CJC-MA 2026 Book of Abstracts

March 2-4, 2026

Ecole nationale des Ponts et Chaussées, Champs-sur-Marne

Contents

Plenary Sessions

Plenary Talk

Flash calculation of chemical equilibria in multiphase reactive mixtures: Unified formulation and efficient computation

Speaker: **Clément Cancès**

Affiliation: Inria Lille

Room: Amphi Cauchy

Timeslot: Monday, March 2, 2:30 PM - 3:30 PM

Abstract: The problem I will address in this talk can be formulated in a simple way: given a certain quantity of different atoms, what configuration in terms of chemical species is the most favorable from an energetic perspective, and thus the most likely to occur. From a mathematical perspective, it amounts to minimizing a 1-homogeneous convex functional under linear constraints encoding the conservation of the atoms, and positivity constraints for the concentrations. The study of this question is of course not new, but still, the practical computation of such chemical equilibria requires most of the computational effort for the simulation of CO2 storage scenarios. The situation is particularly delicate as the model allows for the (dis)appearance of (solid, gaseous, liquid) phases. We propose a new formulation allowing us to treat such phase disappearance by means of persistent variables, and then propose an efficient Newton-based algorithm that shows to outperform the state-of-the-art approaches in terms of robustness and convergence speed. This is a joint work with Ibtihel Ben Gharbia, Thibault Faney, Maxime Jonval and Quang Huy Tran.

Plenary Talk

Optimal transport and applications in statistical analysis

Speaker: **Elsa Cazelles**

Affiliation: IRIT, Toulouse

Room: Amphi Cauchy

Timeslot: Tuesday, March 3, 2:30 PM - 3:30 PM

Abstract: Optimal transport (OT) originated in 1781 with Gaspard Monge's "Mémoire sur la théorie des déblais et des remblais", which posed the problem of the optimal displacement of a pile of sand. This theory reemerged in the 1940s with Leonid Kantorovich, who introduced a relaxed formulation of OT consisting of finding the most efficient (minimal-cost) way to transform one distribution into another. OT then offers a versatile framework for measuring (dis)similarities, interpolating and aligning distributions, while explicitly taking into account the geometry of their underlying space. Today, OT stands as a rich mathematical theory and applied research area, at the intersection of probability, optimisation and partial differential equations, with applications to data such as point clouds, images, words, and continuous data. In this talk, we introduce the fundamental principles of OT (Monge and Kantorovich formulations, Brenier's theorem and numerical methods) and conclude by illustrating how OT can be effectively exploited in statistical data analysis applications.

Plenary Talk

Emile Borel and the probabilistic turn of a worried Cantorian

Speaker: **Laurent Mazliak**

Affiliation: LPSM, Sorbonne Université, Paris

Room: Amphi Cauchy

Timeslot: Wednesday, March 4, 11:30 AM - 12:30 PM

Abstract: In this talk, I shall present the singular way in which Émile Borel, from his studies on the structure of real numbers and a certain rejection of Cantor's abstract vision, found in the calculus of probabilities an adequate tool to formulate a new approach to problems. At the same time, he became aware of its usefulness for the study of phenomena in physics and society and developed a singular viewpoint on the concept of probability, merging subjectivist and objectivist aspects under a specific understanding of its possible application.

Parallel Sessions

Monday, March 2

4:00 PM - 5:30 PM

Session

PDEs for geophysical problems: modelling, analysis, numerics

Room: Amphi Cauchy

Timeslot: Monday, March 2, 4:00 PM - 5:30 PM

Chaired by TBA

1. A posteriori error estimators and adaptivity for CO2 sequestration.

Speaker: Ibtissem Lannabi

Affiliation: Inria ; IFP Energies nouvelles, 1-4 Av. du Bois Préau, 92852 Rueil-Malmaison, France

Co-authors: Eric Flauraud, Martin Vohralík, Soleiman Yousef

Keywords: A posteriori error estimates, adaptive stopping criteria, CO2 sequestration

Abstract: Geological carbon storage (GCS) technology has become increasingly relevant due to global warming. Numerical simulations play a crucial role in understanding and implementing this technology, as well as in assessing long-term storage risks. To provide a common baseline for GCS numerical simulations, the Society of Petroleum Engineers launched the 11th Comparative Solution Project (SPE11).
The problem considered is modeled by a highly nonlinear system of degenerate partial differential equations governing a multicomponent, multiphase porous media flow. The numerical simulation of such models is computationally expensive, particularly for long-time simulations. The central question in the numerical approximation is how large the simulation error is.

In this work, we focus on the Coats model for the SPE11 benchmark, approximated using a finite volume scheme in space and a backward Euler scheme in time. The resulting nonlinear equations are solved using Newton's iterative algorithm, and the linear systems obtained after linearization are solved with an iterative algebraic solver. Another important question that arises at this stage is whether it is possible to improve the computational efficiency without compromising the accuracy of the results.

To answer the two above questions, we first propose to bound the total relative error by a fully

computable a posteriori error estimate. We then quantify the contribution of each individual error component, namely those arising from spatial, temporal, and linearization approximations. Next, based on these a posteriori error estimate components, we propose to improve the computational efficiency through adaptive stopping criterion for the Newton algorithm and adaptive control of the time-step size.
Numerical results are performed using the Geoxim platform, which is based on Arcane.

2. Modeling and numerical simulation of floating structures in shallow-water flows

Speaker: Sacha Cardonna

Affiliation: Institut Montpelliérain Alexander Grothendieck – CNRS, Université de Montpellier – France

Keywords: water waves, nonlinear shallow water, floating structures, high, order methods, Monolithic DG/FV, HHO

Abstract: This work presents a high-order numerical framework for the simulation of fluid–structure interactions governed by the nonlinear shallow-water (NSW) equations coupled with a set of ODEs and an interior elliptic diffusion problem. The physical configuration involves a partly immersed rigid body, either of cylindrical or pontoon type, interacting with a free-surface flow in two spatial dimensions.

3. Mathematical analysis of an ocean-atmosphere coupling model

Speaker: Emile Deléage

Affiliation: Laboratoire Jean Kuntzmann – CNRS, Université Grenoble Alpes – France

Keywords: Partial differential equations, fluid mechanics, climate models

Abstract: In this talk, I will present a system of partial differential equations that is used in climate models for the ocean-atmosphere interface. I will first explain some physical and mathematical assumptions that are used in the derivation of the model. I will then give some elements for the theoretical analysis of the corresponding problem.

Session

Risks and extreme events in environment and energy

Room: B 102

Timeslot: Monday, March 2, 4:00 PM - 5:30 PM

Chaired by TBA

1. Adaptive confidence intervals for extreme quantiles from heavy-tailed distribution

Speaker: Antoine Franchini

Affiliation: Laboratoire Jean Kuntzmann – INRIA, CNRS, Institut polytechnique de Grenoble : UMR5224 – France

Keywords: Weissman estimator, extreme quantiles, heavy, tailed distributions, confidence intervals, extreme value theory, semi parametric estimation, classification

Abstract: The celebrated Weissman estimator provides a simple way to compute extreme quantiles, lying outside the observation range, from heavy-tailed distributions. Asymptotic confidence intervals can also be built based on its asymptotic normality, but they may suffer from poor coverage properties in practice. We propose several higher order approximations of the Weissman estimator asymptotic distribution together with a data-driven procedure to automatically select the most appropriate one.
The usefulness of the associated adaptive confidence interval is illustrated on an intensive simulation study as well as on two climatic and financial data sets.

2. Reliable criterion for decision-making on critical systems

Speaker: Marie Temple-Boyer

Affiliation: EDF R&D ; Département Composants et Systèmes – Université Gustave Eiffel – France

Co-authors: Guillaume Perrin, Vincent Chabridon, Julien Pelamatti, Emmanuel Remy

Keywords: risk measure, decision, making, failure probability, quantile, superquantile

Abstract: The reliability assessment of a critical industrial system (such as electricity power plant) is based on an analysis of uncertainties and, ultimately, on the estimation of a risk measure characterizing the risk of a system failure. This estimate can be obtained using a numerical simulator that models the behavior of the system in its environment. The risk measures generally used correspond to failure probabilities or high-order quantiles. Nevertheless, a wider range of risk

measures may be considered in practice. For example, the superquantile and the buffered failure probability are quantities used in risk quantification in finance, and may also be relevant in engineering, partly due to their many interesting theoretical properties.

A general formalism for decision-making based on risk measure estimation is proposed in this work. This formalism allows to guarantee, with some confidence level, that a risk measure is below a given threshold. When applied on the failure probability, it provides a criterion to guarantee that the failure probability is below some acceptable risk, and it is equivalent to a decision criterion made on the Wilks estimator of the quantile. If we further assume that output is bounded, then the framework can be applied on the superquantile, giving the guarantee that the superquantile is below a given safety threshold, or equivalently that the buffered failure probability is small enough.

The main interest of such a framework is the non-asymptotical statistical guarantee. However, there is a critical sample size that must be reached to obtain a relevant criterion. For classical Monte-Carlo estimators and when the acceptable risk is close to zero, this critical sample size may be prohibitive. The usage of more advanced estimators, with reduced variance in the rare event case, is therefore studied in this decision-making framework.

3. Modélisation des températures extrêmes à la surface de la Terre fondée sur la physique du climat

Speaker: Laurie Leterrier

Affiliation: Biostatistique et Processus Spatiaux – INRAE – France

Co-authors: Thomas Opitz, Marine Demangeot, Nicolas Meyer, Philippe Naveau

Keywords: Théorie des Valeurs Extrêmes, température, borne supérieure, simulation, statistiques spatiales

Abstract: Le réchauffement climatique amplifie les événements météorologiques extrêmes, et la modélisation des pires scénarios atteignables sur Terre constitue un défi majeur pour la gestion des risques. Les données disponibles sur ces événements sont généralement très limitées. Dans ce travail, nous estimons les distributions statistiques des températures les plus extrêmes, en nous concentrant sur la détermination de leur limite supérieure pour une localisation donnée, cette borne étant supposée finie en raison des contraintes physiques établies dans la littérature récente. Les approches standards basées sur les statistiques des valeurs extrêmes déterminent la borne supérieure à partir des trois paramètres d'une distribution des valeurs extrêmes ajustée aux maxima annuels de température. Cependant, les bornes supérieures estimées sont souvent dépassées par de nouvelles données, même si les hypothèses du modèle sont valables. Cela ne permet donc pas de modéliser correctement les événements les plus extrêmes. La prise en compte de la variation spatio-temporelle des distributions de température avec les coordonnées géographiques comme covariables peut améliorer la modélisation, mais ne résout pas le

problème fondamental. En revanche, des travaux récents en physique du climat présentent une équation déterministe qui contraint la limite supérieure des températures de surface, variables dans l'espace et dans le temps, par trois autres variables atmosphériques, plus lisses spatio-temporellement à grande échelle.
Pour exploiter cette équation, nous reparamétrons les distributions des valeurs extrêmes afin que la limite supérieure soit un paramètre. Nous calculons d'abord une borne à l'aide de la contrainte physique. Ensuite, après l'avoir fixée, nous pouvons estimer de manière flexible les paramètres restants à l'aide d'une approche de régression spatio-temporelle conditionnée par la borne fixe, réduisant le nombre de paramètres à estimer. Notre approche est finalement testée sur des simulations de modèles climatiques physiques en Europe et nous comparons les résultats avec l'approche d'estimation statistique standard.
À l'aide de ces modèles, de nouvelles données peuvent être simulées afin d'évaluer les scénarios les plus pessimistes en matière de températures extrêmes. Cela permet d'obtenir de très grands échantillons à faible coût de calcul, contrairement aux données limitées issues d'observations ou aux simulations coûteuses de modèles climatiques, et facilite l'évaluation des impacts des températures extrêmes les plus défavorables sur les êtres humains, la biodiversité, l'agriculture et de nombreux autres domaines.

Session

Analysis of nonlinear/nonlocal systems of coupled PDEs

Room: B 103

Timeslot: Monday, March 2, 4:00 PM - 5:30 PM

Chaired by TBA

1. Système à diffusion croisée avec potentiels externes différents et diffusion rapide

Speaker: Charles Elbar

Affiliation: Institut Camille Jordan – Université Claude Bernard Lyon 1 – France

Keywords: Diffusion croisée, Diffusion rapide, Interactions

Abstract: Nous étudions un système de diffusion croisée pour deux populations en interaction. De manière surprenante, quand les potentiels externes de chaque espèce sont différents (ce qui modélise une interaction différente avec l'environnement), et même en les supposant lisses, il est difficile de montrer l'existence de solutions. Nous démontrerons que le résultat peut être obtenu dans le cas d'une diffusion rapide, sur le tore et en dimension 1. Le travail est en collaboration avec Filippo Santambrogio: https://arxiv.org/abs/2510.07937

2. On a class of fractional elliptic reaction-diffusion systems

Speaker: Maha Daoud

Affiliation: INSA Toulouse – France

Keywords: Fractional Laplacian, Nonlocal operators, Reaction diffusion systems, Gradient source terms, Numerical simulations

Abstract: Over the past few decades, problems involving the fractional Laplacian, denoted by $(-\Delta)^s$ with $0 < s < 1$, have been the subject of extensive research. These nonlocal operators provide a natural framework for modeling anomalous diffusion and long-range interactions.

In this talk, we present some new results about existence of solutions to a class of elliptic fractional reaction-diffusion systems posed on a bounded open subset of $\mathbb{R}^d$. The nonlinear reactive terms are assumed to satisfy natural assumptions which provide nonnegativity of the solutions. The diffusion operators are of type $u_i \mapsto d_i(-\Delta)^{s_i} u_i$ where $0 < s_i < 1$, and the reaction terms depend on the gradients of the unknowns.

In addition, we employ numerical simulations to address some open theoretical questions and to

gain insight into the existence of nonnegative solutions.

3. 2-phase model of ageing : Stability analysis of coupled non-linear partial differential equations with age structure.

Speaker: Luce Breuil

Affiliation: CMAP, École polytechnique, Route de Saclay 91128 Palaiseau Cedex, France

Keywords: ageing, dynamical system, equilibrium, evolution, discontinuous, two phases

Abstract: Recent biological evidence suggests the presence of a 2-phase ageing process in D. Melanogaster. Following these discoveries, we introduce a system of coupled age-structured partial differential equations to model the evolution of a wild population with two distinct age phases. The goal of this work if to try and understand the evolutionary implications of a discontinuous ageing process, and the behaviour of such a model. The model includes birth, death, transition between phases and non linearities due to competition. We study general properties of the system such as well-posedness, positivity and boundedness under few conditions and using general relative entropy methods. We also propose some simplifications of the system, for which we study the existence and stability of steady states with the semi-group approach. By comparing with classical one-phase ageing models, we motivate the presence of a discontinuity from an evolutionary perspective. Finally, we introduce further assumptions and study the global asymptotic behavior of our system.

Session

Stochastic processes and particle systems I

Room: B 202

Timeslot: Monday, March 2, 4:00 PM - 5:30 PM

Chaired by TBA

1. Uniform-in-N convergence and chaoticity of particle systems under empirical moment constraints

Speaker: François Escolan

Affiliation: CERMICS – Ecole Nationale des Ponts et Chaussées ; MATHERIALS – INRIA – France

Co-authors: Aurelien Alfonsi, Virginie Ehrlacher, Julien Reygner

Keywords: Particle system, Logarithmic Sobolev Inequalities, Large Deviations Theory

Abstract: Moment-constrained optimization problems over the space of probability measures are ubiquitous. A simple strategy to solve them consists in discretizing the moment constraints by approaching the measures with a system of N particles, and adding an entropy regularization to the objective functional. The solution of this relaxed problem then coincides with the invariant measure of a Langevin diffusion on a suitable manifold. We show that this invariant measure converges to the minimum-entropy measure satisfying the moment constraints. In specific cases, uniform-in-N Logarithmic Sobolev Inequalities are established via the Bakry–Émery criterion, ensuring fast convergence of the diffusion. Depending on ongoing progress, we will also propose alternative conditions guaranteeing such inequalities in more general settings.

2. Infinite dimensional Mean-field Belavkin equation: global well-posedness and derivation

Speaker: Théo Hérouard

Affiliation: CMAP – École polytechnique, Centre National de la Recherche Scientifique – France

Keywords: Mean, Field Limits, Stochastic PDE, Open Quantum Systems

Abstract: In quantum physics, one of the fundamental postulates is that direct measurement may strongly perturb the system. If one wants to perform continuous measurements, as in quantum optimal control, indirect measurements are employed to mitigate perturbations of the system. This leads to an open system described by Belavkin's quantum filtering equation. This equation is a stochastic PDE whose solutions are in the space of finite trace operators. However, under certain

conditions on the initial state (i.e. the system is in a pure state), the evolution is described by a stochastic equation on the wave functions, which is easier to study.
If, moreover, the system we wish to measure is made up of multiple interacting particles, simulation and control become very costly. A common approximation for such large systems is the mean-field approximation. In this approximation, the global evolution equation for the N particles is replaced by a tensor product of N independent autonomous equation solutions for one particle. These autonomous equations are called mean-field, and the interaction term between particles is replaced by a Hartree-type nonlinearity that does not depend on the other particles.

First, we focus on the well-posedness of the mean-field SPDE, the proof of which relies on a fixed point argument. Secondly, under additional assumptions, we obtain higher regularity solutions. Thirdly, we show rigorously that this equation can be obtained as a mean-field limit of an N-particle system. When the solutions are sufficiently regular, a speed of convergence is obtained.
This is a joint work with Anne de Bouard and Gaoyue Guo.

3. From Microscopic to Macroscopic: Convergence of Particle Systems to Nonlinear Fokker-Planck PDEs

Speaker: Nicoleta Cazacu

Affiliation: CMAP – École polytechnique – France

Keywords: Stochastic analysis, Fokker, Planck PDE's, McKean, Vlasov SDE's with singular interactions, systems of interacting particles, uniform in time propagation of chaos.

Abstract: Deriving macroscopic evolution equations from interacting particle systems is a classical problem in mathematical physics, dating back to Kac's work on the Boltzmann equation. In the mean-field regime, these systems are expected to converge, as the number of particles tends to infinity, to solutions of nonlinear Fokker-Planck PDEs. In this limit, particles become asymptotically independent, a property known as propagation of chaos, and a key question is whether this convergence holds uniformly in time.
While convergence is well understood for regular interaction kernels, many important models involve singular interactions, such as those in the Keller-Segel model, Coulomb interactions, or Riesz potentials, where fundamental questions remain open.
In this talk, I will first briefly introduce the general framework of interacting particle systems and discuss recent techniques for proving uniform-in-time propagation of chaos for systems with singular kernels. I will then present an ongoing work using a mild formulation of the limiting equation and semigroup estimates, aimed at extending uniform in time propagation of chaos results to more singular kernels (for example Krylov-Rockner type kernels).

Session

Combinatorial optimization

Room: B 05

Timeslot: Monday, March 2, 4:00 PM - 5:30 PM

Chaired by TBA

1. On the Computational Complexity of Covering Multi-Interface Networks

Speaker: Camille Richer

Affiliation: Université Paris Dauphine-PSL – Université Paris sciences et lettres – France ; Orange Labs [Chatillon] – Orange Labs – France

Co-authors: Cristina Bazgan, Morgan Chopin, André Nichterlein

Keywords: multi interface network, wireless network, parameterized complexity

Abstract: We investigate the computational complexity of the problem Minimum Coverage in Multi-Interface Networks (Min CMI), which has applications in the field of Internet of Things (IoT). In this problem, we are given an undirected graph where each vertex represents a device (e.g., smartphones, environmental sensors, smart speakers) capable of activating multiple interfaces (e.g., Bluetooth, Wi-Fi, 4G/5G) to establish connections with one another. The objective is to ensure the connectivity requirement of the network while minimizing its total energy consumption by activating only the necessary interfaces.

Contributing to the computational complexity landscape of Min CMI, we unify and extend previously known algorithmic results and demonstrate their limits. In particular, we analyze two scenarios based on the number of different interfaces across the network. When this number is unbounded, we show that the problem remains fixed-parameter intractable with respect to the number p of active interfaces per node within highly restricted graph classes such as stars and cliques.
Additionally, we show that even in the case that p is a small constant, strong structural parameters like vertex cover number, feedback edge number, or distance to clique do not help to obtain fixed-parameter tractability. When the number of different interfaces is bounded by a constant, the problem, while still NP-hard, allows for more tractable special cases, including sparse graphs with small separators (i.e., low treewidth) and dense graphs.

