Why Computational Finance?

It is hard to overstate the importance of the financial industry to the state, national, and world economies.

The financial industry relies on a wide variety of advanced computing technologies and mathematical modeling techniques.

The availability, volume and significance of financial data lends itself to many interesting research problems.

There are interesting and relevant theories of how markets work which lend themselves to formal analysis.

Why this Seminar?

The material from the first half of this course (financial engineering and time-series data analysis) is traditionally taught in business schools, and practiced by quantitative researchers from economics, finance, and the mathematical sciences.

Computer science researchers have not been as engaged with conceptual problems in finance as much as technological problems, such as encryption and transaction processing.

Courses are intended to teach students, but seminars are intended to teach professors!

This seminar is intended for *advanced* M.S. and Ph.D. students in computer science with an interest in algorithms/analysis.

Special Topics

- Online algorithms and competitive analysis

- Short-term trading strategies

- Correlation-based trading strategies, such as pairs trading

- Technical analysis of stocks

- Text/data mining

Course Projects

The course projects will all concern the acquisition and analysis of financial data.

We will view ourselves as the Quant group of "Baroque Technologies"; official slogan *Go for Baroque!*

I want each class to include an active discussion of the projects people are working on.

Project lists will go out in a few weeks, but I need a few volunteers to start on our "Rapid Response Team", which will run experiments each week to see how the theory matches reality or test trading strategies proposed by the group.

Fundamentals of Investing

The return on an investment is strongly related to its level of *risk*, closely associated with its *volatility*.

U.S. Treasury bills are extremely safe but low-yield investments.

The interest rate paid depends upon how long you are willing to wait for payment, with longer-term notes incurring more risk.

A $1 investment in short (long)-term T-bills/bonds in 1925 grew to $10.46 ($19.20) in 1999, before taxes.

Stocks are much more volatile, but offer higher expected returns. A $1 investment in major blue-chip stocks in 1925 grew to $594.45 in 1999, before taxes.

The relative value of these returns depends upon the amount of *inflation* over the investment period.

Financial Markets

An *exchange* is a place where buyers and sellers trade *securities* such as stocks, bonds, options, futures, and commodities.

Well known exchanges include the New York Stock Exchange (NYSE), NASDAQ, and the American Stock Exchange (AMEX).

Each stock is typically traded on a particular exchange. Each exchange has different rules about the qualifications of companies which can be listed on it.

Exchanges also differ in the *rules* by which they match buyers to sellers. Certain exchanges use people (brokers, market makers) to match buyers and sellers, others use computers (particularly on small orders).

The exact trading rules and mechanisms can have a significant impact on the price one gets for a given security.

The strength of an exchange's rules and their enforcement impacts the *confidence* of investors and their willingness to invest.

Exchanges provide *liquidity*, the ability to buy and sell securities quickly, inexpensively, and at fair market value.

In general, the more trading that occurs in a security, the greater its liquidity.

Common Stocks

Companies sell shares of stock to raise business capital.

Companies "go public" by agreeing to sell a certain number of shares on an exchange.

Each share of stock represents a given fraction of the ownership of the company.

Certain stocks pay *dividends*, cash payments reflecting profits returned to shareholders.

Other stocks reinvest all returns back into the business.

In principle, what people will pay for a stock reflects the health of its current business, future prospects, and expected returns.

However, the current *price* of a stock is completely determined by what people are willing to pay for it.

If there was no differences of opinion as to the value of a stock, there would be no trading.

Stock Prices and Indices

Roughly 70% of an individual stock's price movement reflects the performance of the overall market, with roughly 30% of price movement due to characteristics of the specific stock.

Stock indices (such as the S & P 500 or Dow Jones Industrial Average) are measures of the performance of well-defined collections of stocks.

Mutual funds are investment vehicles representing collections of stocks selected by a given company/manager.

As an small, individual investor, it is likely that your best long-term investment is in a low-expense mutual fund tracking one of the major stock indices (such as the Vanguard 500 fund).

Very few actively managed mutual funds consistently do better than such index funds, demonstrating how difficult it is to beat the market.

The Discrete Nature of Stock Prices

When the price of a share of stock gets so expensive it is unwieldy, each share *splits* into equal-sized pieces which sum to the the original value.

Reverse splits combine several shares into a single more expensive share.

Such games are played for psychological reasons, but also because exchanges set a lower bound on the minimum amount prices can change. Since *decimalization*, the minimum change is typically $0.01, but used to be $0.125 (one eighth).

Reducing this minimum change in principle enables buyers and sellers to get fairer prices.

Bond Markets

Bond markets trade bonds ("loans") made to governments and government agencies, as well as companies.

The ability to trade debt increases the liquidity of such investments.

Bond prices vary according to the *term* (length of time) of the loan, the interest rate and payment schedule, the financial strength of the borrowing party, and the returns available from other investments.

The value V of an asset A after n years of compounding m periods per year at an annual interest rate of r is

$$V = A(1 + r/m)^{mn}$$

In the case of continuous compounding, $m \to \infty$ and

$$V = Ae^{rn}$$

This exponential growth explains why compound interest is a good thing.

Commodity Markets

Commodities are types of goods which can be defined so that they are largely indistinguishable in terms of quality (e.g. orange juice, gold, cotton, pork bellies).

Commodities markets exist to trade such products, from before they are produced to the moment of shipping.

Agricultural futures sell the right to buy a certain amount of a commodity at a particular price at a particular point in the future.

The existence of agricultural futures gives suppliers and consumers ways to protect themselves from unexpected changes in prices.

The prices of agricultural commodities are affected by changes in supply and demand resulting from weather, political, and economic forces.

Currency Markets

The largest financial markets by volume trade different types of currency, such as dollars, Euros, and Yen.

The *spot price* gives the cost of buying a good now, while *futures* permit one to buy the right to buy or sell goods at fixed prices at some future date.

Typically, each seller has a buy and sell price for a given currency, and makes their money from the *spread* between these two prices.

Ideally the demand for buying equals selling, or else the prices must change.

Currency markets are used to (a) acquire funds for international trade, (b) hedge against risks of currency fluctuations, (c) speculate on future events.

Arbitrage versus Speculation

Speculators are investors who deliberately take risks by betting on future events. For example, they will buy a stock because they think it will go up.

Hedgers are investors who trade so as to reduce their exposure to risk. For example, they will both buy and short a stock simultaneously.

Arbitrage is a trading strategy which takes advantage of two or more securities being inconsistently prices relative to each other.

Advanced arbitrage techniques involve sophisticated mathematical analysis and rapid trading.