Department of Statistics

Chair
• Dan Liviu Nicolae, Statistics and Medicine

Professors
• Yali Amit
• Mihai Anitescu, Argonne National Laboratory
• Guillaume Bal
• Lars Peter Hansen, Economics and Statistics
• Steven P. Lalley
• Gregory F. Lawler, Mathematics and Statistics
• Peter McCullagh
• Mary Sara McPeek
• Per Mykland
• Dan Liviu Nicolae, Statistics and Medicine
• John Reinitz
• Mary Silber
• Michael L. Stein
• Matthew Stephens
• Stephen M. Stigler
• Rebecca Willett
• Kirk M. Wolter
• Wei Biao Wu

Associate Professors
• Rina Foygel Barber
• Lek-Heng Lim
• Imre Risi Kondor, Computer Science and Statistics

Assistant Professors
• Chao Gao
• Daniel Sanz-Alonso

Senior Lecturers
• Linda Brant Collins
• Mei Wang

Lecturers
• Kendra S. Burbank
• Yibi Huang

Instructors
• Tingran Gao
• Daniel Massatt
• Fatma Terzioglu
• Ye (Anderson) Zhang

Visiting Professors
• James O. Berger

The Department of Statistics offers an exciting and revamped graduate program that prepares students for cutting-edge interdisciplinary research in a wide variety of fields. The field of statistics has become a core component of research in the biological, physical, and social sciences, as well as in traditional computer science domains such as artificial intelligence. In light of this, the Department of Statistics is currently undergoing a major expansion of approximately ten new faculty into fields of Computational and Applied Mathematics. The massive increase in the data acquired, through scientific measurement on one hand and through web-based collection on the other, makes the development of statistical analysis and
prediction methodologies more relevant than ever. Our graduate program aims to prepare students to address these issues through rigorous training in theory, methodology, and applications of statistics; rigorous training in scientific computation; and research projects in core methodology of statistics and computation as well as in a wide variety of interdisciplinary fields.

The Department of Statistics offers two tracks of graduate study, one leading to the Master of Science (M.S.) degree, the other to the Doctorate of Philosophy (Ph.D.). The M.S. degree is a professional degree. Students who receive this degree are prepared for nonacademic careers in which the use of advanced statistical and computational methods is of central importance. The program also prepares students for possible further graduate study.

During the first year of the Ph.D. program, students are given a thorough grounding in material that forms the foundations of modern statistics and scientific computation, including data analysis, mathematical statistics, probability theory, applied probability and modeling, and computational methods. Throughout the entire program, students attend a weekly consulting seminar where researchers from across the University come to get advice on modeling, statistical analysis, and computation. This seminar is often the source of interesting and ongoing research projects.

In the second year, students have a wide range of choices of topics they can pursue further, based on their interests, through advanced courses and reading courses with faculty. During the second year, students will typically identify their subfield of interest, take some advanced courses in the subject, and interact with the relevant faculty members. The Department maintains very strong connections to numerous other units on campus, either through joint appointments of the faculty or through ongoing collaborations. Students have easy access to faculty in other departments, which allows them to expand their interactions and develop new interdisciplinary research projects. Examples include joint projects with Human Genetics, Ecology and Evolution, Neurobiology, Chemistry, Economics, Health Studies, and Astronomy.

Programs and Requirements for the Ph.D.
All sufficiently well-prepared students take 3 of 4 sequences in their first year:

- Applied Statistics
- Theoretical Statistics
- Probability
- Computation and Machine Learning

All students pass prelim exams in 2 of the 4 subjects by the beginning of their second year. Well-prepared students may be allowed to pass one or both of their exams upon arrival. Students should take a distribution requirement of up to two courses in their second year and are otherwise encouraged to explore the great variety of graduate courses on offer, both inside the department and in other departments.

Starting in their second year, students should find a topic for a Ph.D. dissertation and establish a relationship with a Ph.D. adviser. Taking courses with potential advisers is part of this process. The detailed process is listed here (http://www.stat.uchicago.edu/students/phd_rules.shtml).

The Ph.D.: Training in Teaching, Presentation, and Consulting

Part of every statistician’s job is to evaluate the work of others and to communicate knowledge, experience, and insights. Every statistician is, to some extent, an educator, and the department provides graduate students with training for this aspect of their professional lives. The department expects all doctoral students, regardless of their professional objectives and sources of financial support, to take part in a graduated program of participation in some or all phases of instruction, from grading, course assisting, and conducting discussion sections, to being a lecturer with responsibility for an entire course.

Students also receive training in how to present research in short seminars in the first and second years of study. Later, students present their own work in a dissertation proposal and, eventually, in a thesis defense. The student seminars are listed here (http://www.stat.uchicago.edu/seminars/index.shtml).

Ph.D. students should also participate in the department’s consulting program (http://galton.uchicago.edu/consulting/index.shtml), which is led by faculty members and exposes the students to empirical projects inside the university. Projects are carried out by groups of students under the guidance of a faculty member. The client is a researcher in an applied area, usually associated with the university. An informal seminar meets regularly over lunch to provide a forum for presenting and discussing problems, solutions, and topics in statistical consultation. Students present interesting or difficult consulting problems to the seminar as a way of stimulating wider consideration of the problem and as a means of developing familiarity with the kinds of problems and lines of attack involved. Often the client will participate in the presentation and discussion.

Programs and Requirements for the M.S. degree

The main requirements of the M.S. program are a sequence of at least nine approved courses plus a Master’s paper. Students may take up to two years of courses. A detailed set of regulations can be found here (http://galton.uchicago.edu/students/master.shtml). A substantial fraction of available courses are the same as for the Ph.D. degree.

Facilities

Almost all departmental activities—classes, seminars (http://galton.uchicago.edu/seminars/index.shtml), computation (http://galton.uchicago.edu/local/computing), and student and faculty offices (http://galton.uchicago.edu/people)—are located
in Jones Laboratory. Each student is assigned a desk in one of several offices. A small departmental library and conference room is a common meeting place for formal and informal gatherings of students and faculty. The major computing facilities of the department are based upon a network of PCs running mainly Linux. One computer room currently houses many of these PCs; these rooms are directly and primarily for graduate students in the Statistics Department. In addition, all student offices have limited computer facilities. For further information, consult the department’s computing policies (http://www.stat.uchicago.edu/local/computing/policies/index.shtml).

Statistics Throughout the University

In addition to the courses, seminars, and programs in the Department of Statistics, courses and workshops of direct interest to statisticians occur throughout the University, most notably in the programs in statistics and econometrics in the Booth School of Business (http://www.chicagobooth.edu) and in the research programs in Health Studies (http://health.bsd.uchicago.edu), Human Genetics (http://genes.uchicago.edu), Financial Mathematics and Econometrics (http://stevanovichcenter.uchicago.edu/page/seminars), Computer Science (http://www.cs.uchicago.edu), Economics (http://economics.uchicago.edu) and NORC (http://www.norc.uchicago.edu) (formerly the National Opinion Research Center). The large number of statistics related seminars (http://galton.uchicago.edu/seminars/index.shtml) is perhaps the best indication of the vibrancy of the statistics research community here at the University of Chicago.

Statistics Courses

**STAT 30030. Statistical Theory and Methods Ia. 100 Units.**

This course is the first quarter of a two-quarter sequence providing a principled development of statistical methods, including practical considerations in applying these methods to the analysis of data. The course begins with a brief review of probability and some elementary stochastic processes, such as Poisson processes, that are relevant to statistical applications. The bulk of the quarter covers principles of statistical inference from both frequentist and Bayesian points of view. Specific topics include maximum likelihood estimation, posterior distributions, confidence and credible intervals, principles of hypothesis testing, likelihood ratio tests, multinomial distributions, and chi-square tests. Additional topics may include diagnostic plots, bootstrapping, a critical comparison of Bayesian and frequentist inference, and the role of conditioning in statistical inference. Examples are drawn from the social, physical, and biological sciences. The statistical software package R will be used to analyze datasets from these fields and instruction in the use of R is part of the course.

Instructor(s): Staff Terms Offered: Autumn

Prerequisite(s): STAT 25100 or STAT 25150 or MATH 23500.

Note(s): Some previous experience with statistics helpful but not required. Concurrent or prior linear algebra (MATH 19620 or 20250 or STAT 24300 or equivalent) is recommended for students continuing to STAT 24510. Students may count either STAT 24400 or STAT 24410, but not both, toward the forty-two credits required for graduation.

Equivalent Course(s): STAT 24410

**STAT 30040. Statistical Theory and Methods IIa. 100 Units.**

This course is a continuation of STAT 24410. The focus is on theory and practice of linear models, including the analysis of variance, regression, correlation, and some multivariate analysis. Additional topics may include bootstrapping for regression models, nonparametric regression, and regression models with correlated errors.

Terms Offered: May be offered in Winter.

Prerequisite(s): STAT 24410 and linear algebra (MATH 19620 or MATH 20250 or STAT 24300 or PHYS 22100 or equivalent).

