Operations Research & Financial Engineering


Class of 2017
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Class of '15

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Class of '16

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Class of '17

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Department Web Page

Additional information on the department can be found at our web site: orfe.princeton.edu

All ORFE department offices are located in Sherrerd Hall.
An Introduction to the Department

Humankind has always faced significant challenges. With today's technology, however, we have the ability to collect vast amounts of data to illuminate the problems and opportunities we face. More importantly, we now can apply an array of robust analytical tools to deepen our understanding of the issues, to help us make better decisions and to develop solutions that will enhance our quality-of-life.

While collecting vast amounts of data is becoming easier, collecting the right data remains very expensive. How does one get from vast data to the right data? How should one analyze, understand and appropriately address uncertainty that is present in essentially all societal endeavors? And, how can one exploit these resources to make the best possible decisions and best contribute to an enhanced quality-of-life? These are precisely the questions that form the core of the Department of Operations Research and Financial Engineering. Problems of this kind have appeared for a long time in the understanding of logistics and management, agriculture, the military and micro- and macro-economics. As our ability to handle more data and complexity has expanded, so has our ability to more deeply address traditional applications and venture to tackle new ones in finance, health care, biology and most aspects of our society. The basic mathematical modeling and analytic skills that lie at the heart of ORFE are now essential prerequisites to almost any quantitative discipline, including areas such as data science and statistics, information technology, energy resource management, health care, risk management, and many others. We view ORFE as the ideal quantitative education for the modern world, whether you see your future as a business leader, health care provider, legal/policy/political professional, data scientist, quantitative analyst, or academic researcher. Even poets might find something to love in ORFE.

ORFE is the intersection of six closely interconnected applied mathematical disciplines and application areas that lie at the heart of all activities in the Department: operations research, financial engineering, machine learning, optimization, statistics and probability. Each of these areas is described in more detail below.

Operations Research

The field of operations research traces its foundations to World War II, although it includes dimensions that go as far back as the early days of the telephone at the beginning of the 20th century. It uses mathematical models and optimization methods to rigorously address quantitative problems in business and management, logistics, health care, energy systems, telecommunications, and transportation. The most common theme that runs through these problems is the efficient management of resources, where resources may be natural resources, economic resources, informational resources, equipment, people, and/or physical facilities. Students in operations research may follow a management track into business or consulting, or a more technical path into research or software development. There is a burgeoning marketplace for sophisticated methods to schedule airlines and railroads or to optimize supply chains for large manufacturing and retail enterprises.
Financial Engineering

Financial engineering uses mathematical models of financial markets to design innovative financial instruments and strategies to meet the specific needs of individuals and corporations, including managing risks and cash flows. To this end, financial engineers analyze and ultimately manage risks within an integrated framework, as compared with traditional piecemeal approaches. Often, new instruments are constructed based on the specific requirements of the investor. Solving these problems in a principled manner requires a combination of diverse analytical methods from applied mathematics, probability and statistics, stochastic processes and stochastic calculus, optimization, financial economics, and computation skills. Students grounded in financial engineering are in great demand: they find jobs on Wall Street and with traditional financial companies such as banks, insurance companies, mutual funds, and financial consulting companies, as well as in the CFO office within mainline corporations.

Machine Learning

Machine Learning is a scientific field that aims to design computer programs and algorithms that can automatically learn from data and improve with experience. Machine Learning is routinely used to make fast and accurate predictions and decisions in problems whose scale is too large for humans to handle. Machine learning lies behind many recent technological advances such as self-driving cars, intelligent personal assistants, web search, credit risk analysis, customer preferences analysis and even genomics. At ORFE, we use mathematical tools to develop and analyze new Machine Learning algorithms to discover hidden structure in massive datasets and to make optimal decisions in the face of uncertainty and limited information.

Optimization

Optimization is everywhere. Whether one talks about optimizing revenue, finding the best route to visit all the major cities of the United States, or optimizing the parameters of your new algorithm, there is common thread: one wants to design procedures that can rapidly and accurately optimize a given function of interest. The area of mathematical programming is concerned with the design and analysis of such procedures. At ORFE we are particularly interested in large-scale optimization problems, with potentially millions or billions of variables involved. Indeed these problems are more and more important in our "Big Data" era. We also pay special attention to the interplay between optimization and the domain specificity of the applications, whether it is finance, statistics or machine learning. The cutting-edge domain specific algorithms for large-scale optimization are nowadays critical to the success of most IT companies, this include Google's search engine or Netflix's recommendation system.
Statistics

Statistics is the science of learning from data. Learning what? Well, almost anything: Statistics are behind drug discovery, political campaigns, climate policies, genetic screenings, financial portfolio management and quality control to name only a few. If your senior thesis involves data, statistics will be your best friend. Statistics is a universal framework to make decisions based on data. In the “Big Data” era, statistics is more relevant than ever: it allows us to make predictions and understand the inherent uncertainty associated to these predictions. Moreover, using modern computer resources, statisticians have been able to contemplate richer models that fit better to reality and make groundbreaking scientific discoveries, for example in understanding the human genome.

Hal Varian, the chief economist of Google, has famously said that the statisticians have the sexiest job of the 21st century. One advantage of working in statistics is that you can combine your interest with almost any other field in science, health, technology, or business. Most organizations now collect huge amounts of data and need statisticians to extract relevant information from them.

