Conference on
Control of PDE and related topics,
Booklet of abstract

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Institut de Mathématiques de Toulouse
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1 Talks - titles and abstracts

Karine Beauchard *(ENS Rennes, France)* Email: karine.beauchard@ens-rennes.fr.

Control theory and splitting methods

Abstract: Our goal is to highlight some of the deep links between numerical splitting methods and control theory. We consider evolution equations of the form $x' = f_0(x) + f_1(x)$, where f_0 encodes a non-reversible dynamic, so that one is interested in schemes only involving forward flows of f_0. In this context, a splitting method can be interpreted as a trajectory of the control-affine system $x'(t) = f_0(x(t))+u(t)f_1(x(t))$, associated with a control u which is a finite sum of Dirac masses. The general goal is then to find a control such that the flow of $f_0+u(t)f_1$ is as close as possible to the flow of f_0+f_1. Using this interpretation and classical tools from control theory, we revisit well-known results concerning numerical splitting methods, and we prove a handful of new ones, with an emphasis on splittings with additional positivity conditions on the coefficients. First, we show that there exist numerical schemes of any arbitrary order involving only forward flows of f_0 if one allows complex coefficients for the flows of f_1. Equivalently, for complex-valued controls, we prove that the Lie algebra rank condition is equivalent to the small-time local controllability of a system. Second, for real-valued coefficients, we show that the well-known order restrictions are linked with so-called "bad" Lie brackets from control theory, which are known to yield obstructions to small-time local controllability. We use our recent basis of the free Lie algebra to precisely identify the conditions under which high-order methods exist.

This is a joint work with Adrien Laurent and Frédéric Marbach.

Muriel Boulakia *(Versailles - Saint Quentin, France)* Email: muriel.boulakia@uvsq.fr.

Sequential approach for the identification of a source in the wave equation

Abstract: In this talk, we are interested in the identification of a source in the wave equation from velocity or field measurements. We present a reconstruction method based on an observer and we analyze this method. In particular, with the help of adapted Carleman estimates, we estimate the associated reconstruction error with respect to the noise intensity. The proposed method is then illustrated with numerical simulations.

This work is in collaboration with Maya de Buhan, Tiphaine Delaunay, Sébastien Impériale and Philippe Moireau.

Erik Burman *(UCL, London, United Kingdom)* Email: e.burman@ucl.ac.uk.

Computational Unique Continuation

Abstract: The problem of extending measured data from a limited observation region to a larger domain, subject to a governing partial differential equation (PDE), is known as a unique continuation problem. Such problems arise frequently in data assimilation, inverse problems and control theory. They are typically **severely ill-posed**, making their accurate numerical approximation particularly challenging.

In this talk, we present recent advances in the finite element approximation of unique continuation problems. We place special emphasis on the interplay between **physical stability** (inherent to the PDE) and **numerical stability** (introduced by discretisation). This tension motivates a critical reassessment of classical approaches, such as Tikhonov regularisation applied at the continuous level prior to discretisation.

We introduce a novel computational framework that integrates numerical stability with the conditional stability of the underlying physical problem. This approach yields approximations that are provably optimal under certain conditions. We conclude by exploring several variants and applications of the method, supported by computational illustrations.

Nicolas Burq *(Orsay, France)* Email: nicolas.burq@universite-paris-saclay.fr.

Observability on measurable sets of Schrödinger equations on tori

Abstract: I will present in this talk some new results on the study of the control of Schrödinger equations on tori of arbitrary dimension, with controls acting on a large class of measurable sets. In particular, we obtain the first result of control of a dispersive PDE with controls acting on measurable time sets. I will give in this talk a general introduction to such questions, then will discuss the specifics of the torus geometry and give a flavor of the proof of our results.

Joint work with Hui Zhu, New York University Abu Dhabi.

Piermarco Cannarsa *(Rome, Italy)* Email: cannarsa@mat.uniroma2.it.

Domain invariance for nonlinear diffusion models

Abstract: In the paper [*An optimal partition problem for eigenvalues*, Journal of scientific Computing 31 (2007), 1-2, pp. 5–18], Caffarelli and Lin constructed a bilinear control that keeps the norm of the linear heat flow on a bounded domain constant in time. The construction consists of taking a suitable nonlocal feedback: this problem has therefore clear connections with domain invariance for nonlinear diffusion equations with nonlocal terms.

