## 1.3. OVERVIEW OF NEURAL NETWORKS

[MDU, May 2008]

### 1.3.1. What is Artificial Neural Network ?

An Artificial Neural Network (ANN) is an information-processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. It is composed of a large number of highly interconnected processing elements (neurons) working in parallel to solve specific problems. The weights on the connections encode the knowledge of a network. Each neuron has a local memory and the output of each neuron depends upon only the input signals arriving at the neuron and value in neuron's memory. ANNs, **like people**, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true for ANNs as well.

In many tasks such as recognizing human and understanding speech, current AI systems cannot do better than humans. It is conjectured that the structure of the brain is somehow suited to these tasks and not suited to these tasks such as high speed arithmetic calculation. Rather than by being programmed an ANN can solve the problems simply by example mapping.

The intelligence of a neural network emerges from the collective behavior of neurons, each of which performs only very limited operation. Even though each individual neuron works slowly, they can still quickly find the solution by working in parallel. This fact can explain why humans can recognize a visual scene faster than a digital computer, while an individual brain cell responds much more slowly than a digital cell in VLSI circuit.

Neural Networks are identified by different names such as

(*i*) Artificial Neural Networks

(*ii*) Connectionists Network

(*iii*) Parallel distributed processing systems

### 1.3.2. Advantages of Neural Network

Neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. A trained neural network can be thought of as an "expert" in the category of information it has been given to analyze. Other advantages include:

(*i*) Its structure massively distributed in parallel. The information processing takes place through the iteration of a great amount of computational neurons, each one of them send exciting or inhibiting signals to other nodes in the network. Differing from other classic Artificial Intelligence methods where the information processing can be considered sequential—this is step by step even when there is not a predetermined order, in the Artificial Neural Networks this process is essentially in parallel, which is the origin of its flexibility. Because the calculations are divided in many nodes, if any of them gets deviated from the expected behaviour it does not affect the behaviour of the whole network.

*(ii)* Its ability to learn and generalize. The ANN have the capability to acquire knowledge from its surroundings by the adaptation of its internal parameters, which is produced as a response to the presence of an external stimulus. The network learns from the examples which are presented to it, and generalizes knowlege from them. The generalization can be interpreted as the property of artificial neural networks to produce an adequate response to unknown stimulus which are related to the acquired knowledge.

These two characteristics for information processing make an ANN able to give solution to complex problems normally difficult to manage by the traditional ways of approximation. Additionally, using them gives the following benefits :

**No linearity,** the answer from the computational neuron can be linear or not. A neural network formed by the interconnection of nonlinear neurons, is in itself nonlinear, a trait which is distributed to the entire network. No linearity is important over all in the cases where the task to develop presents a behaviour removed from linearity, which is presented in most of real situations.

**Adaptive learning,** the ANN is capable of determine the relationship between the different examples which are presented to it, or to identity the kind to which belong, without requiring a previous model.

**Self-organization,** this property allows the ANN to distribute the knowledge in the entire network structure, there is no element with specific stored information.

**Fault tolerance :** This characteristics is shown in two senses : The first is related to the samples shown to the network, in which case it answers correctly even when the examples exhibit variability or noise; the second, appears when in any of the elements of the network occurs a failure, which does not impossibilitate its functioning due to the way in which it stores information.

## 1.4. NEURAL NETWORKS VERSUS CONVENTIONAL COMPUTERS

Neural networks take a different approach to problem solving than that of conventional computers. Conventional computers use an algorithmic approach i.e. the computer follows a set of instructions in order to solve a problem. Unless the specific steps that the computer needs to follow are known the computer cannot solve the problem. That restricts the problem solving capability of conventional computers to problems that we already understand and know how to solve. But computers would be so much more useful if they could do things that we don't exactly know how to do.

Neural networks process information in a similar way the human brain does. The network is composed of a large number of highly interconnected processing elements (neurons) working in parallel to solve a specific problem. Neural networks learn by example. They cannot be programmed to perform a specific task. The examples must be selected carefully otherwise useful time is wasted or even worse the network might be functioning incorrectly. The disadvantage is that because the network finds out how to solve the problem by itself, its operation can be unpredictable.

On the other hand, conventional computers use a cognitive approach to problem solving; the way the problem is to solve must be known and stated in small unambiguous instructions. These instructions are then converted to a high-level language program and then into machine code that the computer can understand. These machines are totally predictable; if anything goes wrong is due to a software or hardware fault.

