RESEARCH CENTRE

Inria Paris Center

IN PARTNERSHIP WITH:

Ecole normale supérieure de Paris, CNRS

2022

ACTIVITY REPORT

Project-Team

DYOGENE

Dynamics of Geometric Networks

IN COLLABORATION WITH: Département d'Informatique de l'Ecole Normale Supérieure

DOMAIN

Networks, Systems and Services, Distributed Computing

THEME

Networks and Telecommunications

Inria

Contents

Project-Team DYOGENE

Creation of the Project-Team: 2013 July 01

Keywords

Computer sciences and digital sciences

A1.2.4. – QoS, performance evaluation

A6.1.4. – Multiscale modeling

A6.2.3. – Probabilistic methods

A8.1. – Discrete mathematics, combinatorics

A8.2. – Optimization

A8.3. – Geometry, Topology

A8.6. – Information theory

A8.7. – Graph theory

A8.8. – Network science

A8.9. – Performance evaluation

A9.2. – Machine learning

A9.7. – AI algorithmics

Other research topics and application domains

B4.3. – Renewable energy production

B6.2.2. – Radio technology

B6.3.4. – Social Networks

1 Team members, visitors, external collaborators

Research Scientists

- Bartlomiej Blaszczyszyn [Team leader, INRIA, Senior Researcher, HDR]
- François Baccelli [INRIA, Senior Researcher, HDR]
- Antoine Baker [Inria, Starting Research Position]
- Ana Busic [INRIA, Researcher]
- Christine Fricker [INRIA, Researcher, HDR]
- Ali Khezeli [INRIA, Starting Research Position]
- Marc Lelarge [INRIA, Senior Researcher, HDR]
- Laurent Massoulié [INRIA, Senior Researcher, HDR]
- Sean Meyn [ECE FLORIDA, from Jun 2022 until Aug 2022, Inria International Chair]
- Kevin Scaman [INRIA, Researcher]

Post-Doctoral Fellow

- Ke Feng [INRIA]

PhD Students

- Claire Bizon Monroc [INRIA]
- Matthieu Blanke [INRIA]
- Romain Cosson [Inria, from Sep 2022]
- Michel Davydov [INRIA]
- Bastien Dubail [ENS PARIS]
- Mathieu Even [INRIA]
- Roman Gambelin [INRIA]
- Sayeh Khaniha [INRIA]
- Thomas Le Corre [PSL University]
- Maxime Leiber [SAFRAN]
- Jakob Maier [Inria, from Oct 2022]
- Pierre Popineau [INRIA]
- David Robin [INRIA]
- Bharath Roy Choudhury [INRIA]
- Ilia Shilov [INRIA]
- Guodong Sun [NOKIA]
- Amaury Triboulin [INRIA]
- Lucas Weber [DGA]

Technical Staff

- Thibault La Batide-Alanore [INRIA, Engineer, from Nov 2022, Pre-thèse]

Interns and Apprentices

- Alessia Rigonat [Inria, from Apr 2022 until Oct 2022]
- Solène Delannoy-Pavy [Inria, from Mar 2022 until Jul 2022]
- Thibault La Batide-Alanore [Inria, from Feb 2022 until Jul 2022]
- Jakob Maier [Inria, from Apr 2022 until Sep 2022]

Administrative Assistants

- Helene Bessin Rousseau [INRIA]
- Julien Guieu [Inria, for ERC Nemo]
- Helene Milome [INRIA]

Visiting Scientist

- Mir Omid Haji Mirsadeghi [SUT SHARIF]

External Collaborators

- Charles Bordenave [CNRS, from Jul 2022]
- Pierre Bremaud [Emeritus EPFL, HDR]
- Marc-Olivier Buob [Nokia Bell Labs]
- Serguei Foss [UNIV HERIOT-WATT, from May 2022]
- Alexandre Gaudilliere [CNRS, from Mar 2022]
- Subhroshekhar Ghosh [UNIV SINGAPOUR, from Jun 2022]
- Thomas Hutchcroft [UNIV CAMBRIDGE]
- Sanket Kalamkar [Qualcomm]
- Panogiotis Konstantopoulos [UNIV LIVERPOOL, from Feb 2022]
- Fabien Mathieu [SWAPCARD, HDR]
- Samuel Mellick [ENS DE LYON, from Feb 2022]
- Elizabeth O'Reilly [CALTECH]

2 Overall objectives

The general scientific focus of DYOGENE is on the development of network mathematics. The following theories lie within our research interest: dynamical systems, queuing theory, optimization and control, information theory, stochastic processes, random graphs, stochastic geometry.

Our theoretical developments are motivated by and applied in the context of communication networks (Internet, wireless, mobile, cellular, peer-to-peer), social and economic networks, power grids, and, recently, infectious diseases.

We collaborate with many industrial partners. Our current industrial relations involve EDF, Huawei, Microsoft, Nokia, Orange, Safran.

More specifically, the scientific focus of DYOGENE defined in 2013 was on geometric network dynamics arising in communications. By geometric networks we understand networks with a nontrivial, discrete or continuous, geometric definition of the existence of links between the nodes. In stochastic geometric networks, this definition leads to random graphs or stochastic geometric models.

A first type of geometric network dynamics is the one where the nodes or the links change over time according to an exogeneous dynamics (e.g. node motion and geometric definition of the links). We will refer to this as dynamics of geometric networks below. A second type is that where links and/or nodes are fixed but harbor local dynamical systems (in our case, stemming from e.g. information theory, queuing theory, social and economic sciences). This will be called dynamics on geometric networks. A third type is that where the dynamics of the network geometry and the local dynamics interplay. Our motivations for studying these systems stem from many fields of communications where they play a central role, and in particular: message passing algorithms; epidemic algorithms; wireless networks and information theory; device to device networking; distributed content delivery; social and economic networks, neural networks, and power grids.

3 Research program

Here are our main research accesses.

- Models of infectious diseases 8.1
- Distributed network control and smart-grids 8.2
- Stochastic matching and queueing systems 8.3
- Reinforcement learning 8.4
- Mathematics of wireless cellular networks 8.5
- High-dimensional statistical inference and distributed learning 8.6
- Distributed optimization for machine learning 8.7
- Random Geometry 8.8
- Mathematics of stochastic networks via mean-field analysis 8.9

4 Application domains

4.1 Physical communication networks

Internet, wireless, mobile, cellular networks, transportation networks, distributed systems (cloud, call centers). In collaboration with Nokia Bell Labs and Orange Labs.

4.2 Abstract networks

Social interactions, human communities, economic networks.

4.3 Power grids

Energy networks. In collaboration with EDF and Vito (Belgium).

5 Social and environmental responsibility

6 Highlights of the year

6.1 Awards

- **Solène Delannoy-Pavy** received a research internship award (section Applied mathematics) from Ecole Polytechnique for her internship entitled *"Designing call centers with two levels of service"*.
- **Michel Davydov** received the MNA award for the best junior researcher presentation during the workshop "Mathematical modeling and Statistical Analysis in Neuroscience" at the Institut Henri Poincaré, Paris France;

7 New software and platforms

7.1 New software

7.1.1 pp_syn

Name: Particle gradient descent model for point process generation

Keywords: 2D, Point process generation, Gradient descent, Wavelet phase harmonics

Scientific Description: This paper introduces a generative model for planar point processes in a square window, built upon a single realization of a stationary, ergodic point process observed in this window. Inspired by recent advances in gradient descent methods for maximum entropy models, we propose a method to generate similar point patterns by jointly moving particles of an initial Poisson configuration towards a target counting measure. The target measure is generated via a deterministic gradient descent algorithm, so as to match a set of statistics of the given, observed realization. Our statistics are estimators of the multi-scale wavelet phase harmonic covariance, recently proposed in image modeling. They allow one to capture geometric structures through multi-scale interactions between wavelet coefficients. Both our statistics and the gradient descent algorithm scale better with the number of observed points than the classical k-nearest neighbour distances previously used in generative models for point processes, based on the rejection sampling or simulated-annealing. The overall quality of our model is evaluated on point processes with various geometric structures through spectral and topological data analysis, compared in particular to [Tscheschel, Stoyan (2006) Statistical reconstruction of random point patterns].

Functional Description: Code for the paper "Particle gradient descent model for point process generation" in Statistics and Computing 32 (3) June 2022 Statistics and Computing. Using Kymatio/phaseharmonics software.

URL: `https://github.com/abrochar/pp_syn`

Publication: hal-02980486

Contact: Sixin Zhang

Participants: Antoine Brochard, Sixin Zhang, Bartlomiej Blaszczyszyn

7.1.2 wavelet-texture-synthesis

Name: Generalized Rectifier Wavelet Covariance Model For texture Synthesis

Keywords: Texture Synthesis, Wavelet phase harmonics, Generative Models

Scientific Description: State-of-the-art maximum entropy models for texture synthesis are built from statistics relying on image representations defined by convolutional neural networks (CNN). Such representations capture rich structures in texture images, outperforming wavelet-based representations in this regard. However, conversely to neural networks, wavelets offer meaningful representations, as they are known to detect structures at multiple scales (e.g. edges) in images. In this work, we propose a family of statistics built upon non-linear wavelet based representations, that can be viewed as a particular instance of a one-layer CNN, using a generalized rectifier non-linearity. These statistics significantly improve the visual quality of previous classical wavelet-based models, and allow one to produce syntheses of similar quality to state-of-the-art models, on both gray-scale and color textures. We further provide insights on memorization effects in these models.

Functional Description: Code for the paper: "Generalized Rectifier Wavelet Covariance Model For texture Synthesis" In ICLR 2022 - 10th International Conference on Learning Representation, France, April 2022 ICLR 2022

URL: https://github.com/abrochar/wavelet-texture-synthesis

Publication: hal-03612563

Contact: Sixin Zhang

Participants: Antoine Brochard, Sixin Zhang

8 New results

Participants: All Dyogene.

8.1 Models of infectious diseases

1. ***A computational framework for evaluating the role of mobility on the propagation of epidemics on point processes*** [5] This paper is focused on SIS (Susceptible-Infected-Susceptible) epidemic dynamics (also known as the contact process) on populations modeled by homogeneous Poisson point processes of the Euclidean plane, where the infection rate of a susceptible individual is proportional to the number of infected individuals in a disc around it. The main focus of the paper is a model where points are also subject to some random motion. Conservation equations for moment measures are leveraged to analyze the stationary regime of the point processes of infected and susceptible individuals. A heuristic factorization of the third moment measure is then proposed to obtain simple polynomial equations allowing one to derive closed form approximations for the fraction of infected individuals in the steady state. These polynomial equations also lead to a phase diagram which tentatively delineates the regions of the space of parameters (population density, infection radius, infection and recovery rate, and motion rate) where the epidemic survives and those where there is extinction. A key take-away from this phase diagram is that the extinction of the epidemic is not always aided by a decrease in the motion rate. These results are substantiated by simulations on large two dimensional tori. These simulations show that the polynomial equations accurately predict the fraction of infected individuals when the epidemic survives. The simulations also show that the proposed phase diagram accurately predicts the parameter regions where the mean survival time of the epidemic increases (resp. decreases) with motion rate.

