STAT*6841: Computational Statistical Inference

Winter 2024

Department of Mathematics and Statistics, University of Guelph

1 General information

Course description: Likelihood and Bayesian methods, large sample theory, nuisance parameters, Expectation-Maximization (EM) algorithms, Minorization-maximization/majorization-minimization (MM) algorithm, and other optimization methods, estimating functions, Monte Carlo methods for exploring posterior distributions and likelihoods, data augmentation, importance sampling, and Markov Chain Monte Carlo (MCMC) methods.

Campus: Guelph

Class Schedule and Location: MW 1-2:20pm, in-person lecture at ROZH 109.

Final Exam:

Instructor: Prof. Zeny Feng
Email: zfeng@uoguelph.ca

Office hour: MW 2:30-3:30pm, F 11:30am -12:30pm, MACN540

2 Course Content

Lecture Content:

- Review of probability and distribution theory, random sample and sampling distribution (optional, depending on the class background)

- Large sample theory, stochastic convergence (optional, depending on the class background)

- Maximum likelihood estimation (MLE), properties of MLEs, profile likelihood, conditional likelihood, penalized likelihood, generalized linear models

- Expectation-maximization (EM) algorithm

- Minorization-maximization/majorization-minimization (MM) algorithm

- Bayesian methods, prior distributions, posterior distributions

- Bayesian inference: point estimation, interval estimation, and hypothesis testing

- Monte Carlo methods: Rejection sampling, importance sampling,

- Markov chain Monte Carlo Methods: Metropolis-Hastings algorithm, and Gibbs sampler.

Specific Learning Outcomes:

By the end of this course, students should be able to

- carry out inference procedure based on likelihood methods, such as point estimates, interval estimates, and hypothesis test;

- understand and utilize various likelihood based methods to handle more complex situations. For example, use computational software to implement the EM algorithm for fitting models involving missing data and fitting mixture models; use computational software to implement MM algorithm; use computational software to carry out regularized regression analysis;

- understand the basic principles, concepts, and theory of Bayesian methods: prior distribution, and posterior distribution for the parameter(s) of interest;

- work out the Bayesian estimates of parameters under special situations such as conjugate family of distributions;

- implement the Markov Chain Monte Carlo methods: Gibbs sampler, metropolis-Hasting algorithm, importance sampling, and adaptive sampling, to obtain the Bayesian estimate of parameters;

- know the connections and differences between likelihood based methods and Bayesian methods, and algorithms or procedures related to these two different approaches.

Course Assignments and Tests: This is a tentative schedule. Assignment due dates and test date are subject to change.

- Assignments 30%, due January 25, February 8, March 8, March 22 (all on Thursday)

- Midterm 25%, Wednesday, March 1, in class

- Final exam 45%, TBA

- Bonus 5%, problem solving presentation, in class.

3 Course Resources

Text: There is no required textbook for this course, as the course notes will serve as the primary resource for students. However, students are encouraged to access the following online textbooks or hard copies (and corresponding chapters), available through the University of Guelph Library, as additional resources:

1. Caseller and Berger's *Statistical Inference*, 2nd ed., by Duxbury.

2. Garthwaite, Jollieffe, and Jones' *Statistical Inference*, 2nd edition by Oxford Science Publications.

3. Carlin and Louis' *Bayesian Methods for Data Analysis*, 3rd edition by Chapman and Hall, CRC Press.

4. Gelman, Carlin, Stern, and Rubin's *Bayesian Data Analysis*, 2nd edition by Chapman and Hall, CRC Press.

Lecture Note: An (in)complete set of lecture notes is available from the CourseLink in advance of lectures. It is expected that students bring a copy to be completed during lectures. Filled lecture notes will not be posted online. The lecture notes are not to be re-distributed in any form.

Computer Software: The primary statistical software package that will be used in this course is R, which is freely available for download at http://www.r-project.org/. Students are strongly encouraged to install R on their personal computers. Students are allowed to use other softwares such as Python, Perl, Matlab and etc, whatever they find it suitable.

CourseLink: Course information and material (such as lecture notes, assignments, solutions, other course material, and announcements) will be available on CourseLink. Students are responsible to check the website regularly for undated information and announcements.

4 Course Policies:

Every student is treated the same way according to the evaluation methods and the grading scheme. We will not modify style of tests and exam from in-person to online as this would not be fair to the other students.

Assignment Policies:

- Assignments are due 11:59pm on the due date. Please submit your assignment through the Gradescope.

- No late assignments will be accepted, and late or missed assignments will receive a grade of 0 automatically.

- If you are under special or serious circumstance that you cannot submit your assignment, please contact me in email with your name, id number, within 48 hours before the due time (with supportive documents if applicable), the missed assignment percentage will go to your final exam.

- While you are encouraged to discuss approaches to assignment questions with other students, your submitted assignment must be your own work. Copying any part of another student's work is considered academic misconduct. (Please read the section on academic misconduct at the end of this document and in the undergraduate calendar.)

