

INTRODUCTION:

What is intelligence?

Real intelligence is what determines the normal thought process of a human.

Artificial intelligence is a property of machines which gives it ability to mimic the human thought process. The intelligent machines are developed based on the intelligence of a subject, of a designer, of a person, of a human being.

Now two questions: can we construct a control system that hypothesizes its own control law? We encounter a plant and looking at the plant behavior, sometimes, we have to switch from one control system to another control system where the plant is operating. The plant is may be operating in a linear zone or non-linear zone; probably an operator can take a very nice intelligent decision about it, but can a machine do it? Can a machine actually hypothesize a control law, looking at the model? Can we design a method that can estimate any signal embedded in a noise without assuming any signal or noise behavior?

That is the first part; before we model a system, we need to observe. That is we collect certain data from the system and How do we actually do this? At the lowest level, we have to sense the environment, like if I want to do temperature control I must have temperature sensor. This data is polluted or corrupted by noise. How do we separate the actual data from the corrupted data? This is the second question. The first question is that can a control system be able to hypothesize its own control law? These are very important questions that we should think of actually. Similarly, also to represent knowledge in a world model, the way we manipulate the objects in this world and the advanced is a very high level of intelligence that we still do not understand; the capacity to perceive and understand.

What is AI ?

Artificial Intelligence is concerned with the design of intelligence in an artificial device.

The term was coined by McCarthy in 1956.

There are two ideas in the definition.

1. Intelligence

2. artificial device

What is intelligence?

-Is it that which characterize humans? Or is there an absolute standard of judgment?

-Accordingly there are two possibilities:

- A system with intelligence is expected to behave as intelligently as a human
- A system with intelligence is expected to behave in the best possible manner
- Secondly what type of behavior are we talking about?
 - Are we looking at the thought process or reasoning ability of the system?
 - Or are we only interested in the final manifestations of the system in terms of its actions?

Given this scenario different interpretations have been used by different researchers as defining the scope and view of Artificial Intelligence.

1. One view is that artificial intelligence is about designing systems that are as intelligent as humans. This view involves trying to understand human thought and an effort to build machines that emulate the human thought process. This view is the cognitive science approach to AI.
2. The second approach is best embodied by the concept of the Turing Test. Turing held that in future computers can be programmed to acquire abilities rivaling human intelligence. As part of his argument Turing put forward the idea of an 'imitation game', in which a human being and a computer would be interrogated under conditions where the interrogator would not know which was which, the communication being entirely by textual messages. Turing argued that if the interrogator could not distinguish them by questioning, then it would be unreasonable not to call the computer intelligent. Turing's 'imitation game' is now usually called 'the Turing test' for intelligence.
3. Logic and laws of thought deals with studies of ideal or rational thought process and inference. The emphasis in this case is on the inference mechanism, and its properties. That is how the system arrives at a conclusion, or the reasoning behind its selection of actions is very important in this point of view. The soundness and completeness of the inference mechanisms are important here.
4. The fourth view of AI is that it is the study of rational agents. This view deals with building machines that act rationally. The focus is on how the system acts and performs, and not so much on the reasoning process. A rational agent is one that acts rationally, that is, is in the best possible manner.

Typical AI problems

While studying the typical range of tasks that we might expect an “intelligent entity” to perform, we need to consider both “common-place” tasks as well as expert tasks.

Examples of common-place tasks include

- *Recognizing* people, objects.
- Communicating (through *natural language*).
- *Navigating* around obstacles on the streets

These tasks are done matter of factly and routinely by people and some other animals.

Expert tasks include:

- Medical diagnosis.
- Mathematical problem solving
- Playing games like chess

These tasks cannot be done by all people, and can only be performed by skilled specialists.

Now, which of these tasks are easy and which ones are hard? Clearly tasks of the first type are easy for humans to perform, and almost all are able to master them. However, when we look at what computer systems have been able to achieve to date, we see that their achievements include performing sophisticated tasks like medical diagnosis, performing symbolic integration, proving theorems and playing chess.

On the other hand it has proved to be very hard to make computer systems perform many routine tasks that all humans and a lot of animals can do. Examples of such tasks include navigating our way without running into things, catching prey and avoiding predators. Humans and animals are also capable of interpreting complex sensory information. We are able to recognize objects and people from the visual image that we receive. We are also able to perform complex social functions.

