ELEC3180 Data-Driven Portfolio Optimization

Course Description

Modern portfolio theory started with Harry Markowitz's 1952 seminal paper "Portfolio Selection." He put forth the idea that risk-adverse investors should optimize their portfolio based on a combination of two objectives: expected return and risk. Until today, that idea has remained central in portfolio optimization. However, the vanilla Markowitz portfolio formulation does not seem to behave as expected in practice and most practitioners tend to avoid it. During the past half century, researchers and practitioners have reconsidered the Markowitz portfolio formulation and have proposed countless of improvements and alternatives such as robust optimization methods, alternative measures of risk, regularization via sparsity, improved estimators of the covariance matrix, robust estimators for heavy tails, factor models, volatility clustering models, risk-parity formulations, index tracking, etc. This course will explore the Markowitz portfolio optimization in its many variations and extensions, with special emphasis on Python programming.
Prerequisite(s): (IEDA 2510 OR IEDA 2520 OR IEDA 2540 OR ELEC 2600) AND (MATH 2111 OR MATH 2121 OR MATH 2131 OR MATH 2350)

List of Topics

Theory: Introduction to convex optimization
Practice: A primer on Python for finance

Theory: Convex optimization problems
Practice: Solvers in Python

Markowitz portfolio optimization (portfolios: B&H, uniform, quintile, max-return, GMVP, mean-variance, max-Sharpe ratio)

Data modeling (factor models, shrinkage estimators, Black-Litterman, estimators under heavy tails, VARMA models, volatility clustering models).

Data cleaning: missing values and outliers

Robust portfolio optimization

Portfolio optimization with alternative risk measures (downside risk, semivariance, CVaR, drawdown)

Risk parity portfolio

Sparse index tracking

Graph learning for stocks

Statement of Objectives/Outcomes:

On completion of this course, students will be able to:

CO1 – Acquire basic knowledge on optimization problems

CO2 – Be able to solve optimization problems in practice with Python

CO3 – Learn about portfolio design in financial systems

CO4 – Be able to employ the theoretical and practical knowledge on optimization for portfolio design

CO5 – Learn more sophisticated portfolio optimization formulations and solve them

CO6 – Learn data representation via graphs

Textbook(s) and References:

- Yiyong Feng and Daniel P. Palomar. *A Signal Processing Perspective on Financial Engineering*. Foundations and Trends® in Signal Processing, Now Publishers, 2016. [https://palomar.home.ece.ust.hk/papers/2016/Feng&Palomar-FnT2016.pdf]
- Konstantinos Benidis, Yiyong Feng, and Daniel P. Palomar, *Optimization Methods for Financial Index Tracking: From Theory to Practice*. Foundations and Trends® in Optimization, Now Publishers, 2018. [https://palomar.home.ece.ust.hk/papers/2018/BenidisFengPalomar-FnT2018.pdf]
- S. Boyd and L. Vandenberghe. *Convex Optimization*. Cambridge University Press, 2004. [https://web.stanford.edu/~boyd/cvxbook/]
- G. Cornuejols and R. Tutuncu, *Optimization* Methods *in Finance*. Cambridge Univ. Press, 2007.
- F. J. Fabozzi, P. N. Kolm, D. A. Pachamanova, and S. M. Focardi, *Robust Portfolio Optimization and Management*. Wiley, 2007.

Relationship of Course to Program Outcomes:

Please refer to the Report Section 4.3.2 (iii).

Grading Scheme:

Mid-term Examination	25%
Mid-term Project	
Final Project	50%
Laboratory	
In- and Out-of-Class Activity	25%