Probability

Probability theory, also known as stochastics, is the mathematics of randomness and uncertainty. Probabilistic models lie at the heart of any application that involves uncertain outcomes, be it the arrival of patients and the availability of beds in hospitals, the fluctuations of financial markets, the spread of epidemics, the inheritance of genetic traits, and numerous other applications that span engineering and the sciences. They also provide the fundamental framework for modeling the structure of complex data, and form the foundation of statistical methods for analyzing text, speech, and biological data. At the same time, randomness can serve as an important resource for solving otherwise intractable problems, including simulation methods for estimating risks or for tracking and prediction in uncertain systems, random measurements for exploring customer preferences and for speeding up data acquisition in signal processing, and stochastic optimization algorithms for making optimal decisions on the basis of noisy data. Probability theory provides the tools needed to design and analyze such models and methods and to rigorously understand their behavior.
Academic Program Planning

SEAS Requirements

MAT 103, 104; COS 126; CHM 201 or 207; PHY 103 or 105, 104 or 106; MAT 201, 202 or 203, 204

In addition to the engineering school requirements, there are three components to the curriculum:

1. The core requirements (six courses). These form the intellectual foundation of the field and cover statistics, probability, stochastic processes, and optimization, along with more advanced courses in mathematical modeling.
2. Departmental electives (eight or nine courses). These are courses that either extend and broaden the core, or expose the student to a significant problem area or application closely related to the core program.
3. Senior independent work. A one-semester project or a full-year thesis involving an application of the techniques in the program applied to a topic that the student chooses in consultation with a faculty advisor.

Core Program (6 Courses)

ORF 245 Fundamentals of Engineering Statistics

A study of fundamentals of statistical methods and their applications in engineering. Basic concepts of probability, discrete and continuous distributions, sampling and quality control, statistical inference, empirical models, and least squares.

ORF 307 Optimization

Model formulation, analysis, and optimization of deterministic systems. Introduction to quantitative methods: linear programming, duality theory, large-scale mathematical programs, and network analysis. Emphasis will be on applications to problem areas such as allocation of resources, transportation systems, scheduling, capital budgeting, and network problems. Two 90-minute lectures. Prerequisite: MAT 202. It is strongly recommended that COS 126 or equivalent be taken prior to or concurrently with this course.
ORF 309 Probability and Stochastic Systems
An introduction to probability and its applications. Random variables, expectation, and independence. Poisson processes, Markov chains, Markov processes, and Brownian motion. Stochastic models of queues, communication systems, random signals, and reliability. Prerequisite: MAT 201, 203, 217, or instructor's permission.

ORF 335 Introduction to Financial Mathematics (also ECO 364)
Financial engineers design and analyze products that improve the efficiency of markets and create mechanisms for reducing risk. This course introduces the basics of financial engineering: the notions of arbitrage and risk-neutral probability measure are developed in the case of discrete models; Black-Scholes theory is introduced in continuous-time models, and interest rate derivatives and the term structure of interest rates are discussed. Prerequisites: ECO 100, MAT 104, ORF 309.

ORF 405 Regression and Applied Time Series
Regression analysis: least squares and robust alternatives, nonparametric techniques (splines, projection pursuit, and neural network). Time-series: trends, seasonal effects, clinical models, state space models. Includes a final project in the form of a realistic forecasting game involving portfolio management and economic time-series data. Prerequisites: ORF 245 and Mathematics 202.

ORF 411 Operations and Information Engineering
The management of complex systems through the control of physical, financial, and informational resources. The course focuses on developing mathematical models for resource allocation, with an emphasis on capturing the role of information in decisions. The course seeks to integrate skills in statistics, stochastics, and optimization using applications drawn from problems in dynamic resource management. Students are organized into teams for a competitive game in resource management that tests modeling skills and teamwork. Prerequisites: ORF 245, ORF 307 and ORF 309, or equivalents.
### Typical Course Schedule

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<td>2. MAT 104 Calculus</td>
<td>2. MAT 201 Multivarience Calculus</td>
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<td>3. PHY 103 General Physics</td>
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<td>2. Departmental Electives</td>
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## Elective Checklist

### DEPARTMENTAL ELECTIVES (8 or 9 courses - all graded)

(If course is not from recommended list, provide explanation and obtain approval from Departmental Representative)

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<th>Course</th>
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### HUMANITIES AND SOCIAL SCIENCE ELECTIVES (7 or more courses)

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The Undergraduate Academic Program

In addition to meeting the usual Engineering School requirements, students will complete courses in the following four groups:

- Departments core requirements (6 courses) – These form the intellectual foundation of our field, and cover statistics, probability, stochastic processes, and optimization, along with more advanced courses in mathematical modeling.
- Departmental electives (8 or 9 courses depending on senior thesis choice) - These are additional courses that either extend and broaden the core, or expose the student to a significant problem area or application closely related to the core program.
- Senior Thesis - ORF 478 - A full year effort that involves a major application of the techniques in the program applied to a topic that a student chooses in consultation with a faculty advisor. Students interested in a full-year senior thesis must be willing to spend the appropriate time during both the fall and the spring semesters. Students who are unable to make adequate progress can switch to ORF 479 and be required to take nine departmental electives. Students will enroll in the spring and will receive credit for two course grades given in the spring.
- Senior Independent Project - ORF 479 (Spring semester only) - A short progress report will be due in January, (Dean’s Date) to make sure that the students have chosen a suitable topic and matched up with their advisor. The final outcome will be a report due at the end of the spring semester. The report will fully describe the research project and its results. Typically projects will take approximately 30 to 50 pages. Also, students who take the independent project will need nine departmental electives.
- Humanities and Social Science Electives (7 or more courses). B.S.E. students are required to include one course in at least four of the following six areas:
  - Epistemology and Cognition (EC)
  - Ethical Thought and Moral Values (EM)
  - Foreign Language at the 107/108 level or above (FL)
  - Historical Analysis (HA)
  - Literature and the Arts (LA)
  - Social Analysis (SA)

A student with no advanced standing will still have eight courses required to meet the engineering school requirement of 36 courses (more if the student places out of any of the SEAS requirements). Students are free to select these courses from any department, and are expected to design an academic program with his/her advisor that produces a balanced education. No course may count under more than one heading, under any circumstances.