2. ***Disparities in accessibility to oncology care centers in France*** [42] Background Cancer caused nearly 10 million deaths in 2020. While most of the ongoing research focuses on finding new treatments,

accessibility to oncology care receives less attention. However, access to health services plays a key role in cancer survival. Spatial accessibility methods have been successfully applied to measure accessibility to primary care. Yet, little research to date focused on oncology care specifically. Methods We focused on all care centers with medicine, surgery, or obstetric activity in metropolitan France. We propose a clustering algorithm to automatically label the hospitals in terms of oncology specialization. Then, we computed an accessibility score to these hospitals for every municipality in metropolitan France. Finally, we proposed an optimization algorithm to increase the oncology accessibility by identifying centers which should increase their capacity. Results We labelled 1,662 care centers into 8 clusters. Half of them were eligible for oncology care and 118 centers were identified as experts. We computed the oncology accessibility score for 34,877 municipalities in metropolitan France. Half of the population lived in the top 20% accessibility areas, and 6.3% in the bottom 20% zones. Accessibility was higher near dense cities, where the experts care centers were located. By combining the care centers clusters and the accessibility distributions, our optimization algorithm could identify hospitals to grow, to reduce accessibility disparities. Conclusion Our method made it possible to quantify oncology care accessibility across all metropolitan France, as well as to make suggestions on where to increase hospital capacity to improve accessibility, especially in more populated suburban areas. Our approach was deliberately non-specific to cancer type nor to the kind of stays, but it could be adapted to more specific scenarios. We packaged our method into a web application allowing the users to run the algorithms with various parameters and visualize the results. Highlights We computed the oncology accessibility score for 34,877 municipalities and highlighted disparities. Our optimization algorithm can identify hospitals to grow, to reduce accessibility disparities. We packaged our algorithms and results into a web application, opened to healthcare professionals.

3. ***Geographic and socio-demographic disparities in oncology care pathways*** [34] In France, during year 2018, there was 382,000 new cancer cases and 157,400 deaths. The 2014-2019 Cancer Plan sets new objectives for cancer care in France. In particular, objectives 2 and 7 emphasize the quality of the care pathways: they aim respectively to guarantee the qual- ity and safety of care and ensure comprehensive and personalized care. In order to standardize the care pathways while personalizing care, care trajectories have been introduced. The definition of these optimal care trajectories is based on national and international good practice recommendations. We propose to study in detail the geographical and socio-demographic disparities in the care pathways of cancer patients in France. First, we will try to characterize the health care institutions in France based on their oncology activity. Then, we will study the distribution of these centers on the territory, in order to highlight possible disparities in access to them. Finally, we will try to propose a care center recommendation algorithm, using the French social security database (SNDS). This algorithm will aim at guiding patients towards the optimal center, in order to maximize the quality of the care pathways.

8.2 Distributed network control and smart-grids

4. ***An Equilibrium Analysis of Risk-Hedging Strategies in Decentralized Electricity Markets*** [50] We investigate equilibrium problems arising in various decentralized designs of the electricity market involving riskaverse prosumers. The prosumers have the possibility to hedge their risks through financial contracts that they can trade with peers or purchase from an insurance company. We build several market designs of increasing complexity, from a one-stage market design with inter-agent financial contract trading to a Stackelberg game where an insurance company acts as a leader and prosumers are followers. We derive risk-hedging pricing scheme for each model and show that the Stackelberg game pessimistic formulation might have no solution. We propose an equivalent reformulation as a parametrizated generalized Nash equilibrium problem, and characterize the set of equilibria. We prove that the insurance company can design price incentives that guarantee the existence of a solution of the pessimistic formulation, which is ε close to the optimistic one. We then derive economic properties of the Stackelberg equilibria such as fairness, equity, and efficiency. We also quantify the impact of the insurance company incomplete information on the prosumers' riskaversion levels on its cost and social cost. Finally, we evaluate numerically the proposed risk-hedging market models, using residential data provided by Pecan Street.

5. ***Feature Projection for Optimal Transport*** [41] Optimal transport is now a standard tool for solving many problems in statistics and machine learning. The optimal "transport of probability measures" is also a recurring theme in stochastic control and distributed control, where in the latter application the probability measure corresponds to an empirical distribution associated with a large collection of distributed agents, subject to local and global control. The goal of this paper is to make precise these connections, which inspires new relaxations of optimal transport for application in new and traditional domains. The proposed relaxation replaces a target measure with a "moment class": a set of probability measures defined by generalized moment constraints. This is motivated by applications to control, outlier detection, and to address computational complexity. The main conclusions are (i) A characterization of the solution is obtained, similar to Kantorovich duality, in which one of the dual functions in the classical theory is replaced by a linear combination of the features defining the generalized moments. Hence the dimension of the optimization problem coincides with the number of constraints, even with an uncountable state space; (ii) By introducing regularization in the form of relative entropy, the solution can be interpreted as replacing a maximum with a softmax in the dual; (iii) In applications such as control for which it is not known a-priori if the moment class is non-empty, a relaxation is proposed whose solution admits a similar characterization; (iv) The gradient of the dual function can be expressed in terms of the expectation of the features under a tilted probability measure, which motivates Monte-Carlo techniques for computation.

6. ***Can locational disparity of prosumer energy optimization due to inverter rules be limited?*** [15] To mitigate issues related to the growth of variable smart loads and distributed generation, distribution system operators (DSO) now make it binding for prosumers with inverters to operate under pre-set rules. In particular, the maximum active and reactive power set points for prosumers are based on local voltage measurements to ensure that inverter output does not cause voltage violations. However, such actions, as observed in this work, restrict the range available for local energy management, with more adverse losses on arbitrage profits for prosumers located farther away from the substation. The goal of the paper is three-fold: (a) to develop an optimal local energy optimization algorithm for activation of load flexibility and inverter-interfaced solar PV and energy storage under time-varying electricity prices; (b) to quantify the locational impact on prosumer arbitrage gains due to inverter injection rules prevalent in different energy markets; (c) to propose a computationally efficient hybrid inverter control policy which provides voltage regulation while substantially reducing locational disparity. Using numerical simulations on three identical prosumers located at different parts of a radial feeder, we show that our control policy is able to minimize locational disparity in arbitrage gains between customers at the beginning and end of the feeder to 1.4%, while PV curtailment is reduced by 91.7% compared to the base case with restrictive volt-Var and volt-watt policy.

7. ***A Generalized Nash Equilibrium analysis of the interaction between a peer-to-peer financial market and the distribution grid*** [32] A Generalized Nash Equilibrium analysis of the interaction between a peer-to-peer financial market and the distribution grid.

8.3 Stochastic matching and queueing systems

8. ***Analysis of an optimal policy in dynamic bipartite matching models*** [9] A dynamic bipartite matching model is given by a bipartite matching graph which determines the possible matchings between the various types of supply and demand items. Both supply and demand items arrive to the system according to a stochastic process. Matched pairs leave the system and the others wait in the queues, which induces a holding cost. We model this problem as a Markov Decision Process and study the discounted cost and the average cost problem. We assume that the cost function is linear on the queue sizes. We show that for the -shaped matching graph, an optimal matching control prioritizes the matchings in the pendant edges and is of threshold type for the diagonal edge. In addition, for the average cost problem, we compute the optimal threshold value. We then show how the obtained results can be used to characterize the structure of an optimal matching control for a quasi-complete graph with an arbitrary number of nodes. For arbitrary bipartite graphs, we show that, when the cost of the pendant edges is larger than in the neighbors, an optimal matching policy prioritizes the items in the pendant edges. We also study the -shaped matching graph and, when the cost of the pendant edges is larger than the cost of the middle edge, we conjecture that an optimal matching policy is also of threshold type with priority to the pendant

edges; however, when the cost of the middle edge is larger, we present simulations that show that it is not optimal to prioritize items in the pendant edges.

9. ***Flexibility can hurt dynamic matching system performance*** [10] We study the performance of general dynamic matching models. This model is defined by a connected graph, where nodes represent the class of items and the edges the compatibilities between items. Items of different classes arrive one by one to the system according to a given probability distribution. Upon arrival, an item is matched with a compatible item according to the First Come First Served discipline and leave the system immediately, whereas it is enqueued with other items of the same class, if any. We show that such a model may exhibit a non intuitive behavior: increasing the services ability by adding new edges in the matching graph may lead to a larger average population. This is similar to a Braess paradox. We first consider a quasicomplete graph with four nodes and we provide values of the probability distribution of the arrivals such that when we add an edge the mean number of items is larger. Then, we consider an arbitrary matching graph and we show sufficient conditions for the existence or non-existence of this paradox. We conclude that the analog to the Braess paradox in matching models is given when specific independent sets are in saturation, i.e., the system is close to the stability condition.

10. ***Product form solution for the steady-state distribution of a Markov chain associated with a general matching model with self-loops*** [20] We extend the general matching graph model to deal with matching graph where every node has a self loop. Thus the states on the Markov chain are associated with the independent sets of the matching graph. We prove that under i.i.d. arrivals assumptions the steady-state distribution of the Markov chain has a product form solution.

11. ***Appariements, polytopes et dons d'organes*** [21] Les programmes de dons croisés de reins donnent lieu à un problème d'appariement complexe pour lequel une solution optimale est inconnue. Ce problème peut être décrit par un modèle d'appariement dynamique et aléatoire où des éléments de différentes classes arrivent selon des processus de Poisson indépendants. Chaque élément représente un couple donneur-receveur où le donneur, prêt à donner un rein pour le receveur, est incompatible avec lui ; et la classe encode des propriétés du couple, telles que les groupes sanguins du donneur et du receveur, qui influencent sa compatibilité. Les contraintes d'appariement sont décrites par un graphe non-orienté dont les sommets sont les classes : deux couples ont des classes voisines dans le graphe s'ils peuvent être appariés dans le sens où chaque donneur peut donner son rein au receveur de l'autre couple. Les éléments en attente sont stockés dans une file d'attente. Nous étudions l'efficacité des politiques d'appariement, non seulement en termes de stabilité du système, mais aussi de contrôle des taux d'appariement entre différentes classes. Ce dernier point est important en vue de privilégier les appariements maximisant d'autres mesures de performance, comme la qualité de vie après la transplantation ou le taux de survie du greffon. Cet article présente les principales contributions sur les appariements dynamiques pré-publiés et implantés par les auteurs [CMB22, Mat]. Par souci de concision, les preuves sont omises dans la présente version. La partie 1 formalise le problème et introduit l'équation de conservation qui caractérise les taux d'appariement de toute politique stable. La partie 2 présente une relation simple reliant la structure du graphe, l'équation de conservation, et la stabilité du système. Cette relation nous permet de caractériser dans la partie 3 l'ensemble des solutions de l'équation de conservation comme un polytope convexe. Finalement, la partie 4 montre que tout point du polytope est atteignable ou approchable par des politiques simples qui éliminent certaines arêtes.

