Chapter 2
Soft Computing Based Statistical Time Series Analysis, Characterization of Chaos Theory, and Theory of Fractals

Mofazzal H. Khondekar
Dr. B.C. Roy Engineering College, India

Koushik Ghosh
University Institute of Technology, University of Burdwan, India

Dipendra N. Ghosh
Dr. B.C. Roy Engineering College, India

Anup Kumar Bhattacharya
National Institute of Technology, India

ABSTRACT

The present work is an attempt to analyze the various researches already carried out from the theoretical perspective in the field of soft computing based time series analysis, characterization of chaos, and theory of fractals. Emphasis has been given in the analysis on soft computing based study in prediction, data compression, explanatory analysis, signal processing, filter design, tracing chaotic behaviour, and estimation of fractal dimension of time series. The present work is a study as a whole revealing the effectiveness as well as the shortcomings of the various techniques adapted in this regard.

INTRODUCTION

Time Series is a set of observations, $x(t)$ each one being recorded at time t where time could be equally spaced discrete $t = 1, 2, 3...$, or unequally spaced discrete or continuous $t > 0$.

Time-series analysis comes under the purview of statistics. Applications of real world time series are plentiful in the fields as economics, business, engineering, natural sciences (commonly in the meteorology, geophysics, astrophysics, ecology and biology), social and behavioral sciences, etc. Phenomena like human breath rate, human electrocardiogram, earthquake, stock prices etc. are some other examples of real world time series.

Jean Baptiste Joseph Fourier accompanied Napoleon to Egypt, and was Governor of Lower Egypt in the years just before his formulation of harmonic analysis, in 1807 which eventually appeared as the book "Théorie Analytique de la

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Chaleur" in the year 1822 (Fourier, 1822) which dealt with infinite periodic functions. Only periodic time series have Fourier series representations. This is supposed to be a milestone in the history of development of computational sciences and this can be considered as the inception of time series analysis.

In 1880, Thiele (Lauritzen, 1981, 1999) formulated and analyzed a model for the time series consisting of a sum of a regression component, a Brownian motion and a white noise.

In the field of Economics, in particular, the first application of the method of correlation to a time series, was published in 1901, viz. Hooker's Study of the Marriage Rate and Trade (Annals of the American Academy of Political and Social Science). Statistical analysis of time series was incepted by Yule in the year 1927 (Yule, 1927).

In 1942, Weiner produced a monograph, Extrapolation, Interpolation and Smoothing of Stationary Time Series (Tsay, 2000). Doing the calculations was a challenge then. Several of the geophysical students at MIT recognized that Weiner's method could be a powerful tool for identify the structural interfaces. They started doing time series analysis.

Champernowne went to Oxford as Director of the Oxford Institute of Statistics, becoming Professor of Statistics in the year 1948. In the same year he read an important paper to the Royal Statistical Society on the time series analysis of autoregressive processes. This paper represented the first serious attempt at the application to time-series analysis of the techniques of Thomas Bayes, an 18th century Presbyterian minister at Tunbridge Wells (Tsay, 2000).

Generally speaking, eight important technical advances generated in the second half of last century in the field of time series. The first advancement is the Kalman filtering (Kalman and Bucy, 1961). The second one is the publication of Time Series Analysis: Forecasting and Control by Box and Jenkins in 1970 (Box and Jenkins, 1970) which one was an important milestone for time series analysis. The third one is the use of state-space parameterization (Harrison and Stevens, 1976). The fourth one is the use of Markov Chain Monte Carlo (MCMC) methods (Geltand and Smith, 1990), especially Gibbs sampling and the concept of data augmentation (Tanner and Wong, 1987). The fifth one is the pattern identification methods and the extended autocorrelation function that is capable of handling both stationary and unit root non-stationary time series (Gray et. al, 1978; Tsay et. al, 1984). The sixth one comes in this regard in the form of simple exponential smoothing (Makridakis et.al, 1982). The seventh one came in the form of fractal analysis of time series. Higuchi (Higuchi, 1988; 1990) developed a new method for calculating the fractal dimension of a given time series. The eighth one came in the form of forecasting of time series (Ferraz-Mello, 1981; Scargle, 1980; Bai & Cliver, 1990; Roy et. al, 1999). For the forecasting purpose time variation (periodicity) analysis is a very significant approach.

One of the most important developments in this century in this regard is the scaling analysis of time series and in this field Hurst exponent is the most significant component (Scafetta & Grigolini, 2002) which can determine whether a given time series is persistent or anti-persistent. This Hurst exponent is determined by using Finite Variance Scaling Method (FVSM) on a time series.

Empirical Mode Decomposition (EMD) is a very current development in the field of forecasting of time series (Huang & Zhaohua, 2005).

Multifractality analysis is an interesting achievement in the current research trend (Telesca, 2005). This works as an advancement of the old method of fractal analysis of time series.

One very significant mathematical exercise which has advanced in this century is the detection of sensitivity of a time series to the initial conditions which is known as chaos detection (Gottwald & Melbourne, 2005).

Some of the objectives of statistical Time series analysis are:

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