Time Series Analysis and Its Applications

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The analysis of experimental data that have been observed at different points in time leads to new and unique problems in statistical modelling and inference. A systematic approach to solving the mathematical and statistical questions posed by time correlations of the data is referred as time series analysis.

The impact of time series analysis on scientific applications is undeniable, with many of the most intensive and sophisticated applications of time series methods especially to problems in the physical and environmental sciences.

The objective of this new book in the literature on time series analysis is to provide a unified and reasonably complete exposition of statistical methods used in time series analysis, giving serious consideration to both time and frequency domain approaches. The authors integrated in this context real data from a number of subject fields into the exposition and suggested methods for analysing these data.

The book contains five Chapters, references and an Index.

Chapter 1 *Characteristics of Time Series*, after an introduction to the problems posed in time and frequency domains by time series analysis and a short presentation of the book contents, refers to the nature of time series data, main time series statistical models, measures of dependence on data (auto-correlation and cross-correlation), strictly and weakly stationary time series, estimation of correlation, exploratory data analysis, classical regression and smoothing in the time series context, vector-valued and multidimensional series. This Chapter ends with three Sections dedicated to convergence modes (mean square convergence, convergence in probability and convergence in distribution), central limit theorems and also to the mean and autocorrelation functions.

Chapter 2 *Time Series Regression and ARIMA Models* is strongly oriented to time domain approach, and develops a number of regression techniques for time series that are all related to classical ordinary and weighted or correlated least squares. The authors introduce the autoregressive (AR) and autoregressive moving average (ARMA) models, obtained by the introduction of correlation as a phenomenon that may be generated through lagged linear relations. Adding non-stationary models to the mix leads to the auto-regressive integrated moving average (ARIMA) model. The Box-Jenkins method for identifying a plausible ARIMA model is given in this Chapter, along with techniques for parameter estimation and forecasting for these models.

In the next Sections the authors present long memory ARMA models and fractional differencing, threshold auto-regressive models, regression with ARMA errors, and an extension of the Box-Jenkins method for predicting a single output from a collection of possible input series is considered there where the inputs themselves may follow ARIMA models, commonly referred to as transfer function models. Finally, the auto-regressive conditionally heteroscedastic (ARCH) models and the analysis of volatility are presented. The last three Sections of the Chapter concern some mathematical results including: Hilbert spaces and the projection theorem, causal conditions for ARMA models and large sample distribution of AR estimators.

In **Chapter 3** *Spectral Analysis and Filtering* it is argued the concept of regularity of a series that can best be expressed in terms of periodic variations of the underlying phenomenon that produced the series. This Chapter focuses on frequency domain approaches. The authors summarize an approach to handling correlation generated in stationary time series, that begins with transforming the series to the frequency domain. The following subjects are then discussed in this Chapter: power spectrum and cross-spectrum, the investigation and exploitation of the properties of the time-invariant linear filter, discrete Fourier transform, periodogram, non-parametric spectral estimation, parametric spectral

estimation, lagged regression models, signal extraction and optimum filtering, spectral analysis of multidimensional series. Finally, three sections of the Chapter are dedicated to some theoretical results concerning: spectral representation theorem, large sample distribution of the discrete Fourier transform and the complex multivariate normal distribution.

In **Chapter 4** *State-Space and Multivariate ARMAX Models*, the specific models are treated by making judicious use of the Kalman filters and smoothers, developed originally for estimation and control in space applications. Time series regression is introduced in this Chapter and the state-space model, Kalman filtering and smoothing, multivariate regression and multivariate ARMA models are developed. Special Sections deal with maximum likelihood estimation, missing data modifications, structural models, ARMAX models in state-space form, bootstrapping state-space models, dynamic linear models with switching, nonlinear and non-normal state-space models using Monte-Carlo methods, stochastic volatility, state-space and ARMAX models for longitudinal data analysis, further aspects of multivariate ARMA and ARMAX models.

Chapter 5 *Statistical Methods in the Frequency Domain* discusses, after a short introduction to the specific problems, spectral matrices and likelihood functions, regression for jointly stationary series, regression with deterministic inputs, random coefficient regression, discrimination and cluster analysis, related topics of spectral domain (principal components, canonical analysis and factor analysis), the spectral envelope and basic notions of dynamic Fourier analysis and wavelets.

An array of problems is found at the end of each Chapter, serving a dual purpose: to increase understanding of the material covered and to present new applications or results not covered in the text.

References are given at the end of the book and include most recent work on the topic. An Index constitutes the last Part of the book.

The material of the book is well -organized, presented with clarity, and the reader's understanding is helped with many examples, developed in sufficient detail. Also, all the arguments are clear and logically correct. Its merit goes from the fluency of the style to the absence of typographical errors and the accuracy of graphical material (152 figures), all that making the book an agreeable reading.

We must also mention, as a merit of the book, the many data at hand in illustrating the richness of potential applications to medicine and biology, physical and social sciences. This is the result of collaboration of research workers in the medical, physical, biological sciences, seismology and geophysics. All data sets are posted on a World Wide Web, and are easy accessible to students and general researchers. In addition, an exploratory data analysis program can be downloaded (freeware) from the same website, providing easy access to all of the techniques included in the book. For some modern computing multivariate techniques in time and frequency domains, higher level languages are used, such as MATLAB and S-PLUS.

Extremely large data sets driven by periodic phenomena, such as functional magnet resonance imaging series or the earthquake and explosion data, can be handled using extensions to time series of classical methods, like multivariate regression, analysis of variance, principal components, factor analysis, and discriminant or cluster analysis.

The present book has been intended to be useful as a text for courses in time series analysis at different levels and as a reference work for practitioners facing the analysis of time-correlated data in the physical, biological, environmental, economic, engineering and social sciences. From the pedagogical point of view, is much merit in this book.

Finally, I reiterate that this is a valuable book in terms of the topics selected and the approach adopted, and I recommend it to researchers and practitioners in the field of time series analysis and applications in the fields mentioned above. The series editors inspiredly encouraged the authors to propose this new and interesting book for the "Springer Texts in Statistics".

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