DEPARTMENT OF STATISTICS AND OPERATIONS RESEARCH (GRAD)

The department offers the master of science (M.S.) in statistics, analytics, and data science (STANDS) and doctor of philosophy (Ph.D.) in statistics and operations research (STOR).

The M.S. program is intended for students who wish to pursue careers in data science and analytics or as a preparation for continuing on to further graduate studies in related areas. This program focuses on training students in advanced quantitative thinking due to the increasing demand for skills in data-driven decision making in the modern world. It is possible for motivated students to complete the requirements in three semesters, though the typical duration is four. For students graduating with an undergraduate STAN degree, there is also an option of five-year M.S.-STANDS program.

The Ph.D. degree in STOR is designed for students planning a career in teaching or research. The educational and research profile of the STOR Ph.D. program is focused on the core disciplines of statistics, optimization, probability, and stochastic modeling. These disciplines have driven, and continue to drive, progress in data science and machine learning, as well as business and medical analytics. The STOR Department is one of the few in the U.S. that brings together experts in each of these disciplines under one academic roof. STOR offers a rigorous but flexible interdisciplinary Ph.D. program within which students can benefit from the strength and diverse expertise of the department's core faculty, while also having the opportunity to interact with domain scientists and researchers working in other fields. STOR Ph.D. students complete foundational coursework in the four core disciplines before undertaking more specialized coursework and directed dissertation research. Dissertation research is completed under the supervision of one or more faculty advisers. Research topics may lie within a single core discipline, or may span several core disciplines. Many research topics involve interdisciplinary research, with active collaboration with faculty and students at UNC including Environmental Sciences, Biology, the Lineberger Comprehensive Cancer Center, Computer Science, Biostatistics, Economics, and the Carolina Center for Genome Sciences, as well as industry in the Research Triangle Park and across the U.S. The breadth and depth of the STOR Ph.D. program prepares graduates for a wide variety of careers, ranging from academia to industry, and from the public to the private sector. Recent graduates have taken jobs in mathematics, statistics, IE, OR departments, and high-tech, biotech companies, and government agencies, etc. The Ph.D. degree requires at least three (but usually five) years of full-time graduate study, predicated upon substantial undergraduate mathematical preparation. Research is a central component in the work of doctoral candidates. Research training consists of required core coursework as well as electives that are designed to bring students up to date in their research field and intensive one-on-one work with a faculty member on a specific dissertation topic. Doctoral students who want to pursue academic careers are provided with ample opportunities to teach introductory undergraduate courses, and they are given extensive training to develop their instructional skills. Doctoral students may also participate in paid internships with local industrial employers to gain experience in a business environment. Their professional skills are further enhanced by work on real-world projects with clients in the department's consulting courses. Several courses provide opportunities for students to give technical presentations and refine their communication skills.

Further information on the graduate degree programs can be obtained from the department's website (https://stor.unc.edu/).

Admissions and Financial Aid

Admission to the department is highly competitive, and preference is given to applicants who have solid technical preparation. Although the department welcomes promising students from all disciplines, entering students must have a substantial mathematical background and applicants must satisfy the entrance requirements of The Graduate School. A student admitted with a deficiency in any area must make up for it at the beginning of her or his graduate work. If the deficiency is not severe, this can be accomplished without interrupting the normal program.

Application form (http://gradschool.unc.edu/admissions/)

Students can indicate on this application form (http://gradschool.unc.edu/admissions/) whether they intend to pursue the M.S. degree program or a Ph.D.

Funding basics (https://gradschool.unc.edu/funding/basics/fundingbasics.html) including links for financial aid are provided by The Graduate School.

Most of our Ph.D. students receive some form of financial support, such as Graduate School fellowships, departmental assistantships, research assistantships, or internships. Departmental assistantships involve grading or teaching an undergraduate course. Some of our students are supported as research assistants by faculty. Our supported students receive a tuition and fee waiver, and health insurance for the duration of their studies.

Degree Requirements

M.S. Program

The M.S. degree requires 30 credit hours of coursework and the completion of a master's project. Students can choose from a variety of courses, including a limited number from outside the department. Upon approval of The Graduate School, at most six credit hours may be transferred from another accredited institution or from within UNC–Chapel Hill for courses taken before admission to the M.S. program.

Ph.D. Program

The Ph.D. degree requires at least 45 semester hours of graduate coursework and the successful completion of a doctoral dissertation. Detailed information about specific courses, elective courses and allowable courses outside of the STOR department as well as potential course plans based on interests of accepted students are provided on the graduate admissions section of the program's website (https://stor.unc.edu/phd/program/).