2. Worldwide-Scale Shipper Network Design for a Carmaker Inbound Supply Chain

Speaker: Mathis Brichet

Affiliation: ENPC - CERMICS – Institut Polytechnique de Paris – France

Co-authors: Maximilian Schiffer, Axel Parmentier

Keywords: Shipper Network Design, Large, Scale Iterated Local Search, Flow Consolidation in Supply Chain

Abstract: This work is the fruit of a partnership with Renault. In a context of growing decarbonization effort in society, the automotive industry will have to undergo major transformations. These historical shifts put forward the challenge to design an efficient and resilient supply chain in the long run. One of the facets of this problem is to design the supply chain chain network. This study adresses one facet of this general problem : designing the supply chain network for Renault's inbound operation. The inbound supply chain of a automotive manufacturer is designed to transport car parts from numerous different suppliers to several plants.
For Renault, this worldwide network encompasses several thousand suppliers, producing over tens of thousands types of parts, dozens of intermediate logistics platforms, and dozens of plants to deliver. This logistics operation represents an annual expenditure of approximately one billion euros and results in tens of thousands of tons of CO_2 emissions per year.
Optimizing Renault's logistics network in the long run is therefore imperative. Developing a comprehensive network design optimization tool entails optimizing in an integrated way the transportation network and the flow of car parts within the network. The goal of this optimization is to formulate a long-term network design decisions while providing a corresponding transportation plan to be procured from carriers. To that purpose, we introduce the Shipper Network Design Problem, a rich variant of a multicommodity network design problem (MCNDP). To better align with Renault's specific context and requirements, several extensions to usual network design models are considered. The transportation model used in this work is in itself an extension of a Load Plan Design Problem.
Termed Shipper Transportation Planning Problem, it integrates routing with flexible delivery time, bin-packing consolidation and novel regularity constraints.The design model is also tailored to the specific needs of Renault.As it contracts with logistics providers at platforms, a node design approach is considered. Contracts between Renault and platforms work by geographic units. The car manufacturer partitions the basic units into geographic clusters, and contracts all the supplier-to-platform transport for a given cluster with a single platform. Cluster need to make sense geographically, which basically means that they must be contiguous and compact. Those considerations introduce a novel districting decision in the design model. The computational difficulty of this special MCNDP model stems from its combinatorial nature, integrating in a single model multiple usual combinatorial problems, and the combination of a large time-expanded network, hundreds of thousands of arcs, with several millions of commodities to be routed.

Although recent solution methods from the literature scale to large networks, they don't consider districting as part of the problem and typically handle no more than than fifty thousand commodities while not considering bin-packing consolidation. We present the modeling of this

specialized network design problem and propose two tailored heuristics for solving it at an industrial scale. The first heuristic is based on an Iterated Local Search algorithm, which combines a local search developed for the transportation subproblem with custom network perturbations based on Mixed-Integer Linear Programming relaxations to explore efficiently the solution space and achieve high-quality solutions. The second heuristic employs a learned decomposition of the problem to significantly reduce computation time, addressing the industrial need for interactive algorithm testing and strategic decision improvement. We conduct a data analysis of Renault's instance and establish a lower bound to evaluate algorithm performance. Our numerical experiments demonstrate a substantial improvement over Renault's current solution.

3. Fast SDP certification of neural networks : towards large multi-class datasets

Speaker: Margot Boyer

Affiliation: CEDRIC, Conservatoire national des Arts et Métiers (Cnam)

Keywords: SDP Certification, Adversarial robustness, Neural networks ;

Abstract: We present a new quadratic model for the certification problem in adversarial robustness, which simultaneously accounts for all possible target classes. Building on this model, we propose a novel semidefinite programming (SDP) relaxation for incomplete verification. A key advantage of our approach is that it certifies robustness in a single optimization, avoiding the need for a separate resolution per class. This yields a significant computational speed-up and enables scalability to large datasets with many classes. To further gain in efficiency, we also propose an effective pruning strategy of active neurons, thus reducing the problem dimensionality and accelerating convergence.

Tuesday, March 3

9:00 AM - 10:30 AM

Session

Structure-fluid interaction: modelling, analysis, numerics

Room: B 102

Timeslot: Tuesday, March 3, 9:00 AM - 10:30 AM

Chaired by TBA

1. On the Fritz John problem for a freely floating object

Speaker: Martin Oen Paulsen

Affiliation: Université de Bordeaux – IMB (Institut de Mathématiques de Bordeaux) – France

Co-authors: David Lannes

Keywords: Modelling of fluid structure interactions

Abstract: The Fritz John problem is a linear description of the interactions of an incompressible irrotational free surface fluid with a partially immersed solid object. The model was introduced by John in 1949 and is an important model closely linked to the Cummins equations, which are widely used by naval engineers to compute wave-structure interactions. However, despite their active use, it remains an open question whether the Cummins equations are well-posed. The main difficulty arises from the presence of corners in the fluid domain, which leads to the formation of singularities. In this talk, I will present recent work in collaboration with David Lannes that addresses the well-posedness issue. Moreover, we study the singularities at the corners and their impact on the regularity of the solution.

2. Micro-filament modeling and convergence of an N-link model

Speaker: Jessie Levillain

Affiliation: Centre Borelli (UMR9010) – Université Paris-Saclay, Université Paris Cité, ENS Paris-Saclay, CNRS, SSA, INSERM – France

Co-authors: François Alouges, Aline Lefebvre-Lepot, Clément Moreau

Keywords: well, posedness, convergence, filament elastohydrodynamics, low Reynolds number

Abstract: Simulating and modeling flexible fibers is an crucial issue in many microbiological problems. We focus on a recent result on convergence and well-posedness of the equations governing the dynamics of a discretized version of a continuous, flexible, inextensible filament immersed in a fluid at a low-Reynolds number.
The elastohydrodynamic equation governing the motion of such a filament is a nonlinear 4th-order PDE system. Complexity in analytical and numerical study of the system has led to the use of simplified models, e.g. the "N-link" (F. Alouges, A. DeSimone, L. Giraldi, M. Zoppello, Self-propulsion of slender micro-swimmers by curvature control : N-link swimmers, Int. J. Non-Linear Mech., 2013.), a mechanical discretization into N rigid segments with elastic joints. While numerical evidence shows convergence of this model to the continuous case (C. Moreau, L. Giraldi, H. Gadêlha, The asymptotic coarse-graining formulation of slender-rods, bio-filaments and flagella, J. R. Soc. Interface, 2018), rigorous convergence is nontrivial: the equations of the N-link are not a classical approximation of the underlying PDE.
We prove existence and uniqueness of solutions for the N-link system and demonstrate their convergence to solutions of the classical PDE, leading also to an alternative proof of existence for the continuous PDE, complementing (Y. Mori, L. Ohm, Well-posedness and applications of classical elastohydrodynamics for a swimming filament, Nonlinearity, 2023).

3. Energy-Preserving Finite Volume Discretizations for a Thermo-Hydro-Mechanical Model

Speaker: Mayssam Mohamad

Affiliation: Nantes Université - École Centrale de Nantes – Nantes Université – France

Co-authors: Jad Dabaghi, Frédéric Grondin, Mazen Saad

Keywords: THM model, finite volume, porous media, energy estimates, compressible flow.

Abstract: The storage of hydrogen, produced via water electrolysis, in cementitious cavities offers a solution to the overproduction of electricity from wind farms. However, hydrogen infiltration into the materials could lead to chemical degradation, structural damage, loss of mechanical strength, and possibly an increased leak risk. It is necessary to predict and prevent these issues to ensure safe and efficient storage.

This work aims to propose a Thermo-Hydro-Mechanical model that describes a non-isothermal,

compressible gas flow in a porous medium characterized by small deformations and porosity variations. Linear isotropic thermo-poroelastic constitutive laws are considered for the solid skeleton, assuming small temperature variations around a reference temperature, and thermal equilibrium is assumed between the fluid and the skeleton. This model consists of a system of nonlinear PDEs representing the conservation of fluid mass, the conservation of entropy under reversible mechanical deformations, and the momentum conservation equation.

Firstly, we derive some energy estimates for the compressible flow so as to obtain a control over the solution under certain assumptions. Next, we focus on the numerical analysis of our problem, which is based on an implicit Euler scheme for the time discretization and a two-point flux approximation (TPFA) scheme for the space discretization.
Particular attention is given to the definition of the discrete density at cell interfaces, which is crucial for preserving the energy estimates at the discrete level. Finally, we present some numerical experiments to show the strength of the proposed approach.

Session

Stochastic Optimization

Room: B 103

Timeslot: Tuesday, March 3, 9:00 AM - 10:30 AM

Chaired by TBA

1. Bias-Optimal Bounds for SGD: A Computer-Aided Lyapunov Analysis

Speaker: Lucas Ketels

Affiliation: Laboratoire de Probabilités, Statistique et Modélisation – Sorbonne Université, Centre National de la Recherche Scientifique, Université Paris Cité, Sorbonne Université : UMR_8001, Centre National de la Recherche Scientifique : UMR_8001, Université Paris Cité : UMR_8001 – France ; Bernoulli Institute for Mathematics for Mathematics, Computer Science and Artificial Intelligence Groningen, – Netherlands

Co-authors: Cortild Daniel, Peypouquet Juan, Guillaume Garrigos

Keywords: Stochastic gradient descent, smooth convex optimization, performance estimation problem

Abstract: The analysis of Stochastic Gradient Descent (SGD) typically relies on explicit assumptions about the variance of stochastic gradients-assumptions that are often unverifiable or violated in practice. This paper contributes to a growing line of work that derives guarantees without imposing any variance assumptions, relying solely on (strong) convexity and smoothness. Within this framework, we obtain new bounds from a monotone Lyapunov energy, improving the current state of the art and extending validity to larger step sizes. A central contribution of our work is a *bias-optimal bound*: we show that the bias term in our guarantees is absolutely tight. Specifically, while we do not claim that the overall convergence rate of SGD matches that of deterministic Gradient Descent (GD) along the entire trajectory, we prove that SGD must initially progress at least as fast as GD, up to the point where stochastic variance becomes dominant and the iterates can no longer be precisely tracked. Moreover, in the interpolation regime, where the stochastic gradients vanish at the optimum, we further prove that SGD converges at exactly the same rate as GD. A complementary Performance Estimation Problem analysis confirms that the bias term in our bounds is tight and cannot be improved within our framework.

2. Error Analysis for Stochastic Optimization Schemes

Speaker: Nassim En-Nebbazi

Affiliation: Laboratoire de Mathématiques et de leurs Applications [Pau] – Université de Pau et des Pays de l'Adour – France

Keywords: Stochastic optimization, Numerical Analysis, Modified equations

Abstract: We are interested in two classes of stochastic optimization schemes: stochastic gradient descent and stochastic heavy-ball methods. Assuming that the objective function is strongly convex, we establish time-uniform error estimates for the difference between the solution of the numerical scheme and the solutions of modified (or high-resolution) continuous differential equations of order one and two, as a function of the step size. At first order, the modified equation is deterministic, while at second order it is stochastic and involves a modified objective function.
In contrast with most existing works in the literature (1,2), our analysis focuses on error estimates that are uniform in time and explicitly quantify the dependence on the step size. This framework allows us to rigorously study the complexity of stochastic optimization algorithms in terms of both the step size and the number of iterations.
We will mainly present the results obtained for a gradient-type scheme (3), as well as extensions to inertial heavy-ball-type methods based on first- and second-order modified equations (4,5). Finally, we will compare the theoretical predictions with numerical experiments for both approaches.

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3. Optimized projection-free algorithms for online learning: construction and worst-case analysis

Speaker: Julien Weibel

Affiliation: SIERRA - Inria Paris – Département d'informatique - ENS-PSL, Centre National de la Recherche Scientifique, Centre Inria de Paris – France

Co-authors: Pierre Gaillard, Wouter Koolen, Adrien Taylor

Keywords: Performance Estimation Problem, Semidefinite programming, Algorithm design, Worst, case analysis, Optimised algorithms, Online Convex Optimization, Online Learning, Online Frank, Wolfe, Projection, free algorithms

Abstract: This work studies and develop projection-free algorithms for online learning with linear optimization oracles (a.k.a. Frank–Wolfe) for handling the constraint set. More precisely, this work

- shows how to exploit semidefinite programming to jointly design and analyze online Frank–Wolfe-type algorithms numerically in a variety of settings,
- leverage those design techniques to propose an improved (optimized) variant of an online Frank–Wolfe algorithm along with its conceptually simple potential-based proof, and
- its anytime version which benefits from similar $O(T^{3/4})$ regret rate without requiring to know the time horizon T in advance.

We are not aware of other direct regret guarantees for anytime version of online Frank–Wolfe without using the classical doubling trick.

Based on the semidefinite technique, we conclude with strong numerical evidence suggesting that no pure online Frank–Wolfe algorithm within our model class can have a regret guarantee better than $O(T^{3/4})$ without additional assumptions, that the current algorithms do not have optimal constants, and that multiple linear optimization rounds do not generally help to obtain better regret bounds.

Session

Stabilization and Controlability of PDEs

Room: Amphi Cauchy

Timeslot: Tuesday, March 3, 9:00 AM - 10:30 AM

Chaired by TBA

1. Geometric observability estimates for abstract heat equations

Speaker: Vincent Boulard

Affiliation: École nationale des ponts et chaussées – Institut Polytechnique de Paris – France

Keywords: Observability inequality, subRiemannian Geometry, Riemannian Geometry, Heat equation

Abstract: We answer a long-standing open question posed by Ervedoza and Zuazua concerning a geometric bound on the exponential rate in infinite time integrated observability inequalities for heat equations. Our work establishes this geometric bound in a general abstract setting encompassing a wide variety of operators, including hypoelliptic Laplacians on sub-Riemannian manifolds. The result follows from a unified framework combining finite-speed propagation principles, local spectral asymptotics, and ultracontractivity estimates, providing a comprehensive understanding of sharp observability across diverse geometric contexts.

2. Lyapunov functions and stability of linear two-dimensional hyperbolic systems

Speaker: Yubo Bai

Affiliation: Centre d'Enseignement et de Recherche en Mathématiques et Calcul Scientifique – Ecole Nationale des Ponts et Chaussées – France

Co-authors: Amaury Hayat

Keywords: multi, dimensional hyperbolic systems, Lyapunov functions, stability

Abstract: We study the boundary stability and stabilization of two-dimensional linear hyperbolic systems. In contrast with the 1d case, in multi-dimensional hyperbolic systems, a quadratic Lyapunov function for the L^2 norm is usually a weighted L^2 norm, with weights that must be uniform across all components. Applying such Lyapunov functions to prove stability requires that the system itself already possess a good internal structure. We demonstrate that this limitation can be overcome by considering quadratic Lyapunov functions for higher norm, such as H^1 norm, thereby opening up the possibility of finding quadratic Lyapunov functions for systems that do not satisfy a dissipative structure. We successfully construct a quadratic Lyapunov function for the H^1 norm

for a concrete example, confirming the feasibility of our approach. Furthermore, we can use the aforementioned quadratic Lyapunov function for the H^1 norm to construct a Lyapunov function for the L^2 norm, thereby establishing L^2 stability for such systems.

3. Small-time controllability of Liouville transport equation along a Hamiltonian field

Speaker: Bettina Kazandjian

Affiliation: Laboratoire Jacques-Louis Lions – Sorbonne Université, Centre National de la Recherche Scientifique, Université Paris Cité – France

Co-authors: Eugenio Pozzoli, Mario Sigalotti

Keywords: Group of Hamiltonian diffeomorphisms, controllability, Liouville transport equation

Abstract: In the paper, we investigate the approximate controllability of Liouville transport equations associated with mechanical Hamiltonian vector fields. Admissible trajectories stay in the orbit generated by Hamiltonian diffeomorphisms of the cotangent bundle, and approximately reachable densities are therefore constrained to the closure of this orbit in the L^r topology.
Our first result gives a complete characterization of the closure of this orbit when the base manifold is the Euclidean space or the torus: it coincides with the set of densities having the same measure of level sets as the initial density. This can be seen as an approximate counterpart, in the Hamiltonian setting, of a classical theorem by J. Moser on volume-preserving diffeomorphisms.
We also present examples in the Euclidean space and in the torus showing that, in small time, the Liouville transport equation is approximately controllable.

Session

Stochastic processes and particle systems II

Room: B 202

Timeslot: Tuesday, March 3, 9:00 AM - 10:30 AM

Chaired by TBA

1. Quantitative convergence of observables for stochastic coalescence with a singular kernel

Speaker: Sebastian Baudelet

Affiliation: Centre Inria de Saclay, LIFEWARE – Institut National de Recherche en Informatique et en Automatique – France

Keywords: Particle systems, Hydrodynamic limits, Convergence rates, Optimal transport

Abstract: Coagulation, or coalescence, describes the aggregation of particles and is used to model phenomena such as aerosols, droplet formation, protein aggregation, and other similar systems. The Smoluchowski Coagulation Equation (SCE) describes the macroscopic evolution of particle systems undergoing binary coalescence at a rate given by a kernel K(x,y), where x and y denote the masses of the coalescing particles. It arises as the limit of a stochastic coalescence process when the number of particles tends to infinity. While this convergence is well understood in many classical settings, obtaining explicit rates remains a challenging problem especially for singular kernels.

We focus on singular kernels of the form $K_\alpha(x, y) = x^{-\alpha} + y^{-\alpha}$, with $\alpha > 0$, a case not addressed by most existing analyses. We establish an explicit $O(1/N)$ convergence rate at the level of expectations for a broad class of observables, understood as functionals of the empirical measure. These results improve upon the classical $O(N^{-1/2})$ pathwise bounds, quantifying the bias of the stochastic process.

The proof uses ideas from optimal transport, including derivatives of functionals on spaces of measures and Wasserstein-type distances adapted to the singular behavior of the kernel.

2. On a stochastic Cucker-Smale model of interacting particles with friction and confining potential.

Speaker: Hetranso Ahni

Affiliation: Université Jean Monnet - Faculté des Sciences et Techniques – Université Jean Monnet - Saint-Etienne – France

Keywords: Cucker, Smale, Emerging phenomena, Velocities alignment, Agglomeration, Lyapounov, Stochastic analysis

Abstract: In this talk, we study a *Cucker-Smale* model type stochastic process. Such processes are used for modelling collective behaviours in biological systems such as schooling of fish or swarming of bees, and more generally social systems. In our setting, it corresponds to kinetic interacting particles system with *friction, confinement and noisy environment*. We will show how the structure of the system leads to emerging phenomena such as *agglomeration and velocities alignment*. To that end, we introduce a suitable *random Lyaponouv function* which allows us to exhibit explicit conditions on the intensity of the noises leading to such emerging phenomena. We will also illustrate our findings with numerical simulations.

3. Skew and reflected dynamics appearing as the scaling limit of discrete systems

Speaker: Thomas Le Guerch

Affiliation: LPSM, Sorbonne Université

Keywords: skew Brownian motion ; random walks ; Stochastic PDE ;

Abstract: The skew Brownian motion is a Markov process which is essentially symmetric except that it behaves non-symmetrically at 0. It appears as the scaling limit of the random walk with a local asymmetry at 0 which persists in the limit. I will then introduce the spacetime counterpart of the skew Brownian motion, the skew stochastic heat equation. This equation is very singular and it is remarkable that it should indeed be meaningful. I would like to convince the audience that this equation is natural, by mentioning two results which I am currently working on with C. Labbé and L. Zambotti. I will assume no more than basic knowledge of random walks and PDEs, and I will avoid stochastic calculus entirely.

Session

Quantum

Room: B 05

Timeslot: Tuesday, March 3, 9:00 AM - 10:30 AM

Chaired by TBA

1. High-order method for Brillouin zone integration

Speaker: Ewen Lallinec

Affiliation: Laboratoire de Mathématiques d'Orsay – Université Paris-Saclay, Centre National de la Recherche Scientifique, Centre National de la Recherche Scientifique : UMR8628 – France

Co-authors: Antoine Levitt

Keywords: Brillouin zone Integration, Electronic Structure, High Order Methods, Complex Analysis

Abstract: The Brillouin Complex Deformation (BCD) method offers near–machine-precision computation of electronic densities of states (DOS) in periodic systems. In this talk, we highlight its performance across one-, two-, and three-dimensional models, and discuss the specific conditions under which it can fail-namely, near isolated band crossings at non–van Hove energies, where the DOS may be locally underestimated. We introduce a simple and inexpensive diagnostic based on the sign of the imaginary part of the deformed Hamiltonian spectrum to identify these cases. By comparing BCD with standard methods such as the Periodic Trapezoidal Rule, Linear Tetrahedron, and Iterative Adaptive Integration, we provide practical guidance for using BCD effectively, maximizing accuracy while avoiding pitfalls in challenging regions of the electronic spectrum.

