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Informed Bayesian survival analysis

František Bartoš^{1,2*}, Frederik Aust³ and Julia M. Haaf¹

Abstract

Background: We provide an overview of Bayesian estimation, hypothesis testing, and model-averaging and illustrate how they benefit parametric survival analysis. We contrast the Bayesian framework to the currently dominant frequentist approach and highlight advantages, such as seamless incorporation of historical data, continuous monitoring of evidence, and incorporating uncertainty about the true data generating process.

Methods: We illustrate the application of the outlined Bayesian approaches on an example data set, retrospective re-analyzing a colon cancer trial. We assess the performance of Bayesian parametric survival analysis and maximum likelihood survival models with AIC/BIC model selection in fixed-n and sequential designs with a simulation study.

Results: In the retrospective re-analysis of the example data set, the Bayesian framework provided evidence for the absence of a positive treatment effect of adding Cetuximab to FOLFOX6 regimen on disease-free survival in patients with resected stage III colon cancer. Furthermore, the Bayesian sequential analysis would have terminated the trial 10.3 months earlier than the standard frequentist analysis. In a simulation study with sequential designs, the Bayesian framework on average reached a decision in almost half the time required by the frequentist counterparts, while maintaining the same power, and an appropriate false-positive rate. Under model misspecification, the Bayesian framework resulted in higher false-negative rate compared to the frequentist counterparts, which resulted in a higher proportion of undecided trials. In fixed-n designs, the Bayesian framework showed slightly higher power, slightly elevated error rates, and lower bias and RMSE when estimating treatment effects in small samples. We found no noticeable differences for survival predictions. We have made the analytic approach readily available to other researchers in the RoBSSA R package.

Conclusions: The outlined Bayesian framework provides several benefits when applied to parametric survival analyses. It uses data more efficiently, is capable of considerably shortening the length of clinical trials, and provides a richer set of inferences.

Keywords: Bayesian, Survival analysis, Model-averaging, Bayes factor, Historical data

Background

There has been a steady increase in the popularity and interest in Bayesian statistics in the past years [1]. In this paper, we leverage the advantages of the longstanding Bayesian estimation [2], hypothesis testing [3], and model-averaging [4] approaches and apply them to

parametric survival analysis. This type of Bayesian survival analysis is possible thanks to the recent development of flexible tools for fitting Bayesian models (such as JAGS [5] and Stan [6]) and efficient techniques for estimating marginal likelihoods (such as bridge-sampling [7–9]).

Survival analysis is a frequently used method with important applications in evaluating lifetime outcomes in clinical trials [10, 11]. The most commonly used version of survival analysis is the non-parametric Cox proportional hazard model, which does not require specification of the baseline hazard [12]. There are,

*Correspondence: fbartoš@fmpr.cuni.cz

¹Department of Psychology, University of Amsterdam, Amsterdam, The Netherlands

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Bayesian Survival Analysis

Blanca Sarzo Carles

Bayesian Survival Analysis

Bayesian Survival Analysis Joseph G. Ibrahim, Ming-Hui Chen, Debajyoti Sinha, 2013-03-09 Survival analysis arises in many fields of study including medicine biology engineering public health epidemiology and economics This book provides a comprehensive treatment of Bayesian survival analysis Several topics are addressed including parametric models semiparametric models based on prior processes proportional and non proportional hazards models frailty models cure rate models model selection and comparison joint models for longitudinal and survival data models with time varying covariates missing covariate data design and monitoring of clinical trials accelerated failure time models models for multivariate survival data and special types of hierarchical survival models Also various censoring schemes are examined including right and interval censored data Several additional topics are discussed including noninformative and informative prior specifications computing posterior qualities of interest Bayesian hypothesis testing variable selection model selection with nonnested models model checking techniques using Bayesian diagnostic methods and Markov chain Monte Carlo MCMC algorithms for sampling from the posterior and predictive distributions The book presents a balance between theory and applications and for each class of models discussed detailed examples and analyses from case studies are presented whenever possible The applications are all essentially from the health sciences including cancer AIDS and the environment The book is intended as a graduate textbook or a reference book for a one semester course at the advanced masters or Ph D level This book would be most suitable for second or third year graduate students in statistics or biostatistics It would also serve as a useful reference book for applied or theoretical researchers as well as practitioners

Bayesian Survival Analysis Joseph G. Ibrahim, Ming-Hui Chen, Debajyoti Sinha, 2014-01-15

Bayesian survival analysis Joseph George Ibrahim, Ming-Hui Chen, Debajyoti Sinha, 2001

