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Interest rate next-day variation prediction based on hybrid feedforward neural network, particle swarm optimization, and multiresolution techniques

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A B S T R A C T

Multiresolution analysis techniques including continuous wavelet transform, empirical mode decomposition, and variational mode decomposition are tested in the context of interest rate next-day variation prediction. In particular, multiresolution analysis techniques are used to decompose interest rate actual variation and feedforward neural network for training and prediction. Particle swarm optimization technique is adopted to optimize its initial weights. For comparison purpose, autoregressive moving average model, random walk process and the naïve model are used as main reference models. In order to show the feasibility of the presented hybrid models that combine multiresolution analysis techniques and feedforward neural network optimized by particle swarm optimization, we used a set of six illustrative interest rates; including Moody's seasoned Aaa corporate bond yield, Moody's seasoned Baa corporate bond yield, 3-Month, 6-Month and 1-Year treasury bills, and effective federal fund rate. The forecasting results show that all multiresolution-based prediction systems outperform the conventional reference models on the criteria of mean absolute error, mean absolute deviation, and root mean-squared error. Therefore, it is advantageous to adopt hybrid multiresolution techniques and soft computing models to forecast interest rate daily variations as they provide good forecasting performance.

1. Introduction

Accurate time series forecasting is always an important issue in different economics and business related applications; including prediction of wind speed [1,2], portfolio risk [3,4], energy market volatility [5,6], inflation [7], exchange rate [8], and financial market price index [9,10]. In this context, interest rate forecasting plays a major role in business and economic decision making. Indeed, it is one of the most common factors that affect fixed income securities and derivatives valuation. It also influences asset pricing and serves as a tool for analyzing business cycles. For instance, the expected equilibrium return on risky asset is expressed in terms of excess return relative to the risk free rate; and, business cycle analysis is mainly based on the cost of credit. Thus, numerous statistical and soft computing models have been proposed in the literature to provide investors and managers with more precise predictions.

In the last decades, several mathematical finance and models for capturing the dynamics of interest rates based on market equilibrium theory, no-arbitrage assumption, and Markovian properties of the stochastic processes have been proposed in the literature [11–16]. Although these models are based on economic theory, they fail to predict interest rate

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market behavior in time of crisis [17]. Therefore, there has been an increasing demand for practical and adaptive modeling procedures to model interest rates [17]. For instance, a large number of studies used statistical models as exemplified by the use of regression models to predict interest rate trend; including vector autoregressive (VAR) models, autoregressive conditionally heteroskedastic (ARCH), generalized autoregressive conditionally heteroskedastic (GARCH) models, mixed autoregression moving average (ARMA) and multiple regression models, and other time series analysis approaches [18–27]. However, these statistical models fail to give satisfactory forecasts for some series because of their linear structures, among other inherent limitations [28]. For instance, statistical models assume linearity in the relationship between variables and normality distribution of the errors. Unfortunately, these assumptions are not observable in real world data. Therefore, artificial intelligence approaches, such as genetic algorithms, fuzzy theory, knowledge-based systems and feedforward neural networks, have been shown to be effective alternative tools to forecast interest rates time series than traditional statistical models [28–33].

The purpose of this study is to present a soft computing system for interest rate next-day variation (change) forecasting based on multiresolution analysis techniques and feed-forward neural network (FFNN) [34] optimized by particle swarm optimization (PSO) algorithm [35]. Multiresolution analysis allows decomposing a given signal into several scales to capture its intrinsic dynamics. Multiresolution techniques used in our study include continuous wavelet transform (CWT) [36,37], empirical mode decomposition (EMD) [38], and variational mode decomposition (VMD) [39]. Each multiresolution analysis technique is used for original interest rate variation time series decomposition at different scales. Then, FFNN is employed to forecast interest rate next-day variation and the PSO algorithm is adopted to optimize FFNN initial weights. In order to assess the effectiveness of each multiresolution-based approach, conventional ARMA model, random walk with drift process (RW), and naïve model (NM) are used as main reference models for comparison purpose.

The wavelet transform [40,41] provides a flexible time-frequency representation of a signal by using variable sized windows. Therefore, it allows capturing data features that are local both in time and frequency domains. As result, it is suitable for the analysis of irregular and nonstationary signals. In addition, because of its multiresolution capabilities, it is more appealing than standard econometric models for time series analysis [40]. Due to its advantages, wavelet transform has attracted large attention in business applications; including stock price forecasting [41], equity market volatility prediction [42], demand forecasting in supply chain management [43], and metal markets risk management [44], to name few. The EMD [38] is an adaptive multiresolution decomposition technique that performs a joint space-spatial frequency representation of the signal. Unlike wavelet transform, it is adaptive, fully data driven method, and is suitable for non-linear and non-stationary data analysis. In addition, the EMD does not use any predetermined filter or wavelet functions. Indeed, the major advantage of EMD is that the basis functions are derived directly from the signal itself.

Very recently, Dragomiretskiy and Zosso [39] introduced a new multiresolution technique called variational mode decomposition (VMD) which is an entirely non-recursive variational model where the modes are extracted concurrently [39]. In particular, VMD technique searches for a number of modes and their respective center frequencies, such that the band-limited modes reproduce the input signal exactly or in least-squares sense [39]. In sum, the VMD has the ability to separate tones of similar frequencies contrary to the empirical mode decomposition [39].

In this study, the FFNN [45] is chosen to model information obtained by a given multiresolution technique to forecast interest rate next-day variation. Indeed, the FFNN is suitable for classification of nonlinearly separable patterns [46,47] and to approximate functions [48,49]. Indeed, it has been proven that two layer FFNN can approximate any continuous and discontinuous function [48]. In addition, FFNN was found to be effective in financial time series forecasting [49–52]. During FFNN learning process, the minimum error is achieved by finding the best combination of connection weights and biases. However, FFNN can be trapped in local minima rather than converging to the global minimum. Thus, initial values of weights, biases, and parameters of FFNN may have a significant influence on its performance [53]. The PSO [54] which is a global optimization method is employed to train FFNN. Inspired by social behavior of bird flocking, Eberhart and Kennedy [54] introduced PSO as an evolutionary computation technique. This population based stochastic optimization method is one of the most efficient and practical optimization algorithms in terms of reducing the probability of being trapped in local minima and increasing convergence rates [55,56]. Indeed, it was found that PSO is fast and effective in optimizing parameters of different machine learning techniques; including FFNN [53], radial basis neural networks [57], and SVM [58]. Finally, the quantitative evaluation of each interest rate next-day variation prediction approach (CWT–FFNN–PSO, EMD–FFNN–PSO, VMD–FFNN–PSO, ARMA, RW, naïve model) is based on three statistical metrics: the mean absolute error (MAE), mean absolute deviation (MAD), and root mean-squared error (RMSE).

In sum, the contribution of this paper follows. First, it uses three different multiresolution techniques in the context of daily interest rate variation prediction. Second, the paper compares the predictive ability of systems that hybridize multiresolution techniques, artificial neural networks, and particle swarm optimization. Third, it uses an optimized neural network for interest rate modeling and forecasting unlike previous works [30–33]. Indeed, the performance of a neural network depends on its weights and biases [56,57]. Therefore, optimal values should improve neural network accuracy. Fourth, the effectiveness of each presented hybrid predictive system is compared to that of the conventional ARMA, random walk, and naïve model widely used in time series analysis and forecasting.

The organization of the paper is as follows: methodology is given in Section 2 along with a brief description of CWT, EMD, VMD, FFNN, PSO, ARMA, RW, NM, and performance metrics. In Section 3, experimental results are presented. Finally, in Section 4 conclusions are given.

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