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Activity Report 2014

Project-Team TOSCA

TO Simulate and CAlibrate stochastic models

IN COLLABORATION WITH: Institut Elie Cartan de Lorraine

RESEARCH CENTERS
Sophia Antipolis - Méditerranée
Nancy - Grand Est

THEME
Stochastic approaches

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Project-Team TOSCA

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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 behaviour 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 PDE analysis and stochastic analysis for deterministic non-linear partial differential equations, 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, 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. Then 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, 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. Application Domains

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 practioners 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 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 do so in the presence of 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 behaviour; 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 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 form 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 equtions is an active area of research since very few results still are available in the literature.

5. New Software and Platforms

5.1. Triton

Participant: Antoine Lejay [correspondant].

The Triton software aims at providing a toolbox to analyze nearshore waves images recorded by a camera on the beach. More precisely, it aims at estimating the height, length and speed of waves, to find speed and direction of currents, and to reconstruct the bathymetry from these images.

This is a joint work with Rafael Almar (LEGOS, IRD, Toulouse) and with Stanislas Larnier (LAAS-CNRS, Toulouse), a former post-doctoral student in the Tosca team.

- Version: 1.0

5.2. SDM

Participants: Mireille Bossy [correspondant], Sélim Karia.

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, starting in 2005, we have developed a new method based on the combination of an existing Numerical Weather Prediction model providing a coarse prediction, and a Lagrangian Stochastic Model for turbulent flows. This Stochastic Downscaling Method (SDM) requires a specific modelling of the turbulence closure, and involves various simulation techniques whose combination is totally original (such as Poisson solvers, optimal transportation mass algorithm, original Euler scheme for confined Langevin stochastic processes, and stochastic particle methods).

In 2013, the SDM code became the kernel of the wind farm modelling of the Fundacion Inria Chile. In France, its development is pursuing through the collaborative Modéol project on the evaluation of wind potential.

This is a joint work with Antoine Rousseau from the team LEMON.

- Version: 2.0

5.3. CarbonQuant

Participants: Mireille Bossy [correspondant], Sélim Karia.

CarbonQuant is a simulator project of CO2 allowances prices on a EU-ETS type market, by an indifference price approach.

It aims to demonstrate the high potentiality of stochastic control solvers, to quantify sensibilities of a carbon market with respect to its design.

See also the web page http://carbonvalue.gforge.inria.fr, from where CarbonQuant can be now downloaded for various architectures.

A new version of CarbonQuant is under devellopment that includes a N players game approache on an auction carbon market.

- Version: 2.0

6. New Results

6.1. Probabilistic numerical methods, stochastic modelling and applications

Participants: Mireille Bossy, Nicolas Champagnat, Julien Claisse, Madalina Deaconu, Benoît Henry, James Inglis, Antoine Lejay, Oana Valeria Lupascu, Sylvain Maire, Sebastian Niklitschek Soto, Denis Talay, Etienne Tanré, Denis Villemonais.

6.1.1. Published works and preprints

- M. Bossy and J.-F. Jabir (University of Valparaíso) [13] have proved the well-posedness of a conditional McKean Lagrangian stochastic model, endowed with the specular boundary condition, and further the mean no-permeability condition, in a smooth bounded confinement domain $\mathcal{D}$.
- M. Bossy, N. Champagnat, S. Maire and L. Violeau worked with H. Leman (CMAP, Ecole Polytechnique) and M. Yvinec (Inria Sophia, EPI GEOMETRICA) on Monte Carlo methods for the linear and non-linear Poisson-Boltzmann equations [12]. These methods are based on walk on spheres algorithm, simulation of diffusion processes driven by their local time, and branching Brownian motion. Their code for the linear equation can deal with bio-molecules of arbitrary sizes, based on computational geometry tools from the CGAL C++ Library developed by the GEOMETRICA team. The non-linear equation is solved using branching Brownian motion.
- M. Bossy, O. Faugeras (Inria Sophia, EPI NEUROMATHCOMP), and D. Talay have clarified the well-posedness of the limit equations to the mean-field N-neuron models proposed in [42] and proven the associated propagation of chaos property. They also have completed the modeling issue in [42] by discussing the well-posedness of the stochastic differential equations which govern the behavior of the ion channels and the amount of available neurotransmitters. See [29].

