Data mining, machine learning, and uncertainty reasoning

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Close neighborhood of machine learning

- The general label of machine learning is reserved for artificial intelligence-related techniques, especially for those whose objective is to induce symbolic descriptions that are meaningful and understandable and at the same time help improve performance
- In a broad understanding, the machine learning task can be defined as any computational procedure leading to an increased knowledge or improved performance of some process or skill such as object recognition

Close neighborhood of machine learning

- Learn-to-recognize task is often addressed by methods that are not included in machine-learning paradigm but which have the same or similar objective
- Traditional pattern recognition and statistical data analysis are spawned many useful techniques
- 2 techniques must be mentioned because of their popularity, and because of the many attempts to combine them with machine-learning algorithms : neural networks and genetic algorithms

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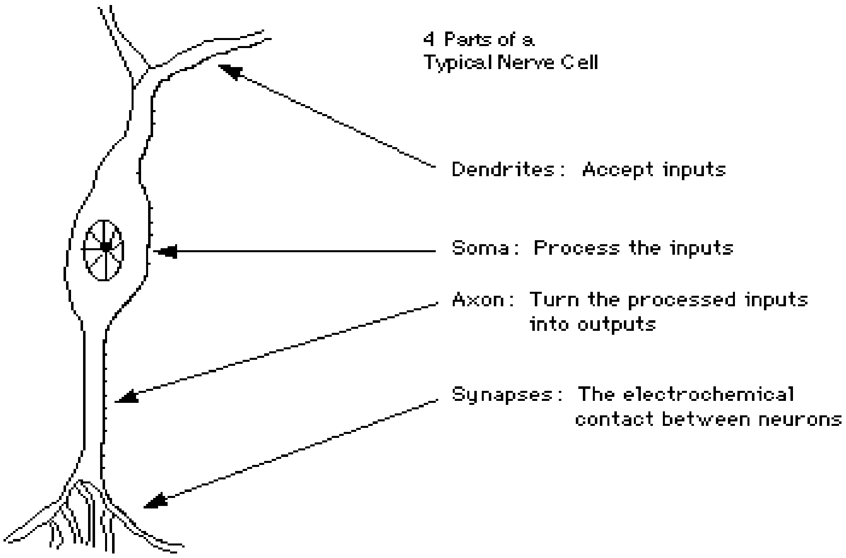
The picture of **Biological Neuron**



The Biological Neuron

- All natural neurons have 4 basic components, which are dendrites(**樹狀突**), soma(**體細胞**), axon(**神經細胞之軸索**), and synapses(**突觸**). Basically, a biological neuron receives inputs from other sources, combines them in some way, performs a generally nonlinear operation on the result, and then output the final result.

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The Biological Neuron

- The most basic element of the human brain is a specific type of cell, which provides us with the abilities to remember, think, and apply previous experiences to our every action. These cells are known as neurons(神經元), each of these neurons can connect with up to 200000 other neurons. The power of the brain comes from the numbers of these basic components and the multiple connections between them.

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Biological Neuron Architecture

- The neuron has two important parts, called the **synapse** and the **dendrite**
- The dentrites are extensions of a neuron which connect to other neurons to form a neural network
- The synapses are a gateway which connects to dentrites that come from other neurons. A biological neuron may be connected to other neurons as well as accepting connections from other neurons

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Biological Neuron Architecture

- Neuron receives information from other neurons, processes it and then relays this information to other neurons
- Neuron integrates the pulses that arrive and when this integration exceeds a certain limit, it emits a pulse
- Dentrites modify the amplitude of the pulses travelling through Neurons. This modification varies with time, as the network ‘learns’

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The Analogy to the Brain

- The most basic components of neural networks are modeled after the structure of the brain. Some neural network structures are not closely to the brain and some does not have a biological counterpart in the brain. However, neural networks have a strong similarity to the biological brain and therefore a great deal of the terminology is borrowed from neuroscience.

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What is Neural network

- It is an attempt to simulate within specialized hardware or sophisticated software, the multiple layers of simple processing elements called neurons. Each neuron is linked to certain of its neighbors with varying coefficients of connectivity that represent the strengths of these connections. Learning is accomplished by adjusting these strengths to cause the overall network to output appropriate results.

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What is Neural network

- Artificial Neural Network is a system loosely modeled on the human brain. The field goes by many names, such as connectionism, parallel distributed processing, neuro-computing, natural intelligent systems, machine learning algorithms, and artificial neural networks.

