Applied Soft Computing 48 (2016) 265–280

Contents lists available at ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

Enhanced accuracy of fuzzy time series model using ordered weighted aggregation

Bindu Garg (Dr.)[a,*], Rohit Garg[b]

[a] Department of Computer Science & Engineering, Bharati Vidyapeeth's College of Engg, New Delhi 110063, India
[b] Tata Consultancy Services, India

ARTICLE INFO

Article history:
Received 11 March 2013
Received in revised form 1 May 2016
Accepted 2 July 2016
Available online 21 July 2016

Keywords:
Fuzzy time series
Fuzzy logic relation
Ordered weighted aggregation (OWA)

ABSTRACT

Accuracy is one of the most vital factors when dealing with forecast using time series models. Accuracy depends on relative weight of past observations used to predict forecasted value. Method of aggregation of past observations is significant aspect in time series analysis where determination of next observation depends only on past observations. Previous research on fuzzy time series for forecasting treated fuzzy relationship equally important which might not have properly reflected the importance of each individual fuzzy relationship in forecasting that introduced inaccuracy in results. In this paper, we propose ordered weighted aggregation (OWA) for fuzzy time series and further design forecasting model signifying efficacy of the proposed concept. Objective of using fuzzy time series is to deal with forecasting under the fuzzy environment that contains uncertainty, vagueness and imprecision. OWA is utilized to generate weights of past fuzzy observations; thereby eliminating the need for large number of historical observations required to forecast value. OWA weights are determined by employing regularly increasing monotonic (RIM) quantifiers on the basis of fuzzy set importance using priority matrix. Experimental study reveals how OWA coalesced with fuzzy time series for designing of forecasting model. It can be observed from comparative study that use of OWA considerably reduces mean square error (MSE) and average forecasting error rate (AFER). Robustness of proposed model is ascertained by demonstrating its sturdy nature and correctness.

1. Introduction

Effectiveness of timely action and adequate preparedness in real time system can be greatly enhanced through forecasting. In past few decades of research and growth, numerous concepts & techniques have been proposed to decipher efficient forecasting. Prediction using time series analysis is one of the oldest and most reliable techniques to prophesy future outcome. Techniques for time series analysis can be broadly divided into two categories: conventional approach also known as statistical techniques and non-conventional approach. Conventional techniques confide on identifying behavior of time series. Box-Jenkins or Auto Regressive Integrated Moving Average (ARIMA), Exponential Smoothing and Multiple Regressions are most widely used statistical methods [41]. These are straightforward and easy to interpret but have several restrictions and drawbacks. Foremost drawback of conventional techniques is inaccuracy of prediction and numerical instability. Due to heavy computational burden, these techniques converge slowly and may diverge in certain cases. Most of them are designed particularly for specific problems without a wide range applicability in other domains. In contrast, non-conventional techniques have been implemented successfully in numerous disciplines. These techniques make fewer assumptions about internal structure of the system and rely on input-output relationships to describe the behavior of time series. Field of time series forecasting is nowvastly different from what it was 20 years ago. It has grown up massively with the advent of greater computing power. More mature soft computing approaches have been proposed to forecast uncertain and vague data. Artificial Neural Network is being used in designing of prediction models due to vast development in the area of artificial intelligence. Garg et al. [1] performed extensive logical survey on implementation of forecasting method using artificial neural network. However, Artificial Neural Network could not generate efficient predictors because of its drawbacks like: (1) it has large training time (2) it can only utilize numerical data pairs (3) It traps in local minima that it deviates from optimal performance. Another soft computing technique which has recently received attention is fuzzy based approach.

* Corresponding author.
E-mail addresses: bindu.garg@bharatividyapeeth.edu (B. Garg), Rohit.garg@tcs.com (R. Garg).

http://dx.doi.org/10.1016/j.asoc.2016.07.002
1568-4946/

Initial work of Zadeh [2,3] on fuzzy set theory has been applied in several diversified areas. In fuzzy treatment, linguistic values or fuzzy sets are utilized to approximate the desired output rather than numbers. Immense work has been done on forecasting problems using fuzzy time series [4–27]. Primary reason for fuzzy time series popularity is that it can relate trend and cyclic component in fuzzy logical relationship. Hence, it can utilize historical data more effectively. Forecasting using fuzzy time series has been emanated as an intelligent approach in the domain where information is vague and imprecise. Moreover, fuzzy time series can handle situations where neither viewing of trend is possible nor visualization of patterns in time series is handled. Substantial work has been done using fuzzy time series for real time forecasting problems.