Statistics Courses for Students From Other Disciplines

A number of STOR courses in probability and statistics are of potential interest to students in other disciplines. At the advanced undergraduate/beginning graduate level, STOR 455 and STOR 556, provide an introduction to applied statistics, including regression, analysis of variance, and time series. STOR 435, STOR 535, and STOR 555 provide introductions to probability theory and mathematical statistics,

respectively, at a postcalculus level while courses like STOR 538 and STOR 572 describe applications of the discipline to fundamental areas such as sports analytics and healthcare analytics.

The three graduate course sequences–(STOR 664, STOR 665), (STOR 654, STOR 655), and (STOR 634, STOR 635)–provide comprehensive introductions to modern applied statistics, theoretical statistics, and probability theory, respectively, at a more mathematical level. In each case it is possible to take only the first course in the sequence. Concerning mathematical prerequisites, STOR 664 and STOR 665 require a background in linear algebra and matrix theory, while the remaining courses require a solid background in real analysis.

Following the faculty member's name is a section number that students should use when registering for independent studies, reading, research, and thesis and dissertation courses with that particular professor.

Professors

Nilay Argon (1), Stochastic Models, Manufacturing and Healthcare Applications, Discrete Event Simulation
Shankar Bhamidi (5), Probability, Random Networks, MCMC, Probabilistic Combinatorial Optimization
Amarjit Budhiraja (2), Probability, Stochastic Analysis, Large Deviations
Jan Hannig (14), Statistics, Fiducial Inference, Stochastic Processes
Vidyadhar G. Kulkarni (6), Stochastic Models of Queues, Healthcare Systems, Supply Chains, Telecommunication Systems, Warranties
Yufeng Liu (8), Carolina Center for Genome Sciences**,** Statistical Machine Learning, Data Mining, Bioinformatics, Experimental Designs
James Stephen Marron (10), (Amos Hawley Distinguished Professor), Object-Oriented Data Analysis, Visualization, Smoothing
Andrew Nobel (11), (Paul Ziff Distinguished Professor), Machine Learning, Data Mining, Computational Genomics
Marianna Olvera-Cravioto (20), Applied Probability, Random Graphs, Heavy-Tailed Large Deviations, Weighted Branching Processes, Stochastic Simulation
Gabor Pataki (12), Convex Programming, Integer Programming
Vladas Pipiras (13), Time Series and Spatial Modeling, Extreme Value Theory, Streaming and Sampling Algorithms
Richard L. Smith (7), (Mark L. Reed Distinguished Professor), Extreme Value Theory, Environmental Statistics, Spatial Statistics
Serhan Ziya (15), Stochastic Modeling, Healthcare Operations, Service Operations, Queueing Design and Control, Revenue Management

Associate Professors

Sayan Banerjee (18), Stochastic Analysis, Probabilistic Couplings, Interacting Particle Systems
Nicolas Fraiman (19), Random Structures, Combinatorial Statistics, Randomized Algorithms
Chuanshu Ji (4), Financial Econometrics, Computational Materials Science, Monte Carlo Methods
Quoc Tran-Dinh (17), Numerical Optimization, Theory and Algorithms for Convex Optimization and Nonconvex Continuous Optimization
Kai Zhang (16), Mathematical Statistics, High Dimensional Inference, Inference After Variable Selection, Large Deviation, Quantum Computing

Assistant Professors

Guanting Chen (9), Sequential Decision Making and Learning Algorithms, Simulation and Applied Probability, Optimization and Applications in Operations Management
Xiangying Huang (22), Interacting Particle Systems, Spatial Stochastic Models, Algorithms on Random Graphs, Dynamic Random Networks
Daniel Kessler (30), Statistical Analysis of Networks, Post-Selective Inference, High-Dimensional Statistics, Human Neuroimaging, Computational and Cognitive Neuroscience, High Performance Computing
Patrick Lopatto (31), Probability Theory and Applications, Causal Inference, Random Matrix Theory
Yao Li (3), Machine Learning, Deep Learning, Adversarial Examples, Recommender System
Michael O'Neill (23), Continuous Nonlinear Optimization, Stochastic Optimization Algorithms, Machine Learning and Data Science Applications
Zhengwu Zhang (21), Brain Connectomics, Medical Imaging, Machine Learning, Bayesian Statistics, Shape and Functional Data Analysis

Teaching Associate Professor

Jeffrey McLean, Statistics

Teaching Assistant Professors

Oluremi Abayomi, Statistics, Data Science
Charles Dunn, Actuarial Models
Mario Giacomazzo, Statistics
William Lassiter, Operations Research

