ST 453 Advanced computing for statistical reasoning

Semester: Spring 2026

Lecture days/times: Tuesdays/Thursdays 15:00–16:15

Location: 200 Cox Hall

3 credit hours

Instructor: Dr. Jonathan P Williams
Email: jwilli27@ncsu.edu
Office location: 5218 SAS Hall
Office hours: 17:00–18:00 Tuesdays or by appointment
Office phone: 919.513.0191

Teaching Assistant: Yichen Hu
Email: yhu37@ncsu.edu
Office location: Tutor room on 1st floor SAS Hall or by Zoom
Office hours: 16:00–17:00 Fridays

Course Description: This course is designed to survey topics and tools needed for an undergraduate statistics major to begin to develop a broad and thorough working knowledge of modern computational techniques for statistical inferences. Statistical methods and the algorithms used to facilitate their computations are motivated by building logical foundations for statistical reasoning. Algorithms surveyed can broadly be categorized as either optimization based or sampling based. Rather than focusing on learning standard software packages for implementing common statistical routines, all codes will be written from scratch using the R programming language (or any other high-level language of the students' choosing). Emphasis is placed on developing a practical understanding of how and why existing methods work, and when to apply a particular method. Some programming proficiency is assumed.

Course Objectives/Goals:

1. Understand statistical theory by computing algorithms from the ground up.

2. Learn to use the R language to compute important statistical methodology.

3. Learn basic data structures, and many of the important computer-based techniques in statistics: singular value decomposition, least squares calculations, maximum likelihood, gradient descent, permutation tests, bootstrapping, Monte Carlo simulation, Bayesian logic and computing.

Student Learning Outcomes:

1. Use likelihood functions and limit theorems.

2. Use gradient-based optimization algorithms and Monte Carlo sampling algorithms.

3. Write efficient code in base R.

4. Design and implement a simulation study.

5. Recognize varied types and consequences of missing data.

6. Write documented workflow files for organizing computer code used in data analyses and simulation studies, for facilitating replicability. This also includes the proper implementation of random number generator seeds.

7. Design and generate synthetic data to test the reproducibility of data analyses and simulation studies.

Prerequisites: Introductory statistics (ST 312 or ST 372), Calculus 3 (MA 242), Introductory linear algebra (MA 305 or MA 405), and Introduction to Stat Programming – R (ST 308)

Optional Texts:
G. Givens and J. Hoeting (2013). *Computational statistics*, 2nd edition. John Wiley & Sons.
A. Hunt and D. Thomas (2000). *The pragmatic programmer: from journeyman to master*. Addison Wesley Longman, Inc.
J. Kloke and J. McKean (2015). *Nonparametric Statistical Methods Using R*. CRC Press.
W. Shotts, Jr. (2013). *The Linux Command Line*, 2nd internet edition.
L. Trefethen and D. Bau (1997). *Numerical linear algebra*. SIAM.

Digital Course Components:
Course website: `https://jonathanpw.github.io/ST453`
Moodle (accessed via `https://wolfware.ncsu.edu`)

Grade Distribution:

Attendance	30%
Assignments	25%
Midterm project: simulation study part 1, evaluating estimators	20%
Final project: simulation study part 2, evaluating predictors	20%
Final presentation	5%

Letter Grade Distribution:

≥ 93.00	A		73.00 - 76.99	C
90.00 - 92.99	A-		70.00 - 72.99	C-
87.00 - 89.99	B+		67.00 - 69.99	D+
83.00 - 86.99	B		63.00 - 66.99	D
80.00 - 82.99	B-		60.00 - 62.99	D-
77.00 - 79.99	C+		≤ 59.99	F

For students taking the course as credit-only, S is equivalent to C- or better; otherwise U.
No expectations beyond attendance apply to students choosing to audit the course.

Midterm project due: 15:00 on Tuesday, 10 March 2026
Final project due: 15:30 on Tuesday, 28 April 2026
Final presentation: 15:30–18:00 on Tuesday, 5 May 2026 in 200 Cox Hall

Personal note to students: Please do not feel intimidated about interacting with me. Regardless of how busy or stressed I may appear to you, teaching your class is a part of my job, and

I take that very seriously. I care deeply about the quality of your learning. Please always reach out to me if you have questions, concerns, or need help. I understand that it can be difficult and can even feel embarrassing to ask for help. However, I was once in your position, and I promise to always treat you with respect, empathy, and kindness. Nobody that ever did anything meaningful did so without first failing over and over again.