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Shank, 1997 Shrinkage Estimation in Nonparametric Bayesian Survival Analysis Kamta Rai, Vyaghreswarudu Susarla, John Van Ryzin, Rand Corporation, 1979

Bayesian Survival Analysis for Prognostic Index Development with Many Covariates

and Missing Data Xiaohui Zhao, University of Newcastle upon Tyne. School of Mathematics and Statistics, 2010

Modelling Survival Data in Medical Research David Collett, 2023-05-31 Modelling Survival Data in Medical Research Fourth Edition

describes the analysis of survival data illustrated using a wide range of examples from biomedical research Written in a non technical style it concentrates on how the techniques are used in practice Starting with standard methods for summarising

survival data Cox regression and parametric modelling the book covers many more advanced techniques including interval

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chapters on Bayesian survival analysis and use of the R software Earlier chapters have been extensively revised and

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models for longitudinal and survival data and modern methods for the analysis of interval censored survival data Features Presents an accessible account of a wide range of statistical methods for analysing survival data Contains practical guidance on modelling survival data from the author s many years of experience in teaching and consultancy Shows how Bayesian methods can be used to analyse survival data Includes details on how R can be used to carry out all the methods described with guidance on the interpretation of the resulting output Contains many real data examples and additional data sets that can be used for coursework All data sets used are available in electronic format from the publisher s website Modelling Survival Data in Medical Research Fourth Edition is an invaluable resource for statisticians in the pharmaceutical industry and biomedical research centres research scientists and clinicians who are analysing their own data and students following undergraduate or postgraduate courses in survival analysis

Frailties in Bayesian Survival Analysis ? John Michael Gay,2003

Bayesian Survival Analysis with Missing Data Using Integrated Nested Laplace Approximation

Muhammad Irfan bin Abdul Jalal,2020

Computational Methods in Biomedical Research Ravindra Khattree,Dayanand Naik,2007-12-12

Continuing advances in biomedical research and statistical methods call for a constant stream of updated cohesive accounts of new developments so that the methodologies can be properly implemented in the biomedical field Responding to this need Computational Methods in Biomedical Research explores important current and emerging computational statistical methods that are used in biomedical research Written by active researchers in the field this authoritative collection covers a wide range of topics It introduces each topic at a basic level before moving on to more advanced discussions of applications The book begins with microarray data analysis machine learning techniques and mass spectrometry based protein profiling It then uses state space models to predict US cancer mortality rates and provides an overview of the application of multistate models in analyzing multiple failure times The book also describes various Bayesian techniques the sequential monitoring of randomization tests mixed effects models and the classification rules for repeated measures data The volume concludes with estimation methods for analyzing longitudinal data Supplying the knowledge necessary to perform sophisticated statistical analyses this reference is a must have for anyone involved in advanced biomedical and pharmaceutical research It will help in the quest to identify potential new drugs for the treatment of a variety of diseases

New Insights in Bayesian Survival Analysis in Ecology Blanca Sarzo Carles,2020

Bayesian Inference and Computation in Reliability and Survival Analysis Yuhlong Lio,Ding-Geng Chen,Hon Keung Tony Ng,Tzong-Ru Tsai,2022-08-01

Bayesian analysis is one of the important tools for statistical modelling and inference Bayesian frameworks and methods have been successfully applied to solve practical problems in reliability and survival analysis which have a wide range of real world applications in medical and biological sciences social and economic sciences and engineering In the past few decades significant developments of Bayesian inference have been made by many researchers and advancements in computational technology and computer performance has laid the groundwork for new opportunities in Bayesian

computation for practitioners Because these theoretical and technological developments introduce new questions and challenges and increase the complexity of the Bayesian framework this book brings together experts engaged in groundbreaking research on Bayesian inference and computation to discuss important issues with emphasis on applications to reliability and survival analysis Topics covered are timely and have the potential to influence the interacting worlds of biostatistics engineering medical sciences statistics and more The included chapters present current methods theories and applications in the diverse area of biostatistical analysis The volume as a whole serves as reference in driving quality global health research

