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Fitting Nonlinear Time-series Model Using Swarm Optimization Technique

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Abstract

The well-known Box-Jenkins' Autoregressive Integrated Moving Average (ARIMA) methodology for fitting time-series data has some major limitations. To this end, Exponential Autoregressive (EXPAR) family of models may be employed. An important characteristic feature of EXPAR is that it is capable of modelling those data sets that depict cyclical variations. Further, it can also be used when data show non-Gaussianity. In this paper, methodology for fitting EXPAR through powerful optimization tool called Particle Swarm optimization (PSO) is described in detail. As an illustration, PSO is used for fitting EXPAR model in India's annual lac export data. Moreover, the performance of fitted EXPAR model is compared with ARIMA from modelling and forecasting point of view. It is concluded that the performance of EXPAR model is better than ARIMA for the dataset under consideration.

Keywords: Time-series, ARIMA, Exponential autoregressive model, Particle Swarm optimization.

1. Introduction

Statisticians have a very well-developed methodology based on linear time-series models, called the Box-Jenkins methodology (Box et al. 2008), for modelling and forecasting of data collected sequentially in time. However, main disadvantage of this approach is that the underlying models are 'linear'. During the last some decades or so, the area of "Nonlinear time-series modelling" has rapidly been growing (Fan and Yao 2003). Practical applications have shown that nonlinear models cannot only provide a better fit to the data but can also reveal rich dynamic behaviour which cannot be captured by linear models. To this end, an important family of parametric nonlinear time-series model called the Exponential autoregressive (EXPAR) was introduced by Haggan and Ozaki (1981) for modelling and forecasting of "periodical" data. A heartening feature of this model is that its parameters clearly explain the type of marginal distribution of the time-series.

2. Description of EXPAR Models and Particle Swarm optimization (PSO)

The EXPAR parametric model, introduced for modelling and forecasting of cyclical data, is a kind of useful nonlinear time-series model that has properties similar to those of nonlinear random vibrations. It is capable of generating time-series data with different types of marginal distributions by restricting the parametric space in various specific regions. A heartening feature of this model is that it captures the non-Gaussian characteristics of the time-series and is also seen to have a marginal distribution belonging to the exponential family (Ghazal and Elhassanein, 2009). An EXPAR (p) model may explicitly be written as

$$X_t\{\varphi_1 + \pi_1 \exp(-\gamma X_{t-1}^2)\}X_{t-1} + \\ +\{\varphi_p + \pi_p \exp(-\gamma X_{t-1}^2)\}X_{t-p} + \varepsilon_t \qquad (2.1)$$

where $\gamma > 0$ is some scaling constant and $\{\varepsilon_t\}$ is white noise process with mean zero and variance σ_ε^2 . The values of γ are selected such that $\exp(-\gamma X_t^2)$ vary reasonably widely over the range (0,1). Also, note that (2.1) has a regime switching behaviour with respect to delayed observation, in the sense that, if $|X_{t-1}|$ is large, then (2.1) is similar to an autoregressive model with parameters approximately equal to$(\varphi_1, \dots, \varphi_p)$, while if $|X_{t-1}|$ is small, then the autoregressive parameters switch to $(\varphi_1 + \pi_1, \dots, \varphi_p + \pi_p)$. Optimum value of order p is determined based on minimum Akaike information criterion (AIC) and Bayesian information criterion (BIC).

The PSO technique, proposed by Kennedy and Eberhart in1995, is a powerful population-based stochastic optimization algorithm. The population, called the 'swarm' is made up of individuals called the 'particles'. The PSO algorithm searches the solution space using a set of particles vector. Each particle of the swarm is a potential solution and is characterized by three quantities: Its velocity, its current position, and its personal best position. The particles interact with one another by sharing information to discover the optimal solution (Parsopoulos and Vrahatis, 2010). Each particle moves in the direction of its personal best position and its global best position.