2. Adaptive mesh refinement quantum algorithm for Maxwell's equations

Speaker: Elise Fressart

Affiliation: cortAIx Labs – Thales Research and Technology, Palaiseau, France. – France ; Centre de Mathématiques Appliquées - Ecole Polytechnique – Ecole Polytechnique, Centre National de la Recherche Scientifique, Centre National de la Recherche Scientifique : UMR7641 – France

Keywords: Quantum computing, Finite element method, Adaptive mesh refinement, Maxwell's equations

Abstract: Simulations of partial differential equations on classical computers can be computationally expensive. Resources can be allocated more efficiently using adaptive schemes. Quantum computers hold promise for inverting linear systems. The question that we address is whether quantum computers could be used in the adaptive framework. In this talk, I will introduce some

tools from quantum computing and present a quantum algorithm for adaptive mesh refinement applied to time harmonic Maxwell's equations.

3. Quantum Approaches to Path Exploration in De Novo Genome Assembly

Speaker: Jui-Ting Lu

Affiliation: LORIA – LORIA Nancy - CNRS, LORIA Nancy - CNRS : Université de Lorraine – France

Co-authors: Jean-Paul G. Adogbo

Keywords: Quantum computing, QAOA, Pathfinding

Abstract: Metagenomic analysis of the microbial dark matter (organisms lacking reference genomes) relies on de novo assembly. We propose a quantum approach that transforms bidirected compressed De Bruijn graphs into directed graphs and formulates the assembly problem as a Quadratic Unconstrained Binary Optimization (QUBO) task, solvable via the Quantum Approximate Optimization Algorithm (QAOA). Using real viral metagenomic data on the quantum emulator, we show that QAOA can identify valid assembly paths in small-scale graphs. This study demonstrates a proof of concept for quantum-enhanced de novo assembly, highlighting both the potential and current limitations of QAOA, while paving the way toward scalable quantum-driven genome reconstruction.

11:00 AM - 12:30 PM

Session

PDEs for fluid dynamics

Room: B 102

Timeslot: Tuesday, March 3, 11:00 AM - 12:30 PM

Chaired by TBA

1. Well-posedness of the stratified Euler equations

Speaker: Théo Fradin

Affiliation: Université de Bordeaux – CNRS : UMR Institut de Mathématiques de Bordeaux, CNRS – France

Keywords: Ocean, well, posedness, Euler equations, density variations

Abstract: The dynamics of the ocean can be described by the incompressible Euler equations, completed by a transport equation on the density. For large-scale dynamics, the ocean is assumed stratified, meaning that it is layered by sheets of constant density, namely isopycnals. The aim of this talk is to present the study of perturbations around shear flows, which are natural equilibria of this system.

2. Path-connectedness for the incompressible Euler equations

Speaker: Philippe Anjolras

Affiliation: Laboratoire de Mathématiques d'Orsay – Université Paris-Saclay – France

Keywords: fluid mechanics, convex integration, stability, Euler equations

Abstract: We study the incompressible Euler equations, modeling the movement of a perfect incompressible fluid, under the viewpoint of convex integration. We show that the set of weak solutions of regularity $C_t^0 L_x^2$ is path-connected for the strong topology of this space, by extending the seminal construction of De Lellis and Székelyhidi (Ann of Math (2) 170:1417-1436, 2009) to a broader geometric framework.

3. On the analysis and numerical solving of a fluid-structure toy problem.

Speaker: Sagbo Mélain Zinsou

Affiliation: Mathématiques Appliquées Paris 5 – Institut National des Sciences Mathématiques et de leurs Interactions - CNRS Mathématiques, Centre National de la Recherche Scientifique, Université Paris Cité – France

Keywords: Fluid, structure interaction problem, physiological flows, Stokes equations, well, posedness, simulations

Abstract: Fluid–structure interaction problems appear in many fields, for instance in the study of physiological flows, such as airflow in deformable bronchi or blood flow in arteries. In this work, we focus on a simplified "toy" fluid–structure interaction problem. We consider the flow of an incompressible, viscous, Newtonian, and homogeneous fluid, described by the Stokes equations, evolving in a domain where one wall is mobile. The motion of this wall is governed by a spring and by the hydrodynamic force exerted by the fluid.
The aim of this talk is to present the modeling of this phenomenon, as well as some theoretical (equilibrium position, stability, invariance, well-posedness, etc) and numerical results (discretization approaches, simulations, etc.) related to this problem. We will also present a set of open questions and future research directions.
This work has been performed in collaboration with Sébastien Martin and Marcela Szopos (MAP5, Université Paris Cité) and Stéphanie Salmon (LMR, Université de Reims Champagne-Ardenne).

Session

Geometric Learning

Room: B 103

Timeslot: Tuesday, March 3, 11:00 AM - 12:30 PM

Chaired by TBA

1. The geometry of neural networks: a Riemannian foliation perspective on robustness.

Speaker: Eliot Tron

Affiliation: Statistique, Analyse et Modélisation Multidisciplinaire (SAmos-Marin Mersenne) – Université Paris 1 Panthéon-Sorbonne – France

Keywords: Neural network, Robustness, Riemannian Foliation, Active Learning, Fisher Information

Abstract: In this presentation, we employ the tools of geometry and statistics to shed light on the relationship between data and neural network predictions. In particular, we draw inspiration from the field of information geometry which combines precisely these two approaches. We interpret the neural network's output as the parameter of a probability distribution. By using the Data Information Matrix (DIM), a variation of the Fisher Information Matrix (FIM), we investigate the network's input/output relationship and reveal its understanding of the data structure. This statistical framework yields a (degenerate) Riemannian metric that we use to analyze the geometry of the data. In particular, we lean on a foliation arising from the kernel of the DIM to conduct our study of the low-dimensional data in the high-dimensional input space.
I will present some applications of this framework among robustness, active learning, explainable AI, etc.

2. Natural gradient descent with momentum for physics informed learning

Speaker: Agustin Somacal

Affiliation: Nantes Université – Laboratoire de Mathématiques Jean Leray – France ; Ecole Central de Nantes – Ecole Central de Nantes – France

Keywords: Physics informed learning, Optimization, Natural gradient

Abstract: Natural gradient descent (NGD) recently received a lot of attention for approximating functions in nonlinear manifolds (1). NGD can be seen as a preconditioned update where parameter changes are driven by a functional perspective (2). In a spirit similar to a second order (or Newton's) method, the NGD update uses, instead of the Hessian, the Gram matrix of the generating

system of the tangent space to the approximation manifold at the current iterate, with respect to a suitable metric (3). Although the assemblage and inversion of the Gram matrix is prohibitively expensive in the context of big machine learning models, it becomes not only feasible but necessary when we look at scientific machine learning problems (4) not requiring as many parameters. For example when searching for the solution of a parametric partial differential equation (pPDE) by solving the forward (given parameters) or inverse (given measurements) problems using Physics Informed Neural Networks (PINNs) traditional ubiquitous solvers like Adam or L-BFGS do not yield reliable solutions or they take too long to converge (5). However, taking the natural gradient perspective allows us to reinterpret gradient descent as a projection of the functional gradient into the tangent space of the approximation manifold obtaining great improvements. That being said, both gradient and natural gradient descent will still get stuck at any local minima. Furthermore, when the loss function is other than the L2 distance (for example when minimising the residual of a pPDE as in PINNs) even the natural gradient might yield non-optimal directions at each step. We will first focus on how we can tackle these situations by introducing a Natural version of classical inertial dynamic methods like Nestorov (6) or heavy-ball (7) and second we will show how this strategy can be used to improve the optimization of PINNs.

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3. Complexity guarantees and polling strategies for Riemannian direct-search methods

Speaker: Bastien Cavarretta

Affiliation: Laboratoire dánalyse et modélisation de systèmes pour láide à la décision – Université Paris Dauphine-PSL – France

Co-authors: Clément W. Royer, Florentin Goyens, Florian Yger

Keywords: derivative, free optimization, positive spanning set, Riemannian optimization

Abstract: Direct-search algorithms are derivative-free optimization techniques that operate by polling the variable space along specific directions forming positive spanning sets (PSSs). When the problem variables are constrained to lie on a Riemannian manifold, polling must be performed along tangent directions. Although Riemannian variants of direct search have already been proposed and endowed with asymptotic guarantees, a proper generalization of PSSs on manifolds remains to be investigated. In particular, a measure of quality for those PSSs is required to obtain complexity bounds for direct search.In this paper, we derive complexity guarantees for a class of Riemannian direct-search techniques, and study two ways of generating positive spanning sets in tangent spaces. We pay particular attention the unit hypersphere case, for which we establish that generating directions directly within the tangent space leads to better complexity properties than projecting PSSs from the ambient space onto the tangent space. Our numerical experiments highlight the impact of dimension and codimension in more general settings.

Session

Analysis of nonlinear PDEs

Room: B 202

Timeslot: Tuesday, March 3, 11:00 AM - 12:30 PM

Chaired by TBA

1. Computer-Assisted Proofs for PDEs on unbounded domains

Speaker: Matthieu Cadiot

Affiliation: Centre de Mathématiques Appliquées de l'Ecole polytechnique – Institut National de Recherche en Informatique et en Automatique, Ecole Polytechnique, Centre National de la Recherche Scientifique – France

Keywords: PDE, Computer, Assisted, Unbounded Domain, Localized Solutions

Abstract: In this talk I will present a computer-assisted methodology for constructively proving the existence of localized solutions for PDEs posed on $\mathbb{R}^m$. Using a Fourier series approximation u0 on a large hypercube, we develop a Newton-Kantorovich approach for proving the existence of a true solution of the PDE in a vicinity of u0. The existence proof being constructive, we are also able to control the spectrum of the linearized operator around the profile, and conclude about stability. Applications to the Swift-Hohenberg PDE and to the Gray-Scott model will be presented.

2. Classification of entire and ancient solutions of the diffusive Hamilton-Jacobi equation

Speaker: Loth Damagui Chabi

Affiliation: Laboratoire Analyse, Géométrie et Applications – Université Sorbonne Paris nord, Université Sorbonne Paris nord : UMR7539 – France

Co-authors: Philippe Souplet

Keywords: Diffusive Hamilton, Jacobi equation, Liouville, type theorem, entire and ancient solutions

Abstract: Consider the diffusive Hamilton-Jacobi equation

$$u_t - \Delta u = |\nabla u|^p \tag{E}$$

with $p > 1$ and Dirichlet conditions, which arises in stochastic control as well as in KPZ type models of surface growth. It is known that, for $p > 2$ and suitably large, smooth initial data, the solution

undergoes finite time gradient blowup on the boundary. On the other hand, Liouville type rigidity or classification properties play a central role in the study of qualitative behavior in nonlinear elliptic and parabolic problems, and notably appear in the famous Berestycki-Caffarelli-Nirenberg conjecture about one-dimensionality of solutions in a half-space. With this motivation, we study the Liouville type classification and symmetry properties for entire and ancient solutions of (E) in $\mathbb{R}^n$ and in a half-space with Dirichlet boundary conditions. First, we show that any ancient solution in $\mathbb{R}^n$ with sublinear upper growth at infinity is necessarily constant. This result is *optimal*, in view of explicit examples of entire solutions, and solves a long standing open problem. Then we turn to the half-space problem, which is largely unexplored. For $p > 2$, we completely classify entire solutions in a half-space: any entire solution is stationary and one-dimensional. The assumption $p > 2$ is sharp, in view of explicit examples for $p = 2$.

3. TBA

Speaker: TBA

Affiliation: TBA

Keywords: TBA

Abstract: TBA

Session

Stochastic processes and particle systems III

Room: B 05

Timeslot: Tuesday, March 3, 11:00 AM - 12:30 PM

Chaired by TBA

1. Modelling horizontal gene transfer : scaling-limit and ancestral lineage

Speaker: Mateo Deangeli Bravo

Affiliation: Centre de Mathématiques Appliquées de l'Ecole polytechnique – Ecole Polytechnique, European Research Council – France

Keywords: Probabilités, Maths pour la Bio, Intégrodifférentielle, Décomposition spinale, Processus de Markov, Renversement, Transfert horizontal, Plasmides

Abstract: Horizontal gene transfer (HGT) enables rapid genomic diversification in bacteria by transferring genetic material independently of reproduction. Conjugation, often mediated by plasmids, can confer advantages (e.g., antibiotic resistance) but imposes fitness costs. The work focuses on plasmid conjugation to answer two questions: can bacteria survive despite the cost of plasmids, and what are the origins of the bacteria observed today? We use a Markovian process to model a population of bacteria characterized by a trait in $X \subset \mathbb{R}$, evolving through birth, death, competition, mutation and trait transfer (horizontal transfer). To answer the first question, we study analytically and numerically the integro-differential equation (and the existence of stationary profiles) obtained by taking the large population limit of the Markovian population process. To answer the second question, we characterize the random process giving the ancestral lineages in the population, i.e. the time reversal of the spinal decomposition of the population process.

2. Convergence of individual-based models in population dynamics to Hamilton-Jacobi equations

Speaker: Anouar Jeddi

Affiliation: CMAP-École Polytechnique – pas de tutelle, pas de tutelle – France

Keywords: Branching process, Hamilton, Jacobi equations, population dynamics

Abstract: We investigate the asymptotic behavior of individual-based models describing the evolution of a population structured by a real trait and subject to selection and mutation. In a regime combining large population size, small mutations, and long time scales, we prove that the logarithmic scaling of subpopulation sizes converges to the viscosity solution of a Hamilton–Jacobi

equation.

3. Metastability between the clicks of the Muller ratchet

Speaker: Aurélien Velleret

Affiliation: LaMME, Université d'Evry

Keywords: Optimal control; Trajectory optimization; Low Earth Orbit; Indirect methods

Abstract: The Muller ratchet model was introduced in theoretical ecology over 40 years ago to represent the counter-selection of deleterious mutations. More specifically, the aim has been to quantify the effectiveness with which natural selection prevents the fixation and accumulation of deleterious mutations through a purely asexual mode of reproduction. Unlike in the sexual case, deleterious mutations can only be purged with the extinction of the lineages that carry them. As a simplification, all mutations are assumed to be deleterious and to have the same effect. The population size is fixed. The average reproduction rate of an individual is given as a function solely of the number of mutations it carries, which is compared to the average reproduction rate of other individuals. Due to uniform genetic variability, it is inevitable that the subpopulation of individuals with the optimal phenotype, i.e., without mutations, will disappear irreversibly. We focus more specifically on the case where the distribution of mutations within the population stabilizes between each of these disappearances (with each time a translation of the profile by one additional mutation). This justifies the name "ratchet" given to this model, in reference to those cogwheels that can only move in one direction with punctual transitions between successive equilibria. The rigorous justification of these quasi-equilibria, punctuated by these random events of transition, will be the subject of my presentation. This justification is particularly delicate in the most refined version of the model, where the associated stochastic process is a diffusion on an infinite-dimensional domain.

Joint work with Etienne Pardoux and Mauro Mariani (PTRF 2025)

Session

Optimal control and numerical methods

Room: Amphi Cauchy

Timeslot: Tuesday, March 3, 11:00 AM - 12:30 PM

Chaired by TBA

1. Control of Collision Orbits

Speaker: Riccardo Daluiso

Affiliation: Laboratoire Jean Alexandre Dieudonné – Université Nice Sophia Antipolis (1965 - 2019), Centre National de la Recherche Scientifique, Université Côte d'Azur – France ; Mathematics for Control, Transport and Applications – Centre Inria d'Université Côte d'Azur – France

Co-authors: Jean-Baptiste Caillau, Alain Albouy

Keywords: Control, Regularization, Collision, min, time, Kepler

Abstract: In the n-body problem, the forces acting between particles approach infinity when the mutual distances approach zero. Therefore, at collision the dynamics has singularities. Since Levi-Civita and Sundman, the double collision has been regularized, i.e. the singularity has been made to disappear by means of algebraic transformations. Levi-Civita obtained first a regularizing transformation of the Kepler problem based on the inverse of the map $z \to z^2$ of the complex plane. This conformal map sends the orbits of the harmonic oscillator in the ones of the Kepler problem. The coordinates transformation is coupled with a slowing down of the motion by means of a time change defined by the differential relation $d\tau = 1/|z|dt$. Based on classical results, the purpose of the work is the application of the regularization theory to optimal control. We consider the control of a spacecraft under the attraction of a celestial body, where the control is the thrust, and with the goal of minimizing the physical time. This system exhibits singularities in zero, and thus the theory fails in the study of collision orbits. By applying the Levi-Civita regularization to the controlled system, we obtain an affine system in the new time τ where the vector fields are polynomials, thus C_ω . In the reparametrized system, we can broaden the concept of controllability at collision, and apply Pontryagin's principle by allowing orbits that collide or come arbitrarily close to the center of attraction. The extension of the procedure in three dimensions is not straightforward, as it encounters algebraic and topological obstructions. We will investigate other regularizations to overcome this issue.

2. Mathematical approaches for assisting in the management of eutrophic lakes

Speaker: Ioana Chiru

Affiliation: Laboratoire d'ingénierie pour les systèmes complexes – Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement – France

Keywords: Partial Differential Equations, Optimal Control, Lake Eutrophication, Finite Element Method

Abstract: Lake eutrophication results from water's enrichment by nutrients (mostly phosphorus in freshwater) causing an excessive proliferation of aquatic plants, algaes or cyanobacterias. This phenomena has two main impacts : one ecological and one sanitary. On one hand, eutrophication can lead to a body of water devoided of oxygen, and so of life and on the other hand, some species of cyanobacterias can be toxic for humans.
To model this phenomena, we use an optimal control problem (P0) depending on a partial differential equation state system (M), with phosphorus concentration P as the control variable. The definition of the problem (P0), its well-posedness and the existence of a global solution for the optimal control problem, from (1), pave the way to a numerical approximation of its solution.

With this aim in mind, we started by defining the adjoint problem of the state model (M) on which we proved a result of existence of a solution using the Schauder fixed-point theorem.
We also discuss ongoing work on the implementation of a finite element method for the numerical resolution of the state system (M) and its adjoint.
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3. Stabilization of Semi-Discrete PDEs by Means of Discontinuous Feedback Laws

Speaker: Yunus Lesport

Affiliation: Laboratoire des Sciences du Numérique de Nantes (LS2N), Université de Nantes

Keywords: Infinite-dimensional systems, control theory, PDEs, Stabilization, Numerical analysis

Abstract: It is well known that numerical discretizations of PDE models do not, in general, preserve the controllability and stability properties that hold in the continuous setting. This issue is already extremely challenging in the absence of disturbances and becomes even more delicate when disturbances act on thesystem,eitherinsidethe spatial domain or throughthe boundary. In this talk, I will first introduce a general approach to the space semi-discretization of linear time- invariant infinite-dimensional control systems and briefly discuss the main difficulties encountered when studying the stabilizability of the resulting discrete systems, illustrating them with classical examples. I will then consider the case where the system is additionally subject to disturbances and show how techniques originating from finite-dimensional control theory can be used to stabilize both continuous PDEs and their spatial semi-discretization by means of discontinuous feedback laws.

4:00 PM - 5:30 PM

Session

Control in population dynamics

Room: B 102

Timeslot: Tuesday, March 3, 4:00 PM - 5:30 PM

Chaired by TBA

1. Optimal Dirac controls for time-periodic bistable ODEs, application to population replacement

Speaker: David Nahmani

Affiliation: Laboratoire Analyse, Géométrie et Applications – Université Sorbonne Paris nord, Université Sorbonne Paris nord : UMR7539 – France

Co-authors: Grégoire Nadin, Nicolas Vauchelet

Keywords: optimal control, optimization, bistable differential equation, time, periodic differential equation, ODE, Wolbachia, population replacement

Abstract: This presentation addresses an optimal control problem on a dynamics governed by a nonlinear differential equation with a bistable time-periodic nonlinearity. This problem, relevant in population dynamics, models the strategy of replacing a population of A-type individuals by a population of B-type individuals in a time-varying environment, the control term standing for the instant release of B-type individuals.
After underlining some interesting properties of the dynamical system, we will dive into the quest of the optimal time at which this release should be operated to guarantee population replacement while minimizing the release effort.
An application to the biocontrol of mosquito populations using Wolbachia-infected individuals illustrates the relevance of the theoretical study. Wolbachia is a bacterium that helps preventing the transmission of some viruses from mosquitoes to humans, making the optimization of Wolbachia propagation in a mosquito population a crucial issue.

