

Bayesian Beta Regression with Bayesianbetareg R-package

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Introduction

Cepeda-Cuervo (2001) propose the beta regression model and a Bayesian method to fit the proposed model, where samples of the posterior distribution are obtained from the posterior conditional distributions of the regression parameters, assuming normal prior distributions for them (Cepeda and Gamerman, 2002).

The conditional posterior distributions are analytically intractable. Then, two normal transition kernel are built in order to apply a Metropolis-Hastings algorithm to obtain posterior samples.

We develop the Bayesianbetareg R-package for the estimation of the beta regression model when mean and precision are modeled (Cepeda-Cuervo et al., 2015), and the extension to mean and variance (in progress).

Beta Regression

The probability density function for a beta variable is

$$f(x|\mu, \nu) = \frac{\Gamma(\mu + \nu)}{\Gamma(\mu)\Gamma(\nu)} x^{\mu-1} (1-x)^{\nu-1} \mathbb{I}_{(0,1)}(x), \quad (1)$$

With the re-parametrization of the beta distribution as a function of the mean, $\mu = E(Y) = \frac{p}{p+q}$, and the precision $\nu = p+q$ parameters, (Jorgensen, 1987; Cepeda-Cuervo, 1991), the beta density function can be written as

$$f(x|\mu, \nu) = \frac{\Gamma(\nu)}{\Gamma(\mu)^2 \Gamma(\nu-\mu+1)} x^{\mu-1} (1-x)^{\nu-\mu-1} \mathbb{I}_{(0,1)}(x), \quad (2)$$

where $p = \mu\nu$, $q = \nu(1-\mu)$ and

$$p^2 = \frac{\mu^2(1-\mu)}{p+1}. \quad (3)$$

The Equation 3 can also be reparametrized as a function of the mean and variance (Cepeda-Cuervo, 2003)

$$p = \frac{\mu^2(1-\mu) - \mu\sigma^2}{\sigma^2} \quad (4)$$

$$q = \frac{(1-\mu)(p^2 - \sigma^2)}{\sigma^2} \quad (5)$$

A random sample $\mathbf{Y}_i \sim \text{Beta}(p_i, q_i)$ is assumed, where the mean and precision (variance) parameters are modeled as

$$g(\mu_i) = \mathbf{X}_i^T \boldsymbol{\beta} \quad (6)$$

$$h(\mu_i) = \mathbf{X}_i^T \boldsymbol{\gamma} \quad (7)$$

$$h(\sigma_i^2) = \mathbf{X}_i^T \boldsymbol{\gamma} \quad (8)$$

where we assume that g is the logit function and h is the exponential function (Cepeda-Cuervo, 2001).

Bayesian method to fit beta regression models

With $L(\boldsymbol{\theta})$ data, the likelihood function, and $p(\boldsymbol{\theta})$, the joint prior distribution $\boldsymbol{\theta} = (\boldsymbol{\beta}, \boldsymbol{\gamma})$, the posterior distribution is $\pi(\boldsymbol{\theta}|\text{data}) \propto L(\boldsymbol{\theta})p(\boldsymbol{\theta})$ (analytically intractable).

Cepeda-Cuervo (2001) proposed to get samples of $\boldsymbol{\theta}$ by sampling $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ from the posterior conditional distributions $\pi(\boldsymbol{\beta}|\boldsymbol{\gamma}, \text{data})$ and $\pi(\boldsymbol{\gamma}|\boldsymbol{\beta}, \text{data})$ from the normal transition kernels.

The kernel transition function q_1 is given by

$$q_1(\boldsymbol{\beta}|\boldsymbol{\beta}^{(i)}, \boldsymbol{\gamma}^{(i)}) = N(\boldsymbol{\beta}^*|\mathbf{B}^*), \quad (9)$$

where

$$\mathbf{B}^* = \mathbf{B}^{(i)}(\mathbf{B}^{(i)-1}\mathbf{b} + \mathbf{X}\boldsymbol{\Sigma}^{-1}\mathbf{Y})$$
$$\mathbf{B}^{(i)} = (\mathbf{B}^{(i-1)} + \mathbf{X}\boldsymbol{\Sigma}^{-1}\mathbf{X}^T)$$

