Conférence pour les 50 ans du CMAP

Rapport sur les contributions

https://indico.math.cnrs.fr/e/11598

ID de Contribution: **1** Type: **Non spécifié**

Ouverture et mot des tutelles : Amphi Faurre 13:20 - 13:40

mercredi 11 septembre 2024 13:20 (20 minutes)

Séance d'ouverture de la conférence

ID de Contribution: **2** Type: **Non spécifié**

T. Bodineau : Statistical properties of a hard sphere gas

mercredi 11 septembre 2024 13:40 (40 minutes)

A gas dynamics can be modelled by a billiard made of hard spheres, moving according to the laws of classical mechanics. Initially the spheres are randomly distributed according to a probability measure which is then transported by the flow of the deterministic dynamics. Since the seminal work of Lanford, it is known that the gas density converges in the kinetic limit towards the Boltzmann equation (at least for a short time). In this talk, we are going to review several results on the fluctuations of the particle system density around the Boltzmann equation. This is based on joint works with I. Gallagher, L. Saint-Raymond and S. Simonella.

ID de Contribution: **3** Type: **Non spécifié**

N. Spillane : Convergence and acceleration of GMRES for solving linear systems

mercredi 11 septembre 2024 14:20 (40 minutes)

The GMRES linear solver, introduced by Y. Saad et M. H. Schultz is the go-to solver for non-symmetric systems that are too large to be factorized. For general matrices, the convergence behaviour of GMRES is not fully understood. Theoretical analysis is a challenge in itself but it also has very important practical implications.

In this talk I will present some existing convergence results for GMRES as well as their limitations. For matrices that have positive-definite symmetric part, I will analyze GMRES in a way that makes explicit the influence of three GMRES accelerators:
- weighting (i.e., changing the inner product),
- preconditioning (i.e., providing a cheap approximate inverse of the matrix),
- deflation (i.e., solving exactly the problem on part of the solution space).

These results provide us with a strategy for accelerating GMRES in the case of positive-definite problems.

This is joint work with Daniel Szyld from Temple University in Philadelphia.

ID de Contribution: **4** Type: **Non spécifié**

S. Allassonnière : Intelligence artificielle en santé : actualités et perspectives.

mercredi 11 septembre 2024 15:30 (40 minutes)

Along my years in the CMAP, I have been able to work with my students on several projects that I will quickly describe here.

First we have provided coherent framework for studying cross-sectional, multimodal and longitudinal manifold-valued data. We have introduced Bayesian mixed-effect models which allow to estimate both a group-representative piecewise-geodesic trajectory in the Riemannian space of shape and inter-individual variability. We have proved theoretical guarantees of the models and the optimisation algorithms. The practical use of these models has led to the creation of a startup named Qairnel.

In this second work we investigate a model-based reinforcement learning approach for a sequential decision making problem in a rare obstetrical disease diagnostic task. The specificities of our case study, namely the data scarcity, the lack of expert demonstration from which we could learn, and the importance of domain knowledge combined with high-dimensionnal issues lead us to an original model learning algorithm proposition. This led to the creation of Sonio.

I will end with a new research topic about data augmentation to accelerate clinical trials.

ID de Contribution: **5** Type: **Non spécifié**

S. Mallat : Des IA génératives jusqu'à la physique statistique

mercredi 11 septembre 2024 16:10 (40 minutes)

Les algorithmes de génération d'images par réseaux de neurones peuvent synthétiser des images de qualités spectaculaires. Es-ce une forme de mémorisation ou sont ils capable de généraliser ? Comment peuvent ils contourner la malédiction de la dimensionnalité, pour des images aussi complexes que celles de notre environnement ? Ces algorithmes échantillonnent des distributions de probabilités, similaires à des modèles de physique statistique. Nous verrons que la physique statistique donne des clefs importantes pour comprendre la nature des modèles construits par ces réseaux de neurones.

