RESEARCH CENTRE

Inria Nancy - Grand Est Center

IN PARTNERSHIP WITH:

Université de Lorraine, CNRS

2022

ACTIVITY REPORT

Project-Team

PASTA

Space-time random processes and applications

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

DOMAIN

Applied Mathematics, Computation and Simulation

THEME

Stochastic approaches

Inria

Contents

Project-Team PASTA

Creation of the Project-Team: 2020 December 01

Keywords

Computer sciences and digital sciences

A6.1.2. – Stochastic Modeling

A6.2.2. – Numerical probability

A6.2.3. – Probabilistic methods

A6.2.4. – Statistical methods

A6.3.3. – Data processing

Other research topics and application domains

B3.3.1. – Earth and subsoil

B3.4.1. – Natural risks

B9.6.3. – Economy, Finance

B9.11. – Risk management

B9.11.1. – Environmental risks

B9.11.2. – Financial risks

1 Team members, visitors, external collaborators

Research Scientists

- Madalina Deaconu [Team leader, INRIA, Researcher, HDR]
- Antoine Lejay [INRIA, Senior Researcher, HDR]

Faculty Members

- Sara Mazzonetto [University of Lorraine, Associate Professor]
- Pascal Moyal [University of Lorraine, Professor, HDR]
- Radu Stoica [University of Lorraine, Professor, HDR]
- Pierre Étoré [GRENOBLE INP, Associate Professor, from Feb 2022 until Aug 2022, On leave, HDR]

PhD Students

- Alexis Anagnostakis [University of Lorraine]
- Jocelyn Begeot [University of Lorraine, ATER]
- Nathan Gillot [University of Lorraine, from Apr 2022 until Sep 2022]
- Thomas Masanet [University of Lorraine, from Sep 2022]
- Thomas Masanet [ENS PARIS-SACLAY, until Aug 2022]
- Christophe Reype [University of Lorraine, until Sep 2022]

Technical Staff

- Katarzyna Adamczyk Chauvat [INRAE, Engineer, until Sep 2022]

Interns and Apprentices

- Gaetano Agazzotti [Mines Nancy, Intern, until Jun 2022]
- Pierre Auburtin [University of Lorraine, Intern, from Apr 2022 until Aug 2022]
- Jean-Armel Bra [LUE University of Lorraine, Intern, from Apr 2022]
- Maxime Charvet [Inria, Intern, from May 2022 until Sep 2022]
- Nasr El-Hamzaoui [Mines Nancy, Intern, from Oct 2022]
- Romain Gout [Inria, Intern, from May 2022]
- Victor Hoffmann [Mines Nancy, Intern, from Sep 2022]
- Audrey Humbert [ANR, Intern, from Apr 2022 until Sep 2022]
- Youssef Mabrouk [Mines Nancy, Intern, from Oct 2022]
- Zakaria Magdoul [Mines Nancy, Intern, from Oct 2022]
- Arthur Tornqvist [Mines Nancy, Intern, from Oct 2022]

Administrative Assistant

- Isabelle Blanchard [INRIA]

Visiting Scientist

- Lucian Beznea [IMAR, Bucharest, from Jul 2022 until Jul 2022]

External Collaborator

- Lionel Lenôtre [UHA]

2 Overall objectives

PASTA is a joint research team between Inria - Nancy Grand Est, CNRS and University of Lorraine, located at Institut Élie Cartan of Lorraine.

PASTA aims to construct and develop new methods and techniques by promoting and interweaving stochastic modeling and statistical tools to integrate, analyze and enhance real data.

The specificity and the identity of PASTA are:

- the embedding of spatio-temporal statistics and stochastic process analysis into models to tackle challenging complex problems that require new mathematical techniques, by combining the strengths of these two scientific domains.
- to deal with the increase of available data, the construction of suitable models which incorporate prior knowledge on their spatio-temporal structures. For this, we design and analyze simulation and inference techniques, and focus on the interpretation, the validation and the explanation of both the models and the algorithms, in close interaction with practitioners.

The leading direction of our research is to develop the topic of *data enriched* spatio-temporal stochastic models, through a mathematical perspective. Specifically, we jointly leverage major tools of probability and statistics: data analysis and the analytical study of stochastic processes. We aim at exploring the three different aspects, namely: shape, time and environment, of the same phenomenon. These mathematical methodologies will be intended for solving real-life problems through inter-disciplinary and industrial partnerships.

3 Research program

Our research program develops three interwoven axes:

- stochastic modeling,
- simulation algorithms,
- inference and data analysis.

In particular, we are interested in the evolution of stochastic dynamical systems evolving in intricate configuration spaces. These configuration spaces could be spatial positions, graphs, physical spaces with singularities, space of measures, space of chemical compounds, and so on.

While facing a new modeling question, we have to construct the appropriate class of models among what we call the *meta-models*. Meta-models and then models are selected according to the properties to be simulated or inferred as well as the objectives to be reached. Among other examples of such meta-models which we regularly use, let us mention *Markov processes* (diffusion, jump, branching processes), *Gibbs measures*, and *random graphs*. On these topics, the team has an intensive research experience from different perspectives.

Finding the balance between usability, interpretability and realism is our first guide. This is the keystone in modeling, and the main difference with black-box approaches in machine learning. Our second guide is to study the related mathematical issues in modeling, simulation and inference. Models are sources of interesting open mathematical questions. We are eager to expand the “capacity” of the models by exploring their mathematical properties, providing simulation algorithms or proposing more efficient ones, as well as new inference procedures with statistical guarantees.

To study and apply the class of stochastic models we have to handle the following questions:

- *modeling*: identifying the quantities of interest, the nature of the randomness, the nature of their dynamical evolution and the useful variables. Finally, we have to specify the statistical properties of the stochastic process at stake: Markov or long-range dependency, time/space-stationarity or transience, integrability, and so on.
- *stochastic analysis*: providing rigorous tools to study the model and evaluating its characteristics in steady state or in transient regime (hitting times of a given state, rare events, etc.).
- *simulation*: this is an important tool to understand the behavior of random systems, but also to solve deterministic problems such as Partial Differential Equations or, in inference, to overcome limitations due to intractable quantities. We then consider open and challenging problems such as considering singular diffusion problems, accurate hitting times simulations, simulation of complex stochastic processes as well as extending perfect simulation and adapted MCMC (Monte Carlo Markov Chain) algorithms. Rigorously proving the amenability of such algorithms for their use in statistical inference is important for their practical applications.
- *inference*: specifying tools to evaluate the model under study in a parametric or non-parametric setting in the appropriate context (frequentist or Bayesian), developing the suitable numerical methods (stochastic algorithms, MCMC) and control the quality of the estimation.

