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BOOK REVIEW

MODELS FOR DEPENDENT TIME SERIES, by Granville Tunnicliffe Wilson, Marco Reale and John Haywood Published by CRC Press, 2016. Total number of pages: 323. ISBN 978-1-58488-650-1

This book is a valuable contribution to researchers and students working with time series with emphasis on multivariate time series including both the time domain and frequency domain approaches. The presentation is accessible to students with intermediate undergraduate level courses in regression analysis and time series analysis. There is an emphasis on basic principles with many unique insightful approaches such as the introduction of frequency domain thinking using harmonic contrasts and many other such insights. Many ideas presented could be used in undergraduate courses since there is strong interest in time series, especially among students in quantitative finance programs.

Most students are motivated by interesting applications, and this book contains a wealth of fascinating multivariate time series ranging from applications in finance, economics, management science, ecology, manufacturing, climate change and biology. The authors provide a website (http://www.dependenttimeseries.com) where data and computer software can be downloaded or contributed by interested researchers. Data available on this website that are analysed in the book include the following:

(1) Infant monitoring. This series includes three variables: blood oxygen, pulse rate and respiration rate that are sampled every 1/10 second for 50 minutes.
(2) Gas furnace series. A new approach using the VAR model is presented, which may be compared with previous methods given the famous books by Box and Jenkins and by Jenkins and Watts.
(3) Moth trappings. Time series of counts per week starting in 1993 for 345 weeks with five variables: moth counts, solar radiation, temperature, wind speed and rainfall.
(4) Gas sendout. A bivariate daily time series from 1 September 1977 to 31 August 1978. The input variable is a negatively correlated predictor from another separate model, and the output is a measure of the gas consumption.
(5) Film extrusion process. Composed of 351 consecutive values for three input variables and one output.
(6) Consumer product sales. Total weekly sales over 4 years with four variables: sales, price, advertising expenditure and Christmas week indicator.
(7) Term rates. Time series for seven US government bonds with different maturity dates.
(8) Pig market. A fresh analysis of a classic multivariate economic time series that exhibits interesting relationships between the variables as well as problems with quarterly seasonality, trend and autocorrelation.
(9) Flour prices. Average price per month in four US cities, August 1972 to November 1980.
(10) Species extinctions and originations. This is an irregular time series derived from marine fossil records.
(11) Climate series. Three annual time series composed of CO_2 concentration, annual temperature anomalies and southern oscillation index.

Chapters 2 and 4 deal with time domain vector autoregression (VAR) and vector autoregression with exogenous inputs (VARX) models with applications to the pig market, gas furnace and consumer sales. The concept of inverse autocorrelations for VAR models is an interesting and non-obvious extension of the univariate counterpart and is shown to provide useful insight into partial correlation in the multivariate case.

Chapter 3 discusses multivariate spectral analysis including tapering and pre-whitening. A more modern term, sample spectrum, is used in preference to the periodogram, and I think this is an improvement since it provides a clearer description. The first method of spectral estimation is based on the sample spectrum, while the second discusses in detail the use of the VAR for spectral estimation. Autoregressive spectral estimation is widely used in the univariate case but has rarely been discussed for the multivariate case. A new algorithm, the simulated delta method, is discussed for providing confidence intervals for spectral estimates of the VAR model. The VAR spectral estimates with these confidence interval may be used as a model diagnostic by comparing with the smoothed sample spectrum. Interesting applications to the first seven time series in the list presented are discussed.

Chapter 5 provides a new approach to the SVAR or structural VAR model. The SVAR is important because it may provide a more parsimonious model than the VAR. The novelty of this chapter is the use of graphical modelling to provide an empirical method for constructing the SVAR model. Graphical modelling is widely used today in regression applications especially in the social sciences, and these methods are adapted for use with multivariable time series. A comprehensive treatment of the basic principles of graphical models is provided. The empirical fitting of SVAR models is illustrated using the pig market and flour price time series datasets. This chapter could provide a useful component in a graduate-level course on time series or regression.

Chapter 6 presents a new multivariate linear time series model, ZVAR. This is an empirical model that may achieve a more parsimonious fit than required by a higher-order VAR model. In the univariate case, we may write this model, ZVAR(p), $x_t = \xi(Z)Bx_{t-1} + e_t$, where e_t is Gaussian white noise, B is the backshift operator on t and $\xi(Z) = \xi_1 + \xi_2 Z + \dots \xi_p Z^{p-1}$, where Z is the generalized shift operator, $Z = (B - \theta)/(1 - \theta B)$ and θ is a parameter, $-1 < \theta < 1$. The vector generalization of this model, ZVAR(p), is the main topic of this chapter. Algorithms similar to those discussed for the VAR model may be used to estimate the model parameters $\theta, \xi_1, \dots, \xi_{p-1}$. In addition to estimation, model identification, diagnostic checking and forecasting are also addressed. This model is loosely inspired by the success of the EWMA model in forecasting applications, especially for lead times greater than one. The advantage of this model is demonstrated with the application to infant monitoring series.

Chapter 7 discusses continuous time models that are widely used in finance and econometrics, as well as in engineering and scientific applications, to provide a more natural model for the underlying phenomenon. Continuous time series are also useful for modelling irregularly sampled series. The extension of continuous time autoregressions or Orstein–Uhlenbeck processes to the vector case, VCZAR, is the principal topic in this chapter. A discussion is given why in principle the VCZAR often provides a better general approximation to continuous stationary processes than is possible with the VCAR alternative. The VCZAR is shown to fit the infant monitoring series.

Chapter 8 continues with two further applications of the VCZAR model. The main application is to modelling and spectral analysis of the species extinctions and originations time series. An additional discussion and technical note on these data is provided with the dataset on the website previously mentioned in this review. A second application of the VCZAR model to the bivariate gas furnace series is discussed.

Chapter 9 reviews the concept of partial coherency for time series and introduces the coherency display array for visualization. This is illustrated with the flour price series, annual climate series and term rates. Partial coherency is useful in constructing graphical models known as the partial coherency graph (PCG). The PCG is illustrated with applications to the flour and term rates. The ZVAR model is extended to its structural version, SVZAR, and applied to fit the term rates.

Basic core time series methods discussed in this book including multivariate spectral analysis, VAR, VARX, SVAR, CAR and graphical models are all available in R (R Development Core Team, 2016; Hojsgaard, 2016; Pfaff, 2007; Wang, 2013). Other high-level computing environments including MatLab and Mathematica provide built support for some of these time series methods as well.

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