12. ***Stochastic dynamic matching: A mixed graph-theory and linear-algebra approach*** [40] The stochastic dynamic matching problem has recently drawn attention in the stochastic-modeling community due to its numerous applications, ranging from supply-chain management to kidney exchange programs. In this paper, we consider a matching problem in which items of different classes arrive according to independent Poisson processes. Unmatched items are stored in a queue, and compatibility constraints are described by a simple graph on the classes, so that two items can be matched if their classes are neighbors in the graph. We analyze the efficiency of matching policies, not only in terms of system stability, but also in terms of matching rates between different classes. Our results rely on the observation that, under any stable policy, the matching rates satisfy a conservation equation that equates the arrival and departure rates of each item class. Our main contributions are threefold. We first introduce a mapping between the dimension of the solution set of this conservation equation, the structure of the compatibility graph,

and the existence of a stable policy. In particular, this allows us to derive a necessary and sufficient stability condition that is verifiable in polynomial time. Secondly, we describe the convex polytope of non-negative solutions of the conservation equation. When this polytope is reduced to a single point, we give a closed-form expression of the solution; in general, we characterize the vertices of this polytope using again the graph structure. Lastly, we show that greedy policies cannot, in general, achieve every point in the polytope. In contrast, non-greedy policies can reach any point of the interior of this polytope, and we give a condition for these policies to also reach the boundary of the polytope.

13. ***Stationary queues in space and time*** [2]

8.4 Reinforcement learning

14. ***Delay-Aware Decentralized Q-learning for Wind Farm Control*** [27] Wind farms are subject to the so-called "wake effect", where upstream turbines facing the wind create sub-optimal wind conditions for turbines located downstream. One strategy to address this issue is to use yaw actuators to misalign the wind turbines with regard to the incoming wind direction, thus deflecting wakes away from downstream turbines. Tractable models for yaw optimization are however subject to inaccuracies, ignore wake dynamics and lack adaptability. This incentivizes the use of model-free methods. In this paper, we propose a delay-aware decentralized Q-learning algorithm for yaw control on wind farms. We introduce a strategy to handle delayed cost collection, and show that our method significantly increases power production in simulations with realistic wake dynamics. We validate our results for two farm layouts on midfidelity wind farm simulator FAST.Farm.

15. ***Particle gradient descent model for point process generation*** [8] This paper presents a statistical model for stationary ergodic point processes, estimated from a single realization observed in a square window. With existing approaches in stochastic geometry, it is very difficult to model processes with complex geometries formed by a large number of particles. Inspired by recent works on gradient descent algorithms for sampling maximum-entropy models, we describe a model that allows for fast sampling of new configurations reproducing the statistics of the given observation. Starting from an initial random configuration, its particles are moved according to the gradient of an energy, in order to match a set of prescribed moments (functionals). Our moments are defined via a phase harmonic operator on the wavelet transform of point patterns. They allow one to capture multi-scale interactions between the particles, while controlling explicitly the number of moments by the scales of the structures to model. We present numerical experiments on point processes with various geometric structures, and assess the quality of the model by spectral and topological data analysis.

8.5 Mathematics of wireless cellular networks

16. ***Energy and Delay Trade-Offs of End-to-End Vehicular Communications using a Hyperfractal Urban Modelling*** [16, 37] We characterize trade-offs between the end-to-end communication delay and the energy in urban vehicular communications with infrastructure assistance. Our study exploits the self-similarity of the location of communication entities in cities by modeling them with an innovative model called "hyperfractal". We show that the hyperfractal model can be extended to incorporate road-side infrastructure and provide stochastic geometry tools to allow a rigorous analysis. We compute theoretical bounds for the end-to-end communication hop count considering two different energy-minimizing goals: either total accumulated energy or maximum energy per node. We prove that the hop count for an end-to-end transmission is bounded by $O(n^{1-\alpha/(d_F-1)})$ where $\alpha < 1$ and $d_F > 2$ is the fractal dimension of the mobile nodes process. This proves that for both constraints the energy decreases as we allow choosing routing paths of higher length. The asymptotic limit of the energy becomes significantly small when the number of nodes becomes asymptotically large. A lower bound on the network throughput capacity with constraints on path energy is also given. We show that our model fits real deployments where open data sets are available. The results are confirmed through simulations using different fractal dimensions in a Matlab simulator.

17. ***Modeling and Analysis of 2-Tier Heterogeneous Vehicular Networks Leveraging Roadside Units and Vehicle Relays*** [39] While roadside units (RSUs) play an essential role in vehicle-to-everything (V2X)

by communicating with users, some users in congestion areas may not be well-served due to data traffic, signal attenuation, and interference. In these cases, vehicle relays can be employed to enhance the network topology to better serve those users. This paper leverages stochastic geometry to propose a novel framework for the performance analysis of heterogeneous vehicular networks with RSUs, vehicle relays, and vehicle users. We present a two-dimensional analytical model where the spatial dependence between RSUs, vehicle relays, vehicle users, and roads is accurately taken into account through a Cox point process structure. Assuming relays are backhauled to RSUs over a reserved wireless resource and users are associated with the closest RSU or relay, we derive the probability that the typical user is associated with either an RSU or a relay. Then, we derive the signal-to-interference ratio (SIR) coverage probability of the typical user. Finally, using the derived formulas, we evaluate the average effective rate of the typical user in the network. This allows us to determine the gain of the average effective rate of users that results from the deployment of relays in the network.

18. ***A Stochastic Geometry Model for Spatially Correlated Blockage in Vehicular Networks*** [11] This paper presents a novel spatially consistent approach for modeling line-of-sight (LOS) paths in vehicular networks. We use stochastic geometry to model transmitters, obstacles, and receivers located in three parallel lines, respec- tively. Their geometric interactions are leveraged to characterize the existence of LOS paths. Specifically, the proposed approach focuses on the role of obstacles in blocking one or more LOS paths, which has been overlooked in most statistical models for blockage. Under the proposed framework, we derive the probability that a typical vehicle is in LOS with respect to transmitters with received signal-to-noise ratios greater than a threshold. The proposed framework and LOS coverage analysis are instrumental to the analysis of LOS-critical applications such as positioning or mmWave communications in vehicular networks.

19. ***A User Centric Blockage Model for Wireless Networks*** [3] This paper proposes a cascade blockage model for analyzing the vision that a user has of a wireless network. This model, inspired by the classical multiplicative cascade models, has a radial structure meant to analyze blockages seen by the receiver at the origin in different angular sectors. The main novelty is that it is based on the geometry of obstacles and takes the joint blockage phenomenon into account. We show on a couple of simple instances that the Laplace transforms of total interference satisfies a functional equation that can be solved efficiently by an iterative scheme. This is used to analyze the coverage probability of the receiver and the effect of blockage correlation and penetration loss in both dense and sparse blockage environments. Furthermore, this model is used to investigate the effect of blockage correlation on user beamforming techniques. Another functional equation and its associated iterative algorithm are proposed to derive the coverage performance of the best beam selection in this context. In addition, the conditional coverage probability is also derived to evaluate the effect of beam switching. The results not only show that beam selection is quite efficient for multi-beam terminals, but also show how the correlation brought by blockages can be leveraged to accelerate beam sweeping and pairing.

8.6 High-dimensional statistical inference and distributed learning

20. ***Partial Recovery in the Graph Alignment Problem*** [14] In this paper, we consider the graph alignment problem, which is the problem of recovering, given two graphs, a one-to-one mapping between nodes that maximizes edge overlap. This problem can be viewed as a noisy version of the well-known graph isomorphism problem and appears in many applications, including social network deanonymization and cellular biology. Our focus here is on partial recovery, i.e., we look for a one-to-one mapping which is correct on a fraction of the nodes of the graph rather than on all of them, and we assume that the two input graphs to the problem are correlated Erdős-Rényi graphs of parameters (n, q, s). Our main contribution is then to give necessary and sufficient conditions on (n, q, s) under which partial recovery is possible with high probability as the number of nodes n goes to infinity. In particular, we show that it is possible to achieve partial recovery in the $nqs = \Theta(1)$ regime under certain additional assumptions.

21. ***Online greedy identification of linear dynamical systems*** [18] This work addresses the problem of exploration in an unknown environment. For multi-input multi-output, linear time-invariant dynamical systems, we use an experimental design framework and introduce an online greedy policy where the control maximizes the information of the next step. We evaluate our approach experimentally and compare

it with more elaborate gradient-based methods. In a setting with a limited number of observations, our algorithm has low complexity and shows competitive performances.

22. ***Spectral alignment of correlated Gaussian random matrices*** [13] In this paper we analyze a simple spectral method (EIG1) for the problem of matrix alignment, consisting in aligning their leading eigenvectors: given two matrices A and B, we compute v_1 and v_1' two corresponding leading eigenvectors. The algorithm returns the permutation $\hat{\pi}$ such that the rank of coordinate $\hat{\pi}(i)$ in v_1 and that of coordinate i in v_1' (up to the sign of v_1') are the same. We consider a model of weighted graphs where the adjacency matrix A belongs to the Gaussian Orthogonal Ensemble (GOE) of size $N \times N$, and B is a noisy version of A where all nodes have been relabeled according to some planted permutation π, namely $B = \Pi^T(A+\sigma H)\Pi$, where Π is the permutation matrix associated with π and H is an independent copy of A. We show the following zero-one law: with high probability, under the condition $\sigma N^{7/6+\epsilon} \to 0$ for some $\epsilon > 0$, EIG1 recovers all but a vanishing part of the underlying permutation π, whereas if $\sigma N^{7/6-\epsilon} \to \infty$, this method cannot recover more than $o(N)$ correct matches. This result gives an understanding of the simplest and fastest spectral method for matrix alignment (or complete weighted graph alignment), and involves proof methods and techniques which could be of independent interest.

23. ***Accelerating abelian random walks with hyperbolic dynamics*** [12] Given integers $d \geq 2, n \geq 1$, we consider affine random walks on torii $(\mathbb{Z}/n\mathbb{Z})^d$ defined as $X_{t+1} = AX_t + B_t \bmod n$, where $A \in \mathrm{GL}_d(\mathbb{Z})$ is an invertible matrix with integer entries and $(B_t)_{t\geq 0}$ is a sequence of iid random increments on $\mathbb{Z}^d$. We show that when A has no eigenvalues of modulus 1, this random walk mixes in $O(\log n \log\log n)$ steps as $n \to \infty$, and mixes actually in $O(\log n)$ steps only for almost all n. These results generalize those on the so-called Chung-Diaconis-Graham process, which corresponds to the case $d = 1$. Our proof is based on the initial arguments of Chung, Diaconis and Graham, and relies extensively on the properties of the dynamical system $x \mapsto A^\top x$ on the continuous torus $\mathbb{R}^d/\mathbb{Z}^d$. Having no eigenvalue of modulus one makes this dynamical system a hyperbolic toral automorphism, a typical example of a chaotic system known to have a rich behaviour. As such our proof sheds new light on the speed-up gained by applying a deterministic map to a Markov chain.

