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Team Mathfi

Financial Mathematics

Rocquencourt

THEME NUM

Activity Report

2006

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2. Overall Objectives

2.1. Overall Objectives

MathFi is a joint project-team with INRIA-Rocquencourt, 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. An important part of the activity is related to the development of 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. Numerical methods for option pricing and hedging

Keywords: *Euler schemes*, *Malliavin calculus*, *Monte-Carlo*, *approximation of SDE*, *finite difference*, *quantization*, *tree methods*.

Participant: all the Mathfi team.

Efficient computations of prices and hedges for derivative products is a major issue for financial institutions.

Monte-Carlo simulations are widely used because of their implementation simplicity and because closed formulas are usually not available. Nevertheless, efficiency relies on difficult mathematical problems such as accurate approximation of functionals of Brownian motion (e.g. for exotic options), use of low discrepancy sequences for nonsmooth functions, quantization methods etc. Speeding up the algorithms is a constant preoccupation in the developement of Monte-Carlo simulations. Another approach is the numerical analysis of the (integro) partial differential equations which arise in finance: parabolic degenerate Kolmogorov equation, Hamilton-Jacobi-Bellman equations, variational and quasi–variational inequalities (see [74]).

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

3.2. Model calibration

One of the most important research directions in mathematical finance after Merton, Black and Scholes is the modeling of the so called *implied volatility smile*, that is, the fact that different traded options on the same underlying have different Black-Scholes implied volatilities. The smile phenomenon clearly indicates that the Black-Scholes model with constant volatility does not provide a satisfactory explanation of the prices observed in the market and 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 [70], [54], CIR [59], Vasicek [84] ,etc. or to the popular class of LIBOR (London Interbank Offered Rates) market models like BGM [55].

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. Application of Malliavin calculus in finance

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

Participants: V. Bally, M.P. Bavouzet, J. Da Fonseca, B. Jourdain, A. Kohatsu-Higa, D. Lamberton, B. Lapeyre, M. Messaoud, A. Sulem, A. Zanette.

The original Stochastic Calculus of Variations, now called the Malliavin calculus, was developed by Paul Malliavin in 1976 [77]. 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 [79], D. Bell [50] D. Ocone [81], B. Øksendal [88]) give expositions of the subject. See also V. Bally [49] 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 [80].

Since then, the Malliavin calculus has raised increasing interest and subsequently many other applications to finance have been found [78], 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 [64] and [63] and the papers by Bally et al, Benhamou, Bermin et al., Bernis et al., Cvitanic et al., Talay and Zheng and Temam in [73].

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 [73]). 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 [73]).

3.4. Stochastic Control and Backward Stochastic Differential equations

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

Participants: V. Bally, J.-Ph. Chancelier, D. Lefèvre, M. Mnif, M. Messaoud, M.C. Kammerer-Quenez, A. Sulem.

Stochastic control consists in the study of dynamical systems subject to random perturbations and which can be controlled in order to optimize some performance criterion. Dynamic programming approach leads to Hamilton-Jacobi-Bellman (HJB) equations for the value function. This equation is of integrodifferential type when the underlying processes admit jumps (see [11]). The theory of viscosity solutions offers a rigourous framework for the study of dynamic programming equations. An alternative approach to dynamic programming is the study of optimality conditions (stochastic maximum principle) which leads to backward stochastic differential equations (BSDE). Typical financial applications arise in portfolio optimization, hedging and pricing in incomplete markets, calibration. BSDE's also provide the prices of contingent claims in complete and incomplete markets and are an efficient tool to study recursive utilities as introduced by Duffie and Epstein [60].

3.5. Anticipative stochastic calculus and insider trading

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

We study controlled stochastic systems whose state is described by anticipative stochastic differential equations. These SDEs can interpreted in the sense of *forward integrals*, which are the natural generalization of the semimartingale integrals [82]. This methodology is applied for utility maximization with insiders.

3.6. Fractional Brownian Motion

Participant: A. Sulem.

The Fractional Brownian Motion $B_H(t)$ with Hurst parameter H has originally been introduced by Kolmogorov for the study of turbulence. Since then many other applications have been found. If $H = \frac{1}{2}$ then $B_H(t)$ coincides with the standard Brownian motion, which has independent increments. If $H > \frac{1}{2}$ then $B_H(t)$ has a *long memory* or *strong aftereffect*. On the other hand, if $0 < H < \frac{1}{2}$, then $B_H(t)$ is *anti-persistent*: positive increments are usually followed by negative ones and vice versa. The strong aftereffect is often observed in the logarithmic returns $\log \frac{Y_n}{Y_{n-1}}$ for financial quantities Y_n while the anti-persistence appears in turbulence and in the behavior of volatilities in finance.

For all $H \in (0,1)$ the process $B_H(t)$ is *self-similar*, in the sense that $B_H(\alpha t)$ has the same law as $\alpha^H B_H(t)$, for all $\alpha > 0$. Nevertheless, if $H \neq \frac{1}{2}$, $B_H(t)$ is not a semi-martingale nor a Markov process [68], [52], [53], and integration with respect to a FBM requires a specific stochastic integration theory.

4. Application Domains

4.1. Application domains

- Option pricing and hedging
- Calibration of financial models
- Modeling of financial asset prices
- 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, B. Jourdain, A. Kolotaev, A. Kohatsu Higa, J. Lelong, B. Lapeyre, V. Lemaire, N. Privault, A. Sulem, P. Tankov, X. Xei, A. Zanette.