2. Reducing Recurrent Competitive Epidemics via Dynamic Resource Allocation

Speaker: Gaspard Abel

Affiliation: CB - Centre Borelli - UMR 9010 – Service de Santé des Armées, Institut National de la Santé et de la Recherche Médicale, Université Paris-Saclay, Centre National de la Recherche Scientifique, Ecole Normale Supérieure Paris-Saclay, Université Paris Cité, Centre National de la Recherche Scientifique : UMR9010 – France ; Centre d'Analyse et de Mathématique sociales – École des Hautes Études en Sciences Sociales, Centre National de la Recherche Scientifique, Centre National de la Recherche Scientifique : UMR8557 – France

Co-authors: Argyris Kalogeratos, Sarao Mannelli Stefano

Keywords: Competitive spreading processes, social contagions, behavioral epidemics, epidemic modeling, agent, based models, epidemic control, dynamic resource allocation, contact networks

Abstract: Motivated by scenarios of epidemic competition, as well as how social contagions spread at the level of individuals, this work considers the competition between two conflicting node states that spread over a social graph according to a generic diffusion process. For this setting, we introduce the *Generalized Largest Reduction in Infectious Edges* (gLRIE), which is a dynamic resource allocation strategy that favors the preferred state against the other. Our analysis assumes a generic continuous-time SIS-like (*Susceptible-Infectious-Susceptible*) diffusion model that allows for: arbitrary node transition rate functions for nodes to change state, and competition between the healthy (positive) and infected (negative) states, which are both diffusive at the same time, yet mutually exclusive at each node. The strategy follows a *minimum-risk-maximum-gain* principle, and its features are particularly relevant for social contagion phenomena. In accordance with the LRIE strategy that we generalize, we show that in this context the gLRIE strategy remains a greedy solution for the minimization of the number of infected network nodes over time. Ultimately, simulations are employed to compare the proposed strategy with other existing alternatives, demonstrating that gLRIE exhibits superior performance across a spectrum of scenarios, including a realistic counter-contagion campaign in a small well-monitored community.

3. Optimal spatial control strategies for pest/vector elimination by the Sterile Insect Technique in n-patch systems.

Speaker: Manon De La Tousche

Affiliation: Compréhension mathématique multi-échelles d'écosystèmes vivants complexes avec structures émergentes – Centre Inria de Paris, Laboratoire Jacques-Louis Lions – France ; Botanique et Modélisation de l'Architecture des Plantes et des Végétations – Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Centre National de la Recherche Scientifique, Institut de Recherche pour le Développement, Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement, Université de Montpellier – France

Co-authors: Pierre-Alexandre Bliman, Dumont Yves

Keywords: Metapopulation, Cooperative Systems, Monotone systems, Sterile Insect Technique, Dynamical systems, Graph theory

Abstract: The sterile insect technique (SIT) is a biological control method to suppress or eliminate populations of agricultural pests or disease vectors by releasing sterilised males, which compete with wild males for mating. Eggs from females that mate with sterile males are infertile, thereby reducing the population. In the literature, most SIT models assume a homogeneous, isolated environment-an idealised scenario that rarely holds in practice.
In this study, spatial structure and environmental heterogeneity are incorporated by modelling the population as distributed across interconnected patches, using a metapopulation framework. Particular attention is given to the oriental fruit fly, a major pest affecting mango orchards in La Réunion.

Using results from the theory of monotone cooperative systems, a sufficient condition for the elimination of the wild population through SIT is derived. This condition relies on the sign of the Perron value of a Metzler matrix incorporating local growth parameters and the dispersal graph. An optimisation problem is then formulated, allowing to minimise the total daily release of sterile insects sufficient to ensure elimination. By exploiting the convexity properties of the Perron value of a Metzler matrix with respect to its diagonal entries, this optimisation problem is shown to be convex.

Numerical simulations illustrate the theoretical results and explore various scenarios. In particular, practical constraints related to manpower and cost prevent the release of sterile males in every patch. Consequently, assuming that releases can be carried out in only a fixed number of patches, an algorithm is proposed that, given the structure of the underlying insect dispersal graph, determines the optimal combination of release patches.

Session

Scientific Machine learning for PDEs

Room: Amphi Cauchy

Timeslot: Tuesday, March 3, 4:00 PM - 5:30 PM

Chaired by TBA

1. Deep Ritz Neural Operators for Phase-field models via energy splitting

Speaker: Chih-Kang Huang

Affiliation: Centre Inria d'Université Côte d'Azur – Université Côte d'Azur, Inria, CNRS, LJAD – France

Co-authors: Ludovick Gagnon, Miha Založnik, Benoît Appolaire

Keywords: Physics Informed Machine Learning, Phase field modelization, Numerical approximation

Abstract: We propose a new neural operator approach that bridges classical convex-concave splitting schemes with physics-informed learning to accelerate the simulation of phase-field models. By training the neural operator with an energy-splitting variational formulation, we enforce the energy dissipation property of the underlying models.

We further introduce a custom Reaction-Diffusion Neural Operator (RDNO), an architecture specifically designed to incorporate the operator-splitting of diffusion and reaction terms in the model equation. In the case of the Allen-Cahn equation and anisotropic dendritic growth simulation, we show that our approach gives better out-of-distribution generalization and higher accuracy than standard FNOs or U-Nets, while achieving faster inference than traditional Fourier spectral methods.

This is joint work with Ludovick Gagnon (Centre Inria d'Université de Lorraine), Miha Založnik (Institut Jean Lamour) and Benoît Appolaire (Institut Jean Lamour) from Université de Lorraine

2. Random sketching of operators and application to learning preconditioners for model order reduction

Speaker: Alexandre Pasco

Affiliation: Nantes Université - École Centrale de Nantes – Nantes Université – France ; Laboratoire de Mathématiques Jean Leray – Centre National de la Recherche Scientifique, Nantes université - UFR des Sciences et des Techniques – France

Co-authors: Oleg Balabanov, Anthony Nouy

Keywords: Random sketching, subspace embedding, Hilbert, Schmidt operators, model order reduction, preconditioner, reduced basis, error estimation.

Abstract: We propose a random sketching approach for embedding high-dimensional Hilbert-Schmidt operators, given input-output pairs.
The new random embedding we propose is composed of three arbitrary classical random embeddings, and inherits their oblivious subspace embedding property.
We apply our sketching approach to construct parameter-dependent preconditioners for projection-based model reduction of high-dimensional parameter-dependent linear equations.
Given a reduced space, we introduce seminorms tailored to the reduced space to assert the quality of a preconditioner.
This model reduction oriented settings allows us to accurately approximate operator seminorms, which are very challenging to optimize, by Hilbert-Schmidt seminorms, which are better suited to optimization especially with our random sketching approach.
These new quantities allow us to bound the quasi-optimality error of the preconditioned Galerkin projection as well as the accuracy of a preconditioned residual-based error estimator.
Additionally, when the terms of the initial problem are parameter separable, our sketching approach yields an efficient and robust to round-off errors offline-online decomposition of all the quantities we introduced.
We illustrate our approach on an acoustic wave scattering partial differential equation in 2D.

3. Mathematical and numerical analysis of the robustness of Data-Driven Identification method

Speaker: Nour Hachem

Affiliation: Institut de recherche en génie civil et mécanique – Nantes Université, Ecole Centrale Nantes, CNRS, GeM, UMR 6183, F-44000 Nantes, France – France

Co-authors: Adrien Leygue, Laurent Stainier

Keywords: Data Driven methods, Identification, Inverse problem, Alternating projection

Abstract: The Data-Driven Identification (DDI) method introduced by Leygue *et al.* (2018) aims to estimate the mechanical response of materials without relying on a predefined constitutive model *a priori*. The main output of DDI is the stress field identified from full-field kinematic measure-

ments and load cell measurements, with the intuition that similar strain values should yield similar stress values. Given the displacement and strain fields, DDI solves an inverse problem based on the principle that clustered strain should yield similar stress, while the latter should at the same time verify mechanical balance equilibrium. Despite the method promising potential for various material behaviors, a rigorous theoretical study assessing its accuracy and convergence toward the true mechanical stress was missing. Consequently, this method relies on algorithmic parameters that are often chosen empirically, which may affect its robustness. In this work, we investigate numerically and algorithmically the preliminary work of Leygue (2024), where a criterion for the uniqueness of the solution was introduced and an error estimate for the identified stress. We first propose an efficient method based on alternating projection for numerically characterizing this criterion. Additionally, a new implementation strategy based on this method is introduced along with a proof of its convergence. This study will help us in the selection of the parameters for DDI. As the DDI parameters are pushed to gain accuracy, the DDI becomes ill-posed. However, it is possible to detect and correct the stress estimate in this case. This can be done through additional non-invasive regularization or through the detection of the few degrees of liberty responsible for the loss of uniqueness.

Session

Numerical analysis for PDE

Room: B 103

Timeslot: Tuesday, March 3, 4:00 PM - 5:30 PM

Chaired by TBA

1. Singular Expansions at Dirichlet–Neumann Junctions for Efficient Computation

Speaker: Audrey Gossard

Affiliation: Laboratoire de Mathématiques Jean Leray – Centre National de la Recherche Scientifique, Nantes université - UFR des Sciences et des Techniques – France ; Centre Inria de l'Université de Rennes – Institut National de Recherche en Informatique et en Automatique – France

Co-authors: Annabelle Collin, Clair Poignard

Keywords: Finite element method, Dirichlet–Neumann junction, Boundary singularities, Asymptotic expansion, Electrode modeling

Abstract: Micro-scale bioimpedance measurements lead to elliptic boundary value problems with mixed boundary conditions, where electrodes impose Dirichlet conditions and the remaining boundary is insulated by Neumann conditions. While finite element methods can approximate the global electric potential accurately, the evaluation of boundary gradients, and hence impedance-related quantities, remains difficult due to the singular behavior induced at Dirichlet–Neumann junctions. This difficulty is particularly pronounced in practical microsystems. In the device presented in (1), electrodes are 75 μm wide and arranged in a spiral geometry around a biological layer only 15 μm thick, while in (2), eight electrodes are placed on top of a 1 mm-thick medium. In both cases, the combination of microscale dimensions, mixed boundary conditions, and complex geometries leads to sharp field variations near electrode edges, making standard finite element simulations highly mesh-dependent and computationally expensive.

We propose a numerically efficient method for impedance evaluation in such configurations. Near a Dirichlet–Neumann junction located on a straight boundary, the solution admits an asymptotic expansion as the distance to the junction tends to zero. In local coordinates, the governing operator can be written as the Laplacian perturbed by a sequence of lower-order differential terms. The leading behavior is described by boundary singular functions associated with the Dirichlet–Neumann transition, while the perturbations generate additional shadow singular functions. The coefficients of the expansion are computed using the dual singular functions method (3): a low-cost finite element solution is first obtained on a coarse, non-refined mesh, and each coefficient is then extracted by integrating this solution over a small surface surrounding the junction point

against an appropriate dual singular function of corresponding order. This procedure captures the singular contributions accurately without local mesh refinement.

The method is analyzed theoretically and validated numerically on a simplified configuration with two planar micro-electrodes. In this setting, standard finite element simulations require several hundred seconds to obtain an accurate current evaluation, whereas the proposed approach achieves comparable precision in under one second. The framework naturally extends to 3D multi-electrode systems, such as those in (1, 2), where it is expected to deliver higher accuracy at significantly reduced computational cost.

(1) T. García-Sánchez et al. Interpulse multifrequency electrical impedance measurements during electroporation of adherent differentiated myotubes. Bioelectrochemistry, 2015.

(2) T. Le Berre et al. Electroporation of spheroids using an electric field gradient: a tool to study intensity-dependent permeabilization. Lab On a Chip, 2026.
(3) C. Poignard et al. Corner asymptotics of the magnetic potential in the eddy-current model. Mathematical Methods in the Applied Sciences, 2013.

2. An asymptotic preserving method for the linear transport equation on general meshes

Speaker: Pierre Anguill

Affiliation: UFR Mathématiques [Sciences] - Université Paris Cité – Université Paris Cité – France

Keywords: finite volume schemes, radiative transfer, asymptotic analysis, computational transport, monotone anisotropic diffusion, unstructured meshes

Abstract: The reference (1) presents a finite-volume scheme for a grey linear transport equation in 2D. This scheme satisfies the following properties: consistency on general meshes; conservation of energy; asymptotic preserving accuracy from free-streaming to diffusion; and flexibility in the choice of the limit diffusion scheme.
Unfortunately, this scheme is not colocated. Thus, handling boundary conditions is difficult, and positivity of the solution is not guaranteed.
Therefore, we propose a new colocated method derived from this scheme to overcome these limitations. The scheme of (1) is positive in the diffusion limit, but not in transport regime. In contrast, an upwind scheme is positive in the transport regime but is not asymptotic preserving. Hence, in the present talk, we introduce the new method whose numerical fluxes are constructed as a hybridization of those associated with these two schemes.

The resulting scheme is implicit, and in order to avoid solving a global linear system of size equal to the number of cells times the number of directions, we employ a sub-cycling strategy. Moreover, the scheme involves a nonlinear diffusion discretization operator. Consequently, sub-cycling is also used to handle the nonlinearity of the diffusion scheme. Thanks to the properties of our

diffusion scheme in 2D (2) and 3D (3), we enforce the solution to remain positive in the diffusion regime. With the hybrid fluxes, we also enforce the solution to remain positive in the free-streaming regime. We expect that an appropriate choice of the hybridization parameter will ensure positivity in all regimes.

We have conducted numerical tests on structured and unstructured 2D meshes, which assess that the expected properties are satisfied. In particular, we carried out the Lattice test problem to compare our results with existing methods, notably the Discontinuous Finite Element (DFE) and the method of (1).

(1) Anguill, P. et al., "An asymptotic preserving method for the linear transport equation on general meshes", Journal of Computational Physics, 450:110859, 2022.
(2) Blanc, X., and Labourasse, E., "A positive scheme for diffusion problems on deformed meshes", Journal of Applied Mathematics and Mechanics (Zeitschrift für Angewandte Mathematik und Mechanik), 96 (6), 2016.
(3) Anguill, P., Blanc, X., and Labourasse, E., "A monotone diffusion scheme for 3D general meshes: Application to radiation hydrodynamics in the equilibrium diffusion limit", Computers and Mathematics with Applications, 158:56-73, 2024.

3. A nonsmooth extension of the Brezzi-Rappaz-Raviart approximation theorem via metric regularity techniques

Speaker: Jules Berry

Affiliation: Laboratoire des signaux et systèmes – CentraleSupélec, Université Paris-Saclay – France

Co-authors: Olivier Ley, Francisco Silva

Keywords: theoretical numerical anaysis, metric regularity, finite element method, mean field games

Abstract: The Brezzi-Rappaz-Raviart (BRR for short) theorem can be seen as quantitative version of the inverse function theorem tailored for the numerical analysis of nonlinear PDEs. More precisely, given Banach spaces X and Y, a mapping $F\colon X \to Y$, approximations $F_h\colon X \to Y$ of F, and a solution $\bar{x} \in X$ to $F(\bar{x}) = 0$, we are interested in finding solutions $\bar{x}_h \in X$ to

$$F_h(\bar{x}_h) = 0 \tag{1}$$

and to quantify the error $\|\bar{x} - \bar{x}_h\|_X$. In its simplest form, the BRR theorem roughly states that, if the mappings F and F_h are of class C^1, with $dF[\bar{x}]$ invertible, if

$$\lim_{h \to 0} F_h(\bar{x}) = 0 \tag{2}$$

and if

$$\lim_{h \to 0} \|dF[\bar{x}] - dF_h[\bar{x}]\|_{\mathcal{L}(X,Y)} = 0, \tag{3}$$

then, for all h small enough, there exists $\bar{x}_h \in X$ solving (1) and we have the error estimate

$$\|\bar{x} - \bar{x}_h\|X \leq 2\|dF[\bar{x}]^{-1}\|\mathcal{L}(X, Y)\|F_h(\bar{x})\|_Y. \tag{4}$$

In other words, under the consistency assumption (2) and the stability assumption (3), there exists a solution to the approximate problems and the error estimate (4) is proportional to the consistency error.

We propose a generalization of this result to the case where the mappings F and F_h are merely Lipschitz continuous. In this case the condition (3) is replaced by a smallness condition on the Lipschitz constant of the difference $F - F_h$. In order to find a substitute for the invertibility of $dF[\bar{x}]$ in this nondifferentiable setting, we make use of the theory of *metrically regular mappings*, a theory that has found significant applications in the context of variational analysis as a replacement for the inverse function theorem. We also discuss applications of our result to finite element approximations of solutions to Hamilton-Jacobi equations and mean field games. Indeed, in this context, the nonlinearities are typically not smooth enough to ensure that F and F_h are of class C^1.

Session

Optimal control and Wasserstein spaces

Room: B 202

Timeslot: Tuesday, March 3, 4:00 PM - 5:30 PM

Chaired by TBA

1. The Mortensen observer on the space of probability measures

Speaker: Martin Morange

Affiliation: Analyse et Calcul d'Estimations fondées sur des connaissances physiques – Centre de Mathématiques Appliquées de l'Ecole polytechnique, Centre Inria de l'Institut Polytechnique de Paris – France

Keywords: Hamilton, Jacobi, Bellman equation, Wasserstein space, Optimal transport, Mortensen oberserver, Deterministic filtering

Abstract: In this talk, we study a deterministic filtering problem formulated directly on the Wasserstein space of probability measures with finite second moment.

To provide context, we begin by reviewing the classical Mortensen observer for finite-dimensional systems governed by ordinary differential equations. In this setting, state estimation is formulated as a deterministic optimal control problem that minimizes an energy functional involving model mismatch and observation error, leading to a value function that is a viscosity solution to a Hamilton–Jacobi–Bellman equation.

Motivated by the Mortensen observer, we consider reconstructing an evolving probability density from partial observations by minimizing an action functional combining a kinetic transport cost with a time-dependent observation criterion. The resulting value function is defined on the infinite-dimensional manifold $(\mathcal{P}_2(\mathbb{R}^d), W_2)$ and satisfies a Hamilton–Jacobi–Bellman equation for a suitable notion of viscosity solutions.

Under regularity and growth assumptions on the observation functional, we establish a dynamic programming principle, continuity of the value function, existence of minimizing trajectories, and viscosity solution properties of the associated Hamilton–Jacobi–Bellman equation. We provide two complementary notions of viscosity solutions: a geometric formulation based on subdifferentials in Wasserstein space, and a formulation inspired by Lions' Hilbertian lifting. This allows us to prove a comparison principle and uniqueness of solutions. Extensions to transport equations with drift are also discussed.

2. Sliced transport maps

Speaker: Gauthier Thurin

Affiliation: ENS - CNRS – École normale supérieure - Paris – France

Keywords: Sliced Wasserstein distance, Stochastic Gradient Descent, Smooth and Non Convex objective, Lojasiewicz inequalities

Abstract: We study measure transportation maps derived from sliced optimal transport.
The Iterative Distribution Transfer algorithm previously defined in the literature can be seen as Stochastic Gradient Descent over probability distributions, where the objective to minimize is the Sliced-Wasserstein distance with respect to some target measure.
Under smoothness assumptions, we derive Polyak-Łojaseiwicz and Kurdyka-Łojaseiwicz inequalities.
Controlling the random constants in these inequalities is key to deduce convergence rates.

3. State-Constrained Optimal Control on Wasserstein Spaces of Riemannian Manifolds

Speaker: Ernesto Treumún

Affiliation: École Nationale Supérieure de Techniques Avancées – Institut Polytechnique de Paris – France

Keywords: Optimal Control, Wasserstein Spaces, Riemannian Manifolds, Hamilton, Jacobi, State Constraints

Abstract: In this talk we study optimal control problems with state constraints in Mayer form over the Wasserstein space $\mathcal{P}_2(M)$ of a not-necessarily compact Riemannian manifold M. We focus on the Hamilton-Jacobi (HJ) equation on $\mathcal{P}_2(M)$ using the viscosity theory, proving a general comparison principle for the HJ equation, and thus establishing the uniqueness of solutions. Finally, using classical tools from optimal control theory, we prove that the value function of the state-constrained optimal control problem is a solution of a certain, but known, HJ equation. An additional result -and a cornerstone of this work- is that, under suitable curvature assumptions on the manifold M, we show that the squared Wasserstein distance is directionally differentiable.

Wednesday, March 4

9:00 AM - 10:30 AM

Session

Modeling human body

Room: B 102

Timeslot: Wednesday, March 4, 9:00 AM - 10:30 AM

Chaired by TBA

1. The human lung : an impossible-to-model organ ?

Speaker: Mabrouk Ben Jaba

Affiliation: IECL – Université de Lorraine, CNRS, IECL, Inria, F-54000 Nancy, France – France

Co-authors: Yannick Privat, Jean-Francois Scheid, Zakaria Belhachmi, Benjamin Mauroy

Keywords: modélisation, poumon, EDO, contrôle optimal

Abstract: The lung constitutes an *essential exchange interface between ambient air and blood*, playing a crucial role in the oxygenation of the latter and the elimination of carbon dioxide. Understanding its functioning therefore represents a major challenge.
Various mathematical models have been developed to study its mechanisms, some involving complex partial differential equations. An alternative approach consists in *considering models that integrate the bronchial tree as a whole*, which is the perspective adopted here.
Our approach is based on the hypothesis that gas exchanges are optimized to maximize the efficiency of the lung, in accordance with principles such as the theory of evolution. To explore this hypothesis and assess this optimality principle, we propose a model based on *ordinary differential equations* describing the *evolution of oxygen concentration in the lung and its transport*. Within this framework, we introduce, analyze, and study an *optimal control problem* aimed at characterizing the *dynamics of the respiratory cycle*.

