BOOK REVIEW

HIDDEN MARKOV MODELS FOR TIME SERIES: AN INTRODUCTION USING R, second edition, by Walter Zucchini, Iain L. MacDonald, Roland Langrock. Monographs on Statistics and Applied Probability 150, Published by CRC Press, 2016. Total number of pages: 28 + 370. ISBN: 978-1-4822-5383-2 (Hardback)

Hidden Markov Models for Time Series: An Introduction Using R (second edition) is a new version of the authors' early book of the same title (Zucchini and MacDonald, 2009). Both of them updated the authors' earlier book *Hidden Markov and Other Models for Discrete-valued Time Series* (MacDonald and Zucchini, 1997). This 2nd edition is an extended book of its first edition, aiming to illustrate the great flexibility of hidden Markov models (HMMs) as general-purpose models for time series data, with provision of a broad understanding of the models and their uses.

After reading the book, I feel at least three features are significant for this 2nd edition. First of all, the book provides a comprehensive, accessible overview of the HMMs oriented to time series data analysis. It demonstrates how the HMMS can be used to model a wide range of types of time series data, including continuous-valued, circular, multivariate, binary, bounded and unbounded counts as well as categorical observations. Secondly, in order for the methods to be applicable in practice, the book also discusses how to implement the methodology by utilising the free statistics software R in computation. This is clearly critical for practical applications. Thirdly, besides the statistical methods and computation introduced on the HMMs, interestingly, the book further explores a variety of applications of the methods in ecology, finance, epidemiology, climatology and sociology. This provides readers with a fantastic demonstration of the HMMs in applications.

Specifically, the book makes a good balance of theory and application through a combination of the key methodological developments with examples and case studies using real time series data. The first part of the book gives an accessible introduction into the model structure, properties and methods on HMMs. It consists of 8 chapters, covering preliminaries in Chapter 1, definitions and properties in Chapter 2, likelihood estimation by direct maximization and EM algorithm in Chapters 3 and 4, forecasting issue in Chapter 5, model selection and checking in Chapter 6 and Bayesian inference in Chapter 7 together with information on R packages related to HMMs in Chapter 8. I believe Part I is a wonderful introduction on HMMs to the beginning learners. Part II, comprising Chapters 9–13, focuses on extensions of the HMMs with a variety of contexts of time series data. It covers HMMs with general state-dependent distribution in Chapter 9, covariates and other extra dependencies in Chapter 10, continuous-valued state processes in Chapter 11, hidden semi-Markov models in Chapter 12 and HMMs for longitudinal data in Chapter 13. Compared with the first edition, the biggest change with this second edition (as the authors addressed in Preface) is that the single, rather terse, chapter on extensions (in Chapter 8 of the first edition) has been replaced by Part II of this second edition. These new chapters update the early edition with recent new developments on HMMs towards time series data analysis, which are advanced topics and clearly useful for researchers, in particular the postgraduate research students, in the research areas related to the methodology of HMMs. Furthermore, Part III, involving Chapters 14–24, presents a range of applications of the HMMs methods to different practical areas. This part first makes an overview of the application areas of the HMMs in Chapter 14, with demonstrations of the modelling for epileptic seizures in Chapter 15, for rainfall occurrence in Chapter 16, for the Older Faithful geyser eruption in Chapter 17, for

animal movement in Chapter 18, for wind direction in Chapter 19, for financial series in Chapter 20, for births at hospital in Chapter 21, for homicides and suicides in Chapter 22, for animal behaviour with feedback in Chapter 23 and for survival rates of Soay sheep from mark-recapture-recovery data in Chapter 24. Obviously this part is of interest for a wide range of practitioners. Finally the book offers some more information in two appendices A and B giving examples of R code and the proofs for five results used principally in Section 4.1. These shall help readers with details that they need.

Overall the book is well presented and structured with clear contents partitioned into three parts. As reviewed in the above, Parts I and II are a good coverage of the topics that are needed for the beginning learners and advanced researchers, respectively. Part III makes helpful illustration of the applications with different areas for practitioners. The applications to these different areas are presented clearly. However, the order of these chapters in Part III seems able to be made in a more coherent and improved way. For example, Chapters 15 and 21 are on epileptic seizures and births at hospital, both of which are related to medical and healthcare issues, so they may be combined into one chapter on medical application; Chapters 18, 23 and 24 are on animal movement, behaviour and survival rates, respectively, so they may also be considered to be put as one chapter; further, Chapters 16 and 19 on rain and wind can be combined as one chapter on climatological application. Therefore, it appears not unreasonable to suggest that Part III be coherently partitioned into medical application (Chapters 15, 21), ecological application (Chapters 18, 23, 24), climatological application (Chapters 16, 19), geophysical application (Chapter 17), financial application (Chapter 20) and sociological application (Chapter 22).

In summary, this second edition is an exciting book on time series statistics with HMMs. It offers comprehensive coverage of the useful topics and materials, the state-of-the-art methodologies and the up-to-date developments as well as the R packages on HMMs for time series data, with an excellent balance of theory and application. I enjoyed reading this book and would recommend it to anyone, either as a learner, a researcher or a practitioner, in Statistics and other related subjects involving hidden Markov modelling and time series modelling as a time-effective introduction or learning of the field.

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