Neural networks and conventional algorithmic computers are not in competition but complement each other. There are tasks are more suited to an algorithmic approach like arithmetic operations and tasks that are more suited to neural networks. Even more, a large number of tasks require systems that use a combination of the two approaches (normally a conventional computer is used to supervise the neural network) in order to perform at maximum efficiency.

**Von Neumann Computer vs. Biological Neural System**

| | | |
|---|---|---|
| processor | complex<br>high-speed<br>one (or a few) | simple<br>low-speed<br>a large number |
| memory | separate<br>localized<br>noncontent addressable | integrated in the neuron<br>distributed<br>content addressable |
| computing | centralized<br>sequential<br>strored-programs | distributed<br>parallel<br>self-learning |
| reliability | vulnerable | robust |
| expertise | numerical<br>symbolic | perceptual problems<br>manipulations |
| environment | well-defined | poorly defined<br>unconstrained |

## 1.5. BIOLOGICAL NEURON AND ARTIFICIAL MODELS

### 1.5.1. How the Information Flow Takes Place in Brain? [MDU, May 2007]

An estimated $10^{11}$ neurons participating in approximately $10^{15}$ interconnections over the transmission path that may range for a meter or more gives the human nervous system a staggering complexity. These special kinds of cells also called nerve cells are organized into a very complicated interconnecting network, in the human brain. Each neuron is physically connected to millions of other and share many characteristics however each neuron has unique capability to receive, process and transmit electrochemical signals over the neural pathway that comprises the brain communication system.

The input to the network is provided by sensors receptors. Receptors deliver stimuli both from within the body as well as from sense organs when the stimuli originate from the external world. Stimuli are in the form of electrical impulses that convey the information into the network of neurons. As a result of information processing in the central nervous systems, the effectors are controlled and give the human responses in the form of miscellaneous actions.

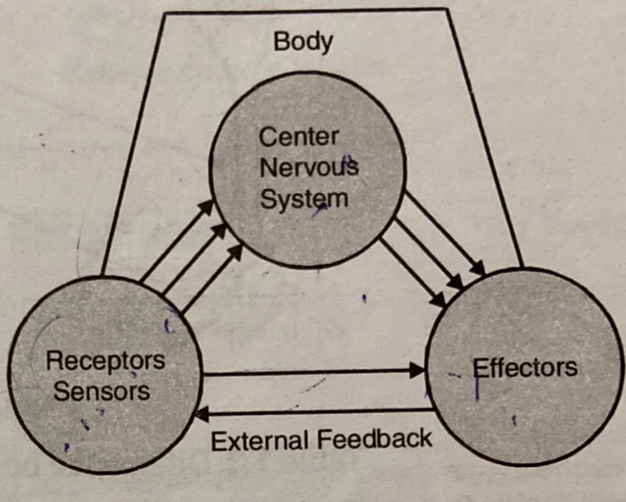


**Fig. 1.3. Information Flow in Nervous System.**

Therefore the three stage system, consisting of receptors, neural network and effectors, in control of the organism and its actions. As it is clear from the Fig. 1.3 the information is processed, evaluated and compared with the stored information in the central nervous system. When necessary, commands are generated there and transmitted to the motor organs. The motor organs are monitored in the central nervous system by the feedback links that verify their actions

### 1.5.2. Biological Neuron

[MDU, Dec. 2007, May 2008, Dec. 2008, Dec. 2009, May 2010, Dec. 2010]

The elementary nerve cell called a neuron is the fundamental building block of biological neural network, The three main components of a biological neuron are:

dendrites

1. A neuron cell body called **soma.**
2. Branching extensions called **dendrites** for receiving input, and
3. An **axon** that carries the neuron's output to the dendrites of other neurons.

In the human brain, a typical neuron collects signals from others through a host of fine structures called *dendrites*. The neuron sends out spikes of electrical activity through a long, thin stand known as an *axon*, which splits into thousands of branches. The axon-dendrite contact organ is called a synapse. At the end of each branch, a structure called a *synapse* converts the activity from the axon into electrical effects that inhibit or excite activity from the axon into electrical effects that inhibit or excite activity in the connected neurons. When a neuron receives excitatory input that is sufficiently large compared with its inhibitory input, it sends a spike of electrical activity down its axon. Learning occurs by changing the effectiveness of the synapses so that the influence of one neuron on another changes. The neuron is able to respond to the total of its inputs aggregated within a short time interval called period of latent summation.

