RESEARCH CENTRE

Inria Centre at Université de Lorraine

IN PARTNERSHIP WITH:

Université de Lorraine, CNRS

2024 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

A6.2.2. – 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

B9.6.10. – Digital humanities

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, until Sep 2024]
- Madalina Deaconu [Team leader, INRIA, Senior Researcher, from Oct 2024]
- Antoine Lejay [INRIA, Senior Researcher]

Faculty Members

- Sara Mazzonetto [UL, Associate Professor, from Sep 2024]
- Sara Mazzonetto [UL, Associate Professor Delegation, until Aug 2024]
- Pascal Moyal [UL, Professor, from Sep 2024]
- Pascal Moyal [UL, Professor Delegation, until Aug 2024]
- Catherine Roth [UHA, Associate Professor Delegation]
- Radu Stoica [UL, Professor]

Post-Doctoral Fellow

- Pierre Mercuriali [INRIA, Post-Doctoral Fellow, until Jun 2024]

PhD Students

- Lorenzo Agabiti [Sorbonne Université, from Oct 2024]
- Julia Budzinski [INRIA]
- Nathan Gillot [UL]
- Christophe Reype [UL, ATER, until Aug 2024]
- Saïd Toubra [CNRS, from Oct 2024]

Technical Staff

- Amélie Ferstler [INRIA, Engineer]

Interns and Apprentices

- Diego Astaburuaga Corveleyn [INRIA, Intern, until Mar 2024]
- Anton Conrad [INRIA, Intern, from Jun 2024 until Oct 2024]
- Abdelkader Metakalard [UL, Intern, from May 2024 until Sep 2024]

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* (2022-2024) 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 New software, platforms, open data

5.1 New platforms

Participants: Antoine Lejay, Sara Mazzonetto, Radu Stoica, Saïd Toubra.

DRLIB is a C++ library built for performing modelling, simulation and statistical inference based on marked point processes with interaction. This library is the result of a joint project of Radu Stoica with Didier Gemmerlé (CNRS research engineer at IECL).

Palamède aims at being a collaborative plateform to vizualize, annotate and analyze texts from the point of view of experts in history, philology or more generally in social sciences. The short term goals are to incorporate tools from Artifical Intelligence to ease the study of texts. This plateform is supported by the ADT Apollon.

6 New results

6.1 Fragmentation equation

Participants: Madalina Deaconu, Antoine Lejay, Anton Conrad.

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.

With Gaetano Agazzotti (former intern in the team), we have studied in [29] the evolution of the moments of a self-similar fragmentation equation from an analytic viewpoint. In particular, we have shown existence for an initial condition which is a measure. We have proved rigorously its asymptotic behavior.

During the internship of Anton Conrad, we have developed the technique of embedding in the shape of polytopes. The main idea is to handle the analysis of a population of geometric shapes, such as one obtained through successive fragmentations, through their embedding. This way, classical techniques of clustering, or other, may be applied to such objects. With Didier Gemmerlé (IECL), we are developing a code on this topic. We are in particular interested in studying the convergence toward some universal shapes.

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 (Université de Bourgogne) 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 [16]. 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.

Together with Samuel Herrmann (Université de Bourgogne) and Cristina Zucca (University of Torino) we pursued our work on the exact simulation of the hitting times of multi-dimensional diffusions. Recenlty, with Samuel Herrmann we started to construct random walks on truncated spheroids with the objective of improving existing results.

6.3 Statistics for self exciting threshold model and singular diffusions

Participants: Antoine Lejay, Sara Mazzonetto.

In a collaboration with Benoit Nieto (former member of École Centrale Lyon, now member of École Polytechnique), we consider several-regimes CKLS (Chan– Karolyi–Longstaff–Sanders) dynamics (including Cox-Ingersoll-Ross model) and we study parameter estimation from high-frequency observations [37]. In an ongoing collaboration we are considering a theoretical result on existence and uniqueness of solutions to stochastic differential equations admitting several regimes. These questions are important because lack of uniqueness may affect approximation or inference results.

With Paolo Pigato (University Tor Vergata, Roma), we studied new estimators from low frequency observations for the parameters of several regimes threshold models which show mean-reversions features [38].