Joint Professors

Joseph Ibrahim, (Alumni Distinguished Professor of Biostatistics), Bayesian Methods, Missing Data, Cancer Research
Michael Kosorok, (Biostatistics), Biostatistics, Empirical Processes, Semiparametric Inference, Machine Learning, Personalized Medicine, Clinical Trials, Dynamic Treatment Regimes
Jayashankar Swaminathan, (Benjamin Cone Research Professor, Kenan–Flagler Business School), Supply Chain, Stochastic Models

Professors Emeriti

George S. Fishman
Douglas G. Kelly
J. Scott Provan
David S. Rubin
Gordon D. Simons
Shaler Stidham Jr.
Jon W. Tolle

STOR

Advanced Undergraduate and Graduate-level Courses

STOR 415. Introduction to Optimization. 3 Credits.
Linear, integer, nonlinear, and dynamic programming, classical optimization problems, network theory.

Rules & Requirements
Requisites: Prerequisites, MATH 347 and STOR 315, 215 or MATH 381.
Grading Status: Letter grade.

STOR 435. Introduction to Probability. 3 Credits.
Introduction to mathematical theory of probability covering random variables; moments; binomial, Poisson, normal and related distributions; generating functions; sums and sequences of random variables; and statistical applications. Students may not receive credit for both STOR 435 and STOR 535.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisites, MATH/STOR 235 or MATH 233; and STOR 215 or MATH 381 or COMP 283.
Grading Status: Letter grade.
Same as: MATH 535.

STOR 445. Stochastic Modeling. 3 Credits.
Introduction to Markov chains, Poisson process, continuous-time Markov chains, renewal theory. Applications to queueing systems, inventory, and reliability, with emphasis on systems modeling, design, and control.

Rules & Requirements
Requisites: Prerequisite, BIOS 660, STOR 435 or 535.
Grading Status: Letter grade.

STOR 455. Methods of Data Analysis. 3 Credits.
Review of basic inference; two-sample comparisons; correlation; introduction to matrices; simple and multiple regression (including significance tests, diagnostics, variable selection); analysis of variance; use of statistical software.

Rules & Requirements
Requisites: Prerequisite, STOR 120, or 155.
Grading Status: Letter grade.

STOR 471. Long-Term Actuarial Models. 3 Credits.
Probability models for long-term insurance and pension systems that involve future contingent payments and failure-time random variables. Introduction to survival distributions and measures of interest and annuities-certain.

Rules & Requirements
Making Connections Gen Ed: QI.
Requisites: Prerequisite, STOR 435, or 535.
Grading Status: Letter grade.

STOR 472. Short Term Actuarial Models. 3 Credits.
Short term probability models for potential losses and their applications to both traditional insurance systems and conventional business decisions. Introduction to stochastic process models of solvency requirements.

Rules & Requirements
Requisites: Prerequisite, STOR 435, or 535.
Grading Status: Letter grade.

STOR 475. Healthcare Risk Analytics. 3 Credits.
This course will introduce students to the healthcare industry and provide hands-on experience with key actuarial and analytical concepts that apply across the actuarial field. Using real world situations, the course will focus on how mathematics and the principles of risk management are used to help insurance companies and employers make better decisions regarding employee benefit insurance products and programs.

Rules & Requirements
Requisites: Prerequisite, STOR 435, or 535.
Grading Status: Letter grade.

STOR 490. Special Topics. 3 Credits.
Examines selected topics from statistics and operations research. Course description is available from the department office.

Rules & Requirements
Repeat Rules: May be repeated for credit. 12 total credits. 4 total completions.
Grading Status: Letter grade.

STOR 493. Internship in Statistics and Operations Research. 3 Credits.
Requires permission of the department. Statistics and analytics majors only. An opportunity to obtain credit for an internship related to statistics, operations research, or actuarial science. Pass/Fail only. Does not count toward the statistics and analytics major or minor.

Rules & Requirements
IDEAs in Action Gen Ed: HI-INTERN.
Making Connections Gen Ed: EE- Academic Internship.
Repeat Rules: May be repeated for credit. 6 total credits. 2 total completions.
Grading Status: Pass/Fail.

STOR 496. Undergraduate Reading and Research in Statistics and Operations Research. 1-3 Credits.
Permission of the director of undergraduate studies. This course is intended mainly for students working on honors projects. May be repeated for credit.

Rules & Requirements
IDEAs in Action Gen Ed: RESEARCH.
Making Connections Gen Ed: EE- Mentored Research.
Repeat Rules: May be repeated for credit; may be repeated in the same term for different topics; 6 total credits. 6 total completions.
Grading Status: Letter grade.