24. ***Markovian linearization of random walks on groups*** [7]In operator algebra, the linearization trick is a technique that reduces the study of a non-commutative polynomial evaluated at elements of an algebra A to the study of a polynomial of degree one, evaluated on the enlarged algebra A x M r (C), for some integer r. We introduce a new instance of the linearization trick which is tailored to study a finitely supported random walk on a group G by studying instead a nearest-neighbor colored random walk on $G \times \{1, ..., r\}$, which is much simpler to analyze. As an application we extend well-known results for nearest-neighbor walks on free groups and free products of finite groups to colored random walks, thus showing how one can obtain explicit formulas for the drift and entropy of a finitely supported random walk.

25. ***Detection thresholds in very sparse matrix completion*** [6] Let A be a rectangular matrix of size $m \times n$ and A_1 be the random matrix where each entry of A is multiplied by an independent $\{0,1\}$-Bernoulli random variable with parameter $1/2$. This paper is about when, how and why the non-Hermitian eigen-spectra of the randomly induced asymmetric matrices $A_1(A-A_1)^*$ and $(A-A_1)^*A_1$ captures more of the relevant information about the principal component structure of A than via its SVD or the eigen-spectra of AA^* and A^*A, respectively. Hint: the asymmetry inducing randomness breaks the echo-chamber effect that cripples the SVD. We illustrate the application of this striking phenomenon on the low-rank matrix completion problem for the setting where each entry is observed with probability d/n, including the very sparse regime where d is of order 1, where matrix completion via the SVD of A fails or produces unreliable recovery. We determine an asymptotically exact, matrix-dependent, non-universal detection threshold above which reliable, statistically optimal matrix recovery using a new, universal data-driven matrix-completion algorithm is possible. Averaging the left and right eigenvectors provably improves the recovered matrix but not the detection threshold. We define another variant of this asymmetric procedure that bypasses the randomization step and has a detection threshold that is smaller by a constant factor but with a computational cost that is larger by a polynomial factor of the number of observed entries. Both detection thresholds shatter the seeming barrier due to the well-known information theoretical limit $d \asymp \log n$ for matrix completion found in the literature.

26. ***The graph alignment problem: fundamental limits and efficient algorithms*** [35] This thesis focuses on statistical inference in graphs (or matrices) in high dimension and studies the graph alignment problem which aims to recover a hidden underlying matching between the nodes of two correlated random graphs. Similarly to many other inference problems in planted models, we are interested in understanding the fundamental information-theoretical limits as well as the computational hardness of graph alignment. First, we study the Gaussian setting, when the graphs are complete and the signal lies on correlated Gaussian edges weights. We prove that the exact recovery task exhibits a sharp information-theoretic threshold, characterize it, and study a simple and natural spectral method for recovery, EIG1, which consists in aligning the leading eigenvectors of the adjacency matrices of the two graphs. While most of the recent work on the subject was dedicated to recovering the hidden signal in dense graphs, we next explore graph alignment in the sparse regime, where the mean degrees are constant, not scaling with the graph size. In this particularly challenging setting, for sparse Erdos-Rényi graphs, only a fraction of the nodes can be correctly matched by any algorithm. Our second contribution is an information-theoretical result which characterizes a regime where even this partial alignment is impossible, and gives upper bounds on the reachable overlap between any estimator and the true planted matching. We next propose an algorithm that performs partial alignment, NTMA, which is based on a measure of similarity – called the tree matching weight – between tree-like neighborhoods of the nodes in the graphs. Under this local approach in the sparse regime, we are brought to study a related problem: correlation detection in random unlabeled trees. This hypothesis testing problem consists in testing whether two trees are correlated or independent. The tree matching weight yields a first method for this question as well; another contribution is to study an optimal test based on the likelihood ratio. In a correlated Galton-Watson model, which is well-known to be the local approximation of sparse Erdos-Rényi graphs, we characterize the regimes of performance of this test. Finally, we come back to graph alignment and propose a message-passing algorithm, MPAlign, naturally inspired by the study of the related problem on trees. This message-passing algorithm is analyzed and provably recovers a fraction of the planted signal in some regimes of parameters.

27. ***Statistical limits of correlation detection in trees*** [46] In this paper we address the problem of testing whether two observed trees (t, t') are sampled either independently or from a joint distribution under which they are correlated. This problem, which we refer to as correlation detection in trees, plays a key role in the study of graph alignment for two correlated random graphs. Motivated by graph alignment, we investigate the conditions of existence of one-sided tests, i.e. tests which have vanishing type I error and non-vanishing power in the limit of large tree depth. For the correlated Galton-Watson model with Poisson offspring of mean $\lambda > 0$ and correlation parameter $s \in (0,1)$, we identify a phase transition in the limit of large degrees at $s = \sqrt{\alpha}$, where $\alpha \sim 0.3383$ is Otter's constant. Namely, we prove that no such test exists for $s \leq \sqrt{\alpha}$, and that such a test exists whenever $s > \sqrt{\alpha}$, for λ large enough. This result sheds new light on the graph alignment problem in the sparse regime (with $O(1)$ average node degrees) and on the performance of the MPAlign method studied in Ganassali et al. (2021), Piccioli et al. (2021), proving in particular the conjecture of Piccioli et al. (2021) that MPAlign succeeds in the partial recovery task for correlation parameter $s > \sqrt{\alpha}$ provided the average node degree λ is large enough.

8.7 Distributed optimization for machine learning

28. ***Muffliato: Peer-to-Peer Privacy Amplification for Decentralized Optimization and Averaging*** [22] Decentralized optimization is increasingly popular in machine learning for its scalability and efficiency. Intuitively, it should also provide better privacy guarantees, as nodes only observe the messages sent by their neighbors in the network graph. But formalizing and quantifying this gain is challenging: existing results are typically limited to Local Differential Privacy (LDP) guarantees that overlook the advantages of decentralization. In this work, we introduce pairwise network differential privacy, a relaxation of LDP that captures the fact that the privacy leakage from a node u to a node v may depend on their relative position in the graph. We then analyze the combination of local noise injection with (simple or randomized) gossip averaging protocols on fixed and random communication graphs. We also derive a differentially private decentralized optimization algorithm that alternates between local gradient descent steps and gossip averaging. Our results show that our algorithms amplify privacy guarantees as a function of the distance between nodes in the graph, matching the privacy-utility trade-off of the trusted curator, up to factors

that explicitly depend on the graph topology. Finally, we illustrate our privacy gains with experiments on synthetic and real-world datasets.

29. ***On Sample Optimality in Personalized Collaborative and Federated Learning*** [23] In personalized federated learning, each member of a potentially large set of agents aims to train a model minimizing its loss function averaged over its local data distribution. We study this problem under the lens of stochastic optimization, focusing on a scenario with a large number of agents, that each possess very few data samples from their local data distribution. Specifically, we prove novel matching lower and upper bounds on the number of samples required from all agents to approximately minimize the generalization error of a fixed agent. We provide strategies matching these lower bounds, based on a gradient filtering approach: given prior knowledge on some notion of distance between local data distributions, agents filter and aggregate stochastic gradients received from other agents, in order to achieve an optimal bias-variance trade-off. Finally, we quantify the impact of using rough estimations of the distances between local distributions of agents, based on a very small number of local samples.

30. ***Correlation detection in trees for planted graph alignment*** [24] Motivated by alignment of correlated sparse random graphs, we introduce a hypothesis testing problem of deciding whether or not two random trees are correlated. We obtain sufficient conditions under which this testing is impossible or feasible. We propose MPAlign, a message-passing algorithm for graph alignment inspired by the tree correlation detection problem. We prove MPAlign to succeed in polynomial time at partial alignment whenever tree detection is feasible. As a result our analysis of tree detection reveals new ranges of parameters for which partial alignment of sparse random graphs is feasible in polynomial time. We then conjecture that graph alignment is not feasible in polynomial time when the associated tree detection problem is impossible. If true, this conjecture together with our sufficient conditions on tree detection impossibility would imply the existence of a hard phase for graph alignment, i.e. a parameter range where alignment cannot be done in polynomial time even though it is known to be feasible in non-polynomial time.

31. ***Robustness in Multi-Objective Submodular Optimization: a Quantile Approach*** [25] The optimization of multi-objective submodular systems appears in a wide variety of applications. However, there are currently very few techniques which are able to provide a robust allocation to such systems. In this work, we propose to design and analyse novel algorithms for the robust allocation of submodular systems through lens of quantile maximization. We start by observing that identifying an exact solution for this problem is computationally intractable. To tackle this issue, we propose a proxy for the quantile function using a softmax formulation, and show that this proxy is well suited to submodular optimization. Based on this relaxation, we propose a novel and simple algorithm called SOFTSAT. Theoretical properties are provided for this algorithm as well as novel approximation guarantees. Finally, we provide numerical experiments showing the efficiency of our algorithm with regards to state-of-the-art methods in a test bed of real-world applications, and show that SOFTSAT is particularly robust and well-suited to online scenarios.

32. ***Asynchronous SGD Beats Minibatch SGD Under Arbitrary Delays*** [26] The existing analysis of asynchronous stochastic gradient descent (SGD) degrades dramatically when any delay is large, giving the impression that performance depends primarily on the delay. On the contrary, we prove much better guarantees for the same asynchronous SGD algorithm regardless of the delays in the gradients, depending instead just on the number of parallel devices used to implement the algorithm. Our guarantees are strictly better than the existing analyses, and we also argue that asynchronous SGD outperforms synchronous minibatch SGD in the settings we consider. For our analysis, we introduce a novel recursion based on "virtual iterates" and delay-adaptive stepsizes, which allow us to derive state-of-the-art guarantees for both convex and non-convex objectives.

33. ***Convergence beyond the over-parameterized regime using Rayleigh quotients*** [29] In this paper, we present a new strategy to prove the convergence of deep learning architectures to a zero training (or even testing) loss by gradient flow. Our analysis is centered on the notion of Rayleigh quotients in order to prove Kurdyka-Łojasiewicz inequalities for a broader set of neural network architectures and loss functions. We show that Rayleigh quotients provide a unified view for several convergence

analysis techniques in the literature. Our strategy produces a proof of convergence for various examples of parametric learning. In particular, our analysis does not require the number of parameters to tend to infinity, nor the number of samples to be finite, thus extending to test loss minimization and beyond the over-parameterized regime.

34. ***Periodic Signal Recovery with Regularized Sine Neural Networks*** [30] We consider the problem of learning a periodic one-dimensional signal with neural networks, and designing models that are able to extrapolate the signal well beyond the training window. First, we show that multi-layer perceptrons with ReLU activations are provably unable to perform this extrapolation task, and lead to poor performance in practice even close to the training window. Then, we propose a modified training procedure for two-layer architectures with sine activations with a more diverse feature initialization and well-chosen non-convex regularization, that is able to extrapolate the signal with low error well beyond the training window. This procedure yields results several orders of magnitude better than its competitors for distant extrapolation (beyond 100 periods of the signal), while being able to accurately recover the frequency spectrum of the signal in a multi-tone setting.

