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Modeling and Forecasting Electricity Price Based on Multi Resolution Analysis and Dynamic Neural Networks

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INTRODUCTION

Forecasting electricity price is an important risk management tool for regulators, consumers, and producers of electricity (Hickey, Loomis, & Mohammadi, 2012). In particular, producers need accurate forecasts of electricity price to better optimize production and bilateral contracts, retailers and large consumers need forecasts to settle their bidding strategy, and regulators use electricity price forecasts to assess market efficiency (Hickey, Loomis, & Mohammadi, 2012). In addition, with deregulation processes taking place in electricity markets around the world, the need for developing accurate models to predict electricity price has received an increasing interest. For instance, electricity prices have frequently been modeled with classical statistical models such as the auto-regressive integrated moving average (ARIMA) models, exponential smoothing (ES) models, regression methods (RM), and stochastic models (Nogales, et al., 2002; Conejo et al., 2005; Taylor et al., 2006; Zhou et al., 2006; Diongue et al., 2009; Tan et al., 2010). However, these conventional statistical models are based on linearity and stationarity assumptions of the underlying data. In addition, they are not robust to noisy data and are not adaptive. As a result, artificial neural networks (ANN) models have been proposed as an alternative to classical statistical models to better model and forecast electricity prices (Darbellay & Slama, 2000; Abraham & Nath, 2001; Zhang et al., 2003; Lin et al., 2010; Coelho & Santos, 2011; Singhal & Swarup, 2011).

BACKGROUND

The purpose of this study is to forecast California electricity price using artificial neural networks (ANN) and continuous wavelet transform (CWT) as multi resolution technique to analyze the original data to extract hidden patterns. In particular, the conventional backpropagation neural network (BPNN), the Elman recurrent neural network, the time delay recurrent neural network (TDNN), and the adaptive time delay recurrent neural network (ATDNN) were used as predictive systems. The TDNN and ATDNN integrate genetic algorithms (GA) to optimize their respective architecture.

This study contributes to the literature as follows: first, the electricity price historical data are decomposed by multi-resolution analysis (Akansu & Haddad, 1992) using the theory of wavelet transform (WT) which is based on signal processing and developed from the Fourier transform basis. The WT has been proposed to process non-stationary signals and to investigate the temporal variation with at different scales. There exist in the literature two types of WT: the discrete wavelet transform (DWT) and the continuous wavelet transform (CWT). The DWT is very popular in data compression as it is usually done in signal and image processing, whilst the CWT is more appropriate to analyze data or time series to discover patterns and hidden information. In addition, the CWT is more suitable in time series analysis than the DWT because the coefficients from CWT are translation invariant. As a result, the CWT is chosen to perform the multi-resolution analysis of electricity price data to obtain its representations by means of coefficients at different scales of analysis. Second, unlike previous works (Darbellay & Slama, 2000; Abraham & Nath, 2001; Zhang et al., 2003;

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Lin et al., 2010; Coelho & Santos, 2011; Singhal & Swarup, 2011), recurrent artificial neural networks are adopted to model the obtained CWT coefficients and eventually to predict electricity price. The main advantage of dynamic neural artificial networks is their ability to capture internal patterns and memory in the data. In particular, two types of recurrent neural networks are considered: the time delay neural network (TDNN) (Waibel et al., 1988) and the adaptive time delay neural network (ATDNN) (Yazdizadeh & Khorasani, 1996). Unlike the standard backpropagation neural network (BPNN) of Rumelhart et al. (1986) used in previous works (Darbellay & Slama, 2000; Abraham & Nath, 2001; Zhang et al., 2003; Lin et al., 2010; Coelho & Santos, 2011; Singhal & Swarup, 2011), recurrent neural networks are dynamic (Waibel et al., 1988) and have a long memory than the general BPNN. As a result, they possess two specific features: a rudimentary memory and capability to exhibit internal chaotic behavior (Karray & De Silva, 2004). In summary, recurrent neural networks allow learning and recognizing temporal patterns in the data; therefore, they have a positive factor to predict financial time series (Castiglione, 2001). Third, the topology of the dynamic neural networks; namely TDNN and ATDNN; is optimized using genetic algorithms (Goldberg, 1989). For comparison purpose, the standard BPNN and the Elman network (Elman, 1990) which is a partially recurrent neural network are also used as reference systems for modeling and forecasting. Finally, the performance of each prediction system will be evaluated according to the root mean of squared errors (RMSE). The daily weighted average of electricity price data in California is considered to conduct our comparative study. Finally, the well-known autoregressive moving average (ARMA) (Box et al., 1994; Hamilton, 1994) model which is a linear statistical process is chosen for comparison purpose against the ANN adopted in our study.

The rest of the article is organized as follows. Next section presents our methodology, followed by a description of the data and a report of the findings. Then, future works are presented. Finally, the last section concludes.

METHODS

The proposed automated stock price prediction system consists of four steps. First, the original stock price time series $x(t)$ is processed with the continuous wavelet transform (CWT). Second, the obtained CWT coefficients at different scales are extracted to form the main feature vector that characterizes the original time series $x(t)$. Third, the resulting feature vector is given as input to the artificial neural networks (ANN) for prediction purpose. Finally, the forecasts are evaluated based on the conventional root mean of squared errors (RMSE). The design of the California electricity price systems is shown in Figure 1. The continuous wavelet transform, artificial neural networks, and performance measures are described in more details next.

Continuous Wavelet Transform

The wavelet transform is expressed as a series of functions which are related with each other by translation and simple scaling. The original WT function is called mother wavelet (Akansu & Haddad, 1992; Daubechies, 1992) used to generate all basis functions. In particular, the continuous WT (CWT) is defined as the convolution of a time series $x(t)$ with a wavelet function $\Psi(t)$:

Figure 1. Flow chart of California electricity price analysis and prediction