RESEARCH CENTRE

Inria Centre at Université de Lorraine

IN PARTNERSHIP WITH:

Université de Lorraine, CNRS

2023 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

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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 [UL, Associate Professor, from Sep 2023, Delegation]
- Pascal Moyal [UL, Professor, from Sep 2023, Delegation, HDR]
- Catherine Roth [UHA, Associate Professor, from Sep 2023, Delegation]
- Radu Stoica [UL, Professor, until Aug 2023, Delegation, HDR]

Post-Doctoral Fellow

- Pierre Mercuriali [INRIA, Post-Doctoral Fellow]

PhD Students

- Jocelyn Begeot [UL, ATER, until Jun 2023]
- Julia Budzinski [INRIA, from Nov 2023]
- Nathan Gillot [UL]
- Thomas Masanet [UL, ATER, until Aug 2023]
- Christophe Reype [UL, ATER]

Technical Staff

- Amélie Ferstler [INRIA, Engineer, from Dec 2023]

Interns and Apprentices

- Saad Jamiri [INRIA, Intern, from Jul 2023 until Sep 2023]
- Saad Jamiri [UL, Intern, from Apr 2023 until May 2023]
- Loic Jean [ENS DE LYON, Intern, from May 2023 until Jun 2023]
- Celia Mazzucotelli-Bertrand [UL, Intern, from May 2023 until Sep 2023]
- Saïd Toubra [INRIA, Intern, from Mar 2023 until Aug 2023]

Administrative Assistant

- Véronique Constant [INRIA]

External Collaborator

- Lionel Lenôtre [UHA]

2 Overall objectives

PASTA is a joint research team between Inria Research Center at Université de Lorraine, CNRS and Université de Lorraine, located at Institut Élie Cartan de 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.

When 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 controlling 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 controlling the quality of the estimation.

4 Application domains

Our main application domains are: economy, geophysics, medicine, astronomy and digital humanities.

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, Université de Lorraine), IMAR (Institute of Mathematics of the Romanian Academy) in Bucharest.

4.2 Astronomy

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 us 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 telecommunication 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 represent at any given time receivers and donors, while edges represent compatibilities. 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 the theory of 'large graph asymptotic' on 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). Telecommunication 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).

4.4 Digital Humanities

Digital Humanities represents an interdisciplinary field of research. We are interested in developing suitable, automatic tools to help experts to study the ideas contained in antique texts. Together with historians of antiquity, we consider one of the founding texts of political sciences, the *Politics* of Aristotle. To fulfill our purposes, we consider techniques both from the history of antiquity, machine learning, and statistics. This also presents some technological challenges to develop suitable tools to load and manipulate the data.

This research is supported by the Inria Exploratory Reasearch Action *Apollon* and involves collaboration with researchers from Archimède (Universities of Strasbourg and Haute-Alsace), IRIMAS and CRESAT (Université de Haute-Alsace) and University of Pavia.

5 Highlights of the year

Madalina Deaconu was plenary speaker at the *14th International Conference on Monte Carlo Methods and Applications* held in Paris in June 2023.

Our survey article [16], published in *Probability Surveys*, is one of the first works introducing a large spectrum of stochastic models that can be used while analysing the fragmentation phenomena. It gives also a simple and efficient numerical algorithm to simulate these processes.

6 New results

6.1 Fragmentation equation

Participants: Madalina Deaconu, Antoine Lejay, Victor Hoffmann.

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 new stochastic process that represents the typical evolution of the mass of a rock or of a snow aggregate subject to successive random breakages.

In a survey article [16], we present various probabilistic representations of the fragmentation equation, and show how they are connected. We focus on the stochastic process which represents the evolution of the mass of a typical particle subject to a fragmentation process. These probabilistic representations range from Markov chains to Stochastic Differential Equations with jumps. In particular, we show how these representations lead to easy numerical simulations.

Further, with Gaetano Agazzotti (former intern in the team), we have studied from an analytic viewpoint the evolution of the moments of a fragmentation equation, and obtain its asymptotic behavior, by expanding his Master thesis [37].

We have also explored, using machine learning techniques, the median size of rocks in blasting operations. In particular, we have used ensemble techniques to combine various approaches to predict the median size [36].

6.2 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. One main result concerns a new technique for the path approximation of one-dimensional stochastic processes [15]. Our method applies to the Brownian motion and to some families of stochastic differential equations whose distributions could be represented as a function of a time-changed Brownian motion (usually known as L and G-classes). We are interested in the ε-strong approximation. We propose an explicit procedure that jointly constructs the sequences of exit times and corresponding exit positions of some well-chosen domains. We prove the convergence of our scheme and how to control the number of steps, which depends on the covering of a fixed time interval by intervals of random sizes. The underlying idea of our analysis is to combine results on Brownian exit times from time-depending domains (one-dimensional heat balls) and classical renewal theory. Numerical examples and issues are also developed in order to complete the theoretical results.

