CHAPTER - 1

INTRODUCTION AND RESEARCH DESIGN

APPLICATION OF NEURAL NETWORKS IN INVESTMENT MANAGEMENT
1.0 INTRODUCTION AND RESEARCH DESIGN

The application of artificial intelligence techniques to aid investment decisions is currently a very active area of research. Financial time series exhibit noisy behaviour and there are no known ways to express the relationships involved precisely.

Intelligent systems are a category of devices that can find patterns and discover relationships in a large number of data. The common feature of an intelligent system is their mimicry of nature. One very useful intelligent system, neural networks, is inspired by the function of nerve cells in the brain. Like humans, neural networks can learn to recognise patterns by repeated exposure to many different examples. They can be used to recognise patterns or salient characteristics whether they are handwritten characters, profitable loans or good trading decisions. Just as humans have the capability to recognise handwritten characters produced by different people who have very different styles, neural networks can also learn to recognise patterns in data that are inexact and incomplete.

Neural networks are now being applied to problems that were previously performed by experts with years of experience. But professionals such as financial analysts have a very high premium on their available time and therefore the capacity to learn directly from data without human intervention becomes very important. A systematic learning approach can also help to overcome the limitations that are inherent in human professionals including the possible existence of gaps, in an expert’s knowledge. Further, as different practitioners have different views on the way to perform a particular task, “objective” learning methods have advantages with respect to consistency.

Market is constantly changing. A specific business process may become quickly outdated because of variety of reasons including changes of macroeconomic conditions, changes due to new
competitive pressures, technological innovations or changes due to Government regulations. Therefore, it is not sufficient to learn the initial knowledge to perform a task, it has also to monitor its performance constantly and revise the knowledge according to the changes in the operating environment. Because of the ever-changing character of the financial markets, the system used for trading should have the ability to adapt to such changes and be able to make successful trading recommendations. In order for this to happen, the system should have the capacity to learn continuously from the market.

When humans make decisions there is an inherent flexibility. Humans can make decisions even when the available information is imprecise and incomplete. If some information about a security is not known, financial traders almost always take decisions with incomplete information. While humans have such flexibility, traditional computer programs do not. Most programs work on strictly 'yes/no' or 'black and white' logic, which does not permit various shades of grey. For this reason, traditional computing systems are not robust in their operation - they fail to function even if a single condition is left unspecified.

In contrast, neural networks have the capacity to make decisions in a flexible manner that is similar to human decision making. They can reason with incomplete information and recognise patterns in conditions that they have not encountered before.

While neural networks have the potential to annotate many different decision making tasks, there are organisational and legal reasons that the decisions they reach should be understood by humans. In the area of investment management, where decisions involve very large amounts of money, even sometimes the lifelong savings of the customers, reassurance as to the soundness of the decision-making procedure is needed. The ability to cite exact conditions and reasoning of a trading decision is often required by managers of fund management companies.
It is also important to have an understanding of the reasoning process in order to improve system. If the system does not produce correct decision due to some reason, it can be corrected, if the reasoning process is correctly understood. On the other hand, if an opaque or black-box decision system ceases to make good decisions, then it will be very difficult to understand what has caused the system to behave in that manner. Moreover, no corrective action can be taken to improve the system.

Not only can neural networks automate the tasks that are currently performed by humans but they also offer possibility of discovering new business processes or relationships that were previously unknown. Knowledge discovery can be defined as the nontrivial extraction of implicit, previously unknown, and potentially useful information from data. Neural networks can surf through large databases and find relationships and business patterns that were previously unknown.

Some of these properties of neural network described are particularly useful in investment management where much is assumed and little is known about the nature of the process determining asset prices.

1.1 RESEARCH DESIGN

The various aspects relating to research design are discussed below.

1.2 OBJECTIVES

The objective of the study is to explore usefulness of neural network model in investment management in order to improve profitability of investments compared to conventional techniques.
Accordingly a model neural network structure and computational algorithm are to be developed. The network should be capable of taking known inputs and produce output to facilitate investment decision. Select securities can be bought or sold based on output of neural network model.

The results obtained from neural network model are to be compared with a conventional technique to ascertain benefits of the model.

1.3 SCOPE

Neural network methodology offers lot of flexibility in network design and formulating input-output relationship. To standardize the analysis, a network with three inputs, one hidden layer consisting of three hidden nodes and a single final output is selected. The input-output relationships are based on a set of equations following sigmoid activation function.

The study is done using market prices of popular stock indexes and a few selected stocks using both daily and monthly price data. The neural network model is adopted for an active trading strategy based on past price movements. The inputs fed to the network are derived from past known prices. The network analyses the input data and makes a forecast for next period’s price. When the network predicts an increase in the asset price the asset is bought, and similarly, when it predicts decrease in the asset price the asset is sold.

A paper trading procedure is developed to calculate profits and losses based on neural network prediction considering appropriate transaction costs.

The performance of the neural network model is compared with performance of a conventional technique. We have used “Buy and Hold” strategy as the benchmark.
1.4 HYPOTHESES

The study tests the following Hypotheses:

**Hypothesis No 1**

*Application of neural network methodology in investment decisions would lead to higher average profits as compared to "Buy and Hold" strategy.*

In statistical term the null and alternative hypotheses are specified as under:

$H_0: \mu_1 = \text{or} < \mu_2$

$H_1: \mu_1 > \mu_2$

$\mu_1 = \text{Average profit using Neural Network model}$

$\mu_2 = \text{Average profit using Buy & Hold Strategy}$.

