CHAPTER 1

INTRODUCTION

The history of mankind is a never-ending chain of human endeavours for survival in the struggle for existence and for achieving mastery over the physical nature. Science and technology which are the outcome of human intelligence, have helped mankind fight a long way through in this war for supremacy. Innumerable are the wonders of nature and inspiring are their ways of manifestations. In man's inquisitive efforts to unravel the mysteries around him, nothing in nature have been spared from his dissection table - not even himself! Many of our scientific achievements are the results of such observations and the successful efforts to mimic nature. The shape of ships and submarines are strikingly similar to that of the big fishes. Birds floating in the infinite blue sky were the inspiring source behind the development of aircrafts. Had it not been for our knowledge of the optical system in animals, the colourful world of photography would never have become a reality. It is rather astounding to understand that a primitive form of radar has already been used by bats since time immemorial as their navigational aid! Recent investigations into the structure and functioning of the human brain and the associated phenomena of cognition and perception have added yet another marvel to the above. And that is the marvel of Artificial Neural Networks (ANN).
1.1 Computers Versus Human Brain

In the world of popular science, the modern computer is often referred to as the "electronic brain". Computers, as they are known today, work in an entirely different manner as compared to the human brain. A numerical calculation performed within a split-second by a supercomputer might take centuries for a human to complete. But the computer cannot do some simple tasks which even an infant baby can, like identifying its mother's face among a few unfamiliar faces. Due to these inherent limitations, it will be a long time before the brain can be substantially mimicked.

Computers and human brain differ basically in their mode of approach to problems and in the way they perform. Conventional computers employ the von Neumann architecture, are logical in execution and can only do logical operations well. Though it is rather impossible for a human brain to surpass the phenomenal speed, accuracy and efficiency of a computer, the computers are left far behind by the brain in solving problems relating to machine-vision and speech recognition.

In essence, it is the difference in design that can account for the difference between the two systems. Computers are designed to carry out instructions sequentially and extremely fast, whereas brain works with many more slower units working in a highly parallel fashion. Such a parallel style is most suited for problems of vision or speech recognition which are also
highly parallel in nature.

1.2 Neural Networks - A Historical Perspective

As early as 1940, neurobiologists and neuroanatomists had come to understand about the brain's "wiring" - which they called "neural networks" - involving hundreds of billions of neurons, each connecting to hundreds or thousands of others, but little of its operation was known. It was W.S. McCulloch and W. Pitts (1943) who showed how these networks could compute; but however, the question as to how they could learn remained unanswered until Donald Hebb proposed the hypothesis [32] called "Hebbian learning" in 1949. Hebb's proposal, which became the starting point for the development of learning algorithms for artificial neural networks, had to wait till 1951 when Dean Edmonds and Marvin Minsky succeeded in building their learning machine. Although Minsky was perhaps the first to come up with a learning machine, the real onset of meaningful learning in neuron-like networks can be traced to the work of Frank Rosenblatt [33] who invented a class of simple neuron-like learning networks called "perceptrons". The techniques of digital computer simulation and formal mathematical analysis which are of fundamental importance to neural network analysis were pioneered by him.

Early successes produced a burst of activity and optimism and it seemed that the secret of intelligence had been found and that the human brain was as simple as a large
enough network! This illusion was soon dispelled when the networks failed to solve some of the problems (which the brain could very well solve!). This led to intense diagnostic analysis by Minsky, S. Papert and others who developed rigorous theorems regarding network operation (1969).

Though the discouraged researchers left the field for more promising areas, dedicated scientists like Teuvo Kohonen, Stephen Grossberg and James Anderson continued their efforts facing many hardships. The research papers published during the period from 1970 to 1980 set a strong theoretical foundation, upon which the more powerful multilayer networks of today are being constructed.

In the past few years, there has been an explosive increase in the amount of research activity in the field of neural networks resulting in regular international conventions, dedicated journals and special issues of journals on neural networks and a flood of research papers in other publications. The substantial amount of innovative investigations parallelly going on in the field of hardware have already resulted in the introduction of a few neural network chips also in the market [11-23].

1.3 Neural Network for Sonar Signal Processing

Sonar signal processing is intended to achieve (a) detection of targets like submarines, surface ships,
torpedoes etc. and (b) accurate estimation of their range, bearing and speed (Doppler). A sonar system has to fulfil these missions under extremely adverse environments like:

1. propagation peculiarities due to sound velocity variation with ocean depth
2. spreading and absorption losses
3. contaminating noise
4. spatial coherence of signals
5. instability of sonar platform at high sea-states
6. low data rates due to low velocity of acoustic propagation
7. extremely stringent dynamic range requirements

The sonar signal processors have to take the above important factors into account. The special features of the sonar environment have to be made use of to the best to realise the most efficient processor that gives maximum probability of detection with minimum false alarm. The ocean environment being nonstationary, the processor has to be adaptive so as to adjust itself to the changing scenario.

Traditional pattern recognition techniques are often used to interpret complex sonar signals. To reduce the amount of computation and to achieve accurate classification, often simplifying assumptions are made about the structure of these signals. For applications where such assumptions are valid, these techniques do perform well. However, if the signals are not simply distributed or are highly correlated, these methods may be inadequate and other more general techniques available are often impractical [25].
In this context, the multi-layered neural networks, which are massively parallel in nature, provide potential alternatives to traditional pattern recognition methods. The learning algorithms they use make far restrictive assumptions about the input pattern structure. Their inherent parallelism allows very rapid parallel search and best-match computations. Capabilities for failure tolerance, error correction and self-organization along with optimised system complexity render neural networks excellent tools for sonar and other applications.

The sophisticated nature of sonar signal processing, coupled with the difficulty to use conventional pattern recognition techniques has been the motivation behind the work under discussion, which explores the possibility of using neural networks for sonar target detection and classification. The chapters to follow, therefore, summarizes the efforts to evolve a neural network for this purpose. Chapter 2 introduces the concept of neural networks and evolves the idea of neural computing using Artificial Neural Networks. The technique of backpropagation to enhance the capability and coverage of neural computing is surveyed in Chapter 3. Chapter 4 outlines the problem of Sonar Target Detection, elaborating on the diverse and complex nature of the problem. The architecture and implementation of a neural network for target recognition, proposed by the author, are discussed in Chapter 5. The results of the simulated runs of the neural network are summarized in Chapter 6. A brief survey of the hardware aspects of neural
networks is made in Chapter 7. Various prospective applications of neural networks in sonar technology which are worth further investigation are also discussed in this chapter.