



Inria

Activity Report 2019

Team TOSCA

TO Simulate and CALibrate stochastic models

Inria teams are typically groups of researchers working on the definition of a common project, and objectives, with the goal to arrive at the creation of a project-team. Such project-teams may include other partners (universities or research institutions).

RESEARCH CENTERS
Sophia Antipolis - Méditerranée
Nancy - Grand Est

THEME
Stochastic approaches

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Team TOSCA

Creation of the Team: 2019 January 01

Keywords:

Computer Science and Digital Science:

- A6.1.2. - Stochastic Modeling
- A6.1.3. - Discrete Modeling (multi-agent, people centered)
- A6.1.4. - Multiscale modeling
- A6.2.2. - Numerical probability
- A6.2.3. - Probabilistic methods
- A6.2.4. - Statistical methods
- A6.4.2. - Stochastic control

Other Research Topics and Application Domains:

- B1.1.6. - Evolutionary biology
- B1.1.8. - Mathematical biology
- B1.2.1. - Understanding and simulation of the brain and the nervous system
- B3.2. - Climate and meteorology
- B3.3.4. - Atmosphere
- B4.3.2. - Hydro-energy
- B4.3.3. - Wind energy
- B9.5.2. - Mathematics
- B9.11. - Risk management
- B9.11.1. - Environmental risks
- B9.11.2. - Financial risks

1. Team, Visitors, External Collaborators

Research Scientists

- Mireille Bossy [Inria, Senior Researcher, Sophia Antipolis - Méditerranée, HDR]
- Denis Talay [Team leader, Inria, Senior Researcher, Sophia Antipolis - Méditerranée, HDR]
- Christophe Henry [Inria, Starting Research Position, Sophia Antipolis - Méditerranée]
- Etienne Tanré [Inria, Researcher, Sophia Antipolis - Méditerranée]
- Olivier Faugeras [Inria, Emeritus Senior Researcher, also member of the team MATHNEURO, Sophia Antipolis - Méditerranée, HDR]
- Nicolas Champagnat [Inria, Senior Researcher, Nancy - Grand Est, HDR]
- Madalina Deaconu [Inria, Researcher, Nancy - Grand Est, HDR]
- Coralie Fritsch [Inria, Researcher, Nancy - Grand Est]
- Antoine Lejay [Inria, Senior Researcher, Nancy - Grand Est, HDR]

Faculty Member

- Denis Villemonais [Univ. de Lorraine, Associate Professor, Nancy - Grand Est, HDR]

Post-Doctoral Fellows

- Igor Honore [Inria, Sophia Antipolis - Méditerranée]
- Kerlyns Martinez Rodriguez [Inria, from Oct. 2019, Sophia Antipolis - Méditerranée]
- Hector Olivero-Quinteros [Univ. Côte d'Azur, Sophia Antipolis - Méditerranée]

Ulysse Herbach [Inria, Nancy - Grand Est]
Édouard Strickler [Inria, since Oct. 2019, Nancy - Grand Est]

PhD Students

Sofia Allende Contador [Univ. Côte d'Azur, from Mar. 2019, Sophia Antipolis - Méditerranée]
Lorenzo Campana [Univ. Côte d'Azur, Sophia Antipolis - Méditerranée]
Quentin Cormier [Univ. Côte d'Azur, Sophia Antipolis - Méditerranée]
Aurore Dupre [Laboratoire de météorologie dynamique, Sophia Antipolis - Méditerranée]
Pascal Helson [Univ. Côte d'Azur, Sophia Antipolis - Méditerranée]
Alexis Anagnostakis [Univ. Lorraine, Nancy - Grand Est]
Vincent Hass [Inria, Nancy - Grand Est]
Rodolphe Loubaton [Univ. Lorraine, Nancy - Grand Est]

Technical staff

Radu Maftai [Inria, Engineer, Sophia Antipolis - Méditerranée, HDR]
Victor Martin Lac [Inria, Engineer, until Jun. 2019, Sophia Antipolis - Méditerranée]

Administrative Assistants

Isabelle Blanchard [Inria, Nancy - Grand Est]
Laurence Briffa [Inria, from Jan. 2019 to Sep. 2019, Sophia Antipolis - Méditerranée]
Sandrine Boute [Inria, since Aug. 2019, Sophia Antipolis - Méditerranée]

Visiting Scientists

Kerlyns Martinez Rodriguez [CIMFAV, Valparaiso, Chile, PhD student, until Sep. 2019, Sophia Antipolis - Méditerranée]
Cyril Mokrani [Marine Energy Research and Innovation Centre, Post-doc, Sophia Antipolis - Méditerranée]
Alvin Tse [University of Edinburgh, PhD student, from Feb. 2019 until Mar. 2019, Sophia Antipolis - Méditerranée]

External Collaborators

Jeremie Bec [CNRS, Senior Researcher at CEMEF, Sophia Antipolis, from Mar. 2019, Sophia Antipolis - Méditerranée]
Areski Cousin [Univ. de Claude Bernard, Professor, Sophia Antipolis - Méditerranée]
Marcos Di Iorio [Marine Energy Research and Innovation Centre, Engineer, from May 2019 to Aug. 2019, Sophia Antipolis - Méditerranée]
Jean-Francois Jabir [University of Edinburgh, Assistant Professor, Sophia Antipolis - Méditerranée]
Nadia Maïzi [Ecole Nationale Supérieure des Mines de Paris, Professor, from Feb. 2019, Sophia Antipolis - Méditerranée]
Samuel Herrmann [Univ. de Bourgogne, Nancy - Grand Est, HDR]
Émilie Soret [Univ. Côte d'Azur, Sophia Antipolis - Méditerranée]

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. 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 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. diamss

KEYWORDS: High-performance calculation - Computation - Stochastic process

FUNCTIONAL DESCRIPTION: Numerical resolution of Keller-Segel equations and several numerical tests.

- Participants: Denis Talay, Hector Olivero-Quinteros and Milica Tomasevic
- Contact: Denis Talay

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

5.3. MOC

Models Of Chemostat

KEYWORD: Simulator

FUNCTIONAL DESCRIPTION: MOC (for Models of Chemostat) is a Python simulator of four chemostat models: a mass-structured stochastic individual based model, a mass-structured integro-differential model, the Crump-Young model and a system of ordinary differential equations. This software allows to simulate one or several of those models with different parameters, to plot graphics of evolution of biomass concentration, number of bacteria and substrate concentration as well as the phase portrait, to determine the law of the extinction time of the bacterial population in case of population extinction.