Survival Analysis: State of the Art John P. Klein,P.K. Goel,2013-03-09 Survival analysis is a highly active area of research with applications spanning the physical engineering biological and social sciences In addition to statisticians and biostatisticians researchers in this area include epidemiologists reliability engineers demographers and economists The economists survival analysis by the name of duration analysis and the analysis of transition data We attempted to bring together leading researchers with a common interest in developing methodology in survival analysis at the NATO Advanced Research Workshop The research works collected in this volume are based on the presentations at the Workshop Analysis of survival experiments is complicated by issues of censoring where only partial observation of an individual's life length is available and left truncation where individuals enter the study group if their life lengths exceed a given threshold time Application of the theory of counting processes to survival analysis as developed by the Scandinavian School has allowed for substantial advances in the procedures for analyzing such experiments The increased use of computer intensive solutions to inference problems in survival analysis in both the classical and Bayesian settings is also evident throughout the volume Several areas of research have received special attention in the volume

Bayesian Nonparametric Data Analysis Peter Müller,Fernando Andres Quintana,Alejandro Jara,Tim Hanson,2015-06-17 This book reviews nonparametric Bayesian methods and models that have proven useful in the context of data analysis Rather than providing an encyclopedic review of probability models the book's structure follows a data analysis perspective As such the chapters are organized by traditional data analysis problems In selecting specific nonparametric models simpler and more traditional models are favored over specialized ones The discussed methods are illustrated with a wealth of examples including applications ranging from stylized examples to case studies from recent literature The book also includes an extensive discussion of computational methods and details on their implementation R code for many examples is included in online software pages

Case Studies in Bayesian Statistical Modelling and Analysis Clair L. Alston,Kerrie L. Mengerson,Anthony N. Pettitt,2012-10-10 Provides an accessible foundation to Bayesian analysis using real world models This book aims to present an introduction to Bayesian modelling and computation by considering real case studies drawn from diverse fields spanning ecology health genetics and finance Each chapter comprises a description of the problem the corresponding model the computational method results and inferences as well as the issues that arise in the implementation

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Table of Contents Bayesian Survival Analysis Bayesian Survival Analysis

1. Understanding the eBook Bayesian Survival Analysis Bayesian Survival Analysis
 - The Rise of Digital Reading Bayesian Survival Analysis Bayesian Survival Analysis
 - Advantages of eBooks Over Traditional Books
2. Identifying Bayesian Survival Analysis Bayesian Survival Analysis
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Bayesian Survival Analysis Bayesian Survival Analysis
 - User-Friendly Interface
4. Exploring eBook Recommendations from Bayesian Survival Analysis Bayesian Survival Analysis
 - Personalized Recommendations
 - Bayesian Survival Analysis Bayesian Survival Analysis User Reviews and Ratings
 - Bayesian Survival Analysis Bayesian Survival Analysis and Bestseller Lists
5. Accessing Bayesian Survival Analysis Bayesian Survival Analysis Free and Paid eBooks
 - Bayesian Survival Analysis Bayesian Survival Analysis Public Domain eBooks
 - Bayesian Survival Analysis Bayesian Survival Analysis eBook Subscription Services
 - Bayesian Survival Analysis Bayesian Survival Analysis Budget-Friendly Options
6. Navigating Bayesian Survival Analysis Bayesian Survival Analysis eBook Formats

- ePub, PDF, MOBI, and More
- Bayesian Survival Analysis Bayesian Survival Analysis Compatibility with Devices
- Bayesian Survival Analysis Bayesian Survival Analysis Enhanced eBook Features

7. Enhancing Your Reading Experience

- Adjustable Fonts and Text Sizes of Bayesian Survival Analysis Bayesian Survival Analysis
- Highlighting and Note-Taking Bayesian Survival Analysis Bayesian Survival Analysis
- Interactive Elements Bayesian Survival Analysis Bayesian Survival Analysis

8. Staying Engaged with Bayesian Survival Analysis Bayesian Survival Analysis

- Joining Online Reading Communities
- Participating in Virtual Book Clubs
- Following Authors and Publishers Bayesian Survival Analysis Bayesian Survival Analysis

9. Balancing eBooks and Physical Books Bayesian Survival Analysis Bayesian Survival Analysis

- Benefits of a Digital Library
- Creating a Diverse Reading Collection Bayesian Survival Analysis Bayesian Survival Analysis

10. Overcoming Reading Challenges

- Dealing with Digital Eye Strain
- Minimizing Distractions
- Managing Screen Time

11. Cultivating a Reading Routine Bayesian Survival Analysis Bayesian Survival Analysis

- Setting Reading Goals Bayesian Survival Analysis Bayesian Survival Analysis
- Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Bayesian Survival Analysis Bayesian Survival Analysis

- Fact-Checking eBook Content of Bayesian Survival Analysis Bayesian Survival Analysis
- Distinguishing Credible Sources

13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
- Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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