Each student selects and schedules courses in consultation with his/her academic advisor and the Departmental Representative. While generally no exceptions in the core courses are allowed, students may design specialized programs through their choice of departmental electives. Specialized programs must be approved by the Departmental Representative.
Department Electives (8 or 9 Courses)

The departmental electives represent courses that further develop a student’s skills in mathematical modeling either by a more in-depth investigation of core methodologies, applying these skills in specific areas of application, or learning about closely related technologies. Students must choose eight courses from the following list, with the following constraints:

- There must be at least one 300 level math course (see list below).
- There must be at least two courses from ORFE.
- There can be no more than three courses from any one department (excluding ORFE).

The following courses satisfy the MAT 3xx requirement. Once the Mat 3xx requirement is satisfied the remaining courses up to a total of three may be used to satisfy part of the departmental requirement.

- MAT 320 - Introduction to Real Analysis
- MAT 322/APC 350 - Methods in Partial Differential Equations
- MAT 375 - Introduction to Graph Theory
- MAT 377 - Combinatorial Mathematics
- MAT 378 - Theory of Games
- MAT 385 - Probability Theory
- MAT 391/MAE 305 - Mathematics in Engineering I or MAT 427, (both may not be taken because content is too similar)
- MAT 392/MAE 306 - Mathematics in Engineering II
- MAT 427 - Ordinary Differential Equations
- MAT 486 - Random Process
- MAT 522 - Introduction to Partial Differential Equations

All Other departmental electives:

- ORF 311 - Optimization Under Uncertainty
- ORF 350 – Analysis of Big Data
- ORF 360 – Decision Modeling in Business Analytics
- ORF 363 – Computing and Optimization for the Physical and Social Sciences
- ORF 375 - Junior Independent Work
- ORF 376 - Junior Independent Work
- ORF 401 - Electronic Commerce
- ORF 406 - Statistical Design of Experiments
- ORF 407 – Fundamentals of Queueing
- ORF 409 - Introduction to Monte Carlo Simulation
- ORF 417 - Dynamic Programming
- ORF 418 - Optimal Learning
- ORF 435 - Financial Risk Management
- ORF 455 – Energy and Commodities Markets
- ORF 467 - Transportation
- ORF 473/474 - Special Topics in Operations Research and Financial Engineering
- CEE 303 - Introduction to Environmental Engineering
• CEE 460 - Risk Assessment and Management
• CHM 303 – Organic Chemistry I
• CHM 304 – Organic Chemistry II
• COS 217 - Introduction to Programming Systems
• COS 226 - Algorithms and Data Structures
• COS 323 - Computing for the Physical and Social Sciences
• COS 340 - Reasoning about Computation
• COS 402 - Artificial Intelligence
• COS 423 - Theory of Algorithms
• COS 425 - Database and Information Management Systems
• ECO 310 - Microeconomic Theory: A Mathematical Approach
• ECO 317 - The Economics of Uncertainty
• ECO 332 – Economics of Health and Health Care
• ECO 341 - Public Finance
• ECO 342 - Money and Banking
• ECO 361 - Financial Accounting
• ECO 362 - Financial Investments
• ECO 363 - Corporate Finance and Financial Institutions
• ECO 414 - Introduction to Economic Dynamics
• ECO 418 - Strategy and Information
• ECO 462 - Portfolio Theory and Asset Management
• ECO 464 - Corporate Restructuring
• ECO 466 - Fixed Income: Models and Applications
• ECO 467 - Institutional Finance
• EEB 323 – Theoretical Ecology
• ELE 485 - Signal Analysis and Communication Systems
• ELE 486 - Digital Communication and Networks
• MAE 433 - Automatic Control Systems
• MOL 345 – Biochemistry
• MOL 457 – Computational Aspects of Molecular Biology
• NEU 437 – Computational Neuroscience
• NEU 330 – Introduction to Connectionist Models

Students often wish to follow a theme in their selection of courses. Below are a few possible themes:
• Applied Mathematics: MAT 375, 378, 320, 486; COS 341, 423; MAE 306
• Engineering Systems: ORF 467; COS 226, 323; ELE 485; MAE 433
• Financial Engineering: ORF 435, 311; ECO 362, 363, 462
• Information Systems: ORF 401, 467; COS 226; ELE 485, 486
• Pre-Med/Health Care: CHM 303, 304; MOL 345, 457; ECO 332; ORF 401, 418
• Statistics: ORF 350, 406, 409, 418, 455, 467
Certificates of Interest to ORFE Students: The following certificate programs complement well with ORFE and are thus popular with students:

- Applications of Computing
- Engineering Management Systems
- Environmental Studies
- Finance
- Program in Applied and Computational Mathematics
- Program in Robotics and Intelligent Systems
- Statistics and Machine Learning
- The Woodrow Wilson School

Taking Courses at Other Schools

Students may take courses at other schools during the summer, during a semester off, or during a year abroad. The rules are slightly different depending on the activity. If you are considering taking a replacement course during the summer or a semester off, you need to obtain a form from West College where you describe the course that is being taken, and what course at Princeton is being replaced. This is particularly important if you want the course to count toward some requirement. Read the form carefully. It requires that you obtain the approval of the home department for the course. For example, if you wish to take a replacement course for MAE 305, you have to get the signature of the Departmental Representative from MAE. A replacement for an ORFE course requires the signature of the Departmental Representative of ORFE. It is a good idea to have a syllabus or at least a detailed description of the course before obtaining approval.