Note(s): Students may count either STAT 24500 or STAT 24510, but not both, toward the forty-two credits required for graduation.

Equivalent Course(s): STAT 24510

**STAT 30100. Mathematical Statistics-1. 100 Units.**

This course is part of a two-quarter sequence on the theory of statistics. Topics will include exponential, curved exponential, and location-scale families; mixtures, hierarchical, and conditional modeling including compatibility of conditional distributions; principles of estimation; identifiability, sufficiency, minimal sufficiency, ancillarity, completeness; properties of the likelihood function and likelihood-based inference, both univariate and multivariate, including examples in which the usual regularity conditions do not hold; elements of Bayesian inference and comparison with frequentist methods; and multivariate information inequality. Part of the course will be devoted to elementary asymptotic methods that are useful in the practice of statistics, including methods to derive asymptotic distributions of various estimators and test statistics, such as Pearson's chi-square, standard and nonstandard asymptotics of maximum likelihood estimators and Bayesian estimators, asymptotics of order statistics and extreme order statistics, Cramer's theorem including situations in which the second-order term is needed, and asymptotic efficiency. Other topics (e.g., methods for dependent observations) may be covered if time permits.

Instructor(s): Staff Terms Offered: Winter

Prerequisite(s): STAT 30400 or consent of instructor
STAT 30200. Mathematical Statistics-2. 100 Units.
This course continues the development of Mathematical Statistics, with an emphasis on hypothesis testing. Topics include comparison of Bayesian and frequentist hypothesis testing; admissibility of Bayes' rules; confidence and credible sets; likelihood ratio tests and their asymptotics; Bayes factors; methods for assessing predictions for normal means; shrinkage and thresholding methods; sparsity; shrinkage as an example of empirical Bayes; multiple testing and false discovery rates; Bayesian approach to multiple testing; sparse linear regressions (subset selection and LASSO, proof of estimation errors for LASSO, Bayesian perspective of sparse regressions); and Bayesian model averaging.
Instructor(s): Staff Terms Offered: Spring
Prerequisite(s): STAT 24500 or STAT 30100

STAT 30400. Distribution Theory. 100 Units.
This course is a systematic introduction to random variables and probability distributions. Topics include standard distributions (i.e. uniform, normal, beta, gamma, F, t, Cauchy, Poisson, binomial, and hypergeometric); properties of the multivariate normal distribution and joint distributions of quadratic forms of multivariate normal; moments and cumulants; characteristic functions; exponential families; modes of convergence; central limit theorem; and other asymptotic approximations.
Instructor(s): Staff Terms Offered: Autumn
Prerequisite(s): STAT 24500 or STAT 24510 and MATH 20500 or MATH 20510, or consent of instructor.

STAT 30600. Adv. Statistical Inference I. 100 Units.
Topics covered in this course will include: Gaussian distributions; conditional distributions; maximum likelihood and REML; Laplace approximation and associated expansion; combinatorics and the partition lattice; Mobius inversion; moments, cumulants symmetric functions, and $k$-statistics; cluster expansions; Bartlett identities and Bartlett adjustment; random partitions, partition processes, and CRP process; Gauss-Ewens cluster process; classification models; trees rooted and unrooted; exchangeable random trees; and Cox processes used for classification.
Terms Offered: To be determined; may not offered in 2019-2020.
Prerequisite(s): Consent of instructor

STAT 30750. Numerical Linear Algebra. 100 Units.
This course is devoted to the basic theory of linear algebra and its significant applications in scientific computing. The objective is to provide a working knowledge and hands-on experience of the subject suitable for graduate level work in statistics, econometrics, quantum mechanics, and numerical methods in scientific computing. Topics include Gaussian elimination, vector spaces, linear transformations and associated fundamental subspaces, orthogonality and projections, eigenvectors and eigenvalues, diagonalization of real symmetric and complex Hermitian matrices, the spectral theorem, and matrix decompositions (QR, Cholesky and Singular Value Decompositions). Systematic methods applicable in high dimensions and techniques commonly used in scientific computing are emphasized. Students enrolled in the graduate level STAT 30750 will have additional work in assignments, exams, and projects including applications of matrix algebra in statistics and numerical computations implemented in Matlab or R. Some programming exercises will appear as optional work for students enrolled in the undergraduate level STAT 24300.
Terms Offered: Autumn
Prerequisite(s): Multivariate calculus (MATH 15910 or MATH 16300 or MATH 16310 or MATH 19520 or MATH 20000 or MATH 20500 or MATH 20510 or MATH 20900 or PHYS 22100 or equivalent). Previous exposure to linear algebra is helpful.
Equivalent Course(s): STAT 24300

STAT 30800. Advanced Statistical Inference II. 100 Units.
This course will discuss the following topics in high-dimensional statistical inference: random matrix theory and asymptotics of its eigen-decompositions, estimation and inference of high-dimensional covariance matrices, large dimensional factor models, multiple testing and false discovery control and high-dimensional semiparametrics. On the methodological side, probability inequalities, including exponential, Nagaev, and Rosenthal-type inequalities will be introduced.
Terms Offered: To be determined; may not be offered in 2019-2020.
Prerequisite(s): STAT 30400, STAT 30100, and STAT 30210, or consent of instructor

STAT 30810. High Dimensional Time Series Analysis. 100 Units.
This course will include lectures on the following topics: review of asymptotics for low dimensional time series analysis (linear and nonlinear processes; nonparametric methods; spectral and time domain approaches); covariance, precision, and spectral density matrix estimation for high dimensional time series; factor models; estimation of high dimensional vector autoregressive processes; prediction; and high dimensional central limit theorems under dependence.
Terms Offered: To be determined

STAT 30850. Multiple Testing, Modern Inference, and Replicability. 100 Units.
This course examines the problems of multiple testing and statistical inference from a modern point of view. High-dimensional data is now common in many applications across the biological, physical, and social sciences. With this increased capacity to generate and analyze data, classical statistical methods may no longer ensure the reliability or replicability of scientific discoveries. We will examine a range of modern methods that provide statistical inference tools in the context of modern large-scale data analysis. The course will have weekly assignments as well as a final project, both of which will include both theoretical and computational components.
Terms Offered: Winter
Prerequisite(s): STAT 24400 or STAT 24410 or consent of instructor.
Equivalent Course(s): STAT 27850
**STAT 30900. Mathematical Computation I: Matrix Computation Course. 100 Units.**

This is an introductory course on numerical linear algebra, which is quite different from linear algebra. We will be much less interested in algebraic results that follow from axiomatic definitions of fields and vector spaces but much more interested in analytic results that hold only over the real and complex fields. The main objects of interest are real- or complex-valued matrices, which may come from differential operators, integral transforms, bilinear and quadratic forms, boundary and coboundary maps, Markov chains, correlations, DNA microarray measurements, movie ratings by viewers, friendship relations in social networks, etc. Numerical linear algebra provides the mathematical and algorithmic tools for analyzing these matrices. Topics covered: basic matrix decompositions LU, QR, SVD; Gaussian elimination and LU/LDU decompositions; backward error analysis, Gram-Schmidt orthogonalization and QR/complete orthogonal decompositions; solving linear systems, least squares, and total least squares problem; low-rank matrix approximations and matrix completion. We shall also include a brief overview of stationary and Krylov subspace iterative methods; eigenvalue and singular value problems; and sparse linear algebra.

Terms Offered: Autumn
Prerequisite(s): Linear algebra (STAT 24300 or equivalent) and some previous experience with statistics.
Equivalent Course(s): CMSC 37810

**STAT 31010. Mathematical Computation II: Optimization. 100 Units.**

The course covers the fundamentals of convex optimization with applications to problems in science, medicine, and engineering, including linear programming, geometric programming, second-order cone programming, semidefinite programming, and linearly and quadratically constrained quadratic programming. The last part of the course examines the generalized moment problem, a singularly powerful technique that allows one to encode all kinds of problems (in probability, statistics, control theory, financial mathematics, signal processing, etc.) and solve them or their relaxations as convex optimization problems.

Terms Offered: Winter
Prerequisite(s): STAT 30900/CMSC 37810, a familiarity with the basics of probability theory.

**STAT 31015. Mathematical Computation IIA: Convex Optimization. 100 Units.**

The course will cover techniques in unconstrained and constrained convex optimization and a practical introduction to convex duality. The course will focus on (1) formulating and understanding convex optimization problems and studying their properties; (2) understanding and using the dual; and (3) presenting and understanding optimization approaches, including interior point methods and first order methods for non-smooth problems. Examples will be mostly from data fitting, statistics and machine learning.

