MATH 584 – Mathematical Methods for Algorithmic Trading

Course Description from Bulletin: (3-0-3)

> This course is concerned with the design and implementation of trading strategies. In particular, it covers the mean-variance portfolio selection problem, utility maximization, pairs trading, market making, and optimal liquidation. The analysis includes such important features as: the construction and usage of predictive signals, finding a tradeoff between risk and return, accounting for transaction costs and market impact. The available mathematical tools and models are presented in each case, and they include: methods for solving constrained optimization problems, stochastic control and dynamic programming principle, time-series analysis. An important part of the course is the implementation of trading algorithms via Python, using real market data. (3-0-3)

Enrollment: Elective for graduate students and upper-level undergraduates

Textbook(s):

- A. Cartea, S. Jaimungal, and J. Penalva , *Algorithmic and High-Frequency Trading,* Cambridge University Press, 2015, ISBN 978-1-107-09114-6

- R. Carmona, *Statistical Analysis of Financial Data in R*, Springer New York Heidelberg Dordrecht London, 2nd ed., 2014, ISBN 978-1-4614-8787-6.

Other required material: None

Prerequisites: Basic knowledge of Probability, Statistics, and computer programming. More specifically, the prerequisites are (marked with * can be taken concurrently)

- One of: MATH 475 (preferred) or MATH 374 or MATH 474 or MATH 481 or MATH 540 or MATH 542 or MATH 543 (all with min. grade of C),
- and one of: MATH 476* (preferred) or MATH 426* or MATH 446* or MATH 474 (with min. grade of C) or MATH 484* or MATH 546* or MATH 563* or MATH 564*.

Objectives:

1. Students will learn the mathematical tools used for designing the optimal trading strategies, including the methods for solving constrained optimization problems, dynamic programming and Hamilton-Jacobi-Bellman equation, and time-series analysis.
2. Students will learn important practical aspects of designing trading strategies, such as: the construction and usage of predictive signals, finding a tradeoff between risk and return, accounting for transaction costs and market impact.
3. Students will learn how to implement trading strategies and evaluate their performance in Python, using simulated and real market data.

Lecture schedule: 2 75 minute lectures per week

Course Outline: Hours

1. Mean-variance portfolio choice 9
    a. Markowitz model, CAPM
    b. Constrained convex optimization
    c. Estimation of covariance matrix
    d. Robust versions

2. Merton problem 6
    a. Dynamic mean-variance and utility maximization
    b. Dynamic programming principle and Hamilton-Jacobi-Bellman equation
    c. Transaction costs

3. Pairs trading 9
    a. Classical time-series models
    b. Cointegration
    c. Dickey-Fuller test and speed of mean-reversion
    d. Optimal entry and exit times, optimal trade size, transaction costs

4. Market microstructure 9
    a. Classification of markets, orders, and market participants
    b. Limit order book, liquidity, bid-ask spread, tick size, latency, market fragmentation
    c. Market-making: inventory models (utility-indifference and Grossman-Miller) and information asymmetry models (Kyle and Glosten-Milgrom)
    d. Volume patterns
    e. Using order flow as a predictive factor

5. Optimal liquidation problem 9
    a. A version of Almgren-Chriss-Obizhaeva-Wang model
    b. Basic execution algorithms
    c. Using order flow to increase expected revenue
    d. Tracking volume (VWAP)
    e. Liquidation with market and limit orders (optimal stopping, limit order imbalance as a predictive factor)

Assessment:		
	Homeworks	40-60%
	Final Project	40-60%

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