4 Application domains

Our main application domains are: insurance, geophysics, geology, medicine, astronomy and finance.

We aim at providing new tools regarding the modeling, simulation and inference of spatio-temporal stochastic processes and other dynamical random systems living in large state-spaces. As such, there are many application domains which we consider.

In particular, we have partnerships with practitioners in: cosmology, geophysics, healthcare systems, insurance, and telecom networks.

We detail below our actions in the most representative application domains.

4.1 Geophysics

Geophysics is a domain which requires the application of a broad range of mathematical tools related to probability and statistics while more and more data are collected. There are several directions in which we develop our methodology in relation with practitioners in the field.

- Avalanches (snow or rock) present intricate dynamical properties, with a wide variety of behaviors that largely depend on their environments. To model such phenomena, we apply tools from fragmentation theory, stochastic calculus, partial differential equations and branching processes. Our approach is new and paves the way to considering and constructing rigorous mathematical models and simulation procedures able to reproduce and control the real phenomenon by introducing more and more issues in the models.
- Understanding the behavior of subsurface and surface fluids is a major challenge in geophysics. We deal with two main axes: (1) using tools for spatial Bayesian statistics which consists in detecting the sources of the various components of fluids from their hydrogeochemical data, and (2) developing the suitable methodological and numerical tools to simulate diffusion processes (pollutant, water...) moving in heterogenous media in the presence of interfaces.
- Earthquake forecasting is notoriously difficult. To grasp the statistical distribution of seismic hazards, we consider setting up tools to detect seismic faults using marked point processes. Such a project presents challenging aspects concerning both the inference and the simulation of the processes.

On such topics, we hold long standing interdisciplinary collaborations with INRAE Grenoble, the RING Team (GeoRessources, University of Lorraine), IMAR (Institute of Mathematics of the Romanian Academy) in Bucharest. We also have the support of the interdisciplinary LUE Deepsurf project (University of Lorraine).

4.2 Astronomy and cosmology

We have longstanding and continuous cooperation with astronomers and cosmologists in France, Spain and Estonia. In particular, we are interested in using spatial statistics tools to detect galaxies and other star patterns such as filaments detection. Such developments require to design specific point processes giving appropriate morpho-statistical distributions, as well as specific inference algorithms which are based on Monte Carlo simulations and able to handle the large volume of data.

4.3 Complex systems for healthcare, insurance, social networks and telecomnunication networks

Graphs are essential to model complex systems such as the relations between agents, the spatial distribution of points that are connected such as stars, the connections in telecommunication networks, and so on. We develop various directions of the study of random graphs that are motivated by a large class of applications:

- The success of organ transplant operations depends on their capacity to comply in real time, with sharp compatibility constraints. Here, vertices represents at any given time receivers and donors, while edges represent compatilities. To improve the quality of such life-saving medical acts, we work on the optimization and control of organ transplant systems by stochastic matching models, namely, queueing models in which elements are matched in real time, following prescribed compatibility constraints.

- The modeling of epidemics, viruses on computer networks and message percolation on large social networks can be addressed using "large graph asymptotic" of random graphs. In particular, we work on Markov exploration algorithms on large Configuration Model graphs, to propose weak, but tractable approximations of such propagation phenomena on large networks.

- We have longstanding collaborations in the domain of performance analysis of telecommunication networks. In particular, we have pursued an intensive research activity on the modeling and analysis of queuing systems with reneging with applications to real-time networking; on the performance analysis of parallel service systems, which are a natural model for server farms and call centers, and the large-network analysis of CDMA-type (Code Division Multiple Access) communication protocols, using random graph modeling (representing the spatial interactions between agents). Telecomnunication and peer-to-peer networks are now completed by the rise of small connected devices and the need to provide appropriate and reliable communication protocols. We also recently moved toward ad-hoc networking and the Internet of Things (IoT). Using graph and game theory techniques, we aim at a proper definition, and dynamical analysis, of the notion of *trust* between agents of these networks.

- Using random field models on graphs, we have considered the simulation and inference of the relations between bibliographical data related to scientific literature. This provides us with an application of our techniques in the field of dynamical evolution of networks.

- We study the spatial distribution of random T-tessellation with the aim of providing models for agricultural parcels. Again, such a problem presents challenging aspects both for simulation and inference.

- Finally, we consider personalized recommendation systems for insurance which are based on life events, using self-excited processes.

We have longstanding collaborations on these topics with Agence de Biomédecine (ABM), Le Foyer (insurance company, Luxembourg), INRAE (Avignon), Dyogene (Inria Paris), Lip 6, UTC, LORIA (computer science laboratory, Nancy), University of Buenos Aires, Northwestern University and LAAS (CNRS, Toulouse).

5 New results

5.1 Modeling, simulation and inference: Fragmentation equation

Participants: Gaetano Agazzotti, Jean Armel Bra, Madalina Deaconu, Antoine Lejay.

We have a strong interest in the fragmentation equation for understanding snow or rock avalanches. Our point of view is to explore the probabilistic representations of transport equations in this framework as well as the possibilities they offer. We developed a stochastic process that represents the typical evolution of the mass of a rock or of a snow aggregate subject to successive random breakages.

In particular, we have studied from analytic viewpoint the size of a population with a fixed rate of fragmentation, as well as models with a diffusion in space and a fragmentation in size [35].

We have also set-up a preliminary program toward the use of neural networks to recover the fragmentation rate and the fragmentation kernel from data using deep recurrent neural networks.

Furthermore, we obtained new results with Oana Lupaşcu-Stamate (Institute of Mathematical Statistics and Applied Mathematics, Bucharest) for a binary coagulation-fragmentation equation which describes the avalanches phenomena. We use tools from self-organized critical systems and construct an adapted stochastic process for this phenomenon. We obtain in particular the asymptotic behaviour of the stochastic process and develop a numerical method in order to approximate the solution [28].

5.2 Modeling, simulation and inference: Hawkes process

Participants: Madalina Deaconu, Antoine Lejay, Laurent Lesage.

Hawkes processes represent a common class of self-excited stochastic processes.

We have studied the use of Hawkes processes in the context of insurance. In particular, we built a recommendation system for insurance products based on individual probabilities of life events. This system was successfully tested on the database from the insurance company Le Foyer (Luxembourg) [24] and it is now used by the company. Other applications of Hawkes processes in insurance have also been studied by introducing and developing the study of multi-variate Hawkes processes [17].

