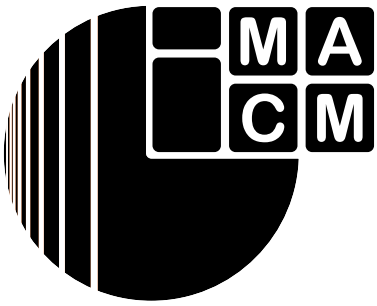

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STRIKE
Novel Methods in Computational Finance

A European mathematical research training network

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STRIKE – Novel Methods in Computational Finance

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Abstract

In recent years the computational complexity of mathematical models employed in financial mathematics has witnessed tremendous growth. Advanced numerical techniques are imperative for most present-day applications in the financial industry. Since January 1, 2013 Bergische Universität Wuppertal is coordinating a Marie Curie structured research training network, "STRIKE – Novel Methods in Computational Finance", with a duration of 48 months and a total budget of nearly €3.6 million. The network consists of 11 university teams from 9 different EU member states and 6 associated partners from academia and industry. Here we report on the outcomes of the first year, the recruitment, the first events, the individual projects that were started. We will organize mini-symposia at the next ECMI-2014 Conference in Taormina, Sicily. We will start a Special Interest Group on Computational Finance under the ECMI umbrella.

Objectives

The main training objective for STRIKE, `http://www.itn-strike.eu`, is to prepare, at the highest possible level, young researchers with a breadth of scientific knowledge, and to teach transferable skills like social awareness, which recent financial crises have shown to be very important. In this research training network the current topic is that the financial crisis affecting the European countries is the result of contagion and herding, and as such lies clearly outside the domain of validity of classical (mostly linear) models. Against this background our aim is to develop on the one hand a deeper understanding of complex financial models, and on the other hand effective and robust numerical schemes for solving problems arising from the mathematical theory of pricing financial derivatives.

The Network

Researchers from the length and breadth of Europe have joined forces in a transdisciplinary network investigating how the consequences of a financial crisis might in future be limited by the development and application of improved mathematical models. Entitled "STRIKE – Novel Methods in Computational Finance", the network also offers doctoral students and postdocs a pan-European training at the highest level. Since January 2013, 14 European universities and 3 financial services providers will be researching at the interface of financial mathematics, modelling, numerical mathematics, optimization, and parallel computing. At the same time the network develops new research training concepts for doctoral students and postdocs in which the boundaries between teaching and research will largely disappear. Doctoral students will spend a large part of their training on secondments to partner universities and firms, where the practical relevance of their research will become immediately evident. Particular emphasis is laid on soft skills – above all, social awareness – whose importance in the light of the recent financial crisis cannot be overestimated.

The direct network consist of: Bergische Universität Wuppertal, Germany (Matthias Ehrhardt, Michael Günther, Jan ter Maten), Comenius University Bratislava, Slovakia (Daniel Sevcovic), Universitat Politècnica de València, Spain (Lucas Jódar), Ruse University Angel Kanchev, Bulgaria (Lyuben Vulkov), Instituto Superior de Economia e Gestão, Lisbon, Portugal (Maria do Rosario Grossinho), Hochschule Zittau/Görlitz, Germany (Ljudmila Bordag), Technische Universität Wien, Austria (Ansgar Jüngel), Technische Universiteit Delft, the Netherlands (Kees Oosterlee), University of Greenwich, London, UK (Choi-Hong Lai), Universität Würzburg, Germany (Alfio Borzi), Universiteit Antwerpen, Belgium (Karel in 't Hout). All partners host Early Stage Researchers (ESR, PhD-students) and some of them Experienced Researchers (ER, PostDocs). We will refer to them as Fellows.

Additional partners are the University of A Coruña (Spain), University of Sussex (UK), Université Paris 6 (France). Partner companies are MathFinance AG, d-fine, Postbank AG. Deloitte AG and Yandex showed interest to join the network.

FIGURE 1: KICKOFF-MEETING AT WUPPERTAL, MARCH 2013.

Motivation for the Project

The complexity of the mathematical models used in the world of finance has grown enormously in recent years. To keep up with this, new models must be analysed and numerical procedures developed. Traders on the Stock Exchange use mathematical models to calculate the probable time within which a security might reach a specific value, what the deviation from this might be, and many other parameters.

As put and call decisions are generally based on such data, small errors in the models can have major effects on the market – all the more so when classical linear Black-Scholes-Merton models are used to calculate the fair price of an option, as these are unable to take account of all the relevant effects. Nonlinear partial differential equations (PDEs), on the other hand, can model transaction costs, illiquid markets, the impact of very large dealers (e.g. national banks) on the market price, and so probable investor risks, thus providing a better basis for option pricing.