Fuzzy time series definitions were proposed by Song and Chissom. Song and Chissom presented the concepts of time variant and time invariant time series [4,5]. It was applied on the time series data of University of Alabama to forecast enrollments. Song and Chissom [6] also proposed an average auto correlation function as a measure of dependency. Chen [7,8] presented simplified arithmetic operations in place of max-min composition operations which were used by Song & Chissom and then, designed high order fuzzy time series forecasted model. Hunrag [9,10], Hwang and Chen [11], Lee Wang and Chen [12], Li and Kozma [13] developed a number of fuzzy forecasting methods with some variations. Singh [14,15] developed forecasting models using computational algorithm. Lee et al. proposed a fuzzy candlestick pattern to improve forecasting results [16]. Then, a multivariate heuristic model was proposed to achieve highly complex matrix computations [17]. Work on determination of length of interval of fuzzy time series was done [18]. [19] performed generalization of forecasting model. Jilani [20] proposed multivariate high order fuzzy time series based forecasting method for car road accidents. Forecasting model based on event discretization function was presented [21] and same was used for forecasting of average length of stay of patient [22]. Subsequently, Garg [22–24] also proposed optimized forecasting models. Garg [25] developed fuzzy based model to forecast number of outpatient visits in hospital.

List of significant improvements of our proposed model over aforementioned fuzzy time series models are summarized as: 1) Conventional time series models such as ARIMA, ARCH,GAR CH, etc can be designed only after making some assumption. These models cannot be used to deal with nonlinear relationship. However, proposed model can capture nonlinearity easily. (2) Almost all previous fuzzy time series models considered fuzzy logical relationship equally important. In proposed model, priority matrix is created to define importance of each fuzzy set in fuzzy time series like importance of each criterion in multiple criterion based decision problems. (3) Past forecasting methods utilized differences of time series data as the universe of discourse. However, increasing and decreasing rate of time series cannot be captured from difference alone. Proposed model eliminates subtlety of the universe of discourse by determining percentage change of data. (4)Previous studies did not consider method of aggregation of past observations although it is a significant factor in designing of forecasting models where next prediction depends only on past observations. Henceforth, proposed model employed OWA for aggregation of data.

It has been observed that various studies have been proposed to perform effective aggregation and these have resulted in significant achievements as well. However, no one explored the use of OWA to aggregate fuzzy time series observations. Prime Objective of proposed model is to capitalize the potency of OWA in fuzzy time series based forecasting model to accomplish higher forecasting accuracy.

Application of forecasting exists in almost every domain be it healthcare or meteorological or financial or agricultural or economical. It is also concurred that in every real life situation, irrespective of its domain, there will always be more than one factor influencing the stats. Moreover, mostly these factors are complex and it is very difficult to estimate their impact on the real time data/stats. For this reason only, time series model came into consideration i.e. to predict the future value in comparatively easier but accurate way; in other terms method which reduces the attached complexities of various external factors. Further, research is being done to enhance the forecasting accuracy of time series models and to build models that can be applied in every sphere of life. In this direction only, its applicability is demonstrated on three spheres of life (healthcare, financial and educational). Proposed model can be applied in other areas as well. Outpatient visits application has been selected for detailed demonstration since healthcare is one of the most important and key aspect of our life.

This study is organized into ten sections. Section 1 has introduction on history of fuzzy time series, OWA efficacy. Section 2 is discussion of related work on the evolution of OWA concepts and OWA based fuzzy time series forecasting models. Section 3 highlights the key features of statistical and fuzzy approach of time series analysis, reveals the concept of fuzzy time series and OWA respectively. Section 4 describes the steps for designing of proposed forecasting model in detail. Also, concise algorithm and its computational complexity are discussed. Section 5 demonstrates usage of proposed model in application domain (predicting outpatient visit in hospital) in detail as an experimental study. Section 6 displays the impact of partitioning of intervals. Section 7 presents impact of order of model and type of defuzzification method. Section 8 discusses the impact of considering OWA weights. Section 9 evaluates and compares the results of proposed forecasting model with previous fuzzy time series and conventional forecasting models and reveals its performance. In Section 10, accurateness of the proposed method is tested on TAIEX stock exchange data and enrollment data of University of Alabama. Section 11 checks the robustness of the proposed method. Section 12 has conclusion and future work.

2. Related work

Preceding research on fuzzy time series for forecasting problems considered fuzzy relationship equally important which might not have properly reflected the importance of each individual fuzzy relationship in forecasting [42]. Employed the concepts of entropy discretization and a fast Fourier Transform algorithm for designing of forecasting model. An ant colony optimization and auto-regression based fuzzy time series model was given [43]. This model was used to trade the actual data of Taiwan capitalization weighted stock index. Chen et al. [44] presented forecasting model based on fuzzy time series and fuzzy variation group to forecast daily Taiwan stock exchange index (TAIEX). A high order fuzzy time series model was proposed based on adaptive expectation method and entropy based partitioning [45]. This model produced decision rules and an efficient high order fuzzy time series model to forecast internet stock. Sun et al. [46] presented a novel forecasting method based on fuzzy sets and multivariate fuzzy time series to predict stock index future prices. Yu [26] used concept of recurrent relationship to generate forecasting model and recommended that different weights must be assigned to fuzzy relationships. Expectation and Grade-Selection method based on transitional weight were developed for calculating weights [27]. This model designed weight transition matrix on basis of findings of visible and hidden linguistic value. This model was success to a certain extent to reduce forecasting error. However this model required large number of historical data for training process which was too complex to maintain. Yager [30] introduced a class of function to generate weights and concept of ordered weighted aggregation (OWA)operators. A flexible aggregation characteristic of OWA accounted for its wider use in