If you wish to take a semester or a year abroad, you need to obtain the signature of the Departmental Representative of ORFE, in addition to the approval of the course of study committee.
Departmental GPA, Graduation Requirement, Honors and Prizes

**Departmental GPA:** Prior to graduation, the department will calculate each student's *Departmental Grade Point Average (GPA).* The Departmental GPA is computed as the average of 10 grades. For students choosing the 2-semester Senior Thesis option (Orf 478) the 10 grades are: twice for Orf 478 plus the best 8 Princeton Graded (some courses may have been taken at other universities and are not eligible) 300-level and above courses from the set of {ORFE Core Courses (Orf 307, 309, 335, 405, 411, Math 300-level) and approved Departmental Electives (either from the published list or individually approved by the departmental representative)}. For students choosing the 1-semester Senior Independent Research option it is the Orf 479 grade plus the best 9 Princeton Graded 300-level and above courses from the set of {ORFE Core Courses and approved departmental electives}. Note, while two 200-level courses may be included among the Departmental Electives, no 200-level courses are counted in the departmental GPA.

A minimum 2.0 Departmental GPA is required for graduation, and as the major, not the sole, determinant of honors. The overall academic quality of the entire ORFE class and academic performance in individual classes is also taken into account in the faculty's decision in awarding honors.

**Graduation Requirement:** Core Courses and Departmental Electives **may not be taken on a PDF (Pass, D, Fail) basis.** Equivalent versions may be taken at other Universities but only prior formal written permission. A passing grade must be received in each ORFE Core Course and each Departmental Elective. To graduate, a student must satisfy the University's 36 course requirement, the SEAS requirements for Physics, Chemistry, Math and Computer Science, ORFE's Core and Departmental Elective requirement and achieve a Departmental GPA of 2.0 or greater.

**Honors:** Highest Honors, High Honors and Honors are awarded by the ORFE faculty to those graduating seniors who have demonstrated the highest levels of academic achievement. Departmental GPA is the major criterion; however, each student's overall academic record and overall quality of the entire class are also considered in the awarding of these honors.

**Prizes:** The ORFE faculty also awards a few individual prizes for specific superior achievement in a few defined categories.
Junior Independent Work

Students wishing to do Junior Independent Work should contact the Departmental Representative, who will help the student identify a faculty mentor and a topic. In preparation for doing one or two semesters of focused research you are required to prepare a prospectus that will serve as a guide for your proposed research. The prospectus must include; a title, a brief description of the proposed research, its purpose, expected findings, and a schedule of tasks/milestones that you expect to achieve throughout the semester. The prospectus will serve as a guide for your semester of study. The prospectus must be submitted to tzigler@princeton.edu prior to enrollment during the registrar’s open enrollment period. The requirements for satisfactory completion of the study (such as reports, examinations, etc.) are set by the faculty mentor, not the Department, and the student should be clear about them when the work is begun.

Senior Thesis (ORF 478)

The senior thesis is a year long undertaking except there will be greater emphasis on the work accomplished during the first semester. Students interested in a full-year senior thesis must be willing to spend the appropriate time during both the fall and the spring semesters. Students who are unable to make adequate progress can switch to the Senior Independent Project (below) and be required to take nine departmental electives. Two course grades will be given in the spring.

A report on the background and research to date will be due at the end of the fall semester (roughly 30+ pages). This report should form a significant portion of the full senior thesis. The research results will be presented to faculty and students at the end of the spring semester.

In addition, there will be a selection process to insure that students will be able to conduct a two-semester research project. As with the independent project, there will be match of faculty and students based on the preferences of the students. A 3-5 page prospectus is expected for students who wish to pursue the senior thesis (due in September).

Senior Independent Project (ORF 479, Spring Semester Only)

Students will choose an advisor during the upcoming spring semester, based on the usual arrangement – attending presentations by the ORFE faculty, reading the shopping guide (which describes faculty interests and expertise), and meeting with individual faculty members. Students will select a broad topic, and rank faculty according to their preferences.

A short progress report will be due in January, (Dean’s Date) to make sure that the students have chosen a suitable topic and matched up with their advisor. The final outcome will be a report due at the end of the spring semester. The report will fully describe the research project and its results. Typically projects will take approximately 30 to 50 pages. Also, students who take the independent project will need nine departmental electives rather than eight.
Faculty and Their Research Interests

Amirali Ahmadi, Assistant Professor

Research interests are broadly in optimization and systems theory with an emphasis on algorithms and efficient computation. Particular focus on design of algorithms for problems defined by polynomial inequalities and arising in operations research, engineering, and statistics. Specific areas of research include semidefinite programming, algebraic methods in optimization and control, Lyapunov analysis of dynamical systems, computational complexity, and approximation algorithms for intractable problems in continuous and combinatorial optimization.

Sebastien Bubeck, Assistant Professor

Machine Learning
Multi-armed bandits
On-line learning
Stochastic optimization
Convex optimization
Combinatorial statistics

Rene A. Carmona, Professor

Stochastic analysis (SPDEs, BSDEs, FBSDEs, stochastic control and large stochastic differential games such as mean field games), high frequency markets, energy and commodity markets, environmental finance and financial mathematics models.

