RSG 92-93

RESEARCH SUPPORT GRANTS
1992-1993 Academic Year
Application Cover Sheet

PATSY RECORD # ________

Project title: A Neural Network Model for Estimating Option Prices

Applicant's Name:

Malliaris	Mary	E
[Last]	[First]	[Initial]

Social Security Number: 442-48-8271

Department: Management Science

Amount Requested: $ 1100.00 [Max: $1,200] (please carry over from detailed Budget Page)

Chairperson's (Dean's) Approval

I have read this proposal and endorse the project.

Signed: [illegible signature] Date: Oct 26, 1992

Abstract Please limit your abstract to the space provided below. Do not photoreduce your material.

There has recently been considerable interest in the development of artificial neural networks for solving a variety of problems. Neural networks, which are capable of learning relationships from data, represent a class of robust, nonlinear models inspired by the neural architecture of the brain. Financial applications which require pattern matching have proven to be excellent candidates for this new technology. In this project, we wish to develop a neural network to estimate the market prices of OEX options (options on the Standard and Poor's 100). The network's ability to estimate option prices will be compared to the Black-Scholes model, a highly structured method developed by using stochastic calculus techniques, which is currently the most widely-used model for the pricing of options.

b. Project Description

A Neural Network Model for Estimating Option Prices

1. Introduction

There has recently been considerable interest in the development of artificial neural networks for solving a variety of problems. Neural networks, which are capable of learning relationships from data, represent a class of nonlinear models inspired by the neural architecture of the brain. Financial applications which require pattern matching, classification, and prediction such as corporate bond rating [5], trend prediction [7], failure prediction [12] and underwriting [4] have proven to be excellent candidates for this new technology. In this project, we wish to develop a neural network to estimate the market prices of OEX options (options on the Standard and Poor's 100) using transactions data for the period January 1, 1990 to June 30, 1990. The network's ability to estimate option prices will be compared to the Black-Scholes model, the most widely-used model for the pricing of options.

2. The Neural Network Model

Inspired by studies of the brain and the nervous system, neural networks are composed of neurons or processing elements and connections, organized in layers. These layers can be structured hierarchically. The first layer is called the input layer, the last layer is the output layer, and the interior layers are called the middle or hidden layers. Feedforward networks map inputs into outputs with signals flowing in one direction only, from the input layer to the output layer. Each connection between neurons has a numerical weight associated with it which models the influence of an input cell on an output cell. Positive weights indicate reinforcement; negative weights are associated with inhibition. During a supervised learning process, connection weights are learned by the network as examples from a training set are presented repeatedly to the network.

Each processing element has an activation level, specified by continuous or discrete values. If the neuron is in the input layer, its activation level is determined in response to input signals it receives from the environment. For cells in the middle or output layers, the activation level is computed as a function of the activation levels on the cells connected to it and the associated connection weights. This function is called the transfer function or activation function.

While basically an information processing technology, neural networks differ from traditional modelling techniques in a fundamental way. Parametric models require that the developer specify the nature of the functional relationship between the dependent variable and the independent variables e.g., linear, logistic. Neural networks with at least one middle layer use the data to develop an internal representation of the relationship between the variables so that a priori assumptions about underlying parameter distributions are not required. As a consequence, neural networks can often discover relationships between the variables which could not be specified in a traditional model.

3. The Black-Scholes Model

In 1973, Black and Scholes [1] proposed a model for computing the current market worth of an option. The Black-Scholes model is widely used as a pricing tool on the trading floor. Although trading began in 1973, in less than 20 years, the volume of option trading has increased dramatically. Currently, the trading volume of calls and puts for the OEX is around 760,000 daily contracts each.