5.3 Modeling and simulation: Hitting times for stochastic differential equations

Participants: Madalina Deaconu.

The numerical approximation of stochastic differential equations (SDEs) and in particular new methodologies to approximate hitting times of SDEs is a challenging problem which is important for a large class of practical issues such as: geophysics, finance, insurance, biology, etc.

With Samuel Herrmann (University of Burgundy) we made important progress on this topic by developing new methods. Recently we introduced methods for the strong convergence and pathwise approximation of one-dimensional SDEs.

In particular, we develop new techniques for the path approximation of Bessel processes of arbitrary dimension, as such a process represents the norm of a multi-dimensional Brownian motion [13]. These are part of the family of the so-called ε-strong approximations. Our approach constructs jointly the sequences of exit times and corresponding exit positions of some well-chosen domains, the construction of these domains being an important step. We construct the algorithm for any dimension and treat separately the integer dimension case and the non integer framework, each situation requiring appropriate techniques. We prove the convergence of the scheme and provide the control of the efficiency with respect to the parameter ε. We expand the theoretical part by a series of numerical developments.

Together with Samuel Herrmann (University of Burgundy) and Cristina Zucca (University of Torino) we pursue our work on the exact simulation of the hitting times of multi-dimensional diffusions.

5.4 Inference: Sticky Brownian motion

Participants: Alexis Anagnostakis, Antoine Lejay.

With Denis Villemonais (IECL, University of Lorraine), we constructed an estimator of the stickyness parameter of the sticky Brownian motion and other general diffusion processes from high frequency observations. This work is based on the construction of suitable estimators for the local time and the occupation time. Besides, this work provides a construction of sticky stochastic differential equations [22, 26, 11].

5.5 Modeling: Rough invariant embedding

Participants: Antoine Lejay.

With Renaud Marty (IECL, University of Lorraine), we are studying an invariant embedding problem, which consists in solving a differential equation whose initial and terminal conditions are linked by a linear relation. Using tools from rough paths an global analysis theories, we consider Rough Differential Equations which extend ordinary differential equations driven by rough signals. In particular, we use our development in the context of equations driven by a Brownian motion while avoiding all the difficulties related to the use of anticipative stochastic calculus [29].

5.6 Inference: expansion of the maximum likelihood estimator

Participants: Antoine Lejay, Sara Mazzonetto.

We are studying an expansion of the maximum likelihood estimator using formal series expansions. The aim of this work is to understand the lack of Gaussianity in the non-asymptotic regime [30]. We apply this expansion to the estimator of the skewness parameter of a skew Brownian motion, whose asymptotic mixed normality is also proved with a rate of convergence of order $1/4$ unlike the usual cases where it is of order $1/2$.

5.7 Inference: self exciting threshold model

Participants: Sara Mazzonetto.

In collaboration with Paolo Pigato (University Tor Vergata, Roma) we previously studied parameter estimation for the linear drift of the self Vasicek model which follows a several-regime Ornstein-Uhlenbeck dynamic. The model fits well the behavior in financial markets related to crisis periods. In addition, in the case of two regimes, we provided a test for detecting the change in the regime. These results, improved with respect to the ones of last year (given only for two regimes) are contained in [32].

After considering high frequency observations, we study new estimators for low frequency observations and the presence of several regimes for different threshold models which show mean-reversions features. This work is in progress.

5.8 Modeling and simulation: stochastic matching models and service systems

Participants: Jocelyn Begeot, Thomas Masanet, Pascal Moyal.

We have made the following advances regarding stochastic matching models:

In [31] we have constructed an original perfect sampling algorithm for CTMC's under a given control condition. This condition is reminiscent of the so-called "Dominated coupling from the past" (DCFTP) of Kendall et al. With this algorithm we are able to perfectly simulate the stationary state of stochastic matching models with reneging, allowing to estimate, by Monte Carlo techniques, the loss probability at equilibrium under various matching policies, a result that have crucial applications in practice, for instance for organ transplants models, which are subject to heavy time constraints.

In [18], with Jean Mairesse (CNRS/Lip6), we build a research program on the general topic of stochastic matching models with reneging, by proposing a new approach of this class of models, generating additional, fictional, classes in the compatibility graph, to account for the balking of items.

In the thesis of Jocelyn Begeot [23], we build on a previous article [36] to obtain an explicit characterization of the stability regions of a wide class of stochastic matching models and skill-based queueing systems.

In [19], with Ohad Perry (Northwestern University) we draw a research program on the essential aspect of correlations of patience times and service times in service systems. To model this, we propose a measure-valued Markov modeling to address services systems with reneging, to account for the correlation between the patience times of the tasks and their service times. This is a theoretically tedious, but essential, task for practical purposes, as most models proposed in the literature address *independent* patience and service times.

5.9 Modeling and simulation: Trust modeling and management in the Internet of Things

Participants: Pascal Moyal.

In the article [21] we propose a first modeling of the Trustworthiness in the IOT by game-theoretical approaches, in the presence of intelligent and malicious intrusions. Our construction is based in a dynamic phase-based modeling of the behavior of malicious nodes.

Following this line of thought, in the submitted papers [34, 19], we propose a framework for extensive simulations of concrete networks, showing the efficiency of our trust allocation management algorithm, based on game theory.

5.10 Modeling and simulation: Dynamics on large random graphs

Participants: Pascal Moyal.

In [12] with Mohamed Habib Diallo Aoudi and Vincent Robin (University of Technology of Compiègne), we obtain a large graph estimate of the matching coverage of local matching algorithms (greedy and minimal residual) on large bipartite random graphs constructed by the configuration model. We proceed by deriving the hydrodynamic limit, in the large-graph asymptotic, of a measure-valued Markov process representing the exploration of the graph together with its sequential construction. We are currently completing a second paper including the proof of convergence (in spaces of measure-valued processes) to the hydrodynamic limit, for general, non-necessarily bipartite, graphs, and for a large class of matching algorithms.

In an ongoing collaboration with Matthieu Jonckheere and Nahuel Soprano-Loto (CNRs/LAAS), we address the question of maximal marriages on the stochastic block model (SBM), in the large graph asymptotic. Here again, we proceed by a sequential construction of the graph, coupled with its exploration, and propose, under certain explicit feasibility condition on the connectivity matrix of the SBM, a matching algorithm that is able to achieve, infinitely often with probability 1, a perfect marriage. A draft is in preparation and will be submitted shortly for publication.

5.11 An interaction point process for Bayesian detection of multiple sources in groundwaters from hydrochemical data

Participants: Madalina Deaconu, Christophe Reype, Radu Stoica.