We develop also 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 [14]. 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 pursued our work on the exact simulation of the hitting times of multi-dimensional diffusions. A one-week workshop meeting was held in Torino in November.

6.3 Self exciting threshold model and singular diffusion

Participants: Antoine Lejay, Sara Mazzonetto.

In collaboration with Benoit Nieto (École Centrale Lyon) we consider several-regimes CKLS (Chan–Karolyi–Longstaff–Sanders) dynamics (including Cox-Ingersoll-Ross model) and we study parameter estimation from high-frequency observations, extending the published work [20] about threshold Vasicek model. The model fits well the behavior in financial markets related to crisis periods.

In a collaboration with Paolo Pigato (University Tor Vergata, Roma), we study new estimators from low frequency observations for the parameters of several regimes threshold models which show mean-reversions features.

Together with Alexis Anagnostakis (LJK Grenoble), we are extending our respective results on high-frequency approximation of the local time of sticky-oscillating-skew diffusion processes. The purpose is to estimate the parameters of stickiness and/or skewness and to model some critical behaviors in financial markets related to crisis periods. Inspired by a previous work [42], we extend the results obtained during the PhD thesis of Alexis Anagnostakis [38] in the context of sticky Brownian motion to more general estimators of local time and to oscillating-skew-sticky Brownian motion. This is a work on its final stage of editing. Our main goal is now to reach rates of convergence for sticky diffusions and so extend the results in [42].

We are continuing our work on an expansion of the maximum likelihood estimator using formal series expansions [41]. The aim of this work is to understand the lack of Gaussianity in the non-asymptotic regime.

In [19], 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 $1/2$.

6.4 Diffusion equations with singular coefficients

Participants: Antoine Lejay, Sara Mazzonetto.

With Géraldine Pichot (Serena, Inria Paris), Giovanni Michele Porta and Elisa Baioni (Politecnico di Milano), we have provided an extension of a Monte Carlo method that allows for the simulation of a diffusion process in a one-dimensional discontinuous media. Using the method of images, the extension consists in finding an approximation of the fundamental solution associated with the process which is suitable for a fast simulation. Our method may be applied to situations in which both the solution and its gradient are discontinuous at some point. In particular, we may consider the case of the Fourier equation with discontinuous coefficients [26, 27].

Together with Alexis Anagnostakis and Pierre Etoré (LJK Grenoble) we are dealing with different questions about the non-uniqueness of solutions for processes solution to stochastic differential equations with a diffusion coefficient admitting jumps and becoming negative. We tackle a conjecture open since the 80's. We have obtained a partial answer and we are seeking for the link with sticky-skew diffusions.

6.5 Hug model: parameter estimation via the ABC Shadow algorithm

Participants: Madalina Deaconu, Christophe Reype, Radu Stoica.

Studying geological fluids mixing systems allows us to understand the interaction between water sources. The Hug model is an interaction point process model that can be used to estimate the number and the chemical composition of the water sources involved in a geological fluids mixing system from the chemical composition of samples [43]. In [24], we construct priors for the parameters of the Hug model using the ABC shadows algorithm [44]. The long term perspective of this work is to integrate geological expertise within fully unsupervised models.

This work is a collaboration with Didier Gemmerlé (IECL, Université de Lorraine) and Antonin Richard (GeoRessources, Université de Lorraine).

6.6 Point processes in cosmology

Participants: Nathan Gillot, Radu Stoica.

Marked point processes and Bayesian inference are powerful tools for analysing spatial data. With respect to a previous work [40], we proposed a new inhomogeneous point process with superposed interaction. The results indicate a correct fit of the model and allow the study of the significance of the parameter at the corresponding prefixed interaction ranges [23]. This work is a collaboration with Didier Gemmerlé (IECL, Université de Lorraine).

With Jenny Sorce (Cristal, Lille) and Elmo Tempel (Tartu Observatory, University of Tartu), we develop in [21, 25] a new algorithm based on an object point process model that can reduce biases and uncertainties in the measurement of peculiar velocities of galaxies. The algorithm uses simulated annealing to maximize the probability density of the point process model, resulting in bias-minimized catalogs. We conducted tests on synthetic catalogs mimicking the second and third distance modulus catalogs of the Cosmicflows project from which peculiar velocity catalogs are derived. By reducing the local peculiar velocity variance in catalogs by an order of magnitude, the algorithm permits the recovery of the expected one, while preserving the small-scale velocity correlation. The expected clustering was also retrieved. The resulting bias-minimized catalogs allowed for the recovery of expected statistical properties and the reconstruction of large-scale structures that matched well with existing redshift surveys of local galaxies. These bias-minimized catalogs can be used for various cosmological studies and simulations of the local Universe.