Instructor(s): Nathan Srebro
Terms Offered: Winter
Prerequisite(s): STAT 30900/CMSC 37810
Equivalent Course(s): BUSN 36903, CMSC 35470, CAAM 31015, TTIC 31070

**STAT 31020. Mathematical Computation IIB: Nonlinear Optimization. 100 Units.**

This course covers the fundamentals of continuous optimization with an emphasis on algorithmic and computational issues. The course starts with the study of optimality conditions and techniques for unconstrained optimization, covering line search and trust region approaches, and addressing both factorization-based and iterative methods for solving the subproblems. The Karush-Kuhn-Tucker conditions for general constrained and nonconvex optimization are then discussed and used to define algorithms for constrained optimization including augmented Lagrangian, interior-point and (if time permits) sequential quadratic programming. Iterative methods for large sparse problems, with an emphasis on projected gradient methods, will be presented. Several substantial programming projects (using MATLAB and aiming at both data-intensive and physical sciences applications) are completed during the course.

Terms Offered: Winter
Prerequisite(s): STAT 30900/CMSC 37810

**STAT 31060. Further Mathematical Computation: Matrix Computation and Optimization. 100 Units.**

This course is primarily about iterative algorithms in matrix computation. For linear systems and least squares problems, we will discuss stationary methods (Jacobi, Gauss-Seidel, SOR), semi-iterative methods (Richardson, steepest descent, Chebyshev, conjugate gradient), and Krylov subspace methods (MINRES, SYMMLQ, LSQR, GMRES, QMR, BiCG). We will cover some basic ideas for preconditioning and stopping conditions. For eigenvalue problems, we will discuss direct (Givens and Householder) and iterative (Lanczos and Arnoldi) methods for reducing a matrix into tridiagonal and Hessenberg forms, as well as power, inverse power, Rayleigh quotient, Jacobi, Jacobi-Davidson, and Francis QR algorithms for extraction of eigenvalues/eigenvectors. Lastly, we will discuss algorithms for generalized and quadratic eigenvalue problems (QZ algorithm) as well as for singular value decomposition (Golub-Kahan and Golub-Reinsch).

Terms Offered: To be determined

**STAT 31080. Numerical Analysis for Statistics and Applied Mathematics. 100 Units.**

This is a beginning graduate course on selected numerical methods used in modern statistics and applied mathematics. Topics include fundamentals of ODEs and PDEs, quadratures, and Monte Carlo methods. Methods of analysis are introduced including error measures and different notions of numerical convergence. Newton's method, convex optimization and elements of nonconvex optimization are covered, together with implementations in selected selected software packages.

Terms Offered: Not offered in 2019-2020
Prerequisite(s): STAT 24300 or background in linear algebra.
STAT 31100. Mathematical Computation III: Numerical Methods for PDE's. 100 Units.
The first part of this course introduces basic properties of PDE's; finite difference discretizations; and stability, consistency, convergence, and Lax's equivalence theorem. We also cover examples of finite difference schemes; simple stability analysis; convergence analysis and order of accuracy; consistency analysis and errors (i.e., dissipative and dispersive errors); and unconditional stability and implicit schemes. The second part of this course includes solution of stiff systems in 1, 2, and 3D; direct vs. iterative methods (i.e., banded and sparse LU factorizations); and Jacobi, Gauss-Seidel, multigrid, conjugate gradient, and GMRES iterations.
Terms Offered: Spring
Prerequisite(s): Some prior exposure to differential equations and linear algebra
Equivalent Course(s): CAAM 31100, CMSC 37812, MATH 38309

STAT 31140. Computational Imaging: Theory and Methods. 100 Units.
Computational imaging refers to the process of forming images from data where computation plays an integral role. This course will cover basic principles of computational imaging, including image denoising, regularization techniques, linear inverse problems and optimization-based solvers, and data acquisition models associated with tomography and interferometry. Specific topics may include patch-based denoising, sparse coding, total variation, dictionary learning, computational photography, compressive imaging, inpainting, and deep learning for image reconstruction.
Instructor(s): R. Willett
Terms Offered: Spring
Equivalent Course(s): CMSC 31140, CAAM 31140

STAT 31150. Inverse Problems and Data Assimilation. 100 Units.
This class provides an introduction to Bayesian Inverse Problems and Data Assimilation, emphasizing the theoretical and algorithmic inter-relations between both subjects. We will study Gaussian approximations and optimization and sampling algorithms, including a variety of Kalman-based and particle filters as well as Markov chain Monte Carlo schemes designed for high-dimensional inverse problems.
Instructor(s): D. Sanz-Alonso
Terms Offered: Autumn
Prerequisite(s): Familiarity with calculus, linear algebra, and probability/statistics at the level of STAT 24400 or STAT 24410. Some knowledge of ODEs may also be helpful.
Equivalent Course(s): CAAM 31150

STAT 31200. Introduction to Stochastic Processes I. 100 Units.
This course introduces stochastic processes not requiring measure theory. Topics include branching processes, recurrent events, renewal theory, random walks, Markov chains, Poisson, and birth-and-death processes.
Instructor(s): Staff
Terms Offered: Autumn or Winter
Prerequisite(s): STAT 25100 and MATH 20500; STAT 30400 or consent of instructor
Note(s): Students with credit for MATH 235 should not enroll in STAT 312.
Equivalent Course(s): CAAM 31210

STAT 31210. Applied Functional Analysis. 100 Units.
This course will cover classical topics of applied functional analysis: description of functional spaces such as Banach spaces and Hilbert spaces; properties of linear operators acting on such spaces, compactness and spectral decomposition of compact operators; and applications to ordinary and partial differential equations.
Terms Offered: Autumn
Equivalent Course(s): CAAM 31210

STAT 31220. Partial Differential Equations. 100 Units.
This is an introduction to the theory of partial differential equations covering representation formulas and regularity theory for elliptic, parabolic, and hyperbolic equations; the method of characteristics; variational formulations for second-order linear elliptic equations; and the calculus of variations.
Terms Offered: Winter
Equivalent Course(s): CAAM 31220

STAT 31230. Inverse Problems in Imaging. 100 Units.
This course focuses on the mathematical description of many inverse problems that appear in geophysical and medical imaging: X-ray tomography, ultrasound tomography and seismic imaging, optical and electrical tomography, as well as more recent imaging modalities such as elastography and photo-acoustic tomography. Seen as reconstructions of constitutive parameters in differential equations from redundant boundary measurements, these continuous models tell us which parameters may or may not be reconstructed, and with which stability with respect to measurement errors. Time-permitting, we will also consider general methodologies to perform such reconstructions (regularization, optimization, Bayesian framework). Some knowledge of PDE and Fourier transforms is recommended.
Terms Offered: Spring
Prerequisite(s): STAT 31220
Equivalent Course(s): CAAM 31230

STAT 31300. Introduction to Stochastic Processes II. 100 Units.
Topics include continuous-time Markov chains, Markov chain Monte Carlo, discrete-time martingales, and Brownian motion and diffusions. Our emphasis is on defining the processes and calculating or approximating various related probabilities. The measure theoretic aspects of these processes are not covered rigorously.
Prerequisite(s): STAT 31200 or consent of instructor
STAT 31410. Applied Dynamical Systems. 100 Units.
This course is an introduction to dynamical systems for analysis of nonlinear ordinary differential equations. The focus is on methods of bifurcation theory, canonical examples of forced nonlinear oscillators, fast-slow systems, and chaos. Examples will be drawn from mathematical modeling of physical and biological systems. While geometric perspectives will be emphasized, assignments will also introduce asymptotic methods for analysis and use numerical simulation as an exploratory tool. This course assumes students have a background in ordinary differential equations and linear algebra at the undergraduate level and an interest in mathematical modeling for applications.
Instructor(s): M. Silber Terms Offered: Spring
Prerequisite(s): ODEs and/or dynamical systems at an undergraduate level or consent of instructor.
Equivalent Course(s): CAAM 31410

STAT 31450. Applied Partial Differential Equations. 100 Units.
Partial differential equations (PDEs) are used to model applications in a wide variety of fields: fluid dynamics, optics, atomic and plasma physics, elasticity, chemical reactions, climate modeling, stock markets, etc. The study of their mathematical structure and solution methods remains at the forefront of applied mathematics. The course concentrates on deriving an important set of examples of PDEs from simple physical models, which are often closely related to those describing more complex physical systems. The course will also cover analytical methods and tools for solving these PDEs; such as separation of variables, Fourier series and transforms, Sturm-Liouville theory, and Green's functions. The course is suitable for graduate students and advanced undergraduates in science, engineering, and applied mathematics.
Terms Offered: Spring
Prerequisite(s): Instructor consent.
Equivalent Course(s): CAAM 31450

STAT 31511. Monte Carlo Simulation. 100 Units.
This class primarily concerns the design and analysis of Monte Carlo sampling techniques for the estimation of averages with respect to high dimensional probability distributions. Standard simulation tools such as importance sampling, Metropolis-Hastings, Langevin dynamics, and hybrid Monte Carlo will be introduced along with basic theoretical concepts regarding their convergence to equilibrium. The class will explore applications of these methods in Bayesian statistics and machine learning as well as to other simulation problems arising in the physical and biological sciences. Particular attention will be paid to the major complicating issues like conditioning (with analogies to optimization) and rare events and methods to address them.
Prerequisite(s): Multivariate calculus and linear algebra

