Artificial Neural Network

Introduction:

Artificial neural networks models have been extensively studied with the aim of achieving human-like performance, especially in the field of pattern recognition.

These networks are composed of a numbers of nonlinear computational elements which operate in parallel and are arranged in a manner reminiscent of biological neural interconnections.

The area of neural networks is nowadays considered from main two perspectives:

- The first perspective is cognitiv science (studying of the mind).
- The second perspective is connectionism, which is a theory of information processing.

What is a Neural networks

- Work on artificial neural network (ANN) commonly referred to as "neural networks" (NN).
- The human brain computes in a way which is differ than the conventional computer. The brain is: ***a highly complex, nonlinear, and parallel computer (information processing system)***. It has the capability to organize its structure constituents known as neurons.

  -The human vision represents an example on the information processing in the brain. In which the brain routinely accomplishes perceptual recognition tasks in approximately 100-200 ms, whereas tasks of much lesser complexity take a great deal longer on a powerful computer.

  -Another example is **the sonar of the bat**. Sonar is an active echolocation system (echo is the repetition of a sound by the reflection of sound waves, or the reflected radio or radar beam). In addition to providing information about ***how far away a target is*** (e.g. a flying insect), bat sonar ***conveys information about the relative velocity of the target***, ***the size of various features of the target***, and ***the azimuth and elevation of the target***. The complex neural computations needed to extract all this information from the target echo occur within a brain of small size. Indeed, an echolocating bat can capture its target with a facility and success rate that would be the envy of a radar or sonar engineer.

- At birth, a brain already has considerable structure and the ability to build up its own rules of behavior through what we usually refer to as "**experience**". Indeed experience is build up over time.
- In general, a neural network is a machine that is designed to model the way in which the brain performs a particular task or function of interest. The network is usually implemented by using electronic components or is simulated in software on a digital computer. To achieve good performance, neural networks employ a massive interconnection of simple computing cells referred to as **"neurons"** or **"processing units"**.-

<u>Definition of a neural network</u>-

A neural network is a massively parallel distributed processor made up of simple processing units that has a natural propensity for storing experiential knowledge and making it available for use. It resembles the brain in two respects:

1- Knowledge is acquired by the network from its environment through a learning process.

2- Interneuron connection strengths known as "synaptic weights" are used to store the acquired knowledge.

The procedure used to perform the learning process is called ***a learning algorithm***, the ***function of which is to modify the synaptic weights*** of the network in an orderly fashion to attain a desired design objective.

- Artificial neural networks have been developed as generalizations of mathematical models of human cognition or neural biology, based on the assumptions that:

1. Information processing occurs at many simple elements called neurons.
2. Signals are passed between neurons over connection links.
3. Each connection link has an associated weight, which, in a typical neural net, multiplies the signal transmitted.
4. Each neuron applies an activation function (usually nonlinear) to its net input (sum of weighted input signals) to determine its output signal.

A neural network is characterized by:

(1) its pattern of connections between the neurons (called its architecture).

(2) its method of determining the weights on the connections (called its training, or learning, algorithm).

(3) its activation function.

<u>Benefits of neural networks</u>

1- **Nonlinearity:** An artificial neuron can be linear on nonlinear. A neural network made up of an interconnection of nonlinear neurons, is itself nonlinear. ***Nonlinearity is a highly important property***, particularly if the underlying physical mechanism responsible for generation of the input signal is inherently nonlinear (e.g., speech signal).

2- **Input-Output mapping:** The learning process involves **modification of the synaptic weights** of N.N by applying a set of labeled **training examples**. Each example consists of a unique input signal and a corresponding desired (target) response. **The training of the networks is repeated** for many examples in the set, until the network reaches a **steady state**. The previously applied training examples may be applied during the training session , but in a different order. ***Thus the network learns from the examples by constructing an input-output mapping for the problem at hand.***

3- **Adaptivity:** N.Ns have a built-in capability to adapt their synaptic weights to change in surrounding environment. And may be designed to change their synaptic weights in real time. The adaptive capability of the network makes it a useful tool in adaptive pattern classification, adaptive signal processing, and adaptive control. ***As a general rule, it may be said that the more adaptive we make the system, all the time ensuring that the system remains stable, the more robust its performance will likely be when the system is required to operate in a nonstationary environment.***

4- **Evidential response :** In the context of ***pattern classification***, a neural network can be designed to provide information not only about which particular pattern to select, but also about the confidence in the **decision made**. This latter information may be used to reject ambiguous patterns, should they arise, and thereby **improve the classification performance** of the network.

<u>Neural Networks Applications</u>

A wide variety of problems in many fields can be solved using neural networks. Some of these applications:

- Aerospace

High performance aircraft autopilots, flight path simulations, aircraft control systems, autopilot enhancements, aircraft component simulations, aircraft component fault detectors

- Automotive

Automobile automatic guidance systems, warranty activity analyzers

- Banking

Check and other document readers, credit application evaluators

- Defense

Weapon steering, target tracking, object discrimination, facial recognition, new kinds of sensors, sonar, radar and image signal processing including data compression, signal/image identification

Electronics

Code sequence prediction, integrated circuit chip layout, process control, chip failure analysis, voice synthesis , nonlinear modeling