6.7 Spatial-point processes in geophysics

Participants: Radu Stoica.

Faults are crucial subsurface features that significantly influence the mechanical behavior and hydraulic properties of rock masses. Interpreting them from seismic data may lead to various scenarios due to uncertainties arising from limited seismic bandwidth and possible imaging errors. Only a few methods addressing fault uncertainties can produce curved and sub-seismic faults at once while quantitatively honoring seismic images and avoiding anchoring in a reference interpretation.

With Fabrice Taty-Moukati, François Bonneau, Guillaume Caumon (GeoRessources, Université de Lorraine) and Xinming Wu (Hefei, University of Science and Technology of China), we use a mathematical framework, namely the Candy model, of marked point processes with interactions to approximate fault networks in two dimensions with a set of line segments. The novelty of this approach lies in using the input image of fault probabilities computed by a Convolutional Neural Network (CNN). The

Metropolis-Hastings algorithm is used to generate various scenarios of fault network configurations, thereby exploring the model space and reflecting the uncertainty. The empty space function produces a ranking of the generated fault networks against an existing interpretation by testing and quantifying their spatial variability. The approach is applied on two-dimensional sections of seismic data, acquired in the Central North Sea.

During geological exploration, the interpretation of faults can be ambiguous and uncertain because of disparate and often sparse observations such as fault traces on 2D seismic images or outcrops. With Amandine Fratani, Guillaume Caumon and Jéremie Guirad (GeoRessources, Université de Lorraine), we propose a hypergraph formalism to generalize the higher-order interactions between fault observations in the multiple-point association problem, by dealing with the likelihood of multiple-point fault data association. A machine learning approach is proposed to enhance or replace the expert geological rules in determining the likelihood of multiple-point fault data association. This involves training a supervised classifier using fault features extracted from known 3D geological models. By formulating the problem as a classification task, the model can determine the probability that fault observations belong to the same fault objects. We also develop a specific technique to prevent overfitting. Overall, this hypergraph-based approach with machine learning integration provides a more advanced and flexible method for interpreting and associating fault observations in geological exploration.

Fractures from systems of complex mechanical discontinuities dramatically impact the physical behavior of rock masses. With François Bonneau and Guillaume Caumon (GeoRessources, Université de Lorraine), we use the mathematical framework of marked point processes to approximate fracture networks in two dimensions with a collection of straight-line segments. Whereas most fracture characterization and modeling focuses on first order statistics (density and mark distribution), and assume independent fractures, we focus on fracture interactions by providing stochastic mathematical models involving simple pairwise interactions between fractures to capture key aspects of fracture network geometry and organization. The model is calibrated using a maximum likelihood, which we apply to real data from Oman mountains.

6.8 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 also results in 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 the creation and disappearance of particles that mimic the physics of the vorticity in the boundary layer.

6.9 Modeling and optimization: Stochastic matching models

Participants: Loïc Jean, Thomas Masanet, Pascal Moyal.

We have made various advances in the analysis and optimization of stochastic matching models:

- In [33], in our long standing collaboration with Ana Busic (Doxygene, Inria Paris) and Jean Mairesse (LIP6, Université Pierre et Marie Curie), we show that all stochastic matching models on general graphs present a remarkable sub-additivity property. This implies that bi-infinite perfect matchings can be constructed explicitly and uniquely. In the particular, practical, case where the buffer

is finite (thereby rendering the state space finite), we deduce a perfect simulation scheme, by showing the existence of infinitely many *erasing words* that cancel out the content of the buffer, by combinatorics arguments.

- In a draft paper that we are completing, we have shown, by a dynamic programming approach, that a threshold-type policy minimizes the holding cost amongst admissible policies for the 'N graph', an approach that we aim at generalizing for a larger class of graphs, including the 'paw graph' with four nodes.
- In [31], in collaboration with the doctors of Agence de la Biomédecine (ABM) we have brought to light, by an extensive set of simulations based on survival analysis for liver transplant systems, that, in the context of real-time matching models, a matching algorithm based on simulated deadlines (the so-called *Earliest Simulated Deadline First*) is optimal in terms of equity between indication classes (various classes of cirrhosis and liver cancer), while keeping the overall death rate equal, with respect to the existing matching policies currently implemented by the ABM.

We have focused on the study and optimization of online algorithms on large random graphs, which are known to be prevalent in practice, for various applications such as job/housing allocation, online adverts, and so on.

- In [35], in a collaboration with Matthieu Jonckheere (LAAS) and Nahuel Soprano-Loto (Univ. Buenos Aires / LAAS), we show that an online matching algorithm of the Max-Weight type is able to guarantee a perfect marriage infinitely often, under natural connectivity conditions *à la* Hall, for a class of stochastic block models, in the large graph limits.
- In a collaboration with Vincent Robin and Habib Dialo Aoudi (UTC), we have proved a hydrodynamic limit for local online matching algorithms depending only on the degrees of the nodes (and not on their neighborhood). By comparing their asymptotics through their hydrodynamic approximation, we have shown that a degree-greedy type algorithm is asymptotically optimal in terms of matching coverage, with respect to greedy algorithms. A paper gathering these results is about to be submitted.