2. A modeling perspective on retinal degeneration

Speaker: Naoufel Cresson

Affiliation: Laboratoire Jacques-Louis Lions – Sorbonne Université, Centre National de la Recherche Scientifique, Université Paris Cité – France ; Centre Inria de Paris – Institut National de Recherche en Informatique et en Automatique – France

Keywords: Biologie, EDPs, Frontière Libre

Abstract: This talk introduces an ongoing research project focused on building mechanistic models to study retinal degeneration, with a particular emphasis on the geometric aspects of the disease progression. As we develop a computational model for retinal degeneration, we will explore how cellular materials behave and how wound-healing mechanisms influence disease progression.

3. A mathematical model for cyclic-sequential brain activity: a neural-field approach to heteroclinic dynamics

Speaker: Virginia Bolelli

Affiliation: Université Paris Saclay, CentraleSupélec – Université Paris Saclay, CentraleSupélec, Université Paris-Saclay, CentraleSupélec – France

Co-authors: Luca Greco, Hugues Mounier, Dario Prandi

Keywords: Neural, fields, Heterocline dynamics, Cyclic and sequential neural activity, Universal Approximation Theorem

Abstract: We present a mathematical framework for modeling cyclic and sequential patterns of brain activity using neural-field models and heteroclinic dynamics. We first show that standard discrete neural-field equations with biologically realistic equilibria cannot sustain heteroclinic cycles. While Lotka–Volterra-type systems can generate such dynamics, they cannot directly be interpreted in terms of neuronal processes. To bridge this gap, we derive a version of the Universal Approximation Theorem, showing that any target dynamics can be approximated by a neural network interpretable as a high-dimensional neural-field system. When the target dynamics contains a heteroclinic channel, the approximating vector field produces a periodic trajectory closely following the heteroclinic connections, and we estimate its period via residence times along the approximated trajectory. As a case study, we apply the model to the cognitive process underlying focused-attention meditation, showing how the model reproduces sequential transitions among cognitive states and providing a neural interpretation of the approximated dynamics.

Session

Probabilistic numerics

Room: B 103

Timeslot: Wednesday, March 4, 9:00 AM - 10:30 AM

Chaired by TBA

1. NeuralSurv: Deep Survival Analysis with Bayesian Uncertainty Quantification

Speaker: Mélodie Monod

Affiliation: Imperial College London – United Kingdom

Co-authors: Alessandro Micheli, Samir Bhatt

Keywords: analyse de survie, apprentissage profond, modèles bayésiens, quantification de l'incertitude, réseaux de neurones bayésiens, inférence variationnelle, données censurées, calibration des modèles, fonction de survie, NeurIPS 2025

Abstract: English (French below):
Disclaimer: This paper was accepted at NeurIPS 2025.

Abstract: We introduce NeuralSurv, the first deep survival model to incorporate Bayesian uncertainty quantification. Our non-parametric, architecture-agnostic framework captures time-varying covariate-risk relationships in continuous time via a novel two-stage data-augmentation scheme, for which we establish theoretical guarantees. For efficient posterior inference, we introduce a mean-field variational algorithm with coordinate-ascent updates that scale linearly in model size. By locally linearizing the Bayesian neural network, we obtain full conjugacy and derive all coordinate updates in closed form. In experiments, NeuralSurv delivers superior calibration compared to state-of-the-art deep survival models, while matching or exceeding their discriminative performance across both synthetic benchmarks and real-world datasets. Our results demonstrate the value of Bayesian principles in data-scarce regimes by enhancing model calibration and providing robust, well-calibrated uncertainty estimates for the survival function.

Francais :

Titre: ”NeuralSurv : Analyse de survie profonde avec quantification bayésienne de l'incertitude”

Avertissement **:** Cet article a été accepté à NeurIPS 2025.
Résumé **:** Nous présentons NeuralSurv, le premier modèle de survie profond intégrant une quantification bayésienne de l'incertitude. Notre cadre non paramétrique et indépendant de l'architec-

ture permet de capturer, en temps continu, les relations dynamiques entre covariables et risque grâce à un nouveau schéma d'augmentation des données en deux étapes, pour lequel nous établissons des garanties théoriques. Pour une inférence postérieure efficace, nous introduisons un algorithme variationnel en champ moyen avec des mises à jour par ascension de coordonnées, dont la complexité évolue linéairement avec la taille du modèle. En linéarisant localement le réseau de neurones bayésien, nous obtenons une conjugaison complète et dérivons toutes les mises à jour de coordonnées sous forme fermée. Expérimentalement, NeuralSurv offre une calibration supérieure à celle des modèles de survie profonds de l'état de l'art, tout en égalant ou dépassant leurs performances discriminantes, tant sur des bancs d'essai synthétiques que sur des jeux de données du monde réel. Nos résultats mettent en évidence l'intérêt des principes bayésiens dans des contextes de données rares, en améliorant la calibration des modèles et en fournissant des estimations d'incertitude robustes et bien calibrées pour la fonction de survie.

2. Solving the Car Dealer Replenishment Problem with Combinatorial-Optimization Augmented Machine Learning

Speaker: Nicolas Corvol

Affiliation: CERMICS, Ecole des Ponts – Ecole des Ponts ParisTech – France

Co-authors: Louis Bouvier, Axel Parmentier

Keywords: combinatorial optimization, machine learning, endogenous uncertainty, revenue management.

Abstract: Car dealers must daily decide which vehicles to purchase from the manufacturer to replenish their stock. This is an integrated sales and operations planning problem. On the sales side, dealers must anticipate customer choices. Operational costs include inventory and lot-sizing costs. We introduce a Markov Decision Process (MDP) that models this car dealer inventory replenishment problem. Four aspects make this problem particularly challenging.

First, the problem has a combinatorial nature. Any vehicle that can be produced can be ordered, leading to a catalog of over 10 Billion possible configurations from different option combinations.

Second, the uncertainty is endogenous. We do not know what customers would have purchased if different vehicles had been offered.

Third, the historical data for demand estimation is censored, which further complicates the problem.

Finally, the problem is an MDP with combinatorial state and action spaces, a class of problems known to be difficult to solve.

We introduce a novel policy based on Combinatorial-Optimization Augmented Machine Learning (COAML) Numerical experiments show results that our policy trained by imitation learning beats classic stochastic optimisation benchmarks. Numerical experiments using DAgger and Mirror Descent to handle the endogenous part of the stochasticity show promising results.

3. Using couplings to analyze and improve Monte Carlo methods

Speaker: Shiva Darshan

Affiliation: ESSEC Business School – ESSEC Business School – France

Keywords: Markov processes, Coupling, Nonasymptotic convergence rates, MCMC sampling, Molecular dynamics, Statistics, Convergence diagnostics

Abstract: Couplings are a classic tool from modern probability theory that have been extensively used to study the longtime behavior of Markov processes. One particularly fruitful application has been proving non-asymptotics converge rates for a large variety of Markov chain Monte Carlo methods. More recently, explicit couplings have been applied to improve various MCMC algorithms. In this talk, we give an introduction to the coupling of Markov processes and present some applications to designing more efficient Monte Carlo methods in statistics and molecular dynamics.

Session

PDEs: Waves and oscillations in complex media

Room: Amphi Cauchy

Timeslot: Wednesday, March 4, 9:00 AM - 10:30 AM

Chaired by TBA

1. Optimisation for the intrinsic impedance scattering problem on extension domains

Speaker: Gabriel Claret

Affiliation: Fédération de Mathématiques de CentraleSupélec – CentraleSupélec, Université Paris-Saclay, Centre National de la Recherche Scientifique – France ; Mathématiques et Informatique pour la Complexité et les Systèmes – CentraleSupélec, Université Paris-Saclay – France

Keywords: Helmholtz equation, acoustic scattering, layer potential operators, Robin boundary condition

Abstract: From sonars to medical imaging or even robot vacuum cleaners, acoustic scattering is at the core of numerous applications. In an acoustic scattering problem, an incident field (solution to the Helmholtz equation) is scattered by an obstacle in such a way that the total field – superposition of the incident and scattered ones – satisfies a given boundary condition. Modelling that problem, a crucial aspect is the geometry of the obstacle (namely, its regularity), and it is known that irregular shapes such as fractals are most relevant to represent the behaviour of real-life objects. In this talk, we discuss the transmission problem for the Helmholtz equation in connection with the scattering problem with impedance (Robin) boundary condition, in the context of extension domains. Those domains can be smooth, Lipschitz, but also fractal, multi-fractal... In particular, they have no specified boundary measure, which means the impedance condition cannot be understood as in the classical case (in L^2), and must be understood with respect to the trace space. We study the well-posedness of the impedance scattering problem in that context, and compare it to the classical case. As an application of our analysis, we focus on an optimisation problem consisting in choosing the impedance at the boundary of an extension domain, so that the far-field power of the scattered field be maximal.

2. Numerical approaches for the long-time simulation of the wave equation in heterogeneous media

Speaker: Yann Bouchereau

Affiliation: Centre d'Enseignement et de Recherche en Mathématiques et Calcul Scientifique – Ecole Nationale des Ponts et Chaussées – France

Keywords: wave equation, multiscale, homogeneization, MsFEM

Abstract: The wave equation in heterogeneous media models wave propagation in environments with rapidly varying material properties, as encountered for instance in geophysics and acoustics. Wave propagation in heterogeneous media can be described by a second order PDE with oscillatory coefficients. The characteristic length of the variation of the coefficients is considered much smaller than the domain size. In the periodic case, the classical homogenization theory provides an effective description for final times independent of the characteristic length of the variation of the coefficients. Corrective terms should be added to obtain an effective description valid for longer times. From a numerical point of view, to correctly approximate the solution of such PDEs, standard methods such as finite element methods (FEM) require a mesh size smaller than the characteristic length in order to capture the oscillation of the coefficients. This leads to linear systems of large size, which can be too expensive for asymptotically small characteristic length. This talk is devoted to the construction of numerical methods for the simulation of the wave equation in heterogeneous media over long times, and that can be put in practice beyond the periodic regime. I will present numerical approaches that aim at capturing the correct macroscopic behavior of the solution beyond the standard homogenization regime, with an emphasis on multiscale finite element methods and long-time error control.

Joint works with C. Le Bris and F. Legoll.

3. Transport and diffusion in saturated media

Speaker: Antonin Chodron de Courcel

Affiliation: IHES

Keywords: Saturated media, Transport equation, nonlinear mobility

Abstract: This talk explores the coexistence of two mechanisms arising in the modeling of transport in saturated media (chemotaxis, porous media).

On the one hand, we will analyze the impact of the interaction potential singularity (Coulomb type), which poses major challenges regarding the uniqueness and regularity of solutions. On the other hand, we will study the role of nonlinear mobility (modeling saturation effects): we will show how this enforces the formation of shocks (discontinuities) in finite time and dictates the speed of support propagation.

Session

Low-rank approximation and tensors

Room: B 202

Timeslot: Wednesday, March 4, 9:00 AM - 10:30 AM

Chaired by TBA

1. Generalized Additive Decompositions of Symmetric Tensors

Speaker: Enrica Barrilli

Affiliation: Inria at Université Côte d'Azur – Université Côte d'Azur – France

Keywords: Tensor decomposition algorithm, Symmetric Tensors, Generalized Additive Decomposition, Artinian Gorenstein algebras

Abstract: Symmetric tensors are fundamental mathematical objects that play a central role in data analysis, signal processing, complexity theory, statistics, and algebraic geometry. They often encode vast and highly structured datasets, and a key challenge is to find minimal, compact representations of such data. This problem naturally translates into the search for efficient polynomial representations, leading to the study of additive decompositions of symmetric tensors. Classically, the Waring decomposition provides such a minimal representation; we explore a broader, optimized formulation, called Generalized Additive Decompositions (GADs), which extends the Waring framework to yield more compact and expressive representations. We present an algebraic formulation of the GAD problem, based on dual linear operators, which provides a canonical measure for tensor GADs. We discuss the difficulty of computing GADs that realize the minimum of such measure, called the GAD-rank, and we present an algorithm that computes such minimal GADs in a regime of low regularity. The proposed algorithm is implemented and validated through numerical experiments in Julia, supporting its accuracy, efficiency, and robustness. This talk is based on the recent preprint "Generalized Additive Decompositions of Symmetric Tensors" by E. Barrilli, B. Mourrain, and D. Taufer (arXiv:2510.25681, 2025).

2. Approximation and learning with compositional tensor trains

Speaker: Charles Miranda

Affiliation: Ecole Centrale Nantes – Ecole Centrale Nantes, Laboratoire de Mathématiques Jean Leray UMR6629 CNRS – France

Co-authors: Martin Eigel, Anthony Nouy, David Sommer

Keywords: compositional tensor networks, tensor train, approximation, natural gradient

Abstract: We introduce compositional tensor trains (CTTs) for the approximation of multivariate functions, a class of models obtained by composing low-rank functions in the tensor-train format. This format can encode standard approximation tools, such as (sparse) polynomials, deep neural networks (DNNs) with fixed width, or tensor networks with arbitrary permutation of the inputs, or more general affine coordinate transformations, with similar complexities.
This format can be viewed as a DNN with width exponential in the input dimension and structured weights matrices. Compared to DNNs, this format enables controlled compression at the layer level using efficient tensor algebra.

On the optimization side, we derive a layerwise algorithm inspired by natural gradient descent, allowing to exploit efficient low-rank tensor algebra. This relies on low-rank estimations of Gram matrices, and tensor structured random sketching. Viewing the format as a discrete dynamical system, we also derive an optimization algorithm inspired by numerical methods in optimal control. Numerical experiments on regression tasks demonstrate the expressivity of the new format and the relevance of the proposed optimization algorithms. Overall, CTTs combine the expressivity of compositional models with the algorithmic efficiency of tensor algebra, offering a scalable alternative to standard deep neural networks.

3. Low-Rank Regularized Convex-Non-Convex Problems for Image Segmentation or Completion

Speaker: Anas El Hachimi

Affiliation: CEA Cadarache – Commissariat à l'énergie atomique et aux énergies alternatives – France

Keywords: Convex, non, convex problem, image completion, image segmentation, low, rank approximation, matrix nuclear normregularization

Abstract: This work proposes a novel convex-non-convex formulation for image segmentation and image completion problems. The proposed approach is based on the minimization of a functional that includes two distinct regularization terms: one promoting a low-rank structure in the solution, and the other enforcing smoothness. To solve the resulting optimization problem, we employ the alternating direction method of multipliers (ADMM). A detailed convergence analysis of the algorithm is provided, and the performance of the method is demonstrated through a series of

numerical experiments.

Posters

Poster Session

Tuesday, March 3, 5:30 PM - 6:30 PM

Hall of the Carnot building

Posters at a glance

Poster 1. Nonlinear infinite-dimensional systems with both unbounded control and observation operators (Sofian Abahmami)

Poster 2. The Structural Method for Partial Differential Equations (Virgile Bertrand)

Poster 3. ANALYSIS OF A DEGENERATE PARABOLIC SYSTEM MODELLING THE DYNAMICS OF CELLS IN INTESTINAL CRYPTS (Mohamad El Hajj Chehade)

Poster 4. Stabilization of Hyperbolic systems : the F-equivalence Problem (Grégoire Elinck)

Poster 5. From Stokes to Viscoelastic Rheology: A Unified Theoretical and Numerical Framework (Nicolas Hertel)

Poster 6. Logarithmic Convexity and impulse Approximate Controllability for Degenerate Parabolic Equations with Robin Boundary Conditions (Ilham Ouelddris)

Poster 7. On the Stability of 2×2 Linear Weakly Hyperbolic Systems of Balance Laws: An Application to Wastewater Treatment (Mohand Ouidir Amirat)

Poster 8. Adapted network-simplex algorithm for unbalanced optimal transport (Gaetano Agazzotti)

Poster 9. A reduced-order model for parametrized optimal transport problems. (Elise Bonnet Weill)

Poster 10. Wrapped Gaussian on Hadamard manifolds (Thibault De Surrel)

Poster 11. Mathematical modeling and parameter inference of telomere length regulation in yeast (Viviana Gavilanes)

Poster 12. Low-degree lower bounds via almost orthonormal bases (Simone Maria Giancola)

Poster 13. Non-parametric estimation of the Lost Lifetime in cancer registries: A deconvolutional approach (Taha Lachab)

Poster 14. Random Process Flow Matching: Generative Implicit Representations of Multivariate Random Fields (Julien Lalanne)

Poster 15. Efficient methods for spatio-temporal models estimation (Alexandre Loret)

Poster 16. Online learning : new regret guarantees for non-exponentially contractive systems (Théo Moret)

Poster 17. Ellipsoidal Small Sets for Multivariate Time Series (Dominika Mosur)

Poster 18. The Contribution of Solving Linear Complementarity Problems and Applications to the Valuation of American Options (Hajar Nafia)

Poster 19. Deep BSDE method for Quantile Hedging (Cyril Nefzaoui Blanchard)

Poster 20. Model-based reinforcement learning for controlling piecewise deterministic semi-Markov processes partially observed (Orlane Rossini)

Poster 21. Scalable multitask Gaussian processes for complex systems with functional covariates (Razak Christophe Sabi Gninkou)

Poster 22. Cyclists route choice modeling in urban areas : a mode-constrained mixture approach (Mohamadou Salifou)

Poster 23. Application of Some Machine Learning Algorithm to Electrical Impedance Tomography (Idaamar Soumaya)

Poster 24. Robust Wavelet-Based Methods for Long-Memory Time Series: Asymptotic Analysis of the NKK Periodogram (Manganaw N'daam)

Poster 25. Dérivation de limites macroscopiques pour des particules "Run-and-Tumble" avec hétérogénéité de vitesse et chimiotaxie (Alejandro Barea Moreno)

Poster 26. Optimal control of a phytoplankton-zooplankton spatiotemporal discrete bioeconomic model (Soukaina Ben Rhila)

Poster 27. Tarification électrique horo-saisonnière : optimisation bi-niveaux et flexibilité (Abdellah Bulaich Mehamdi)

Poster 28. Biologically informed model selection for phylogenetic data, in the context of JAK2-V617F driven Myeloproliferative Neoplasms (Margherita Bruno)

Poster 29. Trajectory optimization for non cooperative RPO (Remi Caresche)

Poster 30. Study of control strategies for sterile insect technique, using unisexual and bisexual releases (Morgane Doukhan)

Poster 31. Geometric optimization of immersed boundaries with Penalized Direct Forcing method (Lucie Groussy)

Poster 32. Multimodal brain MRI and behavioural tests in a mouse model of Down Syndrome: impact of a treatment in utero (Aude Klein)

Poster 33. Mathematical Modeling of Neuroblastoma Growth Based on Tumoroid data (Perla Mallouk)

Poster 34. Mosquito Population Dynamics Under Sterile Insect Control (Leo Micollet)

Poster 35. An Immersed Boundary Method Based on Penalized Direct Forcing with Immersed Wall Functions using RANS k-omega SST Modeling for Nuclear Safety Device Simulations (Julien Pierrat)

Poster 36. Investigating the use of the Discrete Quantum Walk to solve Combinatorial Optimization Problems (Rachel Roux)

Poster 37. Mathematical modeling of active regeneration via a facilitator species strategy: stability and bifurcations (Gouled Souleiman)

Poster 38. Cosserat equation and modelling of snake locomotion (Eliot Thys)

Poster 39. Modelling and contact control of slender locomotors - Applications to bio-inspired robotics (Lucas Vaudron)

Theoretical and Numerical Analysis of PDEs

Poster 1. Nonlinear infinite-dimensional systems with both unbounded control and observation operators

Speaker: **Sofian Abahmami**

Affiliation: University of Salerno – Italy

Keywords: Semigroup, Regular linear systems, Perturbation

Abstract: In this talk, we begin by examining a special class of semilinear equations. We then use this result together with Lax-Phillips semigroup to establish the well-posedness of nonlinear boundary control systems. Toward the end of the talk, we will also discuss the well-posedness of input-output nonlinear systems using regular linear systems theory. An illustrative example will be provided to demonstrate our theoretical results.

