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Activity Report 2016

Project-Team TOSCA

TO Simulate and CALibrate stochastic models

IN COLLABORATION WITH: Institut Elie Cartan de Lorraine (IECL)

RESEARCH CENTERS
Sophia Antipolis - Méditerranée
Nancy - Grand Est

THEME
Stochastic approaches

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Project-Team TOSCA

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Computer Science and Digital Science:

- 6.1.2. - Stochastic Modeling (SPDE, SDE)
- 6.1.3. - Discrete Modeling (multi-agent, people centered)
- 6.1.4. - Multiscale modeling
- 6.2.2. - Numerical probability
- 6.2.3. - Probabilistic methods
- 6.2.4. - Statistical methods
- 6.4.2. - Stochastic control

Other Research Topics and Application Domains:

- 1.1.8. - Evolutionary biology
- 1.1.10. - Mathematical biology
- 1.2. - Ecology
- 1.3.1. - Understanding and simulation of the brain and the nervous system
- 3.2. - Climate and meteorology
- 3.3.4. - Atmosphere
- 4.3.2. - Hydro-energy
- 4.3.3. - Wind energy
- 9.4.2. - Mathematics
- 9.9.1. - Environmental risks
- 9.9.2. - Financial risks

1. Members

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2. Overall Objectives

2.1. Overall Objectives

TOSCA aims to significantly contribute to discern and explore new horizons for stochastic modeling. To this end we need to better understand the issues of stochastic modeling and the objectives pursued by practitioners who need them: we thus need to deeply understand other scientific fields than ours (e.g., Fluid Mechanics, Ecology, Biophysics) and to take scientific risks. Indeed, these risks are typified by the facts that often new and complex models do not behave as expected, mathematical and numerical difficulties are harder to overcome than forecast, and the increase of our knowledge in target fields is slower than wished.

In spite of these risks we think that our scientific approach is relevant for the following reasons:

- On the one hand, physicists, economists, biologists and engineers use a stochastic model because they cannot describe the physical, economical, biological, etc., experiment under consideration with deterministic systems, either because the experiment has a huge complexity, or because accurate calibrations of the parameters of the models would be impossible. However it is far from being enough to add noise to a dynamical system or to substitute random variables as parameters: the probability distribution of the random noises and parameters themselves is a modeling issue and, in addition, the qualitative behavior of the model may dramatically change as a function of this choice; in other terms, adding randomness to capture uncertainties may increase uncertainty instead of aiding. This issue is not so well understood in the literature, where most often probabilistic structures are given A PRIORI rather than studied as questionable choices. **Therefore our works, which concern application fields where stochastic modeling is still in its very beginning, include analysis of the limitations of the models we are elaborating. This analysis is based, either on theoretical estimates, or on our unique experience in stochastic simulations.**

- On the other hand, STOCHASTIC COMPUTATIONAL MODELS are being developed here and there, including by our team, with a fully different point of view from classical modeling approaches: these models are aimed to approximate complex physical laws (e.g. Fluid Mechanics laws for turbulent flows or folding processes for proteins) by statistical properties of artificial objects (e.g. particles interacting with turbulent flows or low dimensional stochastic systems having suitable correlation structures). The design of the stochastic dynamics of these objects is part of the problem to deal with, and the complexity of the underlying physical phenomena leads to huge simulation difficulties. **Therefore we are exploring new frontiers for stochastic numerical methods and developing advanced techniques far beyond our previous works and most of the literature.**

To bring relevant analytical and numerical answers to the preceding problems, we feel necessary to attack in parallel several problems arising from different fields. Each one of these problems contributes to our better understanding of the advantages and limitations of stochastic models and algorithms.

Of course, this strategy allows each researcher in the team to have her/his own main topic. However **we organize the team in order to maximize internal collaborations**. We consider this point, which justifies the existence of Inria project-teams, as essential to the success of our programme of research. It relies on the fact that, to develop our mathematical and numerical studies, we share a common interest for collaborations with engineers, practitioners, physicists, biologists and numerical analysts, and we also share the following common toolbox:

- Stochastic differential calculus;
- Mathematical combinations of both partial differential equations (PDEs) analysis and stochastic analysis for deterministic non-linear PDEs, notably stochastic control equations and McKean-Vlasov-Fokker-Planck equations;
- Original stochastic numerical analysis techniques to get theoretical estimates on stochastic numerical methods, and numerical experiments to calibrate these methods.

We finally emphasize that the unifying theme of our research is to develop analytical tools that can be effectively applied to various problems that come from extremely diverse subjects. For example, as described in more detail below, we study: branching processes and their simulation with the view of advancing our understanding of population dynamics, molecular dynamics, and cancer models; the theory and numerical analysis of McKean-Vlasov interacting particle systems in order to develop our models in biology, computational fluid dynamics, coagulation and fragmentation; hitting times of domains by stochastic processes so that we can improve on the current methods and theory used in finance and neuroscience.

3. Research Program

3.1. Research Program

Most often physicists, economists, biologists and engineers need a stochastic model because they cannot describe the physical, economical, biological, etc., experiment under consideration with deterministic systems, either because of its complexity and/or its dimension or because precise measurements are impossible. Therefore, they abandon trying to get the exact description of the state of the system at future times given its initial conditions, and try instead to get a statistical description of the evolution of the system. For example, they desire to compute occurrence probabilities for critical events such as the overstepping of a given thresholds by financial losses or neuronal electrical potentials, or to compute the mean value of the time of occurrence of interesting events such as the fragmentation to a very small size of a large proportion of a given population of particles. By nature such problems lead to complex modelling issues: one has to choose appropriate stochastic models, which require a thorough knowledge of their qualitative properties, and then one has to calibrate them, which requires specific statistical methods to face the lack of data or the inaccuracy of these data. In addition, having chosen a family of models and computed the desired statistics, one has to evaluate the sensitivity of the results to the unavoidable model specifications. The TOSCA team, in collaboration with specialists of the relevant fields, develops theoretical studies of stochastic models, calibration procedures, and sensitivity analysis methods.

In view of the complexity of the experiments, and thus of the stochastic models, one cannot expect to use closed form solutions of simple equations in order to compute the desired statistics. Often one even has no other representation than the probabilistic definition (e.g., this is the case when one is interested in the quantiles of the probability law of the possible losses of financial portfolios). Consequently the practitioners need Monte Carlo methods combined with simulations of stochastic models. As the models cannot be simulated exactly, they also need approximation methods which can be efficiently used on computers. The TOSCA team develops mathematical studies and numerical experiments in order to determine the global accuracy and the global efficiency of such algorithms.

The simulation of stochastic processes is not motivated by stochastic models only. The stochastic differential calculus allows one to represent solutions of certain deterministic partial differential equations in terms of probability distributions of functionals of appropriate stochastic processes. For example, elliptic and parabolic linear equations are related to classical stochastic differential equations (SDEs), whereas nonlinear equations such as the Burgers and the Navier–Stokes equations are related to McKean stochastic differential equations describing the asymptotic behavior of stochastic particle systems. In view of such probabilistic representations one can get numerical approximations by using discretization methods of the stochastic differential systems under consideration. These methods may be more efficient than deterministic methods when the space dimension of the PDE is large or when the viscosity is small. The TOSCA team develops new probabilistic representations in order to propose probabilistic numerical methods for equations such as conservation law equations, kinetic equations, and nonlinear Fokker–Planck equations.

4. Application Domains

4.1. Domain

TOSCA is interested in developing stochastic models and probabilistic numerical methods. Our present motivations come from models with singular coefficients, with applications in Geophysics, Molecular Dynamics and Neurosciences; Lagrangian modeling in Fluid Dynamics and Meteorology; Population Dynamics, Evolution and Genetics; Neurosciences; and Financial Mathematics.

4.1.1. *Stochastic models with singular coefficients: Analysis and simulation*

Stochastic differential equations with discontinuous coefficients arise in Geophysics, Chemistry, Molecular Dynamics, Neurosciences, Oceanography, etc. In particular, they model changes of diffusion of fluids, or diffractions of particles, along interfaces.