Together with Alexis Anagnostakis (former member LJK Grenoble, now member of IECL Metz), we extended our respective results on high-frequency approximation of the local time of sticky-oscillating-skew diffusion processes. We estimate the parameters of stickiness and/or skewness [36]. Our main goal is now to reach rates of convergence for sticky diffusions and so extend the results in [34]. We obtained a partial interesting result for sticky Brownian motion in [35].

We continued our work on an expansion of the maximum likelihood estimator using formal series expansions [32] (preprint submitted to a journal). The aim of this work is to understand the lack of Gaussianity in the non-asymptotic regime.

6.4 Diffusion equations with singular coefficients

Participants: Antoine Lejay, Sara Mazzonetto.

With Géraldine Pichot (Serena project-team, 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 [13, 14].

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 Spatial point process modelling and Bayesian inference for large data sets

Participants: Nathan Gillot, Radu Stoica.

Modelling the galaxy distribution in our Universe is with no doubt a very important statistical challenge since the Universe contains around 200 billion galaxies. Among the typical available characteristics for the galaxies one must consider their position, mass, luminosity, and shape. Due to this, marked point processes appear as a natural modelling tool. There exists statistical methodology able to extract relevant information from marked point configurations. We take the first step in [26] and propose to use non-parametric exploratory analysis and Bayesian posterior based inference in order to explore the first characteristic, namely the positions of more than 30,000 galaxies. A new parametric multi-interaction point process model is introduced and fitted to the selected galaxy patterns. The quality of the estimation procedure and the significance of the estimated parameters is also assessed. Analysing several patterns allows us to have more insight into the stationary character of the entire observed data set and to depict perspectives with respect to the possible strategies for the general model fitting challenge.

This work is a collaboration with Didier Gemmerlé (IECL, Université de Lorraine) and Aila Särkkä (Chalmers University, Sweden).

6.6 Inhomogeneous interacting marked point processes for studying morphostructures in paleobiological data

Participants: Diego Astaburuaga, Radu Stoica.

The work [25] develops inhomogeneous marked point processes with interactions that are applied to the analysis of morphostructures exhibited by a paleo-biological dataset presented in Kolesnikov (2018). Specifically, due to the nature of the dataset, we model the probability density function describing the models by considering three effects: the distance to the nearest edge, the distance to the lower right corner, and the distance to a reference circle. Furthermore, interactions between the points through the observed marks are introduced. This is done using the Strauss and Area-Interaction processes. The `C++` library `DRLib` is the main programming tool used to perform model simulations, while the `R` package `spatstat` is used for the exploratory analysis, the ABC Shadow algorithm, the model verification analysis by global envelope tests and the graphical presentation of the results.

This work is a collaboration with Francisco Cuevas (Universidad Tecnica Federico Santa Maria, Chile) and Didier Gemmerlé (IECL, Université de Lorraine).

6.7 Statistical inference for random T-tessellations models: application to agricultural landscape modeling

Participants: Radu Stoica.

The Gibbsian T-tessellation models allow the representation of a wide range of spatial patterns. We propose in [12] an integrated approach for statistical inference. Model parameters are estimated via Monte Carlo maximum likelihood. The simulations needed for likelihood computation are produced using an adapted Metropolis-Hastings-Green dynamics initialized using pseudolikelihood estimates. A real data application is performed on three French agricultural landscapes. The Gibbs T-tessellation models simultaneously provide a morphological and statistical characterization of these data.

This work is a collaboration with Katarzyna Adamczyk-Chauvat (INRAe Jouy-en-Josas, Université Paris Saclay).

6.8 From fault likelihood to fault networks: stochastic seismic interpretation through a marked point process with interactions

Participants: Radu Stoica.

Faults are critical subsurface features influencing rock mass mechanical and hydraulic properties. Interpreting them from seismic data involves uncertainties from limited bandwidth and imaging errors. In [23], we use a marked point process framework to approximate fault networks in two dimensions, introducing the Candy Model that captures fault segment interactions. The approach innovatively conditions the stochastic model using fault probability images from a Convolutional Neural Network. The Metropolis-Hastings algorithm generates fault network scenarios, exploring model space and uncertainty. Probability level sets and empty space function provide insights into fault network realizations and parameters, with the method applied to seismic data from the Central North Sea.

This work is a collaboration with Fabrice Taty-Moukati, François Bonneau, and Guillaume Caumon (GeoRessources, Université de Lorraine).