- Participants: Coralie Fritsch and Fabien Campillo
- Contact: Coralie Fritsch
- URL: <https://github.com/coraliefritsch/modelsOfChemostat>

5.4. SDM

Stochastic Downscaling Method

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, 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 modeling 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).

- Participants: Antoine Rousseau, Antoine Rousseau, Claire Chauvin, Frederic Bernardin and Mireille Bossy
- Contact: Mireille Bossy

5.5. SDM-Log

- Participants: Antoine Rousseau, Claire Chauvin, Frederic Bernardin, Jacques Morice and Mireille Bossy
- Contact: Mireille Bossy

5.6. WindPoS-SDM-LAM

KEYWORDS: Numerical simulations - 3D - Fluid mechanics

FUNCTIONAL DESCRIPTION: Software platform for wind modeling.

- Authors: Antoine Rousseau, Cristian Paris Ibarra, Jacques Morice, Mireille Bossy and Sélim Kraria
- Contact: Mireille Bossy
- URL: <https://windpos.inria.fr>

5.7. WindPoS-ATM

KEYWORDS: 3D - Co-simulation - Fluid mechanics

- Authors: Philippe Drobinski, Antoine Rousseau, Mireille Bossy, Jacques Morice and Thomas Dubos
- Partners: Ecole Polytechnique - Laboratoire de Météorologie Dynamique
- Contact: Mireille Bossy
- URL: <https://windpos.inria.fr/projects/windpos/>

5.8. WindPoS-CIV

WinsPoS-CIV (Configuration Interface and Visualization)

- Authors: Sélim Kraria, Antoine Rousseau and Mireille Bossy
- Contact: Mireille Bossy

5.9. SBM

Skew Brownian Motion

KEYWORDS: Monte-Carlo methods - Skew Brownian Motion

FUNCTIONAL DESCRIPTION: SBM is a code allowing exact or approximated simulations of the Skew Brownian Motion. This code is used for the simulation, with a Monte-Carlo approach, of a 1D diffusion process with a discontinuous diffusion coefficient. Several benchmark tests are also implemented.

NEWS OF THE YEAR: - Refactoring and Cmake compilation - Automatic non regression tests on ci-inria.fr - Full documentation - Open source project on gitlab-inria

- Authors: Antoine Lejay and Géraldine Pichot
- Contact: Antoine Lejay
- Publication: [Simulating diffusion processes in discontinuous media: Benchmark tests](#)
- URL: <https://gitlab.inria.fr/lejay/sbm>

6. New Results

6.1. Probabilistic numerical methods, stochastic modeling and applications

Participants: Sofia Allende Contador, Alexis Anagnostakis, Mireille Bossy, Lorenzo Campana, Nicolas Champagnat, Quentin Cormier, Madalina Deaconu, Aurore Dupre, Coralie Fritsch, Vincent Hass, Pascal Helson, Christophe Henry, Ulysse Herbach, Igor Honore, Antoine Lejay, Rodolphe Loubaton, Radu Maftai, Kerlyns Martinez Rodriguez, Victor Martin Lac, Hector Olivero-Quinteros, Édouard Strickler, Denis Talay, Etienne Tanré, Denis Villemonais.

6.1.1. Published works and preprints

- H. AlRachid (Orléans University), M. Bossy, C. Ricci (University of Florence) and L. Szpruch (University of Edinburgh and The Alan Turing Institute, London) introduced several new particle representations for *ergodic* McKean-Vlasov SDEs. They construct new algorithms by leveraging recent progress in weak convergence analysis of interacting particle system. In [12] they present detailed analysis of errors and associated costs of various estimators, highlighting key differences between long-time simulations of linear (classical SDEs) versus non-linear (McKean-Vlasov SDEs) process.
- M. Di Iorio (Marine Energy Research and Innovation Center, Santiago, Chile), M. Bossy, C. Mokrani (Marine Energy Research and Innovation Center, Santiago, Chile), and A. Rousseau (LEMON team) obtained advances in stochastic Lagrangian approaches for the simulation of hydrokinetic turbines immersed in complex topography [42].
- M. Bossy, J.-F. Jabir (University of Edinburgh) and K. Martinez (University of Valparaiso) consider the problem of the approximation of the solution of a one-dimensional SDE with non-globally Lipschitz drift and diffusion coefficients behaving as x^α , with $\alpha > 1$ [44]. They propose an (semi-explicit) exponential-Euler scheme and study its convergence through its weak approximation error. To this aim, they analyze the $C^{1,4}$ regularity of the solution of the associated backward Kolmogorov PDE using its Feynman-Kac representation and the flow derivative of the involved processes. From this, under some suitable hypotheses on the parameters of the model ensuring the control of its positive moments, they recover a rate of weak convergence of order one for the proposed exponential Euler scheme. Numerical experiments are analyzed in order to complement their theoretical result.
- L. Campana et al. developed some Lagrangian stochastic model for anisotropic particles in turbulent flow [35]. Suspension of anisotropic particles can be found in various industrial applications. Microscopic ellipsoidal bodies suspended in a turbulent fluid flow rotate in response to the velocity gradient of the flow. Understanding their orientation is important since it can affect the optical or rheological properties of the suspension (e.g. polymeric fluids). The equations of motion for the orientation of microscopic ellipsoidal particles was obtained by Jeffery. But so far this description has been always investigated in the framework of direct numerical simulations (DNS) and experimental measurements. In this work, the orientation dynamics of rod-like tracer particles, i.e. long ellipsoidal particles (in the limit of infinite aspect-ratio) is studied. The size of the rod is assumed smaller than the Kolmogorov length scale but sufficiently large that its Brownian motion need not be considered. As a result, the local flow around a particle can be considered as inertia-free and Stokes flow solutions

can be used to relate particle rotational dynamics to the local velocity gradient. The orientation of rod can be described as the normalised solution of the linear ordinary differential equation for the separation vector between two fluid tracers, under the action of the velocity gradient tensor. In this framework, the rod orientation is described by a Lagrangian stochastic model where cumulative velocity gradient fluctuations are represented by a white-noise tensor such that the incompressibility condition is preserved. A numerical scheme based on the decomposition into skew/symmetric part of the process dynamics is proposed.