For practitioners in these fields, Monte Carlo methods are popular as they are easy to interpret — one follows particles — and are in general easy to set up. However, dealing with discontinuities presents many numerical and theoretical challenges. Despite its important applications, ranging from brain imaging to reservoir simulation, very few teams in mathematics worldwide are currently working in this area. The Tosca project-team has tackled related problems for several years providing rigorous approach. Based on stochastic analysis as well as interacting with researchers in other fields, we developed new theoretical and numerical approaches for extreme cases such as Markov processes whose generators are of divergence form with discontinuous diffusion coefficient.

The numerical approximation of singular stochastic processes can be combined with backward stochastic differential equations (BSDEs) or branching diffusions to obtain Monte Carlo methods for quasi-linear PDEs with discontinuous coefficients. The theory of BSDEs has been extensively developed since the 1980s, but the general assumptions for their existence can be quite restrictive. Although the probabilistic interpretation of quasi-linear PDEs with branching diffusions has been known for a long time, there have been only a few works on the related numerical methods.

Another motivation to consider stochastic dynamics in a discontinuous setting came to us from time evolution of fragmentation and coagulation phenomena, with the objective to elaborate stochastic models for the avalanche formation of soils, snow, granular materials or other geomaterials. Most of the models and numerical methods for avalanches are deterministic and involve a wide variety of physical parameters such as the density of the snow, the yield, the friction coefficient, the pressure, the basal topography, etc. One of these methods consists in studying the safety factor (or limit load) problem, related to the shallow flow of a visco-plastic fluid/solid with heterogeneous thickness over complex basal topography. The resulting nonlinear partial differential equation of this last theory involves many singularities, which motivates us to develop an alternative stochastic approach based on our past works on coagulation and fragmentation. Our approach consists in studying the evolution of the size of a typical particle in a particle system which fragments in time.

4.1.2. Stochastic Lagrangian modeling in Computational Fluid Dynamics

Stochastic Lagrangian models were introduced in the eighties to simulate complex turbulent flows, particularly two-phase flows. In Computational Fluid Dynamics (CFD), they are intensively used in the so-called Probability Density Functions (PDF) methods in order to model and compute the reaction-phase terms in the fundamental equations of fluid motions. The PDF methods are currently developed in various laboratories by specialists in scientific computation and physicists. However, to our knowledge, we are innovating in two ways:

- our theoretical studies are the pioneering mathematical analysis of Lagrangian stochastic models in CFD;
- our work on the Stochastic Downscaling Method (SDM) for wind simulation is the first attempt to solve the fundamental equations themselves by a fully 3D stochastic particle method.

We emphasize that our numerical analysis is essential to the SDM development which takes benefits from our deep expertise on numerical schemes for McKean-Vlasov-non-linear SDEs.

4.1.3. Population Dynamics, Evolution and Genetics

The activity of the team on stochastic modeling in population dynamics and genetics mainly concerns application in adaptive dynamics, a branch of evolutionary biology studying the interplay between ecology and evolution, ecological modeling, population genetics in growing populations, and stochastic control of population dynamics, with applications to cancer growth modeling. Stochastic modeling in these areas mainly considers individual-based models, where the birth and death of each individual is described. This class of model is well-developed in Biology, but their mathematical analysis is still fragmentary. Another important topic in population dynamics is the study of populations conditioned to non-extinction, and of the corresponding stationary distributions, called quasi-stationary distributions (QSD). This domain has been the object of a lot of studies since the 1960's, but we made recently significant progresses on the questions of existence, convergence and numerical approximation of QSDs using probabilistic tools rather than the usual spectral tools.

Our activity in population dynamics also involves a fully new research project on cancer modeling at the cellular level by means of branching processes. In 2010 the International Society for Protons Dynamics in Cancer was launched in order to create a critical mass of scientists engaged in research activities on Proton Dynamics in Cancer, leading to the facilitation of international collaboration and translation of research to clinical development. Actually, a new branch of research on cancer evolution is developing intensively; it aims in particular to understand the role of proteins acting on cancerous cells' acidity, their effects on glycolysis and hypoxia, and the benefits one can expect from controlling pH regulators in view of proposing new therapies.

4.1.4. Stochastic modeling in Neuroscience

It is generally accepted that many different neural processes that take place in the brain involve noise. Indeed, one typically observes experimentally underlying variability in the spiking times of an individual neuron in response to an unchanging stimulus, while a predictable overall picture emerges if one instead looks at the average spiking time over a whole group of neurons. Sources of noise that are of interest include ionic currents crossing the neural membrane, synaptic noise, and the global effect of the external environment (such as other parts of the brain).

It is likely that these stochastic components play an important role in the function of both the neurons and the networks they form. The characterization of the noise in the brain, its consequences at a functional level and its role at both a microscopic (individual neuron) level and macroscopic level (network of thousands of neurons) is therefore an important step towards understanding the nervous system.

To this end, a large amount of current research in the neuroscientific literature has involved the addition of noise to classical purely deterministic equations resulting in new phenomena being observed. The aim of the project is thus to rigorously study these new equations in order to be able to shed more light on the systems they describe.

4.1.5. Stochastic modeling in Financial Mathematics

4.1.5.1. Technical Analysis

In the financial industry, there are three main approaches to investment: the fundamental approach, where strategies are based on fundamental economic principles; the technical analysis approach, where strategies are based on past price behavior; and the mathematical approach where strategies are based on mathematical models and studies. The main advantage of technical analysis is that it avoids model specification, and thus calibration problems, misspecification risks, etc. On the other hand, technical analysis techniques have limited theoretical justifications, and therefore no one can assert that they are risk-less, or even efficient.

4.1.5.2. Financial Risks Estimation and Hedging

Popular models in financial mathematics usually assume that markets are perfectly liquid. In particular, each trader can buy or sell the amount of assets he/she wants at the same price (the “market price”). They moreover assume that the decision taken by the trader does not affect the price of the asset (the small investor assumption). In practice, the assumption of perfect liquidity is never satisfied but the error due to liquidity is generally negligible with respect to other sources of error such as model error or calibration error, etc.

Derivatives of interest rates are singular for at least two reasons: firstly the underlying (interest rate) is not directly exchangeable, and secondly the liquidity costs usually used to hedge interest rate derivatives have large variation in times.

Due to recurrent crises, the problem of risk estimation is now a crucial issue in finance. Regulations have been enforced (Basel Committee II). Most asset management software products on the markets merely provide basic measures (VaR, Tracking error, volatility) and basic risk explanation features (e.g., “top contributors” to risk, sector analysis, etc).

4.1.5.3. Energy and Carbon Markets

With the rise of renewable energy generation (from solar, wind, waves...), engineers face new challenges which heavily rely on stochastic and statistical problems.

Besides, in the context of the beginning of the second phase (the Kyoto phase) in 2008 of the European carbon market, together with the fact that French carbon tax was scheduled to come into law on Jan. 1, 2010, the year 2009 was a key year for the carbon price modeling. Our research approach adopts the point of view of the legislator and energy producers. We used both financial mathematical tools and a game theory approach. Today, with the third phase of the EU-ETS, that didn't yet start, and the report from the Cour des Comptes (October 2013) that pointed out (among many others point) the lack of mathematical modeling on such carbon market design, we continue our research in this direction.

4.1.5.4. Optimal Stopping Problems

The theory of optimal stopping is concerned with the problem of taking a decision at the best time, in order to maximise an expected reward (or minimise an expected cost). We work on the general problem of optimal stopping with random discounting and additional cost of observation.

4.1.5.5. First hitting times distributions

Diffusion hitting times are of great interest in finance (a typical example is the study of barrier options) and also in Geophysics and Neurosciences. On the one hand, analytic expressions for hitting time densities are well known and studied only in some very particular situations (essentially in Brownian contexts). On the other hand, the study of the approximation of the hitting times for stochastic differential equations is an active area of research since very few results still are available in the literature.

5. New Software and Platforms

5.1. AGH

FUNCTIONAL DESCRIPTION

AGH (for Analysis of Galton-Watson Harris paths) is a Matlab toolbox providing methods for statistical analysis of ordered trees from their Harris paths in a user-friendly environment. More precisely it allows to easily compute estimators of the relative scale of trees which share the same shape. These estimators have been introduced for Galton-Watson trees conditioned on their number of nodes but may be computed for any ordered tree.

