APMA 2610/1740: Recent Applications in Probability & Statistics

This is a course on the formal mathematical and the informal intuitive foundations of modern applications of statistics.

The main topics are:

(1) The maximum entropy principle for large systems and large deviations

(2) Modeling and inference

(3) Computation and inference for graphical models

Topic (1) will touch on ideas from statistical physics, large deviations, and information theory, and introduce the exponential families, a set of probability distributions that play a fundamental role in almost all applications of statistical modeling and inference. Topic (2) will introduce some of the key concepts from classical statistics, and then focus on generative, discriminative, and algorithmic methods for modeling and inference with high-dimensional complex data. Topic (3) will introduce graphical models and highlight some important tools like dynamic programming, MCMC, and EM.

(1) Gibbs ensembles, maximum entropy principle, large deviations, relative entropy, Sanov's theorem, exponential families, lossless source coding, entropy, exchangeability, asymptotic independence, Maxwell's distribution

(2) Statistical estimation, consistency, bias, variance, mean squared error, mean integrated squared error, kernel density estimation, bandwidth, cross-validation, Stone's theorem, curse of dimensionality, maximum likelihood estimation, classification, error probabilities, Bayesian classification rule, Neyman-Pearson lemma, ROC curves, statistical classification, generative models, linear discriminant analysis, quadratic discriminant analysis, naïve Bayes, discriminative models, logistic regression, k nearest neighbors, maximum margin classifiers, support vector machines, kernel methods

(3) Undirected graphical models, Gibbs random fields, Markov random fields, Hammersley-Clifford theorem, derived dependency graphs, dynamic programming, hidden Markov models, Gibbs sampling, Markov chain Monte Carlo, exponential families, latent variable models, minorization-maximization, expectation- maximization

Graduate Credit: For 2,000-level credit enroll in 2610; for 1,000-level credit enroll in 1740.

Prerequisites: Rigorous calculus-based statistics, programming experience, and strong mathematical background are essential. For 2610, some graduate level analysis is strongly suggested.

Course goal: Many of the concepts arise in multiple disciplines, including physics, engineering, statistics, and mathematics. The goal is to achieve both an intuitive and a rigorous understanding, through multiple viewpoints and computational experiments, as well as formal definitions and derivations.

Instructor: Stuart Geman (http://www.dam.brown.edu/people/geman), course website at canvas.brown.edu

Lectures: Tues. & Thurs. 10:30am-11:50am

Homework: Eight or nine assignments that include pencil-and-paper math problems and computational experiments

Exams: (tentatively) A final exam and one or two midterm exams. Grade weighting: (tentatively) 40% assignments, 35% final exam, 25% midterm(s)

Required materials: There is no required textbook or programming language. Matlab is the only supported programming language, and is strongly encouraged. Matlab is freely available through Brown.

Approximate minimum time commitment: Lectures – 30 hours; Assignments – 128 hours (8 assignments × 16 hr/assignment); Midterm(s) and final exam - 24 hours. Total – 182 hours. Estimates for assignments and exams include studying and reviewing.

Additional and updated information: Please refer to the canvas website for additional and up-to-date information, including office hours, TA information, and course and grading policies.

Accessibility and inclusion: Brown University is committed to full inclusion of all students. Please inform me early in the term if you may require accommodations or modification of any of course procedures. You may speak with me after class, during office hours, or by appointment. If you need accommodations around online learning or in classroom accommodations, please be sure to reach out to Student Accessibility Services (SAS) for their assistance (seas@brown.edu, 401-863-9588). Undergraduates in need of short-term academic advice or support can contact an academic dean in the College by emailing college@brown.edu. Graduate students may contact one of the deans in the Graduate School by emailing graduate_school@brown.edu.