## STAT 545 — Introduction to Computational Statistics

**Fall 2018**

**Credit Hours:** 3

**Lectures:** Tuesday & Thursday / 10:30 - 11:45 AM / UNIV 017

**Professor:** Vinayak Rao
Office: MATH 212
Office Hours: Tue 130pm-230pm
Phone number: 765-494-3956
E-mail: varao@purdue.edu

**Course Website:** https://varao.github.io/stat545_fall18/
Piazza (https://piazza.com/class/jl2ibo81kis1lf)

**Required Textbook:** No textbook required

**Supplementary Textbooks:** Bishop C.M. (2006). *Pattern Recognition and Machine Learning*. Springer-Verlag. ISBN 978-0387310732.

G.H. Givens and J.A. Hoeting (2012). *Computational Statistics*. Wiley Series in Computational Statistics, Wiley.

Paul Teetor (2011). *R cookbook*. OReilly, Beijing.

N. Matloff (2011). *The Art of R Programming: A Tour of Statistical Software Design*. No Starch Press.

G. James, D. Witten, T. Hastie, and R. Tibshirani (2014). *An Introduction to Statistical Learning: with Applications in R*. Springer Texts in Statistics. Springer New York.

**Prerequisites:**

- ***Familiarity with R: this is not a course to learn R or programming.*** It assumes reasonable knowledge of R (atleast at the level of STAT598z). Familiarity with an other language like Python or Matlab is sufficient if you are willing to learn R by yourself: all assignments and project work must be carried out in R.
- Introductory graduate-level courses in probability and statistics, such as STAT 516 and 517, and familiarity with computing.

**Course Description:** The primary aim of this course is (along with STAT546) to prepare statistics PhD students for the computational statistics qualifying examination. The course provides a thorough introduction to computation statistics i.e. algorithms to facilitate statistical inference. The focus is on a theoretical justification of computational algorithms with assignments providing a hands-on approach to understanding the application of these tools to realistic problems. Topics include: matrix computation, dynamic programming, the Baum-Welch algorithm for hidden Markov models, the expectation-maximization algorithm, convex optimization, Monte Carlo and Markov chain Monte Carlo methods. Specific topics and the course outline are subject to change as the semester progresses. All topics will be motivated by problems from the physical, life, social, and management sciences.

1. Introduction to numerical linear algebra and algorithms: including matrix norms, eigenvalues and eigenvectors, elements of stability analysis, SVD, Cholesky, spectral decomposition.

   Statistical applications: Principal components analysis (PCA) etc.

2. Graphical models including HMM: Learning in graphical models and HMM. Forward-backward, Viterbi, Baum-Welch, Kalman filters.

   Statistical Applications: Target tracking, dynamic time series models.

3. Data structures, sorting, basic complexity analysis and dynamic programming.

4. Introduction to EM: Introduction to K-means, Exponential families, latent variables, EM, generalized EM.

5. Basic Monte Carlo and numerical integration: Importance sampling, rejection sampling, Rao-Blackwellization, Gaussian quadrature etc.

   Statistical applications: Sampling from arbitrary non-standard densities.

6. Intro to MCMC: Including M-H, Gibbs, intro. to data augmentation.

   Statistical applications: Inference in Bayesian models. Sampling from the posterior.

7. Intro to optimization: Gradient descent, stochastic gradient descent, Newtons method.

**Course Work and Requirements:** Your final grade will be curved.

| | Percentage of Grade |
|---|---|
| Homework | 30% |
| Midterm 1 | 20% |
| Midterm 2 | 20% |
| Project | 25% |
| Class participation | 5% |

- *Homework* will generally be posted on a Thursday, and due two weeks later (**before lecture begins**). No late homework will be accepted. There will be 7 homework assignments accounting for 30% of your course grade. The lowest homework score will be dropped. R Markdown should be used for homework submission. A short tutorial can be found here: `http://tinyurl.com/gqyoaxm`.
- *Group projects* will be due at the end of the semester. Specific details on the project will be given in a separate handout.

## Course Policies

**Addressing Questions via E-mail:** Please post questions than you think will be of general interest to the whole class on the piazza webpage: If the instructor or TA does not respond immediately, you are likely to receive help from other students. Activity on piazza can contribute to points for class-performance. Questions that you think are specific to you, and that you think your colleagues will be unable to answer can be emailed directly to the instructor or the TA. Reserve those that involve extensive computation or mathematical expressions for office hours. If your question

involves programming, please be sure to e-mail a minimal working example of your code along.

**Incompletes:** Incompletes will only be given under emergency circumstances, e.g., a serious auto accident, death of family member, etc. (see the grief absence policy for further information). Incompletes will not be given to students failing the course.

**Grading:** Grades for this course will be curved, however a good performance will earn you a good grade (so, while it is important not to fall behind your colleagues, there is no competition for a fixed number of A's).

**Evaluation:** Student feedback is essential for any course to be successful. Feedback questionnaires will be included in each assignment. These evaluations should be taken seriously, and will be addressed directly by the instructor.

**Re-grading:** All grade disputes are to be made on paper, and submitted *directly* to Professor Rao. Discussions or arguments for re-grades will *not* be done in person. A student has until one week after receiving his/her grade to dispute the grade (in writing). Handling re-grades in this manner eliminates the "end of the semester" digging for points.