35. ***Convergence Rates of Non-Convex Stochastic Gradient Descent Under a Generic Łojasiewicz Condition and Local Smoothness*** [31] Training over-parameterized neural networks involves the empirical minimization of highly nonconvex objective functions. Recently, a large body of works provided theoretical evidence that, despite this non-convexity, properly initialized over-parameterized networks can converge to a zero training loss through the introduction of the Polyak-Łojasiewicz condition. However, these analyses are restricted to quadratic losses such as mean square error, and tend to indicate fast exponential convergence rates that are seldom observed in practice. In this work, we propose to extend these results by analyzing stochastic gradient descent under more generic Łojasiewicz conditions that are applicable to any convex loss function, thus extending the current theory to a larger panel of losses commonly used in practice such as cross-entropy. Moreover, our analysis provides high-probability bounds on the approximation error under sub-Gaussian gradient noise and only requires the local smoothness of the objective function, thus making it applicable to deep neural networks in realistic settings.

36. ***Sample Optimality and All-for-all Strategies in Personalized Federated and Collaborative Learning*** [44] In personalized Federated Learning, each member of a potentially large set of agents aims to train a model minimizing its loss function averaged over its local data distribution. We study this problem under the lens of stochastic optimization. Specifically, we introduce information theoretic lower bounds on the number of samples required from all agents to approximately minimize the generalization error of a fixed agent. We then provide strategies matching these lower bounds, in the all-for-one and all-for-all settings where respectively one or all agents desire to minimize their own local function. Our strategies are based on a gradient filtering approach: provided prior knowledge on some notions of distances or discrepancies between local data distributions or functions, a given agent filters and aggregates stochastic gradients received from other agents, in order to achieve an optimal bias-variance trade-off.

37. ***On Non-Linear operators for Geometric Deep Learning*** [49]

8.8 Random Geometry

38. ***A Unified Framework for Generalizing the Gromov-Hausdorff Metric*** [47] In this paper, a general approach is presented for generalizing the Gromov-Hausdorff metric to consider metric spaces equipped with some additional structure. A special case is the Gromov-Hausdorff-Prokhorov metric which considers measured metric spaces. This abstract framework also unifies several existing generalizations which consider metric spaces equipped with a measure, a point, a closed subset, a curve or a tuple of such structures. It can also be useful for studying new examples of additional structures. The framework is provided both for compact metric spaces and for boundedly-compact pointed metric spaces. In addition, completeness and separability of the metric is proved under some conditions. This enables one to study random metric spaces equipped with additional structures, which is the main motivation of this work.

39. ***An Improved Lower Bound on the Largest Common Subtree of Random Leaf-Labeled Binary Trees*** [48] It is known that the size of the largest common subtree (i.e., the maximum agreement subtree)

of two independent random binary trees with n given labeled leaves is of order between $n^{0.366}$ and $n^{1/2}$. We improve the lower bound to order $n^{0.4464}$ by constructing a common subtree recursively and by proving a lower bound for its asymptotic growth. The construction is a modification of an algorithm proposed by D. Aldous by splitting the tree at the centroid and by proceeding recursively.

40. ***Wavelet-based representations of point processes for modelling and statistical learning*** [33] This dissertation presents a class of representations of spatial point processes. Inspired from the success of wavelet methods in signal processing, these descriptors rely on the convolution of a point process with a family of wavelet filters. From these convolutions are built sets of statistical descriptors of stationary point process, by applying non-linear operators, followed by a spatial averaging. Much like classical summary characteristics for point processes, these statistics are designed to extract information about the process with a relatively small number of numerical values, by describing its geometry. Their goal is to describe whether the atoms of the process tend to repel each other, or cluster together, and by doing so, form possibly complex geometric shapes. By construction, these descriptors enjoy several properties that make them suitable for statistical analysis and learning tasks. To illustrate the quality of these representations as statistical descriptors, we study several problems involving statistical analysis of point processes. In a first experiment, we seek to estimate an unknown function that takes as input a point pattern, and returns a marked version of this pattern, where a numerical value is associated to each atom of the pattern. We use a wavelet-based representation of point patterns to estimate the relation between their non-marked and marked version. We then study, in a second experiment, the ability of such representations to model the distribution of a point process, by defining a maximum entropy model defined by a set of wavelet-based statistics, computed on a single observation. For these two problems, we observe that our representations lead to better performance than summary statistics commonly used in the literature on point processes. Finally, to study to what extent such representations can capture geometric structures of texture images, we define a maximum entropy model relying on similar wavelet statistics, yielding syntheses of similar visual quality to state-of-the-art models based on deep convolutional neural networks representations.

41. ***Counter examples to invariant circle packing*** [17] In this work, a unimodular random planar triangulation is constructed that has no invariant circle packing. This disputes a problem asked in [9]. A natural weaker problem is the existence of point-stationary circle pack-ings for a graph, which are circle packings that satisfy a certain mass transport principle. It is shown that the answer to this weaker problem is also false. Two examples are provided with two different approaches: Using indistinguishability and finite approximations.

42. ***Generalized Rectifier Wavelet Covariance Models For Texture Synthesis*** [19] State-of-the-art maximum entropy models for texture synthesis are built from statistics relying on image representations defined by convolutional neural networks (CNN). Such representations capture rich structures in texture images, outperforming wavelet-based representations in this regard. However, conversely to neural networks, wavelets offer meaningful representations, as they are known to detect structures at multiple scales (e.g. edges) in images. In this work, we propose a family of statistics built upon non-linear wavelet based representations, that can be viewed as a particular instance of a one-layer CNN, using a generalized rectifier non-linearity. These statistics significantly improve the visual quality of previous classical wavelet-based models, and allow one to produce syntheses of similar quality to state-of-the-art models, on both gray-scale and color textures.

43. ***Coupling from the Past for the Null Recurrent Markov Chain*** [36] The Doeblin Graph of a countable state space Markov chain describes the joint pathwise evolutions of the Markov dynamics starting from all possible initial conditions, with two paths coalescing when they reach the same point of the state space at the same time. Its Bridge Doeblin subgraph only contains the paths starting from a tagged point of the state space at all possible times. In the irreducible, aperiodic, and positive recurrent case, the following results are known: the Bridge Doeblin Graph is an infinite tree that is unimodularizable. Moreover, it contains a single bi-infinite path, which allows one to build a perfect sample of the stationary state of the Markov chain. The present paper is focused on the null recurrent case. It is shown that when assuming irreducibility and aperiodicity again, the Bridge Doeblin Graph is either an infinite tree or a forest made of a countable collection of infinite trees. In the first case, the infinite tree in question has a single end, is not unimodularizable in general, but is always locally unimodular. These key properties are

used to study the stationary regime of several measure-valued random dynamics on this Bridge Doeblin Tree. The most important ones are the taboo random dynamics, which admits as steady state a random measure with mean measure equal to the invariant measure of the Markov chain, and the potential random dynamics which is a random extension of the classical potential measure, with a mean measure equal to infinity at every point of the state space.

44. ***Nash equilibrium structure of Cox process Hotelling games*** [1] We study an N-player game where a pure action of each player is to select a non-negative function on a Polish space supporting a finite diffuse measure, subject to a finite constraint on the integral of the function. This function is used to define the intensity of a Poisson point process on the Polish space. The processes are independent over the players, and the value to a player is the measure of the union of its open Voronoi cells in the superposition point process. Under randomized strategies, the process of points of a player is thus a Cox process, and the nature of competition between the players is akin to that in Hotelling competition games. We characterize when such a game admits Nash equilibria and prove that when a Nash equilibrium exists, it is unique and comprised of pure strategies that are proportional in the same proportions as the total intensities. We give examples of such games where Nash equilibria do not exist. A better understanding of the criterion for the existence of Nash equilibria remains an intriguing open problem.

8.9 Mathematics of stochastic networks via mean-field analysis

45. ***A new stochastic model for carsharing suited to free-floating*** [45] Free-floating has an increasing popularity in carsharing but imbalance problem shows the need of stochastic modelling and analysis. In this paper, a new stochastic model suited to free-floating is proposed, taking into account the sharing of public space between private and free-floating cars.The capacity seen by free-floating cars in such a model turns out to be random. We show that unlike station-based car-sharing systems, it is not bounded. Moreover, a stochastic averaging principle governs the free-floating car behavior. We exhibit a phase transition between a non-saturated regime where free-floating cars can always be parked and a saturated one where free-floating cars do not find an available parking space with positive probability. This probability is completely determined by the environment which implies that the operator cannot act on the proportion of saturated areas, i.e. without parking parking spaces. We solve the dimensioning problem; the more free-floating cars in the system, the more satisfied users are.

46. ***Replica-Mean-Field Limits of Fragmentation-Interaction-Aggregation Processes*** [4] Network dynamics with point-process-based interactions are of paramount modeling interest. Unfortunately , most relevant dynamics involve complex graphs of interactions for which an exact computational treatment is impossible. To circumvent this difficulty, the replica-mean-field approach focuses on randomly interacting replicas of the networks of interest. In the limit of an infinite number of replicas , these networks become analytically tractable under the so-called "Poisson Hypothesis". However, in most applications, this hypothesis is only conjectured. Here, we establish the Poisson Hypothesis for a general class of discrete-time, point-process-based dynamics, that we propose to call fragmentation-interaction-aggregation processes, and which are introduced in the present paper. These processes feature a network of nodes, each endowed with a state governing their random activation. Each activation triggers the fragmentation of the activated node state and the transmission of interaction signals to downstream nodes. In turn, the signals received by nodes are aggregated to their state. Our main contribution is a proof of the Poisson Hypothesis for the replica-mean-field version of any network in this class. The proof is obtained by establishing the propagation of asymptotic independence for state variables in the limit of an infinite number of replicas. Discrete time Galves-Löcherbach neural networks are used as a basic instance and illustration of our analysis.

47. ***Propagation of chaos and Poisson Hypothesis for replica mean-field models of intensity-based neural networks*** [43] Neural computations arising from myriads of interactions between spiking neurons can be modeled as network dynamics with punctuate interactions. However, most relevant dynamics do not allow for computational tractability. To circumvent this difficulty, the Poisson Hypothesis regime replaces interaction times between neurons by Poisson processes. We prove that the Poisson Hypothesis holds at the limit of an infinite number of replicas in the replica-mean-field model, which consists of randomly interacting copies of the network of interest. The proof is obtained through a novel application

of the Chen-Stein method to the case of a random sum of Bernoulli random variables and a fixed point approach to prove a law of large numbers for exchangeable random variables.

48. ***Mean field analysis of stochastic networks with reservation*** [38] The problem of reservation in a large distributed system is analyzed via a new mathematical model. A typical application is a station-based car-sharing system which can be described as a closed stochastic network where the nodes are the stations and the customers are the cars. The user can reserve the car and the parking space. In the paper, we study the evolution of the system when the reservation of parking spaces and cars is effective for all users. The asymptotic behavior of the underlying stochastic network is given when the number N of stations and the fleet size increase at the same rate. The analysis involves a Markov process on a state space with dimension of order N 2. It is quite remarkable that the state process describing the evolution of the stations, whose dimension is of order N , converges in distribution, although not Markov, to an non-homogeneous Markov process. We prove this mean-field convergence. We also prove, using combinatorial arguments, that the mean-field limit has a unique equilibrium measure when the time between reserving and picking up the car is sufficiently small. This result extends the case where only the parking space can be reserved.