- N. Champagnat and D. Villemonais obtained criterions for existence and uniqueness of quasi-stationary distributions and Q-processes for general absorbed Markov processes [31]. A quasi-stationary distribution is a stationary distribution conditionally on non-absorbtion, and the Q-process is defined as the original Markov process conditioned to never be absorbed. The criterion that they obtain ensures exponential convergence of the conditioned t-marginal of the process conditioned not to be absorbed at time t, to the quasi-stationary distribution and also the exponential ergodicity of the Q-process.
- M. Deaconu and S. Herrmann continued and completed the study of the simulation of the hitting time of some given boundary for Bessel processes. They constructed an original approximation method for hitting times of a given threshold by Bessel processes with non-integer dimension. In this work, they combine the additivity property of the laws of squared Bessel processes with their previous results on the simulation of hitting times of Bessel processes with integer dimension, based on the method of images and on the connexion with the Euclidean norm of the Brownian motion [33].
- M. Deaconu, S. Herrmann and S. Maire introduced a new method for the simulation of the exit time and position of a δ-dimensional Brownian motion from a domain. The main interest of this method is that it avoids splitting time schemes as well as inversion of complicated series. The idea is to use the connexion between the δ-dimensional Bessel process and the δ-dimensional Brownian motion thanks to an explicit Bessel hitting time distribution associated with a particular curved boundary. This allows to build a fast and accurate numerical scheme for approximating the hitting time [34].
- M. Deaconu and O. Lupaşcu worked with L. Beznea (Bucharest, Romania) on the construction and the branching properties of the solution of the fragmentation equation and properly associate a continuous time càdlàg Markov process. The construction and the proof of the path regularity of the Markov processes are based on several newly developed potential theoretic tools.
- J. Inglis, together with O. Faugeras (Inria NEUROMATHCOMP) finalized their article [18] on the well-posedness of stochastic neural field equations within a rigorous framework.
- J. Inglis and E. Tanré together with F. Delarue and S. Rubenthaler (Univ. Nice – Sophia Antipolis) finalized their article [16] on the global solvability of a networked system of integrate-and-fire neurons proposed in the neuroscience literature.
- J. Inglis and E. Tanré together with F. Delarue and S. Rubenthaler (Univ. Nice – Sophia Antipolis) completed their study of the mean-field convergence of a highly discontinuous particle system modeling the behavior of a spiking network of neurons, based on the integrate-and-fire model [17]. Due to the highly singular nature of the system, it was convenient to work with a relatively unknown Skorohod topology.
- J. Inglis and D. Talay introduced in [38] a new model for a network of spiking neurons that attempted to address several criticisms of previously considered models. In particular the new model takes into account the role of the dendrites, and moreover includes non-homogeneous synaptic weights to describe the fact that not all neurons have the same effect on the others in the network. They were able to obtain mean-field convergence results, using new probabilistic arguments.
- A. Lejay have worked with G. Pichot (EPI SAGE) on benchmarks for testing Monte Carlo methods to simulate particles in one-dimensional media, and applied this statistical methodology to four methods, including the exact method developed previously [45]. This work led also to empirical observations that should guide the design of new methods [24].
- S. Maire is working with the Bulgarian Academy of sciences on Monte Carlo algorithms for linear equations based on killed random walks. In a first work, with I. Dimov and J-M. Sellier [37], a new Monte Carlo method to solve linear systems of equations has been introduced. This method can either compute one component of the solution or all components simultaneously. In a second work, with Ivan Dimov and Rayna Georgieva, a new Monte Carlo method to solve Fredhom integral equations of the second kind is developed [36].

- D. Villemonais worked with P. Del Moral (Univ. Sydney) on the conditional ergodicity of time inhomogeneous diffusion processes [35]. 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 proved a Foster-Lyapunov type criterion which ensures the exponential ergodicity of a Fleming-Viot type particle system whose particles evolve as birth and death processes. The criterion also ensures the tightness of the sequence of empirical stationary distributions considered as a family of random measures. A numerical study of the speed of convergence of the particle system is also obtained under various settings [41].

6.1.2. Other works in progress

- M. Bossy and J-F. Jabir (University of Valparaíso) proved the validity of a particle approximation of a (simplified) Lagrangian Stochastic Model submitted to specular reflections at the boundary and satisfying the mean no-permeability condition. This work achieves to extend our previous study [43] to the multidimensional case.
- N. Champagnat and D. Villemonais obtained criterions for existence, uniqueness and exponential convergence in total variation of quasi-stationary distributions and Q-processes for general absorbed and killed diffusion processes. The criterion obtained is equivalent to the property that a diffusion on natural scale coming down from infinity has uniformly (w.r.t. the initial condition) bounded expectation at a fixed time t. A study of nearly critical cases allow to conjecture that this property is true for all diffusion processes on natural scale coming down from infinity. This work is currently being written.
- N. Champagnat and B. Henry worked on the long-time behavior of the frequency spectrum for the Splitting Tree models under the infinitly-many alleles model. They obtained, using a new method for computing the expectation of an integral with respect to a random measure, the asymptotic behavior of the moments of the frequency spectrum. As an application, they derived the law of large number and a new central limit theorem for the frequency spectrum. This work is currently being written.
- J. Claisse defended his PhD. under the supervision of N. Champagnat and D. Talay on stochastic control of population dynamics. He completed a finite-horizon optimal control problem on branching–diffusion processes. He also created and studied a hybrid model of tumor growth emphasizing the role of acidity. Key therapeutic targets appear in the model to allow investigation of optimal treatment problems.
- J. Claisse and D. Talay in collaboration with X. Tan (Univ. of Paris Dauphine) extended their previous work on a pseudo-Markov property enjoyed by the solutions of controlled stochastic differential equations and its application to the proof of the dynamic programming principle. A paper is being finished.
- M. Deaconu and O. Lupascu are working with L. Beznea (Bucharest, Romania) on a stochastic model for avalanche phenomena involving rupture properties that occur in the physical and deterministic models for snow avalanches. This approach is based on their recent results on fragmentation processes by stochastic differential equation and branching processes.
- M. Deaconu and O. Lupascu are working on a numerical probabilistic algorithm for an avalanche-type process. The originality of this approach is to use a coagulation/fragmentation model to describe the avalanche phenomenon. More precisely, they consider a particular fragmentation kernel which introduces “rupture-type” properties of deterministic models for snow avalanches.
- An important issue in neuroscience is the modelling of spike trains of a single neuron. In this context, the membrane potential of a neuron can be described by using a simple stochastic differential equation with periodic input, that is reset to a rest potential each time it hits a certain threshold. J. Inglis, A. Richard, D. Talay, and E. Tanré study how the law of these hitting times is affected when one changes the white noise (in the SDE) into a correlated noise. Practically, they use a fractional