Patrick Cheridito, Professor

Stochastic modeling, optimal control, finance, insurance, risk management.

Erhan Çınlar, Professor


Jianqing Fan, Professor

Research interests focus on statistical analysis and its applications in finance, biological science and health sciences. They include Financial Econometrics, Computational biology, high-dimensional statistical learning, time series, and other statistical theory and methods.
Alain L. Kornhauser, Professor

Development and application of operations research and other analytical techniques in various aspects of Autonomous Vehicles, aka "SmartDrivingCars", including

- The fundamental design of computer vision techniques for the rapid classification and identification of the driving environment,
- Analysis and classification of collision-free driving scenarios,
- Quantification of accident risk and the investigation, formulation and design of "pay-as-you-drive, pay-as-the-car-drives" insurance,
- Investigation and creative design of the human-computer interfaces for SmartDrivingCars
- Operational and feasibility analyses of autonomousTaxi (aTaxi) systems

Han Liu, Assistant Professor

Statistical machine learning and its scientific applications. Theoretical research interests include high dimensional nonparametric inference, probabilistic graphical models, statistical optimization, uncertainty assessment for massive and high dimensional data analysis. Applied research interests include brain imaging, genomics, and multivariate time series.

William A. Massey, Professor

Management in communications and healthcare, queueing theory, dynamic rate queues, stochastic networks, dynamic optimization.

John M. Mulvey, Professor

Expert on optimization under uncertainty, with emphasis on financial planning applications. Develops strategic planning systems for financial organizations, such as American Express, Towers Perrin - Tillinghast, Merrill Lynch and Siemens. Interested in the optimization of large organizations by means of decentralized optimization methods. Current research involves optimizing multi-strategy hedge funds.

Warren B. Powell, Professor

Warren Powell is interested in computational stochastic optimization, which includes subfields such as approximate dynamic programming, stochastic search, and optimal learning. His research spans theory, algorithms, models and applications, which include energy (a major focus), optimal learning in materials science, business, economics, and health. Applications in energy include designing energy contracts, simulating high penetrations of wind and solar energy, optimizing generation under uncertainty, planning and control of energy storage, and making distribution grids robust to storms. His optimal learning research focuses on planning expensive experiments, which arise in settings such as health, business, and laboratory sciences. For more information, please see http://www.castlelab.princeton.edu.
Philippe Rigollet, Assistant Professor
High-dimensional statistics, statistical learning theory, computational complexity, aggregation theory, online learning.

Birgit Rudloff, Assistant Professor

Ronnie Sircar, Professor
Financial Mathematics; stochastic models, especially for market volatility; optimal investment and hedging strategies; analysis of financial data; credit risk; employee stock options; dynamic game theory; energy and commodities markets.

Robert J. Vanderbei, Professor
Algorithms for, and applications of, linear and nonlinear optimization. Applications of special interest include high-contrast imaging, orbital dynamics/mechanics, parametric linear programming as it arises in, say, machine learning, and parameter estimation under sparse sampling as it arises for example in generating level-of-difficulty measures.

Ramon van Handel, Assistant Professor
I am broadly interested in probability theory and its applications to different areas in science and engineering. Probability theory, i.e., the study of randomness, is a very rich subject: it combines many different types of mathematics, and is used to solve a surprisingly diverse range of problems. Models of random phenomena and probabilistic methods arise in physics, chemistry, biology, geology, neuroscience, and the social sciences, as well as in many areas of engineering, statistics, computer science, and (applied) mathematics. I am interested both in the mathematical foundations of probability theory, and in its interactions with other fields and applications in which probabilistic ideas enter the picture.

Mengdi Wang, Assistant Professor
Stochastic optimization, large-scale/distributed optimization, decision making under uncertainty, dynamic programming, statistical learning, algorithms in statistics and finance applications.
Research and Teaching Studios

Students in the department often participate in the research interests of the faculty, and may take advantage of the facilities used for this work. This includes:

- **CASTLE Labs** specializes in computational stochastic optimization and learning, with applications in energy (primarily), business processes, transportation and logistics, and health. Most of the undergraduate research focuses on mathematical models and algorithms for energy systems, spanning topics such as integration of renewables, pricing of energy contracts, pricing, demand response, energy challenges in international settings, and energy markets. Some students get involved in purely algorithmic challenges, advancing the state of the art in approximate dynamic programming, stochastic search and optimal learning. To learn more about CASTLE Lab, see its web page: http://www.castlelab.princeton.edu. Be sure to visit the PENSA website for energy research at http://energysystems.princeton.edu. The Financial Engineering Studio provides students with access to financial data support research into methods for managing risk. Research topics include the development of advanced financial instruments which can be used by insurance companies, major manufacturing companies and investment houses to control risk exposure.

- The **Financial Econometrics Studio** works on a variety of quantitative problems from finance using statistical techniques and financial economic theory. These include valuation of financial derivatives, optimal portfolio allocation, risk modeling and management, volatility estimation, modeling and analysis of financial data, and simulation of financial system. The studio also studies financial econometrics theory and provides various fundamental insights into the statistical inference problems from financial markets.

- The **Statistics Studio** studies statistics theory and methods with focus on high-dimensional statistics, biostatistics, nonparametric techniques, and large-scale statistical computing. The studio engages cutting-edge research on statistical modeling from various problems in machine learning, biomedical studies, computational biology, analysis of Big Data, network data, and financial data. It designs statistical methods and algorithms for these modeling issues and provides fundamental understanding and theoretical foundation on statistical and computational efficiency of these methods and algorithms. This expands into other scientific frontiers where the statistics discipline is useful.