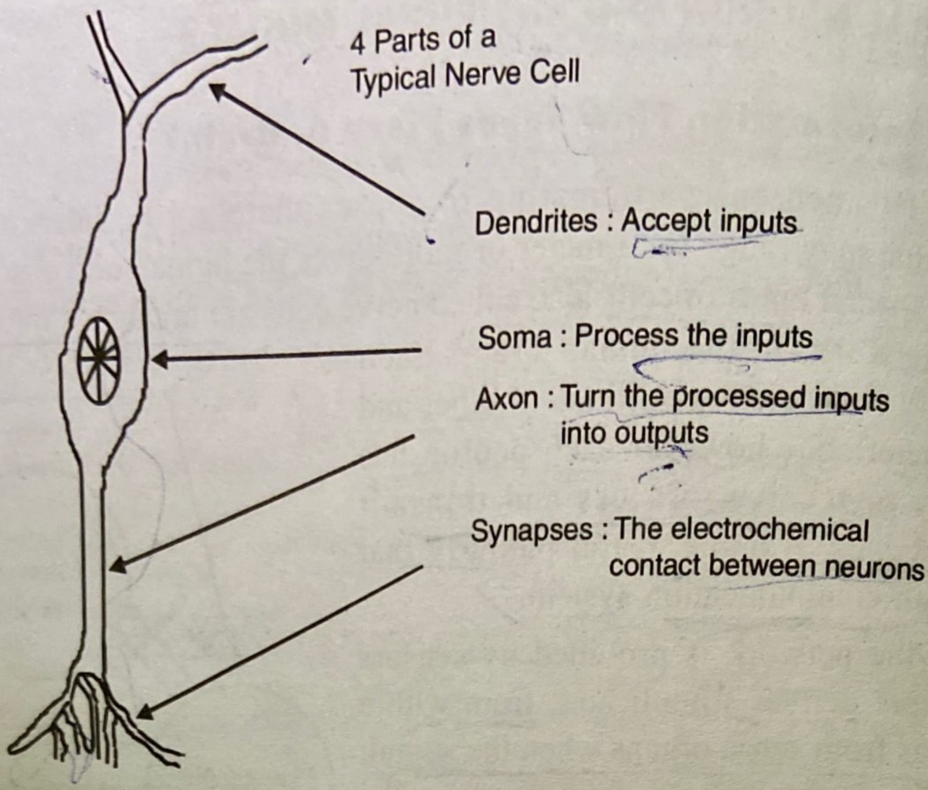


**Fig. 1.4. Biological Neuron.**

**Table 1.3. Difference between ANN and Biological Networks.**

| ANN | Biological Networks |
|---|---|
| ANNs have usually been limited to 10000 units with hundreds of connections per unit. | The human brain is extremely large for a neural network containing $10^{11}$ neurons and there exists $10^{15}$ interconnections. |
| The memory has an organized behaviour and the data retrieved follows an ordered sequence. | The memory follows a pattern of distributed representation and data retrieval depends on retention capacity of the brain |
| Learning takes place by a formulated set of rules and hence the system is less faulty. The processing elements receive many signals and sum up the weighted inputs. These networks can be retrained in case of significant damage (*i.e.* loss of data). | Learning takes place arbitrarily and hence the system is bound for failure. Biological networks are fault tolerable and even in a traumatic loss, other neurons can take over the functions of damaged cells. |
| Redundancy can increase the reliability of the system, allowing it to function even when some of the neural units are destroyed. | Redundancy is used. When some cells die, the nervous system appears to perform the same. It can counteract source of noise in biological systems. |
| The strength of neuron depends on whether it is active or inactive and has relatively simpler interconnections. | The strength of neuron depends on active chemicals present and connections are stronger or weaker as a result of structure layer rather than individual synapses. |
| ANNs focus on learning a single task. | Biological systems have broad capabilities and can address many different types of tasks. |
| Artificial systems are slow to converge and usually require hundreds or thousands of training presentations for learning to take place | Biological systems have the property of being able to learn with as little as one training presentation. A face that is viewed once, can be recognized again. |