The development of Premia software is a joint activity of INRIA and ENPC/CERMICS, undertaken within the MathFi project. Its main goal is to provide C/C++ routines and scientific documentation for the pricing of financial derivative products with a particular emphasis on the implementation of numerical analysis techniques. It is an attempt to keep track of the most recent advances in the field from a numerical point of view in a well-documented manner. The aim of the Premia project is threefold: first, to assist the R&D professional teams in their day-to-day duty, second, to help the academics who wish to perform tests of a new algorithm or pricing method without starting from scratch, and finally, to provide the graduate students in the field of numerical methods for finance with open-source examples of implementation of many of the algorithms found in the literature.

5.1.1. Consortium Premia.

Premia is developed in interaction with a consortium of financial institutions or departments presently composed of: CALYON, the Crédit Industriel et Commercial, EDF, Société générale, Natexis and IXIS CIB (Corporate & Investment Bank) now unified as Natixis. The participants of the consortium finance the development of Premia (by contributing to the salaries of expert engineers hired by the MathFi project every year to develop the software) and help to determine the directions in which the project evolves. Every year, during a “delivery meeting”, a new version of Premia is presented to the consortium by the members of the MathFi project working on the software. This presentation is followed by the discussion of the features to be incorporated in the next release. In addition, between delivery meetings, MathFi project members meet individual consortium participants to further clarify their needs and interests. After the release of each new version of Premia, the old versions become available on Premia web site http://www.premia.fr and can be downloaded freely for academic and evaluation purposes. At present, this is the case for the first five releases.

5.1.2. Content of Premia.

The development of Premia started in 1999 and 9 are released up to now. Release 1,2 and 4 contain finite difference algorithms, tree methods and Monte Carlo methods for pricing and hedging European and American options in the Black-Scholes model in one and two dimensions.

Release 3 is dedicated to Monte Carlo methods for American options in high dimension (Longstaff-Schwartz, Barraquand-Martineau, Tsitsklis-Van Roy, Broadie-Glassermann) and is interfaced with the Scilab software.
Release 5 and 6 contain more sophisticated algorithms such as quantization methods for American options and methods based on Malliavin calculus for both European and American options. It also contains algorithms for pricing, hedging and calibration in some models with jumps, local volatility and stochastic volatility.
Release 7 implements routines for pricing vanilla interest rate derivatives in HJM and BGM interest rate models (Vasicek,Hull-White, CIR, CIR++, Black-Karasinsky, Squared-Gaussian, Li-Ritchken-Sankarasubramanian, Bhar-Chiarella and the Libor Market Model). It also contains calibration algorithms for various models (including stochastic volatility and jumps) and numerical methods based on Malliavin calculus for jump processes.
Premia 8 is devoted mainly to Lévy models: Exponential Lévy models (Merton's model and more generally other finite intensity Lévy processes with Brownian component (Kou)), Tempered stable process, Variance gamma, Normal inverse Gaussian). Various numerical methods (Fourier transform, Finite difference methods)are implemented to price and hedge European options and barrier options on stocks in these models. An algorithm for non-parametric calibration of finite-intensity exponential Lévy models to prices of market-traded is also included. Option pricing methods for the following interest rate models were implemented: affine models, jump diffusion Libor Market Model and Markov functional Libor Market Model. Premia 8 also implements reduced-form models for pricing and hedging Credit Default Swap.
Premia 9, the last release of the software developed in 2006 will be presented to the consortium members in February 2007. It contains in particular a calibration toolbox for Libor Market model using a database of swaption and cap implied volatility provided by CDC-IXIS, a participant of Premia consortium.

N. Privault has supervised postdoctoral research engineer and interns at INRIA for the implementation of algorithms in calibration of LIBOR interest rate models, pricing of LIBOR derivatives using Lévy jump models, optimal exercise of Bermudan options. P. Tankov has developed new calibration and hedging modules for Premia. Afef Sellami has implemented an algorithm for the pricing of swing options with a quantization approach. Moreover Anton Kolotaev (expert engineer), P. Tankov, J. Lelong, J-Ph. Chancelier are working on the architecture and interface of Premia (Excel and NSP, the New Scilab project).

5.1.3. Detailed content of Premia Release 9 developped in 2006

- **Interest Rate Derivatives**
  - Andersen Brotherton-Ratcliffe Extended Libor market models with stochastic volatility [47]
  - Eberlein Kluge : The Lévy LIBOR term structure model [62].
  - Eberlein Ozkan : The Lévy LIBOR model [61].
  - Kolodko Schoenmakers algorithm : Iterative Construction of Optimal Bermudan stopping time [72]
- **Calibration Interest Rate Derivatives**
  - Calibration in BGM Models [85], [83], [56]
- **Pricing Credit Risk Derivatives Multi Names (CDO)**
  - Monte Carlo with control variate
  - Hull-White [69]
  - Laurent Gregory : Basket Default Swaps, CDO's and Factor Copulas [75]
  - Andersen-Sidenious [48]
  - A comparative anailsys of CDO pricing models [57]
- **Pricing Equities in stochastic volatility models**
  - Sparse wavelet approach [67]

- Improvement in the Ninomiya-Victoir Scheme.
- Kusuoka-Ninomiya-Ninomiya Scheme.
- Generalized Sobol sequence.

- **Monte Carlo Methods in Lévy models.**
- **Finite Difference Methods in Lévy models.**
- **Finite Difference Method for American Options Pricing in the KoBol model. [76].**
- **Pricing Equity**
  - Finite Difference for 3D problems (collaboration with Prof.Natalini IAC Rome).
  - Monte Carlo Methods for Mountains Range Options in Local Volatility models using a stochastic algorithm approach .
  - Finite Difference for American Lookback Options in BS model
  - Laplace Transform for Parisian Options in BS Models
- **Energy Derivatives**
  - Pricing of Swing options ([58], [71])

6. New Results

6.1. Numerical methods for option pricing

6.1.1. Call-Put Duality

Participants: A. Alfonsi, B. Jourdain.