Intelligent behaviour

This discussion brings us back to the question of what constitutes intelligent behaviour. Some of these tasks and applications are:

1. Perception involving image recognition and computer vision
2. Reasoning
3. Learning
4. Understanding language involving natural language processing, speech processing
5. Solving problems
6. Robotics

Practical applications of AI

AI components are embedded in numerous devices e.g. in copy machines for automatic correction of operation for copy quality improvement. AI systems are in everyday use for identifying credit card fraud, for advising doctors, for recognizing speech and in helping complex planning tasks. Then there are intelligent tutoring systems that provide students with personalized attention.

Thus AI has increased understanding of the nature of intelligence and found many applications. It has helped in the understanding of human reasoning, and of the nature of intelligence. It has also helped us understand the complexity of modeling human reasoning.

Approaches to AI

Strong AI aims to build machines that can truly reason and solve problems. These machines should be self aware and their overall intellectual ability needs to be indistinguishable from that of a human being. Excessive optimism in the 1950s and 1960s concerning strong AI has given way to an appreciation of the extreme difficulty of the problem. Strong AI maintains that suitably programmed machines are capable of cognitive mental states.

Weak AI: deals with the creation of some form of computer-based artificial intelligence that cannot truly reason and solve problems, but can act as if it were intelligent. Weak AI holds that suitably programmed machines can simulate human cognition.

Applied AI: aims to produce commercially viable "smart" systems such as, for example, a security system that is able to recognise the faces of people who are permitted to enter a particular building. Applied AI has already enjoyed considerable success.

Cognitive AI: computers are used to test theories about how the human mind works--for example, theories about how we recognise faces and other objects, or about how we solve abstract problems.

Limits of AI Today

Today's successful AI systems operate in well-defined domains and employ narrow, specialized knowledge. Common sense knowledge is needed to function in complex, open-ended worlds. Such a system also needs to understand unconstrained natural language. However these capabilities are not yet fully present in today's intelligent systems.

What can AI systems do

Today's AI systems have been able to achieve limited success in some of these tasks.

- In Computer vision, the systems are capable of face recognition
- In Robotics, we have been able to make vehicles that are mostly autonomous.
- In Natural language processing, we have systems that are capable of simple machine translation.
- Today's Expert systems can carry out medical diagnosis in a narrow domain
- Speech understanding systems are capable of recognizing several thousand words continuous speech
- Planning and scheduling systems had been employed in scheduling experiments with the Hubble Telescope.
- The Learning systems are capable of doing text categorization into about a 1000 topics
- In Games, AI systems can play at the Grand Master level in chess (world champion), checkers, etc.

What can AI systems NOT do yet?

- Understand natural language robustly (e.g., read and understand articles in a newspaper)
- Surf the web
- Interpret an arbitrary visual scene
- Learn a natural language
- Construct plans in dynamic real-time domains
- Exhibit true autonomy and intelligence

Applications:

We will now look at a few famous AI system that has been developed over the years.

1. ALVINN: Autonomous Land Vehicle In a Neural Network

In 1989, Dean Pomerleau at CMU created ALVINN. This is a system which learns to control vehicles by watching a person drive. It contains a neural network whose input is a 30x32 unit two dimensional camera image. The output layer is a representation of the direction the vehicle should travel.

The system drove a car from the East Coast of USA to the west coast, a total of about 2850 miles. Out of this about 50 miles were driven by a human, and the rest solely by the system.

2. Deep Blue

In 1997, the Deep Blue chess program created by IBM, beat the current world chess champion, Gary Kasparov.

3. Machine translation

A system capable of translations between people speaking different languages will be a remarkable achievement of enormous economic and cultural benefit. Machine translation is one of the important fields of endeavour in AI. While some translating systems have been developed, there is a lot of scope for improvement in translation quality.

4. Autonomous agents

In space exploration, robotic space probes autonomously monitor their surroundings, make decisions and act to achieve their goals.

NASA's Mars rovers successfully completed their primary three-month missions in April, 2004. The Spirit rover had been exploring a range of Martian hills that took two months to reach. It is finding curiously eroded rocks that may be new pieces to the puzzle of the region's past. Spirit's twin, Opportunity, had been examining exposed rock layers inside a crater.

5. Internet agents

The explosive growth of the internet has also led to growing interest in internet agents to monitor users' tasks, seek needed information, and to learn which information is most useful

What is soft computing?

An approach to computing which parallels the remarkable ability of the human mind to reason and learn in an environment of uncertainty and imprecision.

It is characterized by the use of inexact solutions to computationally hard tasks such as the solution of nonparametric complex problems for which an exact solution can't be derived in polynomial of time.

Why soft computing approach?

