INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Team Mathfi

Financial Mathematics

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THEME NUM

Activity Report

2008

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2. Overall Objectives

2.1. Highlights of the year

Concerning research, a lot of effort has been put again this year in the study of Lévy processes in financial modeling.

Two new members have joined the PREMIA consortium: Bank Austria and RZB (Raiffeisen Zentralbank Österreich AG).

Concerning staff, Céline Labart and Jérôme Lelong (Postdocs in the Mathfi team in 2008) have been recruted in September 2008 as assistant professors at the Universty Pierre et Marie Curie (Paris 6) and ENSTA respectively.

2.2. Introduction

MathFi is a joint INRIA project-team with ENPC (CERMICS) and the University of Marne la Vallée, located in Rocquencourt and Marne la Vallée.

The development of increasingly complex financial products requires the use of advanced stochastic and numerical analysis techniques. The scientific skills of the MathFi research team are focused on probabilistic and deterministic numerical methods and their implementation, stochastic analysis, stochastic control. Main applications concern evaluation and hedging of derivative products, dynamic portfolio optimization in incomplete markets, calibration of financial models. Special attention is paid to models with jumps, stochastic volatility models, asymmetry of information. The MathFi project team develops the software Premia dedicated to pricing and hedging options and calibration of financial models, in collaboration with a consortium of financial institutions. Premia web site: http://www.premia.fr .

3. Scientific Foundations

3.1. Simulation of Stochastic Differential Equations

Keywords: *Euler schemes*, *approximation of SDE*.

Participants: B. Jourdain, A. Alfonsi, D. Lamberton, M. Sbai.

Most financial models are described by SDEs. Except in very special cases, no closed-form solution is available for such equations and one has to approximate the solution via time-discretization schemes in order to compute options prices and hedges by Monte Carlo simulations. Usually this is done by using the standard explicit Euler scheme since schemes with higher order of strong convergence involve multiple stochastic integrals which are difficult to simulate. In addition, the weak order of convergence of the explicit Euler scheme can be improved by using Romberg-Richardson's extrapolations. Nethertheless, some schemes with weak order of convergence two or more have been designed recently. The idea is either to replace the multiple Brownian integrals by discrete random variables which share their moments up to a given order or to integrate Ordinary Differential Equations associated with the vector fields giving the coefficients of the Stochastic Differential Equation up to well-chosen random time-horizons. Another interesting new direction of investigation is the design of exact simulation schemes.

Three directions of research have been investigated in the Mathfi project. First, fine properties of the Euler scheme have been studied [66], [7], [68]. Secondly, concerning SDEs for which the Euler scheme is not feasible, A. Alfonsi and V. Lemaire [1] have proposed and analysed new schemes respectively for Cox-Ingersoll-Ross processes and for equations with locally but not globally Lipschitz continuous coefficients. Last, the team has contributed to the new directions of research described above. For CIR processes, A. Alfonsi has designed a scheme with weak order two even for large values of the volatility parameter. Adapting exact simulation ideas, B. Jourdain and M. Sbai [8] have proposed an unbiased Monte Carlo estimator for the price of arithmetic average Asian options in the Black-Scholes model.

3.2. Numerical methods for option pricing and hedging and model calibration

Keywords: *Malliavin calculus*, *Monte-Carlo*, *finite difference*, *tree methods*.

Participant: all the Mathfi team.

Efficient computations of prices and hedges for derivative products is a major issue for financial institutions (see [70]) .

This is done by using either Monte-Carlo methods or partial differential equations techniques. Monte-Carlo simulations are widely used because of their implementation simplicity and because closed formulas are usually not available. Speeding up the algorithms is a constant preoccupation in the developement of Monte-Carlo simulations. The team is mainly concerned with *adaptive versions* which improve the Monte-Carlo estimator by relying only on stochastic simulations.

The team has also been active on numerical methods in models with jumps and large dimensional problems.

This activity in the MathFi team is strongly related to the development of the Premia software.

3.2.1. Model calibration:

A important research direction in mathematical finance is the modeling of the so called *implied volatility smile* which clearly indicates that the Black-Scholes model with constant volatility does not provide a satisfactory explanation of the prices observed in the market. It has led to the appearance of a large variety of extensions of this model aiming to overcome the above difficulty. Some popular model classes are: the local volatility models (where the stock price volatility is a deterministic function of price level and time), diffusions with stochastic volatility, jump-diffusions, and so on. An essential step in using any such approach is the *model calibration*, that is, the reconstruction of model parameters from the prices of traded options. The main difficulty of the calibration problem comes from the fact that it is an inverse problem to that of option pricing and as such, typically ill-posed.

The calibration problem is yet more complex in the interest rate markets since in this case the empirical data that can be used includes a wider variety of financial products from standard obligations to swaptions (options on swaps). The underlying model may belong to the class of short rate models like Hull-White [67], [61], CIR [63], Vasicek [77] etc. or to the popular class of LIBOR (London Interbank Offered Rates) market models like BGM [62].

The choice of a particular model depends on the financial products available for calibration as well as on the problems in which the result of the calibration will be used.

The calibration problem is of particular interest for MathFi project because due to its high numerical complexity, it is one of the domains of mathematical finance where efficient computational algorithms are most needed.

3.3. Malliavin calculus and applications in finance

Keywords: *Malliavin calculus*, *anticipative calculus*, *greek computations*, *insider trading*, *sensibility calculus*, *stochastic variations calculus*.

Participants: V. Bally, B. Jourdain, A. Kohatsu-Higa, D. Lamberton, B. Lapeyre, A. Sulem, A. Zanette.

The original Stochastic Calculus of Variations, now called the Malliavin calculus, was developed by Paul Malliavin in 1976 [71]. It was originally designed to study the smoothness of the densities of solutions of stochastic differential equations. One of its striking features is that it provides a probabilistic proof of the celebrated Hörmander theorem, which gives a condition for a partial differential operator to be hypoelliptic. This illustrates the power of this calculus. In the following years a lot of probabilists worked on this topic and the theory was developed further either as analysis on the Wiener space or in a white noise setting. Many applications in the field of stochastic calculus followed. Several monographs and lecture notes (for example D. Nualart [73], D. Bell [60] D. Ocone [75], B. Øksendal [78]) give expositions of the subject. See also V. Bally [57] for an introduction to Malliavin calculus.

From the beginning of the nineties, applications of the Malliavin calculus in finance have appeared : In 1991 Karatzas and Ocone showed how the Malliavin calculus, as further developed by Ocone and others, could be used in the computation of hedging portfolios in complete markets [74].

Since then, the Malliavin calculus has raised increasing interest and subsequently many other applications to finance have been found [72], such as minimal variance hedging and Monte Carlo methods for option pricing. More recently, the Malliavin calculus has also become a useful tool for studying insider trading models and some extended market models driven by Lévy processes or fractional Brownian motion.