Detecting the number and composition of multiple sources in groundwaters from hydrochemical data has remained highly challenging. In this work we develop a new interaction point process that integrates geological knowledge for the purpose of automatic sources detection of multiple sources in groundwaters from hydrochemical data. The key assumption of this approach is to consider the unknown sources to be the realization of a point process. The probability density describing the sources distribution is built in order to take into account the multidimensional nature of the data and specific physical rules. The method was first calibrated on synthetic data and then tested on real data from geothermal and ore-forming hydrothermal systems [33], [25].

This work is a collaboration with Antonin Richard (University of Lorraine, GeoRessources).

5.12 Minimizing peculiar velocity catalog biases with point process modeling and Bayesian inference

Participants: Radu Stoica.

Galaxy peculiar velocities are excellent cosmological probes provided that biases inherent to their measurements are contained before any study. We propose a new algorithm based on an object point process model whose probability density is built to minimize the effects of Malmquist biases and uncertainties due to lognormal errors in radial peculiar velocity catalogs. The resulting configurations are bias-minimized catalogs. Tests are conducted on synthetic catalogs mimicking the second and third distance modulus catalogs of the Cosmicflows project, and then on observational catalogs. The large scale structure reconstructed with the Wiener filter technique applied to the bias-minimized observational catalogs matches with great success the local Universe cosmic web as depicted by redshift surveys of local galaxies. These new bias-minimized versions of Cosmicflows catalogs can now be used as a starting point for several studies including the production of simulations constrained to reproduce the local Universe.

This work is a collaboration with Jenny Sorce (CNRS Cristal - Lille) and Elmo Tempel (Tartu Observatory - University of Tartu).

5.13 Spatio-temporal modelling of the spread of Armillaria Ostoyae: a fungus in coniferous forests

Participants: Katarzyna Adamczyk Chauvat, Nathan Gillot, Radu Stoica.

Economic forests represent today an important part of the wood production on a global scale. Measuring and understanding the impact of diseases that occur in this type of forest with a very low variety of species is therefore an economic matter today. Our interest is focused on a parasitic fungus impacting coniferous forests, Armillaria Ostoyae.

The approach consists in considering a Markovian model with multiple labels on a lattice of the same size as the data, a Potts-type model: each tree will have a life span and a spatial neighborhood. We use statistical inference techniques, both classical (pseudo-likelihood) and recent (ABC methods: ABC Shadow), which we apply to a 20-year dataset.

5.14 Two dimensional seismic fault network interpretation using marked point processes

Participants: Radu Stoica.

Seismic fault interpretation is an important input to subsurface models. Since in seismic images the dominant features are reflection events corresponding to horizons, fault interpretation can be achieved by computing a fault probability image. We aim at quantifying the uncertainties related to the number and connectivity of faults honoring a given probability image, as all the possible fault networks can yield different outcomes in terms of subsurface behavior (*e.g.,* reservoir flow). Fault networks are seen as realization of marked-point processes whose density are defined by an energy function. We use a simulated annealing framework based on Metropolis-Hastings algorithms, which makes it possible to find the global maximum of the probability density, built in the form of a Gibbs density. We apply the proposed approach to a 2-D seismic cross-section extracted from the Volve seismic cube (provided by Equinor).

This work is a collaboration with Fabrice Taty-Moukati, François Bonneau, Guillaume Caumon (University of Lorraine, GeoRessources) and Xinming Wu (University of Science and Technology of China, Hefei).

5.15 Statistical analysis and stochastic simulation of fracture networks

Participants: Radu Stoica.

Fracture networks (FN) are systems of complex mechanical discontinuities in rocks. They dramatically impact fluid flow acting as a drain or a barrier. With François Bonneau (University of Lorraine, Georessources), we propose to use marked-point processes to build a stochastic mathematical model for fracture characterization and to approximate FN with a collection of marked-points standing for straight-line segment with a record of the length and the strike azimuth of the horizon. Geologists usually use a characterization workflow integrating density or mark distributions, which are first-order metrics, to describe the number and the geometry of fractures. Recently, second-order characteristics have been used to characterize FN's inner correlation and spatial variability. We then investigate stochastic models whose realizations reproduce the first and second order characteristics of the observations. This work may open the path to a thinner classification of FN and to predictive stochastic simulations.

5.16 Modeling and inference: Estimation of singular diffusions

Participants: Alexis Anagnostakis, Pierre Etoré, Sara Mazzonetto.

We are extending our respective results on high frequency approximation of the local time of oscillating-skew-sticky diffusion processes. The purpose is to estimate the parameters of stickiness and skewness separately and to model some critical behavior in financial markets related to crisis periods. We managed to extend the results obtained during the PhD thesis of Alexis Anagnostakis in the context of sticky BM to more general estimators of local time and to oscillating-skew-sticky Brownian motion. Our goal is to reach rates of convergence obtained in [37]. We are also dealing with the different problem non-uniqueness of solutions in this context.

5.17 Modeling and simulation: Navier-Stokes equation - stochastic modeling

Participants: Madalina Deaconu.

With Lucian Beznea (IMAR, Bucharest) and Oana Lupaşcu-Stamate (Institute of Mathematical Statistics and Applied Mathematics, Bucharest) we are developing a stochastic approach for the two-dimensional Navier-Stokes equation in a bounded domain. More precisely we consider the vorticity equation and construct a specific non-local branching process. This approach is new and can conduct to important advances as it will give also a new numerical algorithm if successful.

In particular, we obtained several results concerning the construction of a duality - time reversal process and also in the development of a numerical algorithm with a non-local branching process involving creation and disapearance of particles that mimic the physics of the vorticity in the boundary layer.

6 Partnerships and cooperations

6.1 International initiatives

6.1.1 Participation in other International Programs

Participants: Antoine Lejay, Pascal Moyal.

Title: Biostochastic Research Network

Funding: Conicyt Chile

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 (coordinator for France), D. Villemonnais, R. Schott.

Duration: April 2018 - April 2022

Goal: scientific exchange around probabilistic models in population ecology.

Title: EnhanceD Data stream Analysis (EDDA)

Program: ANR call IA ANR-DFG-JST

International Partner (Institution - Laboratory - Researcher): Japan Agency for Marine-Earth Science and Technology (Japan) University of Greifswald (Germany) CNRS, Inria & IECL - Institut Élie Cartan de Lorraine (France) - M. Clausel (coordinator for France), A. Lejay.

Duration: Dec 2019 - Dec 2022

Goal: Develop new machine learning techniques based on signature methods and iterated integrals.

