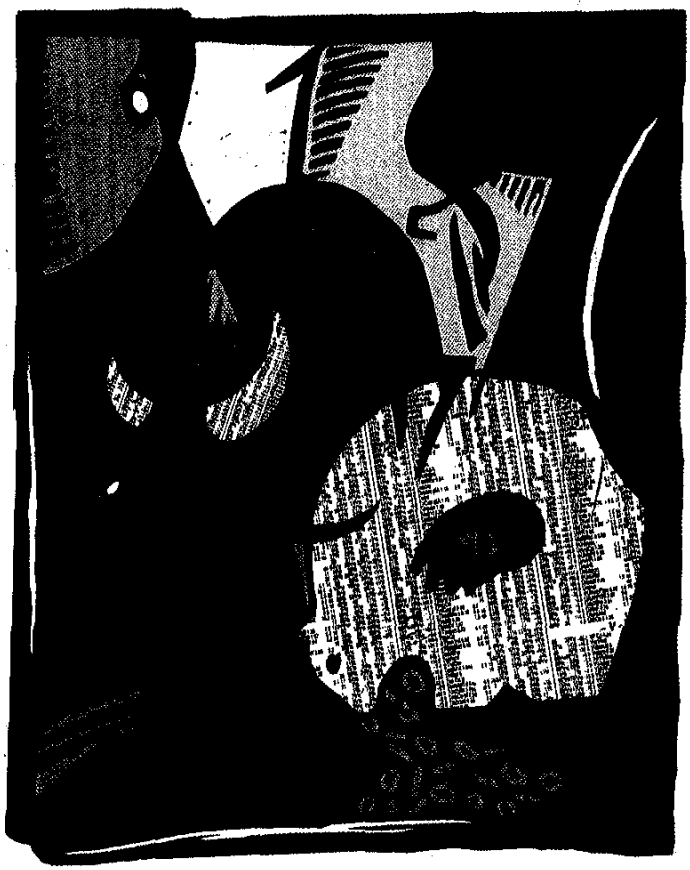
COMPUTATIONAL FINANCE

Over the past 50 years, first in the US and then throughout the rest of the world, involvement in financial markets has grown spectacularly. Whether directly, through the purchases of securities, or indirectly, through pension plans and mutual funds, the financial industry now touches hundreds of millions of people.



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An emerging discipline

Large-scale computing technology has been central to this growth in two ways. First, the markets could not operate without the transaction-processing systems that handle the placing, execution, and settlement of trades. Second, as the markets have grown, new branches of finance have emerged, particularly in the last 20 years, to leverage the volume and liquidity of products and securities sold. These new approaches depend on the availability of sophisticated analysis and computing resources to design and model—preferably in near real time—products and markets. This emerging discipline, which integrates mathematics, economics, and large-scale numeric computation, has come to be known as computational finance.

Practitioners of computational finance must deal with computational issues familiar to many *CiSE* readers. Financial data sets are large, often noisy, and might be incomplete. Valuation models require careful design of numerical algorithms and code implementation. Also, for many products, extensive simulation might be the only practicable pricing method.

Added to these issues are various requirements probably more visible in this business setting. Risk management, especially at the corporate level, requires combining forecasts across dozens of products, markets, and future scenarios. Then there is time-to-market. Nowadays, new financial products rapidly become commodities with narrow margins, or, if the market moves, they can lose profitability overnight.

In this issue

For this issue, we sought articles that demonstrate various computational-finance business applications and discuss current research directions and opportunities.

Using financial derivatives, or structured products, to achieve a specific financial goal or to limit and hedge the risk of a course of action is nothing new. Options have been around for a long time. The modern derivatives industry stems from the introduction of practical options-pricing models in the early 1970s. Since then, the market for tailored products has grown enormously in size and sophistication. James Gatheral, Yonathan Epelbaum, Jining Han, Kishor Laud, Olga Lubovitsky, Elaine Kant, and Curt Randall illustrate how to design a new financial product and develop its pricing model. In business applications, completing a deal might require transitioning from analysis to production support for trading and risk management in a few days. This article describes how software synthesis techniques can generate production-quality numerical code, and how to package the code to support a trading desk.

As competition between institutional investors, such as pensions and mutual funds, has grown, asset managers have sought to improve performance and minimize the cost of trading. Quantitative trading must deal with designing and implementing strategies for managing portfolios of assets. A particular concern is what happens if the positions to be traded are comparable to typical daily volumes in the markets. Financial theory depends on the presence of a liquid market; without it, price distortions and excessive execution costs are inevitable. Dimitris Bertsimas, Paul Hummel, and Andrew Lo discuss how to trade large positions at a reasonable cost, with minimal impact on prices. Using stochastic dynamic programming, they show how to find an optimal sequence of trades in an equities market.

Financial markets are an extremely complex and dynamic environment. For all the advances in technology and modeling, the vast majority of the inputs into the market result from human decisions. The systems advise and implement but rarely decide. Creating a realistic model of the behavior of financial markets is an open research problem. Not surprisingly, computational finance has attracted workers from many disciplines, both as practitioners and, more recently, as researchers. In a broad survey, Doyne Farmer looks at many of the areas offering interesting and challenging opportunities, and reviews recent contributions made outside mainstream finance and economics. These include empirical studies of regularities in prices, random-process models, agent-based models and market evolution, and some practical applications.

Risk management is at the core of finance. The consequences of not fully knowing the risk exposure can be extremely unpleasant, as some have discovered. However, actually combining all the risk measures that the various business units of a large firm use is difficult. In a future *CiSE* issue, Ron Dembo will discuss an approach to an integrated valuation and risk methodology. His framework separates market-evolution scenarios from the valuation models and risk measurements of a product.

We hope this special issue illustrates challenges for computational scientists in the financial markets. Many opportunities exist for research, but practical applications in the financial industry will not wait for the completion of research programs. As this year's appearance of online trading demonstrates, the markets develop at their own pace. Business users will continue to demand accurate modeling, rapid implementation, and the ability to deliver without delay.

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