STAT 31521. Applied Stochastic Processes. 100 Units.
This course concerns the estimation of the dynamic properties of time-dependent stochastic systems. The class will begin with an introduction to the numerical simulation of continuous time Markov processes including the discretization of stochastic (and ordinary) differential equations. Problems associated with multiple time scales will be discussed along with methods to address them (implicit discretizations, multiscale methods and dimensional reduction). The class will also cover interacting particle methods and other techniques for the efficient simulation of dynamical rare events.
Prerequisite(s): Multivariate calculus and linear algebra

STAT 31550. Uncertainty Quantification. 100 Units.
This course will cover mathematical, statistical, and algorithmic questions that arise at the interface of complex modeling and data processing. Emphasis will be given to characterizing and quantifying the uncertainties inherent in the use of models and to exploring principled ways to reduce said uncertainty by the use of data. Specific topics include Bayesian inverse problems and data assimilation.
Terms Offered: Winter
Prerequisite(s): STAT 30200 or consent of instructor

STAT 31700. Introduction to Probability Models. 100 Units.
This course introduces stochastic processes as models for a variety of phenomena in the physical and biological sciences. Following a brief review of basic concepts in probability, we introduce stochastic processes that are popular in applications in sciences (e.g., discrete time Markov chain, the Poisson process, continuous time Markov process, renewal process and Brownian motion).
Instructor(s): Staff Terms Offered: May be offered in Autumn or Winter
Prerequisite(s): STAT 24400 or STAT 24410 or STAT 25100 or STAT 25150
Equivalent Course(s): STAT 25300
STAT 31900. Introduction to Causal Inference. 100 Units.
This course is designed for graduate students and advanced undergraduate students from the social sciences, education, public health science, public policy, social service administration, and statistics who are involved in quantitative research and are interested in studying causality. The goal of this course is to equip students with basic knowledge of and analytic skills in causal inference. Topics for the course will include the potential outcomes framework for causal inference; experimental and observational studies; identification assumptions for causal parameters; potential pitfalls of using ANCOVA to estimate a causal effect; propensity score based methods including matching, stratification, inverse-probability-of-treatment-weighting (IPTW), marginal mean weighting through stratification (MMWS), and doubly robust estimation; the instrumental variable (IV) method; regression discontinuity design (RDD) including sharp RDD and fuzzy RDD; difference in difference (DID) and generalized DID methods for cross-section and panel data, and fixed effects model. Intermediate Statistics or equivalent such as STAT 224/PBHS 324, PP 31301, BUS 41100, or SOC 30005 is a prerequisite. This course is a prerequisite for "Advanced Topics in Causal Inference" and "Mediation, moderation, and spillover effects."
Instructor(s): G. Hong, K. Yamaguchi Terms Offered: Winter
Prerequisite(s): Intermediate Statistics or equivalent such as STAT 224/PBHS 324, PP 31301, BUS 41100, or SOC 30005
Note(s): Linear algebra at the level of STAT 24300. Knowledge of probability and statistical estimation techniques (e.g. Financial Mathematics can enroll without prerequisites.)
Equivalent Course(s): STAT 24620

STAT 32400. Probability and Statistics. 100 Units.
This Ph.D.-level course (in addition to BUSF 41902/STAT 32500) provides a thorough introduction to Classical and Bayesian statistical theory. The two quarter sequence provides the necessary probability and statistical background for many of the advanced courses in the Chicago Booth curriculum. The central topic is probability. Basic concepts in probability are covered. An introduction to martingales is given. Homework assignments are given throughout the quarter. Course subject description is subject to change. Please visit the Booth portal and search via the course search tool for the most up to date information:
http://boothportal.chicagobooth.edu/portal/server.pt/community/course_search
Terms Offered: Autumn
Equivalent Course(s): BUSN 41901

STAT 32900. Applied Multivariate Analysis. 100 Units.
The course will introduce the basic theory and applications for analyzing multidimensional data. Topics include multivariate distributions, Gaussian models, multivariate statistical inferences and applications, classifications, cluster analysis, and dimension reduction methods. Course content is subject to change in order to keep the contents up-to-date with new development in multivariate statistical techniques. The course is offered in alternate years by the Statistics Department (S15, S17, ...) and the Booth Business School (S16, S18, ...). When the course is offered by the Booth school, please visit the Booth portal and search via the course search tool: http://boothportal.chicagobooth.edu/portal/server.pt/community/course_search for the most up to date information.
Equivalent Course(s): BUSN 41912

STAT 32940. Multivariate Data Analysis via Matrix Decompositions. 100 Units.
This course is about using matrix computations to infer useful information from observed data. One may view it as an "applied" version of Stat 30900 although it is not necessary to have taken Stat 30900; the only prerequisite for this course is basic linear algebra. The data analytic tools that we will study will go beyond linear and multiple regression and often fall under the heading of "Multivariate Analysis" in Statistics. These include factor analysis, correspondence analysis, principal components analysis, multidimensional scaling, linear discriminant analysis, canonical correlation analysis, cluster analysis, etc. Understanding these techniques require some facility with matrices in addition to some basic statistics, both of which the student will acquire during the course. Program elective.
Instructor(s): L. Lim Terms Offered: Autumn
Equivalent Course(s): CAAM 32940, FINM 33180

STAT 32950. Multivariate Statistical Analysis: Applications and Techniques. 100 Units.
This course focuses on applications and techniques for analysis of multivariate and high dimensional data. Beginning subjects cover common multivariate techniques and dimension reduction, including principal component analysis, factor model, canonical correlation, multi-dimensional scaling, discriminant analysis, clustering, and correspondence analysis (if time permits). Further topics on statistical learning for high dimensional data and complex structures include penalized regression models (LASSO, ridge, elastic net), sparse PCA, independent component analysis, Gaussian mixture model, Expectation-Maximization methods, and random forest. Theoretical derivations will be presented with emphasis on motivations, applications, and hands-on data analysis.
Terms Offered: Spring
Prerequisite(s): (STAT 24300 or MATH 20250) and (STAT 24500 or STAT 24510). Graduate students in Statistics or Financial Mathematics can enroll without prerequisites.
Note(s): Linear algebra at the level of STAT 24300. Knowledge of probability and statistical estimation techniques (e.g. maximum likelihood and linear regression) at the level of STAT 24400-24500.
Equivalent Course(s): STAT 24620

STAT 33100. Sample Surveys. 100 Units.
This course covers random sampling methods; stratification, cluster sampling, and ratio estimation; and methods for dealing with nonresponse and partial response.
Instructor(s): K. Wolter Terms Offered: Autumn
Prerequisite(s): Consent of instructor
STAT 33211. Mediation, Moderation, and Spillover Effects. 100 Units.
This course is designed for graduate students and advanced undergraduate students from social sciences, statistics, health studies, public policy, and social services administration who will be or are currently involved in quantitative research. Research questions about why an intervention works, for whom, under what conditions, and whether one individual's treatment could affect other individuals' outcomes are often key to the advancement of scientific knowledge yet pose major analytic challenges. This course introduces cutting-edge theoretical concepts and methodological approaches with regard to mediation of intervention effects, moderated intervention effects, and spillover effects in a variety of settings. The course content is organized around six case studies. In each case, students will be involved in critical examinations of a working paper currently under review. Background readings will reflect the latest developments and controversies. Weekly labs will provide supplementary tutorials and hands-on experiences with mediation and moderation analyses. All students are expected to contribute to the knowledge building in class through participation in discussions. Students are encouraged to form study groups, while the two written assignments are to be finished and graded on an individual basis.
Instructor(s): J. Paulsen Terms Offered: Autumn
Note(s): G. Hong
Equivalent Course(s): CHDV 30318, CHDV 32411, CCTS 32411, PBPL 29411, PSYC 32411

STAT 33500. Time-series Analysis for Forecasting and Model Building. 100 Units.
Forecasting plays an important role in business planning and decisionmaking. This Ph.D.-level course discusses time series models that have been widely used in business and economic data analysis and forecasting. Both theory and methods of the models are discussed. Real examples are used throughout the course to illustrate applications. The topics covered include: (1) stationary and unit-root non-stationary processes; (2) linear dynamic models, including Autoregressive Moving Average models; (3) model building and data analysis; (4) prediction and forecasting evaluation; (5) asymptotic theory for estimation including unit-root theory; (6) models for time varying volatility; (7) models for time varying correlation including Dynamic Conditional Correlation and time varying factor models; (8) state-space models and Kalman filter; and (10) models for high frequency data. Course description is subject to change. Please visit the Booth portal and search via the course search tool for the most up to date information: http://boothportal.chicagobooth.edu/portal/server.pt/community/course_search/
Prerequisite(s): BUSF 41901/STAT 32400 or instructor consent.
Equivalent Course(s): BUSN 41910