ID de Contribution: **6** Type: **Non spécifié**

Session Poster - Apéritif salé et sucré

mercredi 11 septembre 2024 17:00 (1 heure)

ID de Contribution: **7** Type: **Non spécifié**

C. Hillairet : Actuarial modeling for the systemic component of Cyber-risk

jeudi 12 septembre 2024 09:30 (40 minutes)

With the rise of digital economy, cyber risk has become a major threat for the financial system, while the scale of losses linked to cyber-risk is rising sharply (more than 1% of the global GDP). Facing this risk, cyber insurance is an essential lever for economic resilience, but its development encounters some pitfalls, with important uncertainties. Indeed the emerging and evolving nature of cyber-risk and its potential systemic component questions its insurability. After an introduction to the specificities on cyber risk, we present a stochastic model to capture the cluster features in the arrival of cyber-events, namely Marked Hawkes processes. These mathematical objects turn out to be difficult to study. Using new technics at the crossroad of the so-called Poisson imbedding and Malliavin's calculus, we develop theoretical results on such processes and present several applications in terms of risk quantification.

This talk is based on joint works with Anthony Réveillac, Mathieu Rosenbaum, and Thomas Peyrat

ID de Contribution: **8** Type: **Non spécifié**

J.-M. Roquejoffre : Large time dynamics in the Fisher-KPP equation

jeudi 12 septembre 2024 10:10 (40 minutes)

The Fisher-KPP equation (the acronym KPP stands for Kolmogorov, Petrovskii and Piskunov) is an ubiquitous model that arises in the applied sciences, such as ecology or combustion science. It aslo arises in probability theory, as its solution starting from an appropriate initial datum accounts for the behaviour of the rightmost particle in the one-dimensional Branching Brownian Motion.

In a fundamental work of 1937, KPP proved that the level sets of the solutions at asymptotically constant speed. With the aid of elaborate probabilistic arguments, Bramson (circa 1980) discovered an asymptotically logarithmic in time correction. This fostered an important activity in the study of the Branching Brownian Motion .

Viewed from the PDE side, this logarithmic behaviour has remained intriguing for a long time, as many models for front propagation do not exhibit it.The goal of the talk is to explain the mechanism leading to this type of behaviour with purely analytical arguments, and to present asymptotics of the solutions beyond Bramson's correction. Further insights into the Branching Brownian Motion, allowed by the PDE ideas that we have developped, will also be discussed.

Joint works with L. Mytnik, J. Nolen, L. Ryzhik.

ID de Contribution: **9** Type: **Non spécifié**

D. Villemonais : Binary branching processes with Moran type interactions

jeudi 12 septembre 2024 11:20 (40 minutes)

During this talk, we will consider the large population limit of a binary branching particle system with Moran type interactions introduced recently: this is a model where particles evolve, reproduce and die independently and, with a probability that may depend on the configuration of the whole system, the death of a particle may trigger the reproduction of another particle, while a branching event may trigger the death of an other one. We study the occupation measure of the new model, explicitly relating it to the Feynman-Kac semigroup of the underlying Markov evolution and quantifying the L^2 distance between their normalisations. This model extends the fixed size Moran type interacting particle system. We will consider applications of our model as a numerical application scheme and study its convergence uniform in time under spectral gap assumptions for the underlying semi-group.

ID de Contribution: **10** Type: **Non spécifié**

H. Ammari : 50 ans d'ondes au CMAP

jeudi 12 septembre 2024 12:00 (40 minutes)

Les ondes ont été et continuent d'être un domaine de recherche majeur au CMAP. L'objectif de cette présentation est de retracer l'histoire des ondes au CMAP et de présenter les derniers développements dans ce domaine.

ID de Contribution: **11** Type: **Non spécifié**

J. Josse : Leveraging causal inference to generalize trial results to diverse population.

jeudi 12 septembre 2024 14:10 (40 minutes)

Randomized Controlled Trials (RCTs) are pivotal in evidence-based medicine, estimating average treatment effects by avoiding confounding factors. However, concerns about RCT limitations—strict eligibility criteria, real-world impracticality, and small sample sizes—threaten their generalization to diverse populations. In this talk, I will first present transportability methods by integrating non-randomized observational data to extend trial findings to other populations, potentially facing distributional shifts. Then, I will focus on which causal measure is easier to generalize, whether absolute as the Risk Difference or relative as the Risk Ratio, Odds Ratio, etc. In particular, I will demonstrate that only the Risk difference can disentangle the treatment effect from the baseline risk at both population and strata levels.