Let us try to give an idea why Malliavin calculus may be a useful instrument for probabilistic numerical methods. We recall that the theory is based on an integration by parts formula of the form $E(f'(X)) = E(f(X)Q)$. Here X is a random variable which is supposed to be "smooth" in a certain sense and non-degenerated. A basic example is to take $X = \sigma\Delta$ where Δ is a standard normally distributed random variable and σ is a strictly positive number. Note that an integration by parts formula may be obtained just by using the usual integration by parts in the presence of the Gaussian density. But we may go further and take X to be an aggregate of Gaussian random variables (think for example of the Euler scheme for a diffusion process) or the limit of such simple functionals.

An important feature is that one has a relatively explicit expression for the weight Q which appears in the integration by parts formula, and this expression is given in terms of some Malliavin-derivative operators.

Let us now look at one of the main consequenses of the integration by parts formula. If one considers the *Dirac* function $\delta_x(y)$, then $\delta_x(y) = H'(y-x)$ where H is the *Heaviside* function and the above integration by parts formula reads $E(\delta_x(X)) = E(H(X-x)Q)$, where $E(\delta_x(X))$ can be interpreted as the density of the random variable X. We thus obtain an integral representation of the density of the law of X. This is the starting point of the approach to the density of the law of a diffusion process: the above integral representation allows us to prove that under appropriate hypothesis the density of X is smooth and also to derive upper and lower bounds for it. Concerning simulation by Monte Carlo methods, suppose that you want to compute $E(\delta_x(y)) \sim \frac{1}{M}\sum_{i=1}^{M}\delta_x(X^i)$ where $X^1, ..., X^M$ is a sample of X. As X has a law which is absolutely continuous with respect to the Lebesgue measure, this will fail because no X^i hits exactly x. But if you are able to simulate the weight Q as well (and this is the case in many applications because of the explicit form mentioned above) then you may try to compute $E(\delta_x(X)) = E(H(X-x)Q) \sim \frac{1}{M}\sum_{i=1}^{M}E(H(X^i-x)Q^i)$. This basic remark formula leads to efficient methods to compute by a Monte Carlo method some irregular quantities as derivatives of option prices with respect to some parameters (the *Greeks*) or conditional expectations, which appear in the pricing of American options by the dynamic programming). See the papers by Fournié et al [65] and [64] and the papers by Bally et al, Benhamou, Bermin et al., Bernis et al., Cvitanic et al., Talay and Zheng and Temam in [69].

L. Caramellino, A. Zanette and V. Bally have been concerned with the computation of conditional expectations using Integration by Parts formulas and applications to the numerical computation of the price and the Greeks (sensitivities) of American or Bermudean options. The aim of this research was to extend a paper of Reigner and Lions who treated the problem in dimension one to higher dimension - which represent the real challenge in this field. Significant results have been obtained up to dimension 5 [5] and the coresponding algorithms have been implemented in the Premia software.

Moreover, there is an increasing interest in considering jump components in the financial models, especially motivated by calibration reasons. Algorithms based on the integration by parts formulas have been developped in order to compute Greeks for options with discontinuous payoff (e.g. digital options). Several papers and two theses (M. Messaoud and M. Bavouzet defended in 2006) have been published on this topic and the corresponding algorithms have been implemented in Premia. Malliavin Calculus for jump type diffusions - and more general for random variables with localy smooth law - represents a promising field of research, also for applications to credit risk problems.

More recently the Malliavin calculus has been used in models of insider trading. The "enlargement of filtration" technique plays an important role in the modeling of such problems and the Malliavin calculus can be used to obtain general results about when and how such filtration enlargement is possible. See the paper by P.Imkeller in [69]). Moreover, in the case when the additional information of the insider is generated by adding the information about the value of one extra random variable, the Malliavin calculus can be used to find explicitly the optimal portfolio of an insider for a utility optimization problem with logarithmic utility. See the paper by J.A. León, R. Navarro and D. Nualart in [69]).

A. Kohatsu Higa and A. Sulem have studied a controlled stochastic system whose state is described by a stochastic differential equation with anticipating coefficients. These SDEs can be interpreted in the sense of *forward integrals*, which are the natural generalization of the semimartingale integrals, as introduced by Russo and Valois [76]. This methodology has been applied for utility maximization with insiders.

3.4. Optimal stopping, Stochastic Control and Backward Stochastic Differential equations

Keywords: *BSDE*, *Hamilton-Jacobi-Bellman*, *Stochastic Control*, *free boundary*, *optimal stopping*, *risk-sensitive control*, *singular and impulse control*, *variational and quasi-variational inequalities*.

Participants: A. Alfonsi, V. Bally, J.-Ph. Chancelier, B. Jourdain, C. Labart, D. Lamberton, M.C. Kammerer-Quenez, A. Sulem.

The theory of American option pricing has been an incite for a number of research articles about optimal stopping. Our recent contributions in this field concern optimal stopping for one dimensional diffusions and American options in exponential Lévy models.

In the context of general one-dimensional diffusions, we have studied optimal stopping problems with bounded measurable payoff functions. We have obtained results on the continuity of the value function and its characterization as the unique solution of a variational inequality in the sense of distributions, both in finite and infinite horizon problems (collaboration between D. Lamberton and Michail Zervos, London School of Economics).

We have explained how to calibrate a continuous and time-homogeneous local volatility function from the prices of perpetual American Call and Put options (A. Alfonsi and B. Jourdain).

The use of jump diffusions in financial models goes back to Merton (1976). More recently, there has been a growing interest for more sophisticated models, involving Lévy processes with no diffusion part and infinite activity (see, in particular, papers by Carr, Geman, Madan and Yor). One of our PhD students (M. Mikou) works on the qualitative properties of American option prices in exponential Lévy models. A number of results on the exercice boundary and on the so called smooth fit property have been established.

B. Øksendal (Oslo University) and A.Sulem have written a book on Stochastic control of Jump diffusions [11]). The types of control problems covered include classical stochastic control, optimal stopping, impulse control and singular control. Both the dynamic programming method and the maximum principle method are discussed, as well as the relation between them. Corresponding verification theorems involving the Hamilton-Jacobi Bellman equation and/or (quasi-)variational inequalities are formulated. There are also chapters on the viscosity solution formulation and numerical methods. In the second edition (2007), a chapter on optimal control of stochastic partial differential equations driven by Lévy processes and a section on optimal stopping with delayed information have been added. Applications to portfolio optimization problems and insurance problems have been studied.

In the context of risk measures, M.C. Quenez (assistant professor at UMLV until 2007, now Prof Paris VII) has shown how some dynamic measures of risk can be induced by Backward Stochastic Differential Equations and A. Sulem and B. Øksendal have studied risk-indifference pricing in incomplete markets with jumps using stochastic control theory and PDE methods.

4. Application Domains

4.1. Application domains

- Option pricing and hedging
- Calibration of financial models
- Portfolio optimization
- Insurance-reinsurance optimization policy
- Insider modeling, asymmetry of information

5. Software

5.1. Development of the software PREMIA for financial option computations

Keywords: *calibration*, *hedging*, *options*, *pricer*, *pricing*.

Participants: A. Alfonsi, V. Bally, J-Ph.. Chancelier, A. De la Vaissière, H. Galicher, B. Jourdain, A. Kbaier, A. Kohatsu Higa, O Kudryavtsev, C. Labart, A. Kolotaev, B. Lapeyre, J. Lelong, D. Pommier, A. Sulem, X. Wei, A. Zanette, V. Zherder.