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The Artificial Neuron

- The basic unit of neural networks, the artificial neurons, simulates the 4 basic functions of natural neurons. Artificial neurons are much simpler than the biological neuron

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Artificial neural network

- Mark Rosenblatt suggested to use for pattern-recognition application by a simple device inspired by mathematical models of biological neurons
- He dubbed this device a perceptron, and showed how it can be trained for the recognition job simply by automatic adjustments of its parameters, based on a set of pre-classified examples

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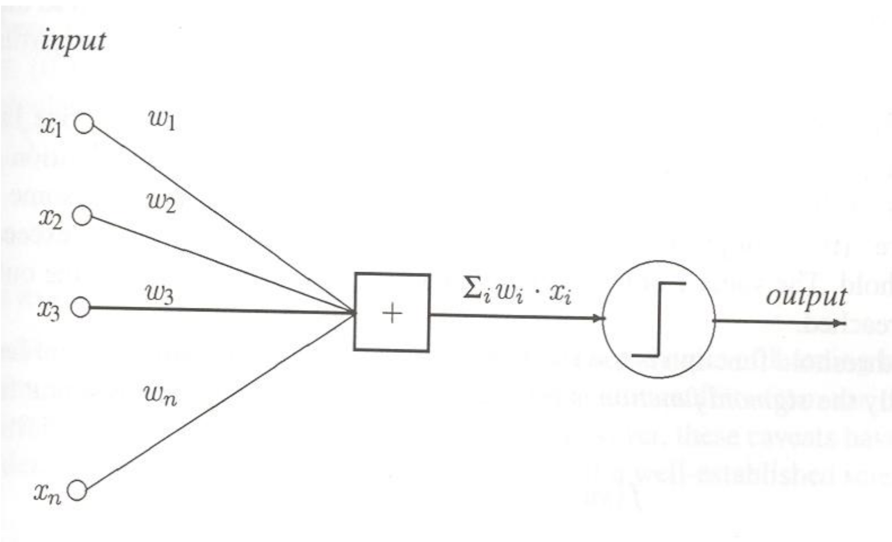
General scheme of perceptron



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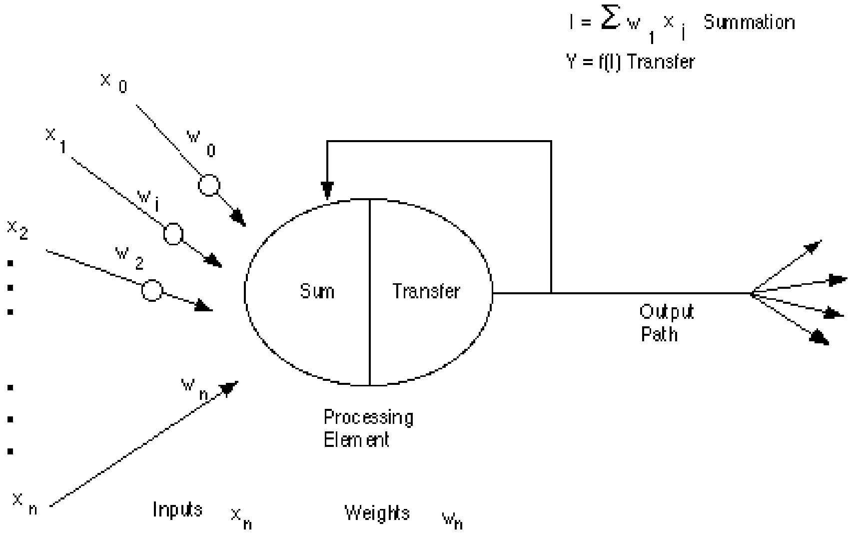
The picture of **Artificial Neuron**