- Together with M. Andrade-Restrepo (Univ. Paris Diderot) and R. Ferrière (Univ. Arizona and École Normale Supérieure), N. Champagnat studied deterministic and stochastic spatial eco-evolutionary dynamics along environmental gradients. This work focuses on numerical and analytical analysis of the clustering phenomenon in the population, and on the patterns of invasion fronts [13].
- Together with M. Benaïm (Univ, Neuchâtel), N. Champagnat and D. Villemonais studied stochastic algorithms to approximate quasi-stationary distributions of diffusion processes absorbed at the boundary of a bounded domain. They study a reinforced version of the diffusion, which is resampled according to its occupation measure when it reaches the boundary. They show that its occupation measure converges to the unique quasi-stationary distribution of the diffusion process [43].
- N. Champagnat, C. Fritsch and S. Billiard (Univ. Lille) studied models of food web adaptive evolution. They identified the biomass conversion efficiency as a key mechanism underlying food webs evolution and discussed the relevance of such models to study the evolution of food webs [51].
- N. Champagnat and J. Claisse (Univ. Paris-Dauphine) 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 quasi-stationary distribution of the processes controlled by Markov controls [18].
- N. Champagnat and B. Henry (Univ. Lille 1) studied a probabilistic approach for the Hamilton-Jacobi limit of non-local reaction-diffusion models of adaptive dynamics when mutations are small. They used a Feynman-Kac interpretation of the partial differential equation and large deviation estimates to obtain a variational characterization of the limit. They also studied in detail the case of finite phenotype space with exponentially rare mutations, where they were able to obtain uniqueness of the limit [19].
- N. Champagnat and D. Villemonais solved a general conjecture on the Fleming-Viot particle systems approximating quasi-stationary distributions (QSD): in cases where several quasi-stationary distributions exist, it is expected that the stationary distributions of the Fleming-Viot processes approach a particular QSD, called minimal QSD. They proved that this holds true for general absorbed Markov processes with soft obstacles [20].
- N. Champagnat and D. Villemonais studied the geometric convergence of normalized unbounded semigroups. They proved in [47] that general criteria for this convergence can be easily deduced from their recent results on the theory of quasi-stationary distributions.
- N. Champagnat, S. Méléard (École Polytechnique) and V.C. Tran (Univ. Paris Est Marne-la-Vallée) studied evolutionary models of bacteria with horizontal transfer. They considered in [46] a scaling of parameters taking into account the influence of negligible but non-extinct populations, allowing them to study specific phenomena observed in these models (re-emergence of traits, cyclic evolutionary dynamics and evolutionary suicide).
- M. Bahlali (CEREA, France), C. Henry and B. Carissimo (CEREA, France) clarify issues related to the expression of Lagrangian stochastic models used for atmospheric dispersion applications. They showed that accurate simulations are possible only if two aspects are properly addressed: the respect of the well-mixed criterion (related to the incorporation of the mean pressure-gradient term in the mean drift-term) and the consistency between Eulerian and Lagrangian turbulence models (regarding turbulence models, boundary and divergence-free conditions).

- A. Lejay and A. Brault have continued their work on rough flows, which provides an unified framework to deal with the theory of rough paths from the point of view of flows. In particular, they have studied consistency, stability and generic properties of rough differential equations [45].
- A. Lejay and P. Pigato have provided an estimator of a discontinuous drift coefficients [30], which follows their previous work on the oscillating Brownian motion and its application to financial models.
- A. Lejay and H. Mardones (U. la Serenan, Chile), have completed their work on the Monte Carlo simulation of the Navier-Stokes equations based on a new representation by Forward-Backward Stochastic Differential Equations [53].
- O. Faugeras, E. Soret and E. Tanré have obtained a Mean-Field description of thermodynamics limits of large population of neurons with random interactions. They have obtained the asymptotic behaviour for an asymmetric neuronal dynamics in a network of linear Hopfield neurons. They have a complete description of this limit with Gaussian processes. Furthermore, the limit object is not a Markov process [50].
- E. Tanré, P. Grazieschi (Univ. Warwick), M. Leocata (Univ. Pisa), C. Mascart (Univ. Côte d’Azur), J. Chevallier (Univ. of Grenoble) and F. Delarue (Univ. Côte d’Azur) have extended the previous work [9] to sparse networks of interacting neurons. They have obtained a precise description of the limit behavior of the mean field limit according to the probability of (random) interactions between two individual LIF neurons [24].
- P. Helson has studied the learning of an external signal by a neural network and the time to forget it when this network is submitted to noise. He has constructed an estimator of the initial signal thanks to the synaptic currents, which are Markov chains. The mathematical study of the Markov chains allow to obtain a lower bound on the number of external stimuli that the network can receive before the initial signal is forgotten [52].
- Q. Cormier and E. Tanré studied with Romain Veltz (team MATHNEURO) the long time behavior of a McKean-Vlasov SDE modeling a large assembly of neurons. A convergence to the unique (in this case) invariant measure is obtained assuming that the interactions between the neurons are weak enough. The key quantity in this model is the “firing rate”: it gives the average number of jumps per unit of times of the solution of the SDE. They derive a non-linear Volterra equation satisfied by this rate. They used methods from integral equation to control finely the long time behavior of this firing rate [21].
- E. Tanré has worked with Nicolas Fournier (Sorbonne Université) and Romain Veltz (MATHNEURO Inria team) on a network of spiking networks with propagation of spikes along the dendrites. Consider a large number n of neurons randomly connected. When a neuron spikes at some rate depending on its electric potential, its membrane potential is set to a minimum value v_{min} , and this makes start, after a small delay, two fronts on the dendrites of all the neurons to which it is connected. Fronts move at constant speed. When two fronts (on the dendrite of the same neuron) collide, they annihilate. When a front hits the soma of a neuron, its potential is increased by a small value w_n . Between jumps, the potentials of the neurons are assumed to drift in $[v_{min}, \infty)$, according to some well-posed ODE. They prove the existence and uniqueness of a heuristically derived mean-field limit of the system when $n \rightarrow \infty$ [23].
- O. Faugeras, James Maclaurin (Univ. of Utah) and E. Tanré have worked on the asymptotic behavior of a model of neurons in interaction with correlated gaussian synaptic weights. They have obtained the limit equation as a singular non-linear SDE and a Large Deviation Principle for the law of the finite network [49].
- E. Tanré has worked with Alexandre Richard (Centrale-Supelec) and Soledad Torres (Universidad de Valparaíso, Chile) on a one-dimensional fractional SDE with reflection. They have proved the existence of the reflected SDE with a penalization scheme (suited to numerical approximation). Penalization also gives an algorithm to approach this solution [55].

