STAT-517 – Stochastic Modeling of Scientific Data II

Instructor

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Course Description

The course covers various classes of stochastic processes, including Markov random fields, continuous-time Markov chains, Poisson and Hawkes processes, Brownian motion, and Gaussian processes. Emphasis is placed on the use of this processes to model real data arising in various application fields, and on procedures for statistical inference, both frequentist and Bayesian.

Class format

The class meets for lectures twice a week. All lectures will be in person. No Zoom access or class recordings will be available.

- Tuesdays 2:30-3:40 THO135
- Thursdays 2:30-3:40 THO135

Some of the lectures will be "lab" sessions focused on computational implementation. Please make sure to bring your own laptop to those sessions.

Bibliography

There is no specific textbook for the class. The class schedule below includes recommended readings for each week, which are a mixture of sections from a few different books:

- (GUTTORP) Guttorp, P. (1995). Stochastic modeling of scientific data. Chapman and Hall/CRC.
- (RUE-HELD) Rue, H., & Held, L. (2005). Gaussian Markov random fields: theory and applications. Chapman and Hall/CRC.

- (ROSS) Ross, S. M. (1996) Stochastic Processes. Second Edition. John Wiley & Sons.
- (MO-PE) Morters, P. and Peres, Y. (2010) Brownian Motion. Cambridge University Press.
- (RASS-WILL) Rassmusen, C. E. & Williams, C. K. I. (2005) Gaussian Processes for Machine Learning. MIT Press.

Additional readings, typically papers, are listed in the class schedule below

Course assessment/expectations

There are two components for the evaluation

- Three homework's, each worth 10% of the final grade.
- Mid-term take-home exam, worth 30% of the final grade.
- Final take-home exam, worth 40% of the final grade.

Preliminary Course Schedule

The following course schedule is subject to change.

Week 1: Markov Random Fields

- Gibbs distributions.
- Introduction to the Ising and Potts Models
- The Hammersley-Clifford lemma
- Simulating from the Ising and Potts models.
- Statistical inference for Ising and Potts models.

Recommended readings:

- GUTTORP, Chapter 4.
- Huber, M. (2003). A bounding chain for Swendsen-Wang. Random Structures & Algorithms, 22(1), 43-59.
- Ghosal, P., & Mukherjee, S. (2020). Joint estimation of parameters in Ising model. *The Annals of Statistics*, *48*(2), 785-810.
- Møller, J., Pettitt, A. N., Reeves, R., & Berthelsen, K. K. (2006). An efficient Markov chain Monte Carlo method for distributions with intractable normalizing constants. *Biometrika*, *93*(2), 451-458.

Week 2: Markov Random Fields (cont)

- Introduction to Gaussian Markov Random Fields.
- Inference for Guassian Markov Random Fields.
- Clipped Gaussian Markov Random Fields as an alternative to the Ising model.
- Hidden Markov Random Fields
- Inference for hidden Markov Random Fields

Recommended readings:

- GUTTORP, Chapter 4.
- RUE-HELD Chapters 2.1 to 2.3.
- De Oliveira, V. (2000). Bayesian prediction of clipped Gaussian random fields. Computational Statistics & Data Analysis, 34(3), 299-314.
- Bach, S. H., Broecheler, M., Huang, B., & Getoor, L. (2017). Hinge-loss markov random fields and probabilistic soft logic. Journal of Machine Learning Research.

Week 3: Markov Random Fields (cont) + Continuous-time Markov chains

- Lab session on Markov Random Fields.
- Continuous-time Markov chains
- Birth and death processes.

Recommended readings:

- RUE-HELD Chapters 2.4.
- ROSS Chapter 5.1 to 5.3

Week 4: Continuous-time Markov chains (cont)

- Kolmogorov equations
- Limiting probabilities
- Semi-Markov process
- Inference for continuous-time Markov chains

Recommended readings:

- ROSS Chapter 5.4 and 5.5
- GUTTORP Chapter 3.3, 3.4 and 3.7

Week 5: Continuous-time Markov chains (cont) + Point Processes

- Lab session on continuous-time Markov chains
- Definition and general properties of point processes
- Homogeneous Poisson processes on R^+: definition and properties.

Recommended readings:

- ROSS chapter 2

Week 6: Point Processes

- Non-homogenous Poisson processes on R^+.
- Poisson processes on R^d.
- Marked Poisson processes.
- Simulation of Poisson processes
- Inference for Poisson process
- The Hawkes process on R^+.
- Cluster point process construction of the Hawkes process on R^+.