In this talk, we will discuss abstract evolution equations in Hilbert and Banach spaces, for which we will give necessary and sufficient conditions for the invariance of a space domain. Then, we will apply these results to concrete PDE models that generalize the one studied by Caffarelli and Lin. In particular, we will show how the addition of nonlocal terms, allows to force the flow of nonlinear heat equations and the Navier-Stokes system to remain in specific space domains such as a sphere or a hyperplane in the configuration space.

Anna Doubova *(Sevilla, Spain)* Email: doubova@us.es.

Geometric Inverse Problems for PDE's: uniqueness and reconstruction

Abstract: This conference delves into geometric inverse problems for partial differential equations, aiming to identify subdomains within multidimensional sets. We will explore two crucial aspects: uniqueness and numerical reconstruction. Several geometric inverse problems will be considered, some involving unknown initial data. Our primary focus will be on linear parabolic systems where the non-homogeneous part of the equation is expressed as a function of separate space and time variables. We establish uniqueness results

by incorporating observations from the boundary or an interior domain, thereby deriving information about the initial data. The main tools for the proofs include unique continuation, time analyticity of solutions, and semigroup theory. Additionally, we will present some numerical results for reconstructing the unknown domain.

Philippe Jaming *(Bordeaux, France)* Email: philippe.jaming@math.u-bordeaux.fr.

Observability of the 1D Schrödinger equation along space-time curves

Abstract: In this talk, we consider the 1D free periodic fractional Schrödinger equation

$$\partial_t u = (-\partial_x)^s u = 0$$

with initial data $u(0,x) = u_0(x)$ in $L^2(\mathbb{T})$. We prove that this equation is observable from certain curves $x = \gamma(t)$, $0 < t < T$.

When the curves are straight lines, this is based on Ingham Inequalities and is joint work with V. Komornik. For more general curves, we use different techniques based on stationary phase estimates and is ongoing work with B. Haak, M. Wang and Y. Wang.

Karl Kunisch *(Graz, Austria)* Email: karl.kunisch@uni-graz.at.

Solving the Hamilton Jacobi Bellman equation of optimal control: towards taming the curse of dimensionality

Abstract: The characterization of optimal feedback for nonlinear dynamical systems involves solving a Hamilton-Jacobi-Bellman equation. This is a nonlinear first order hyperbolic equation in a space whose dimension is that of the state-space of the underlying system. Thus solving this system in practice one is confronted with a curse of dimensionality.

In this talk we present techniques which either, in part, circumvent the necessity of solving the HJB equations directly, or use system reduction techniques to alleviate the difficulty associated with high dimensions. Specifically, we briefly describe experience with a succinct use of policy iteration, we introduce a data-driven technique which exploits higher order information, and we explain the 'Averaged Feedback Learning Scheme'. - Frequently the solution to the HJB equation is semi-concave. This motivates the last point in our talk: an approximation scheme which is structure preserving.

This is joint work with Behzad Azmi, Uni-Konstanz; S. Dolgov, Uni-Bath; Donato Vaquez-Varas, Radon Institute, Austrian Academy of Sciences; and Daniel Walter, Humboldt University Berlin.

Kévin Le Balc'h *(Paris, France)* Email: kevin.le-balc-h@inria.fr.

The Graph Geometric Control Condition

Abstract: We introduce a novel concept called the Graph Geometric Control Condition (GGCC). It turns out to be a simple, geometric rewriting of many of the frameworks in which the controllability of PDEs on graphs has been studied. We prove that (GGCC) is a necessary and sufficient condition for the exact controllability of the wave equation on metric graphs with internal controls and Dirichlet boundary conditions. We then investigate the internal exact controllability of the wave equation with mixed boundary conditions and the one of the Schrödinger equation, as well as the internal null-controllability of the heat equation. We show that (GGCC) provides a sufficient condition for the controllability of these equations and we provide explicit examples proving that (GGCC) is not necessary in these cases.

Joint work with Kaïs Ammari, Alessandro Duca and Romain Joly.