6.9 Multiple point fault observation association using random forest from analog structural models

Participants: Radu Stoica.

During geological modelling, 3D fault interpretation can be ambiguous from incomplete observations like fault traces in 2D seismic images. The problem of associating partial fault observations has been formalized using a graph where nodes represent observations and edges show potential associations. We propose extending this approach with a multiple-point likelihood computation and using machine learning to infer association probabilities. By training on fault features from known 3D geological models and splitting the domain into training and testing sectors, we aim to create a probabilistic representation of fault associations that improves upon existing pairwise methods. To mitigate the problem of expert rules defined on highly dimensional problems, we propose to augment or replace them by inference from analog or partly observed data.

This work is a collaboration with Amandine Fratani, Guillaume Caumon (GeoRessources, Université de Lorraine) and Jeremie Giraud (Centre for Exploration Targeting (School of Earth Sciences), University of Western Australia).

6.10 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.

6.11 Modeling and optimization: Stochastic matching models

Participants: Pascal Moyal.

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

- In collaboration with Ana Busic (Dyogene project-team, Inria Paris) and Jean Mairesse (LIP6, Université Pierre et Marie Curie), where we show a remarkable sub-additivity property for general stochastic matching models on general graphs [21].

- In [19] we analyze the performance of a similar perfect simulation scheme for general stochastic matching models with reneging.

6.12 Markovian algorithms on large random graphs

Participants: Pascal Moyal.

We have pursued an intensive research activity on the Markovian analysis of various Markovian exploration algorithms on random graphs, analyzed and/or approximated to the large graph limits, using scaling limits of stochastic processes. These various techniques apply to three distinct classes of random graphs: Stochastic block models, Configuration models and Preferential attachment models.

- With Vincent Robin and Mohamed Habib Dialo Aoudi (UTC), we prove a hydrodynamic large-graph limit for various local online matching algorithms depending only on the degrees of the nodes (and not on their neighborhood), among which, *greedy* and *degree-greedy* algorithms, on Configuration model (CM) random graphs [31]. For doing so, we follow the so-called *constructing while exploring* approach of the CM. By comparing their asymptotic behaviors through the hydrodynamic limits of a suitable sequence of measure-valued processes (rather than local limits), we have shown that the degree-greedy type algorithm is asymptotically optimal in terms of matching coverage, with respect to greedy algorithms.

- In an ongoing collaboration with Mariana Olvera-Cravioto (University of North Carolina), we investigate the connected out-component of a typical vertex in a large, oriented, preferential attachment random graph (Barabasí- Albert model). By a Markov in-depth exploration and coupling methods, we show that the local limits of the construction of the out-component is a suitable Galton-Watson process. This result has crucial implications for the asymptotics analysis of the main properties of preferential attachment models, which are prevalent in many applications, such as epidemiological models and social media. An article gathering these advances is under preparation.

6.13 Reinforcement learning, and applications to queueing

Participants: Pascal Moyal.

With Céline Comte (LAAS-CNRS), we work on an optimization scheme for the access control of various queueing systems by using reinforcement learning techniques. We have shown that a wide class of systems (encountered in telecom networking, supply chains or call centers) exhibit the same type of quasi-reversibility property, leading to a “universal” product-form type stationary distributions. Then, if the access control enjoys a general balance property, we show this product-form structure remains. We then resort to a model-free (or partially observable model) approach, and apply a class of reinforcement learning algorithms called *Policy-gradient*, which are able to optimize the access control of the considered models. We are currently finishing the redaction of a paper gathering these results, which we will soon submit for publication.

6.14 Speed of convergence in functional central limit theorems

Participants: Pascal Moyal.

In collaboration with Eustache Besançon (Telecom Paris), Laurent Decreusefond (Telecom Paris) and Laure Coutin (Université Paul Sabatier, Toulouse), in which we have shown universal bounds for the speed of convergence in the functional Central Limit Theorems for Lipschitz continuous functionals of Poisson random measures [15]. These results allow us to characterize the accuracy of diffusion approximations of many practical processes appearing in epidemiology, biology of development and telecom networks.

6.15 Game theoretical modeling for trust management in IoT networks

Participants: Pascal Moyal.