STAT 33600. Time Dependent Data. 100 Units.
This course considers the modeling and analysis of data that are ordered in time. The main focus is on quantitative observations taken at evenly spaced intervals and includes both time-domain and spectral approaches.
Instructor(s): Staff
Prerequisite(s): STAT 24500 w/B- or better or STAT 24510 w/C+ or better is required; alternatively STAT 22400 w/B- or better and exposure to multivariate calculus (MATH 16300 or MATH 16310 or MATH 19520 or MATH 20000 or MATH 20500 or MATH 20510 or MATH 20800). Graduate students in Statistics or Financial Mathematics can enroll without prerequisites. Some previous exposure to Fourier series is helpful but not required.
Equivalent Course(s): STAT 26100

STAT 33700. Multivariate Time Series Analysis. 100 Units.
This course investigates the dynamic relationships between variables. It starts with linear relationships between two variables, including distributed-lag models and detection of unidirectional dependence (Granger causality). Nonlinear and time-varying relationships are also discussed. Dynamic models discussed include vector autoregressive models, vector autoregressive moving-average models, multivariate regression models with time series errors, co-integration and error-correction models, state-space models, dynamic factor models, and multivariate volatility models such as BEKK, Dynamic conditional correlation, and copula-based models. The course also addresses impulse response function, structural specification, co-integration tests, least squares estimates, maximum likelihood estimates, principal component analysis, asymptotic principal component analysis, principal volatility components, recursive estimation, and Markov Chain Monte Carlo estimation. Empirical data analysis is an integral part of the course. Students are expected to analyze many real data sets. The main software used in the course is the MTS package in R, but students may use their own software if preferred.
Equivalent Course(s): STAT 26100

STAT 33810. Probability for Risk Management. 50 Units.
The course starts at a rather introductory level, but the progress is swift. It covers a brief survey of basic probability theory, and provides an introduction to some useful statistical distributions, both univariate and multivariate. A discussion of copulas and various correlation measures. Risk measures and ideas behind a reasonable risk measure. A few elements from Monte Carlo simulation.
Instructor(s): J. Paulsen Terms Offered: Autumn
Equivalent Course(s): FINM 33410

STAT 33820. Statistical Inference for Risk Management. 50 Units.
Statistical estimation, the maximum likelihood method and nonparametric methods. Asymptotic properties of estimators. Goodness of fit tests and model selection. Extreme value theory.
Instructor(s): J. Paulsen Terms Offered: Autumn
Prerequisite(s): FINM 33410: Probability for Risk Management
Note(s): Cannot be taken for elective credit if 33400 has already been taken.
Equivalent Course(s): FINM 33420
STAT 33910. Financial Statistics: Time Series, Forecasting, Mean Reversion, and High Frequency Data. 100 Units.
This course is an introduction to the econometric analysis of high-frequency financial data. This is where the stochastic models of quantitative finance meet the reality of how the process really evolves. The course is focused on the statistical theory of how to connect the two, but there will also be some data analysis. With some additional statistical background (which can be acquired after the course), the participants will be able to read articles in the area. The statistical theory is longitudinal, and it thus complements cross-sectional calibration methods (implied volatility, etc.). The course also discusses volatility clustering and market microstructure.
Terms Offered: Winter
Prerequisite(s): STAT 39000/FINM 34500 (may be taken concurrently), also some statistics/econometrics background as in STAT 24400–24500, or FINM 33150 and FINM 33400, or equivalent, or consent of instructor.
Equivalent Course(s): FINM 33170

STAT 34000. Gaussian Processes. 100 Units.
Gaussian processes are commonly used in statistical models for spatial and spatial-temporal processes and for computer model output. They are also frequently used as building blocks for non-Gaussian process models. This course will begin with an overview of the theory for Gaussian processes, with a focus on stationary processes and their associated spectral properties and how these relate to problems of spatial interpolation. With this foundation, we will proceed to discuss a variety of approaches to developing useful classes of Gaussian process models, with a focus on spatial-temporal processes. Computational problems and possible solutions for fitting Gaussian process models to large, irregularly observed datasets will form the last part of the class. Applications to environmental monitoring data, computer model output and possibly other areas will be considered. This class is aimed at PhD students in Statistics, but may be accessible to others with a strong background in Statistics (say, STAT 24500 and 34300), some background in analysis and previous exposure to stochastic processes.
Prerequisite(s): STAT 24500 and STAT 34300, or some background in analysis and previous exposure to stochastic processes.

STAT 34300. Applied Linear Stat Methods. 100 Units.
This course introduces the theory, methods, and applications of fitting and interpreting multiple regression models. Topics include the examination of residuals, the transformation of data, strategies and criteria for the selection of a regression equation, nonlinear models, biases due to excluded variables and measurement error, and the use and interpretation of computer package regression programs. The theoretical basis of the methods, the relation to linear algebra, and the effects of violations of assumptions are studied. Techniques discussed are illustrated by examples involving both physical and social sciences data.
Terms Offered: Autumn
Prerequisite(s): Graduate student in Statistics or instructor consent.
Note(s): Students who need it should take Linear Algebra (STAT 24300 or equivalent) concurrently.

STAT 34700. Generalized Linear Models. 100 Units.
This applied course covers factors, variates, contrasts, and interactions; exponential-family models (i.e., variance function); definition of a generalized linear model (i.e., link functions); specific examples of GLMs; logistic and probit regression; cumulative logistic models; log-linear models and contingency tables; inverse linear models; Quasi-likelihood and least squares; estimating functions; and partially linear models.
Instructor(s): Staff Terms Offered: Winter
Prerequisite(s): STAT 34300 or consent of instructor

STAT 34800. Modern Methods in Applied Statistics. 100 Units.
This course covers latent variable models and graphical models; definitions and conditional independence properties; Markov chains, HMMs, mixture models, PCA, factor analysis, and hierarchical Bayes models; methods for estimation and probability computations (EM, variational EM, MCMC, particle filtering, and Kalman Filter); undirected graphs, Markov Random Fields, and decomposable graphs; message passing algorithms; sparse regression, Lasso, and Bayesian regression; and classification generative vs. discriminative. Applications will typically involve high-dimensional data sets, and algorithmic coding will be emphasized.
Terms Offered: Spring

STAT 34900. Data Analysis Project. 100 Units.
The first half of this class will focus on general principles of data analysis and how to report the results of an analysis, including taking account of the context of the data, making informative and clear visual displays, developing relevant statistical models and describing them clearly, and carrying out diagnostic procedures to assess the appropriateness of adopted models. The second half of the class will focus on individualized data analysis projects. Students working on a data analysis project in another context (e.g., for an MS paper or for consulting) may, with proper permission, use that project for this course as well. It is intended that some projects in this class may develop into MS papers.
Terms Offered: To be determined
Prerequisite(s): STAT 34700 or permission of instructor
STAT 35201. Introduction to Clinical Trials. 100 Units.
This course will review major components of clinical trial conduct, including the formulation of clinical hypotheses and study endpoints, trial design, development of the research protocol, trial progress monitoring, analysis, and the summary and reporting of results. Other aspects of clinical trials to be discussed include ethical and regulatory issues in human subjects research, data quality control, meta-analytic overviews and consensus in treatment strategy resulting from clinical trials, and the broader impact of clinical trials on public health.
Instructor(s): Y. Ji Terms Offered: Winter
Prerequisite(s): PBHS 32100 or STAT 22000; Introductory Statistics or Consent of Instructor
Equivalent Course(s): PBHS 32901

STAT 35400. Gene Regulation. 100 Units.
This course covers the fundamental theory of gene expression in prokaryotes and eukaryotes through lectures and readings in the primary literature. Natural and synthetic genetic systems arising in the context of E. coli physiology and Drosophila development will be used to illustrate fundamental biological problems together with the computational and theoretical tools required for their solution. These tools include large-scale optimization, image processing, ordinary and partial differential equations, the chemical Langevin and Fokker-Planck equations, and the chemical master equation. A central theme of the class is the art of identifying biological problems which require theoretical analysis and choosing the correct mathematical framework with which to solve the problem.
Terms Offered: To be determined; may not offered in 2019-2020.
Prerequisite(s): Consent of instructor
Equivalent Course(s): CAAM 35400, MGCB 35401, ECEV 35400

STAT 35410. Genomic Evolution I. 100 Units.
Canalization, a unifying biological principle first enunciated by Conrad Waddington in 1942, is an idea that has had tremendous intellectual influence on developmental biology, evolutionary biology, and mathematics. In this course we will explore canalization in all three contexts through extensive reading and discussion of both the classic and modern primary literature. We intend this exploration to raise new research problems which can be evaluated for further understanding. We encourage participants to present new ideas in this area for comment and discussion.
Instructor(s): M. Long, J. Reinitz, and C-I. Wu Terms Offered: TBD. not offered in 2018-19
Equivalent Course(s): ECEV 35901, EVOL 35901