49. ***Mean field analysis of an incentive algorithm for a closed stochastic network*** [28] The paper deals with a load-balancing algorithm for a closed stochastic network with two zones with different demands. The algorithm is motivated by an incentive algorithm for redistribution of cars in a large-scale car-sharing system. The service area is divided into two zones. When cars stay too much long in the low-demand zone, users are encouraged to pick up them and return them in the high-demand zone. The zones are divided in cells called stations. The cars are the network customers. The mean-field limit solution of an ODE gives the large scale distribution of the station state in both clusters for this incentive policy in a discrete Markovian framework. An equilibrium point of this ODE is characterized via the invariant measure of a random walk in the quarter-plane. The proportion of empty and saturated stations measures how the system is balanced. Numerical experiments illustrate the impact of the incentive policy. Our study shows that the incentive policy helps when the high-demand zone observes a lack of cars but a saturation must be prevented especially when the high-demand zone is small.

9 Bilateral contracts and grants with industry

9.1 Bilateral contracts with industry

Participants: François Baccelli, Bartłomiej Błaszczyszyn, Ana Bušić, Guodong Sun.

9.1.1 Contract with EDF

Collaborative research in the area of demand dispatch of flexible loads. PI: A. Bušić.

9.1.2 CRE with Orange Labs

Two year contract titled *Guaranteed throughput and millimeter waves in the dimensioning of 5G cellular networks* between Inria and Orange Labs started 2022 and attached to the joint Inria-Orange lab "IOLab". It is a part of a long-term collaboration between TREC/DYOGENE, represented by B. Błaszczyszyn and Orange Labs, represmnted by M. K. Karray on the development of mathematical methods and engineering analytical tools for the dimensioning of wireless cellular networks enabling operators to solve critical technical and economic issues related to the main business related to the permanent evolution of radio technology. They capture the macroscopic relation between antenna deployment, frequency allocation, the volume of traffic carried on the network, and QoS parameters, such as the average and variation in bandwidth available to end users. The math solutions developed in cooperation with Orange Labs are implemented by Orange Labs in their internal toolbox and used for dimensioning studies by *Direction des Affaires Réglementaires* of Orange, *Orange France* in relation to ARCEP (*Autorité de Régulation des Communications Électroniques, des Postes et de la Distribution de la Presse*) and Orange affiliates.

9.1.3 CIFRE with Nokia Bell Labs

Contract with Nokia Bell Labs France started in 2021 for the co-advising by F. Baccelli of a PhD student Guodong Sun.

10 Partnerships and cooperations

10.1 International initiatives

10.1.1 IFCAM poject

Participants: Bartłomiej Błaszczyszyn, Antoine Brochard, Romain Gambelin.

Indo-French Centre for Applied Mathematics (IFCAM) project Geometric statistics of stationary point processes started in 2018 and extended to March 2023 with coordinators B. Błaszczyszyn (Inria), Yogeshwaran D. (ISI Bangalore). The project is investigating the asymptotic properties of the geometric statistics of point processes, which have recently gained importance in stochastic geometry, in particular for more general point processes, for which theory still lags far behind Poisson point processes. Our main contribution and results are as follows. (1) In the theory of point processes, we introduce the concept of *de-correlation* to general marked point processes and show that this "asymptotic independence" of the structure — an essential element of limit theory — appears when points and marks have this property separately. (2) This allows us to study limit results for more general models, in particular *spatially dependent interacting particle systems* in Euclidean space, permitting for dependent sites and initial states, unbounded interaction range and general (and non-necessarily Markovian) updates. (3) We prove or mention the *results of the central limit theorem* for several examples of these modes (as sequential adsorption, ballistic deposition, majority dynamics, epidemic models) allowing for non-Poisson locations of particles and their dependent initial states. We shall also investigate some applications to the theory of signal processing. (4) In general, *limits of variance or asymptotics of covariance* are commonly accepted in central limit theorems. In two complementary projects, we show that volume-order variance asymptotics are preserved under quasi-local perturbations of a stationary random measure satisfying some mixing condition. We also show possible covariance asymptotics for different test statistics of general stationary random measures. (5) Finally, in a related project, we are also interested in *optimization of large particle systems* considered in the framework of stationary marked point process to formalize novel optimization concepts: intensity-optimal and locally optimal marking. Our main results provide general conditions when the intensity-optimal solution exists and when both optimization solutions are equivalent. We discuss several applications ranging from theoretical probability to applications in statistical physics, combinatorial optimization and communications.

10.1.2 Alliance Communauto Montreal

Participants: Christine Fricker.

Dyogene participates in 4-year research project (2023-2027) co-funded by Communauto, NSERC and MItacs in Montreal.

10.2 International research visitors

Scientists speaking at the DYOGENE's seminar in 2022

- Céline Compte (Eindhoven University of Technology),
- Senya Shlosman (Centre de Physique Theorique; Skoltech Center of Advance Studies),

- Nicolas Curien (Université Paris-Saclay),
- Samuel Mellick (ENS de Lyon),
- Umberto de Ambroggio (University of Bath),
- Takis Konstantopoulos (University of Liverpool),
- Alexandre Gaudillière (CNRS),
- Jean-François Le Gall (Université Paris-Saclay),
- David Aldous (UC Berkeley),
- Eva Löcherbach (Université Paris 1),
- Vsevolod Shneer (Heriot-Watt University),
- Sergey Foss (Heriot-Watt University),
- Hermann Thorisson (University of Iceland),
- Sergey Foss (Heriot-Watt University),
- Pierre Calka (University of Rouen),
- Matteo D'Achille (Université Paris-Est - Créteil Val-de-Marne),
- Eliza O'Reilly (California Institute of Technology),
- Charles Bordenave (Institut de Mathématiques de Marseille),
- Milad Barzegar (Sharif University of Technology),
- Anita Winter (University of Duisburg-Essen),
- Payam Delgosha (University of Illinois),
- Payam Delgosha (University of Illinois),
- Nicolas Gast (Inria).

Inria International Chair

Participants: Ana Busic, Sean Meyn.

Prof Sean Meyn (University of Florida) is holding Inria International Chair from 2019 to 2023 in association with Dyogene and Sierra teams.

10.3 European initiatives

10.3.1 ERC NEMO

Participants: François Baccelli, Bartłomiej Błaszczyszyn, Bharath Roy Choudhury, Ke Feng, Sayeh Khaniha, Ali Khezeli, Pierre Popineau.

NEMO NEtwork MOtion, Inria/NEMO is an ERC Advanced Grant (2019 – 2024, PI François Baccelli). It is an inter-disciplinary proposal centered on network dynamics. The inter-disciplinarity spans from communication engineering to mathematics, with an innovative interplay between the two. NEMO's aim is to introduce dynamics in stochastic geometry. General mathematical tools combining stochastic geometry, random graph theory, and the theory of dynamical systems will be developed. NEMO will leverage interactions of Inria with Ecole Normale Supérieure on the mathematical side, and with Nokia Bell Labs and Orange on the engineering side.

10.3.2 Collaboration with VITO (Belgium)

Participants: Ana Busic, Ilia Shilov.

Collaboration with VITO Belgium. Co-advising of PhD student I. Shilov. Started: Nov 2019. Topic: "Algorithmic Games and Distributed Learning for Peer-to-Peer Energy Trading". PhD scholarship by VITO.

10.4 National initiatives

10.4.1 PRAIRIE Institute

Participants: Marc Lelarge, Laurent Massoulié.

The Prairie Institute (PaRis AI Research InstitutE) is one of the four French Institutes for Interdisciplinary Artificial Intelligence Research (3IA), which were created as part of the national French initiative on AI announced by President Emmanuel Macron on May 29, 2018. It brings together five academic partners (CNRS, Inria, Institut Pasteur, PSL University, and University of Paris) as well as 14 industrial partners.

10.4.2 GdR GeoSto

Participants: François Baccelli, Bartłomiej Błaszczyszyn, Bharath Roy Choudhury, Michel Davydov, Romain Gambelin, Sayeh Khaniha, Ali Khezeli.

Members of Dyogene participate in Research Group GeoSto (Groupement de recherche, GdR 3477) gdr-geostoch.math.cnrs.fr on Stochastic Geometry currenly led by Hermine Biermé [Université de Tours]. This is a collaboration framework for all French research teams working in the domain of spatial stochastic modeling, both on theory development and in applications.

10.4.3 GdR RO

Participants: Ana Busic, Thomas Le Corre, Lucas Weber.

Members of Dyogene participate in the group Recherche Opérationelle GdR-RO working on Stochastic optimization and control, modeling and simulation COSMOSlead by A. Busic and E. Hyon (LIP 6).

10.4.4 Défi Inria FedMalin

Participants: Kevin Scaman, Laurent Massoulié.

Members of Dyogene participate in the FedMalin Inria défi on Federated Learning.

10.5 Regional initiatives

10.5.1 LINCS

Participants: All Dyogene.

Laboratory of Information, Networking and Communication Sciences Dyogene participates in LINCS, a research centre co-founded by Inria, Institut Mines- Télécom, UPMC and Alcatel-Lucent Bell Labs (currently Nokia Bell Labs) dedicated to research and innovation in the domains of future information and communication networks, systems and services.

11 Dissemination

All Dyogene

11.1 Promoting scientific activities

11.1.1 LINCS+NEMO workshop on vehicular networks

ERC Nemo co-organized an international Workshop on vehicular networks, hosted a LINCS in Paris; March 10-11. The 14 guest speakers covered a wide range of questions relating to the scientific and industrial challenges of this type of communication network:

- *Analysis of the reliability* of the various radio links (safety messages, exchanged between vehicles, pedestrians or cyclists). Presentations by C.S. Choi (Hongik Univ.), H. Dhillon (Virginia Tech.), M. Haenggi (ETH), V. Mancuso (IMDEA) and O. Shagdar (VEDECOM).
- *Integrating communications and measurements*: N. Gonzalez-Prélcic (NCSU), V. Petrov (Nokia) and H. Wymeersh (Chalmers).
- *Distributed systems aspects*, including distributed usage of AI at the edge of the network. C. Chiasserini (PoliTO), F. Dressler (TU Berlin) and R. Heath (NCSU).
- *Industrial issues*: O. Altintas (Toyota) and T.V. Nguyen (Qualcomm).
- *The standardization*: T. Ernst (YoGoKo).

The Presentations and recorded talks as well as the discussions are available on LINCS-NEMO coference website.