Brownian motion, and since the computation of the hitting times of such a non-Markovian, non-semimartingale process is still an open question, they rather try to compute the deviations from the white noise model. This is expected to give insights on the relevance of models with memory and long-range dependence.

- J. Inglis started a collaboration with B. Hambly and S. Ledger at the University of Oxford, in which interacting mean-field particle systems with common noise are being studied. Such systems are representative of systems of spiking neurons or portfolio defaults. In previous studies each particle was driven by a noise that was assumed independent from particle to particle (i.e. intrinsic noise). By considering a common driving noise in addition to the intrinsic noise, it is possible to model the fact that the environment in which the particles live is also noisy. This leads to the study of a new type of conditional McKean-Vlasov equation.
- J. Inglis, in collaboration with J. Maclaurin (EPI NEUROMATHCOMP) and W. Stannat (Berlin), has begun working on a new framework to understand the effect of noise on neural field equations. Deterministic neural field equations exhibit traveling wave solutions, and so the effect of noise on these solutions is of great interest. The idea is to decompose the solution into various components, which allow one to see directly how the noise affects the solution in the direction of the moving wave front. In particular, the goal is to reconcile mathematically the previous works of P. Bressloff and W. Stannat on the same subject, and to obtain a large deviation principle.
- J. Inglis and D. Talay are in the process of studying the emergence of spatio-temporal noise starting from microscopic models of neuron conductance.
- A. Lejay continued his collaboration with S. Torres (Universidad de Valapraíso, Chile) and E. Mordecki (Universidad de la República, Uruguay) on the estimation of the parameter of the Skew Brownian motion. This work is related to the modelling of diffusion processes in media with interfaces and has potential applications in many domains, such as population ecology.
- Together with R. Rebolledo (Pontificia Universidad Católica, Santiago, Chile), A. Lejay continued his review work on the mathematical modelling of the Wave Energy Converter Called the Oscillating water column, within the framework of the CIRIC project.
- A. Lejay continued his work on the Snapping out Brownian motion to perform numerical tests for the computation of the mean residence time in a diffusive medium with semi-permeable membranes, such as the one encountered in the mathematical modelling of diffusion Magnetic Resonance Imaging.
- A. Lejay continued his collaboration with L. Coutin (Universté Paul Sabatier, Toulouse) on the sensitivity of rough linear differential equations, by providing general results on the derivatives of the solution of rough differential equations with respect to parameters or the starting point.
- S. Niklitschek Soto and D. Talay completed their stochastic analysis of diffraction parabolic PDEs with general discontinuous coefficients in the multidimensional case.
- P. Guiraud (University of Valparaíso) and E. Tanré study the effect of noise in the phenomenon of spontaneous synchronisation in a network of connected leaky integrate-and-fire neurons. They detail cases in which the phenomenon of synchronization persists in a noisy environment, cases in which noise permits to accelerate synchronization, and cases in which noise permits to observe synchronization while the noiseless model does not show synchronization. (Math Amsud program SIN)
- O. Faugeras (EPI NEUROMATHCOMP) and E. Tanré worked on an extension of [44] to a context of several populations of homogeneous neurons. They study the limit mean field equation of the membrane potential as the number of neurons increases in a network with correlated synaptic weights. A paper is in preparation.
- C. Graham (CMAP, Ecole polytechnique) and D. Talay are writing the second volume of their series published by Springer on the Mathematical Foundations of Stochastic Simulations.

- In collaboration with N. Touzi (CMAP, Ecole polytechnique), D. Talay is studying stochastic differential equations involving local times with stochastic weights, and extensions of classical notions of viscosity solutions to PDEs whose differential operator has discontinuous coefficients and transmission boundary conditions.