Poster 2. The Structural Method for Partial Differential Equations

Speaker: **Virgile Bertrand**

Affiliation: Institut de Recherche Mathématique Avancée – université de Strasbourg, Centre National de la Recherche Scientifique, L'Institut National de Recherche en Informatique et e n Automatique (INRIA) – France

Keywords: PDE, Structural method, high order method

Abstract: The order of convergence of Finite Difference methods is limited by the stencil size. For exemple, a 3-point scheme cannot be more than 2nd order accurate. Taking a larger stencil allows for higher order schemes, at the cost of lower spectral resolution and some special care for boundary points.

The Structural Method overcomes those limitations by introducing state variables for the differential operators involved in the PDE. Thanks to the local information of the state variables, such a scheme can be of order 6th while keeping a compact 3-point stencil, thus having nice spectral properties.

In the presentation, we will first introduce the structural method, comparing it to classical finite differences. We will then explain how to automatically compute the structural equations given a stencil and state variables. The properties of the structural method will finally be shown on simulations of multi-dimensional stationary PDEs (e.g., Stokes, Maxwell).

Poster 3. ANALYSIS OF A DEGENERATE PARABOLIC SYSTEM MODELLING THE DYNAMICS OF CELLS IN INTESTINAL CRYPTS

Speaker: **Mohamad El Hajj Chehade**

Affiliation: Université de Technologie de Compiègne – UTC Labo LMAC – France

Keywords: cross diffusion systems, diffusion reaction system, existence of weak solutions

Abstract: We present a mathematical model for the spatio-temporal evolution of interacting cell populations in intestinal crypts. The model includes important biological processes such as cell growth, differentiation and movement. The model is formulated as a system of degenerate reaction-cross diffusion equations. By working with initial data of bounded variation, we establish uniform BV bounds for a regularized problem and use compactness arguments to prove the existence of weak solutions.

Poster 4. Stabilization of Hyperbolic systems : the F-equivalence Problem

Speaker: **Grégoire Elinck**

Affiliation: Centre d'Enseignement et de Recherche en Mathématiques et Calcul Scientifique – Ecole Nationale des Ponts et Chaussées – France

Keywords: Stabilization, System of PDEs, Hyperbolic, F, equivalence, spectral theory

Abstract: In this talk we investigate the stabilization problem for linear hyperbolic 22 systems. The F-equivalence method proposes that we find an isomorphism between our origin control system and a suitable chosen stable target system. This method has the benefits to stabilize the origin system but also to give the feedback operator involved.

Poster 5. From Stokes to Viscoelastic Rheology: A Unified Theoretical and Numerical Framework

Speaker: **Nicolas Hertel**

Affiliation: Centre de Mise en Forme des Matériaux – Mines Paris - PSL (École nationale supérieure des mines de Paris), Centre National de la Recherche Scientifique – France

Keywords: rheological/generalized Stokes, type problems/VMS

Abstract: We present a unified theoretical and numerical framework aimed at reproducing in a computational workench the rheological behavior of hyperelastic materials. Starting from the formalism of generalized Stokes-type problems, we investigate theoretically (existence and uniqueness) and numerically (discretization and stabilization) the solution to the considered initial and boundary value problems, and their discrete counterparts with low-order finite elements.By sys-

tematically questioning and com- paring the different formulations—saddle-point, strong formulation, weak formulation, and minimization approach— we propose a coher- ent methodology for the simulation of hyperelastic materials, under the form of classical virtual rheological tests; in particular mechanical spectroscopy. In this context, oscillations are imposed to measure the storage modulus G' and the loss modulus G", as well as tractions under large deformations. The conditions under which numerical dissipation can be interpreted as a residual of G" are investigated, making it possible to quantify the artificial effect of this dissipation and the independence of the phase relationship in the absence of intrinsic theoretical dissipation of the material. This methodology reveals a direct correspondence between physical notions (energy storage, dissipation) and numerical artifacts (numerical viscosity: dissipation; artificial numerical phase shift: dispersivity of the discrete operator), thereby providing a rheological interpretation of the behavior of stabilized schemes of the VMS type. The study shows how these schemes approach the linear elastic stress and analyzes under which conditions numerical dissipation exceeds spurious discrete dispersion, thus offering guidelines for the future simulation of quasi-elastic materials with long relaxation times.

Poster 6. Logarithmic Convexity and impulse Approximate Controllability for Degenerate Parabolic Equations with Robin Boundary Conditions

Speaker: **Ilham Ouelddris**

Affiliation: Faculty of Sciences Semlalia – Bd Prince Moulay Abdellah, Marrakesh, Morocco., Morocco

Keywords: Impulsive approximate controllability, impulse control problems, Carleman commutator, logarithmic convexity, degenerate equation, non divergence form

Abstract: Impulsive systems are a class of dynamical systems that experience sudden changes at specific moments in time. In this work, we investigate the approximate controllability of a class of one-dimensional degenerate parabolic equations with Robin boundary conditions. The degeneracy occurs at one endpoint of the spatial domain, and we apply an impulsive control in a small region at a fixed moment. Our main result establishes an observability inequality for the adjoint system, from which we deduce approximate controllability at final time . The proof relies on a logarithmic convexity argument, developed through a Carleman commutator approach.

Poster 7. On the Stability of 2×2 Linear Weakly Hyperbolic Systems of Balance Laws: An Application to Wastewater Treatment

Speaker: Mohand Ouidir Amirat

Affiliation: Laboratoire d'automatique, de génie des procédés et de génie pharmaceutique – Université Claude Bernard Lyon 1, École supérieure de Chimie Physique Electronique de Lyon, Centre National de la Recherche Scientifique – France

Keywords: Linear partial differential equations, Weakly hyperbolic systems, Exponential stability, Dynamic boundary conditions, Laplace domain analysis, Strict Lyapunov functionals

Abstract: We investigate the exponential stability of steady-states for a one-dimensional linear weakly hyperbolic system of balance laws, characterized by a non-diagonalizable coefficient matrix with equal characteristic velocities. In contrast to the well-studied strictly hyperbolic case (see Bastin and Coron (2016)), we shall see that the lack of diagonalizability introduces new challenges in the stability analysis, motivating a rigorous examination of suitable dissipative boundary conditions for this class of systems. Sufficient conditions ensuring exponential stability are established through analyses conducted in both the Laplace domain and the time domain, employing Lyapunov-based techniques. Numerical examples are provided to illustrate the effectiveness of the proposed approach. Finally, several perspectives are presented for extending the analysis to the nonlinear case, in particular to the stabilization of shock steady-states, which are physically relevant in the context of wastewater treatment applications.

Probability, Statistics, Optimal Transport, and Machine Learning

Poster 8. Adapted network-simplex algorithm for unbalanced optimal transport

Speaker: Gaetano Agazzotti

Affiliation: CEREMADE (CNRS, Paris-Dauphine PSL) – CNRS, université Paris Dauphine, PSL Resarch University – France ; Laboratoire d'analyse et modélisation de systèmes pour l'aide à la décision – Université Paris Dauphine-PSL, Centre National de la Recherche Scientifique – Place de Lattre de Tassigny 75775 PARIS CEDEX 16, France

Keywords: Optimal transport, network simplex

Abstract: Optimal transport is nowadays widely used in various fields. The provided results makes this distance a reference when studying mass displacement on a specific metric space. However, its rigidity and numerical complexity have drawn attention on a relaxed version called unbalanced optimal transport. We propose here an adaptation of the network simplex algorithm, state-of-the-art method to solve the optimal transport problem, to solve the the exact unbalanced problem. Our algorithm has simple iterates that become explicit and even simpler for L^2 and Kullback-Leibler relaxations in both unbalanced and semi-unbalanced case.

Poster 9. A reduced-order model for parametrized optimal transport problems.

Speaker: Elise Bonnet Weill

Affiliation: CERMICS – Ecole Nationale des Ponts et Chaussées – France

Keywords: Optimal transport, Model order reduction

Abstract: In this work, we aim at solving efficiently a parametrized family of optimal transport problems by using model reduction methods. In our context, the marginals are defined as convex combinations of probability measures. We build a reduced-order model by looking for solutions of the primal (respectively of the dual) of the discrete problem in a non-negative cone (respectively in a vector space) of smaller dimension. The reduced problem reads as a linear program with a small number of space variables and constraints. We prove that, under some conditions, this reduced-order model has solutions. We build an a posteriori error estimator that bounds the error between the optimal values of the high-fidelity problem and the reduced-order model. As this estimator requires the computation of non linear terms (with respect to the reduction of dimension), we use an Empirical Interpolation Method (EIM) and Greedy indice Selection algorithm (GiS) to compute numerically efficiently this estimator. We apply numerically this whole method on some examples,

and compare its performances (velocity and precision) to Sinkhorn algorithm.

Poster 10. Wrapped Gaussian on Hadamard manifolds

Speaker: **Thibault De Surrel**

Affiliation: Laboratoire dánalyse et modélisation de systèmes pour láide à la décision – Centre National de la Recherche Scientifique : UMR7243 / FRE3234 / UMR7024, Université Paris Dauphine-PSL, Centre National de la Recherche Scientifique : UMR7024, Centre National de la Recherche Scientifique – France

Keywords: Gaussian distribution, Wrapped distributions, Hadamard manifolds, Estimation, Riemannian geometry, Geometric Statistics

Abstract: Modeling data using a Euclidean flat geometry often fail to capture the intrinsic structure of data lying on curved manifolds. In this work, we derive a *wrapped Gaussian* distribution onto a manifold using the exponential mapping. This process yields a distribution that is defined directly on the manifold, while still being tractable in practice. In this study, we focus on a specific class of manifolds, *Hadamard manifolds*, where the exponential map is a global diffeomorphism, avoiding issues related to the cut locus. We study the general properties of this wrapped Gaussian and instantiate it on examples of Hadamard manifolds: the Euclidean space, the manifold of Symmetric Positive Definite (SPD) matrices and the hyperbolic space, resolving critical identifiability issues of our model. Finally, we demonstrate that parameters can be consistently recovered using a Maximum Likelihood Estimator, validated through synthetic experiments.

Poster 11. Mathematical modeling and parameter inference of telomere length regulation in yeast

Speaker: **Viviana Gavilanes**

Affiliation: Centre de Mathématiques Appliquées de l'Ecole polytechnique – Institut National de Recherche en Informatique et en Automatique, Ecole Polytechnique, Centre National de la Recherche Scientifique – France ; Biologie Computationnelle, Quantitative et Synthétique [Paris] (ex LCQB) – Institut National de la Santé et de la Recherche Médicale, Sorbonne Université, Centre National de la Recherche Scientifique, Institut de Biologie Paris Seine – France ; Mathématiques pour l'évolution, la reproduction, la croissance et l'émergence – Centre de Mathématiques Appliquées de l'Ecole polytechnique, Institut Polytechnique de Paris, Centre Inria de l'Institut Polytechnique de Paris – France

Keywords: Stochastic modeling, Markov chains, ergodicity, parameter inference, mathematical biology

Abstract: Telomere length regulation in *Saccharomyces cerevisiae* has been described through biologically established single-telomere rules combining deterministic shortening and stochastic telomerase elongation. Based on these rules, previous work introduced a stochastic model and

explored its long-term behavior mainly through numerical simulations. The model depends on parameters $\theta = (a, L_s, \beta, p)$ controlling shortening, length-dependent telomerase activation, and random elongation.

In this work, we provide a mathematical formulation of this model by describing the single-telomere dynamics as a discrete-time Markov chain. On a truncated finite state space, we prove ergodicity of the chain, ensuring the existence and uniqueness of a stationary distribution π_θ. This invariant distribution admits an explicit spectral characterization, yielding a deterministic forward map $\theta \mapsto \pi_\theta$. As a result, computationally intensive stochastic simulations can be replaced by a direct and efficient deterministic computation, which allows for parameter inference.

While the stationary distribution π_θ characterizes the long-term behavior of the model, its dependence on the parameters raises a nontrivial identifiability issue. To address this question, we derive a generating-function identity linking the stationary distribution to the length-dependent probability of telomerase-mediated elongation. Parameter estimation is formulated as the minimization of the 1-Wasserstein distance between model stationary distributions and empirical telomere length distributions obtained from nanopore sequencing experiments; this minimization problem is solved using the CMA-ES optimization algorithm.

To connect the discrete stochastic dynamics to a more tractable analytic description, we derive a discrete to continuous scaling limit of the model. Under a suitable scaling regime in which the geometric elongation law converges to an exponential kernel, the discrete Markov chain converges to a transport renewal integro-differential equation. Finally, a coupled two-telomere extension, motivated by asymmetric replication, leads to non-factorized invariant measures and captures inter-telomere dependencies.

Poster 12. Low-degree lower bounds via almost orthonormal bases

Speaker: **Simone Maria Giancola**

Affiliation: Laboratoire de Mathématiques d'Orsay – Université Paris-Saclay, Centre National de la Recherche Scientifique, Centre National de la Recherche Scientifique : UMR8628 – France

Keywords: Low degree method, statistical to computational gaps, average case hardness

Abstract: Low-degree polynomials have emerged as a powerful paradigm for providing evidence of statistical-computational gaps across a variety of high-dimensional statistical models [Wein25]. For detection problems – where the goal is to test a planted distribution $\mathbb{P}'$ against a null distribution $\mathbb{P}$ with independent components – the standard approach is to bound the advantage using an

Poster 13. Non-parametric estimation of the Lost Lifetime in cancer registries: A deconvolutional approach

Speaker: **Taha Lachab**

Affiliation: Sciences Economiques et Sociales de la Santé & Traitement de lÍnformation Médicale – Institut de Recherche pour le Développement, Aix Marseille Université, Institut National de la Santé et de la Recherche Médicale – France

Keywords: Relative survival, Lost lifetime, Deconvolution, Non, parametric estimation, Model selection, Penalized contrast Function

Abstract: Relative survival analysis is the currently standard framework to estimate the mortality from a given cause in population-based cancer studies, where the exact cause of death is unavailable. Traditional approaches rely on the concept of excess hazard, which assumes a hypothetical scenario where only the disease of interest leads to death. These approaches have issues estimating correctly the Lost Lifetime (L) due to the disease, a key metric in these studies.

In this work, we propose an alternative modeling paradigm to refocus on the distribution of L. We model the observed survival time O as O = P - L, where P represents the potential survival time derived from general population mortality tables.

Estimating the distribution of L is formulated as a deconvolution problem. A major challenge in this setting is that the “noise” variable (P) follows a heterogeneous distribution that varies across individuals (non-i.i.d.). We propose to develop a non-parametric adaptive estimator for the density of L using projection methods on the Hermite basis. We define a penalized empirical contrast function to select the optimal model dimension, thereby resolving the bias-variance tradeoff. We provide theoretical guarantees by establishing risk bounds for the selected estimator and illustrate its finite-sample performance through a simulation study.

This framework offers a more interpretable metric (the full conditional distribution of L) for public health decision-making while introducing a robust mathematical approach to deconvolution with non-identically distributed noise.

Poster 14. Random Process Flow Matching: Generative Implicit Representations of Multivariate Random Fields

Speaker: **Julien Lalanne**

Affiliation: Laboratoire Navier – Centre National de la Recherche Scientifique, Université Gustave Eiffel, Ecole Nationale des Ponts et Chaussées – France ; TotalEnergies – TOTAL, CSTJF, Pau – France

Keywords: Flow Matching ; Implicit Neural Representation ; Gaussian Process ; Interpolation ; Inverse Problem ; Calibrated Uncertainty ; Self supervised

Abstract: This talk explores the coexistence of two mechanisms arising in the modeling of transport in saturated media (chemotaxis, porous media).

On the one hand, we will analyze the impact of the interaction potential singularity (Coulomb type), which poses major challenges regarding the uniqueness and regularity of solutions. On the other hand, we will study the role of nonlinear mobility (modeling saturation effects): we will show how this enforces the formation of shocks (discontinuities) in finite time and dictates the speed of support propagation.

Poster 15. Efficient methods for spatio-temporal models estimation

Speaker: **Alexandre Loret**

Affiliation: UMR MIA Paris-Saclay – AgroParisTech, INRA - Université Paris-Saclay – France ; Mines Paris - PSL (École nationale supérieure des mines de Paris) – Université Paris sciences et lettres – 60, boulevard Saint-Michel 75006 Paris, France

Keywords: Statistics, Geostatistics, Deep Learning

Abstract: In spatio-temporal data analysis, Gaussian processes are commonly used to predict values at unobserved locations. Such data are typically assumed to arise from a particular realization of a Gaussian random field. To infer the parameters generating this Gaussian field, maximum likelihood estimation (MLE) is a classical approach. However, in practice, this method quickly becomes computationally prohibitive as the size of the dataset increases.

The objective of this poster is to present the first results of a PhD thesis aimed at developing alternatives to this traditional approach. One of the main challenges lies in the complex spatio-temporal dependencies of the models, which may arise from advection or other physical mechanisms.

Following recent studies that address this issue using Simulation-Based Inference (SBI), we propose several neural network architectures designed to learn the parameters of Gaussian spatio-temporal models. The networks are trained on simulations generated by the Gaussian random field model itself. We compare the different architectures in terms of accuracy and computational cost. The proposed approach has the advantage of being amortized: unlike classical MLE, once training is completed, parameter inference is almost instantaneous.

Poster 16. Online learning : new regret guarantees for non-exponentially contractive systems

Speaker: **Théo Moret**

Affiliation: Laboratoire de Probabilités, Statistique et Modélisation – Sorbonne Université, Centre National de la Recherche Scientifique, Université Paris Cité, Sorbonne Université : UMR_8001, Centre National de la Recherche Scientifique : UMR_8001, Université Paris Cité : UMR_8001 – France

Keywords: Online Learning, Inventory Problem, Optimisation, Control

Abstract: We study the control of time-varying dynamical systems in which actions are selected sequentially through policies. The goal is to chose those actions on-the-fly while improving decisions over time. Each action incurs a cost, and we aim to control the cumulative cost incurred during the interaction, called the regret. Such problems arise naturally in operations research, in particular in inventory problems.

This is a hard problem for many reasons. First the cost is unkown to us and has a nontrivial dependency on the system state. Second, early suboptimal decisions can propagate through the dynamics, preventing the learner from designing algorithms with meaningful guarantees.

A standard idea is to consider contractive systems which dampen the influence of past actions at an exponential rate. In this setting, a variant of online gradient descent algorithm is known to yield strong guarantees. We show that an exponential contraction is, in fact, not necessary. More precisely, we prove that milder contractions—such as polynomial contraction—can be handled without deteriorating the guarantees.

We finally discuss a new interesting connection between our framework and online learning problems for which the adversary can exploit an unbounded memory. In particular, we highlight how the latter problem can be seen as controlling a dynamical system whose contraction reflects the Lipschitz structure of the adversary's loss sequence.

Poster 17. Ellipsoidal Small Sets for Multivariate Time Series

Speaker: **Dominika Mosur**

Affiliation: Institut Mathématique de Marseille (I2M), Aix-Marseille Université

Keywords: TBA

Abstract: Regenerative methods for dependent data rely on the existence of smallsets, which play a central role in both theoretical analysis and resampling procedures for Markovian time series. In [1], optimal small sets are constructed using rectangular regions of the state space, providing a practical framework for regenerative block bootstrap methods. However, in multivariate settings, for instance when vectorizing AR(p) models or Periodic AR(p), such rectangular parametrizations may be restrictive and computer intensive since they require optimization and calibration of

multiple parameters. In this work, we propose an alternative approach to smallset construction based on an ellipsoidal parametrization. Instead of optimizing over multidimensional rectangular regions, we describe the size of the smallset using a single scalar parameter that controls the volume of an ellipsoid adapted to the dependence structure of the data. This parametrization significantly reduces the dimensionality of the calibration problem. We consider multivariate time series represented in a vector autoregressive (VAR) framework and estimate the model parameters together with the innovation covariance matrix from the data. Based on these estimates, we define a data-driven criterion measuring the frequency of returns to the proposed smallest and study how this criterion can be optimized to calibrate an atomic extension of the chain. The procedure is repeated over multiple realizations in a simulation study, allowing us to investigate the stability of the optimized small set and the distribution of the associated criterion.

[1] Bertail P., Cl´emen¸con S., Regenerative block bootstrap for Markov chains, Bernoulli, 12.4 (2006), 689-712.

Poster 18. The Contribution of Solving Linear Complementarity Problems and Applications to the Valuation of American Options

Speaker: **Hajar Nafia**

Affiliation: Laboratoire d'Analyse, Modélisation et Simulation, Faculté des Sciences Ben M'Sik – Morocco

Keywords: American option, linear complementarity problem, Black and Scholes model, Crank Nickolson approach, Pricing American put options, oil options, Exxon Mobil Corporation, finite difference method, P matrix

Abstract: In this work, we recast the valuation of American put options within the rigorous framework of a Linear Complementarity Problem (LCP). The spatial and temporal domains are discretized via a finite difference scheme based on the Crank–Nicolson method, thereby yielding a numerical formulation in which the option value is characterized as the solution of the resulting LCP. To ensure both accuracy and computational efficiency, we employ a fast iterative algorithm specifically tailored to the structure of the discretized problem.