The STRIKE network is engaged both in creating new models, and in developing nonlinear extensions of the Black-Scholes-Merton model. By using kinetic models of market players,

nonlinear partial differential equations, and stochastic optimal control techniques, suggestions for the avoidance of financial crises can be made on a purely mathematical basis.

Research

The current topic within the network is modelling the European financial crisis as the product of contagion and herding, which is not possible with classical linear finance-mathematical models. The contagion effect can be seen in the way Spain and Portugal began to stumble when Greece could no longer service its loans from Madrid or Lisbon, or in the way an Italian parliamentary crisis could trigger a debt cut that pulled other countries into the financial whirlpool.
The newly developed models will be tested and applied with the help of robust and effective arithmetical techniques. For this purpose network fellows are instructed in state-of-the-art languages like CUDA or OpenFOAM in order to program graphics processing units (GPUs) and write OpenFOAM libraries. The resultant programs and libraries, along with the specialist articles about them, will be archived in a Computational Finance Toolbox held at the Bergische Universität Wuppertal. At least part of this archive will be publicly accessible. Table 1 lists the individual research projects.

TABLE 1: RESEARCH PROJECTS.

BU Wuppertal	Compact Finite Difference Methods on Special Meshes
BU Wuppertal	Model Order Reduction Techniques for Energy Derivatives
CU Bratislava	Modelling of nonlinear Black-Scholes Equations
UP Valencia	Numerical Analysis of Finite Difference Methods for nonlinear Black-Scholes Models
U Ruse/Rousse	Fitted Operator Methods in Computational Finance
ISEG Lisbon	Analysis of Lévy Market Models and Partial Integral Differential Equations
UA Zittau	Lie Group Analysis of nonlinear Black-Scholes Equations
TU Vienna	Herding and Contagion Effects in Financial Markets and possible Counteractions proposed by Optimal Control Techniques
TU Delft	Modelling and Numerical Techniques for Credit Valuation Adjustment
U Greenwich	Newton-like Methods for the Commodity Market
U Würzburg	Optimal Control Tools in Computational Finance
U Antwerp	ADI-Schemes for nonlinear multi-dimensional Black-Scholes Equations

Working Structure

The network contains four work packages, each of them directed by a different network partner. Each package involves four or five tasks for PhD and postdoctoral fellows, in which they directly assist the package director, and in this way also receive organizational training.
Participating teams have agreed to deploy their competencies in widely varying fields, among them Lie group theory, modelling herding effects, nonlinear PDE analysis, compact finite difference methods, Fourier methods of option pricing, multilevel Monte Carlo methods, singular disturbed PDE methods, special lattices, optimal control methods, and model order reduction (MOR) techniques (see also Table 1).
Work packages are devoted to the typical steps of modelling, analysis, numerical calculation, and calibration:

- derivation and analysis of a new class of nonlinear option pricing models for illiquid and incomplete markets
- analysis of resultant nonlinear PDEs for option pricing
- construction of efficient higher order numerical methods for option pricing
- implementation of numerical codes for parallel computers
- calibration of resultant nonlinear models with real market data, and estimation of other key factors

As an example we briefly describe the two PhD-projects at Bergische Universität Wuppertal.

Compact finite difference methods for special meshes

The project aims to design and analyse new types of compact finite difference method for a general class of nonlinear Black-Scholes equations suitable for modelling transaction costs, illiquid markets, and the impact of very large dealers etc. The most recent results of transformation techniques for nonlinear Black-Scholes equations and of Lie group analysis for discrete systems are being applied to the generation of hybrid analytic numerical procedures that will provide exact results for nonlinear Black-Scholes equations.

Model order reduction (MOR) techniques for energy derivatives

This project applies MOR techniques to the efficient simulation of high dimensional mathematical models for financial processes. In this context MOR provides a way of automatically extracting a surrogate low dimensional PDE model, and hence of maintaining the correlation between input data (correlation matrix, yield profile, interest, dividend etc.) and output data (option price). This surrogate model will then be used in the University of Würzburg PhD-project to determine robust control mechanisms for the original problem. As this new finance mathematical application also investigates the impact of stochastic parameters on the MOR, it constitutes a research field in its own right.

Training

The network's transnational research and training program for doctoral students is based on four complementary elements:

- research project (modelling, analysis, simulation, validation)
- structured training in financial mathematics, analysis and numerical procedures
- scientific computing training in design, programming and use of high performance computers, GPUs and CFD toolboxes like OpenFOAM;
- training in transferable competencies (scientific method, management, communication).

Summary of first outcomes

During the first year all 12 Early Stage Researchers (ESRs, PhD-students, 3-year contracts) were appointed. Also one Experienced Researcher (ER) was appointed; we (still) need to select four more (each with a one-year contract). A gender balance of at least 40% females has been achieved. The Fellows did come from Bulgaria (1), Italy (2), Portugal (2), Russia (2), Slovakia (1), Spain (2), Vietnam (1), Zimbabwe (1).

