SYLLABUS

IEOR E4500 – Application Programming for FE

Term: Fall 2013
Department: Industrial Engineering and Operations Research (IEOR)

Instructor: Iraj Kani
TAs: Jiaming Kong, TBD
CAs: Xiaoqian Gui, Faisal Ahmad, TBD

References:


The C Programming Language, Brian W. Kernighan, Dennis M. Richie, Prentice-Hall 1988


Option Pricing, Mathematical models and computation, Paul Wilmott, Jeff Dewynne, Sam Howison, Oxford Financial Press, 1993


Requirements: Basic understanding of financial markets, securities and instruments is highly recommended. Some knowledge of stochastic processes, time series models and econometric methods is very helpful. Basic familiarity with numerical methods is very useful. Some knowledge of C/C++, Java or similar programming languages, and application development environments is recommended. Familiarity with Microsoft Excel, VBA and Microsoft office environment is also recommended.
Assignments and Grading: There will be 6-7 homework assignments and a final group project, which together determine the grade for this course. Homework assignments may involve implementation in C/C++, Java, or Excel/VBA environment. All assignments will be performed by groups of 4-6 students based on the class size. Grades are individually assigned, based on overall performance on assignments (60%), final project (30%), and class participation (10%).

Office Hours: There will be 3-4 office hours by each TA/CA during assignments, with the location and other details to be announced.

Course Website: CourseWorks (E4500)

Course Description

Application programming plays a central role in the development and practice of financial engineering. This course focuses on the exercise of application programming in the context of optimization models and methods in financial economics. During the past two decades optimization models have played an increasingly important role in financial decision making. Optimization methods have been successfully applied to a range of important problems in mathematical finance including asset allocation, risk management, option pricing, and model calibration. A typical optimization model addresses optimal allocation of resources (decision variables) among possible alternative uses in order to maximize an objective function (e.g. estimated profit), often in the presence of constraints. Decision variables, the objective function, and constraints are all essential elements of any optimization problem. In this course we will examine efficient solutions to both unconstrained optimization and constrained optimization problems, discuss duality, feasibility criteria and optimality for each problem class.

Several classes of optimization problems will be discussed in this course, including linear programming (LP), quadratic programming (QP), dynamic programming (DP), and stochastic programming (SP), each encountered in variety of financial models and settings. We will review essential theoretical underpinnings and efficient solution methods for each problem class, and examine important applications in mathematical finance (e.g. mean-variance optimization, volatility estimation, option pricing techniques) that can be modeled in each context. We will also focus on efficient numerical implementations of optimization models and methodologies in the C/C++ programming language framework and develop applications in context of Microsoft Excel/VBA development environment.

Course Outline

Introduction to Optimization Models
• Optimization problems
  o Linear, Quadratic, Conic, Dynamic programming
• Optimization with uncertainty
  o Stochastic programming, Robust optimization
• Financial models and applications
  o Portfolio selection and asset allocation
  o option pricing and hedging
  o risk management
  o asset/liability management

Overview of C/C++ Programming Language
• Introduction to C programming language
• Object oriented programming concepts
• Introduction to C++ programming language
• Java programming and other extensions
• Excel/VBA and Microsoft development environment

Linear Programming Theory and Algorithms
• The linear programming problem
• Duality
• Feasibility and optimality conditions
• Simplex algorithm
• LP models: Asset/liability cash flow matching
  o Dedication
  o Sensitivity analysis of linear programming
• LP models: Asset pricing and arbitrage
  o Replication and option pricing
  o No arbitrage conditions

Nonlinear Programming Theory and Algorithms
• The nonlinear programming problem
• Univariate optimization
  o Line search
  o Newton’s method
• Unconstrained and Constrained optimizations
  o Generalized reduced gradient method
  o Sequential linear programming
  o Subgradient methods
  o Newton’s method
• Karush-Kuhn-Tucker (KKT) theorem
• NLP models: Volatility estimation

Quadratic Programming Theory and Algorithms
• The quadratic programming problem
- Optimality conditions
- Interior point methods
- QP models: portfolio optimization
  - Mean-variance optimization
  - Black-Litterman model
  - Sharpe ratio maximization
  - Return-based style analysis
  - Recovering volatility from option prices

**Dynamic Programming Methods**
- The dynamics programming problem
- Backward recursion
- Forward recursion
- Stochastic dynamic programming
- DP models: option pricing
  - Early exercise and American options
  - Binomial lattice
  - Trinomial and other lattice frameworks
  - Finite difference methods
- DP models: asset back securities
  - Structuring the trenches
  - Mortgage backed securities and CMOs

**Stochastic Programming Theory and Algorithms**
- Two-stage problems with recourse
- Multi-stage problems
- Autoregressive model
- SP models: Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR)
  - Risk measures
  - VaR and CVaR minimization
  - Credit risk and bond portfolio optimization
- SP models: asset/liability management
  - Asset/liability and corporate debt management problem
  - Synthetic options
  - Option pricing with transaction costs

**Robust Optimization Theory and Algorithms**
- The robust optimization problem
- Different flavors of robustness
- Tools and strategies for robust optimization
- Robust optimization models in finance
  - Robust multi-period portfolio models
  - Robust portfolio selection
  - Robust arbitrage