STAT 35420. Stochastic Processes in Gene Regulation. 100 Units.
This didactic course covers the fundamentals of stochastic chemical processes as they arise in the study of gene regulation. The central object of study is the Chemical Master Equation and its coarse-grainings at the Langevin/Fokker-Planck, linear noise, and deterministic levels. We will consider both mathematical and computational approaches in contexts where there are both single and multiple deterministic limits.
Instructor(s): J. Reinitz Terms Offered: To be determined; may not be offered in 2019-2020.
Prerequisite(s): Consent of instructor.
Equivalent Course(s): ECEV 35420, CAAM 35420, MGCB 35420

STAT 35450. Fundamentals of Computational Biology: Models and Inference. 100 Units.
Covers key principles in probability and statistics that are used to model and understand biological data. There will be a strong emphasis on stochastic processes and inference in complex hierarchical statistical models. Topics will vary but the typical content would include: Likelihood-based and Bayesian inference, Poisson processes, Markov models, Hidden Markov models, Gaussian Processes, Brownian motion, Birth-death processes, the Coalescent, Graphical models, Markov processes on trees and graphs, Markov Chain Monte Carlo.
Instructor(s): J. Novembre, M. Stephens Terms Offered: Winter
Prerequisite(s): STAT 244
Equivalent Course(s): HGEN 48600

STAT 35460. Fundamentals of Computational Biology: Algorithms and Applications. 100 Units.
This course will cover principles of data structure and algorithms, with emphasis on algorithms that have broad applications in computational biology. The specific topics may include dynamic programming, algorithms for graphs, numerical optimization, finite-difference schemes, matrix operations/factor analysis, and data management (e.g. SQL, HDF5). We will also discuss some applications of these algorithms (as well as commonly used statistical techniques) in genomics and systems biology, including genome assembly, variant calling, transcriptome inference, and so on.
Instructor(s): Xin He, Mengjie Chen Terms Offered: Spring
Equivalent Course(s): HGEN 48800
STAT 35490. Introduction to Statistical Genetics. 100 Units.
As a result of technological advances over the past few decades, there is a tremendous wealth of genetic data currently being collected. These data have the potential to shed light on the genetic factors influencing traits and diseases, as well as questions of ancestry and population history. The aim of this course is to develop a thorough understanding of probabilistic models and statistical theory and methods underlying analysis of genetic data, focusing on problems in complex trait mapping, with some coverage of population genetics. Although the case studies are all in the area of statistical genetics, the statistical inference topics, which will include likelihood-based inference, linear mixed models, and restricted maximum likelihood, among others, are widely applicable to other areas. No biological background is needed, but a strong foundation in statistical theory and methods is assumed.
Terms Offered: Spring
Prerequisite(s): STAT 24500 or STAT 24510
Note(s): STAT 26300 can count as either a List A or List B elective in the Statistics major.
Equivalent Course(s): STAT 26300

STAT 35500. Statistical Genetics. 100 Units.
This is an advanced course in statistical genetics. We will take an in-depth look at statistical methods development in recent genetics literature, with the aim of achieving a deep understanding of the modeling approaches and assumptions, statistical principles, mathematical theorems, computational issues, and data analytic approaches underlying the methods. The goal is for the student to be able to ultimately apply the principles learned to future statistical methods development for genetic data analysis. This is a discussion course and student presentations will be required. Topics depend on the interests of the participants and will be based on recent published literature. Topics may include, but are not limited to, statistical problems in genetic association mapping, population genetics, integration of different types of genetic data, and genetic models for complex traits. The course material changes every year, and the course may be repeated for credit.
Prerequisite(s): Either HGEN 47100 or both STAT 24400 and 24500. Students without these prerequisites may enroll on a P/ NP basis with consent of the instructor.

STAT 35700. Epidemiologic Methods. 100 Units.
This course expands on the material presented in "Principles of Epidemiology," further exploring issues in the conduct of epidemiologic studies. The student will learn the application of both stratified and multivariate methods to the analysis of epidemiologic data. The final project will be to write the "specific aims" and "methods" sections of a research proposal on a topic of the student's choice.
Instructor(s): B. Chiu Terms Offered: Winter
Prerequisite(s): PBHS 30700 or PBHS 30900 or PBHS 30910 AND PBHS 32400 or applied statistics courses through multivariate regression.
Equivalent Course(s): PBHS 31001

STAT 35800. Statistical Applications. 100 Units.
This course provides a transition between statistical theory and practice. The course will cover statistical applications in medicine, mental health, environmental science, analytical chemistry, and public policy. Lectures are oriented around specific examples from a variety of content areas. Opportunities for the class to work on interesting applied problems presented by U of C faculty will be provided. Although an overview of relevant statistical theory will be presented, emphasis is on the development of statistical solutions to interesting applied problems.
Instructor(s): R. Gibbons Terms Offered: Autumn
Prerequisite(s): PBHS 32700/STAT 22700 or STAT 34700 or consent of instructor.
Equivalent Course(s): PBHS 33500

STAT 35920. Applied Bayesian Modeling and Inference. 100 Units.
This course begins with basic probability and distribution theory, and covers a wide range of topics related to Bayesian modeling, computation, and inference. Significant amount of effort will be directed to teaching students on how to build and apply hierarchical models and perform posterior inference. The first half of the course will be focused on basic theory, modeling, and computation using Markov chain Monte Carlo methods, and the second half of the course will be about advanced models and applications. Computation and application will be emphasized so that students will be able to solve real-world problems with Bayesian techniques.
Instructor(s): Y. Ji Terms Offered: TBD
Prerequisite(s): STAT 24400 and STAT 24500 or master level training in statistics.
Equivalent Course(s): PBHS 43010
STAT 36350. Algorithms for Sequential Estimation. 100 Units.
The course objective is to present introductory, foundational, and advanced topics in sequential parameter and state estimation. The focus of the class is on algorithms for such problems, their properties, and computations involving them but some theoretical concepts of the underlying problems will also be presented. We will cover both discrete and continuous time problems. Computations in class and for homework will be carried out in Matlab. The topics covered are: 1. Review of optimization, linear algebra, probabilistic and dynamic systems concepts. Stability. Observability. 2. Sequential parameter estimation. Constrained, linear and nonlinear methods. 3. Sequential State Estimation. Kalman Filters (KF), including unscented, extended, and ensemble KF. Adaptive and Robust Methods. Particle Filters. Algorithmic and Numerical Stability. 4. Batch State Estimation. Smoothing. The Riccati Equation. Adjoint computations for problems with long horizons. Limited Memory Methods. 5. Optimal Control and Estimation Theory (if time permits). The estimation/control duality. Calculus of variations. Differential Equation Constraints. Pontryagin Optimality Conditions. Stochastic linear quadratic Gaussian control. Course website: https://wiki.uchicago.edu/display/SE3/Sequential+Estimation+STAT+36350
Prerequisite(s): STAT 30900/CMSC 37810 or consent of instructor.

STAT 36600. Decision Theory. 100 Units.
This course covers statistical decision theory with examples drawn from modern high-dimensional and nonparametric estimation. Topics that will be covered include basic information theory, decision theory, asymptotic equivalence, Gaussian sequence model, sparse regression, model selection, aggregation, and large covariance matrix estimation. Lower bound techniques such as Bayes, Le Cam, and Fano’s methods will be taught.

STAT 36700. History of Statistics. 100 Units.
This course covers topics in the history of statistics, from the eleventh century to the middle of the twentieth century. We focus on the period from 1650 to 1950, with an emphasis on the mathematical developments in the theory of probability and how they came to be used in the sciences. Our goals are both to quantify uncertainty in observational data and to develop a conceptual framework for scientific theories. This course includes broad views of the development of the subject and closer looks at specific people and investigations, including reanalyses of historical data.
Instructor(s): D. Hedeker Terms Offered: Spring
Prerequisite(s): Prior statistics course
Equivalent Course(s): STAT 26700, CHSS 32900, HIPS 25600

STAT 36900. Applied Longitudinal Data Analysis. 100 Units.
Longitudinal data consist of multiple measures over time on a sample of individuals. This type of data occurs extensively in both observational and experimental biomedical and public health studies, as well as in studies in sociology and applied economics. This course will provide an introduction to the principles and methods for the analysis of longitudinal data. Whereas some supporting statistical theory will be given, emphasis will be on data analysis and interpretation of models for longitudinal data. Problems will be motivated by applications in epidemiology, clinical medicine, health services research, and disease natural history studies.
Instructor(s): S. Stigler Terms Offered: Spring
Prerequisite(s): PBHS 32400/STAT 22400 or equivalent, and PBHS 32600/STAT 22600 or PBHS 32700/STAT 22700 or equivalent; or consent of instructor.
Equivalent Course(s): PBHS 33300

