Introduction to the Issue on Financial Signal Processing and Machine Learning for Electronic Trading

THE financial sector has been historically served by experts in quantitative finance, econometrics, risk management, and electronic trading. However, it also presents a very rich and diverse application area for signal processing methods and technologies. These techniques span across multiple specialties of signal processing field and change dramatically depending on the trading frequency, ranging from stochastic volatility and covariance modeling to short-term prediction based on market microstructure arising from the limit-order book. Moreover the adoption of such computationally demanding analytical techniques from signal processing and machine learning have been accelerated by advances in high-performance distributed computing and DSP technologies (FPGA, GPU).

This special issue aims to compile relevant research contributions from the disciplines of finance, mathematics, data science and engineering to facilitate scientific cross-fertilization. It will also serve the signal processing community to be exposed to the state of the art in mathematical finance, financial engineering, financial signal processing an electronic trading, and to foster future research in this emerging area. We have received 27 submissions, out of which 12 were accepted. We sincerely thank the reviewers, the editorial board and the staff of IEEE JSTSP for the hard work to prepare this issue.

The main themes of submissions in this special issue include using tools from machine learning and signal processing that help to address some of the main problems arising in quantitative finance: modeling risk and correlations of financial instruments and their baskets, returns and liquidity, and problems involving risk-aware resource allocation—namely portfolio optimization. These problems involve tools from convex and discrete optimization, non-parametric statistics, time-series modeling, graph theory and high-dimensional covariance estimation. We now provide a brief synopsis of each submission:

In “Covariance versus Precision Matrix Estimation for Efficient Asset Allocation” the authors undertake a comprehensive comparative study of large-scale covariance estimation techniques for European equities, with the purpose of quantifying the impact of risk estimation in the problem of portfolio allocation. The authors consider a variety of approaches, including factor models for covariance sparse and precision matrix estimates, with realistic constraints such as short-sale constraints in a detailed experimental evaluation on historical financial data.

The paper “Filtering of an HMM-driven multivariate Ornstein-Uhlenbeck model with application to forecasting market liquidity” considers modeling market and funding liquidity risk using a Hidden Markov modeling approach for multivariate mean-reverting time-series. The authors consider three main proxies for market stress and liquidity, Treasury-Eurodollar spread, the Volatility Index (VIX), and measures based on the bid-ask spread in SP500 futures.

The paper “Covariance matrix estimation for interest rate risk modeling via smooth and monotone regularization” studies high-dimensional covariance estimation for interest-rate curves and futures curves, where the authors observe a natural smoothness and monotonicity property. Contracts which have nearby durations are more correlated than contracts with durations further apart. The authors model the penalized covariance estimation problem as a convex semi-definite programming problem with linear monotonicity constraints, derive efficient fast first-order solvers, and show on historical time-series of Eurodollar futures that the estimator provides excellent out-of-sample covariance forecasts.

In “Gaussian Process Regression Stochastic Volatility Model for Financial Time Series” the authors consider the Gaussian Process Regression approach to time-varying volatility estimation. They argue that the traditional GARCH and Stochastic Volatility models are too rigid, and the flexibility of Gaussian Processes can significantly improve volatility forecasts. The authors evaluate the approach both on simulated and on historical financial time-series.

In “Data-driven Stochastic Pricing and Application to Electricity Market” the authors consider derivative pricing using stochastic models estimated from historical data and propose an approach to compute the probability integrals. In particular, they build directly from the data nonparametric probability distribution models, as opposed to traditional parametric approaches such as the celebrated Black-Scholes model, as a solution to a convex optimization problem, which then are numerically evaluated. The proposed method is applied to the procurement contract in the day-ahead bulk market for electricity.

The article “Estimating Tipping Points in Feedback-Driven Financial Networks” by Kostanjcar et al. establishes a framework for testing for tipping points in financial markets based on a network of bargaining agents which either collaborate or compete. The degree of market overpricing is also taken into account and the framework is verified on the S&P500 index, demonstrating a hysteresis and a tipping point which agree with model predictions.

In “Solving the Optimal Trading Trajectory Problem Using a Quantum Annealer” the authors study the application of quantum computing in finance. In particular, they consider discrete multi-period portfolio optimization with transaction costs, including temporary and permanent market impact, formulated as an integer programming. This is a non-convex NP-hard problem and they propose an implementation to solve it based on quantum annealing technology. It has been argued that quantum annealing has an advantage over classical

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optimizers due to quantum tunneling, which allows an easier search of the solution space.

In "Sequential Detection of Market shocks with Risk-averse CVaR Social Sensors" the authors study the performance of agent-based models to detecting the financial market shocks based on a Bayesian change-point detection framework.

In "An environment for rapid derivatives design and experimentation", the authors developed a "Generic Pricing Engine" (GPE) that can be used to experiment with a variety of derivatives, including the common European and Asian options. The authors compare their GPE with a dedicated implementation of a Basket Options Pricing Engine (BOPE) and show that the GPE gives up some parallel (GPU) performance compared with the dedicated BOPE, but is still significantly faster than the single-core implementation. This makes the GPE a viable tool for those who want to quickly experiment with new derivatives.

In "Mid-Price prediction in a limit order book" the authors propose several non-parametric methods (four conditional feature-based predictors, as well as share imbalance and order flow imbalance predictors) to forecast short-term mid-price changes in limit order books. The simulation experiments performed on liquid NASDAQ's stocks show that two of the proposed predictors produce statistically significant trading cost improvements with respect to uniform trading strategies, and seem to outperform the competing Obizhaeva–Wang strategy. The results have direct implications in practice for asset managers dealing with large portfolio turnovers.

The paper "Risk-Averse Multi-Armed Bandit Problems under Mean-Variance Measure" investigates how taking risk into account affects the policies for multi-armed bandits, by using a quadratic measure of risk. The authors determine lower bounds on the regret, and derive policies which achieve these lower bounds.

Hemakom *et al.* propose a metric called Assessment of Latent Index of Stress (ALIS) to determine transitions from normal (relaxed) to abnormal (stressed) periods in financial markets. They show the merit of ALIS for Dow Jones Industrial Average, NASDAQ Composite, Standard & Poor's 500 (S&P 500), and Russell 2000 indices that revealed high stress for the periods of Internet bubble burst and sub-prime mortgage crisis.

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Emmanuelle Jay received the Ph.D. degree in signal and image processing from the University of Cergy-Pontoise, Cergy, France in collaboration with The French Aerospace Lab. (also known as ONERA), Palaiseau, France. She currently works as both an Expert Consultant in IT & risk management at La Banque Postale Asset Management (LBPAM) and responsible for the research program at Fideas Capital. Prior to her current position, she was with Lyxor Asset Management (formerly SGAM AI) as a Research Engineer for almost seven years and then joined Aequam Capital as the Co-head of R&D. In the same period, she co-founded QAMLab SAS, an engineering and consulting firm where she was the President and responsible for the R&D. She is also a Lecturer at ENSEA, a leading French graduate school in electrical & computer engineering and telecommunications, co-authored a book published by Wiley&Sons and is a Co-editor-in-Chief for the Quant Finance Series published by ISTE & Elsevier. Her research interests include SP for finance, quantitative and statistical finance, risk management and hedge funds analysis. She is a Guest Editor of the IEEE JOURNAL ON SELECTED TOPICS IN SIGNAL PROCESSING.

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