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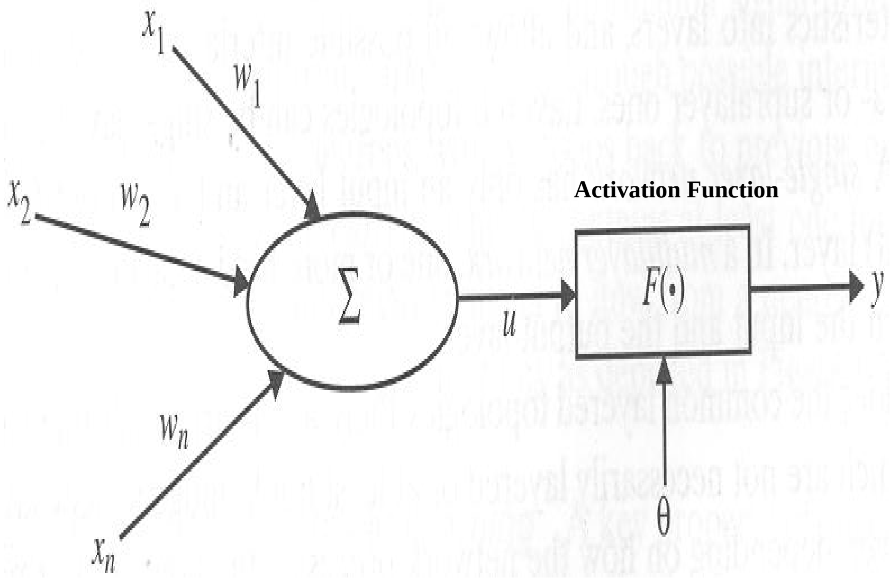
Basic neuron model



Artificial neural network

- Several input signals, x_i, each multiplied by a weight w_i, are attached to a summation unit
- The resulting sum is subjected to a step function ensuring that if the sum exceeds a certain threshold Θ, the output of the perceptron is 1, otherwise the output is 0. as an alternative to the value1 and 0, any other pair of outputs can be considered, say 1, -1

$$sum = \sum_i x_i \bullet w_i$$

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Artificial neural network

- Proper adjustments of the weights w_i and of the threshold Θ ensure that the perceptron will react to input vectors with the required output value
- The information is encoded in the weights assigned to each individual input, each input representing an attribute
- More relevant attributes are assigned more weight and less relevant attributes have less weight

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Artificial neural network

- Perceptron’s learning algorithm seeks such weight values that will accomplish the requested mapping from the space of input vectors to the set of 2 binary values, $R^n \rightarrow \{0,1\}$ or $\{1, -1\}$
- Some concepts cannot be acquired by the perceptron. That is why perceptrons are rarely used in isolation
- They are interconnected in structures such as the multilayer perceptron

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Neural network -- XOR signal

- The multilayer perceptron consists of one layer of input nodes, output nodes, and one or more ‘hidden’ layer between them
- During the recognition phase, the components of the input vectors are clamped to the input layer
- Each neuron is represented by a McCulloch-Pitts model, which uses a threshold function for its activation function
- Bit 0 and 1 are represented by the levels 0 and +1