and where $\boldsymbol{\Sigma}$ is a diagonal matrix with diagonal entries σ_i^2 , $i = 1, 2, \dots, n$, and (Cepeda-Cuervo, 2001; Cepeda and Gamerman, 2002)

$$\sigma_i = \mathbf{X}_i^T \boldsymbol{\beta}^{(i)} + \frac{\mathbf{p}_i - \mathbf{p}_i^2}{(\mathbf{p}_i^2(1-\mathbf{p}_i))}, \quad i = 1, 2, \dots, n, \quad (10)$$

And the normal transition kernel q_2 is given by

$$q_2(\boldsymbol{\gamma}|\boldsymbol{\gamma}^{(i)}, \boldsymbol{\beta}^{(i)}) = N(\boldsymbol{\gamma}^*|\mathbf{G}^*), \quad (11)$$

where

$$\boldsymbol{\gamma}^* = \mathbf{G}^{(i)}(\mathbf{G}^{(i)-1}\mathbf{g} + \mathbf{Z}\boldsymbol{\Psi}^{-1}\mathbf{Y})$$
$$\mathbf{G}^{(i)} = (\mathbf{G}^{(i-1)} + \mathbf{Z}\boldsymbol{\Psi}^{-1}\mathbf{Z}^T)$$

$\boldsymbol{\Psi}$ is a diagonal matrix with entries σ_i^2 for $i = 1, 2, \dots, n$ and let us

$$\hat{\mu}_i = \mathbf{X}_i^T \boldsymbol{\gamma}^{(i)} + \frac{\mathbf{p}_i - \mathbf{p}_i^2}{\mathbf{p}_i} - 1, \quad i = 1, 2, \dots, n. \quad (12)$$

For σ_i^2

$$\hat{\sigma}_i = \mathbf{X}_i^T \boldsymbol{\gamma}^{(i)} + \frac{(\mathbf{p}_i - \mathbf{p}_i^2)}{\sigma_i^2} - 1, \quad i = 1, 2, \dots, n. \quad (13)$$

An application of the Bayesianbetareg

We carry out an example of the Bayesianbetareg package using the dykema data set presented in Smithson and Verbeulen (2006), in which the response variable represents the scores obtained by 41 children in a reading accuracy test. The explanatory variables correspond to the dykema (D) or lack of status (L) (the standardized non-verbal IQ) and their interaction. This database is available in the betareg package (R Core Team, 2014).

Table 1. Estimation Results

	Estimate	StdErr	LCredInt	UCredInt
beta.X0	1.00	0.23	0.23	1.76
beta.X1	-1.11	0.23	-1.58	-0.64
beta.X2	1.79	0.23	1.27	2.30
beta.X3	-1.00	0.23	-1.58	-0.42
gamma.D0	1.00	0.23	0.99	1.01
gamma.D1	0.03	0.24	-0.44	0.47
gamma.D2	0.00	0.07	0.00	0.00



Figure 1. Plot - Chain of beta parameter



Figure 2. Plot - Chain of gamma parameter

Conclusions

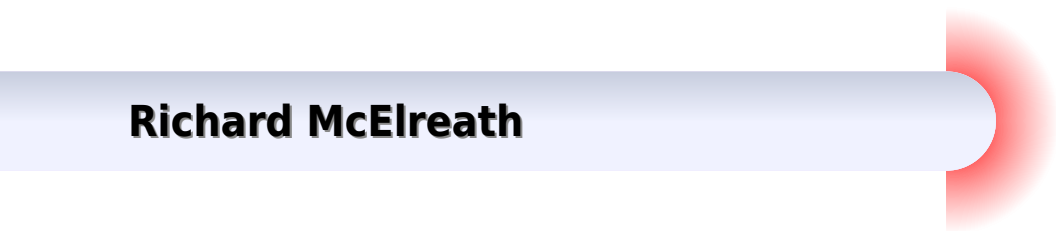
- the Bayesianbetareg R package, can be used to fit beta regression with mean and precision
- The program for fit beta regression with mean and variance is in progress