- Participants: Romain Azaïs, Alexandre Genadot, Benoît Henry
- Contact: Benoît Henry
- URL: <http://agh.gforge.inria.fr/>

5.2. ExitBM

FUNCTIONAL DESCRIPTION

The exitbm library provides methods to simulate random variables related to the first exit time and position of the Brownian motion from simple domains, namely intervals, squares and rectangles.

- Participants: Madalina Deaconu and Antoine Lejay
- Contact: Antoine Lejay
- URL: <http://exitbm.gforge.inria.fr/>

5.3. SDM-WindPoS

Stochastic Downscaling Method and Wind Power Simulation

FUNCTIONAL DESCRIPTION

The computation of the wind at small scale and the estimation of its uncertainties is of particular importance for applications such as wind energy resource estimation. To this aim, we have developed a computer code belonging to the family of codes of atmospheric flow calculation, in the atmospheric boundary layer. SDM-windpos especially concerns the simulation of wind at small space scales (meaning that the horizontal resolution is one kilometer or less), based on the combination of an existing Numerical Weather Prediction model providing a coarse prediction, and a Lagrangian Stochastic Model for turbulent flows.

The ability of SDM-WindPoS to recompute the wind computation in the horizontal scale but also in the vertical scale is of particular interest for wind farm power production assessment. WindPoS couples direct actuator disk approach and SDM Atmospheric Boundary Layer (ABL) model for wind farm simulation.

This year we start to introduce more accurate ABL convection models in SDM. Moreover, we start to add the possibility to introduce more accurate topography when SDM is running with some coarse scale atmospheric input data. Our dedicated GUI was also improved (better rendering for the 2D and 3D views).

- Participants: Mireille Bossy
- Contact: Mireille Bossy
- URL: <http://windpos.inria.fr>

6. New Results

6.1. Probabilistic numerical methods, stochastic modelling and applications

Participants: Mireille Bossy, Nicolas Champagnat, Madalina Deaconu, Coralie Fritsch, Pascal Helson, Benoît Henry, Kouadio Jean Claude Kouaho, Antoine Lejay, Radu Maftci, Sylvain Maire, Paolo Pigato, Alexandre Richard, Denis Talay, Etienne Tanré, Milica Tomasevic, Denis Villemonais.

6.1.1. Published works and preprints

- M. Bossy with H. Quinteros (UCHile) studied the rate of convergence of a symmetrized version of the Milstein scheme applied to the solution of one dimensional CEV type processes. They prove a strong rate of convergence of order one, recovering the classical result of Milstein for SDEs with smooth diffusion coefficient. In contrast with other recent results, the proof does not rely on Lamperti transformation, and it can be applied to a wide class of drift functions. Some numerical experiments and comparison with various other schemes complement the theoretical analysis that also applies for the simple projected Milstein scheme with same convergence rate ([14] accepted for publication in Bernoulli Journal).
- M. Bossy, R. Maftci, J.-P. Minier and C. Profeta worked on numerically determining the rate of convergence of the weak error for the discretised Langevin system with specular reflection conditions. The article [29] presents a discretisation scheme and offers a conjecture for the rate of convergence of the bias produced. Numerically, these conjectures are confirmed for the specular reflection scheme but also for the absorption scheme, which models perfect agglomeration. The scheme numerically follows a linear decrease. The Richardson-Romberg extrapolation is also presented with a quadratic decrease.
- M. Bossy, A. Rousseau (LEMON Inria team), J. Espina, J. Morice and C. Paris (Inria Chile) studied the computation of the wind circulation around mills, using a Lagrangian stochastic approach. They present the SDM numerical method and numerical experiments in the case of non rotating and rotating actuator disc models in [13]. First, for validation purpose they compare some numerical experiments against wind tunnel measurements. Second, they perform numerical experiments at the atmospheric scale and present some features of the numerical method, in particular the computation of the probability distribution of the wind in the wake zone, as a byproduct of the fluid particle model and the associated PDF method.
- Together with M. Baar and A. Bovier (Univ. Bonn), N. Champagnat studied the adaptive dynamics of populations under the assumptions of large population, rare and small mutations [11]. In this work, the three limits are taken simultaneously, contrary to the classical approach, where the limits of large population and rare mutations are taken first, and next the limit of small mutations [57]. We therefore obtain the precise range of parameters under which these limits can be taken, and provide explicit biological conditions for which our approximation is valid.
- N. Champagnat and J. Claisse (Ecole Polytechnique) studied the ergodic and infinite horizon controls of discrete population dynamics with almost sure extinction in finite time. This can either correspond to control problems in favor of survival or of extinction, depending on the cost function. They have proved that these two problems are related to the QSD of the processes controlled by Markov controls [36].
- N. Champagnat and C. Fritsch worked with F. Campillo (Inria Sophia-Antipolis, LEMON team) on the links between a branching process and an integro-differential equation of a growth-fragmentation-death model [15]. They proved that the two representations of the model lead to the same criteria of invasion of a population in a given environment. They also studied the variations of the principal eigenvalue (resp. the survival probability) of an integro-differential equation (resp. branching process) of growth-fragmentation models with respect to an environmental parameter in [35].

- N. Champagnat and D. Villemonais consider, for general absorbed Markov processes, the notion of quasi-stationary distributions (QSD), which is a stationary distribution conditionally on non-absorption, and the associated Q -process, degenerated as the original Markov process conditioned to never be absorbed. They prove that, under the conditions of [17], in addition to the uniform exponential convergence of conditional distributions to a unique QSD and the uniform exponential ergodicity of the Q -process, one also has the uniform convergence of the law of the process conditioned to survival up to time T , when $T \rightarrow +\infty$. This allows them to obtain conditional ergodic theorems [41].
- N. Champagnat, K. Coulibaly-Pasquier (Univ. Lorraine) and D. Villemonais obtained general criteria for existence, uniqueness and exponential convergence in total variation to QSD for multi-dimensional diffusions in a domain absorbed at its boundary [37]. These results improve and simplify the existing results and methods.
- Using a new method to compute the expectation of an integral with respect to a random measure, N. Champagnat and B. Henry obtained explicit formulas for the moments of the frequency spectrum in the general branching processes known as Splitting Trees, with neutral mutations and under the infinitely-many alleles model [16]. This allows them to obtain a law of large numbers for the frequency spectrum in the limit of large time.
- N. Champagnat and D. Villemonais obtained criteria for existence, uniqueness and exponential convergence in total variation to QSD for discrete population processes with unbounded absorption rate, using a non-linear Lyapunov criterion [38]. For logistic multidimensional birth and death processes absorbed when one coordinate gets extinct, they show that their criterion covers cases stronger intra-specific competition than inter-specific competition.
- N. Champagnat and D. Villemonais extended their work [17] to general penalized processes, including time-inhomogeneous Markov processes with absorption and Markov processes in varying environments [40]. Their method allows to improve significantly the former results of [58], [59].
- M. Deaconu worked with L. Beznea and O. Lupaşcu (Bucharest, Romania) and analyzed the description of rupture phenomena like avalanches, by using fragmentation models. The main physical properties of the model are deeply involved in this study. They obtained new results on a stochastic equation of fragmentation and branching processes related to avalanches [12].
- M. Deaconu and S. Herrmann continued and completed the study of the simulation of hitting times of given boundaries for Bessel processes. These problems are of great interest in many application fields, such as finance and neurosciences. In a previous work, the authors introduced a new method for the simulation of hitting times for Bessel processes with integer dimension. The method was based mainly on explicit formula for the distribution of the hitting times and on the connexion between the Bessel process and the Euclidean norm of the Brownian motion. The method does not apply for a non-integer dimension. In this new work they consider the simulation of the hitting time of Bessel processes with non integer dimension and provide a new algorithm by using the additivity property of the laws of squared Bessel processes. Each simulation step is splitted in two parts: one is using the integer dimension case and the other one exhibits hitting time of a Bessel process starting from zero [20].
- M. Deaconu and S. Herrmann studied the Initial-Boundary Value Problem for the heat equation and solved it by using a new algorithm based on a random walk on heat balls [44]. Even if it represents a sophisticated and challenging generalization of the Walk on Spheres (WOS) algorithm introduced to solve the Dirichlet problem for Laplace's equation, its implementation is rather easy. The definition of the random walk is based on a new mean value formula for the heat equation. The convergence results and numerical examples allow to emphasize the efficiency and accuracy of the algorithm.
- M. Deaconu, B. Dumortier and E. Vincent (EPI MULTISPEECH) are working with the Venathec SAS on the acoustic control of wind farms. They constructed a new approach to control wind farms based on real-time source separation. They expressed the problem as a non-linear knapsack problem and solve it using an efficient branch-and-bound algorithm that converges asymptotically to the global

optimum. The algorithm is initialised with a greedy heuristic that iteratively downgrades the turbines with the best acoustical to electricity loss ratio. The solution is then regammaed using a depth-first search strategy and a bounding stage based on a continuous relaxation problem solved with an adapted gradient algorithm. The results are evaluated using data from 28 real wind farms [46].