- The **Transportation Center** conducts research on information and decision engineering technologies and how these technologies can be used to improve transportation related decision making.
Career Paths

Updates from Recent ORFE Graduates

Meghan Fehlig, ’02
I’m working as a transportation engineer in the transportation planning department at Parsons Brinckerhoff (Princeton, NJ office). I became interested in this field after taking Prof. Kornhauser’s transportation course and doing senior thesis research on the traffic woes of the Route 1 Corridor. Rarely a day goes by that I don’t rely on something I learned during my thesis research or ORFE courses, be it traffic condition analysis, general research skills, MS Excel work, or NJ transportation history. A real bonus about being in this field with an ORFE degree is having a solid background in economics. Many of the exciting transportation innovations are market-based solutions and my ORFE studies have uniquely positioned me to work on these innovations with a different approach from my civil engineer and urban planner colleagues.

Daniel Nash, ’03
I am a Director of New Growth Platforms at Avery Dennison, a $6.5 billion dollar manufacturing and consumer products company with expertise in pressure-sensitive technology, and retail branding and information solutions. As such, I am responsible for identifying and building new growth opportunities for the company. For the past year, I have focused on the healthcare industry, working to leverage Avery Dennison’s RFID technology to improve key processes in hospitals. Prior to Avery Dennison, I worked as a consultant for the Boston Consulting Group serving in both the Singapore and Boston office, and in the Corporate Finance department of The Walt Disney Company. I received my MBA from Harvard Business School in 2008.

My ORFE education continues to provide a significant advantage relative to my peers. The ORFE department taught me how to quickly identify the key drivers of a new market or successful product launch, so that I can efficiently validate my assumptions and limit my downside risk. I believe there is no better education for a successful career in business.

Katherine Milkman, ’04
After completing my ORFE degree, I received a Ph.D. from Harvard University’s joint doctoral program in Computer Science and Business. I am now an assistant professor at the Wharton School at the University of Pennsylvania where I teach undergraduates and MBAs about decision making and behavioral economics. When I’m not in the classroom, I spend my time on research that documents various ways in which individuals systematically deviate from making optimal choices. I am particularly interested in understanding what factors lead people to undersave for retirement, exercise too little, eat too much junk food, and watch too many lowbrow films. Recently, I have also begun to study race and gender discrimination, focusing on how a decision’s context can alter the manifestation of bias. I have published articles in leading academic journals such as Management Science and the Proceedings of the National Academy of Sciences, and my work has been featured by numerous media outlets including The New York Times, BusinessWeek, The Economist, and NPR. In 2011, I was recognized as one of the top 40 business school professors under 40 by Poets and Quants.
Kimberly Mattson, ’05

I am an Investment Associate at Bridgewater Associates, an institutional hedge fund manager in Westport, CT. We deal with large institutions - pension funds, college endowments, central banks. Most of my work revolves around solving problems that deal with portfolio structuring. I use a lot of the concepts I learned in ORFE in my day-to-day work. I use a lot of the portfolio math I learned in ORF 435 to figure out a portfolio's risk and return characteristics. We also have a tool that calculates a client's optimal portfolio using a Monte Carlo simulation process. I've even used some of the ideas I developed in my senior thesis, which used implied volatility in currency options to estimate the chance of a currency crisis, in my job, since Bridgewater manages currencies and options as part of its investment strategy. In my opinion an ORFE degree is the most flexible major to have at Princeton because it teaches a wide array of skills to apply basically anywhere after college.

Jacqueline Ng, ’06

Since graduating as an ORFE in 2006, I have worked in a variety of roles that have drawn upon the knowledge and skills I gained as an ORF major. After graduation, I spent nearly 6 years at Morgan Stanley, where I worked in US Government Bond Trading, Sales & Trading Strategy and US Equity Research. During my time at Morgan, I also pursued an executive-MBA at Columbia University. I recently left Morgan Stanley to work for Microsoft in a strategy and finance type position for their consumer advertising support business.

My undergraduate degree in ORFE has aided me tremendously in each one of my job functions. At a high level, my ORF classes taught me how to think quantitatively and analytically – which has been a versatile skill that has helped me grasp new concepts quickly in the workplace. The vigorous ORFE curriculum prepared me well for the challenges of the workplace, and has given me confidence when faced with complex problems.

On a more specific level, I find myself constantly drawing upon the knowledge I gained in my ORFE classes. For example, Professor Sircar’s ORFE 335 class (Introduction to Financial Engineering) taught me about various fixed income products and pricing models. As a bond trader, I frequently used similar pricing models on a day-to-day basis, in addition to various probability models, statistics and historical regressions. Additionally, my undergraduate classes prepared me well for business school, where my solid foundation in operations facilitated my understanding of our operations management MBA coursework. Finally, in my current role at Microsoft, I find that the knowledge I’ve gained as an ORF major accompanies me both directly and indirectly in every challenge and problem I face in the workplace.

Raj Hathiramani, ’07

Since graduating in 2007, I have worked in a few different roles that have drawn upon valuable concepts I learned from the ORFE program. I spent about 4 years working at Citadel Investment Group, first in quantitative research and derivatives trading and later in fundamental long/short equities, covering financial services. ORFE courses in financial engineering and asset pricing were instrumental in understanding how to value both stocks and derivatives.

After Citadel, I started working at Google, helping lead the sales strategy and financial analytics for the company's display advertising products. Prof. Carmona's class on regression and applied time series enabled me to use R and SQL to analyze and set targets for Google's revenue growth and present business insights to senior management.

