

# Forecasting the Stock Market with ANNs and Autonomous Agents

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## INTRODUCTION AND BACKGROUND OF ORGANIZATION

Investment strategies usually aim at achieving maximum profitability what, according to current management theory (Refenes, Burgess, & Bentz, 1997), can be obtained by the construction of well balanced investment portfolios that seek to maximum return and minimum risks.

In order to provide users with information to plan a good investment portfolio, we present an e-commerce Web site solution that enables users to estimate in advance investments return and risks. The application, which is based on computational intelligence techniques, aims at forecasting and divulging the share prices of the main companies listed in the stock market.

Artificial neural networks (ANNs) (Haykin, 1999) that have been used successfully in many other financial time series applications (Braga, Carvalho, Lurdemir, Almeida, & Lacerda, 2002; Refenes, et al., 1997; Zhang, 2003) were used as the main forecasting engine of the system. Autonomous agents (Paolucci, Sycara, & Kawamura, 2003; Russel & Norvig, 1995) are responsible for collecting, on a daily basis, information regarding sale and purchase of shares. The information collected is then used by the ANN to forecast future stock market trends and closing values. The Web site offers free of charge services, such as access to forecasting charts, simulation of investments and general guidelines for buying and selling shares.

## DESCRIPTION OF E-COMMERCE, E-GOVERNMENT, AND/OR MOBILE COMMERCE

The application consists of an intelligent system capable of anticipating share prices of the main companies listed in the stock market. This task entails daily collection of market information for calculation time series future values. The data collected is used as exogenous variables of the neural model.

Autonomous agents are responsible for collecting data, divulging forecast indexes on the Web site and generating dynamic Web pages that interact with the data repository. Since they are activated daily, the agents behave as an autonomous intelligent system capable of operating without the intervention of the user or programmer. The *Sections* that follow describe the main techniques that form the structure of the e-commerce application: Artificial Neural Networks and Autonomous Agents.

## Artificial Neural Networks

Artificial neural networks (ANNs) (Bishop, 1995; Haykin, 1999) have been widely used to forecast financial time series in the last few years (Berardi & Zhang, 2003; Cao & Tay, 2003; Zhang, 2003). Characteristics inherent to neural models such as learning and generalization based on a set of data and universality in the approximation of linear and non-linear multi-variable continuous functions (Cybenko, 1988) make ANNs a very attractive tool for modeling and forecasting non-stationary time series, such as stock market values.

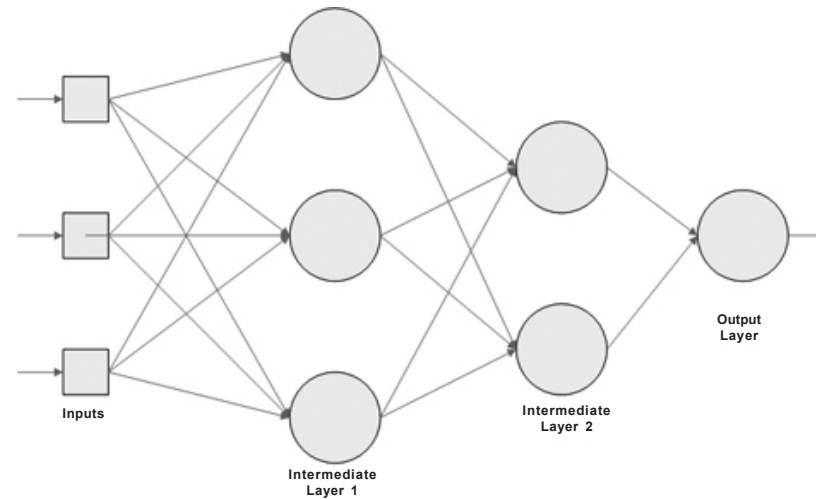
The forecasting models were based on multi layer perceptron (MLP) feed-forward networks (Haykin, 1999) that consist of a set of sensorial input units, one or two hidden (intermediate) layers and an output layer of computational elements (neurons). The entry signal propagates from the inputs to the outputs through each network layer. Figure 1 illustrates a MLP with two hidden layers.

In forecasting financial time series, the inputs of the MLP network are the independent or exogenous variables. The functional relationship estimated by an MLP network can be defined by the *equation* (Zhang, Patuwo, & Hu, 1998):

$$y = f(x_1, x_2, \dots, x_p),$$

where  $x_1, x_2, \dots, x_p$  are the independent variables  $p$  and  $y$  is the dependent variable. In this sense, this feed-forward neural model is functionally equivalent to a nonlinear regression model.

Figure 1. Typical MLP network with two hidden layers



Usually, in time series forecasting models, the inputs correspond to the exogenous variables delayed in time and the output to the future value predicted. This input-output functional mapping implemented by the neural network can be described by the equation (Zhang et al., 1998):

$$y_{t_1} = f(x_{1t}, x_{1t-1}, \dots, x_{1t-m}, x_{2t}, x_{2t-1}, \dots, x_{2t-n}, \dots, y_t, y_{t-1}, \dots, y_{t-p})$$

where the indexes  $t, t-1, \dots, t-p$  represent the delays of time in relation to  $t$ ;  $x_1$  and  $x_2$  are exogenous variables. Therefore, the MLP network can be seen as a nonlinear regression model for time series forecasting (Brockwell & Davis, 1996). The neural models developed use past values of the series as well as explanatory exogenous variables collected from Internet sites in order to predict future values.

The training process of an MLP network consists of defining the adequate values of the synaptic weights  $w$  and bias  $b$  present in the acyclic arcs that provide the links between the units (sensorial or computational) of the adjacent layers (Haykin, 1999). The knowledge acquired by the network during training is stored in these elements. Training of MLPs is supervised (Haykin, 1999) and each desired response (target) for each input pattern (example) is available in the training data. A training algorithm is used to search the values of the weights  $w$  and bias  $b$ , by minimizing an error measure such as the sum of square errors (SSE) or the sum of mean square errors (MSE) (Zhang et al., 1998). As a result, the training problem of an MLP network can be seen as a problem of non-linear minimization of a cost function (Bishop, 1995). Typically, an objective function (SSE) to be minimized during the training process is described by the equation:

$$E = \frac{1}{2} \sum_{i=1}^N (y_i - a_i)^2,$$

where  $a_i$  is the current output of the network,  $y_i$  is the desired output and  $N$  corresponds to the number of samples in the training set. There are a number of algorithms based on optimization methods for training MLPs, such as, for example, the Backpropagation algorithm (Rumelhart, Hinton, & Williams, 1986), the Levenberg Marquardt algorithm (Hagan & Menhaj, 1994), the GRG2 algorithm (Lasdon & Waren, 1986) and the MOBJ algorithm (Teixeira, Braga, Takahashi, & Saldanha, 1999).

## Autonomous Agents

According to Russel and Norvig (1995) “an agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators” (p. 32). An autonomous agent is a software component capable of working for the performance of tasks to the benefit of its users (Paolucci et al., 2003).

The ideal architecture of an agent will directly depend on the type of task it performs and on the environment it is in (Nilsson, 1998). The autonomous agents forming the intelligent system can be classified as information or Internet agents introduced following a demand for tools capable of helping managing the boom of information on the Internet. They manage and collect information from a wide variety of sources. They are programs capable of retrieving information from remote Web sites by means of Internet protocols (Paolucci et al., 2003), storing it in a data

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