2025 *Activity Report*

RESEARCH CENTRE: **Inria Paris Centre at Sorbonne University**
IN PARTNERSHIP WITH: **CNRS, Sorbonne Université**

Project-Team

CAGE

Control and Geometry

In collaboration with Laboratoire Jacques-Louis Lions (LJLL)

Project-Team CAGE

Creation of the Project-Team: 2018 August 01

Each year, Inria research teams publish an Activity Report presenting their work and results over the reporting period. These reports follow a common structure, with some optional sections depending on the specific team. They typically begin by outlining the overall objectives and research programme, including the main research themes, goals, and methodological approaches. They also describe the application domains targeted by the team, highlighting the scientific or societal contexts in which their work is situated. The reports then present the highlights of the year, covering major scientific achievements, software developments, or teaching contributions. When relevant, they include sections on software, platforms, and open data, detailing the tools developed and how they are shared. A substantial part is dedicated to new results, where scientific contributions are described in detail, often with subsections specifying participants and associated keywords. Finally, the Activity Report addresses funding, contracts, partnerships, and collaborations at various levels, from industrial agreements to international cooperations. It also covers dissemination and teaching activities, such as participation in scientific events, outreach, and supervision. The document concludes with a presentation of scientific production, including major publications and those produced during the year.

Keywords

Computer sciences and digital sciences

A6. – Modeling, simulation and control

A6.1. – Methods in mathematical modeling

A6.1.1. – Continuous Modeling (PDE, ODE)

A6.4. – Automatic control

A6.4.1. – Deterministic control

A6.4.3. – Observability and Controlability

A6.4.4. – Stability and Stabilization

A6.4.5. – Control of distributed parameter systems

A6.4.6. – Optimal control

Other research topics and application domains

B2. – Digital health

B2.6. – Biological and medical imaging

B4.2.2. – Fusion

B5.2.4. – Aerospace

B5.11. – Quantum systems

Contents

1 Team members, visitors, external collaborators

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- Ugo Boscain [CNRS, HDR]
- Barbara Gris [CNRS, Researcher]
- Kévin Le Balc'h [INRIA, ISFP]
- Christophe Zhang [Corps des mines, from Apr 2025]

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- Jean-Michel Coron [SORBONNE UNIVERSITE, Professor]
- Ihab Haidar [ENSEA, Associate Professor Delegation, until Aug 2025]
- Emmanuel Trélat [SORBONNE UNIVERSITE, Associate Professor, HDR]

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2 Overall objectives

CAGE's activities take place in the field of mathematical control theory, with applications in several directions: control of quantum mechanical systems, stability and stabilization, in particular in presence of uncertain dynamics, optimal control, and geometric models for vision. Although control theory is nowadays a mature discipline, it is still the subject of intensive research because of its crucial role in a vast array of applications. Our focus is on the analytical and geometrical aspects of control applications.

At the core of the scientific activity of the team is the **geometric control** approach, that is, a distinctive viewpoint issued in particular from (elementary) differential geometry, to tackle questions of controllability, motion planning, stability, and optimal control. The emphasis of such a geometric approach is in intrinsic properties, and it is particularly well adapted to study nonlinear and nonholonomic phenomena [107, 83]. The geometric control approach has historically been associated with the development of finite-dimensional control theory. However, its impact in the study of distributed parameter control systems and, in particular, systems of **controlled partial differential equations** has been growing in the last decades, complementing analytical and numerical approaches by providing dynamical, qualitative, and intrinsic insight [98]. CAGE has the ambition to be at the core of this development.

One of the features of the geometric control approach is its capability of exploiting **symmetries and intrinsic structures** of control systems. Symmetries and intrinsic structures (e.g., Lagrangian or Hamiltonian structures) can be used to characterize minimizing trajectories, prove regularity properties, and describe invariants. The geometric theory of **quantum control**, in particular, exploits the rich geometric structure encoded in the Schrödinger equation to design adapted control schemes and to characterize their qualitative properties.

