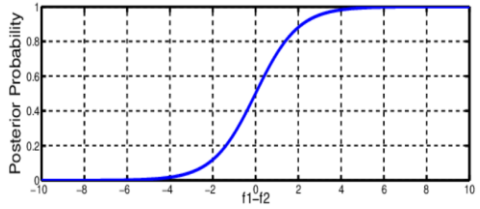
Tan-h / Hyperbolic tangent



ReLU (Rectified Linear Unit)



Leaky ReLU



Softmax

https://medium.com/@snaily16/what-why-and-which-activation-functions-b2bf748c0441

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