Mathematical model & analysis can be done for relatively simple systems. More complex systems arising in biology, medicine and management systems remain intractable to conventional mathematical and analytical methods. Soft computing deals with imprecision, uncertainty, partial truth and approximation to achieve tractability, robustness and low solution cost. It extends its application to various disciplines of Engineering and science.

Typically human can:

1. Take decisions
2. Inference from previous situations experienced
3. Expertise in an area
4. Adapt to changing environment
5. Learn to do better
6. Social behaviour of collective intelligence

Intelligent control strategies have emerged from the above mentioned characteristics of human/ animals. The first two characteristics have given rise to Fuzzy logic; 2nd, 3rd and 4th have led to Neural Networks; 4th, 5th and 6th have been used in evolutionary algorithms.

Characteristics of Neuro-Fuzzy & Soft Computing:

1. Human Expertise
2. Biologically inspired computing models
3. New Optimization Techniques
4. Numerical Computation
5. New Application domains
6. Model-free learning
7. Intensive computation
8. Fault tolerance
9. Goal driven characteristics
10. Real world applications

Intelligent Control Strategies (Components of Soft Computing): The popular soft computing components in designing intelligent control theory are:

1. Fuzzy Logic
2. Neural Networks
3. Evolutionary Algorithms

Fuzzy logic:

Most of the time, people are fascinated about fuzzy logic controller. At some point of time in Japan, the scientists designed fuzzy logic controller even for household appliances like a room heater or a washing machine. Its popularity is such that it has been applied to various engineering products.

Fuzzy number or fuzzy variable:

We are discussing the concept of a fuzzy number. Let us take three statements: zero, almost zero, near zero. Zero is exactly zero with truth value assigned 1. If it is almost 0, then I can think that between minus 1 to 1, the values around 0 is 0, because this is almost 0. I am not

very precise, but that is the way I use my day to day language in interpreting the real world. When I say near 0, maybe the bandwidth of the membership which represents actually the truth value. You can see that it is more, bandwidth increases near 0. This is the concept of fuzzy number. Without talking about membership now, but a notion is that I allow some small bandwidth when I say almost 0. When I say near 0 my bandwidth still further increases. In the case minus 2 to 2, when I encounter any data between minus 2 to 2, still I will consider them to be near 0. As I go away from 0 towards minus 2, the confidence level how near they are to 0 reduces; like if it is very near to 0, I am very certain. As I progressively go away from 0, the level of confidence also goes down, but still there is a tolerance limit. So when zero I am precise, I become imprecise when almost and I further become more imprecise in the third case.

When we say fuzzy logic, that is the variables that we encounter in physical devices, fuzzy numbers are used to describe these variables and using this methodology when a controller is designed, it is a fuzzy logic controller.

Q3

Neural networks :

Neural networks are basically inspired by various way of observing the biological organism. Most of the time, it is motivated from human way of learning. It is a learning theory. This is an artificial network that learns from example and because it is distributed in nature, fault tolerant, parallel processing of data and distributed structure.

The basic elements of artificial Neural Network are: input nodes, weights, activation function and output node. Inputs are associated with synaptic weights. They are all summed and passed through an activation function giving output y . In a way, output is summation of the signal multiplied with synaptic weight over many input channels.