- The Neutron Transport Equation (NTE) describes the flux of neutrons over time through an inhomogeneous fissile medium. A probabilistic solution of the NTE is considered in order to demonstrate a Perron-Frobenius type growth of the solution via its projection onto an associated leading eigenfunction. The associated eigenvalue, denoted k_{eff} , has the physical interpretation as being the ratio of neutrons produced (during fission events) to the number lost (due to absorption in the reactor or leakage at the boundary) per typical fission event. Together with A. M. G. Cox, E. L. Horton and A. E. Kyprianou (Univ. Bath), D. Villemonais developed the stochastic analysis of the NTE by giving a rigorous probabilistic interpretation of k_{eff} [48].
- In [34], D. Villemonais obtained a lower bound for the coarse Ricci curvature of continuous-time pure-jump Markov processes, with an emphasis on interacting particle systems. Applications to several models are provided, with a detailed study of the herd behavior of a simple model of interacting agents.
- In collaboration with C. Coron (Univ. Paris Sud) and S. Méléard (École Polytechnique), D. Villemonais studied in [22] the way alleles extinctions and fixations occur for a multiple allelic proportions model based on diffusion processes. It is proved in particular that alleles extinctions occur successively and that a 0-1 law holds for fixation and extinction: depending on the population dynamics near extinction, either fixation occurs before extinction, or the converse, almost surely.
- Mean telomere length in human leukocyte DNA samples reflects the different lengths of telomeres at the ends of the 23 chromosomes and in an admixture of cells. Together with S. Toupance (CHRU Nancy), D. Germain (Univ. Lorraine), A. Gégout-Petit (Univ. Lorraine and BIGS Inria team), E. Albuissou (CHRU Nancy) and A. Benetos (CHRU Nancy), D. Villemonais analysed telomere length distributions dynamics in adults individuals. It is proved in [33] that the shape of this distribution is stable over the lifetime of individuals.
- J. Bion-Nadal (Ecole Polytechnique) and D. Talay have pursued their work on their Wasserstein-type distance on the set of the probability distributions of strong solutions to stochastic differential equations. This new distance is defined by restricting the set of possible coupling measures and can be expressed in terms of the solution to a stochastic control problem, which allows one to deduce a priori estimates or to obtain numerical evaluations [15].

A notable application concerns the following modeling issue: given an exact diffusion model, how to select a simplified diffusion model within a class of admissible models under the constraint that the probability distribution of the exact model is preserved as much as possible? The objective being to select a model minimizing the above distance to a target model, approximations of the optimal model have been established. The construction and analysis of an efficient stochastic algorithm are being in progress.

- D. Talay and M. Tomašević have continued to work on their new type of stochastic interpretation of the parabolic-parabolic Keller-Segel systems. It involves an original type of McKean-Vlasov interaction kernel. At the particle level, each particle interacts with all the past of each other particle. D. Talay and M. Tomašević are studying the well-posedness and the propagation of chaos of the particle system related to the two-dimensional parabolic-parabolic Keller-Segel system.
- V. Martin Lac, R. Maftai D. Talay and M. Tomašević have continued to work on theoretical and algorithmic questions related to the simulation of the Keller-Segel particle systems. The library DIAMSS has been developed.
- H. Olivero (Inria, now University of Valparaiso, Chile) and D. Talay have continued to work on their hypothesis test which helps to detect when the probability distribution of complex stochastic simulations has a heavy tail and thus possibly an infinite variance. This issue is notably important when simulating particle systems with complex and singular McKean-Vlasov interaction kernels which make it extremely difficult to get a priori estimates on the probability laws of the mean-field limit, the related particle system, and their numerical approximations. In such situations the standard limit theorems do not lead to effective tests. In the simple case of independent and identically distributed sequences the procedure developed this year and its convergence analysis are based on deep tools coming from the statistics of semimartingales.

- I. Honoré and D. Talay have worked on statistical issues related to numerical approximations of invariant probability measures of ergodic diffusions. These approximations are based on the simulation of one single trajectory up to long time horizons. I. Honoré and D. Talay handle the critical situations where the asymptotic variance of the normalized error is infinite.
- V. Martin Lac, H. Olivero-Quinteros and D. Talay have worked on theoretical and algorithmic questions related to the simulation of large particle systems under singular interactions and to critical numerical issues related to the simulation of independent random variables with heavy tails. A preliminary version of a library has been developed.
- C. Graham (École Polytechnique) and D. Talay have ended the second volume of their series on Mathematical Foundation of Stochastic Simulation to be published by Springer.

6.1.2. Other works in progress

- K. Martinez, M. Bossy, C. Henry, R. Maftai and S. Sherkarforush work on a refined algorithm for macroscopic simulations of particle agglomeration using population balance equations (PBE). More precisely, their study is focused on identifying regions with non-homogeneous spatial distribution of particles. This is indeed a major drawback of PBE formulations which require a well-mixed condition to be satisfied. The developed algorithm identifies higher/lower density regions to treat them separately.
- S. Allende (CEMEF, France), J. Bec (CEMEF, France), M. Bossy, L. Campana, M. Ferrand (EDF, France), C. Henry and J.P. Minier (EDF, France) work together on a macroscopic model for the dynamics of small, flexible, inextensible fibers in a turbulent flow. Following the model developed at Inria, they perform numerical simulations of the orientation of such fibers in wall-bounded turbulent flows and compare it to microscopic simulations obtained with Direct Numerical Simulation (DNS). This work is performed under the POPART project.
- N. Champagnat, C. Fritsch and U. Herbach are working with A. Harlé (Institut de Cancérologie de Lorraine), J.-L. Merlin (ICL), E. Pencreac'h (CHRU Strasbourg), A. Gégout-Petit, P. Vallois, A. Muller-Gueudin (Inria BIGS team) and A. Kurtzmann (Univ. Lorraine) within an ITMO Cancer project on modeling and parametric estimation of dynamical models of circulating tumor DNA (ctDNA) of tumor cells, divided into several clonal populations. The goal of the project is to predict the emergence of a clonal population resistant to a targeted therapy in a patient's tumor, so that the therapy can be modulated more efficiently.
- N. Champagnat and R. Loubaton are working with P. Vallois (Univ. Lorraine and Inria BIGS team) and L. Vallat (CHRU Strasbourg) on the inference of dynamical gene networks from RNAseq and proteome data.
- N. Champagnat, E. Strickler and D. Villemonais are working on the characterization of convergence in Wasserstein distance of conditional distributions of absorbed Markov processes to a quasi-stationary distribution.
- N. Champagnat and V. Hass are studying evolutionary models of adaptive dynamics under an assumption of large population and small mutations. They expect to recover variants of the canonical equation of adaptive dynamics, which describes the long time evolution of the dominant phenotype in the population, under less stringent biological assumptions than in previous works.
- Q. Cormier, E. Tanré and Romain Veltz (team MATHNEURO) are working on the local stability of a stationary solution of some McKean-Vlasov equation. They also obtain spontaneous oscillation of the solution for critical values of the external currents or the interactions.
- M. Deaconu, A. Lejay and E. Mordecki (U. de la República, Uruguay) are studying an optimal stopping problem for the Snapping Out Brownian motion.
- M. Deaconu and A. Lejay are currently working on the simulation and the estimation of the fragmentation equation through its probabilistic representation.