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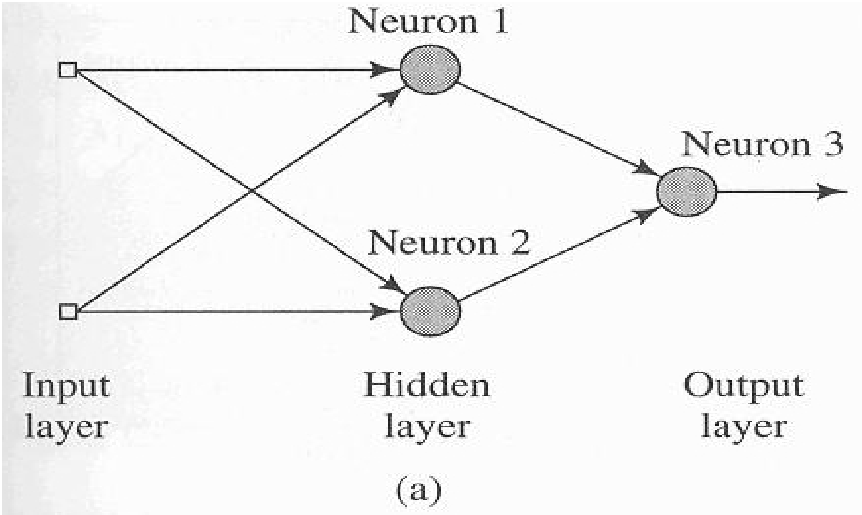
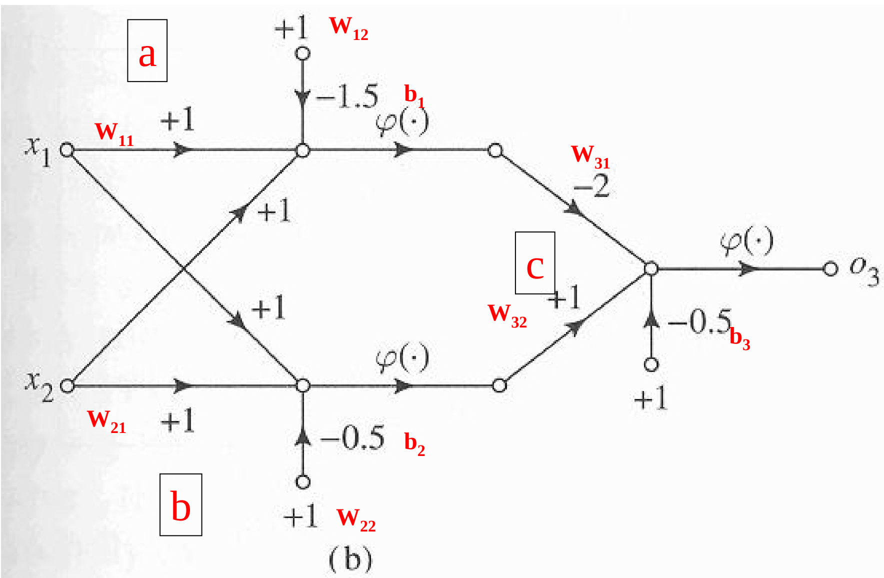
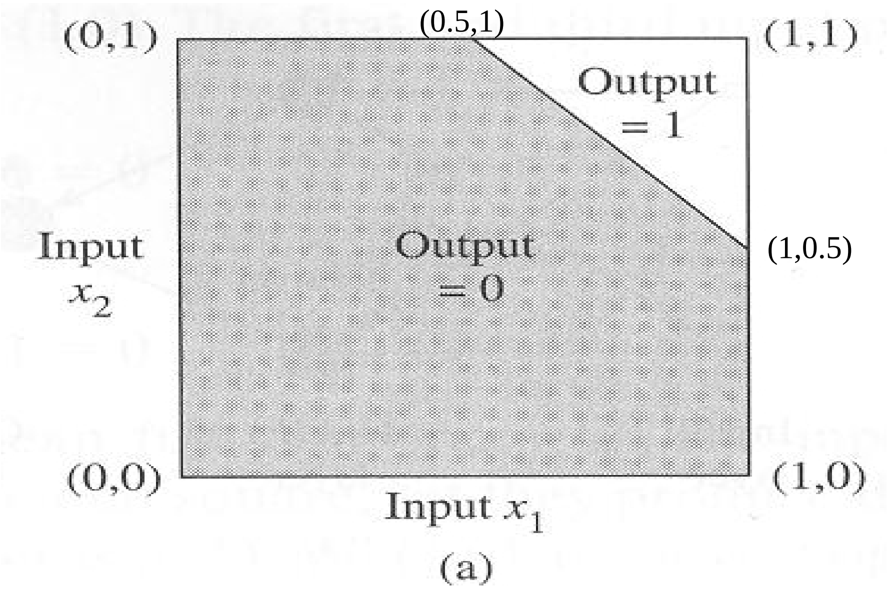
XOR signal flow graph