Figure 1.

5.1.1. Description of Premia

PREMIA is a platform dedicated to the development of algorithms and scientific documentation for *option pricing*, *hedging* and *model calibration* (http://www.premia.fr).

This project keeps track of the most recent advances in the field of computational finance in a well-documented way. It focuses on the implementation of numerical analysis techniques for both probabilistic and deterministic numerical methods. An important feature of the platform Premia is the detailed documentation which provides extended references in option pricing.

Premia is thus a powerful tool to assist Research & Development professional teams in their day-to-day duty. It is also a useful support for academics who wish to perform tests on new algorithms or pricing methods without starting from scratch.

Besides being a single entry point for accessible overviews and basic implementations of various numerical methods, the aim of the Premia project is:

1. to be a powerful testing platform for comparing different numerical methods between each other;
2. to build a link between professional financial teams and academic researchers;
3. to provide a useful teaching support for Master and PhD students in mathematical finance.

The development of Premia started in 1999 and 11 are released up to now and registered at the APP agency.

5.1.2. Content of Premia

Premia contains various numerical algorithms (Finite-differences, trees and Monte-Carlo) for pricing vanilla and exotic options on equities, interest rate, credit and energy derivatives.

1. Equity derivatives:

   The following models are considered:

   Black-Scholes model (up to dimension 10), stochastic volatility models (Hull-White, Heston, Fouque-Papanicolaou-Sircar), models with jumps (Merton, Kou, Tempered stable processes, Variance gamma, Normal inverse Gaussian), Bates model.

   For high dimensional American options, Premia provides the most recent Monte-Carlo algorithms: Longstaff-Schwartz, Barraquand-Martineau, Tsitsklis-Van Roy, Broadie-Glassermann, quantization methods Malliavin calculus based methods.

   Dynamic Hedging for Black-Scholes and jump models is available.

   Calibration algorithms for some models with jumps, local volatility and stochastic volatility are implemented.

2. Interest rate derivatives

   The following models are considered:

   HJM and Libor Market Models (LMM): affine models, Hull-White, CIR++, Black-Karasinsky, Squared-Gaussian, Li-Ritchken-Sankarasubramanian, Bhar-Chiarella, Jump diffusion LMM, Markov functional LMM, LMM with stochastic volatility.

   Premia provides a calibration toolbox for Libor Market model using a database of swaptions and caps implied volatilities.

3. Credit derivatives: CDS, CDO

   Reduced form models and copula models are considered.

   Premia provides a toolbox for pricing CDOs using the most recent algorithms (Hull-White, Laurent-Gregory, El Karoui-Jiao, Yang-Zhang, Schönbucher)

4. Hybrid products:

   PDE solver for pricing derivatives on hybrid products like options on inflation and interest or change rates is implemented.

5. Energy derivatives: swing options

   Mean reverting and jump models ar considered.

   Premia provides a toolbox for pricing swing options using finite differences, Monte-Carlo Malliavin-based approach and quantization algorithms.

Premia 10 has been delivered to the consortium members in February 2008. It contains routines for pricing interest rate derivatives in the Libor Market Model, Inflation-Indexed Derivatives, Credit Risk Derivatives and various algorithms for pricing equity derivatives in high dimensions.

5.1.3. Latest features

Oleg Kudryavtsev has developped numerical algorithms for option pricing in models with jumps, such as Lévy temperate stable [47]. He has developped and implemented numerical methods for pricing American and barrier options using the Wiener-Hopf approach.

D. Pommier has developed a numerical procedure based on sparse grid methods for pricing European vanilla options in stochastic volatility model.

C. Labart and Qi Zhong have implemented a pricing algorithm for CDOs using the Stein method, based on the two following papers:

- “Stein’s method and Zero Bias Transformation for CDO’s tranche pricing”, N. El Karoui and Y. Jiao
- “Gauss and Poisson Approximation: Application to CDO’s Tranche Pricing”, N. El Karoui, Y. Jiao and D. Kurtz

C. Labart is still working on CDOs and especially on the hedging of CDOs. She aims to implement in PREMIA the algorithms of the following papers

- Hedging Default Risks of CDOs in Markovian Contagion Models. by J.P. Laurent A.Cousin J.D.Fermanian
- Dynamic hedging of synthetic CDO-tranches with spread-and contagion risk Frey, R. and Backhaus, J. , preprint, department of mathematics, University of Leipzig
- Pricing and Hedging of Credit Derivatives via Nonlinear Filtering preprint, department of mathematics, Frey, R. and Schmidt, T. and Gabih, University of Leipzig.

New algorithms for the release 11 of Premia to be delivered in February 2009 to the Consortium

- Interest Rate Derivatives
  - A stochastic volatility Libor model and its robust calibration *Working paper Belomestny Mathew Schoenmakers (2007)*
  - S.Levendorskiy N.Boyarchenko : Fast pricing/fitting method for quadratic term structure models with jump.
  - C. Bayer J.Teichmann: Cubature on Wiener space in infinite dimension. Finite difference methods for SPDEs and HJM-equations.*preprint arXiv:0712.3763v1*
- Credit Risk Derivatives
  - Approximation of Large Portfolio Losses by Stein’s Method and Zero Bias Transformation *El Karoui, Jiao (2006).*
  - A dynamic approach to the modelling of credit derivatives using Markov chains *Rogers, Di Graziano 2006*
  - Calibration of CDO Tranches with the dynamical Generalized-Poisson Loss model,*Brigo, Pallavicini, Torresetti (2006).*
- Equity Derivatives
  - D. Pommier : Wavelet sparse approach for stochastic volatility models with jumps.
  - E. Dia and D. Lamberton : Monte Carlo Methods for pricing path-dependent options in Lévy (Kou, CGMY, Merton) models
  - Kudrayvtsev O., S.Levendorskiy : Fast pricing of American and barrier options under Lévy processes
  - Pricing Variance Swaps : Consistent Variance Curve Models *H. Buehler Finance and Stochastics, Volume 10, Number 2 / April, 2006*
  - J. Lelong B. Jourdain: Variance Reduction for multi-dimensional models.
  - Primal-Dual Simulation Algorithm for Pricing Multidimensional American Options. *L. Andersen M. Broadie Management Science Vol. 50, No. 9, September 2004, pp. 1222-1234*
  - "Partially exact and bounded approximations for arithmetic Asian options", Lord, R. (2006). Journal of Computational Finance, vol. 10, no. 2.
  - Efficient Simulation of the Heston Stochastic Volatility Model *L.Andersen Journal of Computational Finance, Volume 11 / Number 3, 2008*

- An almost exact simulation method for the Heston model *by Robert D. Smith Journal ofComputational Finance, Volume 11 / Number 1, Fall 2007*
- A Comparison of Biased Simulation Schemes for Stochastic Volatility Models *R.Lord, R.Koekkoek, D.J.C.Van Dijk, Tinbergen Institute Discussion Paper No. 06-046/4*
- Efficient, Almost Exact Simulation of the Heston Stochastic Volatility Model *by A.Van Haastrect A.Pelsser preprint*
- Fast strong approximation Monte-Carlo schemes for stochastic volatility models *C. Kahl, P.Jackel, Journal of Quantitative Finance , Vol. 6, 2006, pp. 513-536*
- Exact Simulation of Option Greeks under Stochastic Volatility and Jump Diffusion Models *M.Broadie O.Kaya preprint*
- A Simple and Exact Simulation Approach to Heston Model *Jianwei Zhu preprint*
- M. Gaudenzi A. Zanette : Singular points methods for pricing options with discrete dividends.
- Vellekoop, M.H. and Nieuwenhuis : Efficient Pricing of Derivatives on Assets with Discrete Dividends, Applied Mathematical Finance 13(3), pp. 265-284 (2006).

