STA2311: Advanced Computational Methods for Statistics I (Fall 2023)

Course Instructor:	Radu Craiu	**Course TA:**	Rob Zimmerman
Course Email:	sta2311@utoronto.ca	**Lectures:**	Tuesdays 2–5PM
Course Website:	q.utoronto.ca/courses/327472	**Location:**	TF 200

Course Description: This is the first part of a two-semester sequence of PhD courses focused on computational methods in Statistics. In the Fall semester, we will examinine optimization and sampling techniques. We will focus on understanding the underlying motivation for each technique, with enough theoretical justification to enable students who have learned the material to tweak the existing algorithms to suit their problems.

Prerequisites: Students attending the class are expected to have a solid knowledge of real analysis, linear algebra, probability, and statistical inference at an advanced undergraduate level.

Lectures: Lectures will be used to go through theory and examples; see the lecture schedule below for a list of topics. Lectures will be held from 2–5PM in ES B142. Lectures will not be recorded, but annotated slides will be posted on Quercus following each lecture.

Office Hours: Instructor office hours will take place online on Mondays from 4–6PM, while TA office hours will take place in-person on Thursdays from 4:30–5:30PM. The exact weekly schedule, Zoom links, and room numbers will be posted on Quercus towards the start of the course.

Piazza: We have a Piazza page for the course: https://piazza.com/utoronto.ca/fall2023/sta2311. This resource is meant only to provide help with course concepts and clarify brief administrative questions, so off-topic posts may be removed. While the teaching team will try to monitor the page, it is no substitute for office hours and there is no guarantee that every post will be responded to. You are strongly encouraged to participate and answer the questions of your fellow students (correct and helpful answers will be endorsed). If you do opt to use this service, make sure you're comfortable with the implications for your privacy; the ways that Piazza shares your personal information are outlined in the Privacy Policy and Terms of Service.

Additional References: There is *no* course textbook – the course is self-contained. However, each class will include several references to external papers or websites that you may refer to for additional details.

Marking Scheme: Final grades will be calculated according to the following scheme:

Homeworks	$2 \times 15\% = 30\%$
Midterm	30%
Final Exam	40%

Homework 1 will be due before class on October 31; Homework 2 will be due before class on November 28. More details (submission instructions, etc.) will be provided on Quercus. The midterm will take place during class time on October 17, 2023. The date for the final exam is TBD.

Missed Assessments: If you need to miss a homework or the midterm for a *legitimate* reason (such as an illness), you must send an email to sta2311@utoronto.ca before the due date (in the case of a homework) or within a day after the midterm. A missed homework or midterm will have its weight transfered to the final exam. However, missing more than 40% of the course components (e.g., a homework and the midterm) will result in an automatic course failure, as it is not possible to assign a meaningful grade with so much course work missed. If you miss the final exam, a make-up final may be offered sometime during or after the December final exam period; note that this make-up assessment may have a different format from the original (for example, it may be an oral exam).

Tentative Schedule:

Class	Date	Class Topic
1	September 12, 2023	**Introduction and Validation** • Reproducibility • Accuracy measures • Cross-validation
2	September 19, 2023	**Classical Optimization Methods** • Fixed-point methods • Newton-Raphson and Gauss-Newton • Gradient descent
3	September 26, 2023	**The EM Algorithm** • Missing data mechanisms • The ascent property • Louis' method and the fraction of missing information
4	October 3, 2023	**Stochastic Optimization** • Stochastic gradient descent • Simulated annealing • Genetic algorithms
5	October 10, 2023	**Variational Inference** • KL divergence and the ELBO • Mean field variational inference • Beyond the mean field approximation
	October 17, 2023	**Midterm**
6	October 24, 2023	**Simulation and Monte Carlo** • Random number generators and the inverse cdf method • Importance and rejection sampling • Monte Carlo integration • Variance reduction and swindles: control variates and antithetic variates
7	October 31, 2023	**MCMC Basics** • Gibbs sampling and variants: collapsed Gibbs and blocked Gibbs • Basic Metropolis-Hastings: independence sampling, RWM, Metropolis-within-Gibbs • Metropolis-Hastings variants: multiple-try MH, pseudo-marginal MH
8	November 7, 2023	**MCMC Tuning and Diagnostics** • Variance calculations • Proposal choices, reparametrization, optimal acceptance rates, ESS • ACF plots, burn-in, multiple chains, Gelman-Rubin statistic
9	November 14, 2023	**More MCMC Algorithms I** • Langevin algorithm • Slice samplers • Hamiltonian Monte Carlo • Consensus Monte Carlo and MCMC for big data
10	November 21, 2023	**More MCMC Algorithms II** • Data augmentation • Unbiased MCMC • Perfect sampling
11	November 28, 2023	**Intractable Likelihoods** • Doubly-intractable likelihoods • Approximate Bayesian computation • Bayesian synthetic likelihood

Accessibility Services: Students with diverse learning styles and needs are welcome in this course. If you have a disability/health consideration that may require accommodations, please contact Accessibility Services at (416) 978-8060 or http://studentlife.utoronto.ca/as.

Academic Integrity: The University of Toronto's Code of Behaviour on Academic Matters outlines the behaviours that constitute academic misconduct, the processes for addressing academic offences, and the penalties that may be imposed. You are expected to be familiar with the contents of this document. Potential offences on tests include — but are not limited to — the following:

- Using unauthorized aids
- Communicating with fellow students during a written assessment
- Misrepresenting your identity and/or using any kind of exam writing service
- Submitting altered tests for regrading
- Sending or receiving aid to/from anyone else

Academic offenses will be taken very seriously and dealt with accordingly. If you have any questions about what is or is not permitted in this course, please do not hesitate to contact the course instructor.