- In [27], we propose a novel game-theoretical approach for the modeling and analysis of the so-called crowdsourcing IoT (Internet of Things), by an evolutionary game in which the agents (in particular, the service provider and the service requestor) are possibly irrational, non-homogeneous and change strategy over time. We conduct a theoretical analysis and numerical results, to analyze the influence of the strategy changes.
- In [22], we introduce another game-theoretical role-based attack-resilient trust management (TM) model for community-driven IoT, which takes in account in particular the trust between different communities in terms of cooperativeness. We thoroughly analyze and simulate this TM under various scenario, to show the effectiveness in evaluating both intra and inter-community trustworthiness, and to validate the model in practice.

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

- Programme ECOS SUD-CHILI *Nonsmooth Analysis in Stochastic Systems and Optimal Control Theory*. The PI is Nabil Kazi-Tani (IECL, Metz). The project involves the PASTA team-project member Sara Mazzonetto.

8.2 International research visitors

8.2.1 Visits of international scientists

Other international visits to the team

Aila Särkkä

Status: full professor

Institution of origin: Chalmers University

Country: Sweden

Dates: 13 - 17 October, 2024

Context of the visit: scientific collaboration between Aila Särkkä and Radu Stoica

Mobility program/type of mobility: research stay, seminar

Ed Cohen

Status: associate professor

Institution of origin: Imperial College London

Country: United Kingdom

Dates: 8-9 February, 2024

Context of the visit: scientific collaboration between Ed Cohen and Radu Stoica

Mobility program/type of mobility: research stay

André Ribeiro

Status: post-doc

Institution of origin: Imperial College London

Country: United Kingdom

Dates: 21 October - 08 November, 2024

Context of the visit: scientific collaboration between André Ribeiro and Radu Stoica

Mobility program/type of mobility: Imperial College grant, research stay, seminar

8.2.2 Visits to international teams

Research stays abroad

Madalina Deaconu

Visited institution: Institute of Mathematics of the Romanian Academy

Country: Romania

Dates: 22-29 November 2024

Context of the visit: scientific collaboration with Lucian Beznea and Oana Lupaşcu-Stamate

Mobility program/type of mobility: research stay

Nathan Gillot

Visited institution: Chalmers University

Country: Sweden

Dates: 15 March - 15 May, 2024

Context of the visit: scientific collaboration between Aila Särkkä and Radu Stoica

Mobility program/type of mobility: LUE Dreams/research stay, seminar

Sara Mazzonetto

Visited institution: Isaac Newton Institute in Cambridge

Country: Great Britain

Dates: November 2024

Context of the visit: participant of the Programme *Stochastic systems for anomalous diffusion*

Mobility program/type of mobility: research stay

Radu Stoica

Visited institution: Chalmers University

Country: Sweden

Dates: 21 - 26 April, 2024

Context of the visit: scientific collaboration between Aila Särkkä and Radu Stoica

Mobility program/type of mobility: French Institute in Sweden/research stay, seminar

Radu Stoica

Visited institution: Imperial College London

Country: United Kingdom

Dates: 04 -08 June, 2024

Context of the visit: scientific collaboration between Ed Cohen and Radu Stoica

Mobility program/type of mobility: RING consortium + Imperial College grant/research stay, seminar

8.3 European initiatives

8.3.1 Horizon Europe

HORIZON WIDERA TWINNING EU Project: EXCOSM - Building excellence in the study of galaxies and cosmology at the University of Tartu. Partners: University of Tartu (Estonia), Leibniz Institute for Astrophysics Potsdam (Germany), University of Groningen (The Netherlands), Université de Lorraine (France).

Radu Stoica is the project leader from Université de Lorraine.

8.4 National initiatives

Participants: Antoine Lejay, Sara Mazzonetto, Saïd Toubra.

- 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: Antoine Lejay, Amélie Ferstler, Sara Mazzonetto andSaïd Toubra in a collaboration with Lionel Lenotre (Irimas, Université of Haute-Alsace), Maria-Teresa 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).
- Programme Blanc MITI *Némésis* (funding CNRS). This grant, whose PI are Antoine Lejay and Maria-Teresa Schettino (Archimède, Université de Haute-Alsace), supports the interdisciplinary research in the field of Digital Humanities, namely the development of the Palamède software within the Apollon project and the PhD thesis of Saïd Toubra.
- Insmi PEPS project on Local time approximation. PIs Alexis Anagnostakis (LJK, Grenoble) and Pasta project-team member Sara Mazzonetto.