5.1.4. Software organization

The software Premia provides a collection of C/C++ routines and scientific documentation in PDF and HTML. More precisely, Premia is composed of :

- a library designed to describe derivative products, models, pricing methods and which provides basic input/output functionalities.
- a collection of pricing routines: in this way, the routines of Premia can easily be plugged into other financial softwares.
- a scientific documentation system. It is created from hyperlinked PDF files which describe the pricing routines and the general numerical methods involved like Monte Carlo methods, lattice methods, etc.

Premia is available for Windows and Linux operating systems. It provides Excel and Scilab/Nsp interfaces. Reports in PDF can be automatically generated at the end of each computation session.

The size of Premia is around 500 Mb, with 12 Mb of source code in C.

In 2008, the architecture and interface of Premia have been improved.

- J. Lelong and D. Pommier are developing a numerical library for Premia to give the contributors a unified scientific library. J. Lelong has started to backport the modifications enduced by this library to the existing code.
- J. Lelong has integrated an external CDO pricer into the core of Premia.
- J. Lelong has further developped the graphical Nsp interface and the scripting interface. He has started to write a documentation on the way to use the Nsp interface. J. Lelong and D. Pommier have settled an automatic testing procedure for Premia using Nsp. With J.P. Chancelier, they have proceed the cross-compilation of Premia and Nsp to provide Premia/Nsp to Windows users.
- The Excel interface documentation has been completed (A. de la Vaissière).
- D. Pommier and J. Lelong are taking care of the maintenance of the code and test of the new routines.
- The scientific documentation (interdependent LaTeX files) has been re-organized (A. de la Vaissière, J. Lelong).
- Microsoft Windows compatibility has been improved (A. de la Vaissière, J. Lelong).
- The website www.premia.fr has been updated (A. de la Vaissière, J. Lelong).
- Inria Gforge tools are used for the development of Premia Software. We were convinced by the user friendly administration interface and some neat features regarding mailing of information from subversion.

5.1.5. Consortium Premia

Premia is developed in interaction with a consortium of financial institutions or departments presently composed of: CALYON, Société Générale, Natixis, Bank Austria and RZB (Raiffeisen Zentralbank Österreich AG) - new members. The participants of the consortium contribute to finance the development of Premia and help to determine the directions in which the project evolves. They have access to the complete software with the source and the documentation. Every year, a new release is delivered to the Consortium members.

Moreover, a restricted version of Premia is available on Premia web site http://www.premia.fr and can be downloaded with a special license for academic and evaluation purposes.

6. New Results

6.1. Joint modeling of indexes and stocks

Participants: M. Sbai, B. Jourdain.

B. Jourdain and M. Sbai have developed a model coupling an index with its underlying stock components [46]. These stocks are supposed to be influenced by the index which reflects the view of the investors on the state of the economy. More precisely, the return of each stock is decomposed into a systemic part driven by the index and an idiosyncratic part driven by the stock itself. In the limit of a large number of stocks, the index evolves according to a local volatility model and each stock according to a stochastic volatility model driven by the index. According to Dupire's formula, it is then possible to fit the smile of the index. Then the idiosyncratic part of the dynamics of each stock may be calibrated using a well chosen system of interacting stochastic differential equations. Such a procedure which gives priority to the calibration of the index is natural since the options written on the index are more liquid than those written on the composing stocks. This research has benefited from numerous discussions with L. Bergomi and J. Guyon (Société Générale).

6.2. Monte Carlo simulations and stochastic algorithms

Keywords: *Monte-Carlo*, *variance reduction*.

Participants: E.H.A. Dia, B. Jourdain, C. Labart, D. Lamberton, J. Lelong.

6.2.1. Adaptive variance reduction methods

When computing the expectation of a random variable by a Monte Carlo approach, the stratified sampling variance reduction technique consists in computing the expectation of the random variable conditioned to belong in each stratum of a partition of the state space. In this approach, the probability of each stratum has to be known analytically and simulation according to the corresponding conditional law must be feasible. It is well-known that allocation of the numbers of random drawings in the strata proportional to their probability achieves variance reduction. But the optimal allocation which involves the conditional variances in the strata is unknown. For fixed strata, P. Etoré and B. Jourdain have developed an algorithm aimed at adaptively estimating the optimal allocation of the drawings between the strata when computing the stratified Monte-Carlo estimator of the expectation. For their estimator, they prove a central limit theorem with asymptotic variance equal to the optimal variance and confirm its performance by numerical experiments. With G. Fort and E. Moulines, they have developed a stochastic algorithm able to optimize dynamically the stratification direction orthogonal to the boundaries between the strata when these boundaries are hyperplanes. The optimization of the stratification direction is easier and more efficient in terms of variance reduction than the optimization of the abscissae of the strata boundaries along this direction. Indeed, according to theoretical results obtained in this work, in the asymptotics of a large number of strata, the variance of the estimator does not depend on these abscissae.

B. Jourdain and J. Lelong have developed a robust adaptive importance sampling algorithm for the computation of the expectation of a function of a normal random vector. They propose to optimize a vector translating the normal random vector which corresponds to an Esscher's transform change of measure. As a function of this translation parameter, the empirical approximation of the variance of the importance sampling estimator is a strongly convex function and its gradient and Hessian have explicit expressions. The translation parameter minimizing this empirical approximation is easily obtained by a few iterations of Newton's algorithm. B. Jourdain and J. Lelong propose to use the same samples to compute this translation parameter and to approximate the expectation of interest by the importance sampling estimator corresponding to this parameter. Despite the dependance between the random variables which appear in the resulting estimator, they prove that this estimator is convergent and asymptotically normal with optimal limiting variance.

6.2.2. Monte-Carlo methods for exotic options in models with jumps

D. Lamberton and his PhD student El Hadj Aly DIA's have obtained some results concerning lookback options in jump-diffusion models, in particular, estimates for expectations involving discrete vs continuous maxima of the sample paths of a Lévy process.

6.2.3. Backward Stochastic Differential equations (BSDEs)

C. Labart has implemented the numerical algorithm for solving BSDEs (presented in her PhD thesis) in dimension $d > 1$. She is now working on the use of this algorithm to solve forward backward stochastic differential equations and on the proof of its convergence in this more general case

6.3. Optimal stopping and American Options

Participants: C. Labart, D. Lamberton, M. Mikou.