Furthermore, artificial intelligence methods are integrated into the modelling process to enhance parameter calibration and to capture nonlinear market dynamics that are not easily addressed by classical numerical approaches. These artificial intelligence driven components contribute to improving both the robustness and the interpretability of the obtained valuations. The practical relevance of the proposed methodology is demonstrated through its application to American-style options on crude oil.

Poster 19. Deep BSDE method for Quantile Hedging

Speaker: **Cyril Nefzaoui Blanchard**

Affiliation: Université Paris-Saclay, LaMME – LaMME – France

Keywords: Quantile Hedging Deep BSDE

Abstract: We consider the popular Deep BSDE method of E–Han–Jentzen and tailor it to the quantile hedging problem in the weak stochastic-target framework initiated by Bouchard–Élie–Touzi and Bouchard–Élie–Réveillac. The success-probability state is modeled as a constrained martingale with square-integrable unbounded controls. We combine piecewise-constant controls with a projected Euler time discretization and an endogenous stopping rule to preserve the constraint, yielding an implementable discrete-time control problem. Within the policy-timestep framework of Krylov - Jakobsen–Picarelli–Reisinger , we provide a convergence study tailored to the state constraint, unbounded controls, and BSDE-type criteria with convex drivers.

Unlike previous works that focus mainly on pricing, our approach outputs both the value function and the associated quantile hedging strategy within the same solver. On classical benchmarks, numerical experiments are consistent with the Föllmer–Leukert results and confirm the accuracy and interpretability of the method. This is a joint work with Cyril Bénézet and Sergio Pulido

Poster 20. Model-based reinforcement learning for controlling piecewise deterministic semi-Markov processes partially observed

Speaker: **Orlane Rossini**

Affiliation: Institut Montpelliérain Alexander Grothendieck – Centre National de la Recherche Scientifique, Université de Montpellier – UMR CNRS 5149 - Université Montpellier 2, Case courrier 051, 34095 Montpellier cedex 5 - France, France

Keywords: Stochastic control, Markov Processes, Reinforcement Learning, Neural Networks

Abstract: Sequential decision-making in partially observable systems with unknown dynamics is a major challenge, especially when available data is limited. This type of situation is common in medicine, where the patient's condition is observed intermittently and where the progression of the disease varies greatly from one individual to another. In this context, personalized treatment strategies aim to tailor follow-up to each patient's specific dynamics in order to reduce unnecessary treatments and promote early detection of relapses. This requires models that can capture overall dynamics while adapting to individual specificities.

Piecewise deterministic Markov processes (PDMPs) are particularly well suited to modeling diseases such as cancer, whose progression is largely deterministic, punctuated by random events. However, optimal control of these processes is difficult, particularly in cases of partial observations or uncertainty regarding the model.

In this work, we propose transforming the problem into a Bayesian Adaptive Partially Observable Markov Decision Process (BAPOMDP) in order to incorporate uncertainty about the dynamics. The dynamics are then modeled probabilistically. This type of model is then solved using deep reinforcement learning algorithms capable of handling continuous state space.

Poster 21. Scalable multitask Gaussian processes for complex systems with functional covariates

Speaker: **Razak Christophe Sabi Gninkou**

Affiliation: Laboratoire de Matériaux Céramiques et de Mathématiques – Université Polytechnique Hauts-de-France, INSA Institut National des Sciences Appliquées Hauts-de-France – France

Keywords: computer experiments, surrogate modeling, machine learning, functional data analysis, uncertainty quantification

Abstract: Functional covariates are ubiquitous in scientific and engineering applications, where operating conditions, loading paths, or boundary conditions are naturally described as curves or fields. Gaussian process models provide a flexible probabilistic framework for emulating such computer models, while offering principled uncertainty quantification. However, most existing GP-based approaches focus either on functional inputs or on multi-output responses, and only rarely address both aspects jointly.

This work introduces a multitask Gaussian process framework designed to handle functional covariates together with multiple correlated outputs. Task dependencies and functional similarities are captured through a fully separable covariance structure, leading to a Kronecker product representation of the global covariance operator. This structure enables exact and scalable inference via tensorized linear algebra and GPU-accelerated computations.

The methodology is illustrated on a realistic mechanical application involving a complex simulator, where both inputs and outputs are force–displacement curves. The proposed multitask formulation improves predictive accuracy and uncertainty calibration while significantly reducing computational cost compared with independent GP models.

Poster 22. Cyclists route choice modeling in urban areas : a mode-constrained mixture approach

Speaker: **Mohamadou Salifou**

Affiliation: Laboratoire Interdisciplinaire Solidarités, Sociétés, Territoires – École des Hautes Études en Sciences Sociales, Université Toulouse - Jean Jaurès, École Nationale Supérieure de Formation de l'Enseignement Agricole de Toulouse-Auzeville, Institut national universitaire Champollion, Centre National de la Recherche Scientifique – France

Keywords: Route choice inference, mode, constrained mixture, bike share, trip duration, travel behaviour

Abstract: Cities increasingly rely on bike-sharing systems to promote sustainable mobility. These systems generate massive but low-granularity data. Unlike GPS datasets, trip records provide only the origin station, destination station, and total duration, making it difficult to infer route structure or behavioral heterogeneity. Despite this limited granularity, studies conducted in Toulouse have shown that trip-duration distributions for each station pair are typically bimodal and well represented by a mixture of log-normal distributions. Moreover, a strong empirical linear relationship has been identified between the mode of the first (fastest) component and the theoretical fastest duration obtained through OpenStreetMap (OSM). This observation motivates a mode-constrained mixture model, in which the mode of the dominant component is anchored to an affine function of the OSM travel time.

We validate this approach on 2.4 million trips recorded in Helsinki–Espoo in 2024, which include both durations and distances. For each station pair with at least 100 trips, the duration and distance distributions show strong structural coherence, and the constrained model significantly improves the agreement between temporal and spatial analyses. Furthermore, the constraint stabilizes parameter estimation and enhances behavioral interpretability.

This transferable method offers urban planners a reliable tool to infer route choice without GPS data, supporting the design of cycling infrastructure and the modeling of travel demand.

Poster 23. Application of Some Machine Learning Algorithm to Electrical Impedance Tomography

Speaker: **Idaamar Soumaya**

Affiliation: Hassan I University of Settat, Morocco – Morocco

Keywords: Electrical Impedance Tomography, inverse problem, optimization, Adam optimizer, image reconstruction

Abstract: Electrical Impedance Tomography (EIT) is a non-invasive imaging technique that reconstructs the internal electrical conductivity of biological tissues using boundary voltage measurements. Its safety and wide range of potential clinical applications have driven substantial research interest. EIT image formation requires solving a highly ill-posed inverse problem, typically addressed through iterative optimization methods. Consequently, the choice of optimization strategy plays a crucial role in the quality and efficiency of the reconstruction.

In this work, we investigate the performance of the Adam optimizer for solving the EIT inverse problem. Our numerical experiments show that Adam achieves notably faster convergence, reduced reconstruction time, and improved image quality compared to traditional gradient-based approaches. In particular, Adam provides better anomaly localization and higher reconstruction

accuracy while maintaining computational efficiency. We also discuss suitable parameter configurations for Adam within the EIT framework, offering practical guidance for future studies.

Overall, our results demonstrate that Adam is a highly effective optimization method for EIT image reconstruction and represents a promising direction for advancing inverse problem solutions in this modality.

Poster 24. Robust Wavelet-Based Methods for Long-Memory Time Series: Asymptotic Analysis of the NKK Periodogram

Speaker: Manganaw N'daam

Affiliation: Statistique, Analyse et Modélisation Multidisciplinaire (SAmos-Marin Mersenne) – Université Paris 1 Panthéon-Sorbonne – France

Keywords: Biomathematics, Mathematical physics, and Engineering applications

Abstract: Long-memory processes play a central role in the analysis of many applied time series, particularly in finance, telecommunications, and signal processing. The presence of long-range dependence combined with heavy-tailed innovations makes statistical estimation especially challenging. In long-memory stochastic volatility (LMSV) models, classical semiparametric estimators such as the Geweke–Porter-Hudak log-periodogram estimator are highly sensitive to non-Gaussian noise and outliers, leading to substantial bias.

In this work, we propose a robust wavelet-based approach for estimating the long-memory parameter. Using the maximal overlap discrete wavelet transform (MODWT) of the log-volatility process, we introduce a new robust wavelet periodogram, referred to as the NKK periodogram, constructed from harmonic estimators obtained via least absolute deviations (LAD). This framework significantly reduces sensitivity to non-Gaussian distributions while preserving the time–frequency localization properties of wavelets.

The NKK periodogram is then incorporated into a semiparametric log-periodogram regression, yielding a new estimator of the long-memory parameter. Under general assumptions allowing for dependent and possibly infinite-variance stationary innovations, we establish the consistency of the estimator and derive the asymptotic distribution of the periodogram, which converges to a quadratic form of a Gaussian vector. This non-standard limiting distribution extends classical results based on least squares methods. Simulation studies demonstrate the superior performance of the proposed approach in terms of mean squared error, particularly for moderate sample sizes and noisy data.

Biomathematics, Mathematical physics, and Engineering applications

Poster 25. Dérivation de limites macroscopiques pour des particules "Run-and-Tumble" avec hétérogénéité de vitesse et chimiotaxie

Speaker: **Alejandro Barea Moreno**

Affiliation: Wien Universität – Austria

Keywords: kinetic theory, EDPs, Biologie Cellulaire

Abstract: La migration cellulaire collective est un processus fondamental du développement embryonnaire, pourtant la plupart des modèles mathématiques supposent une population homogène d'agents identiques. Motivés par des données expérimentales sur les cellules de la crête neurale crânienne, nous étudions comment l'hétérogénéité des vitesses individuelles influence la dynamique émergente du groupe. Nous proposons un système de particules en interaction (IPS) stochastique basé sur un mécanisme de "course et culbute" (*run-and-tumble*), où les cellules transitent entre des états de "course" (mouvement actif) et de "culbute" (réorientation).

Contrairement aux modèles standards, nous introduisons de l'hétérogénéité en divisant la population en espèces "rapides" et "lentes" 4, ainsi qu'en considérant un spectre continu de vitesses5. Notre approche fait le lien entre les échelles microscopiques et macroscopiques. Nous dérivons formellement les équations cinétiques associées pour les distributions de densité de particules f_0 (culbute) et f_1 (course). À l'aide d'une analyse asymptotique avec interactions localisées, nous déduisons les limites macroscopiques (hydrodynamiques), aboutissant à un système d'équations de transport couplées qui décrivent l'évolution de la densité cellulaire et de l'orientation moyenne sous l'influence de gradients chimiques mu(x) et de potentiels répulsifs.

Nous validons ces résultats théoriques par des simulations numériques, en analysant des quantificateurs clés tels que la vitesse de groupe par rapport à la vitesse individuelle moyenne, la cohésion du groupe et l'efficacité du mouvement. Nos résultats explorent si l'hétérogénéité de vitesse confère un avantage collectif dans des environnements confinés et fournissent un cadre mathématique rigoureux pour comprendre comment la variabilité phénotypique affecte l'auto-organisation biologique.

Poster 26. Optimal control of a phytoplankton-zooplankton spatiotemporal discrete bioeconomic model

Speaker: **Soukaina Ben Rhila**

Affiliation: Department of Mathematics and Computer Science, Faculty of Sciences Ben M'Sik, – Morocco ; Laboratory of Analysis Modelling and Simulation, Department of Mathematics and Computer Science, Faculty of Sciences Ben M'Sik, – Morocco

Keywords: Bioeconomic model, Discrete, time model, Planktonic organisms, Multi, fishing areas, Chlorophyl a, Fishing effort, Optimal control, Forward, backward sweep method

Abstract: Recently, some planktonic organisms have been put to use in biotechnological applications, and their usefulness has been discovered in the development of alternative and healthy foods, natural medicines, and cosmetics. Therefore, the management of plankton production is a major challenge for the development of aquaculture. In order to achieve this goal, chlorophyll a, a pigment present in all photosynthetic organisms, is generally and historically used as an estimator of the biomass of planktonic organisms. In this work,we propose a bioeconomic spatiotemporal discretemodel in amulti-fishing zone to describe the predation interaction between phytoplankton and zooplankton (Crustacean) organisms by taking into consideration the harvesting activity. To guarantee the survival of two organisms, we consider two harvesting control strategies. The existence of optimal controls and their characterization are proved by using the discrete version of Pontryagin's maximum principle. Based on the concentration of chlorophyll a in the maritime zones of Morocco, we control and compare the biomass of the planktonic organisms in two situations (without and with control). As a major result, we found that after controlling the exploitation of planktonic organisms, their biomasses achieve a level that can ensure their sustainability. The achieved outcomes in the numerical simulations are given by using the forward-backward sweep method (FBSM).

Poster 27. Tarification électrique horo-saisonnière : optimisation bi-niveaux et flexibilité

Speaker: **Abdellah Bulaich Mehamdi**

Affiliation: CMAP, EDF, et INRIA – CMAP, École Polytechnique, Electricité de France - EDF, INRIA – France

Keywords: Optimisation bi—niveaux, tarification

Abstract: Nous proposons un modèle de tarification électrique horo-saisonnière formulé comme un problème d'optimisation bi-niveau de type Stackelberg. Le fournisseur d'électricité (leader) conçoit une stratégie tarifaire pour maximiser son profit en anticipant les réactions des clients. Chaque client (suiveur) optimise conjointement son choix de contrat et sa consommation flexible pour minimiser ses coûts. Ce cadre capture fidèlement la hiérarchie décisionnelle caractéristique des marchés de l'électricité où les fournisseurs fixent les prix avant que les clients ne réagissent,

cf. [1,2].

[1] Besançon, M., Anjos, M. F., Brotcorne, L., & Gomez-Herrera, J. A. (2020). A bilevel approach for optimal price-setting of time-and-level-of-use tariffs. *IEEE Transactions on Smart Grid*, *11*(6), 5462-5465. [2] Jacquet, Q., van Ackooij, W., Alasseur, C., & Gaubert, S. (2024). Quadratic regularization of bilevel pricing problems and application to electricity retail markets. *European Journal of Operational Research*, *313*(3), 841-857.

Poster 28. Biologically informed model selection for phylogenetic data, in the context of JAK2-V617F driven Myeloproliferative Neoplasms

Speaker: Margherita Bruno

Affiliation: Mathématiques et Informatique pour la Complexité et les Systèmes – CentraleSupélec, Université Paris-Saclay – France

Keywords: Phylogenetics, hematopoietic stem cells, cell dynamic, Approximate Bayesian Computation, model selection

Abstract: Myeloproliferative neoplasms (MPN) are blood cancers that arise mainly from the acquisition of the JAK2-V617F mutation in hematopoietic stem cells years before symptoms appear. Estimating the acquisition age of this mutation is essential in understanding MPN oncogenesis and enabling early diagnosis.

Previous approaches by Van Egeren et al. (Cell Stem Cell, 2021) and Williams et al. (Nature, 2022) have been developed by collecting patient data structured as phylogenetic trees, establishing mathematical stochastic models of clonal development, and estimating model parameters using Approximate Bayesian Computation (ABC). The first study describes the process using an integer-time Wright-Fisher model, which is suitable but general, and the second one models the dynamics as a process with multiple cell compartments at equilibrium, adding complexity that makes the inference procedure computationally challenging.

These models are built ad hoc for the specific case, which limits the biological insights that can be extracted from them. In general, how we model the biological process and how we perform inference can impact the results. We propose an adaptation of the model from Hermange et al. (PNAS 2022), which has been established and validated to describe JAK2-V617F-driven malignant hematopoiesis in MPN patients, for the construction of phylogenetic trees. Our model enables mathematical approximations that reduce the computational cost of the inference procedure, and it describes the process with biologically meaningful parameters and sufficient detail to yield easily interpretable results for biologists.

These methods have never been evaluated in a cohesive, comprehensive study, raising concerns

about the robustness of the results. Our objective, then, is to propose a robust Sequential Monte Carlo ABC framework for model selection that allows us to determine the posterior probability of each model to describe the data while still estimating model-specific parameters for each patient. We implement the method on four different JAK2-mutated patient datasets from previous research.

In ABC fashion, simulations from the different models are compared to the data using meaningful summary statistics and a specified distance metric. We introduced the notion of a combined distance, which integrates phylogenetic structure information (lineages through time plots) with molecular data (clonal fraction). We implemented the ABC-SMC strategy with Gaussian perturbation kernels, reducing variance at each step to improve convergence.

The model-selection procedure reveals variations in the estimated acquisition ages for the JAK2-V617F driver mutation that depend on the chosen model and the significant selection of a particular model for each patient. The estimation of the model probability extends the results obtained for the acquisition age of the mutation, allowing the evaluation of each model's robustness and helping to understand the appearance and development of the disease. In particular, comparing the performance of data-specific models with that of more general ones.

As a prospect, we intend to increase the number of patients and perform hierarchical Bayesian inference to retrieve population-common probability distributions for the model parameters. In addition, we will extend the model to familial MPN cases carrying the 14q32 germline predisposition factor, for which we will need a robust inference procedure.

Poster 29. Trajectory optimization for non cooperative RPO

Speaker: **Remi Caresche**

Affiliation: ISAE-ONERA, ACDC (Analyse, Commande Dynamique et Conception des systèmes)

Keywords: Optimal control; Trajectory optimization; Low Earth Orbit; Indirect methods

Abstract: This work addresses trajectory optimization for non-cooperative rendezvous and proximity operations in Low Earth Orbit within an indirect optimal control framework. The problem is formulated using Pontryagin's Maximum Principle, leading to a nonlinear two-point boundary value problem with adjoint variables. A central difficulty lies in the initialization of the costates, which strongly impacts convergence of shooting methods. We propose a Lyapunov-based construction to generate structured initial guesses for the adjoint variables, providing a geometrically consistent approximation of the optimal solution. The approach aims at improving robustness and convergence properties of indirect methods applied to constrained orbital transfer problems.

Poster 30. Study of control strategies for sterile insect technique, using unisexual and bisexual releases

Speaker: **Morgane Doukhan**

Affiliation: Laboratoire Jacques-Louis Lions – Sorbonne Université – France

Keywords: Mathematical modeling, Mathematical biology, Sterile Insect technique, Oriental fruit fly, Population dynamics, Biological control

Abstract: The oriental fruit fly *Bactrocera dorsalis* is a major invasive fruit pest whose females damage many host plants. Established in La Réunion since 2017, the fly currently threatens to spread to Europe. To manage these populations sustainably, the Sterile Insect Technique (SIT) can be employed, releasing sterile insects to drive the wild population toward suppression or extinction. Since released females contribute to fruit damage, male-only releases are preferred, however, sex-sorting methods are unavailable for many species or are too expensive for large-scale implementation. Consequently, bisexual releases are often implemented, in particular against *B. dorsalis*. To date, the majority of mathematical frameworks for SIT have either disregarded sex structure or assumed male-only releases despite the need to evaluate bisexual-release strategies.

This work presents and analyzes a population dynamics model aimed at quantifying the impact of unisexual and bisexual release protocols on the efficiency and cost-effectiveness of SIT programs. We establish the existence of a critical release rate above which pest extinction is achieved. Finally, we explore the dependence of this threshold upon sterile female parameters and discuss its minimization.

Poster 31. Geometric optimization of immersed boundaries with Penalized Direct Forcing method

Speaker: **Lucie Groussy**

Affiliation: Laboratoire d'études et de modélisations des systèmes – Cea Cadarache – France

Keywords: Shape Optimization, Lagrangian, Immersed Boundary Method, Penalized Direct Forcing method

Abstract: In the event of a hypothetical loss-of-coolant accident in a pressurized water loop reactor, it is important to minimize the outflow from the vessel and manage the water reserves available for safety injections, with the aim of preventing or delaying core dewatering and its possible degradation. To achieve this, a passive system based on the hydraulic diode principle is envisaged, similar to in-vessel flow limiters or advanced accumulators. The aim of this thesis is to optimize the geometry of this type of device in order to maximize inlet/outlet pressure drops in one direction of flow. In order to be able to consider several geometric shapes of these devices, without having to remesh the computational domain, a immersed boundary method has been introduced (Penalized Direct Forcing method) into the TRUST/TrioCFD software, under vari-

ous spatial discretizations for the thermal-hydraulic simulation of laminar or turbulent regimes.

This thesis focuses on the possibilities of deterministic geometric optimization during simulation. The expected result is a tool for the constrained optimization of the geometry of a hydraulic diode.