Inspired by my managers at Google, I decide to pursue an MBA at Wharton, where I am currently a first year student. While at Wharton, I have also been working part-time as a portfolio consultant at First Round Capital, a seed-stage venture capital fund, conducting strategy projects for portfolio companies and assisting with diligence for the firm's potential investments.
Zachary Kurz, '08

I am working as an investment banking analyst in Morgan Stanley’s Mergers & Acquisitions Group. I am responsible for building financial models in Excel and creating presentations for our senior bankers to present to the Firm’s clients. I have been part of some really interesting transactions, including the recent $46 billion merger of Merck and Schering-Plough, two large pharmaceutical companies. I frequently use a lot of the math skills I learned as an ORFE major and the rigorous foundation has definitely given me a leg up on other young people at the Firm. In particular, a lot of the programming skills I acquired at Princeton have been incredibly useful. I am still unsure about where my career is headed but I am eager to further immerse myself in the financial world.

Jonathan Lange, '09

I am an associate in the private equity group at Bain Capital. We invest in market-leading companies in a wide range of industries and try to optimize operations during our ownership. In my first year, I have evaluated several interesting potential transactions, primarily in media and technology. Prior to Bain Capital, I spent two years as an analyst in the Technology, Media, and Telecommunications investment banking group at Goldman Sachs, where we advised companies on mergers, acquisitions, IPOs, and other financing transactions. Through my roles at Goldman Sachs and Bain Capital, I have had the chance to travel to across North and South America and work directly with management teams, both as an advisor and investor. My ORFE education definitely gave me a great foundation in financial modeling and has been a huge advantage as I work through the theoretical aspects of valuation and the financial impacts of potential transactions.

Kate Hsih '10

At Princeton, I studied an interdisciplinary curriculum that treaded not only in ORFE courses, but also in the natural sciences, global health, and even the humanities. My goal was to develop a holistic understanding of quantitative and qualitative approaches to interpreting and solving real world problems. After graduating in 2010, I worked as a Princeton ReachOut56-81 International Fellow with Wellbody Alliance (formerly Global Action Foundation), a global health NGO focusing on sustainable community-based health interventions in the rural diamond-mining district of Sierra Leone. There, I was involved in a wide range of projects including HIV home-based care, reproductive health peer education, social entrepreneurship in agriculture, amputee health, primary care in resource-limited environments, and more. I also learned about what it takes to operate a startup in this field and about the challenges and complexities of navigating in a developing environment with different cultural and professional norms. In addition to working in the NGO space, I became interested in ethnography in Sierra Leone, particularly on the topic of female genital cutting. This year, I am studying a Master of Science degree in Medical Anthropology at the University of Oxford prior to returning to the US for medical school.

While I have not directly applied many of the mathematical skills I learned in my ORFE core courses, my engineering training is omnipresent in managing my day-to-day operations. It shapes the way that I think, analyze, and organize my thoughts when presented with new problems or projects. Moreover, I have found that my ORFE degree and unusual academic and extracurricular background has been an asset in finding internship or employment opportunities because it allows me to bring unique insights to the table. ORFE teaches students to model real-world situations and make optimal and efficient decisions under uncertainty or with limited information - these tools are necessary in virtually any field, particularly in healthcare or global health. I encourage students to consider using their ORFE education to pursue unconventional careers, as it may open doors to greater responsibility and intellectual creativity. I am happy to connect any students interested in the healthcare, international development, or medical anthropology.
Chetan Narain ’11

I’m working at Google on the Search Ads Quality team, which is responsible for deciding which ads to show on the search result page and thus brings in the majority of Google’s revenue. The job is a blend of engineering, computer science, and mathematics, which is exactly what ORFE is all about. I’ve worked on projects where we try to predict how many people will click on an ad, something that requires substantial data crunching, strong mathematical analysis, and a good understanding of how people’s minds works. My position is right at the confluence of mathematics, finance, and computer science, and was a natural extension of the similarly multifaceted education I got in the ORFE program.

Anna Zhao ’12

I work at the NBA League Office in the basketball operations department. My department functions like the government of basketball, as we oversee the on-court activities, manage rule changes, and address any questions or concerns from teams. My most direct ORFE project has been when I used my foundation in probability (ORF 309!) to evaluate teams’ drafting abilities (not gonna lie, I was pretty excited about this). Most of my time has been spent on performing statistical analysis on a variety of areas, such as injuries, the NBA Draft, and the NBA Development League. Even when my job has no math involved, like stuffing All-Star Game gift bags, what I learned about operations research helps increase efficiency. I’m glad that I switched to ORFE because I learned how to approach solving complex problems in real-world situations, how to code to manipulate raw data into a useful form, and how to complete tasks efficiently.

Michael Yaroshefsky ’12

Since graduating Princeton, I have led multiple venture capital investments at Insight Venture Partners in New York. Over the last 18 months, I have been responsible for investing about $100M in high-growth software companies worldwide. I travel frequently to meet with entrepreneurs to evaluate new investments and work with our current portfolio companies to help them continue to grow. Although I did not originally expect to draw much upon my engineering degree, each day I leverage a cross section of the tools I acquired from the ORFE curriculum.

The analytical skills I learned from all of my classes help me quickly analyze business models and form an opinion. I frequently rely on knowledge about software development and e-commerce I learned in Professor Kornhauser’s ORF 401 to evaluate technologies. Professor Powell’s ORF 411 significantly boosted my modeling skills, which helps me develop sophisticated models of a business’s financial performance or the structure of our investment. The programming ability I gained through statistical programming in Professor Carmona’s ORF 405 or classes I took in the Computer Science department has earned me a reputation for being able to engineer my way out of challenges, automate repetitive tasks, or vet a company’s technology as part of our due diligence.

