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Abstract
Prediction of stock market returns is an important issue in finance. Artificial neural networks have been used in stock market prediction during the last decade. Studies were performed for the prediction of stock index values as well as daily direction of change in the index. In some applications it has been specified that artificial neural networks have limitations for learning the data patterns or that they may perform inconsistently and unpredictable because of the complex financial data used.

In Turkey artificial neural networks are mostly used in predicting financial failures. There has been no specific research for prediction of Turkish stock market values. The aim of this paper is to use artificial neural networks to predict Istanbul Stock Exchange (ISE) market index value.

Preliminary research performed on Turkish stock market has suggested that the inputs to the system may be taken as: previous day's index value, previous day's TL/USD exchange rate, previous day's overnight interest rate and 5 dummy variables each representing the working days of the week. After the inputs have been determined, the data have been gathered for the period of July 1, 2001 through February 28, 2003 from the Central Bank of Republic of Turkey. Training set is determined to include about 90% of the data set and the rest 10% will be used for testing purposes.

Network architecture is determined to be Multi Layer Perceptron and Generalized Feed Forward networks. Training and testing is performed using these two network architectures. However, subsystems are considered, which had different number of hidden layers (1, 2 and 4) for a mean-squared error value of 0.003. The results are then compared with the results of moving averages for 5 and 10-day periods, which showed that artificial neural networks have better performances than moving averages.

Keywords: Artificial neural networks; Stock exchange index value; Prediction

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Prediction of stock market returns is an important issue in finance. Artificial neural networks have been used in stock market prediction during the last decade. Studies were performed for the prediction of stock index values as well as daily direction of change in the index. In some applications it has been specified that artificial neural networks have limitations for learning the data patterns or that they may perform inconsistently and unpredictable because of the complex financial data used.

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1. Introduction

Prediction of stock market returns is an important issue in finance. Nowadays artificial neural networks (ANNs) have been popularly applied to finance problems such as stock exchange index prediction, bankruptcy prediction and corporate bond classification. An ANN model is a computer model whose architecture essentially mimics the learning capability of the human brain. The processing elements of an ANN resemble the biological structure of neurons and the internal operation of a human brain. Many simple interconnected linear or nonlinear computational elements are operating in parallel processing at multiple layers. In some applications it has been specified that ANNs have limitations for learning the data patterns. They may perform inconsistently and unpredictable because of the complex financial data used. Sometimes data is so voluminous that learning patterns may not work. Continuous and large volume of data needs to be checked for redundancy and the data size should be decreased for the algorithm to work in a shorter time and give more generalized solutions [1].

Artificial neural networks have been used in stock market prediction during the last decade. One of the first projects was by Kimoto and friends [2] who had used ANN for the prediction of Tokyo stock exchange index. Mizuno and friends [3] applied ANN again to Tokyo stock exchange to predict buying and selling signals with an overall prediction rate of 63%. Sexton and friends [4] concluded in 1998 that use of momentum and start of learning at random points may solve the problems that may occur in training process. Phua and friends [5] applied neural network with genetic algorithm to the stock exchange market of Singapore and predicted the market direction with an accuracy of 81%.

In Turkey ANNs are mostly used in predicting financial failures [6]. There has been no specific research for prediction of Turkish stock market values. The aim of this paper is to use ANNs to forecast Istanbul Stock Exchange (ISE) market index values.

2. Artificial Neural Network Approach

Machine learning approach is appealing for artificial intelligence since it is based on the principle of learning from training and experience. Connectionist models, such as ANNs, are well suited for machine learning where connection weights are adjusted to improve the performance of a network. An ANN is a network of nodes connected with directed arcs each with a numerical weight, $w_{i,j}$, specifying the strength of the connection (Figure-1). These weights indicate the influence of previous node, u_j, on the next node, u_i, where positive weights represent reinforcement; negative weights represent inhibition [7]. Generally the initial connection weights are randomly selected.

Feed-forward networks were first studied by Rosenblatt [8]. Input layer is composed of a set of inputs that feed input patterns to the network. Following the input layer there will be at least one or more intermediate layers, often called hidden layers. Hidden layers will then be followed by an output layer, where the results can be achieved (Figure-2). In feed-forward networks all connections are unidirectional.

Figure-1. Connection weight between nodes.