Title: Matching architectures that connect heterogeneous users and efficient healthcare systems (MATCHES)

Program: ANR PRC

International Partner (Institution - Laboratory - Researcher): Northwestern University (USA) UC London Business School (UK) University of Buenos Aires (Argentina) Agence de la Biomédecine, Lip 6, LORIA, UTC & IECL - Institut Élie Cartan de Lorraine (France) - P. Moyal (coordinator).

Duration: Nov 2018 - Apr 2023

Goal: Stochastic analysis, optimization and control of matching algorithms on graphs, connecting incoming users under random traffic constraints. Applications to Healthcare systems, organ transplants, peer-to-peer networking and collaborative economy.

6.2 International research visitors

6.2.1 Visits of international scientists

Other international visits to the team

Lucian Beznea

Status researcher

Institution of origin: IMAR, Bucharest

Country: Romania

Dates: July 2022

Context of the visit: Invited Professor at University of Lorraine

Mobility program/type of mobility: research stay

Oana Lupaşcu-Stamate

Status researcher

Institution of origin: ISMA

Country: Romania

Dates: 30 June - 9 July, 2022

Context of the visit: scientific collaboration

Mobility program/type of mobility: research stay

6.3 National initiatives

Participants: Alexis Anagnostakis, Madalina Deaconu, Antoine Lejay, Sara Mazzonetto.

- Since October 2020, M. Deaconu is developing with S. Herrmann (University of Burgundy) and C. Zucca (University of Torino), a BQR project, funded by the University of Burgundy, on the *Exact simulation of the exit time of a bounded domain for a random process*.
- Projet Innovant et Risqué (PIR) on *Parallélisation Simplifiée de Méthodes de Monte-Carlo Complexes* (Simplified Parallelization on Monte Carlo methods) was obtained from the University of Haute Alsace by L. Lenôtre and S. Mazzonetto.
- Inria Exploratory Research Action *Apollon*: The goal is to automate the creation of a lexicon of ideas from the Politics of Aristotle. This interdisciplinary project mixes machine learning, history and philology. This project involves the PASTA project-team membres: A. Lejay, S. Mazzonetto, L. Lenôtre (external, Irimas, University of Haute-Alsace) in a collaboration with M.-T. Schettino, A. Pollini, C. Urlacher-Becht (Archimède, University of Haute-Alsace).

7 Dissemination

Participants: Madalina Deaconu, Antoine Lejay, Sara Mazzonetto, Pascal Moyal, Radu Stoica.

7.1 Promoting scientific activities

7.1.1 Scientific events: organisation

General chair, scientific chair

- *INFORMS 2023 Conference*. Pascal Moyal (head).
- *Forum Fédération Charles Hermite*, April 6, 2022. Madalina Deaconu (head).

Member of the organizing committees

- *INFORMS 2023 Conference*. Sara Mazzonetto, Pascal Moyal (Head).
- *Journées de Probabilités 2022*, Obernai, France. Antoine Lejay.
- *TRAG 2022*, Nanterre, 2022. Antoine Lejay.
- Workshop *Singular diffusions: numerical and theoretical aspect*, Nancy, May 2022. Alexis Anagnostakis and Sara Mazzonetto.
- Workshop *ANR MATCHES: Processus d'exploration markoviens sur les grands graphes aléatoires*, Nancy, December 2022, Pascal Moyal (head).

7.1.2 Scientific events: selection

Chair of conference program committees

- Pascal Moyal is the chair of the scientific committee of the forthcoming *INFORMS 2023 Conference*(one of the main conferences in Applied probability - expected 400 participants), to be held in Nancy in June 2023.

Member of the conference program committees

- *INFORMS 2023 Conference* (one of the main conferences in Applied probability - expected 400 participants), to be held in Nancy in June 2023. Madalina Deaconu, Antoine Lejay are members of the scientific committee.
- *Forum Fédération Charles Hermite*, April 6, 2022. Madalina Deaconu (head).
- *Journées de Probabilités 2022*, Obernai, France, June 2022. Antoine Lejay.
- *Spatial Statistics*, Colorado, 2023, Radu Soica.
- *International Association for Mathematical Geosciences - annual conference*, Nancy, 2022, Radu Soica.
- *International Workshop on Spatio-temporal modeling, METMA - Spain, June 2022*, Radu Stoica.

7.1.3 Journal

Member of the editorial boards

- Antoine Lejay is co-editor of *Séminaire de Probabilités*, and associate editor of *Mathematics and Computers in Simulation*.
- Pascal Moyal is associate editor of *Queueing Systems: Theory and Applications*.
- Radu Stoica is associate editor of *Annals of the Institute of Statistical Mathematics* and member of the editorial board of *Spatial Statistics Journal*.

Reviewer - reviewing activities

- Madalina Deaconu wrote reviews for: *Annals of Applied Probability, Methodology and Computing in Applied Probability, Journal of Statistical Physics*, and *Numerical Algorithms NUMA-D*.
- Antoine Lejay wrote reviews for: *Annals of Applied Probability, Annales de l'IHP, probabilités et statistique, Applied Probability Journals, Discrete and Continuous Dynamical Systems Series B, Financial Innovation, Journal of Mathematical Analysis and Applications, Physical Review Letters*, and *Transactions on Modeling and Computer Simulation*.
- Sara Mazzonetto wrote reviews for: *Journal of Computational and Applied Mathematics* and *ESAIM: P&S*.
- Pascal Moyal wrote reviews for: *Annals of Applied Probability, Queueing systems: Theory and applications, Operations Research, Stochastic processes and their applications* and *Mathematics of Operations research*.
- Radu Stoica wrote reviews for: *Annals of the Institute of Statistical Mathematics, Spatial Statistics Journal*.