The recruitment procedure caused some delays (on average 4 months) in actual work. However, because it applies to a big group, it will not immediately influence cooperation in a negative way. For each Fellow a Personal Career and Development Plan has been defined. This is evaluated every year and will, when appropriate, be updated. Care is taken for a good balance between effort spent to research and to training.

A first Progress Meeting for the Fellows took place in Valencia in September 2013. Recently, the Year-1 Meeting took place at the University of Greenwich (January 2014). At ECMI-2014 (June 9-13, 2014, Taormina, Sicily, http://www.taosciences.it/ecmi2014/) a mini-symposium on Computational Finance is organized. Together with the multi ITN HPCFinance (http://www.hpcfinance.eu), two Fellows from each ITN organize a Young Researcher's mini-symposium on High Performance Computational Finance.

Until March 2014, already six main events have been organized – some of them also open to external participants.

- Summer School, Vienna, http://www.asc.tuwien.ac.at/~juengel/sde/sde.html (Sept. 2013) on "Numerical methods for Stochastic Differential Equations", covered several mini courses, like Stability theory for numerical methods for stochastic differential equations, Stochastic simulation in chemistry and finance, Stochastic PDEs and their numerical approximation, Introduction to weak and strong approximation methods for stochastic differential equations. Furthermore, there were invited presentations and contributed talks. Quite a number of external people did attend the Summer School. In total there were more than 60 participants.
- Progress Workshop, Jornadas Conference, Valencia, http://jornadas.imm.upv.es/jornadas/index.html (September 2013). Three mini-symposia on Novel methods in Computational Finance were held. Two progress report sessions were devoted to work done (or to be done) by the Fellows. Outcomes will be published in a special issue of the International Journal of Computer Mathematics, Section B. The Fellows also had a "headless" meeting (i.e., without supervisors involved).
- Compact Course Lie Group Methods, Zittau, http://f-n.hszg.de/fakultaet/hochschullehrerinnen/ljudmila-bordag/ljudmila-bordag/konferenzen/compact-course-lie-group-methods.html (October 2013). The course on the scientific topic was taken from the yet unpublished book "Geometrical Properties of Differential Equations. Applications of the Lie group analysis in Financial Mathematics", by L.A. Bordag. One Fellow led the practical classroom seminars. Special invited speakers did provide several additional lectures each. In addition Communication & Presentation Techniques were practised.
  A special course, entitled "Ethic and Finance: Social awareness in Finance and Economics", gave the main ideas and theoretical background in ethics and was the start of controversially discussions on the role of sciences and especially of mathematics in the recent financial crisis. The central questions were: How to prevent such crisis in the future? How to describe the models (and their assumptions) for non-mathematicians?
- Winter School, Greenwich, http://cse.gre.ac.uk/STRIKE/Winter_School_2013_14.html (January 2014) on Methods for Nonlinear Problems and on practising in Matlab. Special topics did include the Riccati transformation method for solving Hamilton-Jacobi-Bellman equation, a two-grid Newton method for nonlinear models in finance and Markov chain approximation (filter) for estimating parameters of diffusion and jump-diffusion processes.
- Compact Course GPU Computing / OpenFOAM, TU Delft, https://www.aanmelder.nl/tudelft-course/part_program (February 2014) addressed parallel computing, MPI and CUDA, OpenFOAM and programming on GPUs (Graphical Processing Units). It offered several hands-on sessions on a broad range of problems (including incompressible flow, multiphase flow, multi-physics).
- Postbank Workshop, Bonn (March 26-28, 2014). Postbank AG, Deloitte, d-fine, European Patent Office, NAG, Techila Technologies (from ITN HPCFinance), all did provide contributions. Operations at a bank, risk management, credit risk modelling, IPR, parallel and GPU computing for financial problems and cloud computing were amongst the topics.

FIGURE 2: STRIKE FELLOWS AT GREENWICH WINTERSCHOOL.

Forecast

In the next months we will strengthen our cooperation with the Marie Curie Partner ITN HPCFinance, e.g., at ECMI 2014 there will be a joint mini-symposium of the two training networks. In parallel, to establish long lasting effects, we will start an ECMI Special Interest Group on Computational Finance at this event. The next upcoming training event will be a summer school in the framework of Conference MMEI 2014 *Mathematical Methods in Economics and Industry* at Smolenice Castle, close to Bratislava, September 8-12, 2014.

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> "Because this bridge will be rebuilt, the way out of our present dilemma is not to blame the quants. We must instead hire good ones – and listen to them."
>
> *Steven Shreve*

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