STOR 512. Optimization for Machine Learning and Neural Networks. 3 Credits.
This is an upper-level course focusing on optimization aspects of common and practical problems and topics in statistical learning, machine learning, neural networks, and modern AI. It covers several topics such as optimization perspective of linear regression, nonlinear regression, matrix factorization, stochastic gradient descent, regularization techniques, neural networks, deep learning techniques, and minimax models.

Rules & Requirements
Requisites: Prerequisites, STOR 415 or STOR 612; or MATH 233 and MATH 347, or MATH 235, and COMP 110 or COMP 116; or permission of instructor.
Grading Status: Letter grade.

STOR 515. Dynamic Decision Analytics. 3 Credits.
An introduction to algorithms and modeling techniques that use knowledge gained from prior experience to make intelligent decisions in real time. Topics include Markov decision processes, dynamic programming, multiplicative weights update, exploration vs. exploitation, multi-armed bandits, and two player games.

Rules & Requirements
Requisites: Prerequisites, STOR 435 or 535, and MATH 347.
Grading Status: Letter grade.

STOR 520. Statistical Computing for Data Science. 4 Credits.
This course provides hands-on experience working with data sets provided in class and downloaded from certain public websites. Lectures cover basic topics such as R programming, visualization, data wrangling and cleaning, exploratory data analysis, web scraping, data merging, predictive modeling, and elements of machine learning. Programming analyses in more advanced areas of data science. Students may not receive credit for both STOR 320 and STOR 520.

Rules & Requirements
Requisites: Prerequisites, STOR 435 or 535, and STOR 455.
Grading Status: Letter grade.

STOR 535. Probability for Data Science. 3 Credits.
This course is an advanced undergraduate course in probability with the aim to give students the technical and computational tools for advanced courses in data analysis and machine learning. It covers random variables, moments, binomial, Poisson, normal and related distributions, generating functions, sums and sequences of random variables, statistical applications, Markov chains, multivariate normal and prediction analytics. Students may not receive credit for both STOR 435 and STOR 535.

Rules & Requirements
Requisites: Prerequisites, MATH/STOR 235 or MATH 233; and STOR 215 or STOR 315 or MATH 381 or COMP 283.
Grading Status: Letter grade.

STOR 538. Sports Analytics. 3 Credits.
This course will survey the history of sports analytics across multiple areas and challenge students in team-based projects to practice sports analytics. Students will learn how applied statistics and mathematics help decision makers gain competitive advantages for on-field performance and off-field business decisions.

Rules & Requirements
Requisites: Prerequisite, STOR 320 or STOR 455.
Grading Status: Letter grade.

STOR 555. Mathematical Statistics. 3 Credits.
Functions of random samples and their probability distributions, introductory theory of point and interval estimation and hypothesis testing, elementary decision theory.

Rules & Requirements
Requisites: Prerequisite, STOR 435, or 535.
Grading Status: Letter grade.

STOR 556. Time Series Data Analysis. 3 Credits.
This course covers the fundamental theory and methods for time series data, as well as related statistical software and real-world data applications. Topics include the autocorrelation function, estimation and elimination of trend and seasonality, estimation and forecasting procedures in ARMA models and nonstationary time series models.

Rules & Requirements
Requisites: Prerequisites, STOR 435 or 535, and STOR 455.
Grading Status: Letter grade.

STOR 557. Advanced Methods of Data Analysis. 3 Credits.
The course covers advanced data analysis methods beyond those in STOR 455 and how to apply them in a modern computer package, specifically R or R-Studio which are the primary statistical packages for this kind of analysis. Specific topics include (a) Generalized Linear Models; (b) Random Effects; (c) Bayesian Statistics; (d) Nonparametric Methods (kernels, splines and related techniques).

Rules & Requirements
Requisites: Prerequisites, STOR 435 or 535, and STOR 455.
Grading Status: Letter grade.

STOR 565. Machine Learning. 3 Credits.
Introduction to theory and methods of machine learning including classification; Bayes risk/rule, linear discriminant analysis, logistic regression, nearest neighbors, and support vector machines; clustering algorithms; overfitting, estimation error, cross validation.

Rules & Requirements
Requisites: Prerequisites, STOR 215 or MATH 381, and STOR 435 or 535.
Grading Status: Letter grade.

STOR 566. Introduction to Deep Learning. 3 Credits.
Deep neural networks (DNNs) have been widely used for tackling numerous machine learning problems that were once believed to be challenging. With their remarkable ability of fitting training data, DNNs have achieved revolutionary successes in many fields such as computer vision, natural language progressing, and robotics. This is an introduction course to deep learning.