It is well-known that in models with local volatility functions $\sigma(t,x)$ and constant interest and dividend rates, the European Put prices are transformed into European Call prices by time-reversal of the volatility function and simultaneous exchanges of the interest and dividend rates and of the strike and the spot price of the underlying. All the existing proofs of this Call-Put duality rely on some partial differential equation argument. For instance, it is a consequence of Dupire's formula. By a purely probabilistic approach based on stochastic flows of diffeomorphisms, B. Jourdain has generalized the Call-Put duality equality to models including exponential Lévy jumps in addition to local volatility. He has also recovered various generalizations of Dupire's formula to complex options recently obtained by Pironneau.

Aurélien Alfonsi and Benjamin Jourdain have obtained a similar Call Put duality for perpetual American options when the local volatility function does not depend on the time variable. The perpetual American Put price is equal to the perpetual American Call price in a model where, in addition to the previous exchanges between the spot price and the strike and between the interest and dividend rates, the local volatility function is modified. This duality result leads to a theoretical calibration procedure of the local volatility function from the perpetual Call and Put prices. Then they have investigated generalizations to payoff functions of the form $\phi(x,y)$ when ϕ is the positive part of a function concave in each variable and non-increasing (resp. non-decreasing) in x (resp. y). The duality result remains valid for specific choices of ϕ more general than the Call-Put case $(y-x)^+$. This means that the nature of the Perpertual American duality is different from the one of the European duality. Indeed, in the European case, the fact that the second order derivative of $(y-x)^+$ with respect to y is the Dirac mass at x plays a crucial role.

6.1.2. Parisian options

J. Lelong has studied double barrier Parisian options. He has established explicit formula for the Laplace transforms of their prices with respect to the maturity time and have established accuracy results for the procedure we use to numerically invert the Laplace transforms. Moreover he has implemented an algorithm for pricing Parisian options with simple barrier based on a Laplace transform method as described in [35] in the software Premia.

6.2. Discretization of stochastic differential equations

Participants: A. Alfonsi, E. Clément, B. Jourdain, M. Sbai, A. Kohatsu Higa, V. Lemaire, D. Lamberton, J. Guyon, B. Jourdain, V. Lemaire, G. Pagès.

A. Kohatsu-Higa is extending the results obtained in an joint article with E. Clement and D. Lamberton to other situations such as the case of backward SDE's.

A method allowing exact simulation of the solution of one-dimensional stochastic differential equations has been recently proposed by Beskos and Roberts [51] and improved in a joint preprint with Papaspiliopoulos. Under the supervision of B. Jourdain, M. Sbai has started his PhD by studying financial applications of this method. [51]

6.3. Monte Carlo simulations and stochastic algorithms

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

Participants: V. Bally, E.H.A. Dia, D. Lamberton, B. Lapeyre, J. Lelong, P. Tankov.

El Hadj Aly Dia is starting a thesis on Monte-Carlo methods for exotic options in models with jumps.

P. Tankov and J. Poirot have submitted a paper on " Monte–Carlo option pricing for tempered stable (CGMY) processes" to Asia-Pacific financial markets (following a conference in Kanazawa, Japan)

J. Lelong has worked on the convergence rate of stochastic algorithms truncated at randomly varying bounds. He has proved a functional central limit theorem for these algorithms. He has also considered an averaging version of this algorithm and established a component-wise CLT for it.

V. Bally, L. Caramellino and A. Zanette have developped a mixed PDE - Monte Carlo approach for pricing credit default index swaptions. (see [14]).

D. Lamberton and Gilles Pagès have studied the rate of convergence of the classical two-armed bandit algorithm. They have also investigated another algorithm with a penalization procedure. Two papers have been sumitted.

6.4. Functional quantization for option pricing in a non Markovian setting

Keywords: *quantization*.

Participants: G. Pagès, J. Printems, A. Sellami.

G. Pagès and A. Sellami have carried out research on theoretical aspects of optimal Quantization, in both finite and infinite dimesnional settings.

In $\mathbf{R}^d$, G. Pagès solved with S. Graf and H. Luschgy the so-called (r, s)-problem i.e. we elucidated the asymptotic behaviour of a sequence of L^r-optimal quantizers when used as quantizers in L^s. We gave some lower bound or this behaviour and gave sufficient conditions to ensure that they preserve the standard rate of quantization ie $N^{-\frac{1}{d}}$. This has many applications for higher order cubature formula for numerical integration and conditional expectation approximation.

With H. Luschgy, G. Pagès pointed out the strong connection between pathwise L^p regularity of processes $t \mapsto X_t$ and the $L^p(\mathcal{P})$-quantization rate for the pathwise $L^r([0,T], dt)$-norm of these processes. We apply these very general connection to Lévy processes where we showed that grosso modo, the quantization rate of a Lévy process is ruled by $(\log N)^{-\beta(X)}$ where $\beta(X)$ denotes the Blumenthal-Getoor index of the Lévy process. We also provided some rates for the compound Poisson processes.

The above results (as concerns Lévy processes) rely on an extension of an old resulst by Millar about the (absolute) moments of Lévy processes $E|X_t|^r$ as $t \to 0$.

G. Pagès and A. Sellami have made a connection between rough paths and functional quantization with some applications to the pricing of European pth-dependent options.

G. Pagès and J. Printems have launched a large scale computation of optimized quantization grids (from $d = 1$ up to $d = 10$) which improves the former one. They also completed a large scale computation of(quadratic) optimal functional quantization grids for the Brownian motion (from $N = 1$ up to $N = 10000$). Some of them are available on the website devoted to quantization http://www.quantize.maths-fi.com/ G. Pagès and J. Printems developped a pricer of Asian options in the Heston model based on a optimal functional quantization, included in the 2006 issue of Premia.

