Statistical Computing – Stat 771 – Fall 2019

Vivak Patel

Instructor's Contact: Please contact through canvas.

Instructor's Office Hours: Tuesdays and Thursday from 4p to 5p in MSC 1241 from September 5, 2019 to November 26, 2019.

Credits: 3. Each credit-hour is satisfied by 45 hours of learning activities.

Instruction: In-person meetings on Tuesdays and Thursdays from 2:30p to 3:45p.

General Warning: This will be an intense, demanding course. I do not expect the course reviews to be very kind, but I hope that in a few years, as you engage in your own research, you will appreciate the things that you will learn in this course.

Course Prerequisites: I expect students to have a familiarity with linear algebra, multivariate calculus, probability and mathematical statistics at the undergraduate level.

Description and Goals: The goal of this course is to overview the theory and practice of important computational concepts and specific algorithms that have been essential to statistical practice.

Topics: This course will cover a selection from the following topics.

1. Floating Point
    - Positional Numeral Systems
    - Floating point format
    - Errors
    - Operations & Fundamental Axiom
2. Orthogonalization
    - Gram-Schmidt Procedure
    - Methods: Iterated Gram-Schmidt, Householder Reflections, Givens Rotations
    - Numerical Analysis
    - Large least squares problems
3. Symmetric Eigenvalues Problems & Singular Values
    - Existence and Uniqueness of SVD
    - Properties of SVD
    - Symmetric Matrices & Eigenvalues
    - Symmetric QR Algorithm; SVD Algorithm
4. Iterative Linear Solvers

- Splitting Methods
- Column-action: Gradient Descent, CG, GMRES
- Row-Action: Meany Inequality, Kaczmarz, Randomized Kaczmar

5. Nonlinear Iterative Solvers
    - Picard's Method
    - Newton's Methods
    - Inexact Newton's Methods
    - Line Search
    - Random Sketching
6. Optimization
    - Optimality
    - Convexity & Nonconvex Problems
    - Gradient Descent & Convergence
    - Stochastic Gradient Descent & Convergence Issues
    - Robust Stochastic Approximation for constrained problems
7. Data Assimilation
    - Markov Chains & Statistical Filtering
    - Kalman Filtering, MCMC and Sequential Monte Carlo
    - Integration of linear and nonlinear ordinary differential equations
    - Connections to modern stochastic approximation methods
8. Condition Inference
    - Bootstrap
    - Jackknife
    - Permutation tests
    - Bag of bootstraps

References: Here is a list of references. I recommend referring to them for each of the above topics.

- Goldberg, David. ACM Computing Surveys, Vol. 23, No. 1, March 1991.
- Cook, John D. Anatomy of a Floating Point Number. 2009.
- Hingham, Nicholas J. Accuracy and Stability of Numerical Algorithms, 2nd Ed. 2002.
- Golub & Van Loan. Matrix Computations, 4th Ed. 2013.
- Trefethen & Bau. Numerical Linear Algebra. 1997.
- Mahoney. Lecture Notes on Randomized Linear Algebra. 2016.
- Saad. Iterative Methods for Sparse Linear Systems, 3rd Ed. 2000.
- Shewchuck. An Introduction to Conjugated Gradients without the Agonizing Pain. 1994.
- Meany, R.K. A Matrix Inequality. SIAM J. Numer. Anal. 6, 104107. 1969.

- Zorn. Generalized Estimating Equation Models for Correlated Data: A review with applications. American Journal of Political Science. 2001.
- Kelley. Numerical methods for nonlinear equations. Acta Numerica (27). 2018.
- Deuflhard. Newton Methods for Nonlinear Problems: Affine Invariance and Adaptive Algorithms. Vol 35 of Computational Mathematics, Springer. 2004.
- Nocedal & Wright. Numerical Optimization.
- Berstekas. Nonlinear Programming
- Karimi, Nutlnl, Schmidt. Linear Convergence of Gradient and Proximal-Gradient Methods Under the Polyak-Lojasiewicz Condition. 2016.
- Nemirovski, et al. Robust Stochastic Approximation approach to Stochastic Programming. SIAM Journal on Optimization. 2009.
- Simon. Optimal State Estimation: Kalman, H Infinity, and Nonlinear Approaches. 2006.
- Casella. Conditional inference from confidence sets.
- Efron. Bootstrap Methods: Another look at the Jackknife. 1979.
- Cappe, Godsill, Moulines. An Overview of Existing Methods and Recent Advances in Sequential Monte Carlo. 2007.