Rules & Requirements
Requisites: Prerequisites, STOR 435 or 535; and COMP 110 or 116.
Grading Status: Letter grade.

STOR 572. Simulation for Analytics. 3 Credits.
This upper-level-undergraduate and beginning-graduate-level course introduces the concepts of modeling, programming, and statistical analysis as they arise in stochastic computer simulations. Topics include modeling static and discrete-event simulations of stochastic systems, random number generation, random variate generation, simulation programming, and statistical analysis of simulation input and output.

Rules & Requirements
Requisites: Prerequisites, STOR 120 or 155, and STOR 435 or 535.
Grading Status: Letter grade.

STOR 590. Special Topics in Statistics and Operations Research. 3 Credits.
Examines selected topics from statistics and operations research. Course description is available from the department office.

Rules & Requirements
Repeat Rules: May be repeated for credit; may be repeated in the same term for different topics; 12 total credits. 4 total completions.
Grading Status: Letter grade.

STOR 612. Foundations of Optimization. 3 Credits.
STOR 612 consists of three major parts: linear programming, quadratic programming, and unconstrained optimization. Topics: Modeling, theory and algorithms for linear programming; modeling, theory and algorithms for quadratic programming; convex sets and functions; first-order and second-order methods such as stochastic gradient methods, accelerated gradient methods and quasi-Newton methods for unconstrained optimization.

Rules & Requirements
Requisites: Prerequisites, MATH 347 and 521 or permission of the instructor.
Grading Status: Letter grade.

STOR 614. Advanced Optimization. 3 Credits.
STOR 614 consists of three major parts: Integer programming, conic programming, and nonlinear optimization. Topics: modeling, theory and algorithms for integer programming; second-order cone and semidefinite programming; theory and algorithms for constrained optimization; dynamic programming; networks.

Rules & Requirements
Requisites: Prerequisite, STOR 612 or equivalent (or permission of instructor).
Grading Status: Letter grade.

STOR 634. Probability I. 3 Credits.
Required preparation, advanced calculus. Lebesgue and abstract measure and integration, convergence theorems, differentiation. Radon-Nikodym theorem, product measures. Fubini theorems. Lp spaces.

Rules & Requirements
Grading Status: Letter grade.

STOR 635. Probability II. 3 Credits.
Foundations of probability. Basic classical theorems. Modes of probabilistic convergence. Central limit problem. Generating functions, characteristic functions. Conditional probability and expectation.

Rules & Requirements
Requisites: Prerequisite, STOR 634; permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.
Same as: MATH 635.

STOR 641. Stochastic Modeling I. 3 Credits.
The aim of this 3-credit graduate course is to introduce stochastic modeling that is commonly used in various fields such as operations research, data science, engineering, business, and life sciences. Although it is the first course in a sequence of three courses, it can also serve as a standalone introductory course in stochastic modeling and analysis. The course covers the following topics: discrete-time Markov chains, Poisson processes, and continuous-time Markov chains.

Rules & Requirements
Requisites: Prerequisite, Probability background at the level of STOR 435 or STOR 535.
Grading Status: Letter grade.

STOR 642. Stochastic Modeling II. 3 Credits.
This 3-credit course is the second graduate-level course on stochastic modeling that expands upon the material taught in STOR 641. The course covers the following topics: renewal and regenerative processes, queueing models, and Markov decision processes.

Rules & Requirements
Requisites: Prerequisite, STOR 641.
Grading Status: Letter grade.

STOR 654. Statistical Theory I. 3 Credits.
Required preparation, two semesters of advanced calculus. Probability spaces. Random variables, distributions, expectation. Conditioning. Generating functions. Limit theorems: LLN, CLT, Slutsky, delta-method, big-O in probability. Inequalities. Distribution theory: normal, chi-squared, beta, gamma, Cauchy, other multivariate distributions. Distribution theory for linear models.

Rules & Requirements
Grading Status: Letter grade.

STOR 655. Statistical Theory II. 3 Credits.
Point estimation. Hypothesis testing and confidence sets. Contingency tables, nonparametric goodness-of-fit. Linear model optimality theory: BLUE, MVU, MLE. Multivariate tests. Introduction to decision theory and Bayesian inference.

Rules & Requirements
Requisites: Prerequisite, STOR 654.
Grading Status: Letter grade.

STOR 664. Applied Statistics I. 3 Credits.
Permission of the instructor. Basics of linear models: matrix formulation, least squares, tests. Computing environments: SAS, MATLAB, S +. Visualization: histograms, scatterplots, smoothing, QQ plots. Transformations: log, Box-Cox, etc. Diagnostics and model selection.

