IIT Stuart School of Business
ILLINOIS INSTITUTE OF TECHNOLOGY

Master of Mathematical Finance: Course Descriptions

Computer Science

CS 522 Data Mining

This course provides continued exploration of data mining algorithms. More sophisticated algorithms such as support vector machines will be studied in detail. Students will continuously study new contributions to the field. A large project will be required that encourages students to push the limits of existing data mining techniques. (Prerequisite: CS 422)

Math

MATH 512 Partial Differential Equations

This course covers basic model equations describing wave propagation, diffusion and potential functions. Fourier transform, Green's functions, eigenfunction expansions, perturbation techniques, multiple-scale methods, asymptotics, variational techniques, self-similar solutions. Prerequisite: MATH 400 or instructor's consent.

MATH 542 Stochastic Processes

This is an introductory course in stochastic processes. Its purpose is to introduce students into a range of stochastic processes, which are used as modeling tools in diverse fields of applications, especially in the risk management applications for finance and insurance. In addition, students will be introduced to some basic stochastic analysis.MATH 543 Introduction to Stochastic Analysis

MATH 543 Stochastic Analysis

This course will introduce modern finite dimensional stochastic analysis and its applications in finance and insurance. The topics will include: (a) an overview of modern theory of stochastic processes, with focus on semimartingales and their characteristics; (b) stochastic calculus for semimartingales, including Ito formula and stochastic integration with respect to semimartingales; (c) stochastic differential equations (SDEs) driven by semimartingales, with focus on stochastic SDEs driven by Levy processes; (d) absolutely continuous changes of measures for Semimartingales, (e) some selected applications.

MATH 544 Stochastic Dynamics

This is an introductory course in mathematical modeling by stochastic differential equations. It is especially appropriate for graduate students who would like to use stochastic methods in their research, or to learn these methods for long-term career development. Topics include random variables, mean and variance, Brownian motion, stochastic integration and Ito calculus, stochastic differential equations, random dynamics, numerical simulation, and applications to scientific, engineering and financial problems. Prerequisite: MATH 474, MATH 475 or equivalent.MATH 548 Mathematical Finance: Discrete Time

MATH 548 Mathematical Finance I: Discrete Time
This is an introductory course in mathematical finance. Technical difficulty of the subject is kept at a minimum by considering a discrete time framework. Nevertheless, the major ideas and concepts underlying modern mathematical finance and financial engineering are explained and illustrated.

MATH 565 Monte Carlo Methods in Finance
In addition to the theoretical constructs in financial mathematics, there is also a range of computational techniques that allow for the numerical evaluation of a wide range of financial securities. Monte Carlo and Quasi Monte Carlo techniques are computational sampling methods which track the behavior of the underlying securities in an option or portfolio and determine the derivative's value by taking the expected value of the discounted payoffs at maturity. Recent developments with parallel programming techniques and computer clusters have made these methods widespread in the finance industry.

MATH 569 Statistical Learning

MATH 582 Mathematical Finance II: Continuous Time
This course will introduce the student to modern continuous time mathematical finance. The major objective of the course is to present main mathematical methodologies and models underlying the area of financial engineering, and, in particular, those that provide a formal analytical basis for valuation and hedging of financial securities.

MATH 586 Theory and Practice of Fixed Income Modeling*
The course covers basics of the modern interest rate modeling and fixed income asset pricing. The main goal is to develop a practical understanding of the core methods and approaches used in practice to model interest rates and to price and hedge interest rate contingent securities. The emphasis of the course is practical rather than purely theoretical. A fundamental objective of the course is to enable the students to gain a hand-on familiarity with and understanding of the modern approaches used in practice to model interest rate markets.

MATH 587 Theory and Practice of Modeling Credit Risk and Credit Derivatives*
This is an advanced course in the theory and practice of credit risk and credit derivatives.

MATH 589 Numerical Methods for PDEs
Finite difference method, finite volume method, spectral method; order of accuracy, stability and Fourier analysis of numerical schemes.

Finance

MSF 505 Futures, Options and OTC Derivatives

This course provides the foundation for understanding the price and risk management of derivative securities. The course starts with simple derivatives, e.g., forwards and futures, and develops the concept of arbitrage-free pricing and hedging. Based upon the work of Black, Scholes, and Merton, the course extends their pricing model through the use of lattices, Monte Carlo simulation methods, and more advanced strategies. Mathematical tools in stochastic processes are gradually introduced throughout the course. Particular emphasis is given to the pricing of interest rate derivatives, e.g., FRAs, swaps, bond options, caps, collars, and floors.

MSF 524 Models for Derivatives

In this course, students will learn mathematical and computational methods that are applicable to the pricing and risk management of derivatives. These will be implemented in Matlab. The class will include an introduction to option pricing theory, with some basic stochastic calculus, the Black-Scholes partial differential equation, risk-neutral valuation and hedging and portfolio replication. We may also touch on more advanced topics, such as jump processes and stochastic volatility. The course will focus on important numerical techniques used in finance, including variance reduction techniques in Monte Carlo Simulation, finite difference methods applied to partial differential equations, interpolation procedures (e.g. splines) and optimization theory applied to model calibration. These methods will be applied to price exotic options and to model volatility surfaces.

