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Integrating metaheuristics and Artificial Neural Networks for improved stock price prediction

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ABSTRACT

Stock market price is one of the most important indicators of a country's economic growth. That's why determining the exact movements of stock market price is considerably regarded. However, complex and uncertain behaviors of stock market make exact determination impossible and hence strong forecasting models are deeply desirable for investors' financial decision making process. This study aims at evaluating the effectiveness of using technical indicators, such as simple moving average of close price, momentum close price, etc. in Turkish stock market. To capture the relationship between the technical indicators and the stock market for the period under investigation, hybrid Artificial Neural Network (ANN) models, which consist in exploiting capabilities of Harmony Search (HS) and Genetic Algorithm (GA), are used for selecting the most relevant technical indicators. In addition, this study simultaneously searches the most appropriate number of hidden neurons in hidden layer and in this respect; proposed models mitigate well-known problem of overfitting/underfitting of ANN. The comparison for each proposed model is done in four viewpoints: loss functions, return from investment analysis, buy and hold analysis, and graphical analysis. According to the statistical and financial performance of these models, HS based ANN model is found as a dominant model for stock market forecasting.

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1. Introduction

A stock market is a public market to trade the company's stocks and derivative at an approved stock price (Preethi & Santhi, 2012). Stock market provides opportunities for brokers and companies to make investments on neutral ground and is one of the primary indicators of a economic condition of the country (Perwej & Perwej, 2012). However, stock market is characterized by nonlinearities, discontinuities, and high-frequency multi-polynomial components because it is interacted with many factors such as political events, general economic conditions, and traders' expectations (Hadavandi, Shavandi, & Ghanbari, 2010). Also, the fast data processing of these events with the help of improved technology and communication systems has caused the stock prices to fluctuate very fast. Thus many banks, financial institutions, large scale investors and stock brokers have to buy and sell stocks within the shortest possible time and time span of even a few hours between buying and selling is not unusual (Bonde & Khaled, 2012). Robust and agile stock market is also highly desirable in the field of finance, engineering and mathematics due to high return possibility. It is generally seen as a peak investment outlet. For these purposes, many researchers have been investigated the predictability of the stock market by using of fundamental analysis, technical analysis, time series prediction, and machine learning methods (Prasanna & Ezhilmaran, 2013). Besides, most of the companies have created new methods for evaluating financial data and investment decisions (Sureshkumar & Elango, 2012). Among them, ANN approach has been thought as the best forecasting method with a high level of validity in the fields of stock market forecasting. However, some critical points of ANN structure should be carefully analyzed. The definition what constitutes an optimal set of ANN input variables can be considered one of the main problems in ANN structure because the choice of input variables directly affects the forecasting accuracy. Secondly, number of neurons (or units, nodes) in hidden layer is also so important for ANN. It is an adjustable part in ANN but unfortunately, there is no unique method for fixing the optimum number of neurons in hidden layer for a particular problem. Therefore, researchers prefer generally to use trial and error method for this purpose. In this paper, we proposed hybrid methodology for determining input variable and the number of neurons in hidden

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layer. GA and HS are used as a tool for improving ANN's forecasting performance. In literature, GA is often used with ANN for the purpose of training the network, feature subset selection, and architecture optimization. However, HS is generally not used with ANN for these purposes. Therefore, our study is created alternative solution methods for stock market forecasting with better solutions. The contribution is structured as follows. Section 2 describes the related works. Then, we start describing solution methodology in Section 3. Section 4 deals with results and discussions. Finally, Section 5 is devoted to conclusions.