6.10 Speed of convergence in functional central limit theorems

Participants: Pascal Moyal.

In [13], in collaboration with Eustache Besançon (Telecom Paris), Laurent Decreusefond (Telecom Paris) and Laure Coutin (Université Paul Sabatier, Toulouse), we have shown universal bounds for the speed of convergence in the functional Central Limit Theorems for Lipschitz continuous functionals of Poisson random measures. As a by-product, we deduce similar bounds for Continuous Time Markov Chains (CTMCs), by using various tools of stochastic analysis, among which, Malliavin calculus for point processes, and the Stein method in infinite dimension. These results allow us to characterize the accuracy (and thereby the confidence interval) in diffusion approximations of many practical processes appearing in epidemiology (Susceptible, Infectious, or Recovered [SIR] processes) biology of development (Moran process) and telecom networks (queueing processes and the Telegraph process).

7 Bilateral contracts and grants with industry

7.1 Scientific expertise

Participants: Pascal Moyal.

- Pascal Moyal has collaborated, as a scientific expert in Stochastic modeling and Machine learning, with the Start-Up *mAIedge*.

8 Partnerships and cooperations

8.1 International initiatives

8.1.1 Participation in other International Programs

Action ECOS Sud n° C23E06

Participants: Sara Mazzonetto.

Title: Nonsmooth Analysis in Stochastic Systems and Optimal Control Theory

Partner Institution(s):
- Universidad de O'Higgins, Rancagua, Chile
- Universidad Técnica Federico Santa María, Chile.
- University of Lorraine, France.
- University of Burgundy, France.

Date/Duration: 01/01/2024-31/12/2026.

Additionnal info Project leader: Nabil Kazi-Tani (Université de Lorraine). PASTA member Sara Mazzonetto, other members Nicolás Hernández (Universidad Técnica Federico Santa María), Abderrahim Jourani (University of Burgundy), Pedro Pérez and Emilio Vilches (Universidad O'Higgins).

Keywords: Stochastic sweeping process.

ANR PRC MATCHES

Participants: Pascal Moyal.

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

Partner Institution(s):
- 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).

Duration: November 2018 - April 2023.

Coordinator: Pascal Moyal.

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.

8.2 National initiatives

Participants: Antoine Lejay, Sara 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 members: A. Lejay, S. Mazzonetto, in a collaboration with Lionel Lenôtre (Irimas, Université of Haute-Alsace), (M.-T. Schettino (Archimède, Université de Haute-Alsace), Catherine Roth (CRESAT, Université of Haute-Alsace), Cesare Zizza (Department of Humanistic Studies, Università degli Studi di Pavia), Didier Gemmerlé (IECL, Université de Lorraine).

9 Dissemination

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

9.1 Promoting scientific activities

9.1.1 Scientific events: organisation

General chair, scientific chair

- Madalina Deaconu was the head of the Inria group of members in the organizing committee of *Journées INRAE - Inria 2023*, 5-6 July 2023, held in Champenoux.
- Sara Mazzonetto is one of three organizers of *Rencontres on random models* held in Munster in May 2023.
- Pierre Mercuriali is the co-organizer of the Journées de la Fédération Charles Hermite *Représentations du language*.
- Pascal Moyal was the head of the organizing committee of *INFORMS 2023 Conference* (one of the main conferences in Applied probability - more than 400 participants), held in Nancy in June 2023.

Member of the organizing committees

- Sara Mazzonetto and Pascal Moyal are two of the four members of the local organizing committee of *INFORMS 2023 Conference*.

9.1.2 Scientific events: selection

Chair of conference program committees

- Pascal Moyal is the chair of the scientific committee of *INFORMS 2023 Conference*.

Member of the conference program committees

- Madalina Deaconu and Antoine Lejay are members of the scientific committee of *INFORMS 2023 Conference*
- *Journées de Probabilités 2023*, Angers, France, June 2023. Antoine Lejay.
- *Spatial Statistics*, Colorado, 2023, Radu Soica.

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: *Numerical algorithms* and *Nonlinear Analysis Series B: Real World Applications*.
- Antoine Lejay wrote reviews for: *Bulletin of the Iranian Mathematical Society, Finance and Stochastics, Journal of Theoretical Probability, Mathematische Annalen, Stochastic Processes and their Applications, Mathematics and Computers in Simulation*.
- Sara Mazzonetto wrote reviews for: *Applied Mathematical Finance*.
- Pascal Moyal wrote review reports for: *Annals of Applied probability* and *Queueing Systems: Theory and Applications*.