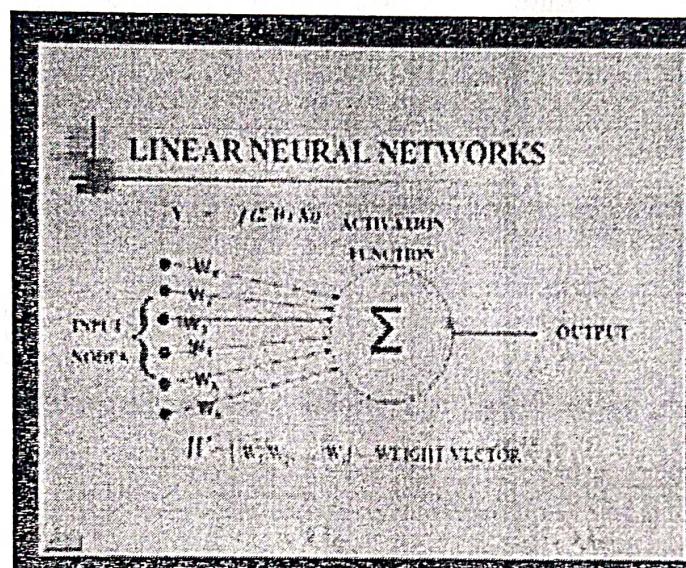


Fig. Basic elements of an artificial neuro

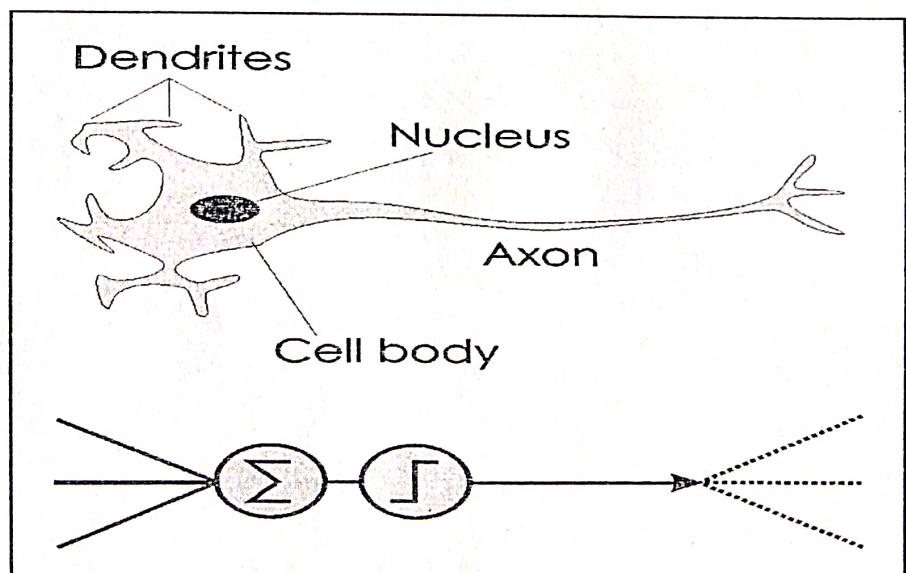


Fig. Analogy of biological neuron and artificial neuron

1.1 Introduction to Soft Computing

Two major problem solving techniques are:

- **Hard computing**

It deals with precise model where accurate solutions are achieved.

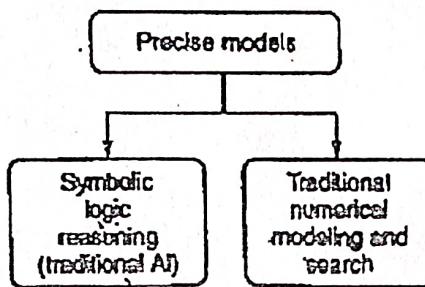


Figure 1.1: Hard Computing

- **Soft computing**

It deals with approximate model to give solution for complex problems. The term "soft computing" was introduced by Professor Lotfi Zadeh with the objective of exploiting the tolerance for imprecision, uncertainty and partial truth to achieve tractability, robustness, low solution cost and better rapport with reality. The ultimate goal is to be able to emulate the human mind as closely as possible. It is a combination of Genetic Algorithm, Neural Network and Fuzzy Logic.

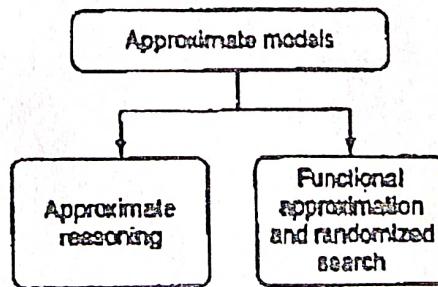


Figure 1.2: Soft Computing

1.2 Biological Neurons

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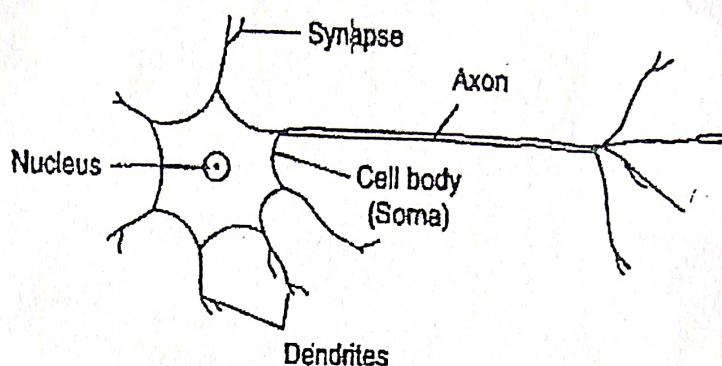


Figure 1.3: Schematic diagram of a biological neuron

The biological neuron consists of main three parts:

- **Soma or cell body**-where cell nucleus is located
- **Dendrites**-where the nerve is connected to the cell body
- **Axon**-which carries the impulses of the neuron

Dendrites are tree like networks made of nerve fiber connected to the cell body. An Axon is a single, long connection extending from the cell body and carrying signals from the neuron. The end of axon splits into fine strands. It is found that each strand terminated into small bulb like organs called as synapse. It is through synapse that the neuron introduces its signals to other nearby neurons. The receiving ends of these synapses on the nearby neurons can be found both on the dendrites and on the cell body. There are approximately 10^4 synapses per neuron in the human body. Electric impulse is passed between synapse and dendrites. It is a chemical process which results in increase/decrease in the electric potential inside the body of the receiving cell. If the electric potential reaches a thresh hold value, receiving cell fires & pulse / action potential of fixed strength and duration is send through the axon to synaptic junction of the cell. After that, cell has to wait for a period called refractory period.

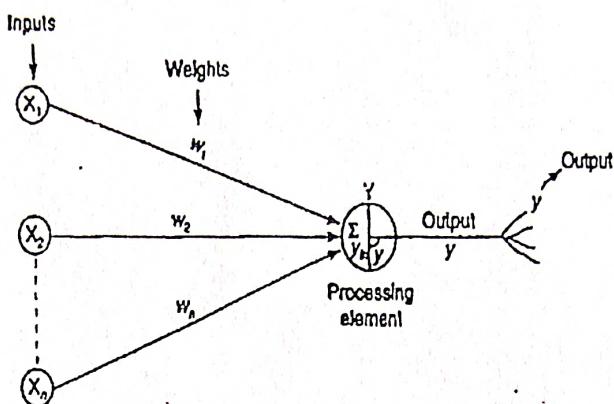


Figure 1.4: Mathematical model of artificial neuron

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

Table 1.1: Terminology relationships between biological and artificial neurons

In this model net input is calculated as

$$y_{in} = x_1 w_1 + x_2 w_2 + \dots + x_n w_n = \sum_{i=1}^n x_i w_i$$

Where, i represents i^{th} processing element. The activation function applied over it to calculate the output. The weight represents the strength of synapses connecting the input and output.

1.3 Artificial neural networks

An artificial neural network (ANN) is an efficient information processing system which resembles the characteristics of biological neural network. ANNs contain large number of highly interconnected processing elements called nodes or neurons or units. Each neuron is connected with other by connection link and each connection link is associated with weights which contain information about the input signal. This information is used by neuron net to solve a particular problem. ANNs have ability to learn, recall and generalize training pattern or

data similar to that of human brain. The ANN processing elements called neurons or artificial neurons.

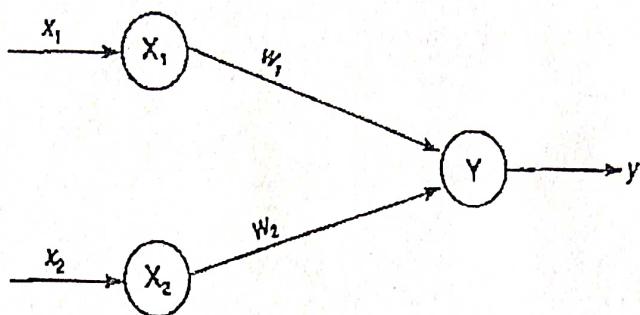


Figure 1.5: Architecture of a simple artificial neuron net

Each neuron has an internal state of its own, called activation or activity level of neuron which is the function of the inputs the neuron receives. The activation signal of a neuron is transmitted to other neurons. A neuron can send only one signal at a time which can be transmitted to several neurons.

Consider the figure 1.5, here X_1 and X_2 are input neurons, Y is the output neuron W_1 and W_2 are the weights net input is calculated as

$$y_{in} = x_1 w_1 + x_2 w_2$$

where x_1 and x_2 are the activation of the input neurons X_1 and X_2 , i.e., is the output of the input signals. The output y of the output neuron Y can be obtained by applying activations over the net input.

$$y = f(y_{in})$$

Output = Function (net input calculated)

The function to be applied over the net input is called activation function. The net input calculation is similar to the calculation of output of a pure linear straight line equation $y=mx$