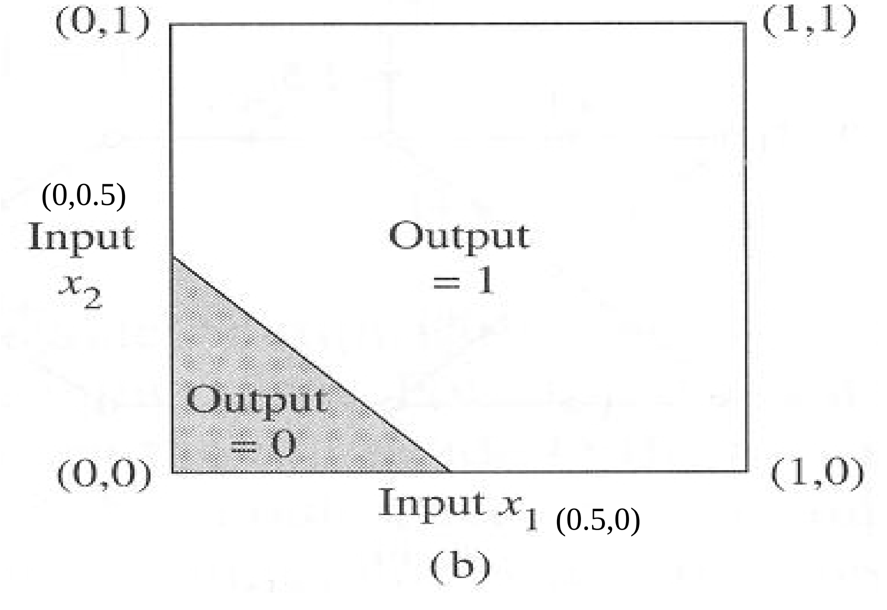
XOR signal flow graph



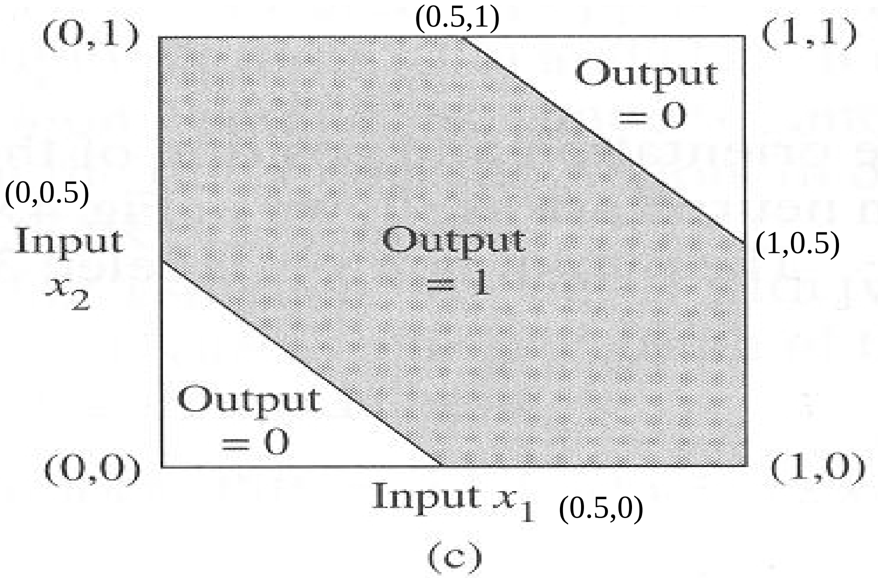
Decision boundary by upper neuron 1



Decision boundary by upper neuron 2



Decision boundary by upper neuron 3



XOR

X	Y	X XOR Y
0	0	0
0	1	1
1	0	1
1	1	0

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Neural network

- Some of the perceptrons ‘fire’ (their output is 1), when the weighted sum of their inputs exceeds the particular threshold
- The value 1 or 0 is propagated to the next layer, until the output of the network is reached
- As the basic threshold function is too rigid (it does not tolerate noise and does not facilitate learning), usually the sigmode function is used to calculate the output of a single unit from its inputs:

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

sum is the weighted sum of the signals at the input unit

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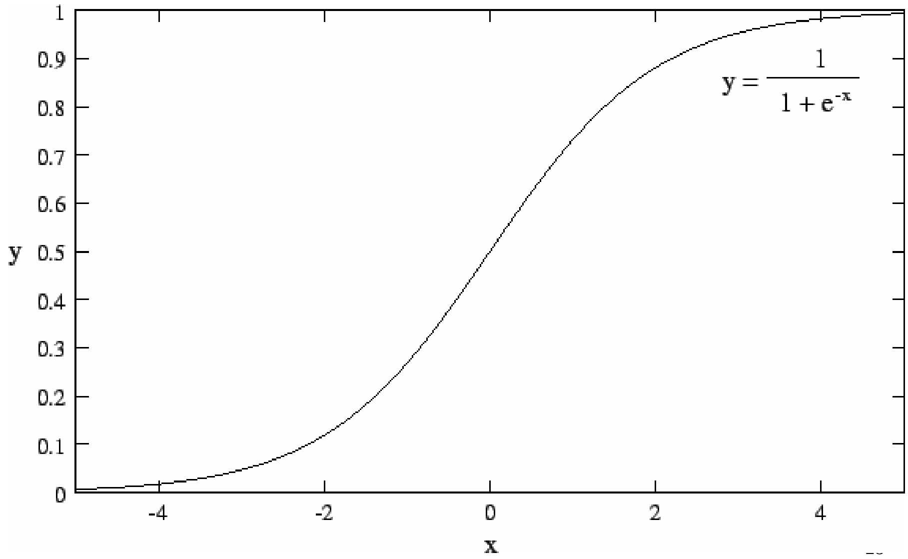
Sigmode function of output