9.1.3 Invited talks

- Madalina Deaconu was invited as a **plenary speaker** to the *14th International Conference on Monte Carlo Methods and Applications* (250 participants), 26-30 June 2023, Paris. She was also invited speaker in *The Tenth Congress of Romanian Mathematicians*, 30 June - 5 July, 2023, Piteşti, Romania.
- Antoine Lejay gave talks at the international conferences *A Random Walk in the Land of Stochastic Analysis and Numerical Probability* in honor of Denis Talay (CIRM, Marseille, September 2023), *L'identité de la classe dirigeante post-syllanienne : politique, religion, culture* (Strasbourg, September 2023), *Réflexion sur les modèles d'apprentissage dans les humanités* (Strasbourg, June 2023) and at national conference *Journées de Probabilités 2023* (Angers, France, June 2023).
- Sara Mazzonetto was invited speaker in the conference *40 years of reflected Brownian motion*, 24-28 April 2023, Roscoff. She also gave a online seminar talk at Université d'Angers in January 2023 and online at the university of Potsdam in February 2023.
- Pierre Mercuriali gave a talk at the *VIIe rencontre internationale du programme La classe dirigeante de la mort de Sylla à la mort de Crassus : les mutations d'une 'culture politique'* (Strasbourg, September 2023), at the *2023 Journée d'étude Enfants, enfances : approches pluridisciplinaires* (Bar-le-Duc, April 2023), and at the *Colloque interdisciplinaire, La Lumière : des sciences aux crises énergétiques, Humanités numériques* (Mulhouse, March 2023).
- Pascal Moyal gave invited talks at the *Inria DIOGENE seminar* (Paris, February 2023), the *ERGO seminar* (Edinburgh research group in optimisation, May 2023), the *Probability seminar* of Heriot-Watt University (Edinburgh, May 2023), the mini-symposium 'Random processes on large random graphs' at the *IWAP 2023* conference (Thessaloniki, June 2023), the mini-symposium 'Stochastic matching and applications' at the *Informs APS 23 conference* (Nancy, June 2023), the *L2 Workshop* Lorraine/Luxembourg (Metz, September 2023), the workshop *Systèmes, réseaux et finance* (Nancy, November 2023), and at the Conference *From Matching to Markets* (CIRM Marseille, December 2023).
- Radu Stoica was invited as **plenary speaker** to the *International Symposium on Symbolic and Numeric Algorithms for Scientific Computing* (SYNASC) (Nancy, September 2023). He gave a talk at the workshop *Spatial Statistics and Image Analysis in Biology* (SSIAB) (Grenoble, May 2023). He was invited to give a talk at the *Online Seminar on Spatial and spatio-temporal Point processes and beyond (OSSP)*, December 2023.

9.1.4 Leadership within the scientific community

- Madalina Deaconu 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).

9.1.5 Research administration

- Madalina Deaconu is *Deputy Head of Science* of Inria Centre at Université de Lorraine since January 2022. She is also, at the national level, member of the Evaluation Commission of Inria.

  She is also member of *Bureau du Comité de Projets* and *Comité des Projets* of Inria Centre at Université de Lorraine.
- Madalina Deaconu was member of two juries CRCN and ISFP at Inria, Bordeaux and Saclay.
- Nathan Gillot is the organizer of the *PhD Student Seminar* of Institut Élie Cartan de Lorraine (IECL).

  He is also the PHD reprensentative for the library committee of Institut Élie Cartan de Lorraine (IECL).
- Antoine Lejay is a member of the board the AMIES.

  He is also the Head of the *Fédération Charles Hermite* for 2023, a federation of research within CNRS and Université of Lorraine, gathering three research laboratories: CRAN (control theory), IECL (mathematics) and LORIA (computer science) with the goal of creating interdisciplinary projects.

  He is also co-head of the COMIPERS, which is the local hiring committee for PhD and post-doctoral students at Centre Inria de l'Université de Lorraine.
- Sara Mazzonetto is member of the Committee of Equal Opportunities of IECL.

  She was also a member of the Hiring Committee for an assistant professor position, Université Claude Bernard, Lyon, 2023.
- Pascal Moyal is Head of the Probability and Statistics team at the Institut Élie Cartan de Lorraine (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 Université de Lorraine.
- Radu Stoica is elected member of the Council of the *Collégium Technologie* of Université de Lorraine from 2022 and of the Council and of the Restricted Council at IUT Charlemagne (Université de Lorraine) from 2016. He is member of the *International Strategy Think Tank* of Université de 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 (Université de Lorraine).

9.2 Teaching - Supervision - Juries

9.2.1 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. For them, we mention here only lectures at Master 1 and Master 2 levels as well as responsibilities.