3 Research program

3.1 Research domain

Our contributions are in the area of **mathematical control theory**, which is to say that we are interested in the analytical and geometrical aspects of control applications. In this approach, a control system is modeled by a system of equations (of many possible types: ordinary differential equations, partial differential equations, stochastic differential equations, difference equations,. . .), possibly not explicitly known in all its components, which are studied in order to establish qualitative and quantitative properties concerning the actuation of the system through the control.

Motion planning is, in this respect, a cornerstone property: it denotes the design and validation of algorithms for identifying a control law steering the system from a given initial state to (or close to) a target one. Initial and target positions can be replaced by sets of admissible initial and final states as, for instance, in the motion planning task towards a desired periodic solution. Many specifications can be added to the pure motion planning task, such as robustness to external or endogenous disturbances, obstacle avoidance or penalization criteria. A more abstract notion is that of **controllability**, which denotes the property of a system for which any two states can be connected by a trajectory corresponding to an admissible control law. In mathematical terms, this translates into the surjectivity of the so-called **end-point map**, which associates with a control and an initial state the final point of the corresponding trajectory. The analytical and topological properties of endpoint maps are therefore crucial in analyzing the properties of control systems.

One of the most important additional objective which can be associated with a motion planning task is **optimal control**, which corresponds to the minimization of a cost (or, equivalently, the maximization of a gain) [135]. Optimal control theory is clearly deeply interconnected with calculus of variations, even if the non-interchangeable nature of the time-variable results in some important specific features, such as the occurrence of **abnormal extremals** [111]. Research in optimal control encompasses different aspects, from numerical methods to dynamic programming and non-smooth analysis, from regularity of minimizers to high order optimality conditions and curvature-like invariants.

Another domain of control theory with countless applications is **stabilization**. The goal in this case is to make the system converge towards an equilibrium or some more general safety region. The main difference with respect to motion planning is that here the control law is constructed in feedback form. One of the most important properties in this context is that of **robustness**, i.e., the performance of the stabilization protocol in presence of disturbances or modeling uncertainties. A powerful framework which has been developed to take into account uncertainties and exogenous non-autonomous disturbances is that of hybrid and switched systems [122, 112, 128]. The central tool in the stability analysis of control systems is that of **control Lyapunov function**. Other relevant techniques are based on algebraic criteria or dynamical systems. One of the most important stability property which is studied in the context of control system is **input-to-state stability** [126], which measures how sensitive the system is to an external excitation.

One of the areas where control applications have nowadays the most impressive developments is in the field of **biomedicine and neurosciences**. Improvements both in modeling and in the capability of finely actuating biological systems have concurred in increasing the popularity of these subjects. Notable advances concern, in particular, identification and control for biochemical networks [120] and models for neural activity [103]. Therapy analysis from the point of view of optimal control has also attracted a great attention [124].

Biological models are not the only one in which stochastic processes play an important role. Stock-markets and energy grids are two major examples where optimal control techniques are applied in the non-deterministic setting. Sophisticated mathematical tools have been developed since several decades to allow for such extensions. Many theoretical advances have also been required for dealing with complex systems whose description is based on **distributed parameters** representation and **partial differential equations**. Functional analysis, in particular, is a crucial tool to tackle the control of such systems [132].

Let us conclude this section by mentioning another challenging application domain for control theory: the decision by the European Union to fund a flagship devoted to the development of quantum technologies is a symptom of the role that quantum applications are going to play in tomorrow's society. **Quantum control** is one of the bricks of quantum engineering, and presents many peculiarities with respect to standard control theory, as a consequence of the specific properties of the systems described by the laws of quantum physics. Particularly important for technological applications is the capability of inducing and reproducing coherent state superpositions and entanglement in a fast, reliable, and efficient way [104].

3.2 Scientific foundations

At the core of the scientific activity of the team is the **geometric control** approach. One of the features of the geometric control approach is its capability of exploiting **symmetries and intrinsic structures** of control systems. Symmetries and intrinsic structures can be used to characterize minimizing trajectories, prove regularity properties and describe invariants. An egregious example is given by mechanical systems, which inherently exhibit Lagrangian/Hamiltonian structures which are naturally expressed using the language of symplectic geometry [94]. The geometric theory of quantum control, in particular, exploits the rich geometric structure encoded in the Schrödinger equation to engineer adapted control schemes and to characterize their qualitative properties. The Lie–Galerkin technique that we proposed starting in [95] builds on this premises in order to provide powerful tests for the controllability of quantum systems defined on infinite-dimensional Hilbert spaces.