When disputing a grade, you should state the question, the dispute, and the number of points you feel you should have received for the question. If you do not state the number of points you think are reasonable for the re-grade, zero points will be give as the re-grade. Please note that when you ask for a question to be re-graded, the entire assignment may be re-graded, and there is a possibility of losing points.

**Dropping the Course:** The instructors reserve the right to *not* sign anyone out of the course once the deadline for dropping without the instructors signature has passed. Please take care to pay attention to these dates.

**Attendance and Participation: Students:** You are expected to attend lectures. You are expected to arrive on time, or before. You are expected to stay until the end of lecture unless you have asked in advance to leave early. You are expected to be prepared and participate. On the rare occasion that a student is extremely close to the cut-off value between letter grades, attendance and class participation may help.

When conflicts or absences can be anticipated, such as for many University sponsored activities and religious observations, you should inform the instructors of the situation as far in advance as possible. For unanticipated or emergency absences when advance notification is not possible, you should contact the instructors as soon as possible by e-mail, or the Department of Statistics main office. When you are unable to make direct contact with the instructors and unable to leave word with the Department of Statistics because of circumstances beyond your control, and in cases of bereavement, you or your representative should contact the Office of the Dean of Students. Links to the complete attendance policy and implications can be found at www.purdue.edu/odos/sac/attendance-and-absence/ and www.purdue.edu/studentregulations/regulations_procedures/classes.html.

**Grief Absence Policy for Students:** Purdue University recognizes that a time of bereavement is very difficult for a student. The University therefore provides the following rights to students facing the loss of a family member through the Grief Absence

Policy for Students (GAPS). Students will be excused for funeral leave and given the opportunity to earn equivalent credit and to demonstrate evidence of meeting the learning outcomes for missed assignments or assessments in the event of the death of a member of the student's family.

**University Emergency Information:** A safety briefing will be conducted on the first day of class. In the event of a major campus emergency or temporary suspension of classes, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructors' control. You can get information about changes in this course by means of the course web page, or contacting the instructors via e-mail or phone. You are expected to read your Purdue e-mail on a frequent basis.

**Violent Behavior Policy:** Purdue University is committed to providing a safe and secure campus environment for members of the university community. Purdue strives to create an educational environment for students and a work environment for employees that promote educational and career goals. Violent behavior impedes such goals. Therefore, violent behavior is prohibited in or on any University Facility or while participating in any university activity. See the following website for more details: www.purdue.edu/policies/pages/facilities_lands/i_2_3.shtml.

**Academic Dishonesty:** Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty." [Part 5, Section III-B-2-a, University Regulations] Furthermore, the University Senate has stipulated that "the commitment of acts of cheating, lying, and deceit in any of their diverse forms (such as the use of substitutes for taking examinations, the use of illegal cribs, plagiarism, and copying during examinations) is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest." [University Senate Document 72-18, December 15, 1972]. **Use of instructor solution manuals or related resources will not be tolerated, and may result in an automatic failure in the course.** For more information, please refer to Purdue's student guide for academic integrity (www.purdue.edu/odos/osrr/academic-integrity-brochure). **Instances of cheating will be reported to the Office of Student Rights and Responsibilities (www.purdue.edu/odos/osrr/report-an-incident), and may result in an automatic failure in the course. Bonus points will be given to students who report instances of cheating.**

**Use of Copyrighted Materials:** Among the materials that may be protected by copyright law are the lectures, notes, and other material presented in class or as part of the course. Always assume the materials presented by the instructors are protected by copyright unless the instructors have stated otherwise. Students enrolled in, and authorized visitors to, Purdue University courses are permitted to take notes, which they may use for individual/group study or for other non-commercial purposes reasonably arising from enrollment in the course or the University generally.

Notes taken in class are, however, generally considered to be "derivative works" of the instructors' presentations and materials, and they are thus subject to the instructors' copyright in such presentations and materials. No individual is permitted to sell or otherwise barter notes, either to other students or to any commercial concern, for

a course without the express written permission of the course instructor. To obtain permission to sell or barter notes, the individual wishing to sell or barter the notes must be registered in the course or must be an approved visitor to the class. Course instructors may choose to grant or not grant such permission at their own discretion, and may require a review of the notes prior to their being sold or bartered. If they do grant such permission, they may revoke it at any time, if they so choose.

**Students with Disabilities:** Purdue University is required to respond to the needs of the students with disabilities as outlined in both the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1990 through the provision of auxiliary aids and services that allow a student with a disability to fully access and participate in the programs, services, and activities at Purdue University.

If you have a disability that requires special academic accommodation, please make an appointment to speak with the instructor within the first three (3) weeks of the semester in order to discuss any adjustments. It is important to talk about this at the beginning of the semester. It is the student's responsibility to notify the Disability Resource Center (http://www.purdue.edu/drc) of an impairment/condition that may require accommodations and/or classroom modifications.

**Nondiscrimination:** Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life.

Purdue University prohibits discrimination against any member of the University community on the basis of race, religion, color, sex, age, national origin or ancestry, genetic information, marital status, parental status, sexual orientation, gender identity and expression, disability, or status as a veteran. The University will conduct its programs, services and activities consistent with applicable federal, state and local laws, regulations and orders and in conformance with the procedures and limitations as set forth in Executive Memorandum No. D-1, which provides specific contractual rights and remedies. Any student who believes they have been discriminated against may visit www.purdue.edu/report-hate to submit a complaint to the Office of Institutional Equity. Information may be reported anonymously.