Neural network

- According to the previous formula, the unit will output a real value between 0 and 1
- For sum=0, the output is 0.5. For large negative values of sum the output converges to 0. For large positive values of sum the output converges to 1
- The formula is more tolerant than the step function with respect to noisy signals
- In many complicated tasks, the hidden layer may be used 2 or more layers

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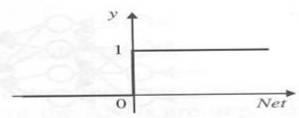
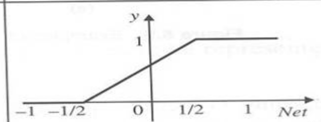
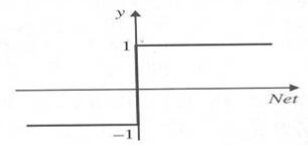
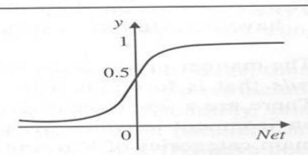
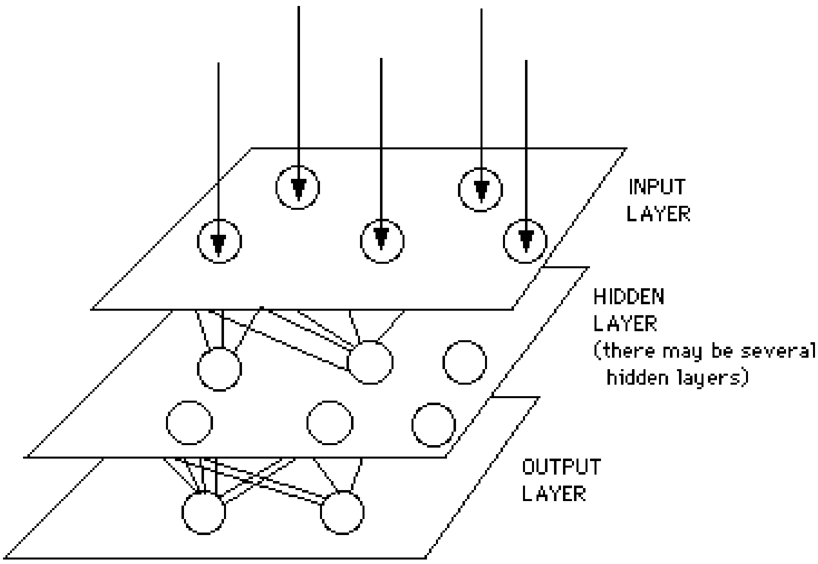
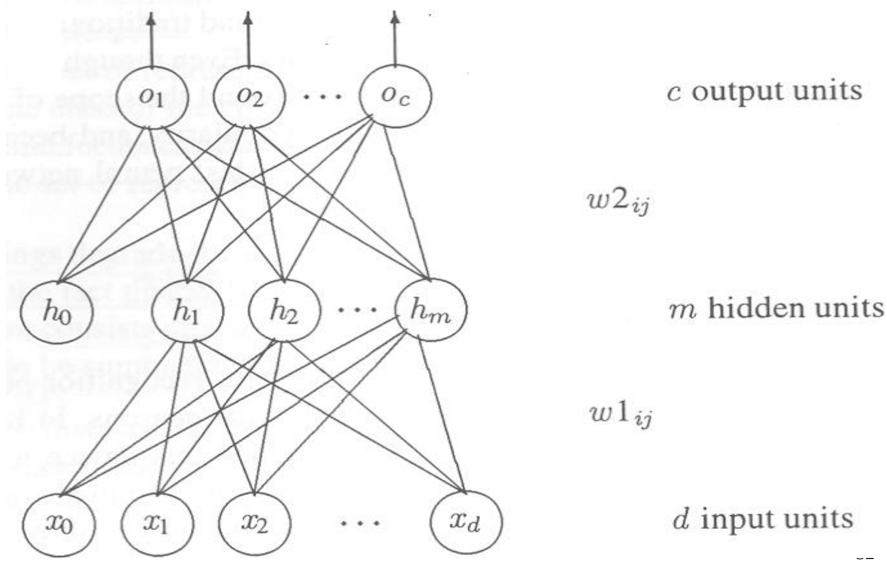
Examples of Activation functions