9 Dissemination

9.1 Promoting scientific activities

9.1.1 Scientific events: organisation

- Antoine Lejay organized a workshop *Calcul scientifique : passage à l'échelle* as an *Atelier du Pôle AM2I* in December, Université de Lorraine.
- Sara Mazzonetto organized a session entitled 'Advances in statistics for stochastic processes' in the *Fourth Italian Meeting on Probability and Mathematical Statistics* in June in Rome. She also co-organized the *Colloquinte* for the probability and statistics team of IECL.
- Pascal Moyal co-organized the workshop *Online Stochastic matching* in Toulouse, in September 2024.
- Pascal Moyal co-organized the M1 *Master-class* of mathematics in Nancy, in January 2024.

Member of the conference program committees

- *Journées de Probabilités 2024*, Bordeaux, France, June 2024. Antoine Lejay.
- *Online stochastic matching conference 2024*, Toulouse, France, September 2024. Pascal Moyal.

9.1.2 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.
- Pascal Moyal was co-editor of two special issues on Product forms, matching models and redundancy systems for *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*.

Reviewer - reviewing activities

- Madalina Deaconu wrote reviews for: *Quantitative Finance*.
- Antoine Lejay wrote reviews for: *Annales de l'IHP, probabilités et statistique*, *Finance & Stochastics*, *Journal of Computational Physics*, *Journal of European Mathematical Society*, *Mathematics and Computers in Simulation*, *Methodology and Computing in Applied Probability*.
- Sara Mazzonetto wrote reviews for *Journal of Theoretical Probability* and *Applied Mathematical Finance*.
- Pascal Moyal wrote reviews for *Annals of applied probability* and *Queueing systems: theory and applications*.
- Radu Stoica wrote reviews for *Annals of the Institute of Statistical Mathematics* and *Bernoulli*.

9.1.3 Invited talks

- Antoine Lejay gave a talk at the *16ème colloque Franco-Roumain* (August, Bucharest, Romania), and the yearly conference of ANR Dreams (September, Metz, France), at the Seminar from Veridis project-team (May, Nancy).
- Amélie Ferstler gave a presentation at the department of antic studies at University La Sapienza (November, Roma, Italy)
- Sara Mazzonetto gave talks at the Workshops Stochastic Reflection (August, INI Cambridge, UK), at the session Statistics of stochastic processes and applications of the Fourth Italian Meeting on Probability and Mathematical Statistics (June, Rome, Italy), at *A lifelong journey in stochastic analysis: from branching processes to statistical mechanics* (May, Paris IHP, France), and at the Calais-Amiens Days (February, Calais, France). She also gave the Statistics seminar in Strasbourg (May, Strasbourg, France).
- Pascal Moyal gave invited talks at the SNAPP seminar (May - International online seminar series), at the *Stoch Mod* conference (June, Milan, Italy), at the SOLACE seminar (September, Toulouse), at the AEP *Atelier d'évaluation de performance* conference (December, Toulouse).
- Radu Stoica gave talks at Chalmers University, Imperial College London, Centre de Geostatistique de Fontainebleau and Université de Lille

9.1.4 Scientific expertise

- Antoine Lejay served as an expert for the HCERES Committee of CERMICS (École des Ponts et Chaussées, Paris), November 2024.
- Pascal Moyal served as an expert for a Personal Research Grant of the *Israel Science foundation*, April 2024.
- Pascal Moyal served as an expert for a CIFRE PhD funding commission, September 2024.

9.1.5 Research administration

- Madalina Deaconu is Deputy Head of Science of Inria Centre at Université de Lorraine and Inria branch at Strasbourg 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.

- Antoine Lejay is a member of the board the AMIES.

  He is also the Vice-Director of the *Pôle AM2I* in charge of scientific animation. The Pôle AM2I gathers 6 laboratories of Université de Lorraine related to mathematics, computer sciences and automatic control (CRAN, IECL, LCFC, LCOMS, LGIPM, LORIA) with the goal of fostering 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 elected member of the IECL Laboratory Council from 2024.

  She was member of a hiring committee for PhD students scholarships at IECL in June 2024.
  In May 2024 she was Member of a hiring committee for an Assistant Professor position in France.
  In February 2024 she was member of the hiring committee for a PostDoc in ERC LoRDeT.

