Artificial Neural Networks

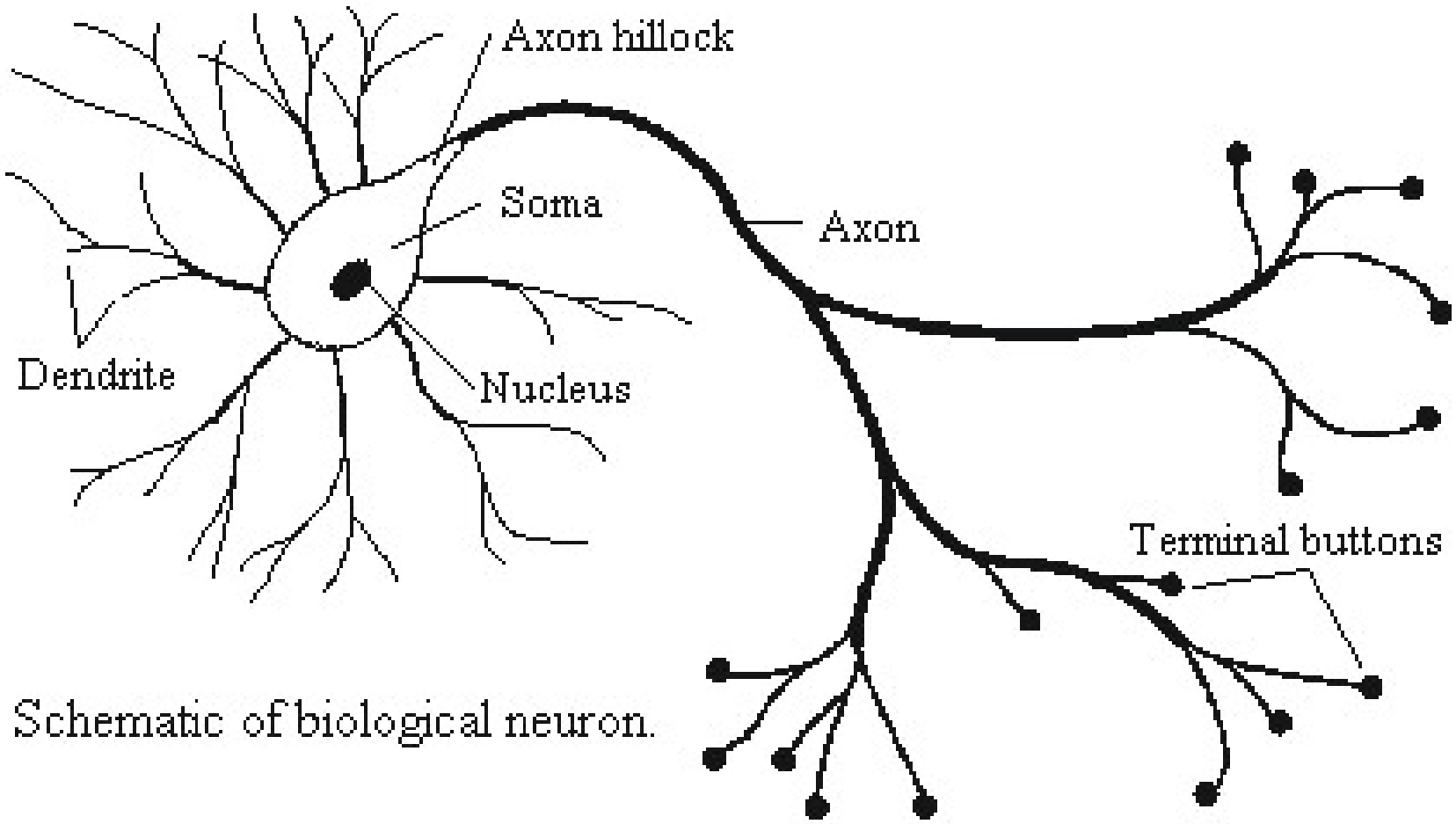
What is Neural Net?

- A neural network is an interconnected group of neurons.