6.2. Financial Mathematics

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

6.2.1. Published works and preprints

- In collaboration with N. Maïzi (CMA - Mines Paristech) and O. Pourtallier (COPRIN team, Inria Sophia Antipolis - Méditerranée), M. Bossy studied the existence of a Nash equilibrium between electricity producers selling their production on an electricity market and buying CO2 emission allowances on an auction carbon market. The producers' strategies integrate the coupling of the two markets via the cost functions of the electricity production. The authors set out the set of Nash equilibria on the electricity market, that constitutes an equivalence class (same prices and market shares) from which they exhibit a dominant strategy. On the coupled markets, given a specific carbon market design (in terms of penalty level and allowances), they compute the bounds of the interval where carbon prices (derived from the previous dominant strategy) evolve. They specify the properties of the associated equilibria (see [30] and [14]).
- In their article [40], N. Champagnat, M. Deaconu, A. Lejay and K. Salhi have constructed a regime switching model for estimating the Value-at-Risk. This model classifies the states in crisis and steady regimes and constructs a mixture of power laws as a model for returns of financial assets.
- In collaboration with V. Reutenauer and C. Michel (CA-CIB), D. Talay and E. Tanré worked on 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. A paper has been submitted [39].

6.2.2. Other works in progress

- In collaboration with J. Bion-Nadal (Ecole Polytechnique and CNRS), D. Talay pursued the study of a new calibration methodology based on dynamical risk measures and stochastic control PDEs.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

- TOSCA Nancy had a bilateral contract coordinated by M. Deaconu with the SME Alphability on financial risk measures with applications in portfolio management. This collaboration will be continued in 2015.
- M. Deaconu is involved in a bilateral contract with Venathec. She is supervising, with E. Vincent (EPI PAROLE), the Ph.D. Thesis of B. Dumortier on the acoustic control of wind farms noise.

7.2. Bilateral Grants with Industry

- TOSCA Sophia is involved in a Cifre convention with Koris International. M. Bossy supervises M. Bonelli's Ph.D. thesis.

7.2.1. Promotion of Mathematics in the industry

- M. Deaconu was invited to give a talk at the Workshop *Modélisation et Simulation Numérique - Applications, Enjeux, Besoins, Interactions Laboratoires/Entreprises*, on November 25 in Nancy.

- 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.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR

- N. Champagnat, J. Claisse and D. Villemonais were members of the ANR MANEGE (Modèles Aléatoires eN Écologie, Génétique et Évolution, ending in April 2014) whose aim is to provide methodological and conceptual advances in the study of stochastic processes modeling ecology, population genetics and evolution of life. This work is sustained by regular exchanges with biologists from several teams in France. http://www.cmap.polytechnique.fr/~anr-manege/index_en.html
- N. Champagnat is member of the ANR NONLOCAL (Phénomènes de propagation et équations non locales, started in October 2014), aiming at understanding, in the greatest generality, the phenomena of propagation in non-local reaction-diffusion equations. These equations can present integral forms of diffusion operators, or speed that depend on integrals of the solution, memory effects, or long-range interactions in source terms. http://www.agence-nationale-recherche.fr/projet-anr/?tx_lwmsuivibilan_pi2[CODE]=ANR-14-CE25-0013
- A. Lejay is member of the ANR H2MNO4 (ANR Cosinus, 2012–2015) on Original Optimized Object Oriented Numerical Model for Heterogeneous Hydrogeology which started in November 2012 (directed by Joceyline Erhel, IRISA, Rennes).

8.1.2. Contract with ADEME

Participants: Mireille Bossy, Sélim Karia.

Modéol Since April 2013, M. Bossy was the coordinator of the MODÉOL collaboration project funded by the French Environment and Energy Agency (ADEME), and involving the IPSL (CNRS) and the French company Maïa Eolis. The overall goal of the project concerns the modeling and prediction of wind potential in France, in particular the quantification of uncertainties and the analysis of multi-scale variability.

Concerning the Inria workpackage, in collaboration with Antoine Rousseau, from the team LEMON, we have almost completed the SDM version with complex terrain description. We also improved the turbulence modelling to better take into account the shear effect near the ground.

8.2. European Initiatives

8.2.1. FP7 & H2020 Projects

- J. Inglis is a member of the European project MatheMACS (European Union Seventh Framework Programme no. 318723).

8.3. International Initiatives

8.3.1. Inria International Labs

The CIRIC Team on *Stochastic Analysis of Renewable Energies: Ocean Energy and Wind Farms; dynamics and numerics* (2012-2014) is managed by TOSCA and ANESTOC (Univ Catolica, Santiago). It is composed of three main projects.

Mireille Bossy is managing the WINDPOS project, in collaboration with Antoine Rousseau (LEMON team) and two engineers of Inria Chile, Cristian Paris and Jacques Morice. Based on the stochastic Lagrangian modeling of the wind at small scale (see SDM SOFTWARE), WINDPOS aims to develop a wind farm simulator software, able to provide fine statistical information for the managing of electricity production.

This year the WINDPOS project focused on the improvement on wind mills modeling in the SDM software (see [28]). This modeling is based on our Lagrangian version of the actuator disc actuator line methods to take the mills into account. We evaluated and compared the case of non rotating and rotating actuator disc, and started to work on the validation of the approach by comparison with measurements.