- S. Allende (CEMEF, France), C. Henry and J. Bec (CEMEF, France) work on the dynamics of small, flexible, inextensible fibers in a turbulent flow. They show that the fragmentation of fibers smaller than the smallest fluid scale in a turbulent flow occurs through tensile fracture (i.e. when the fiber is stretched along its main axis) or through flexural failure (i.e. when the fiber curvature is too high as it buckles under compressive load). Statistics of such events are provided together with measures of the rate of fragmentation and daughter size distributions, which are basic ingredients for macroscopic fragmentation models.
- C. Henry and M.L. Pedrotti (LOV, France) are working together on the topic of sedimentation of plastic that are populated by biological organisms (this is called biofouling). Biofouling modifies the density of plastic debris in the ocean and can lead to their sedimentation towards deeper regions. This work is done under the PLAISE project, which comprises measurements (by the LOV) and simulations (by C. Henry).
- C. Fritsch is working with A. Gégout-Petit (Univ. Lorraine and EPI BIGS), B. Marçais (INRA, Nancy) and M. Grosdidier (INRA, Avignon) on a statistical analysis of a Chalara Fraxinea model.
- C. Fritsch is working with Tanjona Ramiadantsoa (Univ. Wisconsin-Madison) on a model of extinction of orphaned plants.
- A. Lejay and M. Clausel (U. Lorraine) are studying the clustering method based on the use of the signature and the iterated integrals of time series. It is based on asymmetric spectral clustering [41].
- In collaboration with L. Lenotre (postdoc at IECL between Oct. 2018 and Sep. 2019), A. Gégout-Petit (Univ. Lorraine and Inria BIGS team) and O. Coudray (Master degree student), D. Villemonais conducted preliminary researches on branching models for the telomeres' length dynamics across generations.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

- M. Bossy is the Coordinator of the POPART Industrial partnership project at UCA-JEDI on the modeling of fibre transport in turbulent flows. This partnership is granted by EDF and by UCA, and in collaboration with CEMEF (J. Bec and S. Allende).
- M. Bossy is member of a MERIC project (MERIC is the marine energy research & innovation center in Chile) on stochastic Lagrangian models to better estimate energy production variability with water turbine, granted with the LEMON Inria Team.

8. Partnerships and Cooperations

8.1. Regional Initiatives

- C. Henry is the coordinator of the PAIRE project, a TREMPLIN-COMPLEX project funded by University of Côte d'Azur. The project aims at creating new international and cross-sector collaborations to foster innovative solutions for particle contamination in the environment. This will be achieved by bringing together partners in a consortium to submit a research proposal to the European MSCA-RISE-2019 and MSCA-RISE-2020 calls.
- A. Lejay is a member of the Executive board of LUE Impact digitrust on citizens' trust in the digital world (grant of the i-site, U. Lorraine), since 2018.

8.2. National Initiatives

8.2.1. ANR

- N. Champagnat was member of the ANR NONLOCAL (Phénomènes de propagation et équations non locales), coordinated by F. Hamel (Univ. Aix-Marseille), which ended in October.
- C. Henry is the coordinator of the PACE project, a MRSEI project funded by the ANR to help prepare European projects. As for PAIRE, the project aims at creating new international and cross-sector collaborations to foster innovative solutions for particle contamination in the environment. This will be achieved by bringing together partners in a consortium to submit a research proposal to the European MSCA-RISE-2019 and MSCA-RISE-2020 calls.
- U. Herbach is member of the ANR SinCity (Analyses transcriptomiques sur cellules uniques dont la généalogie est identifiée au cours d'un processus de différenciation), coordinated by O. Gandrillon (ENS Lyon).

8.2.2. GDR

A. Lejay is leader of the GdR Project TRAG on rough paths founded by INSMI in 2019.

8.2.3. ITMO Cancer

N. Champagnat, C. Fritsch and U. Herbach are involved in an ITMO Cancer project (INSERM funding) on "Modeling ctDNA dynamics for detecting targeted therapy resistance" (2017-2020), involving researchers from IECL (Institut Elie Cartan de Lorraine), the Inria teams BIGS and TOSCA, ICL (Institut de Cancérologie de Lorraine), CRAN (Centre de Recherche en Automatique de Nancy) and CHRU Strasbourg (Centre Hospitalier Régional Universitaire). This project is coordinated by N. Champagnat.

8.2.4. PEPS

The project SECURE of C. Fritsch obtained a PEPS I3A (Intelligence Artificielle et Apprentissage Automatique).

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

Program: FP7

Project acronym: HBP

Project title: The Human Brain Project

Duration: April 2018 - Mars 2020 (third part)

Coordinator: EPFL

Other partners: see the webpage of the project.

Tosca contact: Etienne Tanré

Abstract: Understanding the human brain is one of the greatest challenges facing 21st century science. If we can rise to the challenge, we can gain profound insights into what makes us human, develop new treatments for brain diseases and build revolutionary new computing technologies. Today, for the first time, modern ICT has brought these goals within sight. The goal of the Human Brain Project, part of the FET Flagship Programme, is to translate this vision into reality, using ICT as a catalyst for a global collaborative effort to understand the human brain and its diseases and ultimately to emulate its computational capabilities. The Human Brain Project will last ten years and will consist of a ramp-up phase (from month 1 to month 36) and subsequent operational phases. This Grant Agreement covers the ramp-up phase. During this phase the strategic goals of the project will be to design, develop and deploy the first versions of six ICT platforms dedicated to Neuroinformatics, Brain Simulation, High Performance Computing, Medical Informatics, Neuromorphic Computing and Neurorobotics, and create a user community of research groups from within and outside the HBP, set up a European Institute for Theoretical Neuroscience, complete a set of pilot projects providing a first demonstration of the scientific value of the platforms and the Institute,

develop the scientific and technological capabilities required by future versions of the platforms, implement a policy of Responsible Innovation, and a programme of transdisciplinary education, and develop a framework for collaboration that links the partners under strong scientific leadership and professional project management, providing a coherent European approach and ensuring effective alignment of regional, national and European research and programmes. The project work plan is organized in the form of thirteen subprojects, each dedicated to a specific area of activity. A significant part of the budget will be used for competitive calls to complement the collective skills of the Consortium with additional expertise.