- C. Fritsch and B. Cloez (INRA, Montpellier) proved central limit theorems for chemostat models in finite and infinite dimensions in [42]. From these theorems, they obtained gaussian approximations of individual-based models and made a numerical analysis for the model in finite dimension in order to discuss the validity of these approximations in different contexts.
- Together with R. Azaïs (BIGS Inria team) and A. Genadot (Univ. Bordeaux), B. Henry studied an estimation problem for a forest of size-constrained Galton-Watson trees [31]. Using the asymptotic behavior of the Harris contour process, they constructed estimators for the inverse standard deviation of the birth distribution. In addition to the theoretical convergence results obtained in this work, they used the method to study the evolution of Wikipedia webpages in order, for instance, to detect vandalism.
- In [49], B. Henry showed a central limit theorem for the population counting process of a supercritical Splitting Tree in the limit of large time. Thanks to the results of [16], he also obtained a central limit theorem for the frequency spectrum of Splitting Trees with neutral mutations and under the infinitely-many alleles model.
- In collaboration with Laure Coutin, A. Lejay have studied the sensitivity of solution of rough differential equations with respect to their parameters using a Banach space version of the implicit function theorem. This result unifies and extends all the similar results on the subject [43].
- A. Lejay have studied the parametric estimation of the bias coefficient of skew random walk, as a toy model for the problem of estimation of the parameter of the Skew Brownian motion [50].
- P. Pigato has continued with V. Bally (Univ. Marne-la-Vallée) and L. Caramellino (Univ. Roma Tor Vergata) his PhD work on the regularity of diffusions under Hörmander-type conditions [32], [33].
- A. Richard and D. Talay ended their work on the sensitivity of the first hitting time of fractional SDEs, when $H > \frac{1}{2}$ [54]. This study is being completed by the rough case $H \in (\frac{1}{4}, \frac{1}{2}]$. In relation to fractional SDEs, another short work on accurate Gaussian-like upper bounds on density of one-dimensional fractional SDEs is almost finished.
- In [21], S. Herrmann and E. Tanré propose a new algorithm to simulate the first hitting times of a deterministic continuous function by a one-dimensional Brownian motion. They give explicit rate of convergence of the algorithm.
- E. Tanré and Pierre Guiraud (Univ. of Valparaiso) have studied the synchronization in a model of neural network with noise. Using a large deviation principle, they prove the stability of the synchronized state under stochastic perturbations. They also give a lower bound on the probability of synchronization for networks which are not initially synchronized. This bound shows the robustness of the emergence of synchronization in presence of small stochastic perturbations. [48]
- V. Reutenauer and E. Tanré have worked on extensions of the exact simulation algorithm introduced by Beskos et al. [56]. They propose an unbiased algorithm to approximate the two first derivatives with respect to the initial condition x of quantities with the form $\mathbb{E}\Psi(X_T^x)$, where X is a one-dimensional diffusion process and Ψ any test-function. They also propose an efficient modification of Beskos et al. algorithm. [53]
- During his internship supervised by E. Tanré, A. Papic worked on multi scales generator of Markov processes. He presents a method to approximate such processes with an application in neuroscience for noisy Hodgkin-Huxley model [52].
- D. Villemonais worked with P. Del Moral (Univ. Sydney) on the conditional ergodicity of time inhomogeneous diffusion processes [45]. They proved that, conditionally on non extinction, an elliptic time-inhomogeneous diffusion process forgets its initial distribution exponentially fast. An interacting particle scheme to numerically approximate the conditional distribution is also provided.

- D. Villemonais worked with his Research Project student William Oçafrain (École des Mines de Nancy) on an original mean-field particle system [51]. They proved that the mean-field particle system converges in full generality toward the distribution of a conditioned Markov process, with applications to the approximation of the quasi-stationary distribution of piecewise deterministic Markov processes.

6.1.2. Other works in progress

- M. Bossy and R. Maftai are working on determining the rate of convergence of the weak error of a discretised scheme for the Langevin system with specular boundary reflection on the position. The velocity process allows for a bounded and smooth drift. In order to determine the optimal rate of convergence, the regularity of the associated PDE is required and also regularity results for the derivative of flow of the process w.r.t. the initial conditions.
- N. Champagnat and B. Henry are studying limits of small mutations in Lotka-Volterra type PDEs of population dynamics using probabilistic representations and large deviations.
- N. Champagnat, C. Fritsch and S. Billiard (Univ. Lille) are working on food web modeling.
- M. Deaconu and S. Herrmann are working on numerical approaches for hitting times of general stochastic differential equations.
- M. Deaconu, O. Lupaşcu and L. Beznea (Bucharest, Romania) worked on the numerical scheme for the simulation of an avalanche by using the fragmentation model. This work will be submitted soon.
- M. Deaconu, B. Dumortier and E. Vincent (EPI MULTISPEECH) work on handling uncertainties in the model of acoustic control of wind farms they develop, in order to design a stochastic algorithm based on filtering methods. They will submit another article to IEEE transaction on sustainable energy.
- C. Fritsch is working with F. Campillo (Inria Sophia-Antipolis, LEMON team) and O. Ovaskainen (Univ. Helsinki) about a numerical approach to determine mutant invasion fitness and evolutionary singular strategies using branching processes and integro-differential models. They illustrate this method with a mass-structured individual-based chemostat model.
- C. Fritsch is working with A. Gégout-Petit (Univ. Lorraine and sc Bigs team), B. Marçais (INRA, Nancy) and M. Grosdidier (INRA, Nancy) on a statistical analysis of a *Chalara fraxinea* model.
- B. Cloez (INRA Montpellier) and B. Henry started a work on the asymptotic behavior of splitting trees in random environment. In addition, they begin the study of scaling limits of splitting trees in varying environment.
- Together with Ernesto Mordecki (Universidad de la República, Uruguay) and Soledad Torres (Universidad de Valparaíso), A. Lejay is working on the estimation of the parameter of the Skew Brownian motion.
- A. Lejay, and P. Pigato are working on the estimation of the parameters of diffusions with discontinuous coefficients, with application to financial data.
- Together with Laure Coutin and Antoine Brault (Université Toulouse 3), A. Lejay is studying application of the Trotter-Kato theorem in the context of rough differential equations, in order to solve some Stochastic Partial Differential Equations.
- A. Lejay and H. Mardones are working on a Monte Carlo simulation of the Navier-Stokes equations which is based on a novel probabilistic representation due to F. Delbaen *et al.* [60].
- In a research visit to Chile, P. Pigato has worked with R. Rebolledo and S. Torres on the estimation of parameters of diffusions from the occupation time and the local time of the process.
- Together with Laure Coutin and Antoine Brault (Université Toulouse 3), A. Lejay is studying application of the Trotter-Kato theorem in the context of rough differential equations, in order to solve some Stochastic Partial Differential Equations.