Threshold	$y = F(Net) = \begin{cases} 1 & Net \geq 0 \\ 0 & \text{otherwise} \end{cases}$	
Piecewise Linear	$y = F(Net) = \begin{cases} 1 & Net \geq 0 \\ 0 & Net \leq \frac{1}{2} \\ Net & -\frac{1}{2} < Net < \frac{1}{2} \end{cases}$	
Hard-Limiter	$y = F(Net) = \begin{cases} 1 & Net \geq 0 \\ -1 & Net < 0 \end{cases}$	
Sigmoid (Logistic)	$y = F(Net) = \frac{1}{1+e^{-Net}} \quad y \in (0,1)$	

Neural network architecture



Multilayer perceptron



The design of neural network

- The developer must go through a period of trial and error in the design decisions before coming up with a satisfactory design. The design issues in neural networks are complex and are the major concerns of system developers.
- The process of designing a neural network is an iterative process

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The design of neural network

- **Designing a neural network consist of:**
  - Arranging neurons in various layers
  - Deciding the type of connections among neurons for different layers, as well as among the neurons within a layer
  - Deciding the way a neuron receives input and produces output
  - Determining the strength (weight) of connection within the network by allowing the network learn the appropriate values of connection weights by using a training data set

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Interlayer connection

- There are different types of connections used between layers, these connections between layers are called inter-layer connections.
  - Fully connected
    Each neuron on the first layer is connected to every neuron on the second layer.
  - Partially connected
    A neuron of the first layer does not have to be connected to all neurons on the second layer.

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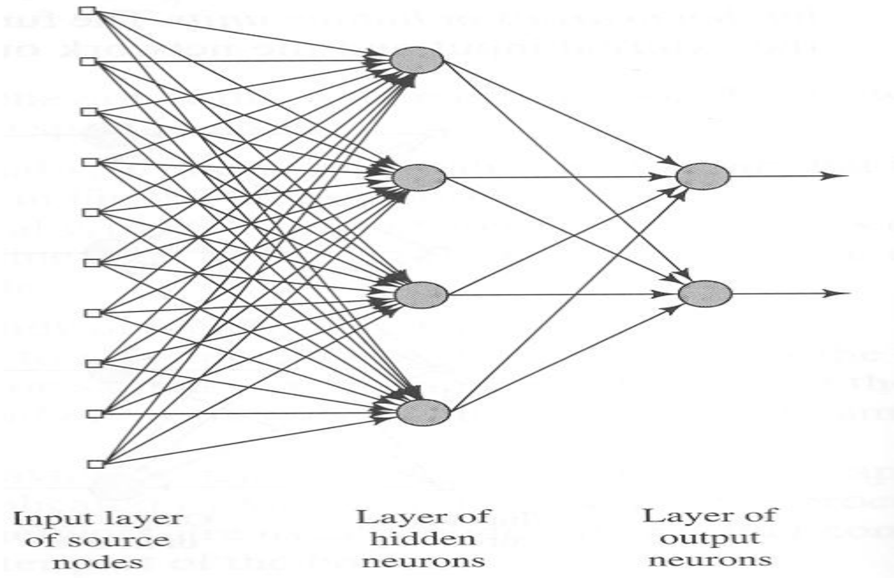
Interlayer connection– Fully connected



Interlayer connection

– Feed forward

The neurons on the first layer send their output to the neurons on the second layer, but they do not receive any input back from the neurons on the second layer.

– Bi-directional

There is another set of connections carrying the output of the neurons of the second layer into the neurons of the first layer. Feed forward and bi-directional connections could be fully- or partially connected.