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Bayesian Beta Regression With Bayesianbetareg R Package

Richard McElreath



Bayesian Beta Regression With Bayesianbetareg R Package:

Bayesian Regression Modeling with INLA Xiaofeng Wang, Yu Ryan Yue, Julian J. Faraway, 2018-01-29 INLA stands for Integrated Nested Laplace Approximations which is a new method for fitting a broad class of Bayesian regression models. No samples of the posterior marginal distributions need to be drawn using INLA so it is a computationally convenient alternative to Markov chain Monte Carlo (MCMC) the standard tool for Bayesian inference. Bayesian Regression Modeling with INLA covers a wide range of modern regression models and focuses on the INLA technique for building Bayesian models using real world data and assessing their validity. A key theme throughout the book is that it makes sense to demonstrate the interplay of theory and practice with reproducible studies. Complete R commands are provided for each example and a supporting website holds all of the data described in the book. An R package including the data and additional functions in the book is available to download. The book is aimed at readers who have a basic knowledge of statistical theory and Bayesian methodology. It gets readers up to date on the latest in Bayesian inference using INLA and prepares them for sophisticated real world work. Xiaofeng Wang is Professor of Medicine and Biostatistics at the Cleveland Clinic Lerner College of Medicine of Case Western Reserve University and a Full Staff in the Department of Quantitative Health Sciences at Cleveland Clinic. Yu Ryan Yue is Associate Professor of Statistics in the Paul H. Chook Department of Information Systems and Statistics at Baruch College, The City University of New York. Julian J. Faraway is Professor of Statistics in the Department of Mathematical Sciences at the University of Bath.

Bayes Rules! Alicia A. Johnson, Miles Q. Ott, Mine Dogucu, 2022-03-03 An engaging sophisticated and fun introduction to the field of Bayesian statistics. Bayes Rules: An Introduction to Applied Bayesian Modeling brings the power of modern Bayesian thinking, modeling and computing to a broad audience. In particular, the book is an ideal resource for advanced undergraduate statistics students and practitioners with comparable experience; the book assumes that readers are familiar with the content covered in a typical undergraduate level introductory statistics course. Readers will also ideally have some experience with undergraduate level probability, calculus and the R statistical software. Readers without this background will still be able to follow along so long as they are eager to pick up these tools on the fly as all R code is provided. Bayes Rules empowers readers to weave Bayesian approaches into their everyday practice. Discussions and applications are data driven. A natural progression from fundamental to multivariable hierarchical models emphasizes a practical and generalizable model building process. The evaluation of these Bayesian models reflects the fact that a data analysis does not exist in a vacuum. Features: Utilizes data driven examples and exercises. Emphasizes the iterative model building and evaluation process. Surveys an interconnected range of multivariable regression and classification models. Presents fundamental Markov chain Monte Carlo simulation. Integrates R code including RStan modeling tools and the bayesrules package. Encourages readers to tap into their intuition and learn by doing. Provides a friendly and inclusive introduction to technical Bayesian concepts. Supports Bayesian applications with foundational Bayesian theory.