  She is one of the organiser of an internal seminar of the Probability and Statistics group at IECL since September 2022.

- Pascal Moyal is Head of the *Probability ans Statistics* team (36 faculty members) at IECL. As such, he is also:

  - Member of the *Executive committee* of IECL;
  - Invited Member of the IECL *Laboratory council*;
  - Member of the *PhD hiring committee* of IECL.

- Pascal Moyal is member of the Internal committee (*commission du personnel*) of IECL.

- Pascal Moyal was member of the hiring committee at *Assistant Professor* level (Maître de conférences) at Université de Franche-Comté, May 2024.

- Radu Stoica is member of the International Strategy Think Tank of the Université de Lorraine.

- Radu Stoica is in charge of the international relations of the IECL Laboratory.

9.2 Teaching - Supervision - Juries

9.2.1 Teaching

Pascal Moyal and Radu Stoica are professors. They have full teaching duties with lectures at all the levels of the university. Sara Mazzonetto is assistant professor, who was on partial leave this year. For them all, 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.

- Sara Mazzonetto, *Probability and Statistics*, 40h, M1, Master IMSD and MFA, Universiy of Lorraine.

- Pascal Moyal is co-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 calculus for finance*, 25h, M2, Master IMSD, Université de Lorraine.

- Pascal Moyal, *Reinforcement learning*, 12h, M2, Master IMSD, Université de Lorraine.
- Pascal Moyal, *Stochastic modelling*, 12h, M2, Master IMSD, Université de Lorraine.
- Pascal Moyal, *Random graphs and their applications*, 30h, M2, Master MFA, Université de Lorraine.
- Pascal Moyal, *Graph theory and Neural networks*, 30h, M1, Master Math., Université de Lorraine.
- Pascal Moyal, *Stochastic calculus*, 24h, Master level,Telecom Paristech,
- Pascal Moyal, *Stochastic networks*, 17h30, Master level, *Mastère Parisien de Recherche Opérationnelle*, CNAM,
- Pascal Moyal, *Operations research*, Master level, *Mastère TET*, École des Ponts et Chaussées,
- Radu Stoica is the co-head of the Master M2 IMSD *Ingénierie Mathématique et Science des Données* (Université de Lorraine).
- 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*, Lorenzo Agabiti, *High-order expansions in rough paths analysis*, Sorbonne Université, October 2024, funding COFUND FSMP, Antoine Lejay and Lorenzo Zambotti (Sorbonne Université, Paris).
- *PhD in progress*: Julia Budzinski, *Simulation of diffusions with discontinuous coefficients*, Université de Lorraine, November 2023, funding Inria, Madalina Deaconu and Sara Mazzonetto.
- *PhD in progress*: Amandine Fratani, *Interpretation of seismic faults by graph-based machine learning*, Université de Lorraine, November 2022, funding RING consortium, Guillaume Caumon (Georessources, Université de Lorraine) and Radu Stoica.
- *PhD in progress*: Nathan Gillot, *Models and algorithms for statistical learning of marked space-time point processes. Application: analysis and characterization of cosmological data*, Université de Lorraine, November 2022, funding CNRS, Radu Stoica.
- *PhD defended in December 2024*: Fabrice Taty Moukati *Construction of a marked point process for the detection and the characterization of seismic faults*, Université de Lorraine, March 2021, funding RING consortium, Guillaume Caumon (Georessources, Université de Lorraine) and Radu Stoica.
- *PhD in progress*: Saïd Toubra, *Geometric Interpretation of Embeddings in Neural Networks*, Université de Lorraine, October 2024, funding CNRS, Antoine Lejay and Lionel Lenotre (IRIMAS, Université de Haute-Alsace).

9.2.3 Juries

- Madalina Deaconu was member of the Jury of “admissibilité” CRCN and ISFP at Center Inria in Paris and Center Inria in Saclay.
- Examinator for the PhD of Benoît Nieto, École Centrale de Lyon, September, Antoine Lejay.
- Examinator for the PhD of El Medhi Harress, École Centrale Supélec, December, Antoine Lejay.
- Reviewer for the HdR of Frédéric Clerc, Université de Rennes, December, Pascal Moyal.

9.3 Popularization

9.3.1 Specific official responsibilities in science outreach structures

- 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).

