# What is a Neural Network?

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First of all, when we are talking about a neural network, we should more properly say "artificial neural network" (ANN), because that is what we mean most of the time. Biological neural networks are much more complicated than the mathematical models we use for ANNs. But it is customary to be lazy and drop the "A" or the "artificial".

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. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. 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 of ANNs as well.

**Some Other Definitions of a Neural Network include:**

According to the DARPA Neural Network Study (1988, AFCEA International Press, p. 60):

... a neural network is a system composed of many simple processing elements operating in parallel whose function is determined by network structure, connection strengths, and the processing performed at computing elements or nodes.

According to Haykin, S. (1994), Neural Networks: A Comprehensive Foundation, NY: Macmillan, p. 2:

A neural network is a massively parallel distributed processor 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 through a learning process.
2.Interneuron connection strengths known as synaptic weights are used to store the knowledge.

ANNs have been applied to an increasing number of real-world problems of considerable complexity. Their most important advantage is in solving problems that are too complex for conventional technologies -- problems that do not have an algorithmic solution or for which an algorithmic solution is too complex to be found. In general, because of their abstraction from the biological brain, ANNs are well suited to problems that people are good at solving, but for which computers are not. These problems includes pattern recognition and forecasting (which requires the recognition of trends in data).

# Why use a 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. This expert can then be used to provide projections given new situations of interest and answer "what if" questions.
Other advantages include:

1.  Adaptive learning: An ability to learn how to do tasks based on the data given for training or initial experience.
2.  Self-Organisation: An ANN can create its own organisation or representation of the information it receives during learning time.
3.  Real Time Operation: ANN computations may be carried out in parallel, and special hardware devices are being designed and manifactured which take advantage of this capability.
4.  Fault Tolerance via Redundant Information Coding: Partial destruction of a network leads to the corresponding degradation of performance. However, some network capabilites may be retained even with major network damage.

# Neural Networks in Practice

Given this description of neural networks and how they work, what real world applications are they suited for? Neural networks have broad applicability to real world business problems. In fact, they have already been successfully applied in many industries.

Since neural networks are best at identifying patterns or trends in data, they are well suited for prediction or forecasting needs including:

- sales forecasting
- industrial process control
- customer research
- data validation
- risk management
- target marketing

But to give you some more specific examples; ANN are also used in the following specific paradigms: recognition of speakers in communications; diagnosis of hepatitis; recovery of telecommunications from faulty software; interpretation of multimeaning Chinese words; undersea mine detection; texture analysis; three-dimensional object recognition; handwritten word recognition; and facial recognition.

## Historical Background of Neural Networks

Neural network simulations appear to be a recent development. However, this field was established before the advent of computers, and has survived at least one major setback and several eras.
Many importand advances have been boosted by the use of inexpensive computer emulations. Following an initial period of enthusiasm, the field survived a period of frustration and disrepute. During this period when funding and professional support was minimal, important advances were made by relatively few reserchers. These pioneers were able to develop convincing technology which surpassed the limitations identified by Minsky and Papert. Minsky and Papert, published a book (in 1969) in which they summed up a general feeling of frustration (against neural networks) among researchers, and was thus accepted by most without further analysis. Currently, the neural network field enjoys a resurgence of interest and a corresponding increase in funding.

The history of neural networks that was described above can be divided into several periods:

1. First Attempts: There were some initial simulations using formal logic. McCulloch and Pitts (1943) developed models of neural networks based

on their understanding of neurology. These models made several assumptions about how neurons worked. Their networks were based on simple neurons which were considered to be binary devices with fixed thresholds. The results of their model were simple logic functions such as "a or b" and "a and b". Another attempt was by using computer simulations. Two groups (Farley and Clark, 1954; Rochester, Holland, Haibit and Duda, 1956). The first group (IBM reserchers) maintained closed contact with neuroscientists at McGill University. So whenever their models did not work, they consulted the neuroscientists. This interaction established a multidiscilinary trend which continues to the present day.

2. Promising & Emerging Technology: Not only was neroscience influential in the development of neural networks, but psychologists and engineers also contributed to the progress of neural network simulations. Rosenblatt (1958) stirred considerable interest and activity in the field when he designed and developed the *Perceptron.* The Perceptron had three layers with the middle layer known as the association layer.This system could learn to connect or associate a given input to a random output unit. Another system was the ADALINE (*ADAptive LInear Element*) which was developed in 1960 by Widrow and Hoff (of Stanford University). The ADALINE was an analogue electronic device made from simple components. The method used for learning was different to that of the Perceptron, it employed the Least-Mean-Squares (LMS) learning rule.

