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Maximum and minimum stock price forecasting of Brazilian power distribution companies based on artificial neural networks

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ABSTRACT

Time series forecasting has been widely used to determine future prices of stocks, and the analysis and modeling of finance time series is an important task for guiding investors' decisions and trades. Nonetheless, the prediction of prices by means of a time series is not trivial and it requires a thorough analysis of indexes, variables and other data. In addition, in a dynamic environment such as the stock market, the non-linearity of the time series is a pronounced characteristic, and this immediately affects the efficacy of stock price forecasts. Thus, this paper aims at proposing a methodology that forecasts the maximum and minimum day stock prices of three Brazilian power distribution companies, which are traded in the São Paulo Stock Exchange BM&FBovespa. When compared to the other papers already published in the literature, one of the main contributions and novelty of this paper is the forecast of the range of closing prices of Brazilian power distribution companies' stocks. As a result of its application, investors may be able to define threshold values for their stock trades. Moreover, such a methodology may be of great interest to home brokers who do not possess ample knowledge to invest in such companies. The proposed methodology is based on the calculation of distinct features to be analysed by means of attribute selection, defining the most relevant attributes to predict the maximum and minimum day stock prices of each company. Then, the actual prediction was carried out by Artificial Neural Networks (ANNs), which had their performances evaluated by means of Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE) calculations. The proposed methodology for addressing the problem of prediction of maximum and minimum day stock prices for Brazilian distribution companies is effective. In addition, these results were only possible to be achieved due to the combined use of attribute selection by correlation analysis and ANNs.

1. Introduction

Time series forecasting consists in a research area designed to solve various problems, mainly in the financial area [1–14]. It is noteworthy that this area typically uses tools that assist in planning and making decisions to minimize investment risks. This objective is obvious when one wants to analyse financial markets and, for this reason, it is necessary to assure a good accuracy in forecasting tasks. As mentioned in [15], the improvements on prediction models are not only very important, but also compelling. In this sense, we highlight the Autoregressive (AR), Moving Average (MA), Autoregressive Moving Average (ARMA) and the Autoregressive Integrated Moving Average (ARIMA) models, which have become widespread methods for time series forecasting.

Nonetheless, when considering the analyses of processes or systems represented by time series, it is common to verify that the data presents a nonlinear behavior. In this context, intelligent systems, such as Artificial Neural Networks (ANN) [1–5,8,11,12,16–18], Fuzzy Inference Systems [6,9], and Neural-Fuzzy Systems [10,13,14,19] are considered useful approaches for addressing problems of time series forecasting.

Regarding the forecast of stock market indexes, in [5], a comparison of intelligent systems to forecast the NASDAQ stock exchange index is presented. The intelligent systems used were: Dynamic Artificial Neural Network (DAN2), ANN with Multilayer Perceptron (MLP) architecture; and Generalized Autoregressive Conditional Heteroskedasticity (GARCH) combined with DAN2 and MLP. The authors used data set cross-validation in the training and testing stages, and it was noted that the MLP provides more reliable results than the other intelligent systems used in this comparison.

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Table 1
Summarized references.

Ref.	Objective	Method
[20]	Stock price trend forecasting	Partially connected ANN
[21]	Stock market forecasting	ANN and adaptive exponential smoothing
[22]	Direction of stock price index	ANN and Support Vector Machine (SVM)
[23]	Stock price index forecasting	ANN, SVM, Random Forest (RF) and naive-Bayes
[24]	Stock price variation forecasting	Taguchi method and BP-ANN
[25]	Stock trading strategy	Fisher method and SVM
[26]	Stock market index forecasting	Support Vector Regression (SVR) with ANN, SVR with RF, SVR with SVR
[27]	Stock price forecasting	Bat-neural network and multi-agent system

In [12], the authors argue that time series of stock prices are non-stationary and highly-noisy. Thus, this has led the authors to propose the use of a Wavelet De-noising-based Backpropagation (WDBP) neural network to predict the monthly closing price of the Shanghai Composite Index. To prove the effectiveness of using WDBP for such predictions, the results provided by the WDBP approach were compared to the ones provided by the conventional backpropagation training algorithm for MLPs. This approach based on the combination of Wavelet Transform (WT) and backpropagation algorithm was designed intending to use the frequency decomposition characteristic of WT to extract the noise of the time series. The authors used data from January 1993 to December 2009; nevertheless, 80% of this data were used in the training stage and the remaining 20% were used for validation. After the validation stage, it was possible to notice that WDBP presented a MAPE (Mean Absolute Percentage Error) of 19.48%, while the MLP with conventional backpropagation achieved a MAPE of 24.92%.