Midterm and Exam Policies: Midterm test will be held in class and therefore no student should have a conflict with the date or time. If a conflict does exist, it is your responsibility to resolve it immediately (e.g. athletic competition). When you find yourself unable to write the midterm please contact me in email with your name, id number, and supportive documents before the midterm, the missed midterm percentage will be distributed to the final exam, or otherwise, no show on midterm will receive a grade of 0. There will be no makeup midterm test.

5   University Policies

Email Communication: As per university regulations, all students are required to check their e-mail account regularly: e-mail is the official route of communication between the University and its students.

When You Cannot Meet a Course Requirement: When you find yourself unable to meet an in-course requirement because of illness or compassionate reasons, please advise the course instructor in writing, with your name, id number, and e-mail contact. The grounds for Academic Consideration are detailed in the Undergraduate and Graduate Calendars.

Graduate Calendar - Grounds for Academic Consideration
https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/index.shtml

Academic Accommodation of Religious Obligations: If you are unable to complete a course requirement due to religious obligations, please let the instructor know within the first two weeks of class. See the academic calendar for more information:
https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-accomrelig.shtml

Illness: The University will not normally require verification of illness (doctor's notes). However, requests for Academic Consideration may still require medical documentation as appropriate.

Academic Misconduct: The University of Guelph is committed to uphold-

ing the highest standards of academic integrity and it is the responsibility of all members of the University community, faculty, staff, and students to be aware of what constitutes academic misconduct and to do as much as possible to prevent academic offences from occurring.

University of Guelph students have the responsibility of abiding by the University's policy on academic misconduct regardless of their location of study; faculty, staff and students have the responsibility of supporting an environment that discourages misconduct. Students need to remain aware that instructors have access to and the right to use electronic and other means of detection.

Please note: Whether or not a student intended to commit academic misconduct is not relevant for a finding of guilt. Hurried or careless submission of assignments does not excuse students from responsibility for verifying the academic integrity of their work before submitting it. Students who are in any doubt as to whether an action on their part could be construed as an academic offence should consult with a faculty member or faculty advisor.

The Academic Misconduct Policy is detailed in Graduate Calendar:
https://www.uoguelph.ca/registrar/calendars/graduate/2014-2015/genreg/sec_d0e2097.shtml

Accessibility: The University promotes the full participation of students who experience disabilities in their academic programs. To that end, the provision of academic accommodation is a shared responsibility between the University and the student.

When accommodations are needed, the student is required to first register with Student Accessibility Services (SAS). Documentation to substantiate the existence of a disability is required, however, interim accommodations may be possible while that process is underway.

Accommodations are available for both permanent and temporary disabilities. It should be noted that common illnesses such as a cold or the flu do not constitute a disability.

Use of the SAS Exam Centre requires students to book their exams **at least**

14 days in advance, and no later than March 1. Similarly, new or changed accommodations for online quizzes, tests, and exams must be approved at least a week ahead of time.

More information: `www.uoguelph.ca/sas`

Mental Health Resources: One out of every five students in Canada experiences some sort of mental health issue at some point in their academic career. If you find yourself facing a mental health crisis, or just need to talk to someone, please consider taking advantage of one of the following resources available to University of Guelph students:

- **Counselling Services:** Visit the Counselling Services website (`https://wellness.uoguelph.ca/counselling`) to get information on resources available to you, both online and in-person. You can also visit them at Health Services (J.T. Powell Building, ext 53244) where they offer individual and group counselling sessions by appointment or walk-in.

- **Student Support Network:** is located in the Wellness & Education Promotion Centre in the J.T. Powell Building and offers confidential, peer-based, drop-in support.

- **Good2Talk:** (1-866-925-5454) is a free, 24/7 student hotline that provides professional counselling and referrals for mental health, addictions and well-being.

- **Here 24/7:** (1-844-437-3247) specializes in assessment, referral and appointment booking and is available 24/7 for crisis support.

You are not alone and you will not be judged for asking help.

Course Policy regarding use of electronic devices and recording of lectures: Presentations that are made in relation to course work - including lectures - cannot be recorded or copied without the permission of the presenter, whether the instructor, a student, or guest lecturer.

Course Evaluation Information: Near the end of the term, you will be given the opportunity to evaluate your instructor and provide comments regarding your experience. The evaluations for this class will be done online,

but an opportunity to complete them in-class will also be provided. Your instructor will inform you of when these are to take place.

Last Day to Drop the Course: Students will have until the last day of classes to drop courses without academic penalty. The deadline to drop two-semester courses will be the last day of classes in the second semester. This applies to all students (undergraduate, graduate and diploma) except for Doctor of Veterinary Medicine and Associate Diploma in Veterinary Technology (conventional and alternative delivery) students. The regulations and procedures for course registration are available in their respective Academic Calendars.

Graduate Calendar - Registration Changes
https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/
genreg-reg-regchg.shtml