Computational Intelligence
Lecture 12: What Are Neural Networks

Farzaneh Abdollahi

Department of Electrical Engineering

Amirkabir University of Technology

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Neuron Modeling of NN
    Activation Function

Neural Architecture

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.

Synaptic connections

Neuron's processing node

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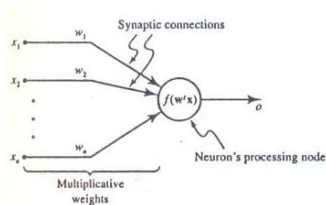
- ▶ The main artificial neuron models that is used later in this course is:
- ▶ Each neuron consists of a processing element with synaptic input connections and a single output
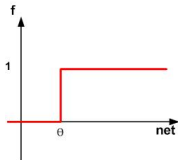- ▶ The neuron output is defined as

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

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

▶ The use of threshold will be more discussed in Perceptron and classification.

▶ 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
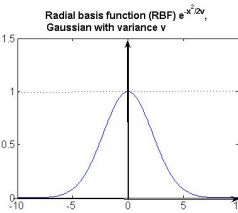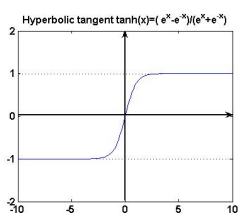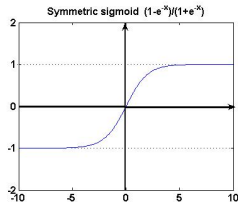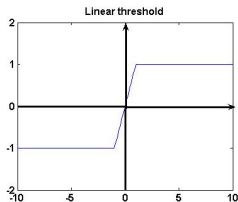
▶ Example:And

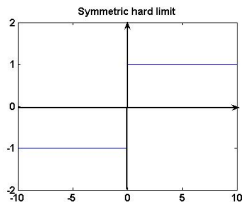| x_1	x_2	$\rightarrow$	y
1	1		1
1	0		0
0	1		0
0	0		0

$$y = \begin{cases} 1 & net \geq \theta \\ 0 & net < \theta \end{cases} , \theta = 2$$
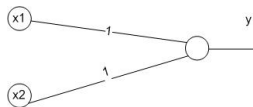
▶ Most popular activation functions:

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

- ▶ 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 weighted 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.
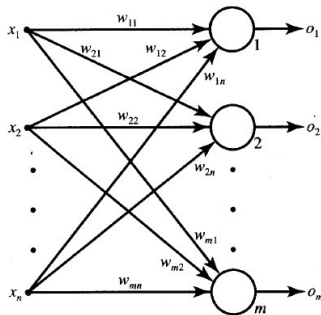
Single layer Network
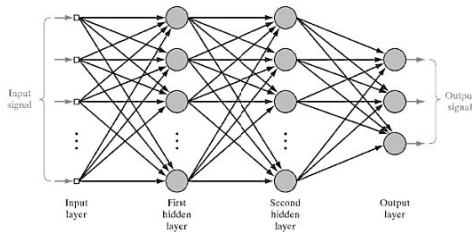
Multi Layer Network

► 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. **Feed Back Networks**

     ► It can be obtained
       from the feed forward
       network and a
       feedback connection
       form the neurons'
       outputs to their
       inputs.
     ► Like Hopfield networks