Course policies and commentary:

- **Assignments**

  - **Homework will be assigned each Tuesday evening, and will be due the following Tuesday at the beginning of class. Completed assignments must be turned in as script files on Moodle. The grader *will* run your code to assess your solutions**.
  - Each homework assignment will receive the same weight in the calculation of the final course grade (i.e., longer (shorter) assignments do not count for a larger (smaller) portion of the overall assignment course grade). For each assignment, each exercise has the following point distribution:
    * 3 points – solution is correct
    * 2 points – solution is mostly correct
    * 1 point – solution is on the right track
    * 0 points – solution is not relevant to the question, or the script file does not run.
  - No late assignments will be accepted, but arrangements will be made on an individual basis for students who experience prolonged health or other issues. Reach out to the instructor if you begin to fall behind!
  - Take responsibility for understanding solutions to all assignments. For example, if you find a solution on StackExchange, then convince yourself that the solution is actually correct.
  - **Learn to distinguish between the things you *do* know and the things you *do not* know** (this is one of the most important results of all education). To understand, to *a* particular degree, that a given statement is true means that you can explain why the statement is true, to *the* particular degree.
  - Assignments will be graded within 1 week.

- **Projects**

  - Students work individually on the midterm and final course projects.
  - A detailed outline of the project requirements is provided on the course website.
  - Projects will be graded within 2 weeks.

- **Attendance**

  - Attendance is recorded. Please confirm your attendance is recorded by the instructor each lecture, beginning on the second lecture of the semester. Each lecture counts for 1 point of attendance, and the total course attendance grade is the average of points across all lectures, excluding the first lecture.
  - Use lecture time as you feel most productive, but do not use it in a way which is distracting to others.

- **Class recording statement**

    – No components of this course will be recorded.

Tentative Course Outline:

- Get up to speed in R

- Linear algebra and singular value decomposition

- Least squares problems and projection matrices

- Gram-Schmidt orthonormalization, QR factorization, and linear models

- Likelihood inference and maximum likelihood estimator

- Introduction to logistic regression

- Gradient descent, ROC curves

- Confidence and prediction intervals for linear regression

- Hypothesis testing and permutation tests

- Bootstrapping

- Simulation and Monte Carlo methods

- Bayesian logic and computing

- Missing data

NCSU Polices, Regulations, and Rules: Students are responsible for reviewing the NC State University Policies, Rules, and Regulations (PRRs) which pertain to their course rights and responsibilities, including those referenced both below and above in this syllabus:

- Equal Opportunity and Non-Discrimination Policy Statement `https://policies.ncsu.edu/policy/pol-04-25-05` with additional references at `https://equalopportunity.ncsu.edu/policies/`

- Code of Student Conduct `https://policies.ncsu.edu/policy/pol-11-35-01`

- Grades and Grade Point Average `https://policies.ncsu.edu/regulation/reg-02-50-03`

- Credit-Only Courses `https://policies.ncsu.edu/regulation/reg-02-20-15`

- Audits `https://policies.ncsu.edu/regulation/reg-02-20-04`

Policy on Academic Integrity: Cheating, plagiarism and other forms of academic dishonesty will not be tolerated. Violations of academic integrity will be handled in accordance with the Student Discipline Procedures (NCSU REG 11.35.02). Be aware of the Code of Student Conduct (NCSU POL11.35.01) and Pack Pledge.

Disability Services for Students: Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must

register with the Disability Resource Office at Holmes Hall, Suite 304, 2751 Cates Avenue, Campus Box 7509, 919-515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation (NCSU REG 02.20.01).

Privacy: Students may be required to disclose personally identifiable information to other students in the course, via digital tools, such as email or web-postings, where relevant to the course. Examples include online discussions of class topics, and posting of student coursework. All students are expected to respect the privacy of each other by not sharing or using such information outside the course.