9.3.2 Participation in Live events

- Antoine Lejay gave a talk at the *Semaine de la Recherche* (LORIA, Nancy, France).
- Pascal Moyal gave a popularization speech for describing the mathematical modeling and analysis of organ transplants, in the *À votre santé* conference series, Nancy, March 2024.

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. '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.

[6] 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.

[7] 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.

[8] 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.

[9] 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.

[10] 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.

[11] 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

[12] K. Adamczyk-Chauvat, M. Kassa, J. Papaïx, K. Kiêu and R. S. Stoica. 'Statistical inference for random T-tessellations models. Application to agricultural landscape modeling'. In: *Annals of the Institute of Statistical Mathematics* 76 (5th Apr. 2024), pp. 447–479. DOI: 10.1007/s10463-023-00893-3. URL: https://hal.inrae.fr/hal-04536390 (cit. on p. 8).

[13] E. Baioni, A. Lejay, G. Pichot and G. M. Porta. 'Modeling diffusion in discontinuous media under generalized interface conditions: theory and algorithms'. In: *SIAM Journal on Scientific Computing* 46.4 (4th July 2024), A2202–A2223. DOI: 10.1137/23M1590846. URL: https://inria.hal.science/hal-04166559 (cit. on p. 7).

[14] E. Baioni, A. Lejay, G. Pichot and G. M. Porta. 'Random walk modeling of conductive heat transport in discontinuous media'. In: *Transport in Porous Media* (2024). DOI: 10.1007/s11242-024-02132-6. URL: https://inria.hal.science/hal-04166562. In press (cit. on p. 7).

[15] E. Besançon, L. Coutin, L. Decreusefond and P. Moyal. 'Diffusive limits of Lipschitz functionals of Poisson measures'. In: *The Annals of Applied Probability* 34.1A (2024), pp. 555–584. DOI: 10.1214/23-AAP1972. URL: https://telecom-paris.hal.science/hal-03283778 (cit. on p. 11).

[16] M. Deaconu and S. Herrmann. 'Strong approximation of some particular one-dimensional diffusions'. In: *Discrete and Continuous Dynamical Systems - Series B* 29.4 (Apr. 2024), pp. 1990–2017. URL: https://hal.science/hal-02799638 (cit. on p. 6).

[17] K. Gardner and P. Moyal. 'Second part of the Special Issue on Product Forms, Stochastic Matching, and Redundancy'. In: *Queueing Systems* 107 (9th Aug. 2024), pp. 199–203. DOI: \url{https://doi.org/10.1007/s11134-024-09922-1}. URL: https://hal.science/hal-04726024.

[18] A. Hudde, M. Hutzenthaler, A. Jentzen and S. Mazzonetto. 'On the Itô-Alekseev-Gröbner formula for stochastic differential equations'. In: *Annales de l'Institut Henri Poincaré (B) Probabilités et Statistiques* 60.2 (11th June 2024), pp. 904–922. DOI: 10.1214/21-AIHP1199. URL: https://hal.science/hal-04149410.

[19] T. Masanet and P. Moyal. 'Perfect sampling of stochastic matching models with reneging'. In: *Advances in Applied Probability* (2024). DOI: 10.1017/apr.2023.62. URL: https://hal.science/hal-03580942. In press (cit. on p. 10).

[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] P. Moyal, A. Bušić and J. Mairesse. 'On the sub-additivity of stochastic matching'. In: *Queueing Systems* 107 (Sept. 2024), pp. 295–339. DOI: 10.1007/s11134-024-09919-w. URL: https://hal.science/hal-04088419 (cit. on p. 10).

[22] R. Su, A. Riahi, E. Natalizio, P. Moyal, A. Saint-Jore and Y.-Q. Song. 'Assessing intra- and inter-community trustworthiness in IoT: A role-based attack-resilient dynamic trust management model'. In: *Internet of Things* 26 (July 2024), p. 101213. DOI: 10.1016/j.iot.2024.101213. URL: https://hal.science/hal-04620889 (cit. on p. 11).

[23] F. Taty Moukati, R. S. Stoica, F. Bonneau, X. Wu and G. Caumon. 'From fault likelihood to fault networks: stochastic seismic interpretation through a marked point process with interactions'. In: *Mathematical Geosciences* (30th July 2024). DOI: 10.1007/s11004-024-10150-9. URL: https://hal.univ-lorraine.fr/hal-04513328. In press (cit. on p. 9).