Learning

Bayesian Models with R Dr. Hari M. Koduvely, 2015-10-28 Become an expert in Bayesian Machine Learning methods using R and apply them to solve real world big data problems About This Book Understand the principles of Bayesian Inference with less mathematical equations Learn state of the art Machine Learning methods Familiarize yourself with the recent advances in Deep Learning and Big Data frameworks with this step by step guide Who This Book Is For This book is for statisticians analysts and data scientists who want to build a Bayes based system with R and implement it in their day to day models and projects It is mainly intended for Data Scientists and Software Engineers who are involved in the development of Advanced Analytics applications To understand this book it would be useful if you have basic knowledge of probability theory and analytics and some familiarity with the programming language R What You Will Learn Set up the R environment Create a classification model to predict and explore discrete variables Get acquainted with Probability Theory to analyze random events Build Linear Regression models Use Bayesian networks to infer the probability distribution of decision variables in a problem Model a problem using Bayesian Linear Regression approach with the R package BLR Use Bayesian Logistic Regression model to classify numerical data Perform Bayesian Inference on massively large data sets using the MapReduce programs in R and Cloud computing In Detail Bayesian Inference provides a unified framework to deal with all sorts of uncertainties when learning patterns from data using machine learning models and use it for predicting future observations However learning and implementing Bayesian models is not easy for data science practitioners due to the level of mathematical treatment involved Also applying Bayesian methods to real world problems requires high computational resources With the recent advances in computation and several open sources packages available in R Bayesian modeling has become more feasible to use for practical applications today Therefore it would be advantageous for all data scientists and engineers to understand Bayesian methods and apply them in their projects to achieve better results Learning Bayesian Models with R starts by giving you a comprehensive coverage of the Bayesian Machine Learning models and the R packages that implement them It begins with an introduction to the fundamentals of probability theory and R programming for those who are new to the subject Then the book covers some of the important machine learning methods both supervised and unsupervised learning implemented using Bayesian Inference and R Every chapter begins with a theoretical description of the method explained in a very simple manner Then relevant R packages are discussed and some illustrations using data sets from the UCI Machine Learning repository are given Each chapter ends with some simple exercises for you to get hands on experience of the concepts and R packages discussed in the chapter The last chapters are devoted to the latest development in the field specifically Deep Learning which uses a class of Neural Network models that are currently at the frontier of Artificial Intelligence The book concludes with the application of Bayesian methods on Big Data using the Hadoop and Spark frameworks Style and approach The book first gives you a theoretical description of the Bayesian models in simple language followed by details of its implementation in the R package Each chapter has illustrations for the use of Bayesian model and

the corresponding R package using data sets from the UCI Machine Learning repository Each chapter also contains sufficient exercises for you to get more hands on practice

Spatial and Spatio-temporal Bayesian Models with R - INLA Marta Blangiardo, Michela Cameletti, 2015-04-07 Spatial and Spatio Temporal Bayesian Models with R INLA provides a much needed practically oriented innovative presentation of the combination of Bayesian methodology and spatial statistics The authors combine an introduction to Bayesian theory and methodology with a focus on the spatial and spatio temporal models used within the Bayesian framework and a series of practical examples which allow the reader to link the statistical theory presented to real data problems The numerous examples from the fields of epidemiology biostatistics and social science all are coded in the R package R INLA which has proven to be a valid alternative to the commonly used Markov Chain Monte Carlo simulations

Bayesian Essentials with R Jean-Michel Marin, Christian P. Robert, 2013-10-28 This Bayesian modeling book provides a self contained entry to computational Bayesian statistics Focusing on the most standard statistical models and backed up by real datasets and an all inclusive R CRAN package called bayess the book provides an operational methodology for conducting Bayesian inference rather than focusing on its theoretical and philosophical justifications Readers are empowered to participate in the real life data analysis situations depicted here from the beginning Special attention is paid to the derivation of prior distributions in each case and specific reference solutions are given for each of the models Similarly computational details are worked out to lead the reader towards an effective programming of the methods given in the book In particular all R codes are discussed with enough detail to make them readily understandable and expandable Bayesian Essentials with R can be used as a textbook at both undergraduate and graduate levels It is particularly useful with students in professional degree programs and scientists to analyze data the Bayesian way The text will also enhance introductory courses on Bayesian statistics Prerequisites for the book are an undergraduate background in probability and statistics if not in Bayesian statistics

Probability and Bayesian Modeling Jim Albert, Jingchen Hu, 2019-12-06 Probability and Bayesian Modeling is an introduction to probability and Bayesian thinking for undergraduate students with a calculus background The first part of the book provides a broad view of probability including foundations conditional probability discrete and continuous distributions and joint distributions Statistical inference is presented completely from a Bayesian perspective The text introduces inference and prediction for a single proportion and a single mean from Normal sampling After fundamentals of Markov Chain Monte Carlo algorithms are introduced Bayesian inference is described for hierarchical and regression models including logistic regression The book presents several case studies motivated by some historical Bayesian studies and the authors research This text reflects modern Bayesian statistical practice Simulation is introduced in all the probability chapters and extensively used in the Bayesian material to simulate from the posterior and predictive distributions One chapter describes the basic tenets of Metropolis and Gibbs sampling algorithms however several chapters introduce the fundamentals of Bayesian inference for conjugate priors to deepen