Damien Lamberton and Mihail Zervos (London School of Economics) have have studied optimal stopping problems of one-dimensional diffusions with irregular reward functions in finite horizon. The value function can be characterized as the unique solution (in the sense of distributions) of a variational inequality. A paper has been submitted.

C. Labart is working with E. Gobet and C. Costantini on the pricing of American options using domain perturbations to find the exercise region.

D. Lamberton and his PhD student Mohammed Mikou have studied the so-called smooth fit property for the American put in the case of general exponential Lévy models.

D. Pommier, T. Arnason and Y. Achdou are investigating a numerical procedure for the calibration of American option in Lévy models. This work in an extension of a previous work of Y. Achdou and O. Pironneau : A numerical procedure for the calibration of the volatility with American options. The aim is to find optimality conditions on the parameters for minimization of a least square problem involving the observed option prices. The topic also involves studying properties of the associated free boundary.

6.4. Sparse grids methods for PDEs

Keywords: *adaptive finite elements*, *finite element*, *lattice-based methods*, *sparse grids*.

Participants: Y. Achdou, D. Pommier.

D. Pommier has defended is thesis on Sparse grid methods. This work presents some numerical approximation of Partial Differential equation (PDE) or Partial integro-differential equation (PIDE) in mathematical finance.

The thesis is split into three part. The first one deals with the study of is presented Sparse Grid techniques. In an introductory chapter, the construction of Sparse Grid spaces and some approximations properties are given. The second chapter is devoted to numerical algorithm to solve PDE on these spaces. It clarifies the finite difference method on Sparse Grid by looking at it as a collocation methods. Some remarks on the practical implementation problems are given.

The second part of the thesis is devoted to the application of Sparse Grid techniques to mathematical finance. Two practical problems. In the first one, we consider a European vanilla contract with a multivariate generalisation of the one dimensional Ornstein-Uhlenbeck-based stochastic volatility model. A relevant generalisation is to assume that the underlying asset is driven by a jump process leading to a Partial Integro Differential Equation (PIDE). Due to the curse of dimensionality, standard deterministic methods are not competitive with Monte Carlo methods. We discuss sparse grids finite difference methods for solving the PIDE arising in this model up to dimension 4. In the second problem, we consider a Basket option on several assets (five in our example) in the Black & Scholes model. We discuss Galerkin methods in a sparse tensor product space constructed with wavelets.

The last part of the thesis is concerned with a posteriori error estimates in the energy norm for the numerical solutions of parabolic obstacle problems allowing for space/time mesh adaptive refinement. These estimates are based on a posteriori error indicators which can be computed from the solution of the discrete problem. We present the indicators for the variational inequality obtained in the context of the pricing of an American option on a two assets basket using the model of Black and Scholes model. Related numerical results are given.

6.5. Stochastic control of jump diffusions and applications

Keywords: *BSDE*, *Malliavin calculus*, *jump diffusions*, *maximum principle*, *risk measures*, *stochastic control*.

Participant: A. Sulem.

In [48], A. Sulem and B. Øksendal (Oslo university) propose various versions of the maximum principle for optimal control of forward-backward SDEs with jumps. This study is motivated by risk minimization via g-expectations. They first prove a general sufficient maximum principle for optimal control with partial information of a stochastic system consisting of a forward and a backward SDE driven by Lévy processes. They then present a Malliavin calculus approach which allows them to handle non-Markovian systems and give examples of applications.

In a new project, A. Sulem and B. Øksendal study robust optimal stochastic control of jump diffusions and equivalent martingale measures.

6.6. Malliavin calculus in models with jumps

Keywords: *Malliavin calculus*.

Participants: V. Bally, A. Kohatsu-Higa.

In continuation of the paper [4] on Malliavin Calculus for Poisson Point Processes and applications by V. Bally, M. P. Bavouzet and M. Messaoud, V. Bally is working in collaboration with E. Clément (Université Paris-Est Marne la Vallée) on some further applications concerning the density of the law of the solution of a stochastic equation with jumps, which has discontinuous coefficients. Two preprints on this subject have been published during the visit of V. Bally at the Mittag Leffler Institute [58], [59]. Moreover, he is studying the smoothness of the law of solutions bidimensional Bolzman equations in collaboration with N. Fournier (University of Creteil).

6.7. Anticipative stochastic calculus in models with jumps

Keywords: *anticipative calculus*, *asymmetry information*, *forward integrals*, *insider*.

Participants: A. Kohatsu-Higa, A. Sulem.

An insider is an agent who has access to larger information than the one given by the development of the market events and who takes advantage of this in optimizing his position in the market . In [37], we consider the optimization problem of an insider who is so influential in the market to affect the price dynamics: in this sense he is called a “large” insider. The optimal portfolio problem for a general utility function is studied for a financial market driven by a Lévy process in the framework of forward anticipating calculus.

We plan to further investigate this domain in 2009 with Francesco Russo.

6.8. Lower bounds for the density of a functional

Participant: V. Bally.

In continuation of the paper [56], V. Bally has three projects on this subject in progress, in collaboration with: B. Fernandez and A. Meda (University of Mexico) on “Tubes evaluations for solutions of non-Markov Stochastic Differential Equations”, in collaboration with L. Caramellino (University of Roma 3) on “Lower bounds for the density of Ito processes under weak regularity assumptions” and finally in collaboration with A. Kohasu-Higa on “Lower bounds for the density of diffusion processes under weak Hormander assumption”.

7. Contracts and Grants with Industry

7.1. Consortium Premia

The consortium Premia is centered on the development of the pricer software Premia. It is presently composed of the following financial institutions: CALYON, Société Générale, Natixis, Bank Austria, Raiffeisen Zentralbank Österreich AG.

8. Other Grants and Activities

8.1. ANR programs

- ANR program GCPMF "Grid Computation for Financial Mathematics" February 2006-June 2009. Partners : Calyon, Centrale, EDF, ENPC, INRIA, Ixis, Paris 6, Pricing Partner, Summit, Supelec.

  Global coordinator: B. Lapeyre.
- ANR program Adap'MC (Adaptative Monte Carlo Methods): Partners ENST, ENPC, University Pari-Dauphine.

  ENPC coordinator: B. Lapeyre.

8.2. Pôle compétitivité

The project “Creditnext” on credit risk derivatives has been accepted in the “Pôle Finance Innovation”. Partners: Euronext Paris, Lunalogic, Pricing Partners, CMAP (Ecole Polytechnique), CERMICS/ENPC, Université Paris-Est Marne la Vallée (Laboratoire de Mathématiques Appliqués), INRIA (projet Mathfi).

8.3. International cooperations

- Part of the European network "Advanced Mathematical Methods for Finance" (AMaMef). This network is supported by the European Science Foundation (ESF).
- Collaborations with the Universities of Oslo, Bath, Chicago, Mexico, Osaka, Rome II and III, Tokyo Institute of Technology

9. Dissemination

9.1. Seminar organisation

- A. Alfonsi : co-organizer of the working group seminar of MATHFI “Stochastic methods and finance”.
- V. Bally : Member of the organization Committee of the “9th Colloque Franco-Roumain de Mathématiques Appliquées”; Brasov Roumania 28 August- 2 September.
- B. Lapeyre :

  - Member of the program committee of the "Conference on Optimization and Practices in Industry", Paris, University Paris-Sorbonne, 26-28 november 2008

  - Member of the scientific Committee of the "Conference on Numerical Methods in Finance", Udine (Italy), 25-27 June 2008.