M. Bossy and C. Henry are involved in the VIMMP H2020 project, started in January 2018. M. Bossy is responsible for the partner Inria. VIMMP is a four years development for a software platform and simulation market place on the topic of complex multiscale CFD simulations.

8.4. International Initiatives

8.4.1. Participation in Other International Programs

Math AmSud SARC

Title: Stochastic and Statistics analysis for Stochastic Differential equations driven by fractional Brownian motion with non regular coefficients.

International Partner (Institution - Laboratory - Researcher):

Universidade Estadual de Campinas (Brasil)

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

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

Duration: 2019 - 2020

Start year: 2019

Keywords: Stochastic differential equations, fractional Brownian motion, Malliavin calculus, Bayesian parametric, and nonparametric statistics.

BRN

Title: Biostochastic Research Network

International Partner (Institution - Laboratory - Researcher):

Universidad de Valparaiso (Chile) - CIMFAV – Facultad de Ingenieria - Soledad Torres, Rolando Rebolledo

CNRS, Inria & IECL - Institut Élie Cartan de Lorraine (France) - N. Champagnat, A. Lejay, D. Villemonais, R. Schott.

Duration: 2018 - 2022

Start year: 2018

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- E. Horton (University of Bath) spent one week in IECL in April to work with D. Villemonais.
- E. Mordecki (U. de la República, Uruguay) spent 3 months in IECL, with an invited professor position (*poste rouge CNRS*).
- H. Olivero Quintos spent one month at Sophia Antipolis.

8.5.1.1. Internships

- Loubna Ben Allal
subject: processus de Hawkes
date: sept. 2019 - june 2020
institution: École des Mines de Nancy
- Wejdene Ben Nasr
subject: méthodes de signature pour les séries temporelles multi-variées
date: sept. 2019 - june 2020
institution: Master IMSD, U. Lorraine.
- Olivier Coudray
subject: transmission de la longueur de télomères entre générations
date: apr. 2019 - aug. 2019
institution: École Polytechnique, Master Mathématiques de l'aléatoire
- Rémi Maréchal
subject: processus de fragmentation pour les avalanches
date: sept. 2019 - june 2020
institution: École des Mines de Nancy
- Seyedafshin Shekarforush
subject: particles in the environment: the adaptative grid generation problem in particle agglomeration and fragmentation dynamics
date: apr. 2019 - aug. 2019
institution: Université Nice Sophia Antipolis

8.5.2. Visits to International Teams

8.5.2.1. Sabbatical programme

D. Villemonais obtained a *délégation CNRS* which ended in August.

9. Dissemination

9.1. Promotion of Mathematics in the industry

- A. Lejay is member of the board of AMIES (Agence Mathématiques en Interactions avec l'Entreprise et la Société). A. Lejay is editor of the *success stories* project.
- 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.
- 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.

9.2. Promoting Scientific Activities

9.2.1. Scientific Events: Organisation

- C. Fritsch organizes with Pascal Moyal (Univ. de Lorraine) the weekly Seminar of Probability and Statistics of IECL, Nancy.
- C. Fritsch organized with Constantin Morarescu (CRAN) a scientific day of the *Fédération Charles Hermite* about multiscale models. (IECL, Nancy, 21 June 2019)

9.2.1.1. Member of the Organizing Committees

- N. Champagnat is member of the organizing committee of the conference *Mathematical Models in Evolutionary Biology*, part of the Thematic Month on Mathematical Issues in Biology (CIRM, Luminy, 10–14 Feb. 2020).
- N. Champagnat was member of the organizing committee of the conference ReaDiNet 2019 *Mathematical Analysis for Biology and Ecology* (Inria Nancy – Grand Est, 23–25 Sep.).
- N. Champagnat and U. Herbach organized the workshop *Modélisation de l'hétérogénéité tumorale et thérapies ciblées* (IECL, Univ. Lorraine, 21–22 Oct.).
- C. Fritsch was member of the organizing committee of the conference *51es Journées de Statistiques* (Nancy, 3–7 June).
- A. Lejay organized the conference *TRAG 2019* (Nancy, 9–11 Oct.).
- E. Tanré and R. Veltz organized the workshop on *Mean-field approaches to the dynamics of neuronal networks* (EITN, 3–4 April).

9.2.1.2. Member of the Conference Program Committees

- M. Bossy is member of the SMAI2019 Conference Scientific Committee and MASCOT NUM 2020 Conference.
- D. Talay is serving as a member of the scientific committee for MasterKesm (Masterclass from kinetic equations to statistical mechanics) summer school to be held in Saint Jean de Monts in 2020.

9.2.2. Journal

9.2.2.1. Member of the Editorial Boards

- A. Lejay is one of the three editors of the *Séminaire de Probabilités* and *Mathematics and Computers in Simulation* (MATCOM).
- N. Champagnat serves as an associate editor of *Stochastic Models*.
- N. Champagnat serves as co-editor-in-chief with Béatrice Laurent-Bonneau (IMT Toulouse) of *ESAIM: Probability & Statistics*.
- D. Talay serves as an Area Editor of *Stochastic Processes and their Applications*, and as an Associate Editor of *Journal of the European Mathematical Society*, *Probability, Uncertainty and Quantitative Risk*, *ESAIM Probability and Statistics*, *Stochastics and Dynamics*, *Journal of Scientific Computing*, *Monte Carlo Methods and Applications*, *SIAM Journal on Scientific Computing*, *Communications in Applied Mathematics and Computational Science*, *Éditions de l'École Polytechnique*. He also served as Co-editor in chief of *MathematicS in Action*.

9.2.2.2. Reviewer - Reviewing Activities

- N. Champagnat wrote reviews for *Stochastic Processes and their Applications* (three times this year), *Electronic Journal of Probability* and *Frontiers of Mathematics in China*.
- C. Fritsch wrote reviews for *PCI Ecology*.
- C. Henry wrote reviews for *Annals of Nuclear Energy*, *Aerosol Science and Technology*, *Building and Environment* and *Journal of Aerosol Science*.

- A. Lejay wrote reviews for *Annals of Institut Henri Poincaré*, *Statistical Inference for Stochastic Processes*, *Journal of Computational and Applied Mathematics*, *Physical Review E*, *Bernoulli*, *Electronic Journal of Probability*, *ESAIM PS*, *Journal Theoretical Probability*, *SIAM Journal on Control and Optimization*, *Applied Probability Journals*, *Journal of Functional Analysis*.
- E. Strickler wrote reviews for *Stochastic Models* and *Stochastic Processes and their Applications*.
- E. Tanré wrote reviews for *The Annals of Applied Probability*, *Electronic Journal of Probability*, *ESAIM PS*, *The Bulletin of the London Mathematical Society*, *Finance and Stochastics*, *The Journal of Mathematical Neuroscience*, *Stochastic Processes and their Applications*.
- E. Tanré serves as a permanent reviewer of *Mathematical Reviews of the American Mathematical Society (MathSciNet)*.
- D. Villemonais wrote reviews for *Markov processes and related fields*, *Electronic communication in Probability* (twice), *The Annals of Applied Probability*, *Stochastic processes and Applications*, *Journal of Statistical Physics* and *Electronic Journal of Probability*.
- D. Talay reported on applications to the Swiss National Science Foundation (SNSF).
- D. Talay reported on applications to the Research Grants Council (RGC) of Hong Kong.