Example : Human brain

- An *Artificial Neural Network* is a mathematical or computational model for information processing based on a connectionist approach to computation.

Biological Neuron

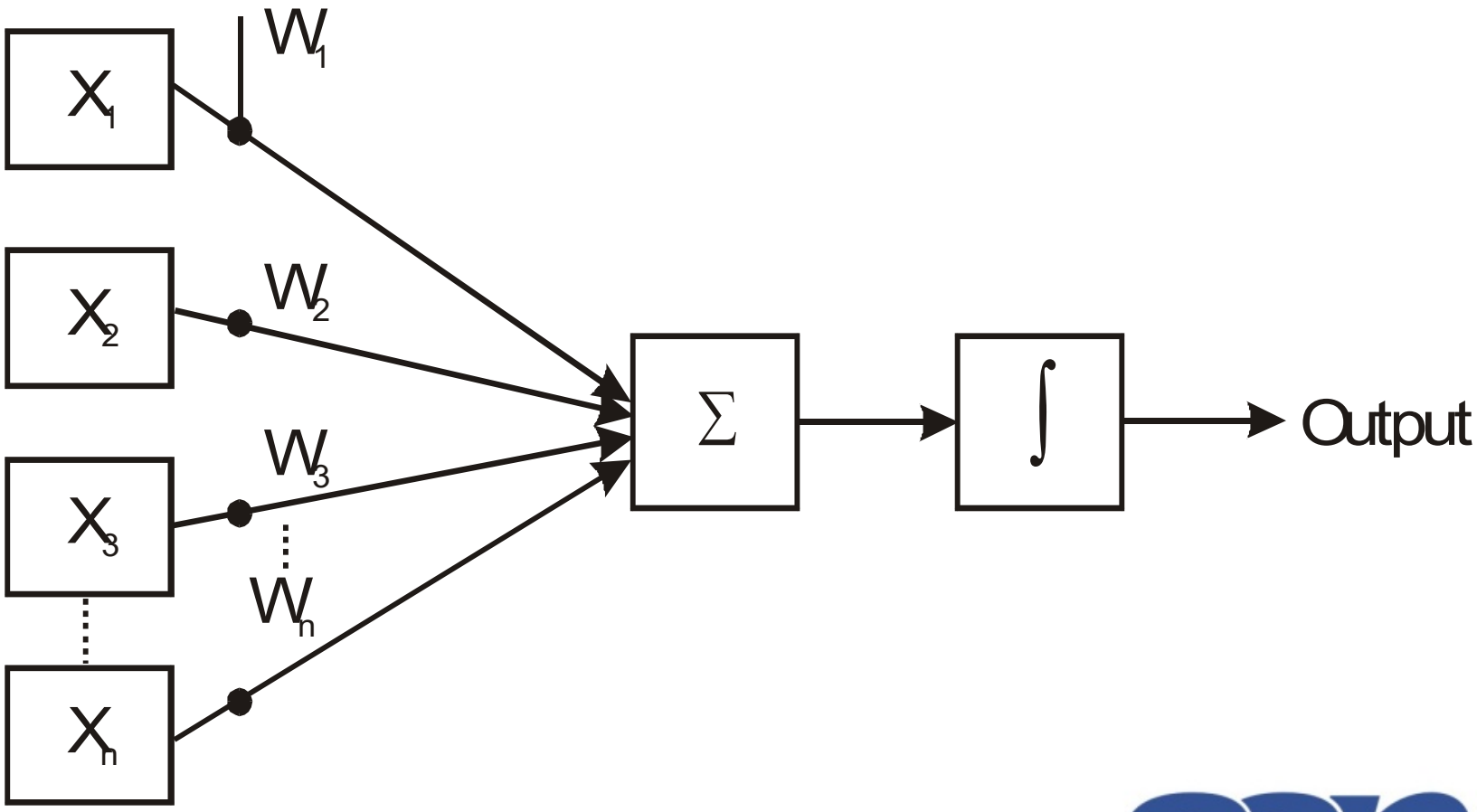


Schematic of biological neuron.