  - Member of the program committee of the "Parallel and Distributed Computing in Finance" May 25-29, 2009, Roma (Italy).
- F. Russo

  - Coorganisation (with E. Valkeila, J.M. Corcuera and F. Biagini) of an AMAMEF workshop on “No semimartingale models in finance”, May 2009, Helsinki, Finland.
- A. Sulem:

  - Member of the Scientific Committee, Second SIAM Conference in Financial Mathematics", Rutgers University, USA, November 7-8 2008.

  - Member of the Scientific Committee of the Optimal stopping with applications symposium, Turku Finland 15-19 June 2009. http://web.abo.fi/fak/mnf/mate/gradschool/optimalstopping2009/

  - Member of the Scientific Amamef Conference on Numerical Methods in Finance, Udine, Italy, 25-28 June 2008.
- A. Zanette:

  Organisation of the Amamef conference on Numerical Methods in Finance, June 2008, Udine, Italy.

9.2. Editorship

- D. Lamberton

  - Associate Editor of *Mathematical Finance* and *ESAIM PS*.
- A. Sulem

  - Associate editor of SIAM Journal on Financial mathematics

9.3. Services to the scientific community

- B. Jourdain

  Deputy head of the doctoral school ICMS, University Paris-Est
- D. Lamberton

  - in charge of the master program “Mathématiques et Aplications" (Universities of Marne-la-Vallée, Créteil and Evry, and Ecole Nationale des Ponts et Chaussées).

  - Director of the Mathematical department (UFR de mathématiques), Université Paris-Est Marne-la-Vallée.

  - Member of the Steering Committee of the ESF European Network "Amamef" (http://www.iac.rm.cnr.it/amamef/); in charge of the GDR "Méthodes Mathématiques pour la finance", which is the national CNRS group related to the network.
- B. Lapeyre
  - President of the Doctoral Department at Ecole des Ponts

- A. Sulem

  - Vice-President of the Inria Evaluation Board (September 2005-June 2008)

  - Member of the evaluation committee of the University Paris-Dauphine.

  - Member of the doctoral board of the the University Paris-Dauphine.

9.4. Teaching

- A. Alfonsi
  - “Probabilités et Statistiques”, first year course at the Ecole des Ponts.
  - “Modéliser, Programmer et Simuler”, second year course at the Ecole des Ponts.
  - “Calibration, Volatilité Locale et Stochastique”, third-year course at ENSTA (Master with Paris I).
- V. Bally

  Master 2, Université Paris-Est Marne la Vallée :

  1. Malliavin Calculus and numerical applications in finance.

  2. Probabilistic methods for risk analysis.
- B. Jourdain : - Course "Probability theory and statistics", first year ENPC

  - Course "Stochastic numerical methods", 3rd year, Ecole Polytechnique

  - Projects and courses in finance, Majeure de Mathématiques Appliquées, 3rd year, Ecole Polytechnique
- B. Jourdain, B. Lapeyre :

  - Course "Monte-Carlo methods in finance", 3rd year ENPC and Master Recherche Mathématiques et Application, University of Marne-la-Vallée
- C. Labart:
  - Lectures on “Discrete time models for finance” at ENSTA (2nd year course), 18 hours and at University Pierre et Marie Curie (Master “Probabilités et Finance”) 12 hours.
  - Lectures on “Stochastic Calculus : applications of Itô’s formula and stochastic differential equations” at University Pierre et Marie Curie (Master IFMA) 12 hours.
  - Lectures on “Random Models: Markov chains and Markov Processes”, at University Pierre et Marie Curie (Master IFMA), 28 hours.
  - Management of projects on the pricing and hedging of exotic options in C/C++ at ENSTA (2nd year course).
- D. Lamberton :

  - Third year of Licence de mathématiques (differential calculus, differential equations), Université Paris-Est Marne-la-Vallée.

  - Préparation à l’agrégation interne de mathématiques, Université Paris-Est Marne-la-Vallée.

  - Master course “Calcul stochastique et applications en finance", Université Paris-Est Marne-la-Vallée.
- B. Lapeyre

  - Ecole des Ponts, 2nd year, "Introduction to mathematical methods for finance", 2008
- J. Lelong
  - Lectures on “Numerical Methods in Finance” at the University of Halmstad (Sweden) in the "Masters program in financial mathematics".

  - Lectures on “Numerical Methods in Finance” at Ecole Nationale Supérieure de Techniques Avancées (second year course)
  - Lectures on “Monte Carlo methods for American option pricing” at Collège de l’Ecole Polytechnique.
  - Practicals on “Markov Chains” (second year course, ENSTA).

- A. Sulem

  - Course on numerical methods in finance, Master II MASEF and EDPMAD, University Paris-Dauphine (21 hours)

9.5. Internship advising

- A. Alfonsi
  - Slim Belazi (supervised by Ahmed Kebaier): Implementation of the GPL model by Brigo, Pallavicini and Torresetti for PREMIA.
  - Moulay Chkifa: Implementation of different algorithms for the simulation of the Heston model (papers from Andersen, Smith, Haastrecht and Pelsser,...) for PREMIA.
  - Frank Ouaki: ”Heston and local volatility models”.
- B. Jourdain:
  - Amine Bellakrid : Implementation of the article by Lord "Partially exact and bounded approximations for arithmetic Asian options", Journal of Computational Finance, Vol. 10, No. 2, pp. 1-52
  - Pierre-Olivier Camus : implementation of Primal-Dual Simulation Algorithm for Pricing Multidimensional American Options.
- C. Labart

  Qi Zhong: second year student from ENSTA on the pricing of CDOs.
- J. Lelong:

  Cunkai Tang: second year student from ENSTA (Ecole Nationale Supérieure de Techniques Avancées) on : “Adaptive control variates for pricing American options in high dimension”.
- D. Pommier:

  Hidane Moncef: second year student from MASTER Modélisation Aléatoire (Universite Paris Diderot) on : “Finite Element Method applied to pricing European option in Heston model”.

9.6. PhD defences

- David Pommier

  Title : “Sparse grid methods applied to option pricing”

  Adviser: Yves Achdou

  Defended November 28th at the University Pierre et Marie Curie (Paris 6).

9.7. PhD advising

- V. Bally

  Since october 2007, S. da Marco, student in Scola Normale Superiore di Pisa, in collaboration with M. Pratelli from the University of Pisa.

- B. Jourdain

  Mohamed Sbai (3rd year)

  "Simulation of stochastic differential equations in finance"

- D. Lamberton

  - Mohammed MIKOU (4th year). American options in exponential Lévy models Allocataire-moniteur at Université Paris-Est Marne-la-Vallée.

  - El Hadj Aly DIA (3rd year). Monte-Carlo methods for exotic options in models with jumps. Allocataire de recherche at Université Paris-Est Marne-la-Vallée.

  - Sidi Mohamed OULD ALY (2nd year). Exotic options and stochastic volatility models.