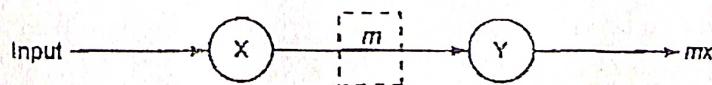
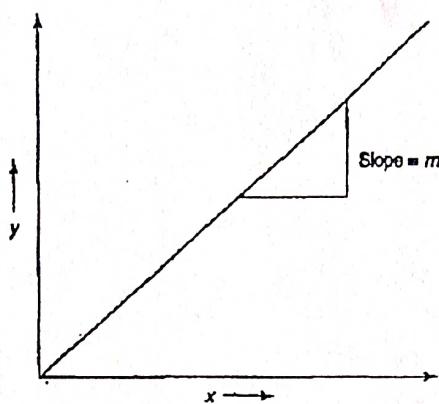


Figure 1.6: Neural net of pure linear equation

Figure 1.7: Graph for $y = mx$

The weight involve in the ANN is equivalent to the slope of the straight line.

1.4 Comparison between Biological neuron and Artificial neuron

Term	Brain	Computer
Speed	Execution time is few milliseconds	Execution time is few nano seconds
Processing	Perform massive parallel operations simultaneously	Perform several parallel operations simultaneously. It is faster than the biological neuron
Size and complexity	Number of Neuron is 10^{11} and number of interconnections is 10^{15} . So complexity of brain is higher than computer	It depends on the chosen application and network designer.
Storage capacity	<ul style="list-style-type: none"> • Information is stored in interconnections or in synapse strength. • New information is stored without destroying old one. • Sometimes fails to recollect information 	<ul style="list-style-type: none"> • Stored in continuous memory location. • Overloading may destroy older locations. • Can be easily retrieved

Tolerance	<ul style="list-style-type: none"> Fault tolerant Store and retrieve information even interconnections fails Accept redundancies 	<ul style="list-style-type: none"> No fault tolerance Information corrupted if the network connections disconnected. No redundancies
Control mechanism	Depends on active chemicals and neuron connections are strong or weak	CPU Control mechanism is very simple

Table 1.2: Comparison between Biological neuron and Artificial neuron

Characteristics of ANN:

- It is a neurally implemented mathematical model
- Large number of processing elements called neurons exists here.
- Interconnections with weighted linkage hold informative knowledge.
- Input signals arrive at processing elements through connections and connecting weights.
- Processing elements can learn, recall and generalize from the given data.
- Computational power is determined by the collective behavior of neurons.
 - ANN is a connection models, parallel distributed processing models, self-organizing systems, neuro-computing systems and neuro - morphic system.

1.5 Evolution of neural networks

Year	Neural network	Designer	Description
1943	McCulloch and Pitts neuron	McCulloch and Pitts	Arrangement of neurons is combination of logic gate. Unique feature is thresh hold
1949	Hebb network	Hebb	If two neurons are active, then their connection strengths 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.
1972	Kohonen self-organizing feature map	Kohonen	Inputs are clustered to obtain a fired output neuron.
1982, 1984, 1985, 1986, 1987	Hopfield network	John Hopfield and Tank	Based on fixed weights. Can act as associative memory nets
1986	Back propagation network	Rumelhart, Hinton and Williams	<ul style="list-style-type: none"> • Multilayered • Error propagated backward from output to the hidden units
1988	Counter propagation network	Grossberg	Similar to kohonen network.
1987- 1990	Adaptive resonance Theory(ART)	Carpenter and Grossberg	Designed for binary and analog inputs.
1988	Radial basis function network	Broomhead and Lowe	Resemble back propagation network, but activation function used is Gaussian function.
1988	Neo cognitron	Fukushima	For character recognition.

Table 1.3: Evolution of neural networks

1.6 Basic models of artificial neural networks

Models are based on three entities

- The model's synaptic interconnections.
- The training or learning rules adopted for updating and adjusting the connection weights.
- Their activation functions

1.6.1 Connections

The arrangement of neurons to form layers and the connection pattern formed within and between layers is called the network architecture. There exist five basic types of connection architecture.

They are:

1. Single layer feed forward network
2. Multilayer feed-forward network
3. Single node with its own feedback
4. Single-layer recurrent network
5. Multilayer recurrent network

Feed forward network: If no neuron in the output layer is an input to a node in the same layer / proceeding layer.

Feedback network: If outputs are directed back as input to the processing elements in the same layer/proceeding layer.

Lateral feedback: If the output is directed back to the input of the same layer.

Recurrent networks: Are networks with feedback networks with closed loop.

1. Single layer feed forward network

Layer is formed by taking processing elements and combining it with other processing elements. Input and output are linked with each other. Inputs are connected to the processing nodes with various weights, resulting in series of outputs one per node.