The methodology used to carry out this work, inspired by the work of F.Feppon et al., is as follows: first, a constrained objective function and its derivation with respect to the immersed geometry will be defined. Next, we will define the adjoint problem associated with this problem. Solving the direct and adjoint problems will enable us to obtain the variables required for iterative calculation of the deformation of the immersed boundary minimizing the objective function. This approach was first applied to a termal case with the study of fuel pellet then we will apply it to thermal-hydraulic case.

Poster 32. Multimodal brain MRI and behavioural tests in a mouse model of Down Syndrome: impact of a treatment in utero

Speaker: **Aude Klein**

Affiliation: Imagerie Multimodale Intégrative en Santé – Laboratoire des sciences de l'ingénieur, de l'informatique et de l'imagerie – France ; Institut de Génétique et de Biologie Moléculaire et Cellulaire – université de Strasbourg, Institut National de la Santé et de la Recherche Médicale, Centre National de la Recherche Scientifique, Institut National de la Santé et de la Recherche Médicale : U964, Centre National de la Recherche Scientifique : UMR7104, université de Strasbourg : UMR7104, Institut National de la Santé et de la Recherche Médicale : U1258 – France

Keywords: Multimodal brain MRI, Voxel, Based Morphometry, Down Syndrome, In utero treatment

Abstract: Down Syndrome (DS) is the most common genetic cause of intellectual disability.

Thus, we investigated whether prenatal inhibition of the DYRK1A – a kinase encoded by the triplicated Dyrk1a gene in DS and linked to cognitive impairments—could modulate brain development in the Ts66Yah mouse model.

Pregnant dams received the selective DYRK1A inhibitor LCTB21 throughout gestation.

Then when offspring reached adulthood, cognitive performance was assessed using the Novel Object Recognition (NOR) test and a multimodal brain-MRI was performed to characterize the functional, anatomical and microstructural changes in the brain.

Firstly, Voxel-Based Morphometry (VBM) was used on anatomical MRI data in order to show off brain volumes differences between trisomic treated, trisomic non-treated, non-trisomic treated and non-trisomic non-treated mice, in both sexes.

Thus, trisomic mice showed cortico, thalamic-, and hippocampal gray-matter reductions, and sub-

cortical fronto-limbic and brainstem enlargements. LCTB21 induced bidirectional modulations across genotypes, reflecting shared and/or genotype-specific neuroanatomical plasticity and underscoring DYRK1A's role in early brain morphogenesis.

In parallel, behavioural data were analyzed using a Deep Learning approach to classify mice across the four groups described above.

Poster 33. Mathematical Modeling of Neuroblastoma Growth Based on Tumoroid data

Speaker: **Perla Mallouk**

Affiliation: MAP5 – Université Paris Cité, CNRS, CNRS : UMR8145 – France

Keywords: Cancer modeling, Deterministic and stochastic model, Gene regulatory network, Spatial structure

Abstract: Neuroblastomas are solid tumors and represent the most common extracranial tumors in children, with no known cause to date. The analysis of tumoroid data (artificial organoids capable of reproducing neuroblastoma growth) has revealed a distinctive spatial organization: cancer stem cells tend to cluster at the center of the tumor. A multiscale agent-based neuroblastoma tumoroid model was developed to simulate neuroblastoma growth. Data provided by this computational model represent a unique opportunity to investigate the genetic causes of neuroblastoma tumors' spatial structures. Our goal is to build a mathematical model that can reproduce the growth of neuroblastoma based on these data, in order to better understand and capture the particular spatial distribution as the result of the stochastic interaction of genes promoting stem or differentiated phenotypes and non-local interactions based on gene dynamics, and ultimately propose more targeted treatments.

We combined an existing deterministic model of tumor growth, which accounts for cell proliferation, diffusion, and differentiation, with a Piecewise Deterministic Markov Process (PDMP) representing the stochastic gene regulatory network. We conducted a mathematical analysis of this model to prove that it is well-posed, using semigroup theory and stochastic process theory. We also performed numerical simulations in both 1D and 2D to observe whether the expected spatial distribution emerges.

Results show that cell proliferation and diffusion occur as expected for each cell type, but the specific clustering of stem cells is not yet reproduced. The model needs to be further refined to better capture this spatial organization, which will be the focus of the next steps of this work.

This work has been done in collaboration with Olivier Gandrillon (Inria, ENS de Lyon) and Thi Nhu Thao Nguyen (Université Paris Cité, Inria, ENS de Lyon).

Poster 34. Mosquito Population Dynamics Under Sterile Insect Control

Speaker: **Leo Micollet**

Affiliation: Mathématiques et Informatique Appliquées – AgroParisTech, Université Paris-Saclay, Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement, Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement : UMR0518 – France

Keywords: Population Dynamics, Stochastic Population Processes, Limiting Diffusion, Sterile Insect Technique

Abstract: Mosquitoes of the genus *Aedes* are major disease vectors, and their control is increasingly challenged by adaptation to new environments, climate change and insecticide resistance. Among alternative strategies, the Sterile Insect Technique (SIT) relies on the release of sterilized males to reduce the mean viable offspring per female, while targeting a single species with limited environmental side effects. However, the efficiency of SIT depends on population dynamics and environmental variability. Using field data from *Aedes polynesiensis* collected on Tetiaroa Atoll (French Polynesia), we develop a stochastic population model with partially observed and latent stages. The model incorporates environmental dependence, density-dependent reproduction and repeated releases of sterile males. We analyze its deterministic and diffusion limits and derive a reduced model involving only the observed compartments. This framework will be the basis for parameter estimation and optimization for SIT deployment.

Poster 35. An Immersed Boundary Method Based on Penalized Direct Forcing with Immersed Wall Functions using RANS k-omega SST Modeling for Nuclear Safety Device Simulations

Speaker: **Julien Pierrat**

Affiliation: Laboratoire d'études et de modélisations des systèmes – Cea Cadarache – France

Keywords: Turbulence Modelling, Immersed Boundary Method, Penalized Direct Forcing, K, Omega SST

Abstract: The accurate and efficient simulation of turbulent thermohydraulic flows in complex geometries is a key requirement for the design and topological optimization of nuclear safety devices. Conventional body- fitted meshing approaches often lead to high computational costs and limited flexibility when moving boundaries or iterative mesh change are involved. To address these challenges, we propose an Immersed Boundary Method (IBM) based on the Penalized Direct Forcing approach, specifically tailored for turbulent nuclear safety applications. A major contribution of this work is the development of immersed wall functions for both velocity and temperature fields, extending the conventional wall-law framework to an immersed setting. These wall functions are further coupled with additional closures for turbulence quantities (k and ω), enabling

the consistent integration of the RANS k - ω SST turbulence model within the IBM framework. This innovation allows the method to capture near-wall behavior without resolving the boundary layer, thereby reducing grid requirements while maintaining accuracy in heat transfer and turbulence predictions. The methodology has been implemented in the open-source platform TRUST/TrioCFD of the CEA. Several validation cases are presented, ranging from canonical turbulent channel and pipe flows to more representative thermohydraulic configurations relevant to nuclear safety. Comparisons against body- fitted simulations with use of wall law demonstrate the robustness of the approach and highlight the computational savings achieved by combining immersed boundary techniques with wall-function modeling. Beyond static configurations, the method is also suited to problems involving moving or deformable boundaries, opening perspectives for the optimization of innovative passive safety devices, and for fluid- structure interaction.

Poster 36. Investigating the use of the Discrete Quantum Walk to solve Combinatorial Optimization Problems

Speaker: **Rachel Roux**

Affiliation: ENSTA, IP-Paris

Keywords: Quantum Optimization

Abstract: Quantum Computing may be a game changer in the next decade for large combinatorial optimization problems when Fault Tolerant Quantum Computer will become available. We expect an advantage on the speedup or the encoding of larger instances at constant cost. This work is based on two problems to test the efficiency of our future approachs: optimal path problem and optimal assignment problem. Some additional constraints make both problems NP-hard. Among quantum algorithms, we studied in particular discrete quantum walks which have in principle the ability to address more graph-structured problems, such as our problems. We investigated the possibility to encode each valid solution on nodes of a ”solution graph” in which only negihbouring solutions are connected, in terms of cost. The key element is that the connection between solutions depend only on local differences between solutions. Encouraging numerical tests show that the stationary distribution of random walk over this solution graph hightlight the optimal solutions. Our main challenge is to find an efficient way to walk quantumly on this ”solution graph”. This work aims to define a quantum walk operator whose 1-eigenvector encodes the searched solution nodes and find the stationary distribution of this new operator.

Poster 37. Mathematical modeling of active regeneration via a facilitator species strategy: stability and bifurcations

Speaker: **Gouled Souleiman**

Affiliation: Laboratoire de Mathématiques Appliquées du Havre – Université Le Havre Normandie, France. – France ; Laboratoire d'Analyse, de Modélisation et d'Optimisation – Djibouti

Keywords: Mathematical modeling, Climate change, Forest ecosystems, Tree mortality, Restoration ecology

Abstract: Climate change affects forest ecosystems worldwide in multiple ways, with vary ing impacts on forest structure and health, and causes the decline of endemic species. In the face of accelerating warming and human pressures, these ecosystems require urgent actions for reforestation, protection, and sustainable management.

In this work, we first model the impact of climate change on forest ecosystems, particularly the effect of warming on tree mortality. In general, for a given species, we identified a temperature range corresponding to its preferred conditions for growth and regeneration, depending on its characteristics and thermal tolerance.

Plant–plant interactions, particularly the role of facilitator species, are crucial for the conser vation of endemic plants, especially in arid and semi-arid regions. To restore a degraded ecosys tem, a natural and effective approach consists of active regeneration via a facilitator species. Therefore, we modeled the introduction of such an enriching species into the forest, capable of promoting the regeneration of endemic species and contributing to ecosystem restoration. Fi nally, we perform a stability and bifurcation analysis to study the conditions required to ensure a sustainable transition toward a restored ecosystem.

Poster 38. Cosserat equation and modelling of snake locomotion

Speaker: **Eliot Thys**

Affiliation: Laboratoire des signaux et systèmes – Centre National de la Recherche Scientifique, CentraleSupélec, Université Paris-Saclay – France

Keywords: Cosserat equation, control theory, partial differential equation, mechanics

Abstract: The Cosserat equations provide a mechanical description of beams that can be used to model elongated animals such as snakes or eels. These equations have been used in robotics to design bio-inspired robotic models with applications ranging from medicine to industry. Casting the Cosserat equations as an infinite-dimensional control system, a dynamical system with an input function called control, is a promising idea to address questions pertaining to biological and robotic locomotion. For instance, whether it is possible for some actuated Cosserat rod to achieve the characteristic follow-the-leader motion (the body follows the trajectory of the head). To ensure the theoretical validity of the framework, this relies first on mathematical analysis of

the Cosserat equations, which are represented by a system of nonlinear hyperbolic partial differential equations. For such systems, existence, uniqueness and regularity of solutions is not always guaranteed.

Therefore in this talk, I will present the Cosserat equations through a Lagrangian formalism on Lie groups. This new description, combining mechanical and geometrical points of view, allows for a concise formulation of the locomotion problem and provides results on the existence of solutions to the Cosserat equations. Finally, I will present future directions concerning the controllability of snake-inspired robots.

Poster 39. Modelling and contact control of slender locomotors - Applications to bio-inspired robotics

Speaker: **Lucas Vaudron**

Affiliation: Robotique Et Vivant – Laboratoire des Sciences du Numérique de Nantes – France

Keywords: Contrôle, Bio, inspiration, Robotique, Locomoteur

Abstract: In this presentation, we will talk about the modeling for control purposes of a slender locomotor driven by contact forces. This type of locomotor has been the subject of increasing attention in recent years due to its remarkable adaptability and energy efficiency, as observed in natural slender organisms such as snakes. Although the topic is not new, a theoretical mathematical model that can capture and explain the complex gaits observed in nature — and that roboticists attempt to reproduce in laboratory settings — has yet to be fully developed, particularly regarding contact modeling. In this presentation, we aim to take a first step in this direction by considering a locomotor moving in a plane, modeled as a discrete system. We derive an affine control system that governs the locomotor's motion. We first focus on the controlability of the system : using available commands, what states can be reached from a given initial state ? We present some results in the one-dimensionnal case before outlining the future challenges we intend to address.

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Inria ; IFP Energies nouvelles, 1-4 Av. du Bois Préau, 92852 Rueil-Malmaison, France

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Ellipsoidal Small Sets for Multivariate Time Series

Institut Mathématique de Marseille (I2M), Aix-Marseille Université

Manganaw N'daam (p. 85)

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Robust Wavelet-Based Methods for Long-Memory Time Series: Asymptotic Analysis of the NKK Periodogram

Statistique, Analyse et Modélisation Multidisciplinaire (SAmos-Marin Mersenne) – Université Paris 1 Panthéon-Sorbonne – France

Hajar Nafia (p. 81)

Poster 18

The Contribution of Solving Linear Complementarity Problems and Applications to the Valuation of American Options

Laboratoire d'Analyse, Modélisation et Simulation, Faculté des Sciences Ben M'Sik – Morocco

David Nahmani (p. 45)

Talk: Tuesday, March 3, 4:00 PM - 5:30 PM; B 102

Optimal Dirac controls for time-periodic bistable ODEs, application to population replacement

Laboratoire Analyse, Géométrie et Applications – Université Sorbonne Paris nord, Université Sorbonne Paris nord : UMR7539 – France

Nassim En-Nebbazi (p. 26)

Talk: Tuesday, March 3, 9:00 AM - 10:30 AM; B 103

Error Analysis for Stochastic Optimization Schemes

Laboratoire de Mathématiques et de leurs Applications [Pau] – Université de Pau et des Pays de l'Adour – France

Ilham Ouelddris (p. 73)

Poster 6

Logarithmic Convexity and impulse Approximate Controllability for Degenerate Parabolic Equations with Robin Boundary Conditions

Faculty of Sciences Semlalia – Bd Prince Moulay Abdellah, Marrakesh, Morocco., Morocco

Alexandre Pasco (p. 49)

Talk: Tuesday, March 3, 4:00 PM - 5:30 PM; Amphi Cauchy

Random sketching of operators and application to learning preconditioners for model order reduction

Nantes Université - École Centrale de Nantes – Nantes Université – France ; Laboratoire de Mathématiques Jean Leray – Centre National de la Recherche Scientifique, Nantes université - UFR des Sciences et des Techniques – France

Martin Oen Paulsen (p. 22)

Talk: Tuesday, March 3, 9:00 AM - 10:30 AM; B 102

On the Fritz John problem for a freely floating object

Université de Bordeaux – IMB (Institut de Mathématiques de Bordeaux) – France

Julien Pierrat (p. 93)

Poster 35

An Immersed Boundary Method Based on Penalized Direct Forcing with Immersed Wall Functions using RANS k-omega SST Modeling for Nuclear Safety Device Simulations

Laboratoire d'études et de modélisations des systèmes – Cea Cadarache – France

Soukaina Ben Rhila (p. 87)

Poster 26

Optimal control of a phytoplankton-zooplankton spatiotemporal discrete bioeconomic model

Department of Mathematics and Computer Science, Faculty of Sciences Ben M'Sik, – Morocco ; Laboratory of Analysis Modelling and Simulation, Department of Mathematics and Computer Science, Faculty of Sciences Ben M'Sik, – Morocco

Camille Richer (p. 18)

Talk: Monday, March 2, 4:00 PM - 5:30 PM; B 05

On the Computational Complexity of Covering Multi-Interface Networks

Université Paris Dauphine-PSL – Université Paris sciences et lettres – France ; Orange Labs [Chatillon] – Orange Labs – France

Orlane Rossini (p. 82)

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Model-based reinforcement learning for controlling piecewise deterministic semi-Markov processes partially observed

Institut Montpelliérain Alexander Grothendieck – Centre National de la Recherche Scientifique, Université de Montpellier – UMR CNRS 5149 - Université Montpellier 2, Case courrier 051, 34095 Montpellier cedex 5 - France, France

Rachel Roux (p. 94)

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Investigating the use of the Discrete Quantum Walk to solve Combinatorial Optimization Problems

ENSTA, IP-Paris

Mohamadou Salifou (p. 83)

Poster 22

Cyclists route choice modeling in urban areas : a mode-constrained mixture approach

Laboratoire Interdisciplinaire Solidarités, Sociétés, Territoires – École des Hautes Études en Sciences Sociales, Université Toulouse - Jean Jaurès, École Nationale Supérieure de Formation de l'Enseignement Agricole de Toulouse-Auzeville, Institut national universitaire Champollion, Centre National de la Recherche Scientifique – France

Agustin Somacal (p. 36)

Talk: Tuesday, March 3, 11:00 AM - 12:30 PM; B 103

Natural gradient descent with momentum for physics informed learning

Nantes Université – Laboratoire de Mathématiques Jean Leray – France ; Ecole Central de Nantes – Ecole Central de Nantes – France

Gouled Souleiman (p. 95)

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Mathematical modeling of active regeneration via a facilitator species strategy: stability and bifurcations

Laboratoire de Mathématiques Appliquées du Havre – Université Le Havre Normandie, France. – France ; Laboratoire d'Analyse, de Modélisation et d'Optimisation – Djibouti

Idaamar Soumaya (p. 84)

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Application of Some Machine Learning Algorithm to Electrical Impedance Tomography

Hassan I University of Settat, Morocco – Morocco

Thibault De Surrel (p. 76)

Poster 10

Wrapped Gaussian on Hadamard manifolds

Laboratoire dánalyse et modélisation de systèmes pour láide à la décision – Centre National de la Recherche Scientifique : UMR7243 / FRE3234 / UMR7024, Université Paris Dauphine-PSL, Centre National de la Recherche Scientifique : UMR7024, Centre National de la Recherche Scientifique – France

Gauthier Thurin (p. 56)

Talk: Tuesday, March 3, 4:00 PM - 5:30 PM; B 202

Sliced transport maps

ENS - CNRS – École normale supérieure - Paris – France

Eliot Thys (p. 95)

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Cosserat equation and modelling of snake locomotion

Laboratoire des signaux et systèmes – Centre National de la Recherche Scientifique, CentraleSupélec, Université Paris-Saclay – France

Manon De La Tousche (p. 46)

Talk: Tuesday, March 3, 4:00 PM - 5:30 PM; B 102

Optimal spatial control strategies for pest/vector elimination by the Sterile Insect Technique in n-patch systems.

Compréhension mathématique multi-échelles d'écosystèmes vivants complexes avec structures émergentes – Centre Inria de Paris, Laboratoire Jacques-Louis Lions – France ; Botanique et Modélisation de l'Architecture des Plantes et des Végétations – Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Centre National de la Recherche Scientifique, Institut de Recherche pour le Développement, Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement, Université de Montpellier – France

Ernesto Treumún (p. 56)

Talk: Tuesday, March 3, 4:00 PM - 5:30 PM; B 202

State-Constrained Optimal Control on Wasserstein Spaces of Riemannian Manifolds

École Nationale Supérieure de Techniques Avancées – Institut Polytechnique de Paris – France

Eliot Tron (p. 36)

Talk: Tuesday, March 3, 11:00 AM - 12:30 PM; B 103

The geometry of neural networks: a Riemannian foliation perspective on robustness.

Statistique, Analyse et Modélisation Multidisciplinaire (SAmos-Marin Mersenne) – Université Paris 1 Panthéon-Sorbonne – France

Lucas Vaudron (p. 96)

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Modelling and contact control of slender locomotors - Applications to bio-inspired robotics

Robotique Et Vivant – Laboratoire des Sciences du Numérique de Nantes – France

Aurélien Velleret (p. 42)

Talk: Tuesday, March 3, 11:00 AM - 12:30 PM; B 05

Metastability between the clicks of the Muller ratchet

LaMME, Université d'Evry

Julien Weibel (p. 27)

Talk: Tuesday, March 3, 9:00 AM - 10:30 AM; B 103

Optimized projection-free algorithms for online learning: construction and worst-case analysis

SIERRA - Inria Paris – Département d'informatique - ENS-PSL, Centre National de la Recherche Scientifique, Centre Inria de Paris – France

Elise Bonnet Weill (p. 75)

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A reduced-order model for parametrized optimal transport problems.

CERMICS – Ecole Nationale des Ponts et Chaussées – France

Sagbo Mélain Zinsou (p. 35)

Talk: Tuesday, March 3, 11:00 AM - 12:30 PM; B 102

On the analysis and numerical solving of a fluid-structure toy problem.

Mathématiques Appliquées Paris 5 – Institut National des Sciences Mathématiques et de leurs Interactions - CNRS Mathématiques, Centre National de la Recherche Scientifique, Université Paris Cité – France