Jérôme Le Rousseau *(Sorbonne Paris Nord, France)* Email: jlr@math.univ-paris13.fr.

Boundary estimation for the Stokes system

Abstract: Neglecting the inertial term in the Navier–Stokes system leads to the Stokes system. We are interested in observing this system from an interior region of a domain. We consider general boundary conditions that include, for instance, the commonly used Dirichlet, Navier, and Neumann conditions. Observation is achieved through a local Carleman estimate near a boundary point, derived from the full system, including the pressure term. We begin by reviewing how boundary estimates can be obtained for first-order scalar operators. Then, we show how various scalar reductions of the Stokes system can lead to such first-order equations, by means of eigenvectors and generalized eigenvectors.

This is joint work with Luc Robbiano.

Cyril Letrouit *(Orsay, France)* Email: cyril.letrouit@universite-paris-saclay.fr.

Nodal sets of eigenfunctions of sub-Laplacians

Abstract: Nodal sets of eigenfunctions of elliptic operators on compact manifolds have been studied extensively over the past decades. In a joint work with S. Eswarathasan, we initiated the study of nodal sets of eigenfunctions of hypoelliptic operators on compact manifolds, focusing on sub-Laplacians (e.g. on compact quotients of the Heisenberg group). Our results show that nodal sets behave in an anisotropic way which can be analyzed with standard tools from sub-Riemannian geometry such as sub-Riemannian dilations, nilpotent approximation and desingularization at singular points.

Sorin Micu *(Craiova, Romania)* Email: sd_micu@yahoo.com.

Inverse source problems approximation with mixed finite elements

Abstract: We consider an inverse problem for the linear one-dimensional wave equation with variable coefficients consisting in determining an unknown source term from a boundary observation. A method to obtain approximations of this inverse problem using a space discretization based on a mixed finite element method is proposed and analyzed. Its stability and convergence properties relay on a new uniform boundary observability inequality with respect to the discretization parameter. This fundamental uniformity property of the observation is not verified in the case of more usual discretization schemes, such as centered finite differences or classical finite elements. For the mixed finite elements it is proved by combining lateral energy estimates with Fourier techniques.

Joint work with Carlos Castro.

Morgan Morancey *(Marseille, France)* Email: morgan.morancey@univ-amu.fr.

Control of parabolic problems and block moment method

Abstract: The goal of this talk is to give an overview of the block moment method and its applications to the study of null controllability for certain parabolic problems in recent years. I will present the method we developed with Assia Benabdallah and Franck Boyer, starting from the motivations that led to its introduction, and moving on to its application to new classes of parabolic problems. I will also relate the block moment method to know results (Komornik-Loreti, Avdonin-Ivanov) on the hyperbolic setting concerning Riesz bases of divided differences of time exponentials, explain how we extended the method to handle quite general control operators in 1D problems including distributed control and present why it is an important tool in the construction of biorthogonal families in higher-dimensional tensorized settings.

This talk is related to different works in collaboration with F. Ammar Khodja, A. Benabdallah, F. Boyer, M. González-Burgos, M. Mehrenberger and L. de Teresa.

Lassi Paunonen *(Tampere, Finland)* Email: lassi.paunonen@tuni.fi.

Damping and Negative Feedback in Hyperbolic PDEs

Abstract: We study a class of abstract linear systems which can especially be used to represent wave equations and other hyperbolic partial differential equations with damping. Our main interest is in formulating sufficient conditions which guarantee that the energy of the solutions of the system decays to zero asymptotically, and in estimating the decay rate of the energy. In studying both the stability and the existence of solutions of our models we employ a control-theoretic viewpoint which allows us to see the damped system as a closed-loop system arising from an undamped model under negative feedback. This in particular naturally connects the stability analysis of the damped model to the observability properties of the undamped open-loop system. We present recent results on the polynomial and non-uniform stability of the damped system. Finally, we introduce new results on well-posedness and asymptotic stability for a class of nonlinear dampings.

The presentation is based on joint work with R. Chill, A. Hastir, D. Seifert, R. Stahn, Y. Tomilov, and N. Vanspranghe.