11.1.2 Other scientific events

- ERC Nemo organized a Workshop on random measures, unimodularity and Palm Theory at Inria Paris; May 9-10.
- F. Baccelli participated in the organization of the Inria national day on communications networks on September 13, 2023 in Rungis.
- A. Khezeli organized the weekly DYOGENE seminar. See see Section 10.2 for the scientists speaking at the DYOGENEs seminar in 2022.
- M. Even et M. Blanke orgnaised the weekly ARGO seminar.
- B. Roy-Chowdhury organized the NEMO reading group

Reviewer

- B. Blaszczyszyn: for Electronic Journal of Statistics, Statistics and Computing, ACM Symposium on Theory of Computing, NWO - The Dutch Research Council.
- K. Scaman: for Journal of Machine Learning Research (2 papers) and Agence Nationale de la Recherche (1 proposal)

11.1.3 Invited talks

- Invited lecture on Particle gradient descent model for point process generation at Journées communes GéoSto MIA, Saint-Étienne-du-Rouvray 22-23 sept. 2022, B. Blaszczyszyn
- Invited lecture on Limit theory for asymptotically de-correlated dynamic spatial random models at Recent Trends in Spatial Stochastic Processes, Eindhoven, Netherlands Oct 03-07, 2022, B. Blaszczyszyn
- Invited lecture on replica mean-field limits for neural networks at the Mathematics Colloquium, University of Houston, Houston, USA, January 31, 2022, F. Baccelli.
- Keynote lecture on vehicular networks at the COST-INTERACT 22 meeting, Lyon, France, June 13-15, 2022, F.Baccelli.
- Invited lecture on contagion-migration processes at "Atelier d'Évaluation de Performance 22", Grenoble, France, July 04-05, 2022, F. Baccelli.
- Keynote lecture on wireless stochastic geometry at IEEE Wiopt, Torino, Italy, September 19-23, 2022, F. Baccelli.
- Invited lecture on unimodular random graphs at the Workshop "Recent Trends in Spatial Stochastic Processes", Eindhoven, Netherlands Oct 03-07, 2022, F. Baccelli.
- Online seminar on stationarity and ergodicity, IPM Geometry and Topology seminars, Feb 2022, A. Khezeli.
- Lecture on unimodular continuum Spaces at the Workshop "Recent Trends in Spatial Stochastic Processes", Eindhoven, Netherlands Oct 03-07, 2022, A. Khezeli.
- Lecture entitled "An Improved Lower Bound on the Largest Common Subtree of Random Leaf-Labeled Binary Trees", IPM Combinatorics, Oct 2022, A. Khezeli.

11.1.4 Scientific expertise

- A. Busic: member of Comission d'Emplois Scientifiques (CES) et Commission de Développement Technologique (CDT)

11.2 Teaching - Supervision - Juries

11.2.1 Teaching

- Licence: B. Błaszczyszyn (Cours) Théorie de l'information et du codage 24 heqTD, L3, ENS Paris. moodle.psl.eu
- Licence: A. Busic (Cours) and Romain Cosson (Cours + TD) Structures et algorithmes aléatoires 60 heqTD, L3, ENS Paris.
- Licence: M. Davydov (Cours) Introduction aux probabilités (L2 Mathématiques) 38h(eqTD) and Bases des mathématiques : semaine de prérentrée (L1 Mathématiques & Informatique) 15h(eqTD), University Paris-Cité.
- Licence: R. Gambelin, CM de "Probabilités approfondies" en seconde année de la CPES de PSL (filière mathématiques et physique).
- Licence: L. Massoulié (Cours) Social and Communication networks 60 heqTD, L3, l'X.
- Master: B. Błaszczyszyn (Cours) "Random Geometric Models", jointly at M2 "Probabilities and Random Models", Sorbonne University and M2 "Applied and Theoretical Mathematics", University Paris-Dauphine-PSL (39heqTD). moodle.psl.eu

- Master: A. Busic (Cours) and L. Weber (TD) Modèles et algorithmes de réseaux 60 heqTD, M1, ENS Paris.
- Master: A. Busic and L. Massoulié (Cours) Fondements de la modélisation des réseaux 37.5 heqTD, M2 MPRI.
- Master: M. Lelarge (Cours) Deep Learning Do it Yourself, X, X-HEC. mlelarge.github.io/dataflowr-web/
- Master: L. Massoulié (Cours) Inference in large random graphs, M2 Université d'Orsay.
- Master: K. Scaman with the participation of M. Lelarge (Cours) Deep Learning, 24 heqTD, M1, ENS Paris.
- Master: K. Scaman (Cours) and M. Even (TD) Mathematics of Deep Learning, 30 heqTD, M2 MASH, Université Dauphine.
- Master: K. Scaman (TD) Machine Learning 2, 21 heqTD, M2 X-HEC, Institut Polytechnique de Paris.
- Master: R. Gambelin, Chargé de TD "Méthodes quantitatives", L2 Eco & Gestion, l'université Paris Descartes.

11.2.2 Supervision

PhD defended:

- Antoine Brochard, "Wavelet-based representations of point processes for modelling and statistical learning", Ecole Normale Supérieure (Paris),March 2022, [33]; supervised by B. Błaszczyszyn
- Eric Daoud, "Geographic and socio-demographic disparities in oncology care pathways", Université Paris-Saclay, December 2022, [34]; supervised by M. Lelarge
- Luca Ganassali, "The graph alignment problem: fundamental limits and efficient algorithms", PSL Research University; Ecole normale supérieure, September 2022, [35]; supervised by Laurent Massoulié and Marc Lelarge

PhD in progress:

- Claire Bizon Monroc, since Nov 2021, supervised by A. Bušić
- Matthieu Blanke since Sep 2021, supervised by M. Lelarge
- Romain Cosson, since Sep 2022, supervised by Laurent Massoulié
- Bharath Roy since Sep 2019, supervised by F. Baccelli
- Michel Davydov, since 2020, supervised by F. Baccelli
- Bastien Dubail since Sep 2020, supervised by Laurent Massoulié
- Mathieu Even since Sep 2021, supervised by Laurent Massoulié
- Roman Gambelin since Sep 2020, supervised by B. Blaszczyszyn
- Cedric Gerbelot since Sep 2021, supervised by M. Lelarge
- Sayeh Khaniha, since Feb 2019, supervised by F. Baccelli
- Thomas Le Corre since Nov 2021, supervised by Bušić
- Maxime Leiber since Feb 2020, supervised by Laurent Massoulié
- Jakob Maier, since Oct 2022, supervised by Laurent Massoulié

- Pierre Popineau, since Sep 2019, supervised by F. Baccelli
- David Robin, since Oct 2021, supervised by Laurent Massoulié
- Ilia Shilov since Sep 2019, supervised by A. Bušić
- Guodong Sun, since 2021, supervised by F. Baccelli
- Amaury Triboulin since Sep 2021, supervised by M. Lelarge
- Lucas Weber since Oct 2021, supervised by A. Bušić

11.2.3 Juries

- F. Baccelli: member of the thesis committee of Quentin Gontier (ULB, Bruxelles).
- B. Błaszczyszyn: member of the thesis committee of Iman Hmedoush (Université Paris Saclay) and Safa Ladgham (Université de Paris Cité).

12 Scientific production

12.1 Publications of the year

International journals

[1] V. Anantharam and F. Baccelli. 'Nash equilibrium structure of Cox process Hotelling games'. In: *Advances in Applied Probability* 54.2 (June 2022), pp. 570–598. DOI: 10.1017/apr.2021.45. URL: https://hal.science/hal-03107798.

[2] F. Baccelli. 'Stationary queues in space and time'. In: *Queueing Systems* 100.3-4 (Apr. 2022), pp. 501–503. DOI: 10.1007/s11134-022-09799-y. URL: https://hal.science/hal-03939956.

[3] F. Baccelli, B. Liu, L. Decreusefond and R. Song. 'A User Centric Blockage Model for Wireless Networks'. In: *IEEE Transactions on Wireless Communications* 21.10 (2022), 10 p. DOI: 10.1109/TWC.2022.3166211. URL: https://hal.science/hal-03646854.

[4] F. Baccelli, M. Davydov and T. Taillefumier. 'Replica-Mean-Field Limits of Fragmentation-Interaction-Aggregation Processes'. In: *Journal of Applied Probability* 59.1 (Mar. 2022), pp. 38–59. DOI: 10.1017/jpr.2021.31. URL: https://hal.science/hal-02607064.

[5] F. Baccelli and N. Ramesan. 'A computational framework for evaluating the role of mobility on the propagation of epidemics on point processes'. In: *Journal of Mathematical Biology* 84.1-2 (Jan. 2022), p. 4. DOI: 10.1007/s00285-021-01692-1. URL: https://hal.science/hal-03542621.

[6] C. Bordenave, S. Coste and R. R. Nadakuditi. 'Detection thresholds in very sparse matrix completion'. In: *Foundations of Computational Mathematics* (2022). URL: https://hal.archives-ouvertes.fr/hal-03029291.

[7] C. Bordenave and B. Dubail. 'Markovian linearization of random walks on groups'. In: *International Mathematics Research Notices* (2022). URL: https://hal.science/hal-03029424.

[8] A. Brochard, B. Blaszczyszyn, S. Zhang and S. Mallat. 'Particle gradient descent model for point process generation'. In: *Statistics and Computing* 32.3 (7th June 2022). DOI: 10.1007/s11222-022-10099-x. URL: https://hal.science/hal-02980486.

[9] A. Cadas, J. Doncel and A. Bušić. 'Analysis of an optimal policy in dynamic bipartite matching models'. In: *Performance Evaluation* 154 (Apr. 2022), p. 102286. DOI: 10.1016/j.peva.2022.102286. URL: https://hal.science/hal-03923091.

[10] A. Cadas, J. Doncel, J.-M. Fourneau and A. Bušić. 'Flexibility can hurt dynamic matching system performance'. In: *ACM SIGMETRICS Performance Evaluation Review* 49.3 (Mar. 2022). DOI: 10.1145/3529113.3529126. URL: https://hal.science/hal-03095292.

[11] C.-S. Choi and F. Baccelli. 'A Stochastic Geometry Model for Spatially Correlated Blockage in Vehicular Networks'. In: *IEEE Internet of Things Journal* 9.20 (15th Oct. 2022), pp. 19881–19889. DOI: 10.1109/JIOT.2022.3168587. URL: https://hal.science/hal-03939964.

[12] B. Dubail and L. Massoulié. 'Accelerating abelian random walks with hyperbolic dynamics'. In: *Probability Theory and Related Fields* 184.3-4 (Dec. 2022), pp. 939–968. DOI: 10.1007/s00440-022-01128-x. URL: https://hal.science/hal-03939665.

[13] L. Ganassali, M. Lelarge and L. Massoulié. 'Spectral alignment of correlated Gaussian random matrices'. In: *Advances in Applied Probability*. 54, Issue 1 54.Issue 1 (Mar. 2022), pp. 279–310. URL: https://hal.science/hal-02941069.

[14] G. Hall and L. Massoulié. 'Partial Recovery in the Graph Alignment Problem'. In: *Operations Research* (13th Jan. 2022). DOI: 10.1287/opre.2022.2355. URL: https://hal.science/hal-03938708.

[15] M. U. Hashmi, D. Deka, A. Bušić and D. van Hertem. 'Can locational disparity of prosumer energy optimization due to inverter rules be limited?' In: *IEEE Transactions on Power Systems* (2022), pp. 1–15. DOI: 10.1109/TPWRS.2022.3223842. URL: https://hal.science/hal-03923049.