Rules & Requirements
Grading Status: Letter grade.

STOR 665. Applied Statistics II. 3 Credits.
ANOVA (including nested and crossed models, multiple comparisons). GLM basics: exponential families, link functions, likelihood, quasi-likelihood, conditional likelihood. Numerical analysis: numerical linear algebra, optimization; GLM diagnostics. Simulation: transformation, rejection, Gibbs sampler.

Rules & Requirements
Requisites: Prerequisite, STOR 664; permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.

STOR 672. Simulation Modeling and Analysis. 3 Credits.
Introduces students to modeling, programming, and statistical analysis applicable to computer simulations. Emphasizes statistical analysis of simulation output for decision-making. Focuses on discrete-event simulations and discusses other simulation methodologies such as Monte Carlo and agent-based simulations. Students model, program, and run simulations using specialized software. Familiarity with computer programming recommended.

Rules & Requirements
Requisites: Prerequisites, STOR 555 and 641.
Grading Status: Letter grade.
Same as: COMP 672.

STOR 674. Statistical and Computational Tools for Reproducible Data Science. 3 Credits.
The purpose of this course is to provide a strong foundation in computational skills needed for reproducible research in data science and statistics. Topics will include computational tools and programming skills to facilitate reproducibility, as well as procedures and methods for reproducible conclusions.

Rules & Requirements
Requisites: Prerequisite, STOR 320 or 664.
Grading Status: Letter grade.

STOR 690. Special Topics. 3 Credits.
Examines selected topics from statistics and operations research. Course description is available from the department office.

Rules & Requirements
Repeat Rules: May be repeated for credit. 12 total credits. 4 total completions.
Grading Status: Letter grade.

STOR 691H. Honors in Statistics and Analytics. 3 Credits.
Permission of the department. Majors only. Individual reading, study, or project supervised by a faculty member.

Rules & Requirements
IDEAs in Action Gen Ed: RESEARCH.
Making Connections Gen Ed: EE- Mentored Research.
Grading Status: Letter grade.

STOR 692H. Honors in Statistics and Analytics. 3 Credits.
Permission of the department. Majors only. Individual reading, study, or project supervised by a faculty member.

Rules & Requirements
IDEAs in Action Gen Ed: RESEARCH.
Making Connections Gen Ed: EE- Mentored Research.
Grading Status: Letter grade.

STOR 697. Capstone. 3 Credits.
This course is designed to give Statistics & Analytics (STAN) majors an opportunity to integrate and apply the knowledge and skills acquired throughout the STAN degree. At the beginning of the semester, the instructor will present to the class a broad description of several problems originating from external industry partners, and covering a wide range of statistics, modeling, optimization, and data science topics. Students will work on these problems throughout the remainder of the semester.

Rules & Requirements
IDEAs in Action Gen Ed: COMMBEYOND.
Requisites: Prerequisite, Students are expected to have completed at least 75% of the core requirements for the STAN major.
Grading Status: Letter grade.

Graduate-level Courses

STOR 701. Statistics and Operations Research Colloquium. 1 Credits.
This seminar course is intended to give Ph.D. students exposure to cutting edge research topics in statistics and operations research and assist them in their choice of a dissertation topic. The course also provides a forum for students to meet and learn from major researchers in the field.

Rules & Requirements
Repeat Rules: May be repeated for credit. 10 total credits. 10 total completions.
Grading Status: Letter grade.

STOR 702. Seminar in Teaching. 1 Credits.
This seminar course is intended to give Ph.D. students exposure to various issues and pedagogy in teaching statistics and operations research. The course also provides a forum for students to observe and learn from current teaching faculty. Students should register for one credit only. STOR Ph.D. students only.

Rules & Requirements
Repeat Rules: May be repeated for credit. 3 total credits. 3 total completions.
Grading Status: Letter grade.

STOR 712. Optimization for Machine Learning and Data Science. 3 Credits.
This course will provide a detailed and deep treatment for commonly used methods in continuous optimization, with applications in machine learning, statistics, data science, operations research, among others.

Rules & Requirements
Requisites: Prerequisite, STOR 612 or equivalent.
Grading Status: Letter grade.

STOR 713. Mathematical Programming II. 3 Credits.
Advanced theory for nonlinear optimization. Algorithms for unconstrained and constrained problems.

Rules & Requirements
Requisites: Prerequisite, STOR 712; permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.

STOR 722. Integer Programming. 3 Credits.
Techniques for formulating and solving discrete valued and combinatorial optimization problems. Topics include enumerative and cutting plane methods, Lagrangian relaxation, Benders' decomposition, knapsack problems, and matching and covering problems.

