Computational Intelligence
Lecture 2: What Are Neural Networks

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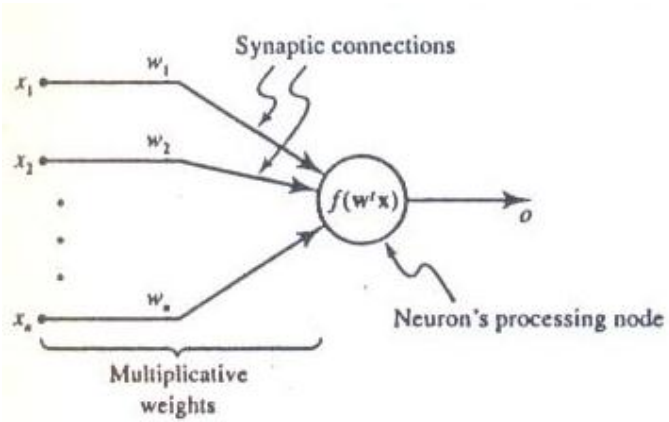
Fall 2011

Neuron Modeling of NN

- McCullouch-Pitts model is introduced in 1943 and the first network is designed
- They found out that more precise computations is achieved by combining several neurons in a NN system.
- The model considers several drastic simplifications:
  - It allows only binary states (0-1)
  - Operates under a discrete time assumption
  - Wights and neuron's threshold are fixed
- Nowadays, Computing algorithms employ a varieties of neuron models with more diversified features.



- The main artificial neuron models that is used later in this course is:
- Each neuron consists of a processing element with synaptic input connections and a single output
- The neuron output is defined as

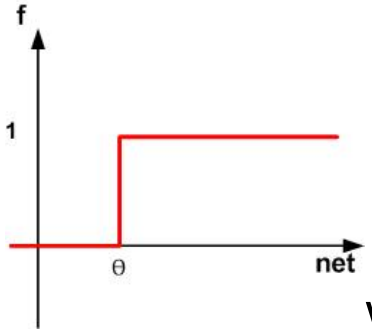
$$o = f(W^T X) = f(\sum_{i=1}^{n} w_i x_i)$$

where $W = [w_1 \ w_2 \ ... \ w_n]^T$ is the weight vector and $X = [x_1 \ x_2 \ ... \ x_n]^T$ is input vector.

- $f(W^T X)$ is activation function.

Activation Function

- The simplest definition of activation function is binary with threshold.



where $net = W^T X$, and θ is threshold level to fire neuron

- Therefore, output y is defined as

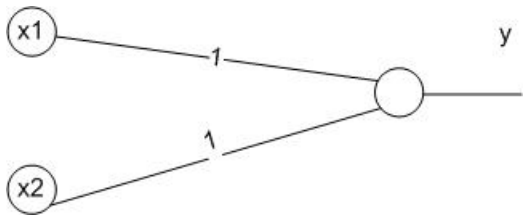
$$y = \begin{cases} 1 & net \geq \theta \\ 0 & net < \theta \end{cases}$$

- Any function $f(net)$ that is monotonically nondecreasing and continuous s.t. $net \in R$ and $f(net) \in (-1, 1)$ can be considered as a NN activation function

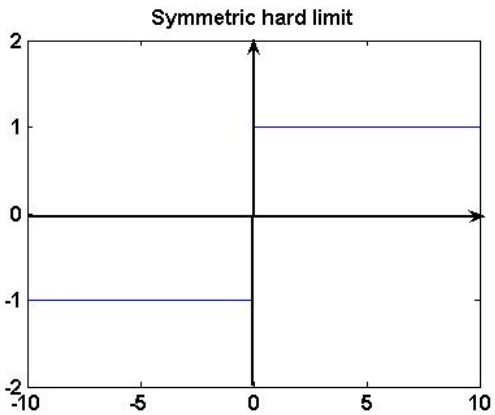
- Example:And

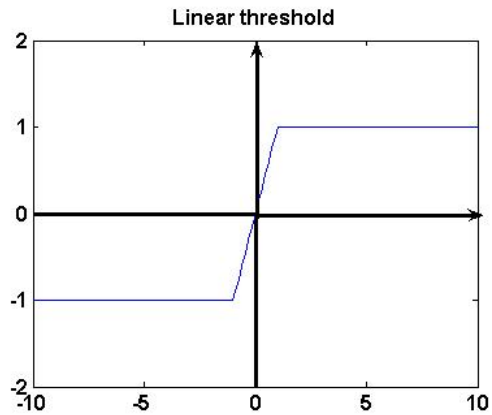
x_1	x_2	$\rightarrow$	y
1	1		1
1	0		0
0	1		0
0	0		0

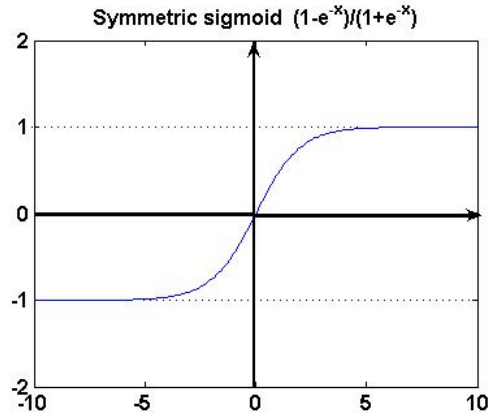
$$y = \begin{cases} 1 & net \geq \theta \\ 0 & net < \theta \end{cases}, \theta = 2$$