ID de Contribution: **12** Type: **Non spécifié**

N. Touzi : Martingale Distributionally Robust Sensitivity

jeudi 12 septembre 2024 14:50 (40 minutes)

Distributionally robust optimization studies the worst deviation of an evaluation functional on the Wasserstein ball centered at the model of interest. We derive explicit sensitivity analysis under marginal and martingale constraints which provide first order hedge against model risk.

ID de Contribution: **13** Type: **Non spécifié**

C. Dapogny : Optimisation de la forme des régions portant les conditions aux limites d'un problème physique

jeudi 12 septembre 2024 16:00 (40 minutes)

Très généralement, l'optimisation de formes vise à optimiser le design d'un domaine du plan ou de l'espace au regard d'un objectif et en respectant certaines contraintes, exprimés comme des fonctions du domaine.

Dans les applications, ces fonctions dépendent de la forme par la solution d'une équation aux dérivées partielles décrivant la physique du problème en jeu, qui est complémentée par des conditions aux limites décrivant l'influence du milieu extérieur. Ainsi une structure mécanique est caractérisée par son déplacement, solution du système de l'élasticité linéaire, équipé de conditions aux limites de Dirichlet homogènes (correspondant aux zones d'attache de la structure), ou de Neumann homogènes (bord libres d'effort) ou inhomogènes (bords sur lesquels une force est appliquée).

Le plus souvent, une seule partie du bord de la forme est optimisée – typiquement, le bord libre en mécanique des structures. L'objectif de ce travail est, au contraire, d'optimiser la répartition des régions du bord de la forme portant les conditions aux limites du problème physique en jeu.

Cette question est abordée sous deux aspects complémentaires :
- D'une part, on étudie la dérivée de forme d'une fonction du domaine au sens de Hadamard lorsque les déformations en jeu ne s'annulent pas au changement des conditions aux limites : on optimise ainsi comment les régions portant les conditions aux limites peuvent "glisser" le long du bord de la forme.
- D'autre part, on étudie la sensibilité de la solution du problème physique en jeu (et d'une quantité d'intérêt qui en dépend) lorsque l'on fait apparaître une petite région portant un certain type de conditions aux limites (par exemple, de Dirichlet) au sein d'une région portant d'autres conditions (par exemple, de Neumann) : ceci conduit à une sorte de "dérivée topologique" décrivant le changement de conditions aux limites sur le bord d'une forme donnée.

On discutera plusieurs applications numériques de ces développements.

Ces travaux ont été réalisés en collaboration avec Eric Bonnetier, Carlos Brito-Pacheco, Nicolas Lebbe, Edouard Oudet et Michael Vogelius.

ID de Contribution: **14** Type: **Non spécifié**

E. Moulines : Solving Bayesian Inverse Problems Using Denoising Diffusion Models

jeudi 12 septembre 2024 16:40 (40 minutes)

Solving Bayesian Inverse Problems Using Denoising Diffusion Models

joint work with: Alain Oliviero-Durmus, Yazid Janati-El-Idrissi (post-doc), Badr Moufad (PhD), Mehdi Abou El Qassime (PhD), Ahmed Ghorbel (Ing), Lisa Bedin (Ing), Ecole polytechnique & FX-Conseil, J. Olsson, KTH, S. Le Corff, Sorbonne Université.

The growing interest in the use of Denoising Diffusion Models (DDMs) as fundamental elements for solving inverse Bayesian problems has recently marked a significant trend. The application of DDMs in this context offers a promising way to harness complex prior distributions. However, one of the major hurdles in this approach is the difficulty of sampling from the posterior distribution that arises when DDMs are used as priors. This challenge is primarily due to the complicated dynamics and high-dimensional nature of the diffusion processes involved.

To overcome this obstacle, previous research efforts have focused on developing strategies to modify the drift term within the diffusion process. These modifications aim to better approximate the true posterior distribution, albeit often at the cost of introducing bias or increased computational complexity. While useful, such methods do not target the “true” posterior.