STAT 37400. Nonparametric Inference. 100 Units.
Nonparametric inference is about developing statistical methods and models that make weak assumptions. A typical nonparametric approach estimates a nonlinear function from an infinite dimensional space rather than a linear model from a finite dimensional space. This course gives an introduction to nonparametric inference, with a focus on density estimation, regression, confidence sets, orthogonal functions, random processes, and kernels. The course treats nonparametric methodology and its use, together with theory that explains the statistical properties of the methods.
Instructor(s): Staff Terms Offered: Autumn
Prerequisite(s): STAT 24400 or STAT 24410 w/B- or better is required; alternatively STAT 22400 w/B+ or better and exposure to multivariate calculus (MATH 16300 or MATH 16310 or MATH 19520 or MATH 20000 or MATH 20500 or MATH 20510 or MATH 20800) and linear algebra (MATH 19620 or MATH 20250 or STAT 24300 or equivalent). Master’s students in Statistics can enroll without prerequisites.
Equivalent Course(s): STAT 27400

STAT 37601. Machine Learning and Large-Scale Data Analysis. 100 Units.
This course is an introduction to machine learning and the analysis of large data sets using distributed computation and storage infrastructure. Basic machine learning methodology and relevant statistical theory will be presented in lectures. Homework exercises will give students hands-on experience with the methods on different types of data. Methods include algorithms for clustering, binary classification, and hierarchical Bayesian modeling. Data types include images, archives of scientific articles, online ad clickthrough logs, and public records of the City of Chicago. Programming will be based on Python and R, but previous exposure to these languages is not assumed.
Instructor(s): Staff Terms Offered: Spring
Prerequisite(s): CMSC 15400 or CMSC 12200 and STAT 22200 or STAT 23400, or by consent.
Note(s): The prerequisites are under review and may change.
Equivalent Course(s): CMSC 25025
STAT 37710. Machine Learning. 100 Units.
This course provides hands-on experience with a range of contemporary machine learning algorithms, as well as an introduction to the theoretical aspects of the subject. Topics covered include: the PAC framework, Bayesian learning, graphical models, clustering, dimensionality reduction, kernel methods including SVMs, matrix completion, neural networks, and an introduction to statistical learning theory.
Terms Offered: Spring
Prerequisite(s): Consent of instructor
Equivalent Course(s): CAAM 37710, CMSC 35400

STAT 37790. Topics in Statistical Machine Learning. 100 Units.
Topics in Statistical Machine Learning” is a second graduate level course in machine learning, assuming students have had previous exposure to machine learning and statistical theory. The emphasis of the course is on statistical methodology, learning theory, and algorithms for large-scale, high dimensional data. The selection of topics is influenced by recent research results, and students can take the course in more than one quarter.
Terms Offered: To be determined
Equivalent Course(s): CMSC 35425

STAT 37810. Statistical Computing A. 50 Units.
This course is an introduction to statistical programming in R. Students will learn how to design, write, debug and test functions by implementing several famous algorithms in statistics such as Gibbs Sampling and Expectation Maximization. A basic familiarity with R is needed, but no prior programming experience is required. The course will also introduce students to the use of version control with Git and consider the differences and similarities between R and Python.
Terms Offered: Autumn
Prerequisite(s): Instructor consent.

STAT 37820. Statistical Computing B. 50 Units.
Statistical Computing B focuses on common data technology used in statistical computing and broader data science. The course takes place in the second half of the autumn quarter, after STAT 37810 (Statistical Computing A). Topics include storage and accessing of large data; basic working knowledge of relational database and its querying language SQL; introduction to distributed file system and example usage of Hadoop; Python and its applications in text analysis; access and usage of high-performance computer clusters, rudimentary parallel computing, web data access. XML and Javascript may be used occasionally. A short introduction to SAS will be given if time permits. The main computing software will be Python with some R.
Terms Offered: Autumn
Prerequisite(s): Instructor consent. STAT 37810 recommended.

STAT 38100. Measure-Theoretic Probability I. 100 Units.
This course provides a detailed, rigorous treatment of probability from the point of view of measure theory, as well as existence theorems, integration and expected values, characteristic functions, moment problems, limit laws, Radon-Nikodym derivatives, and conditional probabilities.
Terms Offered: Winter
Prerequisite(s): STAT 30400 or consent of instructor

STAT 38300. Measure-Theoretic Probability III. 100 Units.
This course continues material covered in STAT 38100, with topics that include Lp spaces, Radon-Nikodym theorem, conditional expectation, and martingale theory.
Terms Offered: Spring
Prerequisite(s): STAT 38100

STAT 38510. Brownian Motion and Stochastic Calculus. 100 Units.
This is a rigorous introduction to the mathematical theory of Brownian motion and the corresponding integration theory (stochastic integration). This is material that all analysis graduate students should learn at some point whether or not they are immediately planning to use probabilistic techniques. It is also a natural course for more advanced math students who want to broaden their mathematical education and to increase their marketability for nonacademic positions. In particular, it is one of the most fundamental mathematical tools used in financial mathematics (although we will not discuss finance in this course). This course differs from the more applied STAT 39000 in that concepts are developed precisely and rigorously.
Terms Offered: Autumn
Prerequisite(s): STAT 38300; or MATH 31200, MATH 31300, and MATH 31400; or consent of instructor.
Equivalent Course(s): MATH 38511
STAT 38620. Social Networks, Probability, Learning, and Game Theory. 100 Units.
This is a research oriented topic course aimed at graduate students. We will first cover some basics of social networks including structure and analysis of such networks and models that abstract their basic properties. Then we will focus on some recent research on a few selected topics/models, and aim to discuss one representative example in each of the following topics: (1) Probabilistic models and statistical learning based on empirical observation; (2) Stochastic processes (such as spread of information) and game-theoretical behavior on social networks as well as corresponding optimization problems; (3) Connections with social choices relating to collective decision making; (4) Some algorithmic aspects of networks. The students should have solid knowledge in at least two of the following areas: (1) Probability theory (either 31200-31300 or 38100-38300), (2) Statistics (either 24400-24500-24610 or 30400-30100-30210), (3) Basic knowledge in game theory and algorithms. In addition, students should be comfortable with undergraduate linear algebra as well as elementary combinatorics.
Prerequisite(s): Consent of instructor. Students need to be familiar with two out of the following three: probability (no need for measure theory)/statistics/game theory (at intro level).

STAT 38660. Random Planar Geometry. 100 Units.
This is a research topic course on certain aspects of random planar geometry. The two central models to be discussed are Liouville quantum gravity which arises from exponentiating a two-dimensional Gaussian free field, as well as uniform infinite planar triangulation/quadrangulation. We will mainly focus on the discrete perspectives of these models, but will also at times discuss the connections to the continuous counterparts. We will concentrate on the metric properties of these random surfaces (including geodesic distances and the electric resistances), as well as their connections to the random motion on these random surfaces.
Prerequisite(s): Recommended 38100/38300 sequence, or experience with measure-theoretical probability.

STAT 39000. Stochastic Calculus. 100 Units.
The course starts with a quick introduction to martingales in discrete time, and then Brownian motion and the Ito integral are defined carefully. The main tools of stochastic calculus (Ito's formula, Feynman-Kac formula, Girsanov theorem, etc.) are developed. The treatment includes discussions of simulation and the relationship with partial differential equations. Some applications are given to option pricing, but much more on this is done in other courses. The course ends with an introduction to jump process (Levy processes) and the corresponding integration theory. Program requirement.
Instructor(s): G. Lawler
Terms Offered: Winter
Equivalent Course(s): FINM 34500

STAT 39800. Field Research. 300.00 Units.
This Summer Quarter course offers graduate students in the Statistics Department the opportunity to apply statistics knowledge that they have acquired to a real industry or business situation. During the summer quarter in which they are registered for the course, students complete a paid or unpaid internship of at least six weeks. Prior to the start of the work experience, students secure faculty consent for an independent study project to be completed during the internship quarter.
Terms Offered: Summer only
Prerequisite(s): Masters or PhD student in Statistics or Consent of instructor and faculty advisor.

