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Application of artificial neural network for the prediction of stock market returns: The case of the Japanese stock market

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ABSTRACT

Accurate prediction of stock market returns is a very challenging task because of the highly nonlinear nature of the financial time series. In this study, we apply an artificial neural network (ANN) that can map any nonlinear function without a prior assumption to predict the return of the Japanese Nikkei 225 index. (1) To improve the effectiveness of prediction algorithms, we propose a new set of input variables for ANN models. (2) To verify the prediction ability of the selected input variables, we predict returns for the Nikkei 225 index using the classical back propagation (BP) learning algorithm. (3) Global search techniques, i.e., a genetic algorithm (GA) and simulated annealing (SA), are employed to improve the prediction accuracy of the ANN and overcome the local convergence problem of the BP algorithm. It is observed through empirical experiments that the selected input variables were effective to predict stock market returns. A hybrid approach based on GA and SA improve prediction accuracy significantly and outperform the traditional BP training algorithm.

1. Introduction

To revive the Japanese economy, the Japanese government has recently developed many significant economic strategies, and each strategy is closely related to the Japanese stock market. As the most widely used market index for the Tokyo Stock Exchange, the Nikkei 225 index, also known as the Nikkei average or simply Nikkei, is a benchmark that is used to evaluate the Japanese economy. Forecasting the stock return of the Nikkei 225 index is an important financial subject that has attracted significant attention in major financial markets around the world. The purpose of this paper is to apply an artificial neural network (ANN) to forecast the return of the Nikkei 225 index.

It has been widely accepted by many studies that nonlinearity exists in financial markets and that an ANN can be used effectively to uncover this relationship [1]. McCulloch and Pitts [2] created a computational model for neural networks based on mathematics and algorithms, and the application of ANNs to financial and investment decisions has been examined by researchers for many years. Compared to regression or the passive buy-and-hold strategy, Motiwalla and Wahab [3] found that ANN models are more successful in predicting returns. Enke and Thawornwong [1] used neural network models for level estimation and classification. They showed that the trading strategies guided by a neural network classification model can generate higher profits than any other model. Hodnett and Hsieh [4] utilized two ANN learning rules to forecast the cross-section of global equity returns. Their findings support the use of ANNs for financial forecasting. Application of ANNs has become the most popular machine learning method, and it has been proven that such an approach can outperform conventional methods [5-13].

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In light of previous studies, it has been hypothesized that various technical indicators may be used as input variables in the construction of prediction models to forecast the return of a stock price index [14]. In most applications, input variables that have been proven effective by previous studies were used to predict stock market returns. Some effective indicators of stock price include lagged returns, interest rate value, foreign exchange rate, consumer price index, industrial production index, and deposit rate [1,15]. In this study, we examined the indicators that were proven valid by prior studies and attempted to determine input variables that have not been previously used to predict stock market returns by assessing the ability of those indicators to predict a stock market index. We collected 71 input variables that cover financial and economic information of the Japanese stock market, most of which have not been examined in previous studies.

Although an ANN can be a very useful tool in the prediction of stock market returns, several studies have shown that ANNs have some limitations because stock market data contain a tremendous amount of noise, non-stationary characteristics, and complex dimensionality [16]. Therefore, we must perform data preprocessing prior to utilizing an ANN to predict stock market returns. This study attempted to implement fuzzy surfaces in the selection of optimal input variables. As a result, 18 valid explanatory variables were selected from the 71 input variables for experimentation.

We first applied a back propagation (BP) algorithm to train the neural network in a large number of experiments. The BP algorithm is a widely applied classical learning algorithm for neural networks. Wong, Bodnovich [17] found that many of the studies that have used ANNs relied on gradient techniques for network training, typically some variation of the BP algorithm. Although, researchers have commonly trained ANNs using the gradient technique of the BP algorithm, limitations of gradient search techniques emerge when ANNs are applied to complex nonlinear optimization problems [18]. The BP algorithm has two significant drawbacks; i.e., slowness in convergence and an inability to escape local optima [19]. In view of these limitations, global search techniques, such as genetic algorithms (GA) and simulated annealing (SA), have been proposed to overcome the local convergence problem for nonlinear optimization problems. This study has attempted to determine the optimal set of initial weights and biases to enhance the accuracy of an ANN using GA or SA. The experimental results show that a hybrid approach improves the prediction accuracy of the return of the Nikkei 225 index and outperforms the BP training algorithm. In addition, the effect on prediction of the combined 18 input variables is effective and can therefore be a good alternative for predicting stock market returns.

The remainder of this paper is organized as follows. Section 2 provides an outline of the prediction procedure. Section 3 describes variable selection. Then, we describe experiments that used the BP algorithm in Section 4, and we discuss improving parameter training using a GA or SA in Section 5. Finally, Section 6 provides a discussion of the experimental results and conclusions. Data descriptions are provided in the Appendix.

2. Prediction procedure

2.1. Data description

The Nikkei 225 index is the most widely used market index for the Tokyo Stock Exchange. It includes 225 equally weighted stocks and has been calculated daily since 1950. To predict the returns of the Nikkei 225 using an ANN, we collected 71 variables that include financial indicators and macroeconomic data. The entire data set covers the period from November 1993 to July 2013, providing a total of 237 months of observations. The data set was divided into two periods. The first period covers November 1993 to December 2007 (170 months), and the second period covers January 2008 to July 2013 (67 months). The first period, i.e., the in-sample data, was divided into training (70% of the period) and prediction (30% of the period) sets. The training data was used to determine model specifications and parameters, and the prediction set was reserved for evaluation and comparison of performance among the prediction models. The second period, i.e., the out-of-sample data, was reserved for testing the performance of the prediction models because this data was not utilized to develop the models.

2.2. Model description

Funahashi [20], Hornik, Stinchcombe [21] have shown that neural networks with sufficient complexity could approximate any unknown function to any degree of desired accuracy with only one hidden layer. Therefore, the ANN model in this study consists of an input layer, a hidden layer and an output layer, and each of which is connected to the other. The architecture of the ANN is shown in Fig. 1. The input layer corresponds to the input variables, with one node for each input variable. The hidden layer is used for capturing the nonlinear relationships among variables. Note that an appropriate number of neurons in the hidden layer needs to be determined by repeated training. The output layer consists of only one neuron that represents the predicted value of the output variable.

2.3. Prediction procedures

The architecture of our experimental process is shown in Fig. 2. First, we applied fuzzy surfaces to the selection of effective input variables prior to modeling. Then, we performed BP algorithm experiments 900 times to determine the most appropriate parameter combination for the ANN. We selected the best BP model for predicting the stock returns. Using the BP algorithm, we can obtain the optimized weights and biases of the network by repeated training. We also applied a GA and SA to improve the ANN parameters. We then trained the network using the BP algorithm with the improved weights and biases. Finally, we