- Madalina Deaconu, *Stochastic Modeling*, 30h, M2, Master IMSD, Université de Lorraine.
- Madalina Deaconu, *Monte Carlo Simulation*, 24h, M1, Financial Mathematical Engineering, Université de Lorraine.
- Madalina Deaconu, *Random Variable simulation*, 12h, M1, École des Mines de Nancy, Université de Lorraine.

- Antoine Lejay, *Simulation des marchés financiers*, 23h, M2, Master PSA, Université de Lorraine.
- Antoine Lejay, *Financial mathematics*, 18h, M2, Master IMSD, Université de Lorraine.
- Antoine Lejay, *Probability*, 9h, École des Mines de Nancy, L3, Université de 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* (Université de Lorraine).
- Pascal Moyal, *Financial mathematics*, 25h, M2, Master IMSD, Université de Lorraine.
- Pascal Moyal, *Stochastic financial modeling*, 45h, M2, Master IMSD, Université de Lorraine.
- Pascal Moyal, *Stochastic networks*, 20h, M2, Master IMSD, Université de Lorraine.
- Pascal Moyal, *Applied linear algebra*, 25h, M1, Master IMSD, Université de Lorraine.
- Pascal Moyal, *MCMC simulation and inference*, M1, Univversité de Lorraine,
- Pascal Moyal, *Random graphs and their applications*, M2, Université de Lorraine,
- Pascal Moyal, *Stochastic calculus*, Master level,Telecom Paristech,
- Pascal Moyal, *Stochastic networks*, Master level, *Mastère Parisien de Recherche Opérationnelle*, CNAM.
- Radu Stoica, *Simulation and Inference via Monte Carlo Methods*, 28h, M1, Master IMSD, Université de Lorraine.
- Radu Stoica, *Spatial Statistics and Bayesian Inference*, 36h, M2, Master IMSD, Université de Lorraine.

9.2.2 Supervision

- *PhD in progress*: Julia Budzinski, Simulation of diffusions with singular coefficients, November 2023, funding Inria, M. Deaconu and S. Mazzonetto.
- *PhD in progress*: Valentin-Ioan Constantinescu, Branching processes and machine learning algorithms with applications in medicine, November 2023, funding IMAR Bucharest, M. Deaconu and L. Beznea (IMAR Bucharest).
- *PhD defended*: Mohamed Habib Diallo Aoudi, Online coupling algorithm in large random graph, UTC, in June 2023, funding LMAC, P. Moyal and V. Robin [39].
- *PhD in progress*: Amandine Fratani, Interpretation of seismic faults by graph-based machine learning, Université de Lorraine, November 2022, funding RING consortium, G. Caumon and R. Stoica.
- *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 Université de Lorraine, R. Stoica.
- *PhD in progress*: Thomas Masanet, Stochastic matching models with impatience, and applications to organ transplant networks, Université de Lorraine, October 2019, grant ANR / Région Grand Est, C. Jacquelinet and P. Moyal.
- *PhD in progress*: Runbo Su, Mathematical modeling of the trust relationship in the Internet of Things, Université de Lorraine, October 2020, funding ANR / Fédération Charles Hermite / LORIA, P. Moyal, E. Natalizio and Y-Q. Song.
- *PhD in progress*: Fabrice Taty-Moukati, Stochastic seismic structural interpretation of geological faults, Université de Lorraine, March 2021, funding RING consortium, G. Caumon and R. Stoica.

9.2.3 Juries

- Reviewer for the PhD of François Ernoult, Université Rennes 1, 2023, Antoine Lejay.
- Reviewer for the Phd of Pol Llagostera Blasco, University of Lleida - Spain, 2023, Radu Stoica
- Reviewer for the PhD thesis of Itidel Abdallah, Université Côte D'Opale, 2023, Pascal Moyal,
- Reviewer for the PhD thesis of Pierre Popineau, Inria Paris and ENS Ulm, 2023, Pascal Moyal,
- Examinator for the PhD thesis of Vincent Haas, Université de Lorraine, 2023, Pascal Moyal,
- Examinator for the PhD thesis of Jana Zaherddine, Inria Paris, 2023, Pascal Moyal.

9.3 Popularization

- 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).

9.3.1 Articles and contents

- 'Chanson bohême', a group picture with the SAER, for the exposition 'Inria au cœur des campus', 2023.
- 'Apollon veut décrypter La Politique d'Aristote', Inria, August 2023
- 'L'action exploratoire : une oeuvre originale et collective', Inria au cœur des campus, 2023
- Portrait of Antoine Lejay, as new head of Fédération Charles Hermite, *Factuel* (Université de Lorraine), April 2023.

9.3.2 Education

- Nathan Gillot is involved in the organization of the *IECL mathematical club*. It consists in hosting middle school and high school pupils and to make them work on different topics in mathematics such as geometry, calculus, problems, etc.