- C. Graham (École Polytechnique) and D. Talay are polishing the second volume of their series on Mathematical Foundation of Stochastic Simulation to be published by Springer.
- In collaboration with J. Bion-Nadal (CNRS and École Polytechnique) D. Talay ended the first paper on an innovating calibration method for stochastic models belonging to a family of solutions to martingale problems. The methodology involves the introduction of a new Wasserstein-type distance and stochastic control problems. The manuscript is being finished.
- Motivated by the study of systems of non-linear PDE's by stochastic methods, M. Tomasevic and D. Talay studied a system of differential equations interacting through a singular kernel, depending on all the past of the solutions. They have proved the existence of a solution in the space of Lipschitz functions in short time interval and performed numerical simulations. In the same time, they studied a non-linear stochastic differential equation whose drift is given as a convolution of a singular kernel with the unknown one dimensional time marginals both in time and space. Combining probabilistic and PDE techniques, they are currently finishing the proof of the existence and uniqueness of a weak solution up to an arbitrary finite time horizon. Properties of the corresponding particle system (well-posedness and propagation of chaos) are also studied.
- A. Richard and E. Tanré's work with Patricio Orío (CINV, Chile) on the modelling and measurement of long-range dependence in neuronal spike trains is almost completed. They exhibit evidence of memory effect in genuine neuronal data and compared their fractional integrate-and-fire model with the existing Markovian models. A. Richard and E. Tanré are still working on the convergence of the statistical estimator that measures this phenomenon.
- A. Richard, E. Tanré are working with S. Torres (Universidad de Valparaíso, Chile) on a one-dimensional fractional SDE reflected on the line. The existence and uniqueness of this process is known in the case $H > \frac{1}{2}$. In addition, they have proved the existence of a penalization scheme (suited to numerical approximation) to approach this object. When $H \in (\frac{1}{4}, \frac{1}{2})$, they have proved the existence in the elliptic case and are working on the question of uniqueness and on the relaxation of ellipticity.
- During his internship supervised by E. Tanré and Romain Veltz (MATHNEURO team), Pascal Helson studied numerically and theoretically a model of spiking neurons in interaction with plasticity. He showed that a simple model without plasticity could reproduce biological phenomena such as oscillations. In order to add plasticity, he enabled synaptic weights to evolve in a probabilistic way, in agreement with biological laws. He is now studying the convergence of this model and the existence of separable time scales, which is part of his thesis.
- D. Villemonais started a collaboration with Camille Coron (Univ. Paris Sud) and Sylvie Méléard (École Polytechnique) on the question of simultaneous/non-simultaneous extinction of traits in a structured population
- D. Villemonais currently works on the computation of lower bounds for the Wasserstein curvature of interacting particle systems.
- D. Villemonais started a collaboration with Éliane Albuissou (CHRU of Nancy), Athanase Benetos (CHRU of Nancy), Simon Toupance (CHRU of Nancy), Daphné Germain (École des Mines de Nancy) and Anne Gégout-Petit (Inria BIGS team). The aim of this collaboration is to conduct a statistical study of the time evolution of telomere's length in human cells.

6.2. Financial Mathematics

Participants: Maxime Bonelli, Mireille Bossy, Nicolas Champagnat, Madalina Deaconu, Antoine Lejay, Sylvain Maire, Khaled Salhi, Denis Talay, Etienne Tanré.

6.2.1. Published works and preprints

- K. Salhi, M. Deaconu, A. Lejay and N. Champagnat worked with N. Navet (University of Luxembourg) [28]. They construct a regime switching model for the univariate Value-at-Risk estimation. Extreme value theory (EVT) and hidden Markov models (HMM) are combined to estimate a hybrid model that takes volatility clustering into account. In the first stage, HMM is used to classify data in crisis and steady periods, while in the second stage, EVT is applied to the previously classified data to rub out the delay between regime switching and their detection. This new model is applied to prices of numerous stocks exchanged on NYSE Euronext Paris over the period 2001-2011. The relative performance of the regime switching model is benchmarked against other well-known modeling techniques, such as stable, power laws and GARCH models.
- K. Salhi wrote a survey paper about option pricing and risk management under exponential Lévy models [55]. He detailed some notions that are not well explained in the literature and he proposed new trends in the risk management of derivatives.
- In [26], D. Talay, E. Tanré, Christophe Michel (CA-CIB) and Victor Reutenauer (fotonower) have studied a model in financial mathematics including bid-ask spread cost. They study the optimal strategy to hedge an interest rate swap that pays a fixed rate against a floating rate. They present a methodology using a stochastic gradient algorithm to optimize strategies.

6.2.2. Other works in progress

- M. Bossy and M. Bonelli (Koris International) are working on the optimal portfolio investment problem under the drawdown constraint that the wealth process never falls below a fixed fraction of its running maximum. They derive optimal allocation programs by solving numerically the Hamilton-Jacobi-Bellman equation that characterizes the finite horizon expected utility maximization problem, for investors with power utility as well as S-shape utility. Using numerical experiments they show that implementing the drawdown constraint can be gainful in optimal portfolios for the power utility, for some market configurations and investment horizons. However, their study reveals different results in a prospect theory context.
- When the underlying asset price is given by a exponential Lévy model, the market is almost incomplete. Under this hypothesis, K. Salhi works on derivatives hedging under a budget constraint on the initial capital. He considers, as criterion of optimization, the CVaR of the terminal hedging risk. First, he rewrites the problem an optimisation problem on the random fraction of the payoff that permits to respect the budget constraint. Then, he approximates the problem by relaxing the constraint and considering only a specific equivalent martingale measure. This approximate problem is solved using Neyman-Pearson's Lemma and, in the case of European options, a numerical valuation of the approximated minimal CVaR based on fast Fourier transform. The article will be submitted soon.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

- TOSCA Sophia is involved in a Cifre convention with Koris International. M. Bossy supervises M. Bonelli's Ph.D. thesis.
- M. Deaconu is involved in a bilateral contract with Venathec. She is supervising, with E. Vincent (EPI MULTISPEECH), the Ph.D. thesis of B. Dumortier on the acoustic control of wind farms noise.

7.2. Bilateral Grants with Industry

- Mireille Bossy is the Coordinator of the PEPS from AMIES granted with the SME Seatopic, on the wind downscaling, using finer local topography, for coastal activities.

- Mireille Bossy is the Coordinator of the TER project from the PGMO (FMJH) granted with the SME METIGATE, on the statistical description of coupled regional temperatures.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR

- N. Champagnat is member of the ANR NONLOCAL (Phénomènes de propagation et équations non locales, 2014–2018) coordinated by F. Hamel (Univ. Aix-Marseille).
- E. Tanré is member of the ANR SloFaDyBio (Slow Fast Dynamics in Biology, ANR-14-CE25-0019, 2015-2017) coordinated by M. Desroches (EPI MATHNEURO, Inria Sophia Antipolis).

8.2. International Initiatives

8.2.1. Inria International Labs

Inria Chile

Associate Team involved in the International Lab:

8.2.1.1. ANESTOC-TOSCA

Title: Stochastic modelling of biology and renewable energies

International Partner (Institution - Laboratory - Researcher):

Pontificia Universidad Católica de Chile (Chile) - ANESTOC Center (ANESTOC) - Rebolledo Rolando

Start year: 2014

See also: <http://www.incidechile.cl/anestoc/teams-involved/>

This French-Chilean Associated Team deals with stochastic modeling and simulation issues for renewable energies (wind and waves) and neurosciences. It is a follow-up of a long collaboration in which each of the side takes benefit from the other side know-how and structures. In particular, this Associated Team is strongly related to the CIRIC project “Stochastic Analysis of Renewable Energy”. This project aims at transferring and valuing to Chilean companies the results of researches on renewable energies, mainly wind prediction at the windfarm’s scale and waves energy potential of a site using video.

8.2.2. Participation in Other International Programs

8.2.2.1. International Initiatives

ECOS Discrelongmem

Title: On discretization procedures in Non-Gaussian long memory processes with applications in non parametric statistics and time series analysis

International Partner (Institution - Laboratory - Researcher):

Universidad de Valparaiso (Chile) - CIMFAV – Facultad de Ingenieria

PI: E. Tanré (France), S. Torrès (Chile)

Duration: 2016 - 2018

Start year: 2016

Keywords: Approximations of non-Gaussian long-memory processes. Fractional Poisson processes (fPp). Skew Fractional Process (SfP).