Cristina Pignotti *(Aquila, Italy)* Email: cristina.pignotti@univaq.it.

Indirect stabilization of nonlinear coupled wave equations in the presence of time delay effects

Abstract: We consider a system of two wave equations with nonlinear source terms coupled through their velocities. One equation is damped, while the other experiences a pointwise time delay. By reformulating the problem in an abstract framework, we use semigroup theory and energy methods to establish well-posedness and derive conditions guaranteeing exponential energy decay for small initial data.

Camille Pouchol *(Paris Cité, France)* Email: camille.pouchol@u-paris.fr.

Convex-analytic techniques for constrained reachability of linear control problems

Abstract: Even in a linear setting, determining whether a given target is reachable (from a fixed initial condition and at a given final time) can be difficult, especially in the presence of control constraints. I will first discuss the case of bounded convex constraints, introducing a method to establish that a target (or more generally, a set of undesirable states) cannot be reached. The approach relies on a dual functional, explicit fine estimates for time (and possible, space) discretisation errors, and interval arithmetic. I will then present a general recipe tailored to treating (unbounded) conic constraints. I show how it generalises the HUM method; as such, it is constructive and provides necessary and sufficient conditions for constrained conic convex reachability. Furthermore, it can be used to tackle nonconvex conic constraints as well, upon relaxation. Throughout the talk, I will highlight how these techniques heavily rely on convex analytic machinery. Examples of applications will be both finite and infinite-dimensional.

The presentation is based on collaborations with Ivan Hasenohr, Yannick Privat, Emmanuel Trélat and Christophe Zhang.

Manuel Rissel *(Shanghaï, China)* Email: manuel.rissel@nyu.edu.

Incompressible fluids driven by degenerate forces

Abstract: Approximate controllability via degenerate controls illustrates a mechanism that propagates a class of forces having only few degrees of freedom to a dense set in the state space. A prominent example are finite-dimensional controls, which belong at each time to a universal finite-dimensional function space. In this context, it is a well-known open problem whether the Navier—Stokes system driven by finite-dimensional and physically localized controls is approximately controllable. In my talk, I will present recent progress in this

direction.

Chenmin Sun *(Créteil, France)* Email: chenmin.sun@cnrs.fr.

New geometric condition for the observability of the Schrödinger equations with magnetic potential on two-dimensional torus.

Abstract: In this talk, we consider the observability problem for the Schrödinger equation on the two-dimensional torus, subject to a first-order perturbation by a magnetic potential. This situation turns out to be dramatically different from the case of the Schrödinger equation with a purely electric potential. More precisely, there is a sufficient and almost necessary geometric control condition for the electromagnetic Schrödinger equation that goes beyond the classical geometric control condition established by Lebeau for the Schrödinger equation. Under this new geometric condition, the high-frequency observability result holds on the semiclassical timescale $O(h^{-3/2})$, much shorter than the $O(h^{-2})$ timescale required for the purely electric Schrödinger operator observed from any nonempty measurable set.

This talk is based on joint work with Kévin Le Balc'h and Jingrui Niu.

Takéo Takahashi *(Nancy, France)* Email: takeo.takahashi@inria.fr.

A Global Carleman inequality for the Oseen system

Abstract: We establish a new Carleman inequality for the Oseen system, using weight functions analogous to the corresponding ones for the heat equation. As a consequence, we obtain the null-controllability of the Oseen system, with a cost of the control of the form $Ce^{C/T}$.

The core of our analysis lies in a careful estimate of the pressure on the boundary. To this end, we decompose the pressure into low- and high-frequency parts. The low-frequency part is treated using weighted estimates obtained via microlocal analysis, while the high-frequency part is analyzed through some energy estimates for the Stokes system.

This is a joint work with Rémi Buffe (Université de Lorraine).

Emmanuel Trélat *(Paris, France)* Email: emmanuel.trelat@sorbonne-universite.fr.