8.3.2. Inria Associate Teams

8.3.2.1. ANESTOC-TOSCA

Title: Stochastic modelling of biology and renewable energies

International Partner (Institution - Laboratory - Researcher):

Pontificia Universidad Católica de Chile (CHILI)

Duration: 2013 - 2016

See also: http://www.anestoc.cl/es/?page_id=1112

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, a part of the Associated Team is strongly related to the CIRIC project “Stochastic Analysis of Renewable Energy”. This project aims at transfering and valuing to Chilean companies the results of researches on renewable energies, mainly wind prediction at the windfarm’s scale by developing and improving the Winpos software based on the downscaling methods, and waves energy potential of a site using video and developping stochastic models for the Wave Energy Converter called Oscillating Water Column.

The other part of this Associated Team is related to neurosciences, more specifically by considering applications to ion-channel dynamics through cell membranes (jointly with biophysicists of the CINV, Neuroscience Centre of Valparaíso).

8.3.3. Participation In other International Programs

8.3.3.1. Math Amsud project SIN

Participant: Etienne Tanré.

It is likely that the stochastic components play an important role in the functions of the neurons and of the networks they form. We describe and study the effect of the noise at different scales of neural activity, such that the level of the ionic channels and the level of neural networks, which are responsible for conveying and processing the information coded in sequences of spikes. The most popular models of this class are leaky integrate and fire (LIF) neural networks. We study the synchronization of neurons in those networks.

The Math Amsud project SIN (Stochastic, Inference, Neuroscience) started in 2013. We worked specifically in 2014 on stochastic modelling in neuroscience.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

- M. Baar (Bonn University) has been visiting TOSCA Nancy for one week in September.
- L. Beznea (Simion Stoilow Institute of Mathematics of the Romanian Academy) has been visiting TOSCA Nancy one week in March and three weeks in July.

- The TOSCA *seminar* organized by J. Inglis in Sophia Antipolis has received the following speakers: Maxime Bonelli (TOSCA), Hector Olivero-Quinteros (Universidad de Chile), Jean-François Jabir (CIMFAV, Fac. de Ingenieria, Universidad de Valparaiso), Tony Lelièvre (École des Ponts ParisTech), Christophe Profeta (Université d'Evry-Val d'Essone), Xiaolu Tan (Ceremade, Univ. Dauphine), Pierre Patie (ORIE, Cornell University), Alexandre Richard (Inria, Regularity), Paola Cinnella (CMI, Université Aix Marseille), Caroline Bauzet (CMI, Université Aix Marseille), Laurent Mertz (Laboratoire J.A. Dieudonné, Univ. Nice – Sophia Antipolis), Charles-Edouard Bréhier (Cermics, École des Ponts).

8.4.1.1. Internships

BEDOUI Akram

Subject: Gestion du risque de portefeuille par la méthode des copules

Date: Feb 2014 - June 2014

Institution: EPT (Tunisie)

DEJAX Florian

Subject: Carbon and electricity markets

Date: from Jun 2014 until Aug 2014

Univ. Paris (France)

FOGUEN TCHUENDOM Rinel

Subject: Bayesian Inference via Markov Chain Monte Carlo methods: A financial case study

Date: March 2014 - August 2014

Institution: Université de Nice – Sophia Antipolis (France)

LALANNE Victor

Subject: Carbon and electricity markets

Date: from Jun 2014 until Aug 2014

Univ. Nice (France)

PAPIC-PONCE Alexis

Subject: Divergence of Euler numerical scheme for SDE with non Lipschitz coefficients

Date: March 2014

Institution: PUC (Chile)

PICCOLOMINI Tatiana

Subject: Probabilistic interpretation of non-linear PDEs with branching diffusion processes

Date: from March 2013 until July 2014

Institution: Universidad de Buenos Aires (Argentina)

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific events organisation

- E. Tanré animates with H. Delingette (EPI ASCLEPIOS) a transverse working group on "Uncertainties in mathematical and numerical models". In 2014, a three days lectures given by O. Le Maître was organized with around 50 participants issued from 10 teams.

9.1.2. Scientific events selection

9.1.2.1. member of the conference program committee

- A. Lejay served as member of the conference program committee of the *CANUM 2014* (Carry-le-Rouêt, May 2014) and the *Journées de Probabilités 2014* (Marseille, May 2014).

9.1.3. Journal

9.1.3.1. member of the editorial board

- M. Bossy serves as an Associate Editor of *Annals of Applied Probability*.
- N. Champagnat serves as an Associate Editor of *Stochastic Models*.
- Together with T. Lelièvre (Ecole des Ponts-ParisTech) and A. Nouy (Ecole Centrale Nantes), N. Champagnat served as co-editor in chief of the special issue of *ESAIM:ProcS* devoted to the CEMRACS 2013.
- A. Lejay serves as co-Editor 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*, *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*.
- D. Talay is serving as a member of the Advisory Board of the Centro de Mathematica da Universidade do Porto (Portugal).
- D. Talay participated in Professor position recruitment committees at Paris 6 University.