3. An Illustration

India's Annual lac export time-series data from 1900 to 2004, obtained from www.indiastat.com is considered. From the total 105 data points, first 95 data points corresponding to the period 1900 to 1994 are used for building the model and remaining 10 data points for validation purpose. In the first instance, kernel density estimate of the time-series data is obtained. It is observed that the density exhibit non

Gaussianity and it is also found that periodogram ordinates are significant. The entire data analysis is carried out using MATLAB, Ver. 7.4 software package

Using PSO, the fitting of EXPAR is carried out. The best identified model on the basis of minimum AIC and BIC value is EXPAR (2) model. The fitted model is given as

$$X_{t+1} = \{0.71 + 8.68\exp(-0.049X_t^2)\}X_t$$
$$+\{0.27 - 2.23\exp(-0.049X_t^2)\}X_{t-1} + \eta_{t+1}, \quad \sigma_\eta^2 = 3012.22$$

To get a visual idea, fitted EXPAR model along with data points is exhibited in Fig. 1.

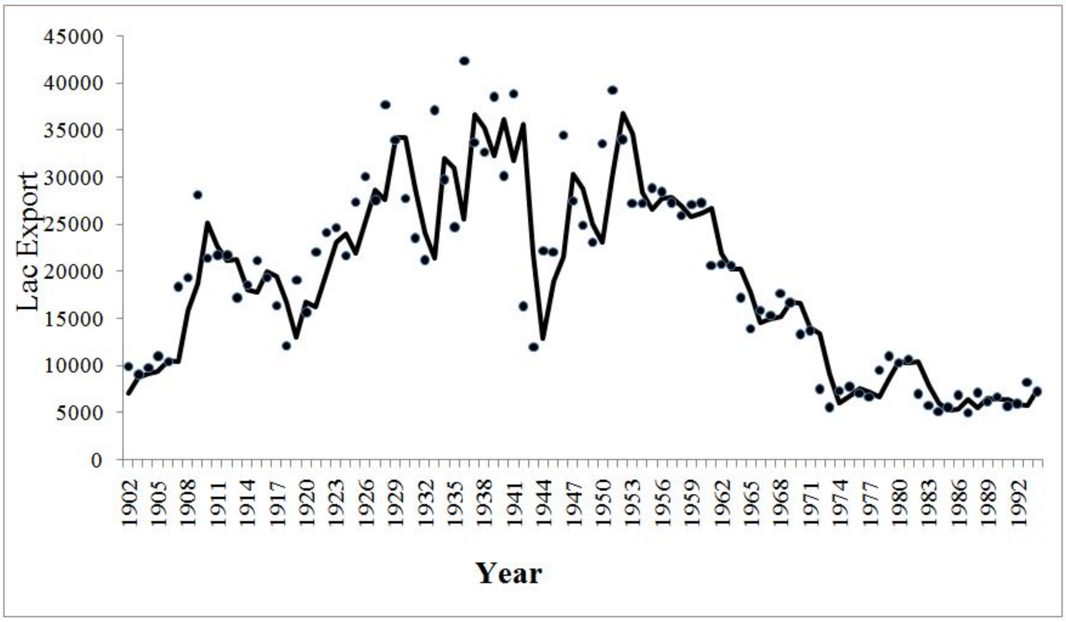

Fig. 1: Fitted EXPAR nonlinear time-series model along with data points.

For comparison purpose the best ARIMA is also fitted to the data. Table 1 indicates that EXPAR model performs comparatively well from modelling point of view.

Table 1:L Goodness of fit of models.

Model / Criterion	ARIMA	EXPAR
AIC	1824.34	1699.59
BIC	1921.97	1737.24
MSE	25134567.4	24536933.6

The fitted model has further been validated by carrying out one-step ahead forecasts. To this end, forecasting performance for 10 data points the period 1995-2004 as hold-out data is studied. The performance of fitted models is compared on the basis of one-step-ahead Mean square prediction error (MSPE), Mean absolute prediction error (MAPE) and Relative mean absolute prediction error (RMAPE). The MSPE, MAPE and RMAPE values for fitted EXPAR model are respectively computed as 1437477.56, 1139.52 and 15.43 which are found to be lower than the corresponding ones for fitted ARIMA model, viz. 3427034.87, 1457.86 and 21.79 respectively.

To sum up, the EXPAR model has performed better than ARIMA for modelling as well as forecasting of the cyclical data under consideration.

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