7.1.4 Invited talks

- Madalina Deaconu was invited as a *Keynote speaker* in the *École 2022 du GdR MathGeoPhy*, Paris, October 2022. Madalina Deaconu gave an invited talk at *The 23rd Conference of the Romanian Society of Probability and Statistics* (IMAR Bucharest, November 2022).
- Antoine Lejay gave talks at the *New Interfaces of Stochastic Analysis and Rough Paths* (BIRMS, Canada, September 2022), *Aida 60* conference (Osaka, Japan, December 2022), *Forum de la Fédération Charles Hermite* (Nancy, April 2022), the *TRAG 2022* conference (Nanterre, May 2022), and the workshop *Singular diffusions: theoretical and numerical aspects* (Nancy, October 2022). He also gave a seminar talk at University of Versailles Saint-Quentin in April 2022.
- Sara Mazzonetto was invited in the session *Advances in statistical inference for continuous-time stochastic processes* of the conference *Third Italian Meeting on Probability and Mathematical Statistics*, Bologna, Italy, June 2022. She was invited at the L^2 Workshop, Luxembourg, September 2022. She also gave a Colloquium at the University of Maynooth (Ireland) in April 2022, and seminars in Lyon 1 University in January 2022 and at LJK in Grenoble in November 2022.
- Pascal Moyal gave a talk at the *Journée de Probabilités 2022* (Orbey, May 30 - June 2, 2022). He was also invited to give a talk at the *EURO 2022 Conference* (Espoo, Finland - July 3-6, 2022), in a mini-symposium on Stochastic modeling of networks. He gave a talk at the Workshop ANR MATCHES *Processus d'exploration markoviens sur les grands graphes aléatoires* (Nancy, December 6, 2022).
- Radu Stoica gave a talk at *International Workshop on Spatio-temporal Modelling (METMA)*, Spain, June 2022 and he presented a poster at *Applied Mathematics, Scientific Computing, Data Science and Artificial Intelligence (Mathias Days)*, TotalEnergies, (October 2022). He gave seminars talks at University of Toronto (Canadian Statistical Sciences Institute, May 2022), University of Quebec,

Montréal (Dpt. de Sciences de la Terre et de l'Athmosphère, May 2022), University of Alberta (School of Mining and Petroleum Engineering, April 2022), Chalmers University (Mathematical Sciences - Statistics Seminar, April 2022)

7.1.5 Leadership within the scientific community

- Madalina Deaconu is *Deputy Head of Science* at Inria Nancy - Grand Est since January 2022. She is also, at the national level, member of the Evaluation Commission of Inria.

  Since January 2018, Madalina Deaconu is the *Head* of the Fédération Charles Hermite, a federation of research within CNRS and University of Lorraine, gathering three research laboratories: CRAN (control theory), IECL (mathematics) and LORIA (computer science) with the goal of creating interdisciplinary projects and partnerships with industry.

  She is also *member of the IECL Laboratory Council*, and of the *Conseil de Pôle AM2I*, University of Lorraine (2018-2022).

  At the national level she is *member of the Scientific Committee* of the CNRS *GdR MathGéoPhys* in mathematics in interaction with geophysics.

- Antoine Lejay is Head of the *GdR TRAG* (INSMI-CNRS). He is also member of the board the AMIES and of the executive committee of Impact *LUE Digitrust* project (University of Lorraine). He is also representative of IECL for program submission on *Interactions: Humans and Sytems in a Digital World* for the LUE (Lorraine Université d'Excellence) call for 2023-2028.

  He was also the Head of the *Probability and Statistics team* of IECL up to October 2022.

- Sara Mazzonetto is a member of the Committee of Equal Opportunities of IECL.

- Pascal Moyal is Head of the Probability and Statistics team at IECL (2022-). As such, he is member of the Laboratory Council of IECL.

  He is also the Head of the Master 2 *Ingénierie Mathématique et Sciences des Données* at University of Lorraine.

- Radu Stoica is elected member of the Council of the *Collégium Technologie* of University of Lorraine from 2022 and of the Council and of the Restricted Council at IUT Charlemagne (University of Lorraine) from 2016. He is member of the *International Strategy Think Tank* of University of Lorraine from 2022, and in charge of the international relations of IECL from 2018. He is also appointed member of the *IECL Laboratory Council* from 2018, and member of the COMEX of the Impact *LUE Deepsurf* project from 2020 (University of Lorraine).

7.2 Teaching - Supervision - Juries

7.2.1 Teaching

Sara Mazzonetto is assistant professor, Pascal Moyal and Radu Stoica are professors. They have full teaching duties with lectures at all the levels of the university. We mention here only lectures at Master 1 and Master 2 levels as well as responsabilities.

- Madalina Deaconu, *Stochastic Modeling*, 30h, M2, Master IMSD, University of Lorraine.
- Madalina Deaconu, *Monte Carlo Simulation*, 24h, M1, Financial Mathematical Engineering, University of Lorraine.
- Madalina Deaconu, *Random Variable simulation*, 12h, M1, École des Mines de Nancy, University of Lorraine.
- Antoine Lejay, *Simulation des marchés financiers*, 29h, M2, Master PSA, University of Lorraine.
- Antoine Lejay, *Financial mathematics*, 18h, M2, Master IMSD, University of Lorraine.
- Sara Mazzonetto, *Statistics*, 22h, M1, ENSEM, Universiy of Lorraine.

- Sara Mazzonetto, *Probability and Statistics*, 40h, M1, Master IMSD and MFA, Universiy of Lorraine.
- Pascal Moyal is the head of the Master M2 IMSD *Ingénierie Mathématique et Science des Données* (University of Lorraine).
- Pascal Moyal, *Financial mathematics*, 25h, M2, Master IMSD, University of Lorraine.
- Pascal Moyal, *Stochastic financial modeling*, 45h, M2, Master IMSD, University of Lorraine.
- Pascal Moyal, *Stochastic networks*, 20h, M2, Master IMSD, University of Lorraine.
- Pascal Moyal, *Applied linear algebra*, 25h, M1, Master IMSD, University of Lorraine.
- Radu Stoica, *Simulation and Inference via Monte Carlo Methods*, 28h, M1, Master IMSD, University of Lorraine.
- Radu Stoica, *Spatial Statistics and Bayesian Inference*, 36h, M2, Master IMSD, University of Lorraine.

7.2.2 Supervision

The following PhD have been defended in 2022:

- *PhD (defended)*: Alexis Anagnostakis, Étude du mouvement brownien collant, University of Lorraine, defended in October 2022, University of Lorraine grant, Antoine Lejay and Denis Villemonais. [22]
- *PhD (defended)*: Jocelyn Begeot, Perfect simulation of infinite-state space Markov chains, University of Lorraine, defended in December 2022, University of Lorraine grant, Irène Marcovici and Pascal Moyal. [23]
- *PhD (defended)*: Laurent Lesage, Data Analysis for Insurance, University of Luxembourg and University of Lorraine, defended in April 2022, funding Le Foyer, Madalina Deaconu and Radu State. [24]
- *PhD (defended)*: Christophe Reype, Simultaneous parameter estimation and pattern detection in spatial data. Applications to the analysis of the dynamic in multi-component fluid mixtures in Geology, University of Lorraine, defended in December 2022, LUE grant, Madalina Deaconu and Radu Stoica. [25]

Regarding the PhD in progress:

- *PhD in progress*: Mohamed Habib Diallo Aoudi, Online Coupling algorithm in large random graph, University of Technology of Compiègne, January 2018, funding LMAC, Pascal Moyal and Vincent Robin.
- *PhD in progress*: Nathan Gillot, Modèles et algorithmes pour l'apprentissage statistique de processus ponctuels spatio-temporels marqués. Application : analyse et caractérisation de données cosmologiques caractérisation des données cosmologiques, September 2022, funding University of Lorraine, Radu Stoica.
- *PhD in progress*: Thomas Masanet, Stochastic matching models with impatience, and applications to organ transplant networks, University of Lorraine, October 2019, grant ANR / Région Grand Est, Christian Jacquelinet and Pascal Moyal.
- *PhD in progress*: Runbo Su, Mathematical modeling of the trust relationship in the Internet of Things, University of Lorraine, October 2020, funding ANR / Fédération Charles Hermite / LORIA, Pascal Moyal, Enrico Natalizio and Ye-Qiong Song.
- *PhD in progress*: Fabrice Taty-Moukati, Stochastic seismic structural interpretation of geological faults, University of Lorraine, March 2021, RING grant, Guillaume Caumon and Radu Stoica.
- *PhD in progress*: Amandine Fratani, Interpretation of seismic faults by graph-based machine learning., University of Lorraine, November 2022, RING grant, Guillaume Caumon and Radu Stoica.

7.2.3 Juries

- Hiring Committee for CRCN and ISFP positions (permanent researchers) at Inria Nancy - Grand Est 2020 & 2022 (Deputy Head), Madalina Deaconu.
- Hiring Committee for CRCN and ISFP positions (permanent researchers) at Inria Paris 2022, Madalina Deaconu.
- Hiring Committee for a professorship position, University of Lorraine, IECL, 2021 (Head) & 2022. Antoine Lejay.
- Hiring Committee for a professorship position, University of Lorraine, IECL, 2021 & 2022 (Deputy Head). Pascal Moyal.
- Jury's member for the HDR of Lionel Cucala (University of Montpellier), 2022. Radu Stoica.

7.3 Popularization

7.3.1 Internal or external Inria responsibilities

- Antoine Lejay is editor in chief of the *Success stories* (2 pages presentation of a successful industrial collaboration, Agence Mathématiques en Entreprises et Interactions (AMIES) and Fondation Sciences Mathématiques de Paris).
- Sara Mazzonetto was in the committee of the TFJM^2 (*Tournoi Français des Jeunes Mathématiciennes et Mathématiciens*) in Nancy, 2022.

7.3.2 Articles and contents

- Sara Mazzonetto and Alexis Anagnostakis interview for Inria on BOUM project from SMAI.
- Sara Mazzonetto released an interview in the occasion of the Research weak of University of Lorraine.

8 Scientific production

8.1 Major publications

[1] L. Beznea, M. Deaconu and O. Lupascu. 'Stochastic equation of fragmentation and branching processes related to avalanches'. In: *Journal of Statistical Physics* 162.4 (8th Feb. 2016), pp. 824–841. DOI: 10.1007/s10955-015-1432-5. URL: https://hal.inria.fr/hal-01216137.

[2] M. Deaconu and S. Herrmann. 'Initial-boundary value problem for the heat equation - A stochastic algorithm'. In: *Annals of Applied Probability* 28.3 (2018), pp. 1943–1976. DOI: 10.1214/17-AAP1348. URL: https://hal.archives-ouvertes.fr/hal-01380365.

[3] A. Hudde, M. Hutzenthaler and S. Mazzonetto. 'A stochastic Gronwall inequality and applications to moments, strong completeness, strong local Lipschitz continuity, and perturbations'. In: *Annales de l'Institut Henri Poincaré, Probabilités et Statistiques* 57.2 (1st May 2021). DOI: 10.1214/20-AIHP1064. URL: https://hal.archives-ouvertes.fr/hal-03293250.

[4] A. Lejay. 'Constructing general rough differential equations through flow approximations'. In: *Electronic Journal of Probability* 27 (2021), pp. 1–24. DOI: 10.1214/21-EJP717. URL: https://hal.inria.fr/hal-02871886.

[5] A. Lejay and P. Pigato. 'Statistical estimation of the Oscillating Brownian Motion'. In: *Bernoulli* 24.4B (2018), pp. 3568–3602. DOI: 10.3150/17-BEJ969. URL: https://hal.archives-ouvertes.fr/hal-01430794.

[6] S. Mazzonetto. *Rates of convergence to the local time of Oscillating and Skew Brownian Motions*. 6th Oct. 2021. URL: https://hal.archives-ouvertes.fr/hal-03367822.

[7] P. Moyal, A. Bušić and J. Mairesse. 'A product form for the general stochastic matching model'. In: *Journal of Applied Probability* 58.2 (June 2021), pp. 449–468. DOI: 10.1017/jpr.2020.100. URL: https://hal.archives-ouvertes.fr/hal-03294756.

[8] Y. Rahme and P. Moyal. 'A stochastic matching model on hypergraphs'. In: *Advances in Applied Probability* 53.4 (2021), pp. 951–980. DOI: 10.1017/apr.2021.8. URL: https://hal.archives-ouvertes.fr/hal-03294780.

[9] C. Reype, A. Richard, M. Deaconu and R. S. Stoica. 'Bayesian statistical analysis of hydrogeochemical data using point processes: a new tool for source detection in multicomponent fluid mixtures'. In: RING Meeting 2020. Nancy, France, 7th Sept. 2020. URL: https://hal.archives-ouvertes.fr/hal-02933268.

[10] R. Stoica, M. Deaconu, A. Philippe and L. Hurtado-Gil. 'Shadow Simulated Annealing: A new algorithm for approximate Bayesian inference of Gibbs point processes'. In: *Spatial Statistics* (10th Apr. 2021). DOI: 10.1016/j.spasta.2021.100505. URL: https://hal.archives-ouvertes.fr/hal-02183506.

8.2 Publications of the year

International journals

[11] A. Anagnostakis, A. Lejay and D. Villemonais. 'General diffusion processes as the limit of time-space Markov chains'. In: *Annals of Applied Probability* (2023). URL: https://hal.inria.fr/hal-02897819.

[12] M. H. A. D. Aoudi, P. Moyal and V. Robin. 'Markovian online matching algorithms on large bipartite random graphs'. In: *Methodology and Computing in Applied Probability* 24.4 (Dec. 2022), pp. 3195–3225. DOI: 10.1007/s11009-022-09973-y. URL: https://hal.science/hal-03294781.