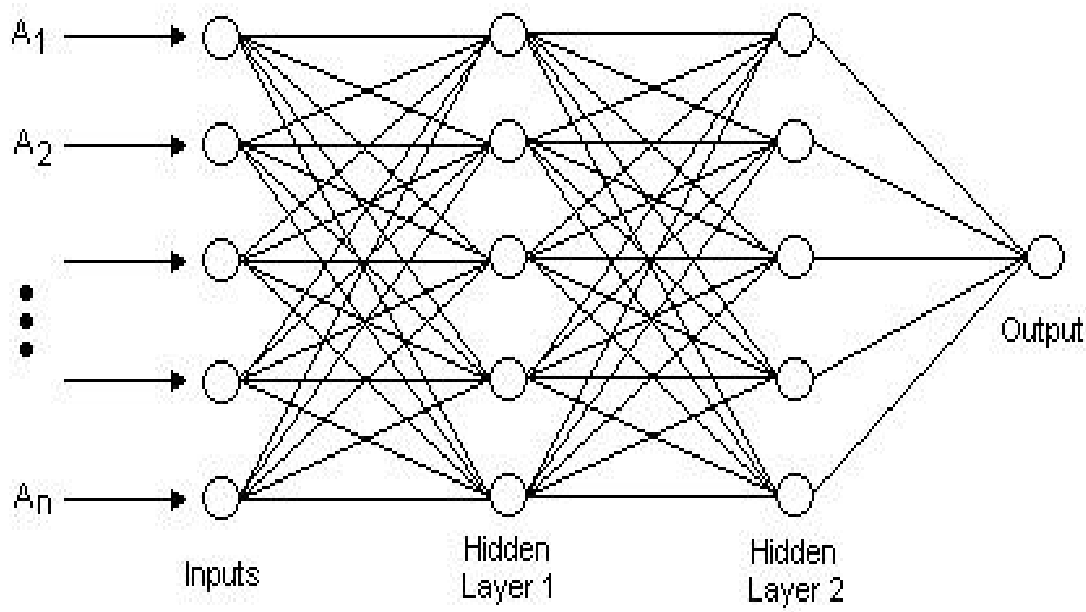

Figure-2. 2-hidden layers network with n inputs and 1 output.

Multi Layer Perceptron (MLP) networks are layered feed-forward networks typically trained with static backpropagation. These networks, also known as backpropagation networks, are mainly used for applications requiring static pattern classification [9]. The backpropagation algorithm selects a training example, makes a forward and a backward pass, and then repeats until algorithm converges satisfying a pre-specified mean squared error value. The main advantage of MLP networks is their ease of use and approximation of any input/output map. The main disadvantage is that they train slowly and require lots of training data.

Generalized feed-forward (GFF) networks are a generalization of the MLP networks where connections can jump over one or more layers, but these networks often solve problems much more efficiently [9].

2.1. Training Algorithm

Training is the process by which the free parameters of the networks (i.e. the weights) get optimal values. Supervised learning models, that are used for MLP and GFF networks, train certain output nodes to respond to certain input patterns and the changes in connection weights, due to learning, cause those same nodes to respond to more general classes of patterns. In these models input layer units distribute input signals to the network. Connection weights modify the signals that pass through it. Hidden layers and output layer contain a vector of processing elements with an activation function. Usually the Sigmoid function is used as the activation function.

Every unit u_i computes its new activation u_i as a function of the weighted sum of the inputs to unit u_i (u_j) from directly connected cells. Therefore, the output of each processing unit for the forward pass will be defined as:

$$S_i = \sum_{j=0}^{n} w_{i,j} * u_j \tag{1}$$

$$u_i = f(S_i) \qquad \text{where} \qquad f(x) = \frac{1}{(1+e^{-x})} \tag{2}$$

The backward pass is the error back-propagation and adjustment of weights. Gradient descent approach with a constant step length, also referred to as learning rate, is used to train the network. This method minimizes the sum of squared errors of the system until a given minimum or stop at a given number of epochs, where epoch is the term specifying the number of iterations to be done over the training set. The error is multi-dimensional and may contain many local minima. A momentum term may be added to avoid getting stuck in local minima or slow convergence. The output of each processing unit for the backward pass is defined as:

$$f'(S_i) = u_i * (1 - u_i) \tag{3}$$

Weights are then updated by the formula where ε is the mean squared error and ρ is the step size:

$$d_i = -\left(\frac{\partial_e}{\partial S_i}\right) \tag{4}$$

$$w^*_{i,j} = w_{i,j} + r d_i u_j \tag{5}$$

After the training process is completed, the network with specified weights can be used for testing a set of data different than those used for training. The results achieved can then be used for generalization of the approximation of the network.