9.2.3. Invited Talks

- M. Bossy has been invited to give talks at the conference Simulation and Optimization for Renewable Marine Energies, at Roscoff in July.
- N. Champagnat has been invited to give a Colloquium talk at the Department of Mathematics and Computer Science of the University of Technology in Eindhoven in February.
- N. Champagnat gave a talk at the Journée Charles Hermite *Modélisation fine versus outils d'analyse et simulation, un problème d'échelle* in Nancy in June.
- Q. Cormier has been invited to give a talk at the workshop on *Mean-field approaches to the dynamics of neuronal networks* at EITN in April.
- Q. Cormier and P. Helson have presented posters at the *International Conference on Mathematical Neuroscience* in Copenhagen in June.
- Q. Cormier and E. Tanré have been invited to give talks at the workshop “Nonlinear Processes and their Applications” in St. Etienne in July.
- C. Fritsch has been invited to give a talk at the workshop of the MAMОВI group in September.
- C. Fritsch gave a talk at the *Journées de Statistiques* in Nancy in June and at the *Mathematical Models in Ecology and Evolution* conference in Lyon in July.
- V. Hass presented a poster at the conference ReaDiNet 2019 *Mathematical Analysis for Biology and Ecology* in Nancy in September.
- U. Herbach has been invited to give talks at the Journée Charles Hermite *Méthodes et Modèles pour comprendre les réseaux biologiques* in January, at the spring school of *chaire MMB (Modélisation Mathématique et Biodiversité)* in Aussois in May, at the *Journée du RIS (Réseau Interdisciplinaire autour de la Statistique)* in Paris in September and at the workshop *Modélisation de l'hétérogénéité tumorale et thérapies ciblées* in Nancy in October.
- U. Herbach gave seminar talks at the *Séminaire de probabilités et statistiques de l'IECL* in Nancy in April, at the *Groupe de travail Maths-Bio* in Orléans in May, at the *Séminaire CIML (Centre d'immunologie de Marseille-Luminy)* in Marseille in May, at the *Groupe de travail du LBMC (Laboratoire de Biologie et Modélisation de la Cellule)* in Lyon in November, at the *Séminaire de probabilités* in Grenoble in November and at the *Groupe de travail Maths-Bio* in Grenoble in November.
- U. Herbach presented a poster at the conference *Probabilistic Modeling in Genomics* in Aussois in October.

- A. Lejay have been invited to give a mini-talk *A short introduction to Rough Paths* at Ritsumeikan University (Kyoto, Japan) in February.
- A. Lejay gave a talk at the conference *TRAG 2019* (Nancy) in October.
- E. Strickler gave seminar talks at the *Séminaire de probabilités* in Toulouse in October and at the *Séminaire de probabilités et statistiques de l'IECL* in Nancy in November.
- D. Villemonais gave seminar talks at the *Séminaire de Probabilités* of Univ. Paris 13 in April and at the *Probability Seminar* of Zurich Univ. in March.
- D. Villemonais has been invited to give talks at the *Journées du réseau A2* (Paris-Sorbonne Univ.) in October and at the *Conference ReaDiNet 2019* (Inria Nancy – Grand Est) in September.
- E. Soret has given an invited talk at ICMNS in Copenhagen in June.
- D. Talay was an invited speaker at the Conference in Honor of Philip Protter, Columbia University, New York, USA, September 2019.
- D. Talay was an invited speaker at the Conference in Honor of Nicole El Karoui, Sorbonne University, Paris, 21-24 May 2019.
- D. Talay was an invited speaker at the ‘Stochastic Analysis and Related Topics’ International Conference, Bucarest, Romania, 6-9 May 2019.
- D. Talay chaired a session at the ‘Journées de l’Académie des Sciences en région’, Nice and Sophia Antipolis, 2-21 June 2019.
- D. Talay gave a seminar talk at École des Ponts ParisTech on 27 November 2019.

9.2.4. Leadership within the Scientific Community

- M. Bossy was serving as a vice president of the Inria Evaluation Committee until September 2019.
- A. Lejay is head of the Probability and Statistics team of Institut Élie Cartan de Lorraine.
- D. Talay continued to chair the Scientific Council of the French Applied Math. Society SMAI.
- D. Talay is a member of the scientific committee of the ‘Institut Mathématiques de la Planète Terre’ project supported by INSMI-CNRS.
- D. Talay served as a member of the scientific council of the Complex System academy of the Université Côte d’Azur Idex.
- D. Talay is serving as a member of the CMUP Advisory Commission (University of Porto).
- D. Talay is a member of the Comité National Français de Mathématiciens.

9.2.5. Scientific Expertise

- N. Champagnat evaluated a research project submitted to the ANR.
- C. Fritsch is member of the Ph.D. monitoring committee of Léo Darrigade (INRA).
- D. Talay served as a member of the committee for positions in Applied Mathematics at the Ecole Polytechnique.
- D. Talay chaired the HCERES evaluation committee for the Toulouse Mathematics Institute (IMT).
- D. Talay is serving as a member of the evaluation committee of the Charles University (Prague, Czech Republic).

9.2.6. Research Administration

- N. Champagnat is a member of the *Comité de Centre*, the *COMIPERS* and the *Commission Information Scientifique et Technique* of Inria Nancy - Grand Est, *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.

- C. Fritsch is member of the *Commission du Développement Technologique* of Inria Nancy - Grand Est, of the *Commission du personnel* and the *Commission Parité-Égalité* of IECL. She is the local Raweb correspondent for the Inria Research Center of Nancy - Grand Est.
- A. Lejay is member of the Executive board of *LUE Impact project digitrust* (Univ. Lorraine), of the Conseil de Pôle AM2I (Univ. Lorraine) and of the CUMI (Inria NGE).
- D. Villemonais is responsible of the “Ingénierie Mathématique” cursus of École des Mines de Nancy and is elected member of the conseil de l’École des Mines de Nancy.

