Neural Network

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Introduction to Neural Network

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- Benefits of Neural Networks
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What is a Neural Network?

- A neural network is:
  - A massively parallel distributed processor made up of simple processing units called neurons.
  - Has tendency for storing knowledge and making it available for use.
  - Has ability to change its structure and modify according to application requirement.
- It resembles the brain in two respects:
  - Knowledge is acquired by the network from its environment through the learning process.
  - Inter neuron connection strengths, known as synaptic weights, are used to store the acquired knowledge.

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Benefits of Neural Networks

- Nonlinearity (NN could be linear or nonlinear)
  - A highly important property, particularly if the underlying physical mechanism responsible for generation of the input signal (e.g. speech signal) is inherently nonlinear.
- Input-Output Mapping
  - Knowledge is acquired by the network from its environment through the learning process.It finds the optimal mapping between an input signal and the output results through learning mechanism that adjust the weights that minimize the difference between the actual response and the desired one. (non parametric statistical inference).
- Adaptivity
  - A neural network could be designed to change its weights in real time, which enables the system to operate in a non stationary environment.

Benefits of Neural Networks

- Evidential Response
  - In the context of pattern classification, a network can be designed to provide information not only about which particular pattern to select, but also about the confidence in the decision made.
- Contextual Information
  - Every neuron in the network is potentially affected by the global activity of all other neurons. Consequently, contextual information is dealt with naturally by a neural network.
- Fault tolerance
  - A neural network is inherently fault tolerant, or capable of robust computation, in the sense that its performance degrades gracefully under adverse operating conditions.

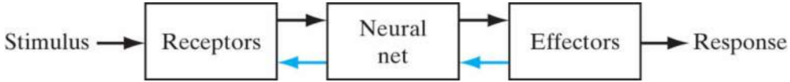
Benefits of Neural Networks

- VLSI Implementation
  - The massively parallel nature of a neural network, makes it potentially fast for a certain computation task, which also makes it well suited for implementation using VLSI technology.
- Uniformity of Analysis and Design
  - Neural networks enjoy universality as information processors:
    - Neurons, in one form or another, represent an ingredient common to all neural networks, which makes it possible to share theories and learning algorithms in different applications.
    - Modular networks can be built through a seamless integration of modules.
- Neurobiology Analogy
  - The design of a neural network is motivated by analogy to the brain (the fastest and powerful fault tolerant parallel processor).

Application of Neural Networks

- Neural networks are tractable and easy to implement, Specially in hardware. This made it attractive to be used in a wide range of applications:
  - Pattern Classifications
  - Medical Applications
  - Forecasting
  - Adaptive Filtering
  - Adaptive Control

- The human nervous system may be viewed as a three-stage system:
  - The brain, represented by the neural net, is central to the system. It continually receive information, perceives it, and makes appropriate decision.
  - The receptors convert stimuli from the human body or the external environment into electrical impulses that convey information to the brain.
  - The effectors convert electrical impulses generated by the brain into distinct responses as system output



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The Human Brain

- There are approximately 10 billion neurons in the human cortex, compared with 10 of thousands of processors in the most powerful parallel computers.
- Each biological neuron is connected to several thousands of other neurons.
- The typical operating speeds of biological neurons is measured in milliseconds $(10^{-3}s)$, while a silicon chip can operate in nanoseconds $(10^{-9}s)$. (Lack of processing units in computers can be compensated by speed.)
- The human brain is extremely energy efficient, using approximately 10^{-16} joules per operation per second, whereas the best computers today use around 10^{-6} joules per operation per second.

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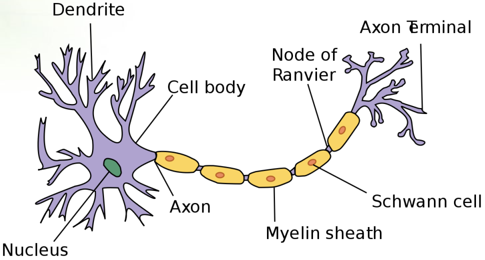
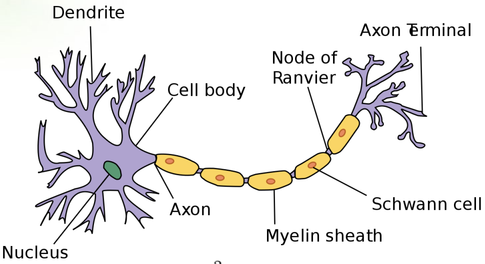
Biological Neuron cell

- The neurons cell body (soma) processes the incoming activations and converts them into output activations.
- Dendrites are fibers which emanate from the cell body and provide the receptive zones that receive activation from other neurons.