  - Abdelmounaim Abbas-Turki (1st year, Funding: "Pôle Finance Innovation" - Créditnext Project) "Smile in large dimension”.

- B. Lapeyre and A. Alfonsi

  Abdel Ahdida (1st year, Funding "Pôle Finance Innovation" - Créditnext Project) "Credit risk derivatives and Numerical aspects".

- Y. Achdou (Paris 6) and A. Sulem

  - David Pommier

  Cifre agreement INRIA and BNP-Paribas “Sparse grid for large dimensional financial issues”.

- F. Russo
  - Nadia Belaribi. Aspects numériques de la représentation probabiliste d’EDP de type milieu poreux généralisées.
  - Cristina Di Girolami (Co-advising Luiss). Calcul via régulariqation en dimension infinie et applications à la finance.
  - Stéphane Goutte. (Co-advising Luiss). Couverture en marché incomplet et applications au marché de l’électricité.
  - Ida Kruk. Calcul de Malliavin pour des processus gaussiens généraux.
  - Stefano Mega. (Co-advising Luiss) Valorisation des services relatifs aux réseaux de télécommunication.

9.8. PhD reports

- V. Bally

  - Referee for the PhD thesis: ‘Méthodes probabilistes pour les conditions au bord artificielles d’EDOP non linéaires en Finance. problême d’arrêt optimal pour une diffusion régulière”, by Mamadou Cisse, Université de Nice, July 10th.

- B. Jourdain

  - Referee for the PhD thesis of Jean-François Jabir: "Modèles stochastiques lagrangiens de type McKean-Vlasov conditionnel et leur confinement", Octobre 10th, Université de Nice.

- D. Lamberton

  - Referee for the PhD thesis of Jean-François Chassagneux, University Paris VII, November 2008.

- B. Lapeyre

  - Referee of the PhD thesis of D. Pommier, Université Paris 6, December 2008.

- F. Russo

  - Referee of the PhD thesis of Simone Scotti. Scuola normale superiore di Pisa et ENPC. October 2008

  - Referee of the PhD thesis of Daniel Conus, EPFL Lausanne. December 2008

- A. Sulem

  - "External Examiner" for the PhD thesis of Sebastien Lleo "Contributions to Risk Sensitive Asset Management', Department of Mathematics, Imperial College, London, June 2008.

  - Referee for the PhD thesis "Méthodes probabilistes pour les conditions au bord artificielles d'EDOP non linéaires en Finance. Problème d'arrêt optimal pour une diffusion régulière" by Mamadou Cisse, Université de Nice, July 10th

  - Referee for the PhD thesis "Contrôle optimal stochastique avec retard, asymetrie d'information et applications en finance et en economie", of Delphine David, November 2008, Université La Rochelle.

9.9. Participation to workshops, conferences and invitations

- A. Alfonsi

  Conference:

  - "High order discretization schemes for the CIR process: application to Heston and Affine models", Bachelier Conference 2008, London (16-07).

  Talks:

  - "Optimal execution strategies in limit order books with general shape functions", Séminaire Bachelier, Paris (01-02) and GT MSF, Marne la Vallée (18-04).
  - "High order discretization schemes for the CIR process: application to Heston and Affine models", Séminaire Bachelier, Paris (10-10) and Osaka University (26-09)

  Invitations:

  - Osaka University, by Arturo Kohatsu-Higa (23-09 to 02-10)
  - Cornell University (Ithaca, NY), by Alexander Schied (17-11 to 23-11)

- V. Bally
  - Invited to the Seminar of Stochastic Analysis, Random Fields and Applications, 14-18 May 2008, Ascona. Talk on "Integration by parts formula for locally smooth laws and applications to equations with jumps".
  - Invited to the 3rd General AmaMeF conference, May 5-10, Pitesti, Roumania. Talk on "Integration by parts formula for locally smooth laws and applications to equations with jumps".
  - Invited to the Workshop on Numerics and Stochastics, Helsinki University of Technology, August 25-29, 2008, organized by AmaMeF. Talk on "Lower bounds for the probability that an Ito process remains in a tube".
  - Invited to the Special Semester on Stochastics with Emphasis on Finance (RICAM-Linz, September-December 2008). Talk on "Lower bounds for the probability that an Ito process remains in a tube."
  - Visit to the University of Mexico (26 July-10 August)

- B. Jourdain
  - Invited speaker Workshop on Computational Methods with Applications in Finance, Linz, 17-21 november 2008 : Robust adaptive variance reduction for normal random vectors
  - Conference on Numerical Methods in Finance, Udine, 25-27 juin 2008 : Adaptive optimal allocation in stratified sampling methods
  - Groupe de travail risque de crédit, université d'Évry, 7 février 2008 : Large portfolio losses, a dynamic contagion model, d'après Dai Pra, Runggaldier, Sartori, Tolotti

- C. Labart
  - Talk at MCQMC'08 conference in Montréal, July 2008.
  - Amamef conference in Udine, Italy, June 2008.
  - Seminar at University Paris 6/Paris 7, October 2008.
  - Seminar at University of Maine, March 2008.
  - Seminar at ISFA Lyon, March 2008.
- D. Lamberton
  - 3rd General AMaMeF Conference, Pitesti (Roumania), May 2008. "Some remarks on american option prices in exponential Lévy models".
  - Conference "Free Boundary Problems. Theory and Applications", STOCKHOLM (Sweden), June 2008. "American Options and Parabolic Integro-Differential Operators".
  - Conference on Numerical Methods in Finance, Udine (Italy), 25-27 June 2008. "American option pricing in exponential Lévy models".
  - Daiwa Lecture Series, Kyoto, August 2008. I was invited to give a short course on "Optimal stopping and American options".
  - Daiwa International Workshop on Financial Engineering, Tokyo (Japan), August 2008. "American option prices in exponential Lévy models".
  - Workshop on Numerics and Stochastics, Helsinki (Finland), August 2008. "American option prices in an exponential Lévy model".
  - Workshop on Optimization and Optimal Control, Linz (Austria), October 2008, "Some properties of American option prices in exponential Lévy models".
- B. Lapeyre
  - Montreal, 6 -11 july 2008, Monte Carlo and quasi-Monte Carlo methods in scientific computing.
  - Udine (Italy), 25-27 June 2008, "Conference on Numerical Methods in Finance".
  - Talk "Finance and mathematics" in the national conference "Avenir de l'enseignement des mathÂmatiques", 26-27 november 2008, , UniversitÂ Paris-La Sorbonne
- J. Lelong
  - Eighth International Conference on Monte Carlo and Quasi-Monte Carlo Methods in Scientific Computing, Montreal (Canada), July 2008.
  - Conference on Numerical Methods in Finance, Udine (Italy), June 2008.
    Tow talks : one on Pricing double barrier Parisian Options using Laplace transforms and an other one on the presentation of Premia.
  - Workshop in Numerical probability and finance, University of Paris 6 and Paris 7, March 2008.
  - Seminar of INRIA Grenoble, March 2008.
  - Seminar of ISFA, University of Lyon 1, March 2008.
  - Working Group Probability/Optimization, CERMICS/ENPC, February 2008.
  - Seminar of Probability, University of Nancy 1, January 2008.
- D. Pommier
  - Conference on Numerical Methods in Finance, Udine (Italy), June 2008.
    talk on High Dimensional PDE's methods applied to option pricing.