Entertainment

Animation, special effects, market forecasting

Financial

Real estate appraisal, corporate financial analysis, currency price prediction

Insurance

Policy application evaluation, product optimization

Manufacturing

Manufacturing process control, product design and analysis, process and machine diagnosis, visual quality inspection systems, computer chip quality analysis, analysis of grinding operations, chemical product design analysis, machine maintenance analysis, planning and management, dynamic modeling of chemical process systems

Medical

Breast cancer cell analysis, EEG and ECG analysis, hospital expense reduction, hospital quality improvement

Oil and Gas

Exploration

Robotics

Trajectory control, forklift robot, manipulator controllers , vision systems

Speech

Speech recognition, speech compression, text to speech synthesis

Telecommunications

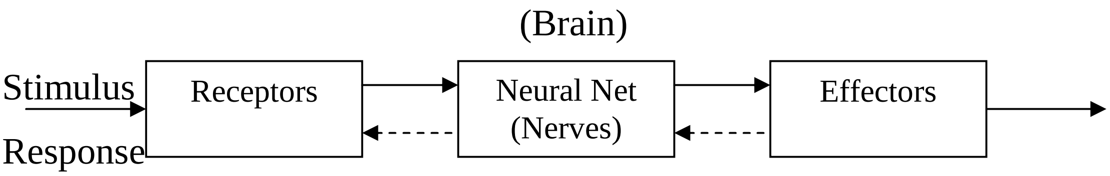
Image and data compression, automated information services, real-time translation of spoken language.

Transportation

Truck brake diagnosis systems, vehicle scheduling, routing systems

The human brain

The human nervous system may be viewed as a three-stage system as shown in fig. (1):



⟶ Forward transmision of information

- - - -▸ Feedback

Fig. (1) Block diagram representation of nervous system

1- Respectors: convert stimula from the human body or the external environment into electrical impulses that convey information to the neural net (brain).

2- Brain: continually receives information, perceive it, and make appropraite decisions.

3- Effectors: convert electrical impulses generated by the neural net into discernible response as system output.

- **Neurons are slower than silicon logic gates**. Events in ***a silicon chip happen in the nanosecond range***, while ***neural events happen in the millisecond***. But the brain have staggering number of neurons with massive iterconnections between them. The net result that the brain is an enormously efficient structure (***there are approximately 10 billion neurons and 60 trillion synapses or connections***).
- ***The energetic efficiency of the brain is approximately 10^{-6} Joules (J) per operation per second***, whereas the corresponding value for the ***best computers is orders of magnitude larger.***
- Synapses or nerve endings are elementary structural and functional units that mediate the interaction between neurons.
- The most common kind of synapse is a chemical synapes, which operates as follows:
  - Synapse ***converts a presynptic electrical signal*** into ***chemical signal*** and ***then back into a postsynaptic electrical signal***, as illustrate in fig. (2).

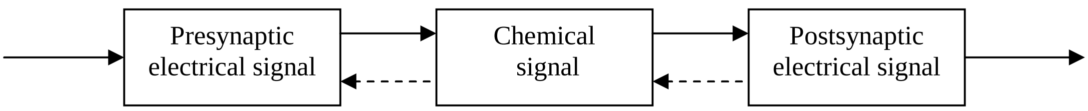
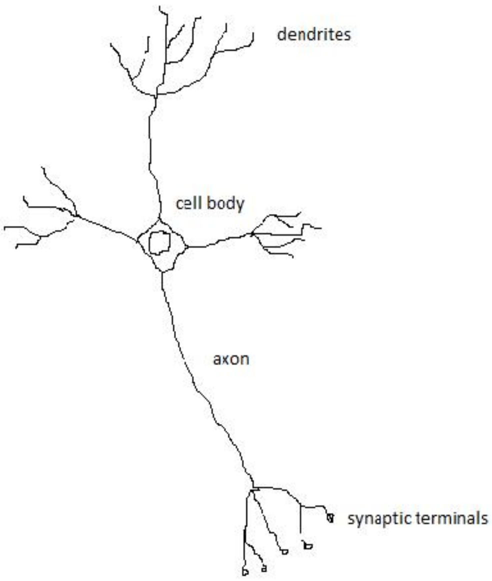


Fig. (2) the operation of chemical synapse

- ***Neurons come in a wide variety of shapes and sizes*** in different parts of the brain. ***<u>Fig. (3) illustrate the shape of pyramidal</u>*** cell, which is one of the most common types.
- The pyramidal cell ***can receive 10,000 or more synaptic contacts***, and it can ***project onto thousands of target cells***.
- The neurons ***encode their outputs as a series of brief voltage pulses*** (known as action potential) originate at or close to the cell

body of the neurons and then propogate across the individual neurons at constant velocity and amplitude. The axon of a neuron is very long and thin and is characterized by high electrical resistance and very large capacitance. The ***axon may therefore be modeled as (RC) transmision line***.



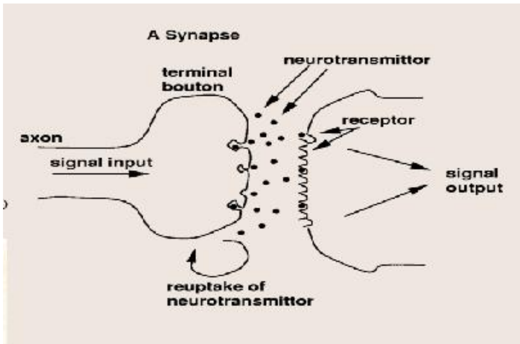


Fig. (3) The pyramidal Cell