9.1.3.2. reviewer

- M. Bossy wrote reviews for manuscripts submitted to *ESAIM:ProcS*, *Progress in Energy and Combustion Science*, *Bernoulli Journal*.
- N. Champagnat wrote reviews for manuscripts submitted to *ESAIM:ProcS*, *Stochastic Processes and their Applications* (twice), *New Phytologist*, *Bernoulli Journal*, *Electronic Journal of Probabiliy*, *The Annals of Applied Probability*, *Applied Mathematics and optimization*.
- M. Deaconu wrote reviews for manuscripts submitted to *Potential Analysis*, *M2AN*, *Journal of Computational and Applied Mathematics*, *Mathematics and Computers in Simulation* and *Statistics and Computing*.
- B. Henry wrote a review for a manuscript submitted to *Stochastic Models*.
- J. Inglis wrote reviews for manuscripts submitted to the *Annales de l'Institut Henri Poincaré* and the *Journal of Mathematical Neuroscience*.
- A. Lejay wrote reviews for manuscripts submitted to *Mathematical finance*, *Séminaire de Probabilités*, *Journal of Computational and Applied Mathematics*, *Electronic Journal of Probability*, *Electronic Communication of Probability*, *Journal of Scientific Computing*, *International Journal of Stochastic Analysis*, *SIAM Journal on Control and Optimization*, ...
- E. Tanré wrote reviews for manuscripts submitted to *Journal of Theoretical Biology*, *Journal of Scientific Computing*, *Annales de l'Institut Henri Poincaré* and *The Journal of Mathematical Neuroscience*.
- D. Villemonais wrote reviews for manuscripts submitted to *The Annals of Applied Probability*, *Applied Mathematics and Optimization*, *Applied Probability Trust*, *Electronic Communications in Probability* and *Electronic Journal of Probability*.

9.1.4. Reviewing for fundings

- M. Bossy wrote reports about research projects submitted to the PACA Region council.
- N. Champagnat wrote reports about research projects submitted to ANR, the Leverhulme trust (UK) and FONDECYT (Chile).
- D. Talay reported on applications to Research Grants Council (RGC) of Hong Kong and grants of the Chilean National Science and Technology Commission.

9.1.5. Institutional commitments

- M. Bossy is a elected member of the Inria Evaluation Board.
- M. Bossy is a member of the Scientific Committee of the *École Doctorale "Sciences Fondamentales et Appliquées"* of the Université de Nice - Sophia Antipolis.
- M. Bossy participated to the junior position recruitment committee at the UPMC.
- M. Bossy has been a member of the Committee for junior permanent research positions of Inria Paris-Rocquencourt.
- M. Bossy is a member of the *Collectif Andromede* of the PACA Region council.
- N. Champagnat is a member of the *Commission de Développement Technologique* of Inria Nancy - Grand Est, a subsitute member of the *Comité de Centre* of Inria Nancy - Grand Est and a member of the *Commission bibliothèque* of IECL. He is also local correspondent of the COERLE (*Comité Opérationel d'Évaluation des Risques Légaux et Éthiques*) for the Inria Research Center of Nancy - Grand Est.
- M. Deaconu is member of *Comité des Projets* and *Bureau du Comité des Projets* at Inria Nancy - Grand Est.
- M. Deaconu has been a member of the Committee for junior permanent research positions of Inria Nancy - Grand Est.
- A. Lejay has been General Secretary of Société des Mathématiques Appliquées et Industrielles (SMAI) up to July 2014, and is a member of the Administration Council of the SMAI.
- A. Lejay is the member of the COMIPERS of Inria Nancy Grand-Est.
- A. Lejay has been a member of the hiring committee for a position of Professor in Dijon (2014).
- D. Talay continued to serve as the Head of Science and Chair of the Project-Teams Committee of Inria Sophia Antipolis - Méditerrannée up to the end of August 2014.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Master: M. Bossy, *Continuous time stochastic models for quantitative Finance*, 45h, 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 Paris 6, France.

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

Master: N. Champagnat, *Introduction to Quantitative Finance*, 18h, M2, École des Mines de Nancy, France.

Master: N. Champagnat, *Processus de Markov et génétique des populations*, 22.5h, M2 MFA, Université de Lorraine, France.

Master: M. Deaconu, *Simulation de variables aléatoires*, 12h, M1, 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.

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

Licence: B. Henry, *Analyse numérique*, 18h, L3, École des Mines de Nancy, France.

Master: J. Inglis, *Numerical Methods for Computational Finance*, 15h, M2, UNSA (Mathmods Erasmus Mundus), France.

Master: J. Inglis and E. Tanré, *Advanced Numerics for Computational Finance*, 40h (2*20h), M2, UNSA (Mathmods Erasmus Mundus), France.

Master: A. Lejay, *Simulation des marchés financiers*, 23h, M2, Université de Lorraine (Metz), France.

Master: A. Lejay, *Probabilités Appliquées*, 15h, M2, Université de Lorraine (Nancy), France.

Master: D. Talay *Stochastic Methods for PDEs with Boundary Conditions*, 18h, M2 Probabilité et Applications, Université Paris 6, France.