10 Scientific production

10.1 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] M. Deaconu and A. Lejay. 'Probabilistic representations of fragmentation equations'. In: *Probability Surveys* 20 (2023), pp. 226–290. DOI: 10.1214/23-PS14. URL: https://inria.hal.science/hal-03483448.

[4] 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.

[5] A. Lejay and S. Mazzonetto. 'Maximum likelihood estimator for skew Brownian motion: the convergence rate'. In: *Scandinavian Journal of Statistics* (6th Feb. 2023). DOI: 10.1111/sjos.12694. URL: https://hal.science/hal-03975966.

[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.

10.2 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: *The Annals of Applied Probability* 33.5 (2023), pp. 3620–3651. DOI: 10.48550/arXiv.2206.03713. URL: https://inria.hal.science/hal-02897819.

[12] J. Begeot, I. Marcovici and P. Moyal. 'Stability regions of systems with compatibilities, and ubiquitous measures on graphs'. In: *Queueing Systems* 103.3-4 (2023), pp. 275–312. URL: https://hal.science/hal-03450251.

[13] E. Besançon, L. Coutin, L. Decreusefond and P. Moyal. 'Diffusive limits of Lipschitz functionals of Poisson measures'. In: *The Annals of Applied Probability* (2023). DOI: 10.48550/arXiv.2107.05339. URL: https://telecom-paris.hal.science/hal-03283778.

[14] M. Deaconu and S. Herrmann. 'Strong approximation of Bessel processes'. In: *Methodology and Computing in Applied Probability* (3rd Feb. 2023). DOI: 10.1007/s11009-023-09981-6. URL: https://hal.science/hal-03244538.

[15] M. Deaconu and S. Herrmann. 'Strong approximation of some particular one-dimensional diffusions'. In: *Discrete and Continuous Dynamical Systems - Series B* (26th Sept. 2023). URL: https://hal.science/hal-02799638.

[16] M. Deaconu and A. Lejay. 'Probabilistic representations of fragmentation equations'. In: *Probability Surveys* 20 (2023), pp. 226–290. DOI: 10.1214/23-PS14. URL: https://inria.hal.science/hal-03483448.

[17] G. Escriva-Boulley, C.-A. Philip, S. Warembourg, L. Lenôtre, P. Flore, P. Faure, T. Michy, V. Letouzey, C. Arnold, C. Piluso, L. Chalmel, R. Kacem, G. F. Blum, R. Detayrac, C. Trocmé, I. Brigaud, U. Herbach, P. Branche, E. Faller and A. Chalabaev. 'Effects of a physical activity and endometriosis-based education program delivered by videoconference on endometriosis symptoms: the CRESCENDO program (inCRease physical Exercise and Sport to Combat ENDOmetriosis) protocol study'. In: *Trials* 24.1 (27th Nov. 2023), p. 759. DOI: 10.1186/s13063-023-07792-1. URL: https://hal.science/hal-04365506.

[18] M. Jonckheere, P. Moyal, C. Ramírez and N. Soprano-Loto. 'Generalized max-weight policies in stochastic matching'. In: *Stochastic Systems* 13.1 (Mar. 2023), pp. 40–58. DOI: 10.1287/stsy.2022.0098. URL: https://hal.science/hal-03354805.

[19] A. Lejay and S. Mazzonetto. 'Maximum likelihood estimator for skew Brownian motion: the convergence rate'. In: *Scandinavian Journal of Statistics* (6th Feb. 2023). DOI: 10.1111/sjos.12694. URL: https://hal.science/hal-03975966.

[20] S. Mazzonetto and P. Pigato. 'Drift estimation of the threshold Ornstein-Uhlenbeck process from continuous and discrete observations'. In: *Statistica Sinica* 34.1 (2024), pp. 313–336. DOI: 10.5705/ss.202021.0275. URL: https://hal.science/hal-03293542.

[21] J. G. Sorce, R. S. Stoica and E. Tempel. 'Statistically bias-minimized peculiar velocity catalogs from Gibbs point processes and Bayesian inference'. In: *Astronomy and Astrophysics - A&A* 679 (2023), A1. DOI: 10.1051/0004-6361/202346288. URL: https://hal.science/hal-04399425.

International peer-reviewed conferences

[22] R. Su, A. Riahi Sfar, E. Natalizio, P. Moyal and Y.-Q. Song. 'A Game Theoretical Model addressing Misbehavior in Crowdsourcing IoT'. In: 20th Annual IEEE International Conference on Sensing, Communication, and Networking (SECON 2023). Madrid, Spain, 11th Sept. 2023. DOI: 10.1109/SECON58729.2023.10287527. URL: https://hal.science/hal-04205286.

Conferences without proceedings

[23] N. Gillot, R. S. Stoica and D. Gemmerlé. 'Study the galaxy distribution characterisation via Bayesian statistical learning of spatial marked point processes'. In: RING Meeting. Nancy, France, Sept. 2023. URL: https://hal.science/hal-04163649.