understanding Strategies for constructing prior distributions are described in situations when one has substantial prior information and for cases where one has weak prior knowledge One chapter introduces hierarchical Bayesian modeling as a practical way of combining data from different groups There is an extensive discussion of Bayesian regression models including the construction of informative priors inference about functions of the parameters of interest prediction and model selection The text uses JAGS Just Another Gibbs Sampler as a general purpose computational method for simulating from posterior distributions for a variety of Bayesian models An R package ProbBayes is available containing all of the book datasets and special functions for illustrating concepts from the book A complete solutions manual is available for instructors who adopt the book in the Additional Resources section

[Bayesian Computation with R](#) Jim Albert, 2007 The purpose of this book is to introduce Bayesian modeling by the use of computation using R language R provides a wide range of functions for data manipulation calculation and graphical displays

[Applied Bayesian Statistics](#) Mary Kathryn Cowles, 2013-01-04 This book is based on over a dozen years teaching a Bayesian Statistics course The material presented here has been used by students of different levels and disciplines including advanced undergraduates studying Mathematics and Statistics and students in graduate programs in Statistics Biostatistics Engineering Economics Marketing Pharmacy and Psychology The goal of the book is to impart the basics of designing and carrying out Bayesian analyses and interpreting and communicating the results In addition readers will learn to use the predominant software for Bayesian model fitting R and OpenBUGS The practical approach this book takes will help students of all levels to build understanding of the concepts and procedures required to answer real questions by performing Bayesian analysis of real data Topics covered include comparing and contrasting Bayesian and classical methods specifying hierarchical models and assessing Markov chain Monte Carlo output

Kate Cowles taught Suzuki piano for many years before going to graduate school in Biostatistics Her research areas are Bayesian and computational statistics with application to environmental science She is on the faculty of Statistics at The University of Iowa

[Bayesian Analysis with Excel and R](#) Conrad Carlberg, 2022-12-15 Leverage the full power of Bayesian analysis for competitive advantage Bayesian methods can solve problems you can't reliably handle any other way Building on your existing Excel analytics skills and experience Microsoft Excel MVP Conrad Carlberg helps you make the most of Excel's Bayesian capabilities and move toward R to do even more Step by step with real world examples Carlberg shows you how to use Bayesian analytics to solve a wide array of real problems Carlberg clarifies terminology that often bewilders analysts and offers sample R code to take advantage of the rethinking package in R and its gateway to Stan As you incorporate these Bayesian approaches into your analytical toolbox you'll build a powerful competitive advantage for your organization and yourself Explore key ideas and strategies that underlie Bayesian analysis Distinguish prior likelihood and posterior distributions and compare algorithms for driving sampling inputs Use grid approximation to solve simple univariate problems and understand its limits as parameters increase Perform complex simulations and regressions with quadratic approximation

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text presents generalized linear multilevel models from a Bayesian perspective relying on a simple logical interpretation of Bayesian probability and maximum entropy It covers from the basics of regression to multilevel models The author also discusses measurement error missing data and Gaussian process models for spatial and network autocorrelation By using complete R code examples throughout this book provides a practical foundation for performing statistical inference Designed for both PhD students and seasoned professionals in the natural and social sciences it prepares them for more advanced or specialized statistical modeling Web Resource The book is accompanied by an R package rethinking that is available on the author s website and GitHub The two core functions map and map2stan of this package allow a variety of statistical models to be constructed from standard model formulas

Flexible Bayesian Regression Modelling Yanan Fan,David Nott,Mike S. Smith,Jean-Luc Dortet-Bernadet,2019-10-30 Flexible Bayesian Regression Modeling is a step by step guide to the Bayesian revolution in regression modeling for use in advanced econometric and statistical analysis where datasets are characterized by complexity multiplicity and large sample sizes necessitating the need for considerable flexibility in modeling techniques It reviews three forms of flexibility methods which provide flexibility in their error distribution methods which model non central parts of the distribution such as quantile regression and finally models that allow the mean function to be flexible such as spline models Each chapter discusses the key aspects of fitting a regression model R programs accompany the methods This book is particularly relevant to non specialist practitioners with intermediate mathematical training seeking to apply Bayesian approaches in economics biology finance engineering and medicine Introduces powerful new nonparametric Bayesian regression techniques to classically trained practitioners Focuses on approaches offering both superior power and methodological flexibility Supplemented with instructive and relevant R programs within the text Covers linear regression nonlinear regression and quantile regression techniques Provides diverse disciplinary case studies for correlation and optimization problems drawn from Bayesian analysis in the wild