[16] P. Jacquet, B. Mans, D. Popescu and B. Blaszczyszyn. 'Energy and Delay Trade-Offs of End-to-End Vehicular Communications using a Hyperfractal Urban Modelling'. In: *Annals of Telecommunications - annales des télécommunications*. special issue on 5+G Network Energy Consumption, Energy Efficiency and Environmental Impact (2023). URL: https://hal.science/hal-03942997.

[17] A. Khezeli. 'Counter examples to invariant circle packing'. In: *Annales de l'Institut Henri Poincaré (B) Probabilités et Statistiques* 58.4 (1st Nov. 2022). DOI: 10.1214/21-AIHP1234. URL: https://hal.inria.fr/hal-03924954.

International peer-reviewed conferences

[18] M. Blanke and M. Lelarge. 'Online greedy identification of linear dynamical systems'. In: *2022 IEEE 61st Conference on Decision and Control (CDC)*. CDC 2022 - 61st Conference on Decision and Control. Vol. 61. Cancun, Mexico: IEEE, 2022, pp. 5363–5368. DOI: 10.1109/CDC51059.2022.9993030. URL: https://hal.science/hal-03938609.

[19] A. Brochard, S. Zhang and S. Mallat. 'Generalized Rectifier Wavelet Covariance Models For Texture Synthesis'. In: ICLR 2022 - 10th International Conference on Learning Representations. Virtual, France, 25th Apr. 2022. DOI: 10.48550/arXiv.2203.07902. URL: https://hal.science/hal-03612563.

[20] A. Bušić, A. Cadas, J. Doncel and J.-M. Fourneau. 'Product form solution for the steady-state distribution of a Markov chain associated with a general matching model with self-loops'. In: EPEW 2022: 18th European Performance Engineering Workshop. Santa Pola, Alicante, Spain, 2022. URL: https://hal.science/hal-03923170.

[21] C. Comte, F. Mathieu and A. Bušić. 'Appariements, polytopes et dons d'organes'. In: AlgoTel 2022 - 24èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications. Saint-Rémy-Lès-Chevreuse, France, 30th May 2022. URL: https://hal.science/hal-03656130.

[22] E. Cyffers, M. Even, A. Bellet and L. Massoulié. 'Muffliato: Peer-to-Peer Privacy Amplification for Decentralized Optimization and Averaging'. In: Advances in Neural Information Processing Systems 35 (NeurIPS). New Orleans, United States, 2022. URL: https://hal-cnrs.archives-ouvertes.fr/hal-03906768.

[23] M. Even, L. Massoulié and K. Scaman. 'On Sample Optimality in Personalized Collaborative and Federated Learning'. In: NeurIPS 2022 - 36th Conference on Neural Information Processing System. New Orleans, United States, 28th Nov. 2022. URL: https://hal.archives-ouvertes.fr/hal-03902927.

[24] L. Ganassali, L. Massoulié and M. Lelarge. 'Correlation detection in trees for planted graph alignment'. In: ITCS 2022 - 13th Innovations in Theoretical Computer Science Conference. Berkeley, United States, 31st Jan. 2022. URL: https://hal.archives-ouvertes.fr/hal-03920968.

[25] C. Malherbe and K. Scaman. 'Robustness in Multi-Objective Submodular Optimization: a Quantile Approach'. In: *Proceedings of the 39 th International Conference on Machine Learning*. ICML 2022 - 39th International Conference on Machine Learning. Baltimore, United States, 17th July 2022. URL: https://hal.archives-ouvertes.fr/hal-03896023.

[26] K. Mishchenko, F. Bach, M. Even and B. Woodworth. 'Asynchronous SGD Beats Minibatch SGD Under Arbitrary Delays'. In: NeurIPS 2022 - Thirty-sixth Conference on Neural Information Processing Systems. Advances in Neural Information Processing Systems. New Orleans, United States, 28th Nov. 2022. URL: https://hal.archives-ouvertes.fr/hal-03867190.

[27] C. B. Monroc, E. Bouba, A. Busic, D. Dubuc and J. Zhu. 'Delay-Aware Decentralized Q-learning for Wind Farm Control'. In: CDC 2022 - IEEE 61st Conference on Decision and Control. Cancun, Mexico: IEEE, 6th Dec. 2022, pp. 807–813. DOI: 10.1109/CDC51059.2022.9992646. URL: https://hal.science/hal-03936271.

[28] B. M. Moreno, C. Fricker, H. Mohamed, A. Philippe and M. Trepanier. 'Mean field analysis of an incentive algorithm for a closed stochastic network'. In: *33rd International Conference on Probabilistic, Combinatorial and Asymptotic Methods for the Analysis of Algorithms (AofA 2022)*. AofA 2022. Vol. 225. Leibniz International Proceedings in Informatics (LIPIcs). Philadelphia, PA, United States: Schloss Dagstuhl – Leibniz-Zentrum für Informatik, 8th June 2022, 13:1–13:17. URL: https://hal.science/hal-03539628.

[29] D. Robin, K. Scaman and M. Lelarge. 'Convergence beyond the over-parameterized regime using Rayleigh quotients'. In: NeurIPS 2022 - 36th Conference on Neural Information Processing System. New Orleans, United States, 28th Nov. 2022. URL: https://hal.science/hal-03896153.

[30] D. Robin, K. Scaman and M. Lelarge. 'Periodic Signal Recovery with Regularized Sine Neural Networks'. In: *Proceedings Track 2022 NeurIPS Workshop on Symmetry and Geometry in Neural Representations*. NeurIPS 2022 Workshop on Symmetry and Geometry in Neural Representations. New Orleans, United States, 3rd Dec. 2022. URL: https://hal.science/hal-03896115.

[31] K. Scaman, C. Malherbe and L. dos Santos. 'Convergence Rates of Non-Convex Stochastic Gradient Descent Under a Generic Łojasiewicz Condition and Local Smoothness'. In: *Proceedings of Machine Learning Research*. ICML 2022 - 39th International Conference on Machine Learning. Vol. 162. Baltimore, United States, 17th July 2022. URL: https://hal.science/hal-03896012.

[32] I. Shilov, H. Le Cadre and A. Bušić. 'A Generalized Nash Equilibrium analysis of the interaction between a peer-to-peer financial market and the distribution grid'. In: ROADEF 2022 - 23ème congrès annuel de la Société Française de Recherche Opérationnelle et d'Aide à la Décision. Villeurbanne - Lyon, France, 23rd Feb. 2022. URL: https://hal.archives-ouvertes.fr/hal-03596153.

Doctoral dissertations and habilitation theses

[33] A. Brochard. 'Wavelet-based representations of point processes for modelling and statistical learning'. Ecole Normale Supérieure (Paris), 31st Mar. 2022. URL: https://theses.hal.science/tel-03666508.

[34] E. Daoud. 'Geographic and socio-demographic disparities in oncology care pathways'. Université Paris-Saclay, 12th Dec. 2022. URL: https://theses.hal.science/tel-03938590.

[35] L. Ganassali. 'The graph alignment problem: fundamental limits and efficient algorithms'. PSL Research University; Ecole normale supérieure, 23rd Sept. 2022. URL: https://hal.archives-ouvertes.fr/tel-03921009.

Reports & preprints

[36] F. Baccelli, M.-O. Haji-Mirsadeghi and S. Khaniha. *Coupling from the Past for the Null Recurrent Markov Chain*. 26th Apr. 2022. DOI: 10.48550/arXiv.2203.13585. URL: https://hal.science/hal-03940021.

[37] B. Blaszczyszyn, P. Jacquet, B. Mans and D. Popescu. *Energy and Delay Trade-Offs of End-to-End Vehicular Communications using a Hyperfractal Urban Modelling*. 27th Jan. 2022. URL: https://hal.archives-ouvertes.fr/hal-03546049.

[38] C. Bourdais, C. Fricker and H. Mohamed. *Mean field analysis of stochastic networks with reservation*. 21st Jan. 2022. URL: https://hal.archives-ouvertes.fr/hal-03539104.

[39] C.-S. Choi and F. Baccelli. *Modeling and Analysis of 2-Tier Heterogeneous Vehicular Networks Leveraging Roadside Units and Vehicle Relays*. 26th Apr. 2022. URL: https://hal.science/hal-03939984.

[40] C. Comte, F. Mathieu and A. Bušić. *Stochastic dynamic matching: A mixed graph-theory and linear-algebra approach*. 25th Feb. 2022. URL: https://hal.archives-ouvertes.fr/hal-03502084.

[41] T. L. Corre, A. Bušić and S. Meyn. *Feature Projection for Optimal Transport*. 2022. URL: https://hal.science/hal-03923065.

[42] E. Daoud, A.-S. Hamy-Petit, E. Dumas, L. Delrieu, B. G. Rejo, C. Le Bihan-Benjamin, S. Houzard, P.-J. Bousquet, J. Hotton, A.-M. Savoye, C. Jouannaud, C.-A. Azencott, M. Lelarge and F. Reyal. *Disparities in accessibility to oncology care centers in France*. 4th Jan. 2022. DOI: 10.1101/2021.09.29.21264296. URL: https://hal-mines-paristech.archives-ouvertes.fr/hal-03511050.

[43] M. Davydov. *Propagation of chaos and Poisson Hypothesis for replica mean-field models of intensity-based neural networks*. 21st Nov. 2022. URL: https://hal.inria.fr/hal-03863810.

[44] M. Even, L. Massoulié and K. Scaman. *Sample Optimality and All-for-all Strategies in Personalized Federated and Collaborative Learning*. 1st Feb. 2022. URL: https://hal.archives-ouvertes.fr/hal-03550407.

[45] C. Fricker, H. Mohamed, A. Rigonat and M. Trépanier. *A new stochastic model for carsharing suited to free-floating*. 14th Jan. 2023. URL: https://hal.science/hal-03938964.

[46] L. Ganassali, L. Massoulié and G. Semerjian. *Statistical limits of correlation detection in trees*. 3rd Jan. 2023. URL: https://hal.archives-ouvertes.fr/hal-03920990.

[47] A. Khezeli. *A Unified Framework for Generalizing the Gromov-Hausdorff Metric*. 2022. URL: https://hal.inria.fr/hal-03927439.

[48] A. Khezeli. *An Improved Lower Bound on the Largest Common Subtree of Random Leaf-Labeled Binary Trees*. 2022. URL: https://hal.inria.fr/hal-03924930.

[49] G. Sergeant-Perthuis, J. Maier, J. Bruna and E. Oyallon. *On Non-Linear operators for Geometric Deep Learning*. 5th July 2022. DOI: 10.48550/arXiv.2207.03485. URL: https://hal.science/hal-03711864.

[50] I. Shilov, H. Le Cadre, A. Bušić and G. de Almeida Terça. *A Stackelberg Game Analysis of Risk-Hedging Strategies in Decentralized Electricity Markets*. 16th Jan. 2023. URL: https://hal.science/hal-03674562.