Grading: Grade ranges will be A (93, 100], AB (84,93], B (73,84], BC (60,73], C (45, 60], D (

- For non-PhD students, your total grade will be one exam with a written component and a programming component.
- For PhD students, 50% of your grade will be the exam (described above) and the remaining 50% will be a research project.

Research Project: The research project can be on *any* topic so long as there is some element of the course that you include. You should engage with other faculty members on campus to find a project by Sept. 27.

- By September 27, please submit a 1 page (1 inch margin, 12 pt font) summary of the project background, what you intend to do, and a short timeline.
- By October 25, please submit a draft of your report (no more than 10 pages excluding references, 1 inch margins, 12 point font).
- By November 29, please submit the final report.

Rules, rights, responsibilities: please see
https://guide.wisc.edu/undergraduate/#rulesrightsandresponsibilitiestext

Academic integrity and data ethics: By virtue of enrollment, each student agrees to uphold the high academic standards of the University of Wisconsin-Madison; academic misconduct is behavior that negatively impacts the integrity of the institution. Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these previously listed acts are examples of misconduct which may result in disciplinary action. Examples of disciplinary action include, but is not limited to, failure on the assignment/course, written reprimand, disciplinary probation, suspension, or expulsion. For detailed information, please see https://conduct.students.wisc.edu/academic-misconduct/.

The members of the faculty of the Department of Statistics at UW-Madison uphold the highest ethical standards of teaching, data, and research. They expect their students to uphold the same standards of ethical conduct. Standards of ethical conduct in data analysis and data privacy are detailed on the ASA website, and include:

- Use methodology and data that are relevant and appropriate; without favoritism or prejudice; and in a manner intended to produce valid, interpretable, and reproducible results.
- Be candid about any known or suspected limitations, defects, or biases in the data that may affect the integrity or reliability of the analysis. Obviously, never modify or falsify data.
- Protect the privacy and confidentiality of research subjects and data concerning them, whether obtained from the subjects directly, other persons, or existing records.

By registering for this course, you are implicitly agreeing to conduct yourself with the utmost integrity throughout the semester.

Accommodations for students with disabilities: McBurney Disability Resource Center syllabus statement: The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (Faculty Document 1071) require that students with disabilities be reasonably accommodated in instruction and campus life. Reasonable accommodations for students with disabilities is a shared faculty and student responsibility. Students are expected to inform me of their need for instructional accommodations by the end of the third week of the semester, or as soon as possible after a disability has been incurred or recognized. I will work either directly with the student or in coordination with the McBurney Center to identify and provide reasonable instructional accommodations. Disability information, including instructional accommodations as part of a student's educational record, is confidential and protected under FERPA.

Diversity and Inclusion: Institutional statement on diversity: Diversity is a source of strength, creativity, and innovation for UW-Madison. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals.

The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background people who as students, faculty, and staff serve Wisconsin and the world. https://diversity.wisc.edu/

Complaints: If you have a complaint about a TA or course instructor, you should feel free to discuss the matter directly with the TA or instructor. If the complaint is about the TA and you do not feel comfortable discussing it with him or her, you should discuss it with the course instructor. Complaints about mistakes in grading should be resolved with the instructor in the great majority of cases. If the complaint is about the instructor (other than ordinary grading questions) and you do not feel comfortable discussing it with him or her, contact the Director of Undergraduate Studies, Professor Cecile Ane, cecile.ane@wisc.edu. If your complaint concerns sexual harassment, please see campus resources listed at https://compliance.wisc.edu/titleix/resources/. In particular, there are a number of options to speak to someone confidentially.

If you have concerns about climate or bias in this class, or if you wish to report an incident of bias or hate that has occurred in class, you may contact the Chair of the Statistics Department Climate & Diversity Committee, Professor Karl Rohe (karlrohe@stat.wisc.edu). You may also use the Universitys bias incident reporting system, which you can reach at https://doso.students.wisc.edu/services/bias- reporting-process/.