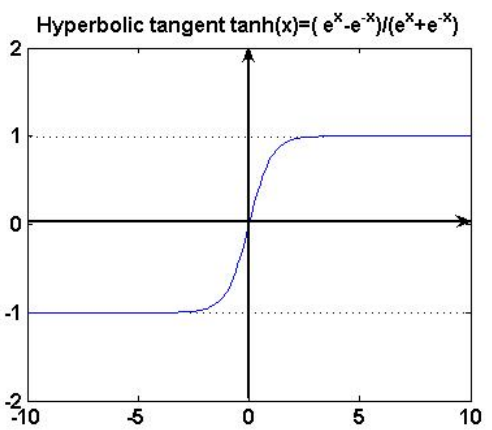


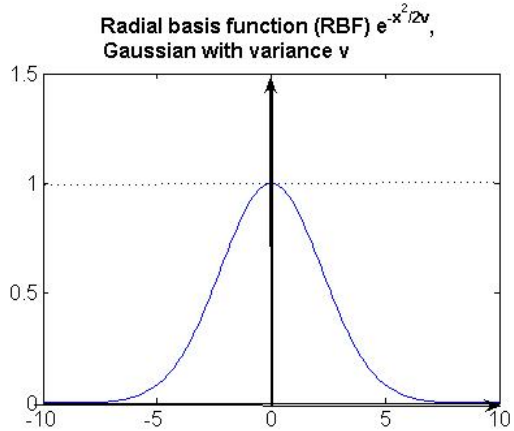
- Most popular activation functions:
  - Linear It is usually used in output layer when continuous functions are required (such as in control): $f(net) = net$







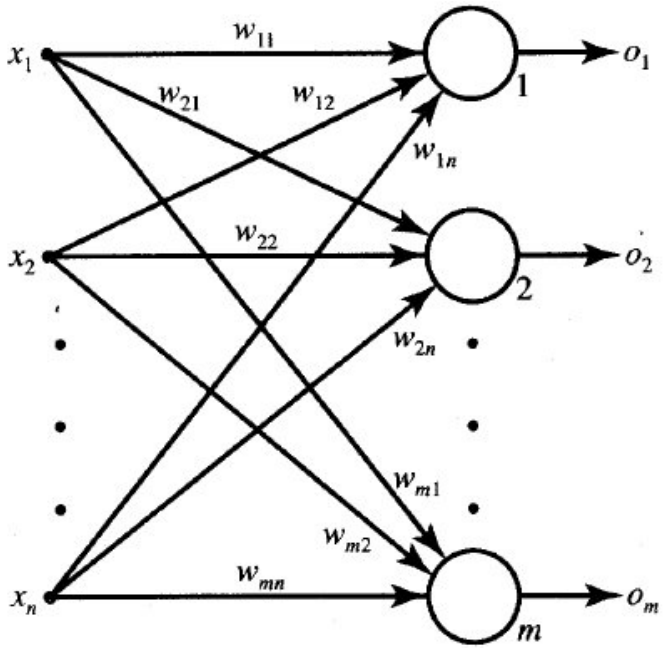




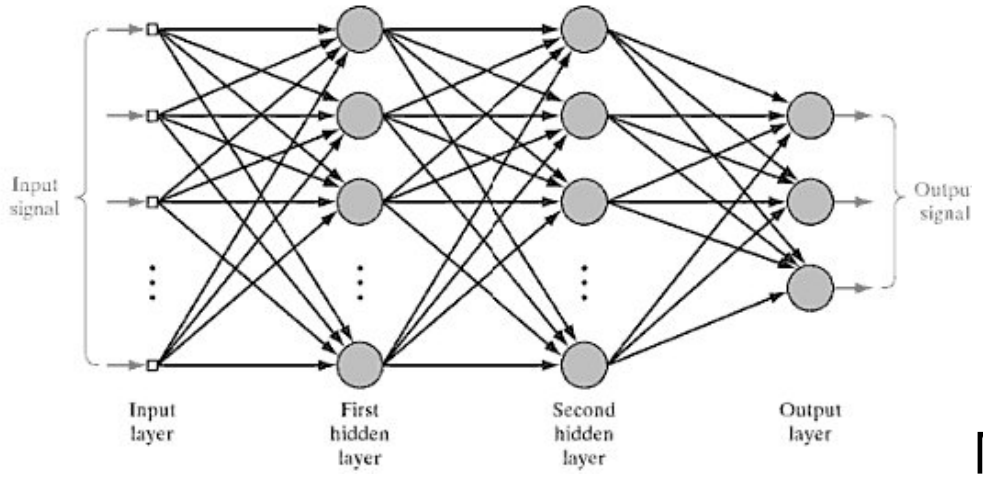
- In discrete NN, the output of each neuron can be
  - unipolar binary: 0 and 1
  - bipolar: -1 and 1
- Sometimes, unipolar functions cannot represent the output properly.
- Unipolar functions are not proper functions for generalization as well

Neural Architecture

- Neurons at NN are arranged in layers
- Neurons in the same layer behave in the same manner.
- Key factors in determining the behavior of a neuron are its activation function and the pattern of its weight connections
- Within each layer, neurons usually have the same activation function and the same pattern of connections to other neurons.
- Neural nets are often classified to:
  1. **Single Layer**
     - includes one layer of connection weights.
     - input units: the units which receive signals from the outside world
     - output units which the response of the net can be read.
  2. **Multi Layer**
     - It has layers of nodes between the input units and the output units. (hidden units)
     - Multilayer nets can solve more complicated problems than can single-layer nets, but training may be more difficult.



Single layer Network



Multi Layer Network

- The NN based on type of the connection can also be categorized to:
  1. **Feed forward Networks**
     - The signals flow from the input units to the output units, in a forward direction.
     - Like Multilayer perceptrons, RBF, etc
  2. **Feedback Networks**
     - It can be obtained from the feed forward network and a feedback connection form the neurons' outputs to their inputs.
     - Like Hopfield networks