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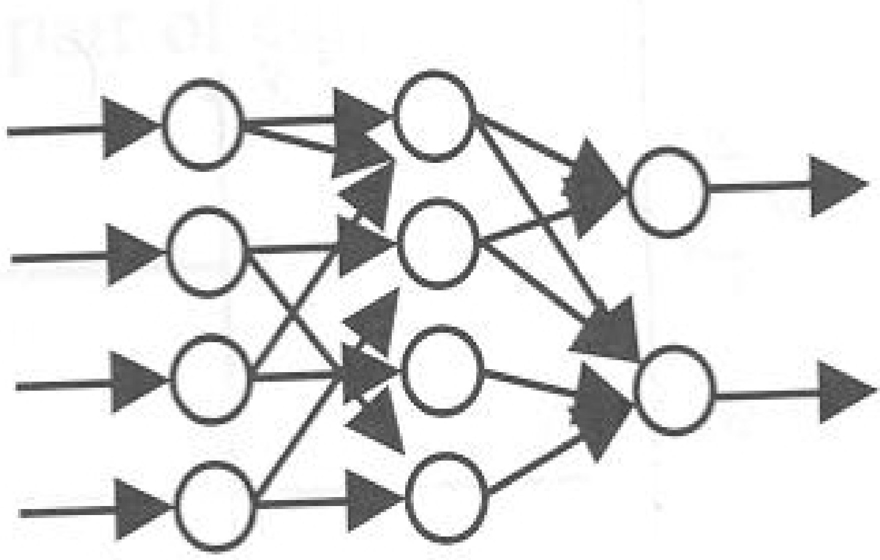
Interlayer connection– Feed Forward



Interlayer connection

- Hierarchical
  If a neural network has a hierarchical structure, the neurons of a lower layer may only communicate with neurons on the next level of layer.
- Resonance(共鳴)
  The layers have bi-directional connections, and they can continue sending messages across the connections a number of times until a certain condition is achieved.

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Intra-layer connection

- In more complex structures the neurons communicate among themselves within a layer, this is known as intra-layer connections. There are two types of intra-layer connections such as Recurrent, On-center/off surround connection

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Intra-layer connection (**Recurrent**)

– **Recurrent**（週期性）

The neurons within a layer are fully- or partially connected to one another. After these neurons receive input form another layer, they communicate their outputs with one another a number of times before they are allowed to send their outputs to another layer. Generally some conditions among the neurons of the layer should be achieved before they communicate their outputs to another layer.

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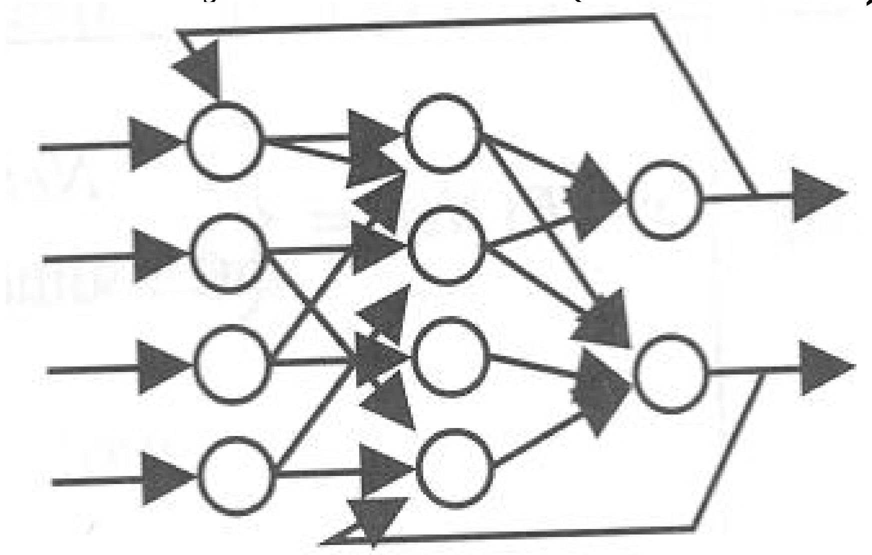
Intra-layer connection (**Recurrent**)



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Intra-layer connection (**Recurrent**)

- There are two types of connections between two neurons, excitatory or inhibitory.
- In the excitatory connection, the output of one neuron increases the action potential of the neuron to which it is connected.

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Intra-layer connection (**Recurrent**)

- When the connection type between two neurons is inhibitory, the output of the neuron sending a message would reduce the activity or action potential of the receiving neuron.
- Excitatory connection causes the summing mechanism of the next neuron to add while the inhibitory connection causes it to subtract.

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Intra-layer connection **(On-center/off surround)**

- A neuron within a layer has excitatory connections to itself
- Its immediate neighbors, has inhibitory connections to other neurons.

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Intra-layer connection **(On-center/off surround)**

- One can imagine this type of connection as a competitive gang of neurons.
- Each gang excites itself and its gang members and inhibits all members of other gangs.
- After a few rounds of signal interchange, the neurons with an active output value will win, and is allowed to update its and its gang member's weights.

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