Springer Texts in Statistics

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Time Series Analysis and Its Applications

With 152 Figures

Springer

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To my wife, Ruth, for her good-humored support and encouragement, and to my teacher, Solomon Kullback, for his guidance and enduring wisdom.
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To my family, Janice, Matthew and Lauren for laughing when I walked into walls, and to my parents, Benjamin and Rose for not laughing when I walked into walls.
D.S.S.

PREFACE

The goals of this book are to develop an appreciation for the richness and versatility of modern time series analysis as a tool for analyzing data, and still maintain a commitment to theoretical integrity, as exemplified by the seminal works of Brillinger (1981) and Hannan (1970) and the texts by Brockwell and Davis (1991) and Fuller (1995). The advent of more powerful computing, especially in the last three years, has provided both real data and new software that can take one considerably beyond the fitting of simple time domain models, such as have been elegantly described in the landmark work of Box and Jenkins (1970). The present book is designed to be useful as a text for courses in time series on several different levels and as a reference work for practitioners facing the analysis of time-correlated data in the physical, biological, and social sciences.

We believe the book will be useful as a text at both the undergraduate and graduate levels. An undergraduate course can be accessible to students with a background in regression analysis and might include Sections 1.1–1.8, 2.1–2.9, and 3.1–3.8. Similar courses have been taught at the University of California (Berkeley and Davis) in the past using the earlier book on applied time series analysis by Shumway (1988). Such a course is taken by undergraduate students in mathematics, economics, and statistics and attracts graduate students from the agricultural, biological, and environmental sciences. At the masters' degree level, it can be useful to students in mathematics, environmental science, economics, statistics, and engineering by adding Sections 1.9, 2.10–2.14, 3.9, 3.10, and 4.1–4.5, to those proposed above. Finally, a two-semester upper-level graduate course for mathematics, statistics and engineering graduate students

can be crafted by adding selected theoretical sections from the last sections of Chapters 1, 2, and 3 for mathematics and statistics students and some advanced applications from Chapters 4 and 5. For the upper-level graduate course, we should mention that we are striving for a less rigorous level of coverage than that which is attained by Brockwell and Davis (1991), the classic entry at this level.

A useful feature of the presentation is the inclusion of data illustrating the richness of potential applications to medicine and in the biological, physical, and social sciences. We include data analysis in both the text examples and in the problem sets. All data sets are posted on the World Wide Web at the following URLs: `http://www.stat.ucdavis.edu/~shumway/tsa.html` and `http://www.stat.pitt.edu/~stoffer/tsa.html`, making them easily accessible to students and general researchers. In addition, an exploratory data analysis program written by McQuarrie and Shumway (1994) can be downloaded (as Freeware) from these websites to provide easy access to all of the techniques required for courses through the masters' level.

Advances in modern computing have made multivariate techniques in the time and frequency domain, anticipated by the theoretical developments in Brillinger (1981) and Hannan (1970), routinely accessible using higher level languages, such as MATLAB and S-PLUS. Extremely large data sets driven by periodic phenomena, such as the functional magnetic resonance imaging series or the earthquake and explosion data, can now 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. Chapters 4 and 5 illustrate some of the immense potential that methods have for analyzing high-dimensional data sets.

The many practical data sets are the results of collaborations with research workers in the medical, physical, and biological sciences. Some deserve special mention as a result of the pervasive use we have made of them in the text. The predominance of applications in seismology and geophysics is a result of joint work of the first author with Dr. Robert R. Blandford of the Center for Monitoring Research and Dr. Zoltan Der of Ensco, Inc. We have also made extensive use of the El Niño and Recruitment series contributed by Dr. Roy Mendelssohn of the Pacific Fisheries Environmental Group of the National Marine Fisheries. In addition, Professor Nancy Day of the University of Pittsburgh provided the data used in Chapter 4 in a longitudinal analysis of the effects of prenatal smoking on growth, as well as some of the categorical sleep-state data posted on the World Wide Web. A large magnetic imaging data set that was developed during joint research on pain perception with Dr. Elizabeth Disbrow of the University of San Francisco Medical Center forms the basis for illustrating a number of multivariate techniques in Chapter 5. We are especially indebted to Professor Allan D.R. McQuarrie of North Dakota State University, who incorporated subroutines in Shumway (1988) into ASTSA for Windows.

Finally, we are grateful to John Kimmel, Executive Editor, Statistics, for his patience, enthusiasm, and encouragement in guiding the preparation and production of this book. Three anonymous reviewers made numerous helpful comments, and Dr. Rahman Azari and Dr. Mitchell Watnik of the University of California, Davis, Division of Statistics, read portions of the draft. Any remaining errors are solely our responsibility.

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August, 1999

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