Conferences without proceedings

[24] K. Adamczyk-Chauvat, M. Kassa, J. Papaïx, K. Kiêu and R. S. Stoica. 'Statistical inference for random T-tessellations models: application to agricultural landscape modeling.' In: 11th International Conference on Spatio-Temporal Modelling METMA XI. Lancaster, United Kingdom, 23rd July 2024. URL: https://hal.inrae.fr/hal-04669756.

[25] D. Astaburuaga, R. S. Stoica, D. Gemmerlé and F. Cuevas-Pacheco. 'Inhomogeneous interacting marked point processes for studying morphostructures in paleobiological data'. In: Ring Meeting 2024. Nancy, France, 17th Sept. 2024. URL: https://hal.science/hal-04653458 (cit. on p. 8).

[26] N. Gillot, R. S. Stoica, A. Särkkä and D. Gemmerlé. 'Spatial point process modelling and Bayesian inference for large data sets'. In: RING Meeting. Nancy, France, 17th Sept. 2024. URL: https://hal.science/hal-04645186 (cit. on p. 8).

[27] R. Su, A. R. Sfar and P. Moyal. 'Game theoretical analysis of strategy changes and influence factors in Crowdsourcing IoT systems'. In: DCOSS-IoT 2024. Abu Dhabi, United Arab Emirates: IEEE, 29th Apr. 2024, pp. 264–268. DOI: 10.1109/DCOSS-IoT61029.2024.00048. URL: https://hal.science/hal-04564953 (cit. on p. 11).

Edition (books, proceedings, special issue of a journal)

[28] *Editorial introduction: special issue on product forms, stochastic matching, and redundancy* 106.3-4 (11th May 2024). DOI: 10.1007/s11134-024-09908-z. URL: https://hal.science/hal-04726038.

Reports & preprints

[29] G. Agazzotti, M. Deaconu and A. Lejay. *Long time asymptotic behavior of a self-similar fragmentation equation*. 26th Feb. 2024. URL: https://hal.science/hal-04477123 (cit. on p. 6).

[30] A. Benetos, C. Fritsch, E. Horton, L. Lenotre, S. Toupance and D. Villemonais. *Stochastic branching models for the telomeres dynamics in a model including telomerase activity*. 15th July 2024. URL: https://hal.science/hal-04648211.

[31] M. H. A. Diallo Aoudi, P. Moyal and V. Robin. *Large graph limits of local matching algorithms on uniform random graphs*. 23rd Oct. 2024. URL: https://hal.science/hal-04750754 (cit. on p. 10).

[32] A. Lejay and S. Mazzonetto. *Beyond the delta method*. 4th Apr. 2024. URL: https://inria.hal.science/hal-03738371 (cit. on p. 7).

[33] L. Lesage, M. Deaconu, A. Lejay, J. A. Meira, G. Nichil and R. State. *A Recommendation System For Insurance Built With A Multivariate Hawkes Process Based On Customers' Life Events*. 4th Oct. 2024. URL: https://hal.science/hal-03483812.

[34] S. Mazzonetto. *Rates of convergence to the local time of Oscillating and Skew Brownian Motions*. 3rd Apr. 2024. URL: https://hal.science/hal-03367822 (cit. on p. 7).

[35] S. Mazzonetto and A. Anagnostakis. *On the number of crossings and bouncings of a diffusion at a sticky threshold*. 28th Oct. 2024. URL: https://hal.univ-lorraine.fr/hal-04755893 (cit. on p. 7).

[36] S. Mazzonetto and A. Anagnostakis. *Sticky-threshold diffusions, local time approximation and parameter estimation*. 2024. URL: https://hal.science/hal-04503682 (cit. on p. 7).

[37] S. Mazzonetto and B. Nieto. *Parameters estimation of a Threshold CKLS process from continuous and discrete observations*. 28th Mar. 2024. URL: https://hal.science/hal-04524431 (cit. on p. 7).

[38] S. Mazzonetto and P. Pigato. *Estimation of parameters and local times in a discretely observed threshold diffusion model*. 11th Mar. 2024. URL: https://hal.science/hal-04500135 (cit. on p. 7).