8.3. International Research Visitors

8.3.1. Visits of International Scientists

- L. Beznea (Simion Stoilow Institute of Mathematics of the Romanian Academy, Bucarest) has been visiting TOSCA Nancy for 11 days in July.
- O. Lupaşcu (Simion Stoilow Institute of Mathematics of the Romanian Academy, Bucarest) has been visiting TOSCA Nancy for one week in October.
- The TOSCA seminar organized by A. Richard in Sophia Antipolis has received the following speakers: Pierre-Emmanuel Jabin (University of Maryland), Christophe Henry (Institute of Fluid Flow Machinery, Polish Academy of Sciences), Tony Lelièvre (ENPC), D. Alberici (University of Bologna), Nicolas Fournier (Université Pierre et Marie Curie), Philip Protter (Columbia University), Jean-François Jabir (CIMFAV – Valparaiso, Chile), Roberto Cortez Milan (CIMFAV – Valparaiso, Chile), Areski Cousin (ISFA, Lyon).

8.3.1.1. Internships

BICHAT Antoine

Subject: Modélisation de populations de cellules irradiées: une approche par processus de branchement

Date: Sep. 2015 - June 2016 (projet recherche)

Institution: Écoles des Mines de Nancy.

CORMIER Quentin

Subject: Study of invariants associated to the dynamic of a neuron network subject to STDP

Date: Oct. 2015 - Feb. 2016

Institution: ENS Lyon

DUPRE Aurore

Subject: Analyse et évaluation de l'adjonction de la modélisation de phénomènes convectifs dans un modèle numérique lagrangien de la couche limite atmosphérique

Date: April 2016 - Oct. 2016

Institution: Université de Reims Champagne-Ardenne

GEORGES Thomas

Subject: Single Particle Tracking Techniques

Date: Sept. 2016 - June 2017 (research project)

Institution: Écoles des Mines de Nancy.

GUERBAB Ismail

Subject: Sums of Pareto distributions

Date: June 2016 - Aug. 2016

Institution: Écoles des Mines de Nancy.

HELSON Pascal

Subject: Spiking Neurons in interaction with Plasticity

Date: April 2016 - Aug. 2016

Institution: Ecole des Ponts et chaussées.

KANTASSI Ameni

Subject: Processus du plus récent ancêtre commun dans des arbres de Galton-Watson

Date: April 2015 - Aug. 2015

Institution: Univ. Lorraine et École Supérieure des Sciences et Technologies d’Hamam Sousse (Tunisie).

PAPIC Alexis

Subject: States Reduction on Markov Processes

Date: Mai 2016 - Aug. 2016

Institution: Univ. Pierre et Marie Curie.

8.3.2. Visits to International Teams

8.3.2.1. Research Stays Abroad

- N. Champagnat and D. Villemonais spent one week in Neuchâtel (Switzerland) in September, to work with Michel Benaïm.
- P. Pigato has spent two weeks in Valparaiso and Santiago (Chile) in March, working with R. Rebolledo and S. Torres.
- P. Pigato has spent one week in Padova (Italy), in June, for a collaboration with P. Dai Pra.
- A. Richard and E. Tanré have spent one week in Valparaíso and one week in Santiago (Chile) in December within the ECOS program (PIs: E. Tanré, S. Torres, C. Tudor), working with S. Torres (Univ. of Valparaiso).
- D. Talay spent ten days at Columbia University in October.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Promotion of Mathematics in the industry

- M. Deaconu and A. Lejay were invited to give a talk at ILAC, Luxembourg in March 2016.
- A. Lejay has been appointed as representative of Inria Nancy-Grand Est in the Agence Mathématiques et Entreprise (AMIES).
- D. Talay continued to serve as the Vice-President of the Fondation d’Entreprise Natixis which aims to contribute to develop research in quantitative finance. He also serves as a member of the Scientific Committee of the Foundation.
- D. Talay continued to serve as a member of the Scientific Committee of the AMIES National Agency aimed to promote interactions between Mathematics and Industry.

9.1.2. Scientific Events Organisation

- N. Champagnat and M. Deaconu organized the mini-symposium “Un panorama de progrès récents sur les méthodes numériques probabilistes” at CANUM 2016 (Congrès d’Analyse Numérique) at Obernai in July 2016.

9.1.2.1. Member of the Organizing Committees

- A. Lejay was member of the conference organizing committees of *CANUM 2016* (Obernai, France).

9.1.3. Scientific Events Selection

9.1.3.1. Member of the Conference Program Committees

- N. Champagnat served as a member of the program committee of CARI 2016 (13ème Colloque Africain sur la Recherche en Informatique et Mathématiques Appliquées), Tunis, 10–14 octobre 2016.
- A. Lejay is member of the conference program committees of *CANUM 2016* (Obernai, France) and *Journées de Probabilités 2016* (Le Mans, France).

- D. Talay served as a member of the XIIIth France-Romania Colloquium in Applied Mathematics.
- E. Tanré served as a member of the program committee of the International Conference on Mathematical NeuroScience (ICMNS 2016), Juan les Pins.

9.1.4. Journal

9.1.4.1. Member of the Editorial Boards

- M. Bossy served as an Associate Editor of *Annals of Applied Probability*.
- N. Champagnat served as an Associate Editor of *Stochastic Models*.
- A. Lejay is one of the three editors of the *Séminaire de Probabilités*.
- D. Talay served as an Associate Editor of: *Stochastic Processes and their Applications*, *ESAIM Probability and Statistics*, *Stochastics and Dynamics*, *Journal of Scientific Computing*, *Monte Carlo Methods and Applications*, *Oxford IMA Journal of Numerical Analysis*, *SIAM Journal on Scientific Computing*, *Communications in Applied Mathematics and Computational Science*, *Éditions de l'École Polytechnique*. He also served as the Co-editor in chief of *MathematicS in Action*.

9.1.4.2. Reviewer - Reviewing Activities

- M. Deaconu wrote reviews for manuscripts submitted to *Journal of Computational and Applied Mathematics*.
- A. Lejay wrote reviews for manuscripts submitted to *Journal of Computational Mathematics, Mathematics and Computers in Simulation, Mathematical Reports, SIAM Journal of Control and Optimization, Communications in Mathematical Physics, Real Analysis Exchange, Annals of Probability, Electronic Journal of Probability*.
- E. Tanré wrote reviews for manuscripts submitted to *Applied Mathematical Finance, Bernoulli, European Journal of Applied Mathematics*.
- E. Tanré serves as a permanent reviewer of *Mathematical Reviews of the American Mathematical Society (MathSciNet)*
- D. Villemonais wrote reviews for *Mathematical Reviews of the American Mathematical Society (MathSciNet)* and for manuscripts submitted to *Stochastic processes and applications* and *Theoretical Population Biology*.

9.1.5. Invited Talks

- M. Bossy has been invited to give a talk at the seminar of the Laboratoire Jacques-Louis Lions, in May.
- M. Bossy has been invited to give a seminar talk at the Rencontre Niçoise de Mécanique des Fluides, at the Observatoire de la Côte d'Azur in Nice, June
- M. Bossy has been invited to give a talk at the symposium *SDE approximation* at the International Conference on Monte Carlo techniques, In Paris, July.
- N. Champagnat has been invited to give talks at the conference *Stochastic PDE's, Large Scale Interacting Systems and Applications to Biology* in Orsay in March, to the CMO-BIRS workshop *Stochastic and Deterministic Models for Evolutionary Biology* in Oaxaca, Mexico, in August and at the conference *Probabilistic structures in deterministic population genetics* in Vienna in November.
- N. Champagnat has been invited to give seminar talks at *TOSCA seminar* in Inria Sophia Antipolis in April, at the *MAPMO probability seminar* in October and at the seminar *Méthodes probabilistes et statistiques en dynamique des populations* in Grenoble in December.
- N. Champagnat has been invited to give a lecture at the CIMPA School *Mathématiques pour la Biologie* (4h) in Tunis in October.
- M. Deaconu was invited to give a talk at the *Colloque Franco Roumain de Mathématiques Appliquées*, Iași (Romania) in August 2016.

