UNH, DURHAM FALL 2021

SYLLABUS CRN: 16140 & 16902

MATH 941.01 /1SY : BAYESIAN AND COMPUTATIONAL STATISTICS

Class Times: Mondays and Wednesdays 11:10am - 12:30pm Eastern Time (USA)

Location: Horton 201, or anywhere **live on-line**

Instructor: Ernst Linder, N321B Kingsbury Hall, 603-862 2687, elinder@unh.edu

Office Hours: TBD

COURSE OUTLINE

In this course, we will be discussing current approaches to Bayesian modeling and data analysis, and computation in statistics and related science fields. The course will be introductory in the beginning but will advance quickly to more current and especially computationally sophisticated methods. The emphasis will be on data, and on methodologies and their application in practice.

Prerequisites: *(Please contact the instructor if you are not sure if you have sufficient background)*

Knowledge of intermediate statistics: Distributions, discrete and continuous random variables, transformation of variables, bivariate and multivariate normal distributions.

Working knowledge of linear regression and analysis of variance.

Some very basic linear algebra: Vectors and matrices, linear spaces, matrix multiplication, inverse of a matrix, positive definiteness. Matrix-vector notation for linear regression and ANOVA

Familiarity with the basic ideas of calculus, in particular conceptual understanding of notation and meaning of integrals and derivatives in one or more dimensions.

R programming. *If you never used R before, **you are required** to work through the first 5 weeks of materials (including quizzes) of MATH 759/859 (1 credit) - Introduction to R.* You should complete this within the first 3 weeks of the semester. You may either register for the course, or ask me for access to the materials.

Required Texts:

1) Turkman ,M. Antónia A, Paulino, Carlos Daniel, , Müller, Peter, (2019). ***Computational Bayesian Statistics***. Cambridge University Press / IMS Textbooks.

Free pdf download: https://web.ma.utexas.edu/users/pmueller/compbayes/

or Hardcopy: (softcover): 1) Become a member of IMS (free for students
2) purchase text via IMS website ~ 24 $ + shipping

2) Gelman, Carlin, Stern, Rubin, Dunson, and Vehtari, ***Bayesian Data Analysis*** (Chapman and Hall - CRC Press, third edition: 2014).

Free pdf download: http://www.stat.columbia.edu/~gelman/book/

Software: We will be using the following software
R (open source, freeware); RStudio (a convenient platform for R)
Stan (freeware) ; (others, see below)

Distance Learning: Course Delivery:

This course is delivered synchronously on-line using ZOOM. http://zoom.unh.edu Make sure to set up your audio (microphone and loudspeakers) functions. Sometimes we recommend earphones or a headset in case your computer lacks feedback-noise suppression. Links to our class meetings will be posted on Canvas (myCourses.unh.edu) and class materials, including recordings will also be posted there.

ZOOM provides a fully interactive platform for course delivery and student participation. ***It is therefore expected that students attend the class either in person in the classroom, or, virtually from a computer during the scheduled class time.*** While the classes are recorded for replay at a later point in time, it is not acceptable for students to never attend class when it is scheduled and simply peruse the recording later. The recordings are to be used for re-play in cases where parts of the lecture were not clearly understood the first time. ***Students who anticipate having time conflicts with the scheduled classes need to inform the instructor of their planned absences from the live class.***

It is also expected that students who attend the class from a distance have the necessary equipment that allows them to fully participate in the course, in particular a microphone (a laptop mic tends to be sufficient).

Course Organization

Homework: Homework assignments will be given on a regular basis. Most homework will require computer-based calculations.

Quizzes : I will use the MyCourses on-line quiz menu occasionally when the material is suitable for that. Online quizzes can be useful to review material in a question-and-answer format.

Discussions: We may occasionally make use of the Discussion Forums in MyCourses.

Final Exam: A comprehensive final take-home exam will be assigned at the end of the semester.

Grade Calculation: Homework ~ 55%, Quizzes and Discussions ~20% : Final Exam: 25 %

Tentative List of Topics: (The aim is to cover most of the Turkman et al. textbook.)

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1    Bayesian Inference
1.1  The classical paradigm 1.2 The Bayesian paradigm
1.3  Bayesian inference

2    Representation of Prior Information
2.1  Non-informative priors
2.2  Natural conjugate priors
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3 Bayesian Inference in Basic
3.1 The binomial and beta model
3.2 The Poisson and gamma model
3.3 Normal (known mu) and inverse gamma model
3.4 Normal (unknown mu, sigma) and Jeffreys' prior
3.5 Two independent normal models and marginal Jeffreys' priors
3.6 Two independent binomials and beta distributions
3.7 Multinomial and Dirichlet model
(3.8 Inference in finite populations)

4 Inference by Monte Carlo Methods
4.1 Simple Monte Carlo
4.2 Monte Carlo with importance sampling
4.3 Sequential Monte Carlo

5 Model Assessment
5.1 Model criticism and adequacy 5.2 Model selection and comparison
5.3 Further notes on simulation in model assessment

6 Markov Chain Monte Carlo Methods
6.1 Definitions and basic results for Markov chains
6.2 Metropolis-Hastings Algorithm
6.3 Gibbs Sampler 6.4 Slice sampler
6.5 Hamiltonian Monte Carlo
6.6 Implementation deta

(7 Model Selection and Trans-dimensional MCMC
7.1 MC simulation over the parameter space
7.2 MC simulation over the model space
7.3 MC simulation over model and parameter space
7.4 Reversible jump MCMC

8 Methods Based on Analytic Approximations
8.1 Analytical methods 8.2 Latent Gaussian models (LGM)
8.3 Integrated nested Laplace approximation (INLA)
8.4 Variational Bayesian inference

9 Software
9.1 Application example
9.2 The BUGS project: WinBUGS and OpenBUGS
9.3 JAGS
9.4 Stan
9.5 BayesX
9.6 Convergence diagnostics: the programs CODA and BOA
9.7 R-INLA and the application example