**Hypothesis No 2**

*Application of neural network methodology in investment decisions exhibit better Market Timing ability.*

The null and alternative hypotheses are specified as under:

$H_0: \gamma = \text{or} < 0$

$H_1: \gamma > 0$

$\gamma = \text{Market Timing ability coefficient in Trenor and Mazuy model and also in Henriksson and Merton model.}$

The success of trading using Neural Network model depends on market timing abilities of the model. Several methods have been suggested in the literature to test market-timing abilities of the fund managers. In this study two measures; one proposed by Trenor and Mazuy and the other suggested by Henriksson and Merton have been used to test the market timing abilities of Neural Network model. These methodologies are explained at Chapter 7.
1.5 KEY TERMS AND DEFINITIONS

The key terms related to neural networks are described separately in Chapter 3. Other financial terms and testing procedures e.g. The Sharpe Ratio, Trenor and Mazuy model, Henriksson and Merton model, etc are explained in Chapter 7.

1.6 SCHEME OF ANALYSIS

A model neural network structure is developed and used for analysis. The network accepts three known inputs based on current price of the security and moving average prices. Appropriate input-output relations are also established. When new inputs are fed, the network predicts whether price in next period will go up (or come down). Before using the network for prediction, the network needs to be trained with past data.

Using neural network prediction a trading procedure is followed and theoretical profit/loss arising out of the trading are added to get cumulative profit for the sample period. This cumulative profit is then compared with profits out of "Buy and Hold" strategy.

In addition to comparing total profits, a few related efficiency measures, e.g., number of transactions, transaction cost, number of profitable trades, number of loss making trades, average profit per day, standard deviation of daily profits, etc. are also calculated both for neural network model and "Buy and Hold" strategy.

For better visual comparison, cumulative profit curves of both the strategies are also plotted in graphical format.
1.7 SOFTWARE IN MICROSOFT EXCEL

The analysis is based on comparison of results of neural network model and "Buy and Hold" strategy. Considering the complexity of input output relationships of neural network model and necessity of using a computer program for training the neural network, the calculations are carried out in a Microsoft Excel Worksheet. The consecutive period's closing price data are entered in each consecutive row of the worksheet and various calculations are performed in different columns of the respective rows. The software used for analysis is described in Chapter 5.

Before using the network for actual application, the network is required to be trained feeding past data. The network is fed both input data and output data (for past data, actual output is known). From the input data the network calculates theoretical output based on given algorithm (input-output relationship) and this theoretical output is compared with actual past output to measure prediction error. The network then adjusts internal weights such that the total error is minimized. These minimization calculations require intensive computational capability and therefore, a computer program "Solver", (which comes along with Microsoft Excel as an add-on program,) can be used for the above training. "Solver" uses the Generalized Reduced Gradient nonlinear optimization code developed by Leon Lasdon, University of Texas at Austin, and Allan Waren, Cleveland State University.

The analysis steps are given in the following flow chart.
1.8 FLOW CHART

SELECT DATA-SERIES
Select a particular financial series (from available series) for analysis

DIVIDE DATA INTO SUB-SETS
The entire data set is divided into several small subsets.

CALCULATE NEURAL NETWORK INPUTS
Three neural network inputs are selected based on moving averages of closing prices.

ESTABLISH INPUT-OUTPUT RELATIONSHIPS
Input-output relationships are based on sigmoid activation function.

TRAIN THE NETWORK
The network is trained separately with each data subset. By using an optimisation programme "Solver" the optimum weights $W_1$ to $W_{12}$ are determined separately for each data subset.

PREDICTION OF PRICES
After weights ($W_1, W_2, \ldots, W_{12}$) are known the same are used for prediction. To avoid in-sample bias, weights obtained out of training from a particular data subset are used for prediction in next data subset. For example, predicting price movements for 2nd data subset, weights of 1st data subset are used. Similarly for predicting prices of 3rd data subset, weights of 2nd data subset are used.

CALCULATE PROFIT/(LOSS)
Based on price prediction paper trading is carried out and profit/loss is calculated.

COMPARE PROFITABILITY
The profitability based on neural network model is compared with buy and hold Strategy for analysis.
1.9 DATA REQUIREMENT AND SOURCES

The analysis is done in two stages: first with daily closing prices and second with monthly prices. The study with data of daily prices consists of three major stock market indices viz., BSE Sensitive Index, S&P CNX Nifty Index and S&P CNX Nifty Junior Index and four individual stocks for a five year period from January 1996 to December 2000.

The study is also extended to monthly data, wherein monthly prices of 24 actively traded stocks are analysed for the period March, 1996 to March, 2002.

The daily closing prices were obtained from www.nseindia.com (website of National Stock Exchange) and www.bseindia.com (website of Bombay Stock Exchange). The monthly closing prices were obtained from www.indiainfoline.com (website of India Infoline Ltd.).

1.10 ASSUMPTIONS

Apart from various assumptions in neural network design, the following trading assumptions are made.

- All paper-trading transactions are carried out at daily closing prices.
- No physical delivery is to be taken and all transactions are to be squared off.
- Transaction costs are taken @ 0.15% for a single transaction.
- There is no restriction of short selling.
- Interest on margin money and time value of money is ignored.