- C. Fritsch has been invited to give talks at the *Workshop on “Approche Interdisciplinaire en Evolution”* in Saint-Martin-de-Londres in December.
- A. Lejay has been invited to give talk at the *Workshop on Numerical Schemes of SDE and SPDE* in Lille in June 2016, and at the *International Conference on Monte Carlo techniques* in Paris in July 2016.
- A. Lejay has been invited to give a seminar talk at the Université de Reims in February 2016.
- P. Pigato gave talks at the Probability Seminar of Luxembourg University, in January, at the Seminar of TOSCA-Sophia Antipolis, in February, at the Seminar of CIMFAV (Valparaíso) in March, at the Journées de Probabilités 2016, in May, at the Probability Seminar of Università degli studi di Padova, in June, and at the London-Paris Bachelier Workshop on Mathematical Finance in September.
- A. Richard gave seminar talks at the LPMA (Paris 6) Probability seminar and the IMT (Toulouse) probability seminar in February, at the Groupe de Travail on stochastic models in finance at Ecole Polytechnique and at the Barcelona probability seminar in April.
- A. Richard had an accepted talk at ICMNS 2016.
- D. Talay gave a lecture at the Mean-field and population-level descriptions of brain dynamics Meeting in February at the EITN, Paris, the opening lecture at the conference in V. Konokov’s honor in Moscow in June, a mini-course at Lille University in June, and an invited lecture at the Workshop on the Numerics for Stochastic Partial Differential Equations and their Applications at RICAM, Linz (Austria) in December.
- E. Tanré gave talks at LPMA (Paris 6) and at the workshop on Numerical schemes for SDEs and SPDEs in Lille in June.
- D. Villemonais has been invited to give talks at the workshop *Stochastic processes under constraints* in July in Augsburg, Germany, at the conference *Colloque franco-roumain de mathématiques* in August in Iași, Romania, and at the *School on Information and Randomness* in December in Santiago, Chile.
- D. Villemonais has been invited to give seminar talks at *Institut Montpelliérain Alexander Grothendieck* in February, at the *Institut de Recherche Mathématique Avancée* in Strasbourg in November, and at the *Modal’X seminar* in Nanterre in December.

9.1.6. Leadership within the Scientific Community

- A. Lejay is the head of the Probability and Statistics team of the Institut Élie Cartan since September 2016.
- A. Lejay was a member of the Administration Council of the SMAI until June 2016.
- D. Talay continued to chair the Scientific Council of the French Applied Math. Society SMAI.
- D. Talay served as a member of the scientific council of the Complex System academy of the UCA Idex.
- D. Talay is serving as a member of the committee in charge of preparing the application of Paris to the International Congress of Mathematicians 2022.

9.1.7. Scientific Expertise

- N. Champagnat reported on an application submitted to CONICYT (Chilean Funding Agency).
- M. Deaconu has been a member of the Committee for junior permanent research positions of Inria Nancy - Grand Est.
- A. Lejay reported on applications to National Science Centre of Poland.
- A. Lejay participated in a Professor position recruitment committee at Université de Lorraine.

9.1.8. Research Administration

- M. Bossy is an elected member of the Inria Evaluation Board.

- M. Bossy has been a member of the DTK-Committee.
- N. Champagnat is a member of the *Commission de Développement Technologique* and the *Commission Information Scientifique et Technique* of Inria Nancy - Grand Est, a substitute member of the *Comité de Centre* of Inria Nancy - Grand Est (until Nov. 2016), *Responsable Scientifique* for the library of Mathematics of the IECL, member of the *Conseil du laboratoire* of IECL (as *responsable scientifique* of the library). He is also local correspondent of the COERLE (*Comité Opérationnel d'Évaluation des Risques Légaux et Éthiques*) for the Inria Research Center of Nancy - Grand Est. This year, together with Aline Wagner (Inria Nancy - Grand Est), he finished to write the new version of the application form for research approval by the COERLE.
- M. Deaconu is a member of the *Bureau du Comité de Projets* of Inria Nancy - Grand Est, and of the *Comité de Projet* of Inria Nancy - Grand Est.
- A. Lejay is a member of the COMIPERS of Inria Nancy Grand-Est and of *Commission des thèses* of the Institut Élie Cartan (Nancy).

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Master: M. Bossy, *Continuous time stochastic models for quantitative Finance*, 30h, M2 IMAFA (Informatique et Mathématiques Appliquées à la Finance et à l'Assurance), École Polytechnique Universitaire, Univ. Nice - Sophia Antipolis, France.

Master : M. Bossy, *Risk on energetic financial markets*, 27h, Master Spécialisé, Ingénierie et Gestion de l'Énergie, Mine ParisTech, France.

Master : M. Bossy *Stochastic Particle Methods for PDEs*, 18h, M2 Probabilité et Applications, Université Pierre et Marie Curie, France.

PhD-level lectures : M. Bossy *McKean SDEs and related stochastic methods for PDEs*, 18h, University of Edinburgh (UK).

PhD-level lectures : M. Bossy *Stochastic numerical methods for turbulence*, Winter school Numerics for Stochastic Partial Differential Equations and their Applications, 10h, at RICAM - University of Linz.

Master: N. Champagnat, *Introduction to Quantitative Finance*, 18h, M1, École des Mines de Nancy, France.

Master: N. Champagnat, *Introduction to Quantitative Finance*, 13.5h, M2, École des Mines de Nancy, France.

Master: N. Champagnat, *Chaînes de Markov*, 22.5h, M2 “double diplôme” Mathématiques et Applications - École Supérieure des Sciences et de Technologie de Hammam Sousse, Tunisie (lieu des cours) - Université de Lorraine, France.

Master: M. Deaconu, *Équations différentielles stochastiques : résolution numérique et applications*, 21h, M2, École des Mines de Nancy, France.

Master: M. Deaconu, *Modélisation stochastique*, 30h, M2, Université de Lorraine, France.

Master: M. Deaconu, *Simulation Monte Carlo*, 24h, M1, Faculté de Droit, Sciences Economiques et Gestion, Université de Lorraine, France.

Master: C. Fritsch, *Introduction à la finance quantitative*, 3h, M1, École des Mines de Nancy, France.

Licence: C. Fritsch, *Décision et Prévision Statistiques*, 20h, L3, École des Mines de Nancy, France.

Licence: C. Fritsch, *Supervision d'un projet de recherche*, 6h, M2, École des Mines de Nancy, France.

Licence: B. Henry, *Statistiques*, 20h, L3, École des Mines de Nancy, France.

Licence: B. Henry, *Probabilités*, 36h, L3, École des Mines de Nancy, France.

Master: A. Lejay, *Simulation des marchés financiers*, 28.5h, M2, Université de Lorraine (Metz), France.

Master: P. Pigato, *Calcul Intégral*, 15h, M1, Université de Lorraine (Nancy), France.

Licence: K. Salhi, *Mathématiques Appliquées et Probabilités*, 24h, L3, Télécom Nancy, France.

Master: K. Salhi, *Statistiques et analyse de données*, 20h, M1, Télécom Nancy, France.

Master: K. Salhi, *Probabilités et Statistiques*, 20h, M1, ENSEM Nancy, France.

Master: D. Talay *Invariant measures of diffusion processes*, 18h, M2 Probabilité et Applications, Université Paris 6, France.

Master: E. Tanré (cours) and M. Tomasevic (exercices), *Advanced Numerics for Computational Finance*, 30h (20h + 10h), M2, UCA (Mathmods Erasmus Mundus), France.

Master: E. Tanré, *Mathematical Methods for Neurosciences*, 37h, M2, ENS - Master MVA / Paris 6 - Master Maths-Bio, France.

Master: E. Tanré (cours) and A. Richard (practical classes) *Numerical probability for mathematical finance*, 20h (8h + 12h), M2, EPU (Master IMAFA), France.

9.2.2. Supervision

PhD: Maxime Bonelli, *Behavioral finance approach to risk assessment in quantitative portfolio management*, Univ. Nice Sophia Antipolis, September 2016, M. Bossy.

PhD : Benoît Henry, *Processus de branchements non markoviens en dynamique et génétique des populations*, Univ. Lorraine, 17/11/2016, Nicolas Champagnat, D. Ritchie (EPI CAPSID).

PhD : Khaled Salhi, *Risques extrêmes en finance : analyse et modélisation*, Univ. Lorraine, 05/12/2016, M. Deaconu and A. Lejay.