G. Pagès and A. Sellami are currently working on the pricing of swing option on commodities : theoretical aspects and numerical methods (optimal quantization).

G. Pagès is also working on multistep Romberg extrapolation in the Monte Carlo method in presence of an expansion of the time discretization error, with application to exotic path-dependent otpions. With his student F. Panloup, he is studying a recursive algorithm for the computation of functional of a stationary jump diffusion.

6.5. Computation of sensitivities (Greeks) and conditional expectations using Malliavin calculus

Keywords: *Malliavin calculus*, *greecks*, *jump diffusions*.

Participants: V. Bally, M.P. Bavouzet, L. Caramellino, A. Kohatsu-Higa, M. Messaoud, N. Privault, A. Zanette.

A. Kohatsu-Higa continues to study simulation methods for greeks in high dimension either with the kernel density estimation method or the integration by parts method of Malliavin Calculus.

N. Privault has worked on Statistical estimation using the Malliavin calculus and sensitivity analysis [32]. He also worked on concentration inequalities with application to bounds on option prices [22].

V. Bally, M. P. Bavouzet and M. Messaoud have obtained results for Malliavin Calculus for Poisson Point Processes and applications to finance. There is one paper which is accepted for publication in Annals of Applyed Probabilities and there is one more paper in progress.

6.6. Lower bounds for the density of a functional

Participant: V. Bally.

V. Bally has obtained results for lower bounds for the density of functionals on the Wiener space (see [12]). Two papers are in progress: one of V. Bally in collaboration with B. Fernandez and A. Meda from the University of Mexico on tubes evaluations for solutions of non-Markov Stochastic Differential Equations, and one of V. Bally with L. Caramellino from the University of Roma 3 on lower bounds for the density of Ito processes under weak regularity assuptions.

6.7. Optimal stopping and American Options

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

- D. Lamberton is working on optimal stopping of one-dimensional diffusions with Mihail Zervos (previously at King's College, London, now at the London School of Economics). They have submitted a paper on the infinite horizon case and are currently working on the finite horizon case.

- D. Lamberton and his 1st year PhD student Mohammed Mikou are studying American options in exponential Lévy models. They have studied some properties of the exercise boundary of the American put option in an exponential Lévy model (continuity of the exercise boundary, behavior near maturity).

M.C. Quenez, Magdalena Kobylanski and Elizabeth Rouy have studied the multitiple stopping time problem $\sup_{\tau_1,\tau_2 \in \mathcal{T}} E[\Psi(\tau_1, \tau_2)]$ where $\mathcal{T}$ is the set of stopping times and $\Psi : (t, s, \omega) \to \Psi(t, s, \omega)$ is $\mathcal{F}_{sup(t,s)}$-adapted. They have shown that under some smoothness assumptions on Ψ (right-continuity w.r.t. t (resp. s) uniformly w.r.t s (resp. t), the value function can be characterized as the Snell enveloppe associated with a progressive reward process which can be completely determined.

6.8. Sparse grids methods for PDEs in Mathematical Finance

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

Participants: Y. Achdou, D. Pommier.

Recent developments have shown that it may be possible to use deterministic Galerkin methods or grid based methods for elliptic or parabolic problems in dimension d, for $4 \leq d \leq 20$: these methods are based either on sparse grids [65] or on sparse tensor product approximation spaces [66], [87].

Sparse grids were introduced by Zenger [86] in order to reduce the number of degrees of freedom of discrete methods for partial differential equations. Standard piecewise linear approximations need $O(h^{-d})$ degrees of freedom, (h is the mesh step), and produce errors of the order of $O(h^2)$. The piecewise-d-linear sparse grid approximation requires only $O\left(h^{-1}|\log h|^{d-1}\right)$ degrees of freedom, while the error is $O\left(h^2|\log h|^{d-1}\right)$.

D. Pommier and Y. Achdou study these methods for the numerical solution of diffusion or advection-diffusion problems introduced in option pricing. They consider the case of a European vanilla contract in multifactor stochastic volatility models. Using Itô's formula, they obtain a 4 dimensional PDE problem, which they solve by means of finite differences on a sparse grid. They compare this accuracy and computing time to those of standard Monte Carlo methods.

A Cifre agreement on this subject between Inria and BNP-Paribas is engaged on this subject for the PhD thesis of David Pommier.

6.9. Stochastic control - Application in finance and assurance

Keywords: *jump diffusions*, *stochastic control*.

Participants: B. Øksendal (Oslo University), D. Hernandez-Hernandez, M.C. Quenez, A. Sulem, P. Tankov.

B. Øksendal (Oslo University) and A.Sulem have written a second edition of their book on Stochastic control of Jump diffusions [11]. In the Second Edition there is a new chapter on optimal control of stochastic partial differential equations driven by Lévy processes. There is also a new section on optimal stopping with delayed information.

In [40], A. Sulem and B. Øksendal consider a stochastic differential game in a financial jump diffusion market, where the agent chooses a portfolio which maximizes the utility of her terminal wealth, while the market chooses a scenario (represented by a probability measure) which minimizes this maximal utility. They show that the optimal strategy for the market is to choose an equivalent martingale measure.

A. Sulem and P. Tankov are studing pricing and hedging in markets with jumps using utility maximization and indifference pricing, and A. Sulem and B. Øksendal are studing risk-indifference pricing in these markets. D. Hernandez-Hernandez and A. Schied have solved the problem of characterization of the indifference price of derivatives for stochastic volatility models [21].