Contd…

- The character of real neuron is not modelled.
- Stimulation of dendrites is done using electro chemical reaction.
- Billion times faster in decision making process.
- More fault tolerant
- Autonomous learning is possible.

Artificial Neuron



Contd…

- The properties are derived by simply adding up the weighted sum as its input.
- A process output is derived using

logical circuits.

- Million times faster in decision making

process.

- Less fault tolerant.
- Autonomous learning is not possible.

Biological neuron Vs AN

Table 2-1 Terminology relationships between biological and artificial neurons

Biological neuron	Artificial neuron
Cell	Neuron
Dendrites	Weights or interconnections
Soma	Net input
Axon	Output

Hebb's rule

Hebb's rule says that the changes in the strength of synaptic connections are proportional to the correlation in the firing of the two connecting neurons. So

Hebb's rule

- Hebb's Law can be represented in the form of two rules:

1. **If two neurons on either side of a connection are activated synchronously, then the weight of that connection is increased.**
2. **If two neurons on either side of a connection are activated asynchronously, then the weight of that connection is decreased**

McCulloch and Pitts Neurons

(1) **a set of weighted inputs** w_i that correspond to the synapses

(2) **an adder** that sums the input signals (equivalent to the membrane of the cell that collects electrical charge)

(3) **an activation function** (initially a threshold function) that decides whether the neuron fires ('spikes') for the current inputs

McCulloch and Pitts Neurons

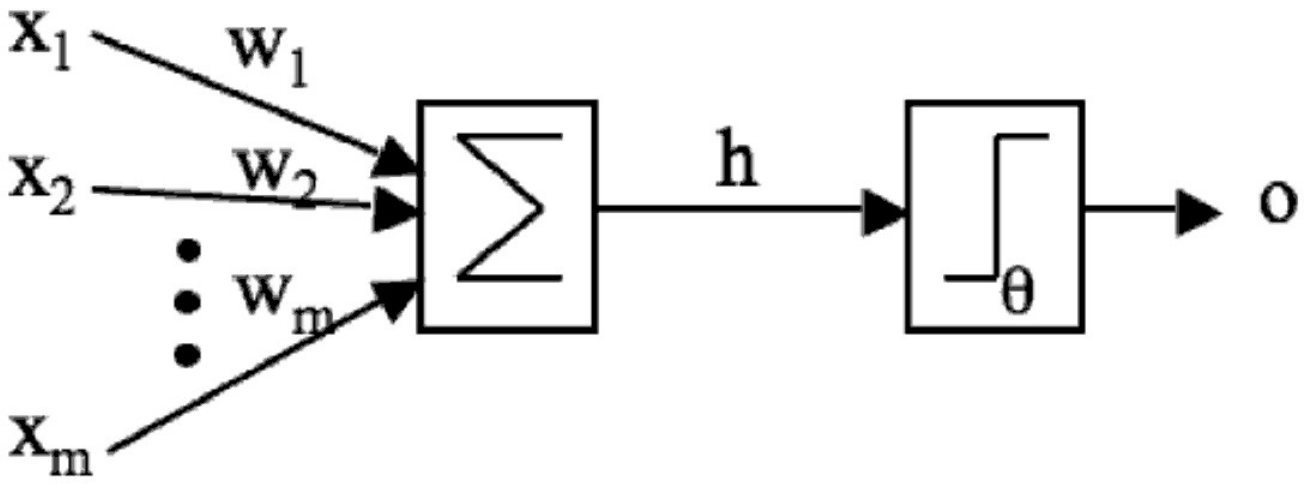


FIGURE 1.6: A picture of McCulloch and Pitt's mathematical model of a neuron. The inputs x_i are multiplied by the weights w_i, and the neurons sum their values. If this sum is greater than the threshold θ then the neuron fires, otherwise it does not.

McCulloch and Pitts Neurons

$$h = \sum_{i=1}^{m} w_i x_i,$$

If the synaptic weights are $w_1 = 1, w_2 = -0.5, w_3 = -1$, then the inputs to our model neuron are $h = 1 \times 1 + 0 \times -0.5 + 0.5 \times -1 = 1 + 0 + -0.5 = 0.5$.