Rules & Requirements
Requisites: Prerequisite, STOR 614; permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.

STOR 734. Stochastic Processes. 3 Credits.
Discrete and continuous parameter Markov chains, Brownian motion, stationary processes.

Rules & Requirements
Requisites: Prerequisite, STOR 435.
Grading Status: Letter grade.

STOR 743. Reinforcement Learning and Markov Decision Processes. 3 Credits.
Markov decision processes (stochastic dynamic programming): finite horizon, infinite horizon, discounted and average-cost criteria; reinforcement learning(RL): design and analysis of model-free, model-based, value-based, and policy-based RL algorithms, RL algorithms in continuous and discrete state and action space, and RL with functional approximation. These algorithms include but are not limited to (deep) Q-learning, asynchronous advantage actor-critic, soft actor-critic, and proximal policy optimization.

Rules & Requirements
Requisites: Prerequisite, STOR 641 or permission of instructor.
Grading Status: Letter grade.

STOR 754. Time Series and Multivariate Analysis. 3 Credits.
Introduction to time series: exploratory analysis, time-domain analysis and ARMA models, Fourier analysis, state space analysis. Introduction to multivariate analysis: principal components, canonical correlation, classification and clustering, dimension reduction.

Rules & Requirements
Requisites: Prerequisites, STOR 435 and 555.
Grading Status: Letter grade.

STOR 755. Estimation, Hypothesis Testing, and Statistical Decision. 3 Credits.
Bayes procedures for estimation and testing. Minimax procedures. Unbiased estimators. Unbiased tests and similar tests. Invariant procedures. Sufficient statistics. Confidence sets. Large sample theory. Statistical decision theory.

Rules & Requirements
Requisites: Prerequisites, STOR 635 and 655.
Grading Status: Letter grade.

STOR 757. Bayesian Statistics and Generalized Linear Models. 3 Credits.
Bayes factors, empirical Bayes theory, applications of generalized linear models.

Rules & Requirements
Requisites: Prerequisite, STOR 555.
Grading Status: Letter grade.

STOR 765. Statistical Consulting. 1.5 Credits.
Application of statistics to real problems presented by researchers from the University and local companies and institutes. (Taught over two semesters for a total of 3 credits.)

Rules & Requirements
Repeat Rules: May be repeated for credit. 3 total credits. 2 total completions.
Grading Status: Letter grade.

STOR 767. Advanced Statistical Machine Learning. 3 Credits.
This is a graduate course on statistical machine learning.

Rules & Requirements
Requisites: Prerequisites, STOR 654, 655, 664, 665 and permission of the instructor.
Grading Status: Letter grade.

STOR 790. Operations Research and Systems Analysis Student Seminar. 1 Credits.
Survey of literature in operations research and systems analysis.

Rules & Requirements
Grading Status: Letter grade.

STOR 822. Topics in Discrete Optimization. 3 Credits.
Topics may include polynomial algorithms, computational complexity, matching and matroid problems, and the traveling salesman problem.

Rules & Requirements
Requisites: Prerequisite, STOR 712; Permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.
Same as: COMP 822.

STOR 824. Computational Methods in Mathematical Programming. 3 Credits.
Advanced topics such as interior point methods, parallel algorithms, branch and cut methods, and subgradient optimization.

Rules & Requirements
Requisites: Prerequisite, STOR 712; Permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.

STOR 831. Advanced Probability. 3 Credits.
Advanced theoretic course, covering topics selected from weak convergence theory, central limit theorems, laws of large numbers, stable laws, infinitely divisible laws, random walks, martingales.

Rules & Requirements
Requisites: Prerequisites, STOR 634 and 635.
Repeat Rules: May be repeated for credit. 9 total credits. 3 total completions.
Grading Status: Letter grade.

STOR 832. Stochastic Processes. 3 Credits.
Advanced theoretic course including topics selected from foundations of stochastic processes, renewal processes, Markov processes, martingales, point processes.

Rules & Requirements
Requisites: Prerequisites, STOR 634 and 635.
Grading Status: Letter grade.

STOR 834. Extreme Value Theory. 3 Credits.
This course covers both mathematical theory and statistical methodology concerned with extreme values in sequences of random variables. IID theory: the three types of extreme value distributions, statistical methods by block maxima and threshold exceedances. Extensions to dependent stochastic sequences: the extremal index and related concepts. Multivariate and spatial extremes, max-stable process. Applications in: engineering and strength of materials; finance and insurance; environment and climate.