3. Modeling of Stock Market Index Value

Forecasting of stock exchange market index values is an important issue in financial sector. The objective of this paper is to illustrate that the ANNs can effectively be used to predict the Istanbul Stock Exchange (ISE) index values using previous day’s index value, previous day’s TL/USD exchange rate, previous day’s overnight interest rate and 5 dummy variables each representing the working days of the week. Supervised learning models have been utilized in which certain output nodes were trained to respond to certain input patterns and the changes in connection weights due to learning caused those same nodes to respond to more general classes of patterns.

3.1. System Model

In this study the following input variables were considered to ultimately affect the stock exchange market index value.

Previous day's ISE National 100 index value (according to closing price) (ISE_PREV)
Previous day's TL/USD exchange rate (average of buying and selling values) (TL_USD_PREV)
Previous day's Simple Interest Rate Weighted Average Overnight (ON_PREV)
Dummy variable 1 representing Monday (will be 1 when the day is Monday, else 0) (M)
Dummy variable 2 representing Tuesday (T)
Dummy variable 3 representing Wednesday (W)
Dummy variable 4 representing Thursday (TH)
Dummy variable 5 representing Friday (F)

Considering the input variables, the following system model was considered for the prediction stock exchange market index value:

$$f_{ISE} = f \text{ (ISE\_PREV, TL\_USD\_PREV, ON\_PREV, M, T, W, TH, F)}$$

3.2. Data Sets

Experimental data were gathered directly from the Central Bank of Republic of Turkey for a period of 417 days starting from July 2, 2001 to February 28, 2003. From this data set, the first 376 cases (about 90%) were taken as training and 41 as testing examples.

3.3. Network Parameters

For the system model described before, two different ANN models (MLP and GFF) were applied with different number of hidden layers (HL = 1, 2, 4) for minimum mean squared error value of 0.003, for the data set. Thus, 6 different ANN models have been used.

3.4. Training Results

In this study, 6 ANN models were applied to the system model, using an ANN software package. ANN models' performances can be measured by the coefficient of determination (R^2) or the mean relative percentage error. This coefficient of determination is a measure of the accuracy of prediction of the trained network models. Higher R^2 values indicate better prediction. The mean relative percentage error may also be used to measure the accuracy of prediction through representing the degree of scatter. For each prediction model, Eq.6 was utilized to calculate the relative error for each case in the testing set. Then, the calculated values were averaged and factored by 100 to express in percentages.

$$\frac{\left|(f_{ISE})_{actual} - (f_{ISE})_{predicted}\right|}{(f_{ISE})_{actual}} \qquad (6)$$

Table-1 shows the ANN models with the R^2 values of the 3 MLP and 3 GFF network models applied to system model.

Number of Hidden Layers	ANN Model	
	MLP	GFF
1	0.81	0.82
2	0.79	0.81
4	0.78	0.81

Table-1 Coefficient of determinations (R^2) for ANN models

3.5. Comparison with Moving Averages

The ANN performances can be compared with Moving Averages (MA) approach. The moving average is the average of lagged index values over a specified past period (5 and 10 days in this study). The mean relative percentage errors were calculated as 0.022 for 5 days and 0.03 for 10 days. Table-2 shows all models with mean relative percentage errors.

Model	Mean Relative Percentage Error (%)
MLP - 1 Hidden Layer	1.62
MLP - 2 Hidden Layers	1.65
MLP - 4 Hidden Layers	1.70
GFF - 1 Hidden Layer	1.59
GFF - 2 Hidden Layers	1.65
GFF - 4 Hidden Layers	1.71
MA - 5 days	2.17
MA - 10 days	3.03

Table-2 Mean relative percentage errors for all models

4. Evaluation

The accuracy of the prediction for each ANN model has been compared by the coefficient of determination. The efficiency of ANN models varied with the number of hidden layers. For both MLP and GFF network models, the highest accuracies are obtained with 1 hidden layer.

The mean relative percentage errors calculated for all models verified that the ANN models were superior to the MA model.

5. Conclusion

This study was aimed at finding the best model for the prediction of Istanbul Stock Exchange market index values. Total of 8 sets of predictions, that result from the application of 6 ANN models and two MA were performed. Results were compared using the coefficients of determination for ANN models and using mean relative percentage errors for all of the models.

Based on the findings of this study it can be concluded that:

1. The prediction models based on ANNs were more accurate than the ones based on MAs.
2. Among the ANN models, GFF network model was found to be more appropriate for the prediction.

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