Biological Neuron cell

- Axons are fibers acting as transmission lines that send activation to other neurons.
- The junctions that allow signal transmission between the axons and dendrites are called synapses. The process of transmission is by diffusion of chemicals called neurotransmitters across the synaptic connection.



Brief History of ANN I

- 1943: McCulloch and Pitts proposed the McCulloch-Pitts neuron model.
- 1949: Hebb published his book The Organization of Behavior, in which the Hebbian learning rule was proposed.
- 1958: Rosenblatt introduced the simple single layer networks now called Perceptrons.
- 1969: Minsky and Paperts book Perceptrons demonstrated the limitation of single layer perceptrons, and almost the whole field went into hibernation.
- 1982: Hopfield published a series of papers on Hopfield networks.
- 1982: Kohonen developed the Self-Organising Maps that now bear his name.
- 1986: The Back-Propagation learning algorithm for Multi-Layer Perceptrons was rediscovered and the whole field took off again.

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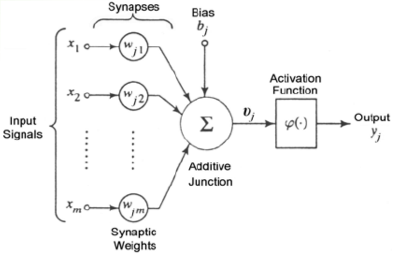
Brief History of ANN II

- 1990: The sub-field of Radial Basis Function Networks was developed.
- 2000: The power of Ensembles of Neural Networks and Support Vector Machines becomes apparent

The artificial neuron is made up of three basic elements:

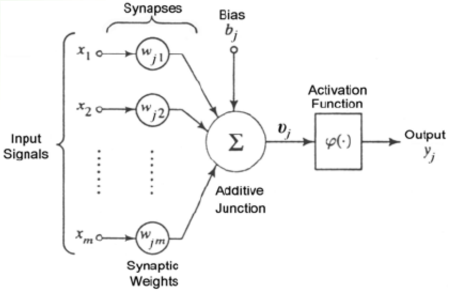
- A set of synapses, or connecting links, each of which is characterized by a weight or strength of its own
- An adder for summing the input signals, weighted by the respective synaptic weight.
- An activation function for limiting the amplitude of the output of a neuron.



Models of a Neuron

In mathematical terms:

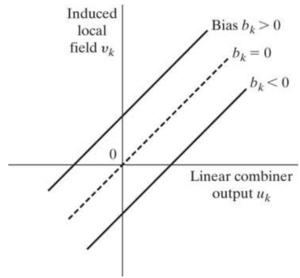
- The output of the summing function is the linear combiner output: $u_k = \sum_{j=1}^{m} w_{kj} x_j$
- and the final output signal of the neuron: $y_k = \varphi(u_k + b_k)$
- $\varphi(.)$ is the activation function.



Effect of a Bias

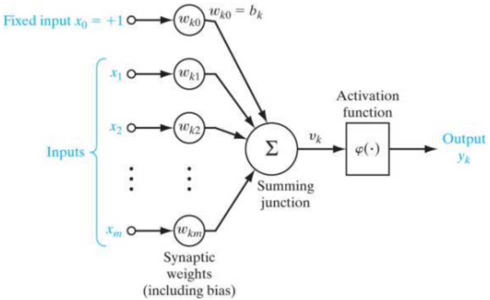
In mathematical terms:

- The use of a bias b_k has the effect of applying affine transformation to the output u_k: $v_k = u_k + b_k$
- That is, the bias value changes the relation between the induced local field, or the activation potential v_k, and the linear combiner u_k as shown in Fig.



Models of a Neuron

- Then we may write: $v_k = \sum_{j=0}^{m} w_{kj} x_j$
- and $y_k = \varphi(v_k)$
- where $x_0 = +1$ and $w_k^0 = b_k$



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