My ORFE degree has been a very flexible foundation from which to launch my career. I look forward to continuing my studies Harvard Business School as a member of the 2+2 program, and I have decided to defer by one year since I am learning so much so quickly in my current role.
William Harrel ’13

I am a Strat in Commodities at Goldman Sachs within the Securities Division. I work closely with the traders to create and maintain models for pricing and calculating risk on trades that we execute. These trades range from common types of trades that we execute multiple times a day to large specialized trades that take us weeks trying to price and determine the different types of risk. In addition to figuring out the risk of individual trades, I work to create ways to aggregate these risks so that traders can see what risks they need to hedge on a large scale.

I spend a lot of time programming, and the computer science courses I took as ORFE electives were a great foundation for this job. To determine risk, we use many methods, ranging from the Black-Scholes equation to Monte Carlo Simulations, which I learned in ORF 335 and ORF 409, respectively. Finally, the most important (and possibly unexpected) skill that I use is the ability to take very large and complex problems and distill them down into workable components. Being a team leader in the OJ Game (ORF 411) was incredible practice in talking a large-scale problem, and I feel that ORFE has prepared me well for all aspects of my job.

Malavika Balachandran ’13

I am working as an Analyst in the Securities Division at Goldman, Sachs & Co. My team is responsible for structuring derivative products for private individuals; I spend most of my day working with clients, providing them with pricing on derivative packages, pitching trade ideas that meet their investment objectives, and explaining how these complex financial products work. It was through my ORFE education, particularly my coursework in Financial Math, that I gained a strong foundation in derivatives pricing theory, which governs the valuation of the products I structure and sell. While I am not solving stochastic calculus problems or developing pricing models every day, understanding how the underlying pricing models work and how a position’s risk and price changes with respect to the input variables is extremely valuable in my job. My interest in math and computer science attracted me to the department, where I developed a strong intellectual interest in derivatives pricing and computational finance, and I am very lucky that I have the opportunity to apply my knowledge and passion in my career.
Class of 2013 Senior Thesis Titles

The Application of Online Learning Algorithms to Regret Minimization

A Survey of Strategies for the Multi-Armed Bandit Problem

High Frequency Markets Analysis from Order Flows and Interactions

A Few Experiments in Portfolio Management

Stochastic Volatility Models for Pricing VIX Options Consistent with VIX and SPX Implied Volatilities: A Simulation Approach

Examining the Effect of Speculation and Open Interest on the Crude Oil Futures Curve

“Raising Capital in the New Age of Venture Finance” A Model and Analysis of Crowdfunding

Exploring the Development and Use of a Multinomial Logit Model to Improve Betting Returns at Saratoga Race Course

False Discoveries in Exchange-Traded Fund Performances: Identifying ETFs that Outperform the Market


Customer Targeting in E-Commerce: A Feature Selection and Machine Learning Approach

Shared Autonomous Taxi Networks: An Analysis of Transportation Demand in NJ and a 21st Century Solution for Congestion

Modeling Spikes, Heavy-Tails, and Volatility Clustering in Electricity by Applying a Stochastic Time-Change to the Ornstein-Uhlenbeck Process

Team Popularity Bias: A Study of NFL Betting Market Efficiency

A Package Ordeal Applying Queuing Theory to Model Princeton Package Room Operations

Patient Preference Scheduling with Dynamic Rate Queues

Keeping Them Honest: How Medical Services can Maximize Profit while Maintaining Quality of Service with and Optimal Control Policy

A Queueing Theory Approach to Modeling Toll Plaza Delay with Applications for Commute User Cost Optimization

Three Angry Men: A Game Theoretic Analysis of How the Two-Sided Unanimous Verdict Rule Affects Outcomes in Jury Trials
Alternative Investing: The Search for Profitable Trading Strategies in the U.S. Commodity Markets

Liquidity and Investment Styles in the Commodity Futures Market

New Opportunities in the Currency Carry Trade

Are We There Yet? A Proposal for an Autonomous Taxi System in New Jersey and a Preliminary Foundation for Empty Vehicle Routing

The Analytic GM: Using Data Mining to Predict NFL Performance

Exploring Alternative Treatment for Bacterial Meningitis Through Optimal Dosing Strategy: Responding to Rising Antibiotic Resistance

The Future of Solar: An Analysis of New Jersey’s Market for Solar Renewable Energy Credits (SRECs)

Nested Newsvendor Optimal Commitment Policies in Day-Ahead and Hour-Ahead Electric Capacity Forward Markets

Replicating Electricity Spot Prices Through Inverse Optimization of Supply Shocks

Methods of Pair Selection in Pairwise Comparisons for Efficient List Ranking

Fishing Within the Limits: A Sustainable Fishing Model

Forex Market Response: Analysis of Natural Disasters and Their Impact on the Foreign Exchange Market

Analysis of Leveraged ETF Compounding Difference

Accounting for Population Structure in Lasso Regression for Genome-Wide Association Studies

Modeling Spikes, Heavy-Tails, and Volatility Clustering in Electricity by Applying a Stochastic Time-Change to the Ornstein-Uhlenbeck Process

Face Detection, Tracking Methods, and Image Processing: A MATLAB Approach

Analyzing and Presenting Modern Temperature Trends

The Linear Simplex Method: Investigations of Cycling and Application to Markov Decision Processes
### Class of 2013 Post Graduate Plans

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