Controllability properties of coupled PDEs

Abstract: In a series of works with Hugo Lhachemi and Christophe Prieur, we investigate the controllability properties of some coupled PDEs, which can be of different natures. For a heat-wave PDE with coupling at the boundary, we establish exact, exact null and approximate controllability in appropriate Hilbert spaces, under sharp assumptions. Our approach relies on an Ingham-Müntz inequality, allowing us to establish an observability inequality for the dual problem. The resulting controllability space, which depends on the coupling function and is characterized in a spectral way, is not a conventional functional space. If time allows, I will also give some results for other cascade systems, providing new results for coupled heat equations where interesting changes happen at some specific times in the controllability properties.

Cristina Urbani *(Rome, Italy)* Email: cristina.urbani@unimercatorum.it.

Small-time bilinear control for a class of nonlinear parabolic evolution equations

Abstract: In this talk, I will present some recent results on small-time reachability properties of a nonlinear parabolic equation, controlled via a bilinear control, defined on a torus of arbitrary dimension. Assuming a saturation condition on the potentials, we establish the small-time approximate controllability between states that share the same sign. Furthermore, in the one-dimensional case, we extend this result by combining

it with a local exact controllability property. This approach allows us to demonstrate the small-time exact controllability of any positive state to the ground state of the evolution operator.

This is a joint work with A. Duca and E. Pozzoli.

Julie Valein *(Nancy, France)* Email: julie.valein@univ-lorraine.fr.

Carleman-based reconstruction algorithm on a wave network

Abstract: In this talk, we are interested in an inverse problem set on a tree shaped network where each edge behaves according to the wave equation with potential, external nodes have Dirichlet boundary conditions and internal nodes follow the Kirchoff law. The main goal is the reconstruction of the potential everywhere on the network, from the Neumann boundary measurements at all but one external vertices. Leveraging from the Lipschitz stability of this inverse problem, we aim at providing an efficient reconstruction algorithm based on the use of an appropriate global Carleman estimate.

This is a joint work with Lucie Baudouin, Maya de Buhan and Emmanuelle Crépeau.

Shengquan Xiang *(Beijing, China)* Email: shengquan.xiang@pku.edu.cn.

Controlled flow of geometric maps

Abstract: In collaboration with J.-M. Coron and J. Krieger, we have recently initiated a study on the controlled dynamics of geometric evolution equations, focusing in particular on wave maps and heat maps. By introducing localized control forces into these systems, we explore fundamental questions of global controllability and stabilization. Our approach highlights the rich interplay between geometric analysis, partial differential equations, and control theory. Remarkably, due to the intrinsic geometric structure of the problem, we establish fast global controllability between homotopic steady states. This contrasts with the longstanding open problem concerning analogous questions for nonlinear heat equations.

2 Short talks - titles and abstracts

Sue Claret *(Clermont-Ferrand, France)* Email: sue.claret@uca.fr.

Exact boundary controllability of semilinear wave equations

Abstract: In this talk, we adress the exact controllability of the semilinear wave equation $\partial_{tt}y-\Delta y+f(y)=0$ posed over a bounded domain Ω of $\mathbb{R}^d$ with initial data in $L^2(\Omega)\times H^{-1}(\Omega)$. We focus on the existence of a Dirichlet boundary control for the equation under a growth condition at infinity on the nonlinearity f of the type $r\ln^p r$, with $p\in[0,3/2)$. This result is based on a Schauder fixed-point argument. Then, assuming additional assumptions on f', we consider the approximation of a control function.

This is a joint work with Arnaud Münch and Jérôme Lemoine.

Cristobal Loyola *(Paris, France)* Email: cristobal.loyola@sorbonne-universite.fr.

Global propagation of analyticity and unique continuation for semilinear waves

Abstract: In this talk, we explore the global propagation of analyticity and unique continuation for solutions to the semilinear wave equation with analytic nonlinearity. We begin by discussing how an analyticity-in-time regularization can be achieved in a finite-time setting for solutions that vanish on a small subset satisfying the Geometric Control Condition (GCC). The proof combines tools from control theory with ideas due to Hale and Raugel on the regularity of attractors in dynamical systems. We then examine a consequence of this

result: a unique continuation property under the natural GCC. If time permits, we will emphasize that the finite-time analyticity regularization was actually obtained in an abstract framework, allowing us to explore similar results for other PDEs.

These results are part of a joint work with C. Laurent (CNRS, LMR).