Recommended readings:

- ROSS chapter 2
- Laub, P. J., Taimre, T., & Pollett, P. K. (2015). Hawkes processes. arXiv preprint arXiv:1507.02822.

Week 7: Point Processes

- Inference for the Hawkes process
- Mattern processes
- Lab on point process.

Recommended readings:

- Laub, P. J., Taimre, T., & Pollett, P. K. (2015). Hawkes processes. arXiv preprint arXiv:1507.02822.
- Rao, V., Adams, R. P., & Dunson, D. D. (2017). Bayesian inference for Matérn repulsive processes. Journal of the Royal Statistical Society: Series B (Statistical Methodology), 79(3), 877-897.

Week 8: Brownian motion

- The Wiener process and its various definitions.
- Donsker's theorem.
- Brownian motion with drift.
- Properties of the Brownian motion.
- Inference for Wiener processes

Recommended readings:

- MO-PE chapters 1 and 2

Week 9: Gaussian processes

- Kolmogorov's consistency conditions.
- Definition of the Gaussian Process
- Properties of the Gaussian process
- Covariance functions.
- The Ornstein–Uhlenbeck process and the relationship with discrete-time AR processes and Markov Random Fields
- Inference for Gaussian processes

Recommended readings:

- RASS-WILL Chapters 2 and 4.

Week 10: TBD.

- Lab of Brownian motion and Gaussian processes
- Catch up and review

Course Policies

Religious Accommodations

Washington state law requires that UW develop a policy for accommodation of student absences or significant hardship due to reasons of faith or conscience, or for organized religious activities. The UW's policy, including more information about how to request an accommodation, is available at Religious Accommodations Policy. Accommodations must be requested within the first two weeks of this course using the Religious Accommodations Request form.

Disability Accommodations

Your experience in this class is important to me. It is the policy and practice of the University of Washington to create inclusive and accessible learning environments consistent with federal and state law. If you have already established accommodations with Disability Resources for Students (DRS), please activate your accommodations via myDRS so we can discuss how they will be implemented in this course.

If you have not yet established services through DRS, but have a temporary health condition or permanent disability that requires accommodations (conditions include but not limited to; mental health, attention-related, learning, vision, hearing, physical or health impacts), contact DRS directly to set up an Access Plan. DRS facilitates the interactive process that establishes reasonable accommodations. Contact DRS at disability.uw.edu.

Face Coverings in the Classroom

The health and safety of the University of Washington community are the institution's priorities. Please review and adhere to the UW COVID Face Covering Policy

Academic Misconduct

The University takes academic integrity very seriously. Behaving with integrity is part of our responsibility to our shared learning community. If you're uncertain about if something is academic misconduct, ask me. I am willing to discuss questions you might have.

Acts of academic misconduct may include but are not limited to:

- Cheating (working collaboratively on quizzes/exams and discussion submissions, sharing answers and previewing quizzes/exams)
- Plagiarism (representing the work of others as your own without giving appropriate credit to the original author(s))
- Unauthorized collaboration (working with each other on assignments)

Concerns about these or other behaviors prohibited by the Student Conduct Code will be referred for investigation and adjudication by the appropriate misconduct office. Students found to have engaged in academic misconduct may receive a zero on the assignment. Repeated violations might lead to the student being failed on the course.

Class absences

Students are expected to attend class and to participate in all graded activities, including midterms and final examinations.

- A student who is anticipating being absent from class due to a Religious Accommodation activity needs to complete the Religious Accommodations request process by the second Friday of the quarter. The instructor will determine if the graded activity or exam can be rescheduled or if there is equivalent work that can be done as an equivalent, as determined by the instructor.
- Students who anticipate missing class due to attendance at academic conferences or field trips, or participation in university-sponsored activities should provide a written notice to the instructor ahead of the absence. The instructor will determine if the graded activity or exam can be rescheduled or if there is equivalent work that can be done as an equivalent, as determined by the instructor.
- If you feel ill, please do not come to class! To protect student privacy and the integrity of the academic experience, students will not be required to provide a medical excuse note to justify an absence from class due to illness. A student who is absent from any graded class activity or examination due to illness must request, in writing, to take a rescheduled examination or perform work judged by the instructor to be the equivalent. Students are responsible for taking any number of examinations for which they are scheduled on a given day and may not request an adjustment for this reason alone.

Safety

Call SafeCampus at 206-685-7233 anytime – no matter where you work or study – to anonymously discuss safety and well-being concerns for yourself or others. SafeCampus's team of caring professionals will provide individualized support, while discussing short- and long-term solutions and connecting you with additional resources when requested.