CS286r: Topics at the Interface between Computer Science and Economics
Spring 2008: Computational Finance
Harvard School of Engineering and Applied Sciences
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Course Summary
Topic for Spring 2008: Computational Finance
Note: Enrollment in this course is limited.
See the course web page for office hours information.

Applications of computer science to the study of modern financial markets. Motivation of finance as a source of important, interesting problems. Introduction to major markets, asset classes and market data. Characterization of price movements: random walks, "crashes", "momentum", mean reversion, etc. Mathematical financial models. Study of modern artificial intelligence (AI) tools and their applications, not only in finance but also in other research areas. Scientific computer analysis of large-scale data corpora to investigate hypotheses in finance research. Examination of behavioral finance with respect to human and computer traders in markets. Applications of AI in derivative pricing, time series analysis and price prediction, risk analysis. Discussion of terabyte-scale and millisecond-response-time systems challenges associated with analysis and trading in modern financial markets. Market impact of trading; reasoning about other traders. Applications of cryptography in securities trading.

Required Background
The course is designed to be accessible to anyone with sufficient mathematical background for graduate study in the social or natural sciences. Ideally, students will collaborate in cross- functional teams (for example, a computer scientist, a statistician and an economist) on assignments and projects so that each team has members familiar with different aspects of the task. While students should have some exposure to computer programming, familiarity with spreadsheets (such as Excel), or statistical analysis software (such as Stata or R), or Matlab will be sufficient for students with strong backgrounds in economics and finance.

Readings
All texts will be on reserve at the Gordon McKay Library in Pierce Hall. See `http://library.seas.harvard.edu/map.php` for a map and operating hours; you may also view the "Reserve Materials" link under "Services" in the left navigation bar.

Required Texts:

Lo, Mackinlay. *A Non-Random Walk Down Wall Street.* Princeton, 2001. ISBN: 978-0691092560. (The 1999 edition is OK.)

Voit. *The Statistical Mechanics of Financial Markets.* Springer, 2005. ISBN: 978-3540262855.

Ross. *An Elementary Introduction to Mathematical Finance: Options and other Topics.* (Second edition). Cambridge, 2002. ISBN: 978-0521814294.

Optional Texts:

Taleb. *The Black Swan: The Impact of the Highly Improbable.* Random House, 2007. ISBN: 978-1400063512

Dacorogna et al. *An Introduction to High-Frequency Finance.* Academic Press, 2001. ISBN: 978-0122796715

Papers and Articles:

Papers will be distributed during class at least one meeting before they are to be read; where possible they will also be made available on the course website.

Data and Trading Platforms

- Trading Technologies is generously donating several copies of its proprietary `X_TRADER` trading platform and API for students to use in a "paper trading" environment during the course. This platform is used by many professional traders.
- Opentick allows for free educational use of historical market data for many major markets. Students may sign up for free at `opentick.com`; a major credit card is required but we have spoken to the data provider, and users will not be billed unless they sign up for real-time data. Real-time data access is *not* required for this course.
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Homework and Grading

Each week has two homework components: assigned reading for the following meeting and homework based on the previous week's reading and discussion. While no formal homework is required for the reading assignments, those who complete the reading will be better prepared for active class participation.

Grading Guidelines:

20%	**Class Participation**
10%	Attendance (up to 1 absence is "free")
10%	Contributions to Class Discussion
	NB: Absent students rarely contribute.
40%	**Homework Assignments**
4%	Each week's assignment
40%	**Final Project**
	Grading guidelines will be issued later.

Course Schedule

The first course meeting will be an introduction to the course and the second week's topics.

Each course meeting will begin promptly at 2:07 and conclude at 5 pm.

After the first meeting, students will begin each meeting by presenting their homework for that week—approximately one hour. We will then discuss how the past week's work relates to final project ideas. After a brief break, we will cover the material from that week's reading, which will introduce the next homework assignment.

Part 1: Introduction to Trading; Asset Classes; Data Sources			
1	Feb	(Lecture)	Course introduction; asset classes; markets; overview of computer science tools we will study
8	Feb	(Homework)	Study and present a particular asset class in depth.
		(Lecture)	Time-series analysis: how do prices move? Examination of prices and trading volume in various markets; correlations between asset classes in different markets.
15	Feb	(Homework)	Study and present price movements and trading volume for the asset class studied in the previous homework.
		(Lecture)	Mathematical tools for studying time series: Black-Scholes, power laws, Lévy flights, stochastic differential equations, etc.
22	Feb	(Homework)	Compare the accuracy of two or more of these tools on many years of price data for some asset in the past homework's asset class.
Section 2: Introduction to Computational Tools			
22	Feb	(Lecture)	Introduction to Artificial Intelligence (AI) and machine learning (ML): neural networks; support vector machines; etc.
29	Feb	(Homework)	Present a history of and non-finance applications of a particular AI/ML tool
		(Lecture)	Graphical models: Hidden Markov Models, Bayesian Networks.
7	Mar	(Homework)	Describe an HMM or BN model for a financial application, and encode it using existing tools.

Section 3: Behavior, Derivatives, and Risk			
7	Mar	(Lecture)	Behavioral finance: time of day/day of week; seasonality; news; noise and naïveté; stock spam; human error; computers behaving badly!
14	Mar	(Homework)	Pick a small behavioral finance research topic and investigate it, either empirically or by reading and presenting a summary of published research.
		(Lecture)	Derivative pricing given mathematical models and behavioral effects; computation tools to estimate derivative prices
21	Mar	(Homework)	Examine a time series of traded derivative prices and actual prices at expiration. Graph the changes in the price, volume, implied volatility and "greeks" in the derivative prices versus price and trading volume in the underlying instrument.
		(Lecture)	Risk analysis: what is the actual risk of a position? Can we even measure it? How do we "hedge" it properly?
28	Mar	SPRING BREAK	
4	Apr	(Homework)	Choose a scenario in the last 400 years when an investment firm, fund, or asset crashed. Using data available prior to the crash, how could you assess the risk of holding that asset? How could you mitigate that risk?
4	Apr	(Discussion)	Project proposals, discussion, and team assignment
Section 3: Computer-Based Trading in Practice			
11	Apr	(Project)	Project description complete
		(Lecture)	Systems: terabyte-scale data challenges; network and hardware challenges for millisecond-response high-frequency trading
18	Apr	(Homework)	Estimate the total cost to obtain and react to all real-time market data for a particular asset class in a given market.
		(Lecture)	Market impact of trading; backtesting versus real trading; other agents' responses to an agent's orders
25	Apr	(Homework)	Describe how to estimate market impact of a trade.
		(Lecture)	Applications of cryptography in financial trading (no homework)
Section 4: Final Projects			
2	May	(Project)	Project Presentations
9	May	(Project)	Postponed project presentations; plenary pizza party
9	May	Trading agent projects: agent code is due	
13	May	Agent project "testing" period ends; summary of raw results due for all projects	
15	May	Complete project writeups are due	