3. Period of Frustration & Disrepute: In 1969 Minsky and Papert wrote a book in which they generalised the limitations of single layer Perceptrons to multilayered systems. In the book they said: "...our intuitive judgment that the extension (to multilayer systems) is sterile". The significant result of their book was to eliminate funding for research with neural network simulations. The conclusions supported the disenhantment of reserchers in the field. As a result, considerable prejudice against this field was activated.

4. Innovation: Although public interest and available funding were minimal, several researchers continued working to develop neuromorphically based computaional methods for problems such as pattern recognition. During this period several paradigms were generated which modern work continues to enhance.Grossberg's (Steve Grossberg and Gail Carpenter in

1988) influence founded a school of thought which explores resonating algorithms. They developed the ART (Adaptive Resonance Theory) networks based on biologically plausible models. Anderson and Kohonen developed associative techniques independent of each other. Klopf (A. Henry Klopf) in 1972, developed a basis for learning in artificial neurons based on a biological principle for neuronal learning called *heterostasis*. Werbos (Paul Werbos 1974) developed and used the *back-propagation* learning method, however several years passed before this approach was popularized. Back-propagation nets are probably the most well known and widely applied of the neural networks today. In essence, the back-propagation net. is a Perceptron with multiple layers, a different thershold function in the artificial neuron, and a more robust and capable learning rule.

Amari (A. Shun-Ichi 1967) was involved with theoretical developments: he published a paper which established a mathematical theory for a learning basis (error-correction method) dealing with adaptive patern classification. While Fukushima (F. Kunihiko) developed a step wise trained multilayered neural network for interpretation of handwritten characters. The original network was published in 1975 and was called the *Cognitron*.

5. Re-Emergence: Progress during the late 1970s and early 1980s was important to the re-emergence on interest in the neural network field. Several factors influenced this movement. For example, comprehensive books and conferences provided a forum for people in diverse fields with specialized technical languages, and the response to conferences and publications was quite positive. The news media picked up on the increased activity and tutorials helped disseminate the technology. Academic programs appeared and courses were inroduced at most major Universities (in US and Europe). Attention is now focused on funding levels throughout Europe, Japan and the US and as this funding becomes available, several new commercial with applications in industry and finacial institutions are emerging.

6. Today: Significant progress has been made in the field of neural networks-enough to attract a great deal of attention and fund further research. Advancement beyond current commercial applications appears to be possible, and research is advancing the field on many fronts. Neurally based chips are emerging and applications to complex problems

developing. Clearly, today is a period of transition for neural network technology.

# Are there any limits to Neural Networks?

The major issues of concern today are the scalability problem, testing, verification, and integration of neural network systems into the modern environment. Neural network programs sometimes become unstable when applied to larger problems. The defence, nuclear and space industries are concerned about the issue of testing and verification. The mathematical theories used to guarantee the performance of an applied neural network are still under development. The solution for the time being may be to train and test these intelligent systems much as we do for humans. Also there are some more practical problems like:

- the operational problem encountered when attempting to simulate the parallelism of neural networks. Since the majority of neural networks are simulated on sequential machines, giving rise to a very rapid increase in processing time requirements as size of the problem expands. Solution: implement neural networks directly in hardware, but these need a lot of development still.
- instability to explain any results that they obtain. Networks function as "black boxes" whose rules of operation are completely unknown.

# The Future

Because gazing into the future is somewhat like gazing into a crystal ball, so it is better to quote some "predictions". Each prediction rests on some sort of evidence or established trend which, with extrapolation, clearly takes us into a new realm.

Prediction 1:
Neural Networks will fascinate user-specific systems for education, information processing, and entertainment. "Alternative ralities", produced by comprehensive environments, are attractive in terms of their potential for systems control, education, and entertainment. This is not just a far-out research trend, but is something which is becoming an increasing part of our daily existence, as witnessed by the growing interest in comprehensive "entertainment centers" in each home.

This "programming" would require feedback from the user in order to be effective but simple and "passive" sensors (e.g fingertip sensors, gloves, or wristbands to sense pulse, blood pressure, skin ionisation, and so on), could provide effective feedback into a neural control system. This could be achieved, for example, with sensors that would detect pulse, blood pressure, skin ionisation, and other variables which the system could learn to correlate with a person's response state.

Prediction 2:
Neural networks, integrated with other artificial intelligence technologies, methods for direct culture of nervous tissue, and other exotic technologies such as genetic engineering, will allow us to develop radical and exotic life-forms whether man, machine, or hybrid.

Prediction 3:
Neural networks will allow us to explore new realms of human capabillity realms previously available only with extensive training and personal discipline. So a specific state of consiously induced neurophysiologically observable awareness is necessary in order to facilitate a man machine system interface.

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