MSF 525 Interest Rates, Term Structure and Credit Models

Upon completion of this course, students should know the strengths, weaknesses, appropriate uses and ways of implementing the major term structure models that are in common use. The course will cover bootstrapping of forward curves, principal component analysis and review basic fixed income derivatives (swaps, swaptions, caps and floors). We will then implement short rate models, such as Ho-Lee, Black-Derman and Toy, and Extended Vasicek/Hull-White, followed by the Heath-Jarrow-Morton model and market rate models. The course will conclude with a brief introduction to credit modeling, covering risk-neutral default probabilities, credit default swap pricing, and structural and reduced-form models of credit risk. Students will implement these term-structure models in Excel/VBA and Matlab.

MSF 526 Computational Finance

Because of the widespread adoption of computer trading platforms, the computational efficiency of financial models has become an issue of increasing concern. This course concentrates on numerical techniques for pricing derivatives found in modern markets. It includes an extensive treatment of numerical solutions of the Black-Scholes equation, using techniques such as efficient binomial/trinomial trees, finite-difference solutions of partial differential equations and Fast Fourier transforms. We will cover optimization theory as used in model calibration. We will apply these methods to various pricing models, such as stochastic volatility models and models used to price credit derivatives. Model implementation will be in Matlab.

MSF 545 Structured Fixed Income Portfolios
Fixed income instruments differ from equities because the cash flows from fixed income instruments are known in the absence of issuer default. As a result, fixed income portfolios tend to have a longer time horizon, tend to be more highly leveraged, and tend to use derivatives for hedging relative to equities. This course develops portfolio management procedures for fixed income portfolios. The course begins at the short end of the curve with multi-currency portfolios of short-term non-deliverable swaps. The course then proceeds out the maturity spectrum to consider investment strategies based upon the shape of the yield curve. Concepts developed in the course will be tested using a simulated trading environment.

MSF 546 Quantitative Investment Strategies
This course develops the primary quantitative tools used in the portfolio selection process. The applied focus of the course centers on the process of moving from a data set of historical information to the formulation of a forecasting model, the estimation of mean-variance efficient portfolios, and the testing of efficiency hypotheses within an in-sample and post-sample setting. The course covers the estimation of efficient portfolios, factor models, forecasting models, and risk analysis.

MSF 554 Market Risk Management
This course introduces the importance of financial risk management by developing practical risk measurement tools. The risk measurement aspect of the course begins with the development of the Value-at-Risk (VaR) methodology for financial instruments traded in open markets including equities, bonds, foreign currencies and their derivatives. The course develops analytic VaR models for instruments with non-linear payoffs and non-normal distributions and it also develops simulation methodologies for risk analysis. Statistical tools in volatility forecasting, tail events, and expected shortfall are introduced as appropriate. The emphasis of the course is on market risk, but in addition to the traditional analysis of trading rooms, the course also considers regulatory and compliance risk, corporate risk and risk analysis for investment managers.

MSF 555 Credit Risk Management
The extensive use of leverage by individuals, corporations, hedge funds and private equity managers has led to a significant increase in the demand for models that analyze credit risk exposures. For many users, the credit risk function has evolved from models used to analyze the quality of an individual borrower to models that aggregate exposure across borrowers,

industries and geographic regions. This course provides an extended overview of the exciting and rapidly developing field of credit risk analysis.

MSF 564 Financial Theory

This course covers the foundations of financial economics and the theoretical underpinnings of contemporary asset pricing models. We will explore the many uses and extensions of the fundamental pricing equation: where Pt is the current price, is the pricing kernel or stochastic discount factor, and is a future random payoff. The "art" of asset pricing is in how one specifies the functional form of the pricing kernel. With different assumptions yields the Capital Asset Pricing Model, the Consumption-CAPM, the Black-Scholes-Merton option-pricing model, and many popular term structure models. The Consumption-CAPM does not fair well in the empirical literature motivating the study a promising group of next-generation risk/return models. The latter part of the course will be devoted to continuous-time asset pricing of options and the modeling of the term structure. The emphasis will be on risk-neutral, Martingale pricing methods, rather than solving partial differential equations. This material is a theoretical complement to the Computational Finance and Financial Modeling sequences.

MSF 565 International Finance Theory

This course will focus on the determination of prices, interest rates and exchange rates within the context of neo-classical equilibrium models. The theoretical foundations of the course will be supplemented by extensive exercises in econometric testing of maintained hypotheses and exercises in real time trading.

MSF 566 Financial Time Series Analysis

This course develops a portfolio of techniques for the analysis of financial time series. Distribution theory covers the normal, Student T, Chi-squared and mixture of normals models. Technical analysis covers a variety of trading rules including filters, moving averages, channels and other systems. The first two topics are then combined into an analysis of non-linear time series models for the mean. The course concludes with a review of volatility models including GARCH, E-Garch and stochastic volatility models.

MSF 567 Bayesian Econometrics

Most statistical applications in finance require that the forecasting models be revised in response to the arrival of new information. This course develops the Dynamic Linear Model (DLM) as an updating model based upon Bayesian decision theory. Applications of the DLM, including regressions, autoregressions, and exponential trend models will be covered. Special emphasis will be given to the development of intervention and monitoring systems and the use of simulation methodologies. Students not familiar with matrix algebra and elementary statistics should plan to make up the deficit early in the course.