Our work introduces a novel paradigm that takes advantage of the unique structural properties of DDMs. We propose a systematic decomposition of the posterior sampling into a sequence of more manageable intermediate tasks. Each of these tasks is designed to progressively refine the approximation of the posterior distribution, utilizing the structure of the DDM prior to effectively guide the sampling process. With this methodology, we can achieve a more accurate approximation of the posterior distribution and significantly reduce the approximation error compared to previous approaches.

Our empirical investigations emphasize the effectiveness of our proposed method in a wide range of applications, ranging to image restoration, ECG reconstruction to urban mobility simulation. This work therefore sets a new benchmark for the use of denoising-diffusion models in solving inverse Bayesian problems and provides both theoretical insights and practical advances in the field.

ID de Contribution: **15** Type: **Non spécifié**

Séance d'interventions historiques : Jean-Claude Nédélec, Claire Mouradian, Geo Boléat, Jeanne Bailleul, Nicole El Karoui, Laurence Halpern, Marc Schoenauer, Mohamed Jaoua, Jean-François Colonna, Robert Brizzi, Éric Bonnetier, François Jouve, et al.

jeudi 12 septembre 2024 17:50 (1 heure)

ID de Contribution: **16** Type: **Non spécifié**

R. Douc : Sampling by auxiliary target distributions: from the teleportation algorithm to the importance sampling Markov chain.

vendredi 13 septembre 2024 09:30 (40 minutes)

This review presentation brings together several works conducted in collaboration with Alain Durmus, Jimmy Olsson, Aurélien Enfroy, Charly Andral, Christian Robert, and Yazid Janati.

In this presentation, we will introduce the teleportation algorithm and the importance sampling algorithm by Markov chains. These two algorithms share the common principle of obtaining a chain targeting a given distribution from a simple transformation of a Markov chain aimed at an auxiliary distribution. Importance sampling by Markov chain is based on decimation and reproduction procedures that enable transitions between modes while reproducing points in the vicinity of the modes. The teleportation algorithm helps to diversify points around the modes and thus acts complementarily to importance sampling by Markov chain. We demonstrate that under weak conditions, essential properties such as the law of large numbers, geometric ergodicity, and the central limit theorem are preserved through these two operations. We will also present some approaches for sequentially combining these two algorithms to gradually transition through a sequence of intermediate laws, from a Markov chain targeting a standard distribution to a chain targeting the desired distribution, thereby providing a promising alternative to sequential Monte Carlo methods.

ID de Contribution: **17** Type: **Non spécifié**

A. Veber : Modéliser le développement d'un champignon filamenteux

vendredi 13 septembre 2024 10:10 (40 minutes)

Les champignons filamenteux forment une très large famille d'espèces ayant un rôle important dans le fonctionnement de nombreux écosystèmes. Ils se développent spatialement grâce à la croissance et à la multiplication de filaments (aussi appelés hyphes) qui permettent l'absorption et le partage de nutriments et d'autres molécules chimiques. Dans cet exposé, on commencera par présenter un modèle simple de croissance-fragmentation multi-type pour le développement du réseau hyphal qui vise principalement à identifier un petit nombre de paramètres-clés décrivant le développement du champignon dans des conditions homogènes et de comprendre et quantifier l'impact de diverses formes de stress sur la croissance du réseau de filaments. Puis on intégrera une dimension spatiale et une régulation locale des dynamiques grâce à un modèle plus complexe dont on considèrera la limite en grande population.

Ces différents travaux sont en collaboration avec Milica Tomasevic et Vincent Bansaye au CMAP, Lena Kuwata au MAP5 et l'équipe pluridisciplinaire du projet ANR NEMATIC rassemblant des mathématiciens, biologistes, physiciens et géomaticiens autour de modèles et expériences de croissance de réseaux sous contraintes.

ID de Contribution: **18** Type: **Non spécifié**

A. Chambolle : Discrete to continuous crystalline curvature flow

vendredi 13 septembre 2024 11:20 (40 minutes)

In this joint work with Daniele DeGennaro (CEREMADE, Parma) and Massimiliano Morini (Parma) we study a fully space and time discrete implicit approximation of the curvature flow, for a surface tension defined by pairwise interactions on the discrete lattice (with bounded range). We study the convergence as the space and time steps go to zero (with different possible regime) and find, surprisingly, that in some cases we get a limiting crystalline curvature flow in any convergence regime.