[24] C. Reype, R. S. Stoica, D. Gemmerlé, A. Richard and M. Deaconu. 'Hug model: parameter estimation via the ABC Shadow algorithm'. In: RING Meeting. Nancy, France, Sept. 2023. URL: https://hal.science/hal-04163654.

[25] J. G. Sorce, R. S. Stoica and E. Tempel. 'Processus ponctuel de Gibbs et inférence Bayésienne pour réduire les biais observationnels : cas des catalogues de vitesse de galaxies'. In: GRETSI. Grenoble, France, 28th Aug. 2023. URL: https://hal.science/hal-04399480.

Reports & preprints

[26] E. Baioni, A. Lejay, G. Pichot and G. M. Porta. *Modeling diffusion in discontinuous media under generalized interface conditions: theory and algorithms*. 19th July 2023. URL: https://inria.hal.science/hal-04166559.

[27] E. Baioni, A. Lejay, G. Pichot and G. M. Porta. *Random walk modeling of conductive heat transport in discontinuous media*. 18th July 2023. URL: https://inria.hal.science/hal-04166562.

[28] A. Benetos, O. Coudray, A. Gégout-Petit, L. Lenôtre, S. Toupance and D. Villemonais. *A branching model for intergenerational telomere length dynamics*. 15th Oct. 2023. URL: https://hal.science/hal-04242595.

[29] A. Hudde, M. Hutzenthaler, A. Jentzen and S. Mazzonetto. *On the Itô-Alekseev-Gröbner formula for stochastic differential equations*. 29th June 2023. URL: https://hal.science/hal-04149410.

[30] A. Lejay and R. Marty. *Rough differential equations with affine boundary conditions*. 6th Feb. 2023. URL: https://inria.hal.science/hal-03626402.

[31] T. Masanet, B. Audry, C. Jacquelinet and P. Moyal. *Toward Organ Shortage Resilient Allocation Policies Using Real-Time Queueing Models For Liver Transplantation*. 23rd Nov. 2023. URL: https://hal.science/hal-04303749.

[32] P. R. Mercuriali. *Symbolic artificial intelligence: a soft introduction to propositional logic for artificial intelligence*. 28th Mar. 2023. URL: https://hal.science/hal-04046674.

[33] P. Moyal, A. Busic and J. Mairesse. *On the sub-additivity of stochastic matching*. 29th Apr. 2023. URL: https://hal.science/hal-04088419.

[34] 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*. 28th Jan. 2023. URL: https://hal.science/hal-03740280.

[35] N. Soprano-Loto, M. Jonckheere and P. Moyal. *Online matching for the multiclass stochastic block model*. 27th Mar. 2023. URL: https://hal.science/hal-04149842.

Other scientific publications

[36] V. Hoffmann. 'Techniques d'apprentissage pour des problèmes de fragmentation'. Nancy: Ecole Nationale Supérieure des Mines de Nancy, 6th June 2023, p. 53. URL: https://inria.hal.science/hal-04142294.

10.3 Cited publications

[37] G. Agazzotti. 'Modélisation des processus de fragmentation à l'aide des processus de branchement'. Ce mémoire a été réalisé dans le cadre d'un "parcours recherche" de l'École des Mines de Nancy ouverts aux étudiants de 2ème année. MA thesis. Ecole des Mines de Nancy, June 2022. URL: https://inria.hal.science/hal-03708575.

[38] A. Anagnostakis. 'Path-wise study of singular diffusions'. Theses. Université de Lorraine, Oct. 2022. URL: https://hal.science/tel-03846475.

[39] M. H. A. D. Aoudi. 'Local matching algorithms on the configuration model'. Theses. Université de technologie de Compiègne, June 2023. URL: https://hal.science/tel-04122066.

[40] L. Hurtado-Gil, R. S. Stoica, V. J. Martínez and P. Arnalte-Mur. 'Morphostatistical characterization of the spatial galaxy distribution through Gibbs point processes'. In: *Monthly Notices of the Royal Astronomical Society* 507.2 (Aug. 2021), pp. 1710–1722. DOI: 10.1093/mnras/stab2268. URL: http://dx.doi.org/10.1093/mnras/stab2268.

[41] A. Lejay and S. Mazzonetto. 'Beyond the delta method'. working paper or preprint. July 2022. URL: https://inria.hal.science/hal-03738371.

[42] 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.

[43] C. Reype. 'Modélisation probabiliste et inférence bayésienne pour l'analyse de la dynamique des mélanges de fluides géologiques : détection des structures et estimation des paramètres'. Theses. Université de Lorraine, Dec. 2022. URL: https://hal.univ-lorraine.fr/tel-03948912.

[44] 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* (Apr. 2021). DOI: 10.1016/j.spasta.2021.100505. URL: https://hal.science/hal-02183506.