Guillaume Olive *(Krakow, Poland)* Email: math.golive@gmail.com.

A method to determine the minimal null control time of 1D linear hyperbolic systems

Abstract: In this talk we present a method to find the minimal control time for the null controllability of 1D first-order linear hyperbolic systems by one-sided boundary controls when the coefficients are regular enough.

This presentation is based on a joint work with Long Hu (https://doi.org/10.1016/j.jde.2025.113455).

Hugo Parada *(Toulouse, France)* Email: hugo.parada@math.univ-toulouse.fr.

Boundary observation of the KdV equation on graphs

Abstract: We investigate the exact controllability of a system of N linear KdV equations posed on a star-shaped graph. Using a combination of Dirichlet and Neumann boundary controls, we analyze observability properties. In certain configurations, observability holds for all lengths L¿, while in others it fails on a specific set of critical lengths. This behavior is linked to the spectral properties of the associated linear operator.

This is joint work with R. A. Capistrano-Filho and J. S. da Silva.

Nicolas Vanspranghe *(Tampere, Finland)* Email: nicolas.vanspranghe@tuni.fi.

Optimal stabilization rate for the wave equation with hyperbolic boundary condition

Abstract: Consider linear waves on a bounded domain in the following setting. One part of the boundary is governed by a coupled lower-dimensional wave equation (i.e., dynamic Ventcel/Wentzell boundary condition) and is subject to viscous damping. The other (possibly empty) part is left at rest. When the dynamic boundary geometrically controls the domain, we show that the total energy of classical solutions decays like 1/t. The proof relies on an analysis of high-frequency quasimodes, suitable boundary estimates obtained in different microlocal regimes, and a special decoupling argument. Optimality is assessed via an appropriate quasimode construction.

Ongoing work with Hugo Parada (Institut de Mathématiques de Toulouse).

Yunlei Wang *(Bordeaux, France)* Email: yunlei.wang@math.u-bordeaux.fr.

Observability of Schrödinger equations on abelian covers of hyperbolic surfaces

Abstract: We present observability of Schrödinger equations on abelian covers of hyperbolic surface. The observability of the Schrödinger equation from periodic open sets on $\mathbb{R}^2$ is given by the observability results on the 2-dimensional torus through bloch transform, which was done by M. Täufer and later extended to measurable sets by K. Le Balc'h and J. Martin. To obtain results on noncompact hyperbolic surface, we use a hyperbolic bloch transform, and establish semiclassical controls on flat bundles over a compact hyperbolic surface.

This is an ongoing work with X. Fu and Y. Gong.

3 Posters - titles

Lucas Davron *(Paris, France)* Email: davron@ceremade.dauphine.fr.

Exact tracking of the 1-d heat equation.

Issa Ibtissam *(L'Aquila, Italy)* Email: ibtissam.issa@univaq.it.

Time-delayed generalized KdV–Burgers equation: well-posedness and exponential decay

Rubén de La Fuente Fernández *(BCAM, Bilbao, Spain)* Email: rdelafuente@bcamath.org.

An optimal fractional Hardy inequality on the discrete half-line

Debanjit Mondal *(Kolkotta, India)* Email: dm20ip005@iiserkol.ac.in.

Global Controllability of Nonlinear Dispersive Equations with Finite-Dimensional Control via Linear Test

Dharmatti Sheetal *(IISER Thiruvananthapuram, India)* Email: sheetal@iisertvm.ac.in.

Separation Property for the Nonlocal Cahn-Hilliard-Brinkman System

Lotfi Thabouti *(Bordeaux, France)* Email: lotfi.thabouti@math.u-bordeaux.fr.

Quantitative unique continuation for non-regular perturbations of the Laplacian.

Anna Valette *(Krakow, Poland)* Email: Anna.Valette@im.uj.edu.pl.

Poincare inequalities on subanalytic sets

Guillaume Valette *(Krakow, Poland)* Email: Guillaume.Valette@im.uj.edu.pl.

PDE's on semi-analytic domains

Zhuo Xu *(Bordeaux, France)* Email: zhuo.xu@math.u-bordeaux.fr.

Global Exponential Stabilization for a Simplified Fluid-Particle Interaction System

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