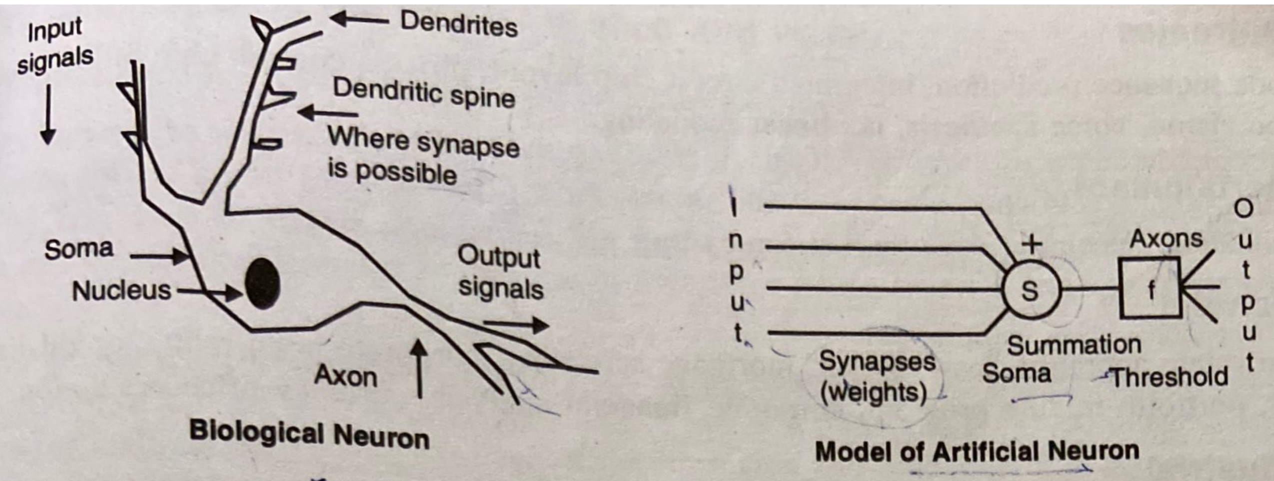


**Fig. 1.5. Similarity between Biological Neuron and ANN.**

## 1.6. APPLICATIONS OF ARTIFICIAL NEURAL NETWORKS [MDU, May 2008]

Neural networks have broad applicability to real world business problems. In fact, they have already been successfully applied in many industries.

### 1. Business Applications

The 1988 DARPA Neural Network Study [DARP88] lists various neural network applications, beginning in about 1984 with the adaptive channel equalizer. This device, which is an outstanding commercial success, is a single- neuron network used in long-distance telephone systems to stabilize voice signals. The DARPA report goes on to list other commercial applications, including a small word recognizer, a process monitor, a sonar classifier, and a risk analysis system. Neural networks have been applied in many other fields since the DARPA report was written. A list of some applications mentioned in the literature follows.

### 2. Aerospace

High performance aircraft autopilot, flight path simulation, aircraft control systems, autopilot enhancements, aircraft component simulation, aircraft component fault detection.

### 3. Automotive

Automobile automatic guidance system, warranty activity analysis.

### 4. Banking

Check and other document reading, credit application evaluation.

### 5. Credit Card Activity Checking

Neural networks are used to spot unusual credit card activity that might possibly be associated with loss of a credit card.

### 6. Defense

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

## 7. Electronics

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

## 8. Entertainment

Animation, special effects, market forecasting

## 9. Financial

Real estate appraisal, loan advisor, mortgage screening, corporate bond rating, credit-line use analysis, portfolio trading program, corporate financial analysis, currency price prediction.

## 10. Industrial

Neural networks are being trained to predict the output gasses of furnaces and other industrial processes. They then replace complex and costly equipment used for this purpose in the past

## 11. Insurance

Policy application evaluation, product optimization

## 12. Manufacturing

Manufacturing process control, product design and analysis, process and machine diagnosis, real-time particle identification, visual quality inspection systems, beer testing, welding quality analysis, paper quality prediction, computer-chip quality analysis, analysis of grinding operations, chemical product design analysis, machine maintenance analysis, project bidding, planning and management, dynamic modeling of chemical process system.

## 13. Medical

Breast cancer cell analysis, EEG and ECG analysis, prosthesis design, optimization of transplant times, hospital expense reduction, hospital quality improvement, emergency-room test advisement

## 14. Oil and Gas

Exploration.

## 15. Robotics

Trajectory control, forklift robot, manipulator controllers, vision systems

## 16. Speech

Speech recognition, speech compression, vowel classification, text-to-speech synthesis

## 17. Securities

Market analysis, automatic bond rating, stock trading advisory systems

## 18. Telecommunications

Image and data compression, automated information services, real-time translation of spoken language, customer payment processing systems

## 19. Transportation

Truck brake diagnosis systems, vehicle scheduling, routing systems