  - Working Group of Laboratoire Jacque Louis Lions, October 2008.
  - Working Group of Université Paris-Est Marne la Vallée , May 2008.
  - Working Group of Ecole Centrale Paris, March 2008.
- F. Russo
  - Purdue (USA), invitation 1 week in October 2008 and Probability Seminar of the Mathematics Department.
  - Oberwolfach (Germany), November 2008. Infinite Dimensional Random Dynamical Systems and Their Applications.
  - Munich (Germany), December 2008. Colloquium “Mathematisches Institut der Universität München”
- A. Sulem
  - Invited as main speaker in the Stochastic Analysis and Financial mathematics conference, Ben Gurion University, Israel, December 2008, math.bgu.ac.il. 2 talks: “Stochastic calculus for Lévy markets” and “Pricing in incomplete Lévy markets”.
  - Haifa University, Israel, December 2008, Talk on “Risk indifference pricing in jump diffusion markets” in the seminar of the department of Economics.
  - Workshop on Optimization and Optimal Control, October 20-24 2008, Special semester on Stochastics with Emphasis on Finance, J. Radon Institute for Computational and Applied Mathematics (RICAM), Linz, Austria; Talk on “Maximum principles for Forward Backward stochastic differential equations”.
- A. Zanette
  - “Pricing Cliquet options by tree methods”, 5th International Conference in Computational Management Science, Imperial College London 2008
  - “Pricing American Barrier options with discrete dividend by binomial trees”, Amamef conference on Numerical Methods in Finance, Udine, Italy, 2008
  - Presentation of PREMIA, GCPMF Distributed and Grid Computing in Computational Finance , Sophia-Antipolis, October 20th 2008. GCPMF

10. Bibliography

Major publications by the team in recent years

[1] A. ALFONSI. *On the discretization schemes for the CIR (and Bessel squared) processes*, in "Monte Carlo Methods and Applications", vol. 11, n° 4, 2005, p. 355–384.

[2] B. AROUNA. *Adaptative Monte Carlo Method, A Variance Reduction technique*, in "Monte Carlo Methods and Applications", vol. 10, n° 1, 2004.

[3] V. BALLY. *An elementary introduction to Malliavin calculus*, Research Report, n° 4718, Inria, Rocquencourt, February 2003, http://hal.inria.fr/inria-00071868.

[4] V. BALLY, M. BAVOUZET, M. MESSAOUD. *Computations of Greeks using Malliavin Calculus in jump type market models*, in "Annals of Applied Probability", vol. 17, 2007, p. 33-66.

[5] V. BALLY, L. CARAMELLINO, A. ZANETTE. *Pricing American options by a Monte Carlo method using a Malliavin calculus approach*, in "Monte Carlo methods and applications", vol. 11, n^o 2, 2005, p. 97–133.

[6] V. BALLY, L. CARAMELLINO, A. ZANETTE. *A mixed PDE - Monte Carlo approach for pricing credit default index swaptions*, in "Decision in Economics and Finance", vol. 29, 2006.

[7] E. CLÉMENT, D. LAMBERTON, A. KOHATSU-HIGA. *A duality approach for the weak approximation of stochastic differential equations*, in "Annals of Applied Probability", vol. 16, n^o 3, August 2006, p. 1124-1154.

[8] B. JOURDAIN, M. SBAI. *Exact retrospective Monte Carlo computation of arithmetic average Asian options*, in "Monte Carlo methods and Applications", vol. 13, n^o 2, 2007, p. 135–171.

[9] A. KOHATSU-HIGA, A. SULEM. *Utility maximization in an insider influenced market*, in "Mathematical Finance", vol. 16, n^o 1, 2006, p. 153–179.

[10] M. N'ZI, Y. OUKNINE, A. SULEM. *Regularity and representation of viscosity solutions of Partial differential equations via backward stochastic differential equations*, in "Stochastic processes and their applications", vol. 116, n^o 9, 2006, p. 1319–1339.

[11] B. ØKSENDAL, A. SULEM. *Applied Stochastic Control of Jump Diffusions*, Universitext, Second Edition, Springer, Berlin, Heidelberg, New York, 257 pages 2007.

Year Publications

Doctoral Dissertations and Habilitation Theses

[12] D. POMMIER. *Sparse grid methods applied to option pricing*, Ph. D. Thesis, Université Pierre et marie Curie (Paris 6), November 28 2008.

Articles in International Peer-Reviewed Journal

[13] Y. ACHDOU, F. HECHT, D. POMMIER. *A posteriori error estimates for parabolic variational inequalities*, in "Journal of Scientific Computing", accepted for publication.

[14] A. ALFONSI. *An introduction to the multiname modelling in credit risk*, in "Banques & Marché", to appear.

[15] A. ALFONSI, B. JOURDAIN. *General Duality for Perpetual American Options*, in "International Journal of Theoretical and Applied Finance", vol. 11, n^o 6, 2008, p. 545-566.

[16] A. ALFONSI, A. SCHIED, A. SCHULZ. *Constrained portfolio liquidation in a limit order book model*, in "Banach Center Publications", to appear.

[17] A. ALFONSI, A. SCHIED, A. SCHULZ. *Optimal execution strategies in limit order books with general shape functions*, in "Quantitative Finance", to appear.

[18] M. ARISAWA. *A remark on the definitions of viscosity solutions for the integro-differential equations with Lévy operators*, in "J. Maths. Pures et Appliques", vol. 89, n^o 6, 2008, p. 567–574.

[19] P. ETORÉ, B. JOURDAIN. *Adaptive optimal allocation in stratified sampling methods*, in "Methodology and Computing in Applied Probability", accepted for publication.

[20] E. GOBET, C. LABART. *Sharp estimates for the convergence of the density of the Euler scheme in small time*, in "Elect. Comm. in Probab", vol. 13, 2008, p. 352-363.

[21] B. JOURDAIN, A. KOHATSU-HIGA. *A review of recent results on approximation of solutions of stochastic differential equations*, in "Banques et Marché", to appear.

[22] B. JOURDAIN, A. ZANETTE. *A Moments and Strike Matching Binomial Algorithm for Pricing American Put Options*, in "Decisions in Economics and Finance", vol. 31, 2008, p. 33-49.

[23] C. LABART, J. LELONG. *Pricing double barrier Parisian Options using Laplace transforms*, in "International Journal of Theoretical and Applied Finance", preprint hal-00220470, to appear.

[24] J. C. LABART, J. LELONG. *Pricing Parisian Options using Laplace transforms*, in "Banques & Marché", to appear.

[25] D. LAMBERTON, M. MIKOU. *The critical exercise price for the American put in an exponential Lévy model*, vol. 12, 2008, p. 561-581.

[26] D. LAMBERTON, G. PAGÈS. *A penalized bandit algorithm*, in "Electronic Journal of Probability", vol. 13, 2008, p. 341-373.

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