2. Literature

The importance of Turkish stock market has increased substantially with the establishment of the Istanbul Stock Exchange in 1986. Since its establishment in 1986, the ISE has followed a fast pace growth in terms of trading volume, market capitalization, number of listed corporations and foreign investment (Adaoglu, 2000). Also, ISE characterized with high volatility in the market and such volatility attracts many local and foreign investors as it provides high return possibility (Cinko & Avci, 2009). Hence, forecasting stock market movement has been the objective of the vast research papers applying different techniques. Among them, ANN is featured as being data driven and, hence, does not require assumptions concerning data. With such a feature ANN is a suitable technique in handling nonlinear, highly complex and dynamic data of stock markets (Karymshakov & Abdykaparov, 2012). In the literature, ANN is clearly explained by Egeli, Ozturan, and Badur (2003). The authors used six different ANNs which includes multi-layer perceptron (MLP) and generalized feed forward to predict ISE market index value. Authors used 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 as inputs. The results showed that for each ANN model, the highest accuracies were obtained with 1 hidden layer and also ANN models give more accurate results than the ones based on moving averages. Guresen, Kayakutlu, and Daim (2011) compared ANN models including MLP, dynamic ANN, and the hybrid neural networks. It is observed that classical ANN model MLP gives more reliable results than the other models used in this comparison. Kara, Boyacioglu, and Baykan (2011) revealed that ANN works better than Support Vector Machine in predicting the direction of stock price movement in the ISE. In the study, parameters of ANN models such as number of neurons in the hidden layer were determined empirically. Also, ten technical indicators were selected as feature subsets by the review of domain experts and prior researches. Şenol and Özturan (2008) statistically demonstrated that ANN outperforms Logistic Regression methodology. In the study, ANN was used to predict the stock price behavior in terms of its direction. The best results were obtained for ANN model with three inputs, 11hidden neurons in the single hidden layer and one output with three indicators, relative strength index of 14 days, stochastic indicator for 14 days, and stochastic moving average. Yildiz, Yalama, and Coskun (2008) utilized ANN for forecasting the direction of the ISE National-100 using the highest and lowest prices paid during the day, the closing price, the exchange rate (as the US dollar), and response rates as an input variables. The results of the previous studies show that accuracy of stock market prediction is generally between 60% and 76%, and hence more robust ANN model is needed to increase prediction accuracy in Turkish stock market.

Having highly functional stock markets and exchanges is incredibly valuable all over the world is a well-known fact. Therefore, so many types of ANN models are developed to search out more efficient forecasting model. Chiu and Chuang (2003) showed that ANN has ability for predicting tendency of Taiwan stock market. Five different ANN models were developed to decide the number of input neurons and hidden neuron. Also, the classification technique and clustering method were used under framework of ANN with quantitative and qualitative factors. Similarly, Aldin, Dehnavi, and Entezari (2012) used ANN for stock price index forecasting on the Taiwan Stock Exchange. Closing price, the high and low price index were converted into technical indicators for predicting the position of stock price movements. In the study, neuron numbers in the hidden layer was determined empirically. Dastgir and Enghiad (2012) evaluated Iran Stock Market by focusing on forecasting Tehran Stock Exchange Price Index which is the most significant index of Iran Stock Market. In the study, two hidden layers were used with many combinations of architecture. The number of neurons in each hidden layer was changed from one to sixteen. Results of the study revealed that ANN model with three hidden neurons on the first hidden layer and four hidden neurons on the second achieved the best performance in Iran Stock Market. Ruxanda and Badea (2014) presented different configured ANNs and compared them in terms of forecasting errors while making predictions on Bucharest Stock Market Index. Input variables were set based on a stepwise forward regression. Adebiyi, Adewumi, and Ayo (2014) found that 10 inputs obtained from the New York Stock Exchange including open price, low price, high price, close price, and volume traded, 17 hidden neurons, and one output neuron give more accurate results in ANN model. Laboissiere, Fernandes, and Lage (2015) used ANN to predict the maximum and minimum day stock prices of Brazilian power distribution companies. In the study, correlation analysis was used to select input variable and different ANN architectures were tested empirically. The best results were found with one hidden layer and only five hidden neurons. Zahedi and Rounaghi (2015) applied ANN and principal component analysis to predict stock price on Tehran Stock Exchange. The results of the study show that ANN model has superiority over its rivals. Also, principal component analysis method can accurately predict stock price on Tehran Stock Exchange using 20 accounting variables.

In this paper we review studies in the ANN literature which have been used for stock market forecasting, results revealed that a different combination of attribute sets was experimented with different ANN model parameter values and each study provides satisfying result in existing condition but ANN architecture is very important which directly affects system performance essentially. Hence, most previous studies were focused on the improvement of the ANN architecture. However, there are few studies on the input variable selection from predetermined data set and there is no clear methodology available for variable selection and determining number of hidden neurons in hidden layer. Therefore, the basic idea that lies behind the proposed models is not only selecting the most relevant input variables that are to be used by ANN models but also setting the number of neurons in hidden layer by manipulating ANN structure via metaheuristics. Thus, proposed models based on GA and HS are applied to improve forecasting accuracy and stability of ANN.

3. Solution methodology

3.1. Technical indicators

This section describes input variable selection methodology. For each case, 45 technical indicators are considered as input variables. Technical indicators are effective tools to characterize the real market situation. Using technical indicators can be more informative than using pure prices (Nikfarjam, Emadzadeh, & Muthaiyah, 2010) and it is very practical way for stock analysts and fund managers to analyze stock market. On the other hand, this technique may not be a good alternative solution for common investors because too many technical indicators are available to be considered as prediction factors and the most commonly used technical indicators are ordinarily not understandable. Therefore, selection of the useful technical indicators accurately is the key issue to make a profit for those stock market investors (Wei & Cheng, 2012). However, no method is successful

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