In [10], an Adaptive Network-based Fuzzy Inference System (ANFIS) was employed to predict the closing price of the Zagreb Stock Exchange Index Crobex (CRO). In this paper, the authors used historical data comprising a period beginning in November 2010 and ending in January 2012. Based on these data, the featured approach predicts the close for CRO in the five subsequent days. It was observed that the predictions have their errors increased for each day ahead, i.e., the 5th day presents, in terms of RMSE (Root Mean Square Error), an error of 0.5 greater than the 1st day.

Due to inherent difficulties in forecasting closing prices, the authors in [4] propose forecasting the direction of change of the Brazilian oil company Petrobras (PETR4) stock price by means of ANNs. Such a prediction is not only an alternative to closing price forecastings, but also a very suitable prediction strategy for stock exchange transactions. The authors propose the use and construction of neural models based on MLP to predict the behavior of PETR4 closing price on the São Paulo Stock Exchange BM&FBovespa in a short-term horizon. Thus, this paper conducts a series of empirical tests to determine which variables will influence the prediction of the change of direction. By means of this methodology, it was possible to validate the ANNs with data acquired from January 2012 to November 2012, where a MAPE of 26.47% was obtained.

Besides the above mentioned papers, other invaluable contributions to the field may be summarized in Table 1.

From Table 1, it is possible to notice that most papers in the literature provide methodologies for determining closing prices and/or directions of change of specific stocks. Besides this, many of them use of intelligent systems due to the non-linearity of time series. In this context, it is possible to notice that ANNs are tools widely employed to forecast stock prices and then assist investors' decision-making. Therefore, this paper is focused on predicting the maximum and minimum day stock prices of Brazilian power distribution companies as an alternative to closing prices and direction of change estimations (due to the difficulties in establishing trusted forecasts to home brokers and small investors), since it may help minimizing the investment risks of day-trades. This study aims at both using and analysing the response of the ANN, as well as defining the variables that most influence the maximum and minimum day stock prices forecast of the following Brazilian power distribution companies CPFL (CPFE3), CEB (CEBR3) and COSERN (CSRN3). It is noteworthy to mention that the selected companies have different stakes in the stock market and this is a factor that cannot guarantee the same influence of all the determined variables.

This paper is organized as follows: Section 2 briefly differs classic from intelligent systems-based methods applied to time series forecasting; Section 3 introduces the proposed methodology and also presents the numerical results and discussions; and, at last, the main contributions of this paper are summarized and highlighted in Section 4.

2. Time series forecasting

According to [15], forecasting based on a time series represents a means of providing information and knowledge to support a subsequent decision. Thus, the analysis of time series focuses on achieving dependency relationships between their historical data. For this reason, a time series may also be referred as a sequence of data specified at regular time intervals during a period. Consequently, the time series analysis is used to determine structures and patterns in historical data and, from this analysis, develop a model that predicts their behavior. So, prediction models aims at determining future values and/or trends of a time series, which are normally treated by means of regression models.

There are some well-known statistical models that can be applied to time series forecasting. Among these models, we highlight the AR, MA, ARMA models that are commonly used to represent stationary time series. Stationary time series consists of data sets that have constant mean and variance along time. However, not every time series can be considered stationary, e.g., most of those found in industry, business and finance [15]. Based on this fact, the ARIMA model emerged and it can be considered as a generalization of ARMA, where the main consideration is taken when defining the polynomial AR model as a unit root model.

As commented above, the ANNs have been widely applied in the forecasting of stock prices. Moreover, among the ANN architectures, the MLP is the most used due to the possibility of employing it in prediction problems [28]. Thus, it is noticeable that the proposed architecture is suitable for the maximum and minimum day stock prices forecast of Brazilian power distribution companies.

2.1. Fundamentals of ANNs

One of the main characteristics of ANNs is their capacity of not only learning by means of examples, but also generalizing from the learned information. ANNs with multilayer perceptron architecture were employed in this work.

The artificial neuron in Fig. 1 consists of a mathematical model with n input terminals (x_1, x_2, …, x_{n-1} and x_n, representing the dendrites) and a single output terminal (y, representing the axon). The synaptic behavior is simulated by means of synaptic weights (w_1, w_2, …, w_{n-1} and w_n), whose values can be either positive or negative. The neuron bias is represented by a threshold value (b). The activation function g is responsible for processing the received information (weighted received inputs and the neuron threshold