9.3. Teaching - Supervision - Juries

9.3.1. Teaching

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, *Problèmes inverses*, 22.5h, M1, École des Mines de Nancy, France.

Master: C. Fritsch, *Probability theory*, 40h, L3, École des Mines de Nancy, France.

Master: A. Lejay, *Probabilités*, 9h, 1st year Mines de Nancy, France.

Master: A. Lejay, *Simulation des marchés financiers*, 29h, M2, Master PSA, Université de Lorraine, France.

Master: E. Tanré (courses and exercices), *Advanced Numerics for Computational Finance*, 30h (20h + 10h), M2, Univ. Côte d’Azur (Mathmods Erasmus Mundus), France.

Master: E. Tanré, *Mathematical Methods for Neurosciences*, 20h, M2, ENS - Master MVA / Paris 6 - Master Maths-Bio, France.

Master: E. Tanré (courses) *Stochastic models in neurocognition*, 15h (7h30 + 7h30), M2, Univ. Côte d’Azur (Master 2), France.

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

9.3.2. Supervision

HdR: Denis Villemonais, *Convergence exponentielle vers une distribution quasi-stationnaire et applications*, Université de Lorraine, 28/11/2019.

PhD in progress: Alexis Anagnostakis, *Étude du mouvement brownien collant*, Université de Lorraine, Octobre 2018, A. Lejay and D. Villemonais.

PhD in progress: Lorenzo Campana, *Stochastic modeling of non-spherical particles transport and deposition by turbulent flow*, Université Côte d’Azur, December 2017, M. Bossy.

PhD in progress: Quentin Cormier, *Biological Networks of Spiking Neurons*, September 2017, E. Tanré and R. Veltz (MATHNEURO Inria team).

PhD in progress: Vincent Hass, *Individual-based models in adaptive dynamics and long time evolution under assumptions of rare advantageous mutations*, Université de Lorraine, October 2018, N. Champagnat.

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: Rodolphe Loubaton, *Caractérisation des cibles thérapeutiques dans un programme génique tumoral*, Université de Lorraine, October 2018, N. Champagnat and L. Vallat (CHRU Strasbourg).

9.3.3. Juries

- M. Bossy served as a referee for the Ph.D. thesis of Pierre Antoine Joulin, *Modélisation à fine échelle des interactions entre parcs éoliens et météorologie locale* at Institut National Polytechnique de Toulouse, December 2019.
- M. Bossy served as an examiner for the Ph.D. theses of Victor Marx, *Diffusive processes on the Wasserstein space: Coalescing models, Regularization properties and McKean-Vlasov equations*, Université Côte d'Azur, November 2019, and Sebastian Reyes Riffo, *Méthodes mathématiques pour l'extraction d'énergie marine*, PSL University November 2019.
- N. Champagnat will serve as an examiner for the habilitation thesis of Nicolas Gast, *Refinements of Mean Field Approximation*, Univ. de Grenoble, 30/01/2020.
- N. Champagnat served as a referee for the Ph.D. thesis of Paulien Jeunesse, *Estimation non paramétrique du taux de mort dans un modèle de population générale : théorie et applications*, Univ. Paris Dauphine, 08/01/2019.
- N. Champagnat served as an examiner for the Ph.D. theses of Frédérique Robin, *Modeling and analysis of cell population dynamics: application to the early development of ovarian follicles*, Univ. Paris Saclay, 26/09/2019, William Oçafrain, *Quasi-stationarité avec frontières mobiles*, Univ. Toulouse 3, 4/07/2019, Martin Andrade-resptrepo, *Mathematical modeling and evolutionary processes*, Univ. Paris 7, 26/06/2019 and Edouard Strickler, *Persistence de processus de Markov déterministes par morceaux*, Univ. Neuchâtel, 21/03/2019.
- A. Lejay served as an examiner for the habilitation thesis of Nicolas Marie, *Quelques contributions à la contrainte et à la statistique des équations différentielles dirigées par le mouvement brownien fractionnaire ainsi qu'à la sélection de modèle*, Université Paris Nanterre, November 2019.
- A. Lejay served as an examiner for the Ph.D. thesis of Carlo Bellingeri, *Itô formulae on stochastic heat equation via regularity structures and rough paths*, Sorbonne Université, July 2019.
- D. Talay served as a referee for the Ph.D. thesis of Grégoire Ferré, *Large Deviations Theory in Statistical Physics: Some Theoretical and Numerical Aspects*, Université Paris Est and École des Ponts ParisTech, 27 November 2019.
- D. Talay served as a referee for the habilitation thesis of Adrien Richou, *Quelques Résultats sur les Equations Différentielles Rétrogrades et les Principes de Grandes Déviations pour les Estimateurs de Paramètres de Diffusions*, université de Bordeaux, 4 November 2019.

9.4. Popularization

9.4.1. Interventions

C. Henry gave a presentation at the Inria Café In on the topic of breakup of elongated particles such as spaghetti.

9.4.2. Creation of media or tools for science outreach

- A. Lejay is editor of the project *Success Stories* (AMIES and FSMP) dedicated to create 2-page sheets to present successful interactions between industry and academia.

10. Bibliography

Major publications by the team in recent years

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- [2] M. BOSSY, J.-F. JABIR. *Lagrangian stochastic models with specular boundary condition*, in "Journal of Functional Analysis", March 2015, vol. 268, n^o 6, pp. 1309–1381, <https://hal.inria.fr/hal-00875040>
- [3] M. BOSSY, N. MAÏZI, O. POURTALLIER. *Game theory analysis for carbon auction market through electricity market coupling*, in "Commodities, Energy and Environmental Finance", M. LUDKOVSKI, R. SIRCAR, R. AID (editors), Fields Institute Communications, Springer, 2015, vol. 74, pp. 335-370 [DOI : 10.1007/978-1-4939-2733-3_13], <https://hal-mines-paristech.archives-ouvertes.fr/hal-01162832>
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- [5] N. CHAMPAGNAT, D. VILLEMONAIS. *Exponential convergence to quasi-stationary distribution and Q-process*, in "Probability Theory and Related Fields", 2016, vol. 164, n^o 1, pp. 243-283, 46 pages [DOI : 10.1007/s00440-014-0611-7], <https://hal.archives-ouvertes.fr/hal-00973509>
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- [14] M. L. BHALALI, C. HENRY, B. CARISSIMO. *On the Well-Mixed Condition and Consistency Issues in Hybrid Eulerian/Lagrangian Stochastic Models of Dispersion*, in "Boundary-Layer Meteorology", October 2019 [DOI : 10.1007/s10546-019-00486-9], <https://hal.inria.fr/hal-02374779>
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