[13] M. Deaconu and S. Herrmann. 'Strong approximation of Bessel processes'. In: *Methodology and Computing in Applied Probability* (2022). URL: https://hal.archives-ouvertes.fr/hal-03244538.

[14] M. Jonckheere, P. Moyal, C. Ramírez and N. Soprano-Loto. 'Generalized max-weight policies in stochastic matching'. In: *Stochastic Systems* (2023). DOI: 10.1287/stsy.2022.0098. URL: https://hal.science/hal-03354805.

[15] Q. Laporte-Chabasse, R. S. Stoica, M. Clausel, F. Charoy and G. Oster. 'Morpho-statistical description of networks through graph modelling and Bayesian inference'. In: *IEEE Transactions on Network Science and Engineering* 9.4 (2022), pp. 2123–2138. DOI: 10.1109/TNSE.2022.3155359. URL: https://hal.archives-ouvertes.fr/hal-03744409.

[16] A. Lejay. 'Constructing general rough differential equations through flow approximations'. In: *Electronic Journal of Probability* 27 (2022), pp. 1–24. DOI: 10.1214/21-EJP717. URL: https://hal.inria.fr/hal-02871886.

[17] L. Lesage, M. Deaconu, A. Lejay, J. A. Meira, G. Nichil and R. State. 'Hawkes processes framework with a Gamma density as excitation function: application to natural disasters for insurance'. In: *Methodology and Computing in Applied Probability* (5th Mar. 2022), p. 29. URL: https://hal.inria.fr/hal-03040090.

[18] J. Mairesse and P. Moyal. 'New frontiers for stochastic matching'. In: *Queueing Systems* 100.3-4 (1st Apr. 2022), pp. 473–475. DOI: 10.1007/s11134-022-09832-0. URL: https://hal.science/hal-03561106.

[19] P. Moyal and O. Perry. 'Many-server limits for service systems with dependent service and patience times'. In: *Queueing Systems* 100.3-4 (Apr. 2022), pp. 337–339. DOI: 10.1007/s11134-022-09800-8. URL: https://hal.science/hal-03561126.

[20] P. Moyal and O. Perry. 'Stability of Parallel Server Systems'. In: *Operations Research* 70.4 (2022), pp. 2456–2476. DOI: 10.1287/opre.2021.2125. URL: https://hal.science/hal-03294778.

[21] R. Su, A. R. Sfar, E. Natalizio, P. Moyal and Y.-Q. Song. 'Ensuring Trustworthiness in IoIT/AIoT: A Phase-Based Approach'. In: *IEEE Internet of Things Magazine* 5.2 (June 2022), pp. 84–88. DOI: 10.1109/IOTM.001.2100190. URL: https://hal.archives-ouvertes.fr/hal-03779426.

Doctoral dissertations and habilitation theses

[22] A. Anagnostakis. 'Path-wise study of singular diffusions'. Université de Lorraine, 18th Oct. 2022. URL: https://hal.archives-ouvertes.fr/tel-03846475.

[23] J. Begeot. 'Around the stability of different stochastic matching models'. Université de Lorraine - Faculté des Sciences et Technologies Nancy, 15th Dec. 2022. URL: https://hal.archives-ouvertes.fr/tel-03904844.

[24] L. Lesage. 'Data analysis for insurance : recommendation system based on a Multivariate Hawkes Process'. Université de Lorraine; Université du Luxembourg, 26th Apr. 2022. URL: https://hal.univ-lorraine.fr/tel-03708811.

[25] C. Reype. 'Probabilistic modelling and Bayesian inference for the analysis of geological fluid mixing systems: pattern detection and parameter estimation'. Université de Lorraine, 14th Dec. 2022. URL: https://hal.univ-lorraine.fr/tel-03948912.

Reports & preprints

[26] A. Anagnostakis. *Functional convergence to the local time of sticky diffusions*. 1st Feb. 2022. URL: https://hal.inria.fr/hal-03551808.

[27] E. Besançon, L. Coutin, L. Decreusefond and P. Moyal. *Diffusive limits of Lipschitz functionals of Poisson measures*. 15th Dec. 2022. URL: https://hal.telecom-paris.fr/hal-03283778.

[28] M. Deaconu and O. Lupaşcu-Stamate. *Asymptotic behaviour of a one-dimensional avalanche model through a particular stochastic process*. 20th Dec. 2022. URL: https://hal.inria.fr/hal-03947249.

[29] A. Lejay and R. Marty. *Invariant imbedding and rough differential equations with affine boundary conditions*. 31st Mar. 2022. URL: https://hal.inria.fr/hal-03626402.

[30] A. Lejay and S. Mazzonetto. *Beyond the delta method*. 26th July 2022. URL: https://hal.inria.fr/hal-03738371.

[31] T. Masanet and P. Moyal. *Perfect sampling of stochastic matching models with reneging*. 25th Feb. 2022. URL: https://hal.archives-ouvertes.fr/hal-03580942.

[32] S. Mazzonetto and P. Pigato. *Drift estimation of the threshold Ornstein-Uhlenbeck process from continuous and discrete observations*. 5th June 2022. DOI: 10.5705/ss.202021.0275. URL: https://hal.archives-ouvertes.fr/hal-03293542.

[33] C. Reype, R. S. Stoica, A. Richard and M. Deaconu. *HUG model: an interaction point process for Bayesian detection of multiple sources in groundwaters from hydrochemical data*. 29th July 2022. URL: https://hal.archives-ouvertes.fr/hal-03740280.

[34] R. Su, A. Riahi Sfar, E. Natalizio, P. Moyal and Y.-Q. Song. *Framework and simulation of a phase-based trust management for service-oriented IoT/IIoT*. Loria, 10th Feb. 2022. URL: https://hal.archives-ouvertes.fr/hal-03363098.

Other scientific publications

[35] G. Agazzotti. 'Modélisation des processus de fragmentation à l'aide des processus de branchement'. Ecole des Mines de Nancy, 7th June 2022. URL: https://hal.inria.fr/hal-03708575.

8.3 Cited publications

[36] J. Begeot, I. Marcovici and P. Moyal. *Stability regions of systems with compatibilities, and ubiquitous measures on graphs*. 25th Nov. 2021. URL: https://hal.archives-ouvertes.fr/hal-03450251.

[37] S. Mazzonetto. 'Rates of convergence to the local time of Oscillating and Skew Brownian Motions'. working paper or preprint. Oct. 2021. URL: https://hal.archives-ouvertes.fr/hal-03367822.