Although the focus of geometric control theory is on qualitative properties, its impact can also be disruptive when it is used in combination with quantitative analytical tools, in which case it can dramatically improve the computational efficiency. This is the case in particular in optimal control. Classical optimal control techniques (in particular, Pontryagin Maximum Principle, conjugate point theory, associated numerical methods) can be significantly improved by combining them with powerful modern techniques of geometric optimal control, of the theory of numerical continuation, or of dynamical system theory [131, 123]. Geometric optimal control allows the development of general techniques, applying to wide classes of nonlinear optimal control problems, that can be used to characterize the behavior of optimal trajectories and in particular to establish regularity properties for them and for the cost function. Hence, geometric optimal control can be used to obtain powerful optimal syntheses results and to provide deep geometric insights into many applied problems. Numerical optimal control methods with geometric insight are in particular important to handle subtle situations such as rigid optimal paths and, more generally, optimal syntheses exhibiting abnormal minimizers.

Optimal control is not the only area where the geometric approach has a great impact. Let us mention, for instance, motion planning, where different geometric approaches have been developed: those based on the **Lie algebra** associated with the control system [116, 113], those based on the differentiation of nonlinear flows such as the **return method** [99, 100], and those exploiting the **differential flatness** of the system [102].

Geometric control theory is not only a powerful framework to investigate control systems, but also a useful tool to model and study phenomena that are not *a priori* control-related. Two occurrences of this property play an important role in the activities of CAGE:

- geometric control theory as a tool to investigate properties of mathematical structures;
- geometric control theory as a modeling tool for neurophysical phenomena and for synthesizing biomimetic algorithms based on such models.

Examples of the first type, concern, for instance, hypoelliptic heat kernels [82] or shape optimization [86]. Examples of the second type are inactivation principles in human motricity [88] or neurogeometrical models for image representation of the primary visual cortex in mammals [92].

A particularly relevant class of control systems, both from the point of view of theory and applications, is characterized by the linearity of the controlled vector field with respect to the control parameters. When the controls are unconstrained in norm, this means that the admissible velocities form a distribution in the tangent bundle to the state manifold. If the distribution is equipped with a point-dependent quadratic form (encoding the cost of the control), the resulting geometrical structure is said to be **sub-Riemannian**. Sub-Riemannian geometry appears as the underlying geometry of nonlinear control systems: in a similar way as the linearization of a control system provides local informations which are readable using the Euclidean metric scale, sub-Riemannian geometry provides an adapted non-isotropic class of lenses which are often much more informative. As such, its study is fundamental for control design. The importance of sub-Riemannian geometry goes beyond control theory and it is an active field of research both in differential geometry [115], geometric measure theory [84] and hypoelliptic operator theory [89].

4 Application domains

4.1 First axis: Quantum control

Quantum control is one of the bricks of quantum engineering, since manipulation of quantum mechanical systems is ubiquitous in applications such as quantum computation, quantum cryptography, and quantum sensing (in particular, imaging by nuclear magnetic resonance).

Quantum control presents many peculiarities with respect to standard control theory, as a consequence of the specific properties of the systems described by the laws of quantum physics. Particularly important for technological applications is the capability of inducing and reproducing coherent state superpositions and entanglement in a fast, reliable, and efficient way. The efficiency of the control action has a dramatic impact on the quality of the coherence and the robustness of the required manipulation. Minimal time constraints and interaction of time scales are important factors for characterizing the efficiency of a quantum control strategy. CAGE works for the improvement of quantum control paradigms, especially for what concerns quantum systems evolving in infinite-dimensional Hilbert spaces. The controllability of quantum system is a well-established topic when the state space is finite-dimensional [101], thanks to general controllability methods for left-invariant control systems on compact Lie groups [93, 108]. When the state space is infinite-dimensional, it is known that in general the bilinear Schrödinger equation is not exactly controllable [133]. The Lie–Galerkin technique [95] combines finite-dimensional geometric control techniques and the distributed parameter framework in order to provide the most powerful available tests for the approximate controllability of quantum systems defined on infinite-dimensional Hilbert spaces. Another important technique to the development of which we contribute is **adiabatic quantum control**. Adiabatic approximation theory and, in particular, adiabatic evolution [117, 129, 136] is well-known to improve the robustness of the control strategy and is strongly related to time scales analysis. The advantage of the adiabatic control is that it is constructive and produces control laws which are both smooth and robust to parameter uncertainty [137, 110, 91].