[Introduction to Bayesian Data Analysis for Cognitive Science](#) Bruno Nicenboim,Daniel J. Schad,Shravan Vasisht,2025-08-21 This book introduces Bayesian data analysis and Bayesian cognitive modeling to students and researchers in cognitive science e g linguistics psycholinguistics psychology computer science with a particular focus on modeling data from planned experiments The book relies on the probabilistic programming language Stan and the R package brms which is a front end to Stan The book only assumes that the reader is familiar with the statistical programming language R and has basic high school exposure to pre calculus mathematics some of the important mathematical constructs needed for the book are introduced in the first chapter Through this book the reader will be able to develop a practical ability to apply Bayesian modeling within their own field The book begins with an informal introduction to foundational topics such as probability theory and univariate and bi multivariate discrete and continuous random variables Then the application of Bayes rule for statistical inference is introduced with several simple analytical examples that require no computing software the main insight here is that the posterior distribution of a parameter

is a compromise between the prior and the likelihood functions The book then gradually builds up the regression framework using the brms package in R ultimately leading to hierarchical regression modeling aka the linear mixed model Along the way there is detailed discussion about the topic of prior selection and developing a well defined workflow Later chapters introduce the Stan programming language and cover advanced topics using practical examples contrast coding model comparison using Bayes factors and cross validation hierarchical models and reparameterization defining custom distributions measurement error models and meta analysis and finally some examples of cognitive models multinomial processing trees finite mixture models and accumulator models Additional chapters appendices and exercises are provided as online materials and can be accessed here <https://github.com/bnicenboim/bayescogsci>

Extended beta regression in R : shaken, stirred, mixed, and partitioned Bettina Grün, Ioannis Kosmidis, Achim Zeileis, 2011 *Learning Bayesian Models with R* Hari Koduvely, 2015 Become an expert in Bayesian Machine Learning methods using R and apply them to solve real world big data problems About This Book Understand the principles of Bayesian Inference with less mathematical equations Learn state of the art Machine Learning methods Familiarize yourself with the recent advances in Deep Learning and Big Data frameworks with this step by step guide Who This Book Is For This book is for statisticians analysts and data scientists who want to build a Bayes based system with R and implement it in their day to day models and projects It is mainly intended for Data Scientists and Software Engineers who are involved in the development of Advanced Analytics applications To understand this book it would be useful if you have basic knowledge of probability theory and analytics and some familiarity with the programming language R What You Will Learn Set up the R environment Create a classification model to predict and explore discrete variables Get acquainted with Probability Theory to analyze random events Build Linear Regression models Use Bayesian networks to infer the probability distribution of decision variables in a problem Model a problem using Bayesian Linear Regression approach with the R package BLR Use Bayesian Logistic Regression model to classify numerical data Perform Bayesian Inference on massively large data sets using the MapReduce programs in R and Cloud computing In Detail Bayesian Inference provides a unified framework to deal with all sorts of uncertainties when learning patterns from data using machine learning models and use it for predicting future observations However learning and implementing Bayesian models is not easy for data science practitioners due to the level of mathematical treatment involved Also applying Bayesian methods to real world problems requires high computational resources With the recent advances in computation and several open sources packages available in R Bayesian modeling has become more feasible to use for practical applications today Therefore it would be advantageous for all data scientists and engineers to understand Bayesian methods and apply them in their projects to achieve better results Learning Bayesian Models with R starts by giving you a comprehensive coverage of the Bayesian Machine Learning models and the R packages that implement them It begins with an introduction to the fundamentals of probability theory and R programming for those who are new to

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