Rules & Requirements
Requisites: Prerequisites, STOR 635 and 654.
Grading Status: Letter grade.

STOR 835. Point Processes. 3 Credits.
Random measures and point processes on general spaces, Poisson and related processes, regularity, compounding. Point processes on the real line stationarity, Palm distributions, Palm-Khintchine formulae. Convergence and related topics.

Rules & Requirements
Requisites: Prerequisite, STOR 635.
Grading Status: Letter grade.

STOR 836. Stochastic Analysis. 3 Credits.
Brownian motion, semimartingale theory, stochastic integrals, stochastic differential equations, diffusions, Girsanov's theorem, connections with elliptic PDE, Feynman-Kac formula. Applications: mathematical finance, stochastic networks, biological modeling.

Rules & Requirements
Requisites: Prerequisites, STOR 634 and 635.
Grading Status: Letter grade.

STOR 854. Statistical Large Sample Theory. 3 Credits.
Asymptotically efficient estimators; maximum likelihood estimators. Asymptotically optimal tests; likelihood ratio tests.

Rules & Requirements
Requisites: Prerequisites, STOR 635 and 655.
Grading Status: Letter grade.

STOR 871. Convex Analysis and Optimization Theory. 3 Credits.
Convex analysis and optimization including sets, functions, basic concepts, minimax theory, duality, and optimality conditions.

Rules & Requirements
Grading Status: Letter grade.

STOR 881. Object Oriented Data Analysis. 1-3 Credits.
Object Oriented Data Analysis (OODA) is the statistical analysis of populations of complex objects. Examples include data sets where the data points could be curves, images, shapes, movies, or tree structured objects.

Rules & Requirements
Grading Status: Letter grade.

STOR 890. Special Problems. 1-3 Credits.
Permission of the instructor.

Rules & Requirements
Repeat Rules: May be repeated for credit.
Grading Status: Letter grade.

STOR 891. Special Problems. 1-3 Credits.
Permission of the instructor.

Rules & Requirements
Repeat Rules: May be repeated for credit; may be repeated in the same term for different topics.
Grading Status: Letter grade.

STOR 892. Special Topics in Operations Research and Systems Analysis. 1-3 Credits.
Permission of the instructor.

Rules & Requirements
Repeat Rules: May be repeated for credit.
Grading Status: Letter grade.

STOR 893. Special Topics. 1-3 Credits.
Advance topics in current research in statistics and operations research.

Rules & Requirements
Repeat Rules: May be repeated for credit; may be repeated in the same term for different topics.
Grading Status: Letter grade.

STOR 894. Special Topics at SAMSI. 3 Credits.
Advanced topics in current research in statistics and operations research. This course is held at SAMSI.

Rules & Requirements
Repeat Rules: May be repeated for credit. 6 total credits. 2 total completions.
Grading Status: Letter grade.

STOR 910. Directed Reading in Statistics and Operations Research. 1-3 Credits.
Students will read selected works under supervision of instructor, and attend discussion meetings. Permission of the instructor.

Rules & Requirements
Repeat Rules: May be repeated for credit. 12 total credits. 12 total completions.
Grading Status: Letter grade.

STOR 930. Advanced Research. 1-3 Credits.
Permission of the instructor.

Rules & Requirements
Grading Status: Letter grade.

STOR 940. Seminar in Theoretical Statistics. 1-3 Credits.
Rules & Requirements
Requisites: Prerequisite, STOR 655.
Repeat Rules: May be repeated for credit.
Grading Status: Letter grade.

STOR 950. Advanced Research. 0.5-21 Credits.
Permission of the instructor.

Rules & Requirements
Grading Status: Letter grade.

STOR 960. Seminar in Theoretical Statistics. 0.5-21 Credits.
Rules & Requirements
Requisites: Prerequisite, STOR 655.
Grading Status: Letter grade.

STOR 970. Practicum. 1-3 Credits.
Students work with other organizations (Industrial/Governmental) to gain practical experience in Statistics and Operations Research.

Rules & Requirements
Repeat Rules: May be repeated for credit.
Grading Status: Letter grade.

STOR 992. Master's (Non-Thesis). 3 Credits.
Permission of instructor.

Rules & Requirements
Repeat Rules: May be repeated for credit.

STOR 994. Doctoral Research and Dissertation. 3 Credits.
Permission of instructor.

Rules & Requirements
Repeat Rules: May be repeated for credit.

Contact Information

Department of Statistics and Operations Research
Visit Program Website (http://stat-or.unc.edu)

Chair
Vladas Pipiras
pipiras@email.unc.edu

Director of Graduate Studies
Nilay Tanık Argon
nilay@unc.edu