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Differential Evaluation Learning of Fuzzy Wavelet Neural Networks for Stock Price Prediction

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Abstract. Prediction of a stock price movement becomes very difficult problem in finance because of the presence of financial instability and crisis. The time series describing the movement of stock price are complex and non stationary. This paper presents the development of fuzzy wavelet neural networks that combines the advantages of fuzzy systems and wavelet neural networks for prediction of stock prices. The structure of Fuzzy Wavelet Neural Networks (FWNN) is proposed and its learning algorithm is derived. The proposed network is constructed on the base of a set of TSK fuzzy rules that includes a wavelet function in the consequent part of each rules. The proposed FWNN structure is trained with differential evaluation (DE) algorithm. The use of DE allows quickly train the FWNN system than traditional genetic algorithm (GA). FWNN is used for modelling and prediction of stock prices. Stock prices are changed every day and have high-order nonlinearity. The statistical data for the last three years are used for the development of FWNN prediction model. Effectiveness of the proposed system is evaluated with the results obtained from the simulation of FWNN based systems and with the comparative simulation results of other related models.

Keywords: Prediction of stock prise; Fuzzy wavelet neural networks; Differential Evolution

1. Introduction

Financial market is characterized with complex, stochastic, nonstationary processes [1-3]. The chaotic behaviour of the stock price movement complicates the stock price prediction. The development an effective model for prediction of a stock price is one of important problem in finance. Depend on results of prediction system, the trading systems implement market actions of buy, sell or hold. Here the goal of is to choose the best stocks when making an investment and to decide when and how many stocks to sell or buy. Timely decisions must be made which result in buy signals when the market is low and sell signals when the market is high. Profitability of the trading system is very much related to the accuracy of the forecasts, the trading strategy used and magnitude of the transaction costs [1].

Numerous techniques have been developed to predict nonlinearity of time series and improve the accuracy of prediction [2-4]. These are well-known Box-Jenkins method [2], Linear Regression (LR), autoregressive random variance (ARV) model, autoregressive conditional hetroscedasiticity (ARCH), general autoregressive conditional heteroskedasticity (GARCH). While these techniques may be good for a particular situation, they do not give satisfactory results for the nonlinear time-series [4]. The traditional methods used for prediction are based on technical analysis of time-series, such as looking for trends, stationarity, seasonality, random noise variation, moving average. Most of them are linear approaches which have shortcomings. Hence the idea of applying non-linear models, like soft computing technologies, such as neural networks (NNs), fuzzy systems (FSs), genetic algorithms (GAs), Support Vector Machines (SVMs), has become important for time series prediction. During the last decade, stocks and futures traders have come to rely upon various types

of intelligent systems to make trading decisions. These methods have shown clear advantages over the traditional statistical ones.

NNs have shown to provide better predictive performance in technical analysis and in predicting future stock price movements by analyzing the past sequence of stock prices. NNs can substantially outperform the conventional statistical models [4-6]. NNs do not require strong model assumptions and can map any nonlinear function without any priori assumption about the properties of the data. The radial based network algorithms for time-series prediction has been considered in [7,8]. Support vector machine (SVM) based on statistical learning theory is a novel neural network algorithm and has been applied in developing an accurate stock market prediction model [9].

During a day, stock prices change from morning to night. In this changeable traffic stock prices are usually described by these four parameters: Open, High, Low, Close. These correspond to market opening price, high and low range of price volatility within a day and closing price. In this paper the integration of fuzzy logic, neural networks and wavelet technology is used in order to describe the stock price values of prediction system. The use of such approach provides better prediction accuracy for achieving the optimal solution, as this was demonstrated in the simulation section of this paper.

Fuzzy theory is applied to stock price forecasting [10-13]. Heuristic model [12], adaptive expectation model [10] for stock price forecasting is proposed to improve stock price forecasting performance. During development of a fuzzy system one of basic problem is generation of IF-THEN rules. Nowadays, the use of neural networks takes more importance for this purpose [14,15,16]. In this paper the integration of NNs and wavelet function is considered. Wavelet function is a waveform that has limited duration and an average value of zero. The integration of the localization properties of wavelets and the learning abilities of NNs shows advantages of wavelet neural networks (WNNs) over NNs in complex nonlinear system modeling. The WNN has been proposed by researchers for solving approximation, classification problems and modeling problems [17-21]. Fuzzy wavelet neural networks (FWNN) combine wavelet theory, fuzzy logic, and neural networks. The different FWNN models are proposed in literature [22-29]. In [22] the membership functions are selected from the family of scaling functions, and a fuzzy system is constructed using wavelet techniques. FWNN is applied for prediction of electricity consumption [26,27]. The combination of wavelet networks and fuzzy logic allows us to develop a system that has fast training speed, and to describe nonlinear objects that are characterized with uncertainty. Wavelet transform has the ability to analyze non-stationary signals to discover their local details. Fuzzy logic allows us to reduce the complexity of the data and to deal with uncertainty. Neural networks has a self-learning characteristic that increases the accuracy of the prediction. In this paper, to increase prediction accuracy and reduce search space and time for achieving the optimal solution, the combination of wavelet neural networks with a fuzzy knowledge base is used for financial time series prediction, in particular, for the prediction of stock prices. The advantage of FWNN prediction system over other prediction systems is given in [27,28]. For designing neuro-fuzzy systems different approaches are used. These are gradient algorithms, clustering algorithms. These algorithms suffer of having local minima problems. GA and DE can solve local minima problem and find global optimal solution [30-35]. Sometimes GA needs more time for parameter updating. In this paper to speed learning and find optimal solution DE algorithm is used.

The paper is organized as follows: Section 2 presents the structure of FWNN prediction model. Section 3 presents parameter update rules of the FWNN system. The brief descriptions of the DE algorithm for learning of FWNN are given. Section 4 contains simulation results of the FWNN used for prediction of stock prices. Comparative results of different models for time series prediction are given. Finally, a brief conclusion is presented in section 5.

2. Fuzzy Wavelet Neural Networks

The knowledge base of fuzzy systems is generally designed using either Mamdani or Takagi-Sugeno-Kanag (TSK) type IF-THEN rules. In the former type, both the antecedent and the consequent parts utilize fuzzy values. The TSK type fuzzy rules utilize fuzzy values in the antecedent part, crisp values or often linear functions in the consequent part. In many research works, it has been shown that TSK type fuzzy neural systems can achieve a better performance than the Mamdani type fuzzy neural systems in learning accuracy [14]. This paper presents fuzzy wavelet neural networks that integrate wavelet functions with the TSK fuzzy model. The consequent parts of TSK type fuzzy IF-THEN rules are represented by either a constant or a function. As a function, most of the fuzzy and neuro-fuzzy models use linear functions. Neuro-fuzzy systems can describe the considered problem by means of combination of linear functions. Sometimes these systems need more rules for modelling complex nonlinear processes in order to obtain the desired accuracy. Increasing the number of the rules leads to increasing number of neurons in the hidden layer of the network. To improve the computational power of the neuro-fuzzy system, we use wavelets in the consequent part of each rule. In this paper, the fuzzy rules that are constructed by using wavelets are used. They have the following form.