PhD in progress: Antoine Brault, *Formules de Trotter-Kato pour les trajectoires rugueuses*, Université Toulouse 3, L. Coutin (U. Toulouse 3), A. Lejay.

PhD in progress: Baldwin Dumortier, *Contrôle acoustique des éoliennes*, October 2014, M. Deaconu and E. Vincent (EPI MULTISPEECH).

PhD in progress: Pascal Helson, *Plasticity in networks of spiking neurons in interaction*, October 2016, E. Tanré and R. Veltz (MATHNEURO Inria team).

PhD in progress: Kouadio Jean Claude Kouaho, *Modélisations stochastique et déterministe de croissance de tumeurs cancéreuses*, Mar. 2016, N. Champagnat, Pierre Vallois (EPI BIGS, Modest N'Zi (UFHB, Abidjan).

PhD in progress: Radu Maftei, *A stochastic approach to colloidal particle agglomeration in turbulent flows*, November 2014, M. Bossy.

PhD in progress: Hernán Mardones, *Numerical solutions of stochastic differential equations with multiplicative noise*, Universidad de Concepción, A. Lejay, C. Mora (U. Concepción).

PhD in progress: Milica Tomasevic, *Stochastic approaches to Keller–Segel equations*, October 2015, D. Talay.

9.2.3. Juries

- M. Bossy served as a referee for the Ph.D. theses of Anthony LE CAVIL, *Représentation probabiliste de type progressif d'EDP nonlinéaires nonconservatives et algorithmes particuliers associés*. Université Paris Saclay, December 9, 2016.
- M. Bossy served as an examiner for the Ph.D. thesis of Ahmed MTIRAOUI, *EDS Progressives Rétrogrades couplées contrôlées, EDDS Rétrogrades et EDP Stochastiques*. Université de Toulon, November the 25th, 2016.

- N. Champagnat served as a referee for the Ph.D. theses of Elma Nessar, *Modèles probabilistes de l'évolution d'une population dans un environnement variable*, Univ. Aix-Marseille, July 4, 2016, and of Joseba Dalmau, *La quasi-espèce pour une population finie*, Univ. Orsay, November 25, 2016.
- N. Champagnat served as an examiner for the Ph.D. thesis of Lucas Mercier, *Grands graphes et grand arbres aléatoires : Analyse du comportement asymptotique*, Univ. Lorraine, May 11, 2016, and of Benoît Henry, *Processus de branchements non markoviens en dynamique et génétique des populations*, Univ. Lorraine, November 17, 2016.
- A. Lejay served as a referee for the Ph.D. theses of Sarav Mazzonetto, *On the exact simulation of (Skew) Brownian Diffusions with Discontinuous Drift*, Potsdam Universität / Université Lille 1, November 2016, of Anis Al Gerbi, *Ninomiya-Victoir scheme: strong convergence, asymptotics for the normalized error and multilevel Monte Carlo methods*, Université Paris-Est, October 2016, and of Joseph El Maalouf, *Méthodes de Monte Carlo stratifiées pour la simulation des chaînes de Markov*, Université de Grenoble / Université Saint Joseph de Beyrouth, December 2016.
- A. Lejay served as an examiner for the Habilitation Thesis of Pierre Étoré, *Quelques contributions à l'étude et à la simulation des diffusions asymétriques*, Université de Grenoble, December 2016.
- M. Deaconu and A. Lejay served as examiners for the Ph.D. thesis of Khaled Salhi, *Risques extrêmes en finance : analyse et modélisation*, Université de Lorraine, December 2016.
- D. Talay chaired the Ph.D. thesis jury of Ahmed Mtiraoui, *Equations différentielles stochastique rétrogrades progressives et leurs applications aux théories de contrôles*, Université de Toulon.
- D. Talay served as a referee for the Ph.D. theses of Daoud Ounaissi, *Méthodes Quasi Monte-Carlo et Monte-Carlo applications aux calculs des estimateurs Lasso et Lasso bayésien*, université de Lille I; and of Ahmed Bel Hadj Ayed *Robustesse de la stratégie de trading optimale*, École Centrale Paris;
- D. Talay chaired the Habilitation à Diriger les Recherches juries of Christophe Blanhet-Scalliet, *Contribution à l'analyse des risques financiers : risque de crédit, asymétrie d'information, analyse chartiste*, École Centrale de Lyon, and of Pierre Étoré, *Quelques contributions à l'étude et à la simulation des diffusions asymétriques*, INP Grenoble.

9.3. Popularization

- D. Talay participated in a scientific France Culture radio program in December.

10. Bibliography

Major publications by the team in recent years

- [1] L. BEZNEA, M. DEACONU, O. LUPASCU. *Branching processes for the fragmentation equation*, in "Stochastic Processes and their Applications", 2015, vol. 125, pp. 1861-1885 [DOI : 10.1016/J.SPA.2014.11.016], <https://hal.inria.fr/hal-00948876>
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- [10] A. LEJAY. *The snapping out Brownian motion*, in "Annals of Applied Probability", September 2015, <https://hal.inria.fr/hal-00781447>

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Articles in International Peer-Reviewed Journals

- [11] M. BAAR, A. BOVIER, N. CHAMPAGNAT. *From stochastic, individual-based models to the canonical equation of adaptive dynamics - In one step*, in "The Annals of Applied Probability : an official journal of the institute of mathematical statistics", 2016, vol. Online first, <https://hal.inria.fr/hal-01188189>
- [12] L. BEZNEA, M. DEACONU, O. LUPASCU. *Stochastic equation of fragmentation and branching processes related to avalanches*, in "Journal of Statistical Physics", February 2016, vol. 162, n^o 4, pp. 824-841, *Accepté pour publication*, <https://hal.inria.fr/hal-01216137>
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- [29] M. BOSSY, R. MAFTEI, C. PROFETA, J.-P. MINIER. *A stochastic approach to colloidal particle collision/agglomeration*, in "ICMF", Firenze, Italy, May 2016, <https://hal.inria.fr/hal-01400678>

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- [30] N. CHAMPAGNAT, M. DEACONU, A. LEJAY. *Méthodes de calcul de la Value-at-Risk et de la Conditional Value-at-Risk*, Inria Nancy - Grand Est (Villers-lès-Nancy, France), January 2016, <https://hal.archives-ouvertes.fr/hal-01305032>

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- [31] R. AZAÏS, A. GENADOT, B. HENRY. *Inference for conditioned Galton-Watson trees from their Harris path*, September 2016, working paper or preprint, <https://hal.archives-ouvertes.fr/hal-01360650>
- [32] V. BALLY, L. CAMELLINO, P. PIGATO. *Diffusions under a local strong Hörmander condition. Part I: density estimates*, July 2016, working paper or preprint, <https://hal.archives-ouvertes.fr/hal-01407409>
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- [34] M. BONINO, M. CAMELIA, P. PIGATO. *A multivariate model for financial indices and an algorithm for detection of jumps in the volatility*, December 2016, 20 pages, 22 figures, <https://hal.archives-ouvertes.fr/hal-01408495>
- [35] F. CAMPILLO, N. CHAMPAGNAT, C. FRITSCH. *On the variations of the principal eigenvalue and the probability of survival with respect to a parameter in growth-fragmentation-death models*, February 2016, working paper or preprint, <https://hal.inria.fr/hal-01254053>
- [36] N. CHAMPAGNAT, J. CLAISSE. *On the link between infinite horizon control and quasi-stationary distributions*, 2016, working paper or preprint, <https://hal.inria.fr/hal-01349663>
- [37] N. CHAMPAGNAT, A. COULIBALY-PASQUIER, D. VILLEMONAIS. *Exponential convergence to quasi-stationary distribution for multi-dimensional diffusion processes*, March 2016, working paper or preprint, <https://hal.archives-ouvertes.fr/hal-01293622>
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- [42] B. CLOEZ, C. FRITSCH. *Gaussian approximations for chemostat models in finite and infinite dimensions*, September 2016, working paper or preprint, <https://hal.archives-ouvertes.fr/hal-01371591>

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- [44] M. DEACONU, S. HERRMANN. *Initial-boundary value problem for the heat equation - A stochastic algorithm*, October 2016, working paper or preprint, <https://hal.archives-ouvertes.fr/hal-01380365>
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