Master: E. Tanré, *Numerical Probability in Finance*, 44h, M2, Ecole PolytechNice (IMAFA), France.

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

9.2.2. Supervision

- PhD: Julien Claisse, *Dynamique des populations : contrôle stochastique et modélisation hybride du cancer*, Université de Nice Sophia Antipolis, 4 July 2014, N. Champagnat, D. Talay.
- PhD in progress: Maxime Bonelli, *Behavioral finance approach to risk assessment in quantitative portfolio management*, September 2013, M. Bossy.
- PhD in progress: Paul Charton, *Hedging strategies for wind energy prices*, September 2010, M. Deaconu and A. Lejay.
- PhD in progress: Baldwin Dumortier, *Contrôle acoustique des éoliennes*, October 2014, M. Deaconu and E. Vincent (EPI PAROLE).
- PhD in progress: Benoît Henry, *Modeling Evolutionary Relationships Between Three-Dimensional Protein Structures*, October 2013, N. Champagnat, D. Ritchie (EPI ORPAILLEUR).
- PhD in progress: Lionel Lenôtre, *Monte Carlo Simulation in fissured and porous media*, September 2012, J. Erhel (Irisa), A. Lejay, G. Pichot (Irisa). L. Lenôtre has a grant from the MESR and stays at Rennes.
- 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 Solution of Stochastic Differential Equations with Multiplicative Noise*, 2009, A. Lejay, C. Mora (Universidad de Concepción, Chile). H. Mardones has a CONYCIT grant and spent 7 months (Nov. 2013-June 2014) in Nancy with a grand Becas Chile.
- PhD in progress: Sebastian Niklitschek-Soto, *Discretized stochastic differential equations related to one-dimensional partial differential equations of parabolic type involving a discontinuous drift coefficient*, September 2010, D. Talay.
- PhD in progress: Khaled Salhi, *Estimation of Risk in Finance*, October 2013, M. Deaconu and A. Lejay.

9.2.3. Juries

- M. Bossy served as a referee for the HDR thesis of Mathias Rousset, *Probability in computational physics and biology: some mathematical contributions*, Université Paris Est, November 27, 2014.
- N. Champagnat served as an examiner for the Ph.D. theses of Julien Claisse, *Dynamique des populations : contrôle stochastique et modélisation hybride du cancer*, Université de Nice Sophia Antipolis, July 4, 2014; of Julien Sainte-Marie, *Contribution à l'intégration des cycles biogéochimiques dans les modèles de croissance forestier à base phénoménologique. Dynamique saisonnière du couvert forestier et décomposition de la matière organique du sol*, Université de Lorraine, September 9, 2014; of Claire Christophe, *Modélisation aléatoire de l'activité des Lymphocites T Cytotoxiques*, Université Paul Sabatier (Toulouse III), December 2, 2014; of Coralie Fritsch, *Approches probabilistes et numériques de modèles individus-centrés du chemostat*, Université Montpellier II, December 8, 2014.
- A. Lejay served as a referee for the Ph.D. thesis of H.T. Nguyen, *Numerical investigations of some mathematical models of the diffusion MRI signal*, Université d'Orsay, January 29, 2014; of M. Ba, *Homogénéisation des diffusions en milieux périodiques*, Université de Provence, July 8, 2014; of W. Sabbagh, *Some contributions on Probabilistic Intepretation for Nonlinear Stochastic PDEs*, Université du Maine, December 8, 2014.
- D. Talay served as a referee for the HDR theses of J-F. Chassagneux, *Quelques contributions à la Finance mathématique et l'Analyse théorique et numérique des équations différentielles stochastiques rétrogrades*, Université Paris Dauphine, November 26, 2014; of F. Panloup, *Contributions à l'étude en temps long de processus stochastiques*, Université Paul Sabatier, Toulouse, December 4, 2014; of J. Guilleminot, *Modélisations stochastiques en Mécanique multi-échelle des matériaux hétérogènes*, Université Paris–Est, December 12, 2014.
- D. Talay served as a referee for the Ph.D. thesis of K. Hajji, *Accélération de la méthode de Monte–Carlo pour des processus de diffusions et applications en Finance*, December 12, 2014.

9.3. Popularization

M. Bossy published in the *Brèves de maths* book [25].

9.4. Participation in congresses, conferences, invitations...

- M. Bossy gave talks at the *Energy Workshop* at Inria Chile and an invited talk at the *10th AIMS Conference on Dynamical Systems, Differential Equations and Applications* in Madrid in July.
- M. Bossy gave seminar talks at CINFAV University of Valparaíso and at the *Séminaire du Mésocentre de Calcul* at Centrale Paris.
- N. Champagnat gave talks at the *Schlumberger workshop on Topics in Applied Probability*, at IHES (Bures-sur-Yvette) in March, at the *10th AIMS Conference on Dynamical Systems, Differential Equations and Applications* in Madrid in July, at the workshop *Population Dynamics and Statistical Physics in Synergy* in Eindhoven (Netherlands) in August, and at the workshop on *Discrete, explicit simulations versus continuous, aggregated models* in Lausanne in October.
- N. Champagnat gave seminar talks at the *Séminaire Modèles Probabilistes pour la Biologie* in Montpellier in January, at the *Séminaire PEIPS (Evolution de Populations et Systèmes de Particules en Interaction)* at École Polytechnique, Palaiseau in November, and at the *Séminaire de Statistique et Probabilités Appliquées* in Grenoble in November.
- B. Henry participated in the *École de Printemps de l'ANR MANEGE* in Aussois in April.
- K. Salhi participated in the *Journées de Probabilités* at Marseille, France in May and presented poster at the *Journées MAS* at Toulouse, France in July.