McCulloch and Pitts Neurons

The McCulloch and Pitts neuron is a binary threshold device. It sums up the inputs (multiplied by the synaptic strengths or weights) and either fires (produces output 1) or does not fire (produces output 0) depending on whether the input is above some threshold. We can write the second half of the work of the neuron, the decision about whether or not to fire (which is known as an **activation function**), as:

$$o = g(h) = \begin{cases} 1 & \text{if } h > \theta \\ 0 & \text{if } h \leq \theta. \end{cases} \tag{1.2}$$

Limitations

- Linear summation
- Synchronous with clock
- Weights can change from positive to negative or vice versa(excitatory or inhibitory in real neuron)
- No link to feedback loop

Neural Net Architecture

- The arrangement of neurons into layers and the connection patterns within and between layers is called the net architecture.
- The network structure is broadly classified into two categories depends on the connection established in the network (network structure) and the number of layers.

Network structure

- Feed Forward Networks

  Represents any arbitrary function, no internal states

  – Single Layer Perceptron

  – Multi Layer Perceptron

- Recurrent Networks

  Output is fed back with delay, has internal states, can oscillate

  – Hopfield Network

  – Boltzmann Machine

Evolution of NN

Table 2-2 Evolution of neural networks

Year	Neural network	Designer	Description
1943	McCulloch and Pitts neuron	McCulloch and Pitts	The arrangement of neurons in this case is a combination of logic functions. Unique feature of this neuron is the concept of threshold.
1949	Hebb network	Hebb	It is based upon the fact that if two neurons are found to be active simultaneously then the strength of the connection between them should be increased.
1958, 1959, 1962, 1988	Perceptron	Frank Rosenblatt, Block, Minsky and Papert	Here the weights on the connection path can be adjusted.
1960	Adaline	Widrow and Hoff	Here the weights are adjusted to reduce the difference between the net input to the output unit and the desired output. The result here is very negligible. Mean squared error is obtained.
1972	Kohonen self-organizing feature map	Kohonen	The concept behind this network is that the inputs are clustered together to obtain a fixed output neuron. The clustering is performed by winner-take all policy.
1982, 1984, 1985, 1986, 1987	Hopfield network	John Hopfield and Tank	This neural network is based on fixed weights. These nets can also act as associative memory nets.

Evolution of NN

1986	Back-propagation network	Rumelhart, Hinton and Williams	This network is multi-layer with error being propagated backwards from the output units to the hidden units.
1988	Counter-propagation network	Grossberg	This network is similar to the Kohonen network; here the learning occurs for all units in a particular layer, and there exists no competition among these units.
1987–1990	Adaptive Resonance Theory (ART)	Carpenter and Grossberg	The ART network is designed for both binary inputs and analog valued inputs. Here the input patterns can be presented in any order.
1988	Radial basis function network	Broomhead and Lowe	This resembles a back propagation network but the activation function used is a Gaussian function.
1988	Neo cognitron	Fukushima	This network is essential for character recognition. The deficiency occurred in cognitron network (1975) was corrected by this network.

Summary

- Human brain structure
- ANN Vs Biological neuron
- Hebb rule
- MC & Pits NN
- NN structure – feed forward, Recurrent
- Evolution of NN

Check your understanding

- The fundamental unit of Brain network is
  a) brain
  b) nucleus
  c) neuron
  d) axon

- Signal transmission at synapse is a?
  a) physical process
  b) chemical process
  c) physical & chemical both
  d) none of the mentioned

Check your understanding

- When the cell is said to be fired?
  a) if potential of body reaches a steady threshold values
  b) if there is impulse reaction
  c) during upbeat of heart
  d) none of the mentioned

- What is hebb's rule of learning
  a) the system learns from its past mistakes
  b) the system recalls previous reference inputs & respective ideal outputs
  c) the strength of neural connection get modified accordingly

Check your understanding

- What was the name of the first model which can perform wieghted sum of inputs?
  a) McCulloch-pitts neuron model
  b) Marvin Minsky neuron model
  c) Hopfield model of neuron