An option is an agreement giving the holder the right to purchase [a call] or sell [a put] some asset at an agreed upon future time, called the date of expiration. The price that will be paid at this future date is called the exercise price of the option. The market price of the option is the price you pay now for the privilege of buying or selling the underlying asset on the expiration date. The Black-Scholes model uses five input variables [exercise price of the option, volatility of the underlying asset, price of the underlying asset, number of days until the option expires, and interest rate] to estimate the price which should be charged for an option. The Black-Scholes option pricing formula for calculating the equilibrium price of call options is shown in (1)

$$C = S \cdot N(d_1) - Xe^{-rT} \cdot N(d_2) \tag{1}$$

where C is the market price to be charged for the option, N is the cumulative normal distribution, T is the number of days remaining until expiration of the option expressed as a fraction of a year, S is the price of the underlying asset, r is the risk-free interest rate prevailing at period t, X is the exercise price of the option and d_1 and d_2 are given by

$$d_1 = \frac{\ln(\frac{S}{X}) + (r + \frac{\sigma^2}{2}) \cdot T}{\sigma\sqrt{T}} \tag{2}$$

and

$$d_2 = d_1 - \sigma\sqrt{T} \tag{3}$$

where σ^2 is the variance rate of return for the underlying asset. For any time interval [0,t] of length t, the return on the underlying asset is normally distributed with variance $\sigma^2 t$ [8].

There are seven assumptions underlying this model which assume ideal conditions in the market [1], [3]. They are:

(a) the interest rate is known and constant through time;

(b) the stock price follows a random walk in continuous time with variance proportional to the square of the stock price; thus the distribution of prices is log-normal and the volatility is constant;

(c) the stock pays no dividends;

(d) the option is European, i.e. it can only be exercised at maturity (expiration date);

(e) there are no transactions costs of buying or selling,

(f) the market operates continuously, and

(g) there are no penalties to short selling.

The derivation of the Black-Scholes model, using stochastic calculus techniques can be found in [9].

Since its introduction in 1973, the Black-Scholes options pricing model has performed better overall than any model. Galai [6] extensively surveyed results from competing models. He found that no alternative model yielded better results on a constant basis than did Black-Scholes, though the Black-Scholes does not give consistently good estimates for deep-in and deep-out-of-the money options. It performs best when estimating market prices at-the-money. Chesney & Scott [2] in a test of 5 models, some variations of the Black-Scholes model, found that the Black-Scholes model had a performance superior to all others tested, as measured by the mean absolute deviation and the mean squared error.

So, the Black-Scholes model remains superior among option pricing equilibrium models, with the possible exception of cases in which trades are made deep-in and deep-out-of-the-money. But the volume of research which continues to proliferate related to the Black-Scholes model, even 20 years after its introduction, indicates there is considerable interest and value in developing a model which is more robust than Black-Scholes.

4. Research Plan and Significance

Daily data have been collected on the variables used by the Black-Scholes equation for six months during the period from January 1, 1990 to June 30, 1990.

Networks have been developed and trained using two-week sections of the collected data. Black-Scholes values have also been calculated for the entire set of six-month inputs. The results obtained in these sample networks are encouraging.

To compare the models on the data analyzed so far, we computed the mean absolute deviation (MAD), mean absolute percent error (MAPE), and mean squared error (MSE) of each set of estimations versus actual prices as reported in the Wall Street Journal. The initial results showed that, compared to the actual prices, the neural network estimations were better than those of the Black-Scholes model 50% of the time. These results indicate that the neural network methodology may offer a valuable alternative to estimating option prices to the traditional Black-Scholes model. The evidence is encouraging, particularly in view of the essentially undisputed superiority of the Black-Scholes model. Analytically, it is remarkable, that the well-developed methodology of Black-Scholes, with its explicit formula for pricing options, derived using sophisticated financial arbitrage arguments and advanced stochastic calculus techniques, can actually be approximated by neural networks, a methodology which makes no restrictions on the underlying distribution of the data. The results of these small data set comparisons have been presented in two peer group sessions and we have been encouraged to explore the problem further [10, 11].

In order to analyze the entire data set and improve the performance of the neural network, it is necessary to graph the entire data set using three-dimensional graphics, to show trends over time, to run statistical analysis programs and to construct networks based on larger groups of data. The packages used for initial studies are student versions which allows the user to look at only two weeks of data at a time. Since the preliminary results show the neural network to be at least as good as the Black-Scholes model over these short time periods, it seems valuable to explore this technique further. The full version of the statistical analysis and graphical software and neural network software would allow the entire six months worth of data to be explored, graphed, and analyzed.

The purpose of this grant request is to fund the purchase of the full version of the software which will allow this longterm analysis to be done.

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d. Plans for publishing results of the work.

The graphing and examination of the data, construction of the networks and analysis of the results should take about four months after the software is received. After writing up the conclusions, the paper will be submitted for publication to either Omega or Applied Intelligence.