M.C. Quenez and Daniel Hernandez-Hernandez are working on the the problem of characterization of the variance optimal martingale measure $\tilde{P}$ in a stochastic volatility model. Recall that the variance-optimal martingale measure appears to be a key tool for characterizing the optimal hedging strategy of the mean-variance hedging problem. Laurent and Pham (1999) have solved the problem in terms of classical solutions of PDEs in the particular case where the coefficients of the model do not depend on time and price process. Quenez and Hernandez-Hernadez consider the general case. The idea is to approximate the value function by a sequence of classical solutions of some Dirichlet problems (which converges unifomly on each compact set of $[0,T]\times\mathbf{R}^d$). Using this property, they derive an estimation of the gradiant of the value function, which allows them to characterize the optimal risk-premium (associated with $\tilde{P}$) as the gradient of the value function (multiplied by a coefficient of the model) [42].

M.C. Quenez and B. Jottreau are studying the problem of portfolio optimization with default. Using dynamic programming they study the aproximation of the associate HJB equation.

6.10. Utility maximization in an insider influenced market

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

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

We have continued to study insider type models. A. Kohatsu-Higa has obtained results on the equilibrum of models with insiders which behave as large traders. In particular he has studied models with insider long term effects with H. Hata and is currently studying the short trem effects in a extension of the Kyle-Back model.

A.Kohatsu-Higa and A.Sulem are working on the extension of their paper [23] to models with jumps.

A. Sulem and B. Øksendal have proposed an anticipative approach for indifference pricing in incomplete markets [46].

7. Contracts and Grants with Industry

7.1. Consortium Premia

Participants: A. Alfonsi, V. Bally, B. Jourdain, A. Kohatsu-Higa, B. Lapeyre, J. Lelong, V. Lemaire, N. Privault, A. Sellami, A. Sulem, P. Tankov, X. Wei, A. Zanette.

The consortium Premia is centered on the development of the pricer software Premia. It is presently composed of the following financial institutions or departments: CALYON, the Crédit Industriel et Commercial, EDF, Société générale, Natexis and IXIS CIB now unifies as Natixis. http://www.premia.fr

Extension to Japan is being formalized through a cooperation with the university of Osaka.

7.2. EDF

Participants: C. Strugarek, P. Carpentier, A. Sulem, project-team MATHFI, Laboratory CERMICS.

CIFRE agreement EDF-ENPC on "Optimisation of portfolio of energy and financial assets in the electricity market"

General industrial convention between EDF and CERMICS on risk issues in electricity markets.

7.3. BNP-Paribas

Participants: D. Pommier, Y. Achdou, A. Sulem.

Cifre agreement BNP-Paribas/INRIA on : "sparse grids for large dimensional financial issues”

7.4. EuroVL

Participants: M. Hamel, N. Privault, A. Sulem.

Cifre agreement between Euro-VL and INRIA on “ Pricing of hybrid financial derivative products on change and interest rate “.

7.5. ANR program

ANR program GCPMF "Grid Computation for Financial Mathematics" (partners : Calyon, Centrale, EDF, ENPC, INRIA, Ixis, Paris 6, Pricing Partner, Summit, Supelec)

Global coordinator: B. Lapeyre

7.6. International cooperations

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

8. Dissemination

8.1. Seminar organisation

- B. Jourdain, M.C. Kammerer-Quenez and J. Guyon: organization of the seminar on stochastic methods and finance, University of Marne-la-Vallée
- M.C. Kammerer-Quenez and A. Kohatsu Higa : members of the organization committee of the Seminaire Bachelier de Mathematiques financieres, Institut Henri Poincaré, Paris.
- A. Kohatsu-Higa

  Organization [2006.08.24-27] of the Workshop on Mathematical Finance and Stochastic Control Kyoto, Japan

  [2005.12.01-02] Financial Engineering and related problems in Mathematical Finance (directed to practitioners in the japanese financial industry)

  [2006.04-04-06] Université de Marne-la-Vallée. journées Analyse et Probabilités
- B. Lapeyre :

  - Coordination of the ANR program "Grid Computation for Financial Mathematics" (partners : Calyon, Centrale, EDF, ENPC, INRIA, Ixis, Paris 6, Pricing Partner, Summit, Supelec), started in February 2006.

  - Session on "Adaptive Monte-Carlo methods et stochastic algorithms", journées MAS 2006, Lille, September 4-6 2006.
- A. Sulem:

  - organisation of a course on numerical methods in Finance, Collège de Polytechnique, December 2006.

  - Co-Organisation (with Peter Imkeller, Esko Valkela and Monique Pontier) of an international Amamef workshop on "Insider models", Toulouse , January 2007 http://www.lsp.ups-tlse.fr/Fp/Baudoin/amamefindex.html
- A. Kohatsu-Higa, D. Lamberton and A. Sulem: Organisation of an Amamef workshop on numerical methods in finance (INRIA-Rocquencourt, 1-3 February 2006).

8.2. Teaching

- A. Alfonsi

  Course on "Probability theory and statistics" directed by B. Jourdain, first year ENPC
- A. Alfonsi, B. Jourdain, M.C. Kammerer-Quenez

  course "Mathematical methods for finance", 2nd year ENPC.
- V. Bally

  - Malliavin Calculus and numerical applications in finance. (Master 2 of the University Marne la Vallee)

  - Probabilistic methods for risk analysis. (Master 2 of the University Marne la Vallée)

- M.P. Bavouzet 1/2 ATER in Paris-Dauphine
- B. Jourdain : - Course "Probability theory and statistics", first year ENPC

  - Course "Introduction to probability theory and simulation", first 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
- A. Kohatsu-Higa:

  Courses on differential equations, mathematical finance and complex analysis at Osaka University

  [2006.07.10-12] Special short course on kernel density estimation methods delivered by Kic Udina (Universitat Pompeu Fabra, Spain)
- D. Lamberton :

  -Second year of Licence de mathématiques et informatique (multivariate calculus), Université de Marne-la-Vallée.