- J. Inglis gave invited talks at the *Mathemacs European Project Meeting*, Max Planck Institute, Leipzig, Germany, at the *Stochastic Analysis Seminar*, Oxford-Man Institute of Quantitative Finance, Oxford, UK, and at the *ALEA seminar*, École Polytechnique, Paris, France, at the *Workshop in Probability and its Applications*, University of Oxford, Oxford, UK.
- J. Inglis participated in the workshop *Inhomogeneous Random Systems*, Institut Henri Poincaré, Paris, France.
- A. Lejay gave a mini-course on rough paths (8 hours) at Université du Maine (Le Mans) in October.
- A. Lejay gave a conference at the *PDE and rough paths* conference in Toulouse in February.
- O. Lupascu gave talks at the *Colloque Franco-Roumain de Mathematiques Appliquees* in Lyon in August and at the *Journées de Probabilités* in Marseille in May. She also presented a poster at the *Journées Modélisation Aléatoire Statistique* in Toulouse in August 2014.
- O. Lupascu gave a seminar talk at the *Seminar of the Partial Derivative Equations* in Chambery in April.
- D. Talay was an invited section speaker at the International Congress of Mathematicians (ICM 2014), Seoul, Korea, in August.
- D. Talay gave a plenary conference at the Colloque Franco-roumain de Mathématiques Appliquées, Lyon, in August.
- D. Talay was an invited speaker at the NASPDE2014 workshop at EPFL, Lausanne, Switzerland, in September; at the 7th symposium on backward stochastic differential equations, Weihai, China, in June; at the Opening workshop ‘Advances in stochastic analysis’ of the Laboratory of Stochastic Analysis and its Applications at the Higher School of Economics, Moscow, Russia, in September.
- D. Talay gave a seminar at the Mathematics department of the university of Oxford in November.
- E. Tanré gave a talk at the HBP-Brainscales Meeting *Missing interactions in spike-based computation* in October.

10. Bibliography

Major publications by the team in recent years

[1] C. BLANCHET-SCALLIET, A. DIOP, R. GIBSON, D. TALAY, E. TANRÉ. *Technical analysis compared to mathematical models based methods under parameters mis-specification*, in "Journal of Banking and Finance", 2007, vol. 31, n° 5, pp. 1351–1373

[2] M. BOSSY, E. GOBET, D. TALAY. *A symmetrized Euler scheme for an efficient approximation of reflected diffusions*, in "J. Appl. Probab.", 2004, vol. 41, n° 3, pp. 877–889

[3] M. BOSSY, B. JOURDAIN. *Rate of convergence of a particle method for the solution of a 1D viscous scalar conservation law in a bounded interval*, in "Ann. Probab.", 2002, vol. 30, n° 4, pp. 1797–1832

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[5] M. DEACONU, N. FOURNIER, E. TANRÉ. *A pure jump Markov process associated with Smoluchowski's coagulation equation*, in "Ann. Probab.", 2002, vol. 30, n° 4, pp. 1763–1796

[6] S. HERRMANN, P. IMKELLER, D. PEITHMANN. *Transition times and stochastic resonance for multidimensional diffusions with time periodic drift: a large deviations approach*, in "Ann. Appl. Probab.", 2006, vol. 16, n° 4, pp. 1851–1892

[7] A. LEJAY. *An introduction to rough paths*, in "Séminaire de Probabilités XXXVII", Berlin, Lecture Notes in Math., Springer, 2003, vol. 1832, pp. 1–59

[8] A. LEJAY, M. MARTINEZ. *A scheme for simulating one-dimensional diffusion processes with discontinuous coefficients*, in "Ann. Appl. Probab.", 2006, vol. 16, n^o 1, pp. 107–139

[9] B. ROYNETTE, P. VALLOIS, M. YOR. *Pénalisations et quelques extensions du théorème de Pitman, relatives au mouvement Brownien et à son maximum unilatère*, in "In memoriam Paul-André Meyer: Séminaire de Probabilités XXXIX", Berlin, Lecture Notes in Math., Springer, 2006, vol. 1874, pp. 305–336

[10] D. TALAY, Z. ZHENG. *Approximation of quantiles of components of diffusion processes*, in "Stochastic Process. Appl.", 2004, vol. 109, n^o 1, pp. 23–46

Publications of the year

Doctoral Dissertations and Habilitation Theses

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