STAT 39900. Masters Seminar: Statistics. 300.00 Units.
This course is for Statistics Master's students to carry out directed reading or guided work on topics related to their Master's papers.
Prerequisite(s): Masters or PhD student in Statistics

STAT 40100. Reading/Research: Statistics. 300.00 Units.
This course allows doctoral students to receive credit for advanced work related to their dissertation topics. Students register for one of the listed faculty sections with prior consent from the respective instructor. Students may work with faculty from other departments; however, they still must obtain permission from and register with one of the listed faculty members in the Department of Statistics.
Terms Offered: All quarters
Prerequisite(s): Masters or PhD student in Statistics or consent of instructor

STAT 41500-41600. High-Dimensional Statistics I-II.
These courses treat statistical problems where the number of variables is very large. Classical statistical methods and theory often fail in such settings. Modern research has begun to develop techniques that can be effective in high dimensions, and that can be understood theoretically. The first quarter introduces a range of statistical frameworks for finding low-dimensional structure in high-dimensional data, such as sparsity in regression, sparse graphical models, or low-rank structure. This quarter emphasizes methods for estimation and inference developed in these areas, along with theoretical analysis of their properties. The second quarter emphasizes foundational aspects of high-dimensional statistics, focusing on principles that are used across a range of problems and are likely to be relevant for methods developed in the future. Topics include "the curse of dimensionality," elements of random matrix theory, properties of high-dimensional covariance matrices, concentration of measure, dimensionality reduction techniques, and handling mis-specified models. The courses may be taken separately.
STAT 41500. High-Dimensional Statistics I. 100 Units.
These courses treat statistical problems where the number of variables is very large. Classical statistical methods and theory often fail in such settings. Modern research has begun to develop techniques that can be effective in high dimensions, and that can be understood theoretically. The first quarter introduces a range of statistical frameworks for finding low-dimensional structure in high-dimensional data, such as sparsity in regression, sparse graphical models, or low-rank structure. This quarter emphasizes methods for estimation and inference developed in these areas, along with theoretical analysis of their properties. The second quarter emphasizes foundational aspects of high-dimensional statistics, focusing on principles that are used across a range of problems and are likely to be relevant for methods developed in the future. Topics include "the curse of dimensionality," elements of random matrix theory, properties of high-dimensional covariance matrices, concentration of measure, dimensionality reduction techniques, and handling mis-specified models. The courses may be taken separately.
Prerequisite(s): STAT 30100 and STAT 30400 and STAT 31015, or consent of instructor

STAT 41600. High-Dimensional Statistics II. 100 Units.
These courses treat statistical problems where the number of variables is very large. Classical statistical methods and theory often fail in such settings. Modern research has begun to develop techniques that can be effective in high dimensions, and that can be understood theoretically. The first quarter introduces a range of statistical frameworks for finding low-dimensional structure in high-dimensional data, such as sparsity in regression, sparse graphical models, or low-rank structure. This quarter emphasizes methods for estimation and inference developed in these areas, along with theoretical analysis of their properties. The second quarter emphasizes foundational aspects of high-dimensional statistics, focusing on principles that are used across a range of problems and are likely to be relevant for methods developed in the future. Topics include "the curse of dimensionality," elements of random matrix theory, properties of high-dimensional covariance matrices, concentration of measure, dimensionality reduction techniques, and handling mis-specified models. The courses may be taken separately.
Prerequisite(s): STAT 30100 or STAT 30400 or STAT 31015, or consent of instructor

STAT 41510. Bayesian Nonparametrics. 100 Units.
Bayesian nonparametric methods are increasingly important tools in machine learning and statistics. We will discuss nonparametric Bayesian approaches to mixture models, latent feature models, hierarchical models, network models, and high-dimensional regression models. Topics that will be covered include Dirichlet process, Chinese restaurant process, Pitman-Yor process, Indian buffet process, Gaussian process, and their computational techniques via Gibbs sampling and variational inference. Frequentist evaluations of posterior distributions will also be discussed in nonparametric and high-dimensional settings.
Instructor(s): C. Gao Terms Offered: Not offered in 2019-2020.
Prerequisite(s): STAT 30200

STAT 41520. Topics in Selective Inference. 100 Units.
This course will study the problem of selective inference where we would like to provide statistical guarantees about hypotheses or parameters whose definitions are influenced by our analysis of the same data set. Performing valid inference is challenging since we must find a way to condition on the outcome of the selection process which is not always simple to characterize. The course will discuss both recent advances and open problems in this field.
Instructor(s): R. Barber Terms Offered: Spring
Prerequisite(s): STAT 27850/30850 or STAT 30200 or consent of instructor

STAT 41600. High-Dimensional Statistics II. 100 Units.
These courses treat statistical problems where the number of variables is very large. Classical statistical methods and theory often fail in such settings. Modern research has begun to develop techniques that can be effective in high dimensions, and that can be understood theoretically. The first quarter introduces a range of statistical frameworks for finding low-dimensional structure in high-dimensional data, such as sparsity in regression, sparse graphical models, or low-rank structure. This quarter emphasizes methods for estimation and inference developed in these areas, along with theoretical analysis of their properties. The second quarter emphasizes foundational aspects of high-dimensional statistics, focusing on principles that are used across a range of problems and are likely to be relevant for methods developed in the future. Topics include "the curse of dimensionality," elements of random matrix theory, properties of high-dimensional covariance matrices, concentration of measure, dimensionality reduction techniques, and handling mis-specified models. The courses may be taken separately.
Prerequisite(s): STAT 30100 or STAT 30400 or STAT 31015, or consent of instructor

STAT 42510. Theoretical Neuroscience: Single Neuron Dynamics and Computation. 100 Units.
This course is the first part of a three-quarter sequence in theoretical/computational neuroscience. It will focus on mathematical models of single neurons. Topics will include: basic biophysical properties of neurons; Hodgkin-Huxley model for action potential generation; 2D models, phase-plane analysis, and bifurcations leading to action potential generation; integrate-and-fire-type models; noise; characterization of neuronal activity with stochastic inputs; spatially extended models; models of synaptic currents and synaptic plasticity; unsupervised learning; supervised learning; reinforcement learning.
Prerequisite(s): Prior exposure to differential equations, linear algebra, probability theory
Equivalent Course(s): CPNS 35510
STAT 42520. Theoretical Neuroscience: Network Dynamics and Computation. 100 Units.
This course is the second part of a three-quarter sequence in theoretical/computational neuroscience. It will focus on mathematical models of networks of neurons. Topics will include: firing rate models for populations of neurons; spatially extended firing rate models; models of visual cortex; models of brain networks at different levels; characterization of properties of specific brain networks; models of networks of binary neurons; mean rates, correlations, reductions to rate models; learning in networks of binary neurons, associative memory models; models of networks of spiking neurons: asynchronous vs synchronous states; oscillations in networks of spiking neurons; learning in networks of spiking neurons; models of working memory; models of decision-making.
Terms Offered: Not offered in 2019-2020
Prerequisite(s): Prior exposure to differential equations, linear algebra, probability theory, STAT 42510 or instructor consent.
Equivalent Course(s): CPNS 35520

STAT 42600. Theoretical Neuroscience: Statistics and Information Theory. 100 Units.
This course begins with an introduction to inference and statistical methods in data analysis. We then cover the two main sections of the course: 1) Encoding and II) Decoding in single neurons and neural populations. The encoding section will cover receptive field analysis (STA, STC and non-linear methods such as maximally informative dimensions) and will explore linear-nonlinear-Poisson models of neural encoding as well as generalized linear models alongside newer population coding models. The decoding section will cover basic methods for inferring stimuli or behaviors from spike train data, including both linear and correlational approaches to population decoding. The course will use examples from real data (where appropriate) in the problem sets which students will solve using MATLAB.
Prerequisite(s): Prior exposure to basic calculus and probability theory, CPNS 35500 or instructor consent.
Equivalent Course(s): ORGB 42600, CPNS 35600

STAT 44100. Consulting In Statistics. 300.00 Units.
This seminar course is an internal training program for graduate students in Statistics. The primary goal is to expose the students to applications that involve statistical thinking and to have hands on experience on real world data. The projects are provided by researchers from the university community. Participating students form teams to work on selected projects under faculty guidance and to present their work to all student consultants and researcher clients.

STAT 45800. Workshop on Collaborative Research in Statistics, Computing, and Science. 100 Units.
This course aims to bring together researchers with expertise in statistics, computation, and basic sciences, to work together to produce a solution to a particular problem. The problem we will focus on is the following: how can we improve the way that statistical comparisons are performed? No knowledge of this problem is assumed: it will be introduced in full at the start of the class, together with an outline for an initial proposed approach to addressing the problem. In brief the motivation is as follows: Many new statistical methods are published without any software implementation, and without any comparisons with existing methods. Even when comparisons are made, usually the comparisons are performed by a single research group who has developed one of the methods, raising the concern that the comparison may unfairly favor this method. Indeed, this problem is almost inevitable, even if the authors are extremely fastidious: any research group will have different levels of expertise with different methods, and tend to be more effective in applying their own method. Indeed, getting a method to work well for a particular problem may in itself be a research project. On top of this, performing these kinds of comparisons is incredibly time-consuming: at a minimum one has to familiarize oneself with a range of software products, their input/output requirements, and their various run-time options; create an infrastructure for running them; and write comparison scripts.
Prerequisite(s): Consent of instructor

STAT 48100. Proseminar in Probability. 100 Units.
This course will explore topics of current research interest in probability theory and stochastic processes. Students will be expected to give presentations based on research articles chosen after consultation with the instructors.
Terms Offered: To be determined.
Prerequisite(s): Consent of instructor

STAT 70000. Advanced Study: Statistics. 300.00 Units.
Advanced Study: Statistics
Font Notice

This document should contain certain fonts with restrictive licenses. For this draft, substitutions were made using less legally restrictive fonts. Specifically:

- Times was used instead of Trajan.
- Times was used instead of Palatino.

The editor may contact Leepfrog for a draft with the correct fonts in place.