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

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

  - Course on "Modelisation and Simulation", ENPC, 2nd year.

  - "Exercise in probability", Ecole Polytechnique, 1st year.

  - Course on "Monte-Carlo methods for finance", Master program in Random analysis and systems, University of Marne la Vallée and Ecole des Ponts.
- D. Lefèvre

  - Assistant professor at ENSTA, in charge of the mathematical finance program.

  - graduate course in Hamlstad, Sweden on “Montecarlo methods in Finance”.
- J. Lelong
  - Cours "Méthodes numériques pour la Finance", 2ème année ENSTA.
  - TD du cours "Introduction aux probabilités et aux statistiques", 1ère année ENSTA
  - TD du cours "Cha?nes de Markov", 2éme année ENSTA
- M.C. Kammerer-Quenez

  - Courses for undergraduate students in mathematics, Université Marne la Vallée (Calculus, algebra)

  - Course on stochastic processes, graduate program, University of Marne-la-Vallée

  - Introductary course on financial mathematics, ENPC.

  - Graduate course on interest rate models, ENPC (in collaboration with Christophe Miche, CA-LYON)
- A. Sulem

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

  - Collège de Polytechnique: Coordinator of a seminar on “Numerical methods in Finance” for professionals and course on numerical methods in stochastic control (December 2006)
- **Guest lecturer, Master Program, Halmstad University, Suède** : (20h) 2006-2007.

- P. Tankov Assistant Professor Paris7

8.3. Internship advising

- A. Alfonsi - Simon Moreau, ENPC student. He has implemented the method presented in the paper of J. Gregory and J-P. Laurent "Basket Default Swaps, CDO's and Factor Copulas".

  - Philippe Basquin, Institut Galilee Paris XIII : Discretization schemes in the Heston model.
- B. Jourdain

  Zouhair Yakhou, "Exact simulation of the Heston stochastic volatility model" following a paper by Broadie and Kaya (March to May)
- A. Kohatsu-Higa

  - Tomonori Nakatsu (master) : kernel density estimation methods in high dimension

  - Yuusuke noguchi (master): valuation of a japanese type of deferred type annuity
- J. Lelong

  Hanping Tong: Second year student of ENSTA on : "Adaptative control variable for variance reduction".
- N. Privault

  - J. Bourgoint, Master I, Ecole Polytechnique.

  - Audrey Drif (with P. Tankov), Master II, DEA Paris I.
- M.C. Quenez

  -advising of 1st year master students on modelisation of financial markets and option pricing in discrete time, Snell enveloppes and optimal stopping problems, Poisson processes ...
- P. Tankov

  Jeremy Poirot:

  "Monte–Carlo option pricing for tempered stable (CGMY) processes", Ecole Centrale de Lyon

8.4. PhD defences

- M. Messaoud

  Thesis defended in January 2006, Universté Paris-Dauphine

  Title: "Contrôle optimal stochastique et calcul de Malliavin appliqués en finance"

  Adviser: A. Sulem
- Y. Elouherkaoui

  Thesis defended in May 2005, Universté Paris-Dauphine

  Title: Etude des problemes de correlation et d'incompletude dans les marches de credit. *Correlation and incompleteness in credit derivatives markets.*

  Adviser: A. Sulem
- A. Alfonsi

  Thesis defended in June 2006

  Title: Modélisation en risque de crédit. Calibration et discrétisation de modèles financiers.

  Adviser: B. Jourdain

- J. Guyon

  Thesis defended in July 2006

  Title: Modélisation probabiliste en finance et en biologie. Théorèmes limites et applications.

  Advisers: J.F. Delmas and B. Lapeyre
- C. Strugarek

  Thesis defended in May 2006, ENPC

  Title: Approches variationnelles et autres contributions en optimisation stochastique

  Advisers: P. Carpentier and A. Sulem
- M.P. Bavouzet

  Title: "Malliavin calcul with jumps and application in Finance". defended at the University Paris-Dauphine in December 2006.

  Advisers: V. Bally and A. Sulem

8.5. PhD advising

- V. Bally and A. Sulem

  M.P. Bavouzet (3rd year), Grant Université Paris Dauphine and INRIA.

  "Malliavin calcul with jumps and application in Finance". (defended December 2006)
- B. Jourdain

  - Aurélien Alfonsi (3nd year), ENPC

  "Credit risk models. Discretization and calibration of financial models." (defended July 2006)

  - Mohamed Sbai

  "Simulation of stochastic differential equations in finance"
- A. Kohatsu-Higa

  Kazuhiro Yasuda : Malliavin Calculus methods for greeks in high dimension

  - Salvador Ortiz (University of Barcelona) Equilibrium models for insiders models

  - Karl Larsson (Lund University. Department of Economics)
- D. Lamberton

  Mohammed MIKOU (2nd year). American options in models with jumps. Allocataire-moniteur at Université de Marne-la-Vallée.

  El Hadj Aly DIA (1st year). Monte-Carlo methods for exotic options in models with jumps. Allocataire at Université de Marne-la-Vallée.
- B. Lapeyre

  - Ralf Laviolette , ENS Cachan (3rd year)

  "Calcul d'options pour des dérivées énergétiques dans des modèles avec sauts".

  - Jérôme Lelong, ENPC grant, UMLV (3rd year)

  "Stochastic algorithms and calibration problems in Finance"

  - Julien Guyon, ENPC Convergence rate in Euler schemes for stochastic differential equations with jumps.
- M.C. Kammerer-Quenez

  - B. Jottreau, UMLV

  "Risk default modeling "

- G. Pagès

  - Fabien Panloup

  - Abass Sagna (2nd year) works on vector quantization and numerical applications.

  - Camille Illand (starting) works on American Asian options.

- N. Privault

  - A. Reveillac, University of La Rochelle. 2005-

  - D. David (codirection with E. Augeraud), University of La Rochelle. 2005-

  - B. Kaffel, (codirection with F. Abid), University of Sfax, Tunisia. 2004-

  - Y. Ma, (codirection with L. Wu), Wuhan University, defense expected 25/11/07. 2004-

  - A. Joulin, University of La Rochelle, defended on 06/10/06. 2003-2006

- A. Sulem

  - David Lefèvre, Université Paris-Dauphine

  “Utility maximisation in partial observation”

  - Marouen Messaoud (3rd year), Université Paris-Dauphine

  "Stochastic control, Calibration and Malliavin calculus with jumps"

  - Youssef Elouerkhaoui : (UBS Londres, Citibank from November)

  "Incomplete issues in credit markets"

- A. Sulem and P. Carpentier (ENSTA)

  Cyrille Strugarek, Cifre agreement ENPC–EDF, 2nd year.

  "Optimisation of portfolio of energy and financial assets in the electricity market"

- J. Printems, Y. Achdou and A. Sulem (Paris 6)

  David Pommier (2nd year)

  Cifre agreement INRIA–CIC

  “Sparse grid for large dimensional financial issues”.

- N. Privault and A. Sulem

  Mathieu Hamel (Cifre agreement Euro-VL (Filière Société-Générale)) started in September 2006.
  Pricing of hybrid financial derivative products on change and interest rate

8.6. Participation to workshops, conferences and invitations

- A. Alfonsi
  - "On the discretization schemes for the CIR (and Bessel squared) process"
  - Colloque sur l’Approximation Numérique des Processus Stochastiques, 23-24 Janvier 2006 ? l’INRIA SOPHIA ANTIPOLIS.
  - VII Workshop on Quantitative Finance, January 26 - 27, 2006
  - Amamef conference, INRIA Rocquencourt, February 1-3, 2006.
  - "Call Put duality for perpetual American options and volatility calibration", Colloque "Jeunes probabilistes et statisticiens" Aussois, 23 avril-28 avril 2006.

- V. Bally
  - March 2006: Visit to the University Roma 3 to work with L. Caramellino on "Lower bounds for the density of Ito processes under weak regularity assuptions"

  - Conference on "Malliavin calculus for jump type diffusions and applications in finance" in the "Conference on stochastic processes and applications in control and finace" held in Kyoto, August 20-24 , 2006.
  - Organizqation of the session of "Probability" in the "Colloque Franco-Roumain de Mathématiques Appliquées" held in Chambery, France, August 28 - September 1st, 2006.
  - Organization of a mini-workshop in the University Marne la Vallee on "lower bounds for the fundamental solutions of PDE problems: analytical and probabilistic approach." There has been two mini-courses given by V. Vespri (university of Firenze) and S. Polidoro (university of Bolgna) and number of talks given by French probabilists.

- B. Jourdain
  - "Call Put duality for perpetual American options and volatility calibration", Amamef conference, INRIA Rocquencourt, February.

- A. Kohatsu-Higa
  - Applications of Malliavin Calculus in Finance. Nakanoshima Center. Financial Engineering and Current problems. December 1, 2006.
  - Recent results on asymmetric information and insider trading. Plenary spaker. Bachelier Congress. August 20, 2006.
  - Euler-Maruyama scheme: Recent results. Meeting of the Japan Mathematical Society. September 20, 2006.
  - Université de Marne-la-Vallée. journées Analyse et Probabilités. UFG conditons for regularity of the law of a diffusion process

- D. Lamberton
  - Optimal stopping of a one dimensional diffusion. Symposium on optimal stopping. Manchester, January 2006.
  - Optimal stopping and American options. Spring school in Finance. Bologna, May 2006.
  - A penalized bandit algorithm. Mathematical Finance Seminar. King's College, London, June 2006.
  - Lectures on mathematical finance, University of Monastir (Tunisia): Arrêt optimal et options américaines, Arbitrage et martingales, Monastir, June 2006.

- B. Lapeyre
  - "CDC Ixis" bank , mini course on "Adaptive Monte-Carlo methods" October 13 2006.
  - Tokyo Institute of Technology, seminar on Financial Engineering, "Premia an experimental option pricer", November 17 2006.
  - Osaka University, Graduate School of Engineering Sciences, "A unified framework for adaptive variance reduction methods", November 21 2006.

- J. Lelong
  - Invited by Professor Syoiti Ninomiya ? Tokyo (Center for Research in Advanced Financial Technology, Tokyo Institute of Technology), Novembre 2006. Talk on : *Truncated Stochastic Algorithms and Variance Reduction: toward an automatic procedure*
  - RESIM 2006, Bamberg (Germany), October 2006: *Truncated Stochastic Algorithms and Variance Reduction: toward an automatic procedure*
  - Journées MAS, Lille, September 2006: *A Central Limit Theorem for Truncating Stochastic Algorithms*

- Société Générale, July 2006: *Stochastic algorithm and Adaptive Variance Reduction Method*
- Working group of the CMAP, Ecole Polytechnique, June 2006: *Central Limit Theorems for Truncating and Averaging Stochastic Algorithms: a functional approach*

- G. Pagès
  - Talk at NMF'06 (Versailles, 02-2006).
  - Invited session (organizer) at SPA 2006 (Paris, July 2006): Optimal Quantization and Applications.
  - Invited plenary speaker at MCQMC'06 (Ulm, Germany, August 2006).
  - Scientific committee of ESANN'06 (Brug es).
- N. Privault
  - Lectures on stochastic analysis on the Poisson space applied to finance, in the framework of the MathFi project at INRIA. (UMLV)
  - "Cálculo estocástico y ecuaciones diferenciales parciales", 8 hours, Universidad Juárez Autónoma de Tabasco, Mexico, 23 october - 3 november 2006.
  - "Financial modeling and numerical methods", 15 hours, CIMPA-IMAMIS School, Open University Malaysia and UKM, Kuala Lumpur, 22 may - 2 june 2006.
  - "Stochastic finance with jumps", 15 hours, Master in Applied Mathematics, University of Tunis, 8-17 march 2006.
- A. Sellami

  Fourth World Congress of the Bachelier Finance Society : Tokyo, 17-20 August 2006
  Quantization of the filter process and applications to optimal stopping problems under partial observation, joint work with H. Pham and W. Runggaldier

  Workshop on mathematical finance and stochastic control : Kyoto, 24-27 August 2006
  Functional quantization of multi-dimensional stochastic differential equations and option pricing, joint work with G. Pagès

  Poster session in NSSWP 2006 Quantization based filtering method using first order approximation and comparison with the particle filtering approach, Cambridge, Nonlinear Statistical Signal Processing Workshop 2006, http://www-sigproc.eng.cam.ac.uk/NSSPW/, 12-14 September 2006.
- A. Sulem
  - Invited Plenary speaker at the " join Conference on Financial Mathematics and Engineering" (FME06), SIAM, Juillet 2006, Boston. http://www.siam.org/meetings/fm06/invited.php
  - Invited conference in the international colloquium "Numerical and Stochastic Models", Paris , Octobre 2006. http://www.proba.jussieu.fr/nsm/
  - Invited conference, Russian-Scandinavian Symposium on "Probability Theory and Applied Probability" August 2006, Petrozavodsk, Russia.
  - Séminaire Bachelier, IHP, Paris, November 2006 http://www.bachelier-paris.com/
  - Invited talk in the seminar on "Viscosity solutions and applications in control and finance", Université Paris-Dauphine, November 2006. http://www.ceremade.dauphine.fr/conferences.php
  - Joint presentation with P. Tankov of the software Premia to the Bayerische Landesbank, Munich, March 2006,

  - Presentation of Premia to La banque Postale, Natexis-Banques Populaires, QuodFinancial, Lexifi ...)

- P. Tankov
  - Numerical methods in finance, February 1-3, 2006, INRIA Rocquencourt "Quadratic hedging in models with jumps"
  - Conference on Stochastics in Science in Honor of Ole E. Barndorff-Nielsen, March 20-24, 2006, Guanajuato, Mexico, "Dependence models for multidimensional Levy processes and applications to finance"
  - 4th world congress of the Bachelier financial society, August 17-20, 2006, Tokyo, Japan, "Optimal quadratic hedging in models with jumps"
  - International conference on mathematical finance and related topics, August 21-23, 2006, Kanazawa, Japan, "Utility-based hedging in jump models" (joint work with Agnes Sulem)
  - Workshop on mathematical finance and stochastic control, August 24-27, 2006, Kyoto, Japan, "Optimal consumption under liquidity risk"
  - Presentations of Premia at different places, in particular at Bayerische Landesbank, Munich

- A. Zanette
  - En efficient finite difference method for pricing American lookback options AMASES Conference Trieste 2006
  - A Mixed PDE-Monte Carlo Approach for Pricing Credit Default Index Swaptions Bachelier Finance Conference Tokyo 2006.

8.7. Miscellaneus

- A. Kohatsu-Higa

  We are also working in establishing a joint project with Inria-ENPC in order to extend the Premia project to Japan where Osaka University will be the representative of Premia in Japan. One step to this has been to obtain the Sakura project.

- D. Lamberton

  - "Associate Editor" of *Mathematical Finance* and *ESAIM PS*.

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

  - 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.

  - Coordinator of an "ACI" "Méthodes d’équations aux dérivées partielles en finance de marché".

- B. Lapeyre
  - President of the Doctoral Department at Ecole des Ponts
  - Global coordinator of the ANR program GCPMF "Grid Computation for Financial Mathematics" (partners : Calyon, Centrale, EDF, ENPC, INRIA, Ixis, Paris 6, Pricing Partner, Summit, Supelec)
  - ENPC coordinator of the ANR Program ADAP’MC "Adaptive Monte-Carlo Method", (partners : ENST, Ecole Polytechnique, ENPC, Université Paris-Dauphine)

- G. Pagès

  Associate Editor of the journal *Stoch. Proc. and their Appl.*

- A. Sulem

  - Vice-President of the Inria Evaluation Board

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

  - referee of the PhD thesis of Marco Corsi : "Valuation an Portfolio optimization in a jump diffusion model under partial observation: theoretical and numerical aspects", University of Padova (Italy) and Université Paris VII, November 2006.

9. Bibliography

Major publications by the team in recent years

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

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

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[5] E. CLÉMENT, D. LAMBERTON, P. PROTTER. *An analysis of a least squares regression method for american option pricing*, in "Finance and Stochastics", vol. 6, 2002, p. 449–471.

[6] B. JOURDAIN, C. MARTINI. *American prices embedded in European prices*, in "Annales de l'IHP, analyse non linéaire", vol. 18, n^{o} 1, 2001, p. 1-17.

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