4.2 Second axis: Stability and stabilization

A control application with a long history and still very challenging open problems is **stabilization**. For infinite-dimensional systems, in particular nonlinear ones, the richness of the possible functional analytical frameworks makes feedback stabilization a challenging and active domain of research. Of particular interest are the different types of stabilization that may be obtained: exponential, polynomial, finite-time, . . . Another important aspect of stabilization concerns control of systems with uncertain dynamics, i.e., with dynamics including possibly non-autonomous parameters whose value and dependence on time cannot be anticipated. **Robustification**, i.e., offsetting uncertainties by suitably designing the control strategy, is a widespread task in automatic control theory, showing up in many applicative domains such as electric circuits or aerospace motion planning. If dynamics are not only subject to static uncertainty, but may also change as time goes, the problem of controlling the system can be recast within the theory of switched and hybrid systems, both in a deterministic and in a probabilistic setting. **Switched and hybrid systems** constitute a broad framework for the description of the heterogeneous systems in which continuous dynamics (typically pertaining to physical quantities) interact with discrete/logical components. The development of the switched and hybrid paradigm has been motivated by a broad range of applications, including automotive and transportation industry [125], energy management [118] and congestion control [114]. Even if both controllability [127] and observability [109] of switched and hybrid systems raise several important research issues, the central role in their study is played by uniform stability and stabilizabilization [112, 128]. Uniformity is considered with respect to all signals in a given class, and it is well-known that stability of switched systems depends not only on the dynamics of each subsystem but also on the properties of the considered class of switching signals. In many situations it is interesting for modeling purposes to specify the features of the switched system by introducing **constrained switching rules**. A typical constraint is that each mode is activated for at least a fixed minimal amount of time, called the dwell-time. Our approach to constrained switching is based on the idea of relating the analytical properties of the classes of constrained switching laws (shift-invariance, compactness, closure under concatenation, . . .) to the stability behavior of the corresponding switched systems. One can introduce **probabilistic uncertainties** by endowing the classes of admissible signals with suitable probability measures. The interest of this approach is that probabilistic stability analysis filters out highly ‘exceptional’ worst-case trajectories. Although less explicitly characterized from a dynamical viewpoint than its deterministic counterpart, the probabilistic notion of uniform exponential stability can be studied using several reformulations of Lyapunov exponents proposed in the literature [87, 97, 134].

4.3 Third axis: Motion planning and optimal control

Geometric optimal control allows the development of general techniques, applying to wide classes of nonlinear optimal control problems, that can be used to characterize the behavior of optimal trajectories and in particular to establish regularity properties for them and for the cost function. Hence, geometric optimal control can be used to obtain powerful optimal syntheses results and to provide deep geometric insights into many applied problems. Geometric optimal control methods are in particular important to handle subtle situations such as rigid optimal paths and, more generally, optimal syntheses exhibiting abnormal minimizers.

Although the focus of geometric control theory is on qualitative properties, its impact can also be disruptive when it is used in combination with quantitative analytical tools, in which case it can dramatically improve the computational efficiency. This is the case in particular in **optimal control**. Classical optimal control techniques (in particular, Pontryagin Maximum Principle, conjugate point theory, associated numerical methods) can be significantly improved by combining them with powerful modern techniques of geometric optimal control, of the theory of numerical continuation, or of dynamical system theory [131, 123]. Applications of optimal control theory considered by CAGE concern, in particular, motion planning problems for aerospace (atmospheric re-entry, orbit transfer, low cost interplanetary space missions, . . .) [90, 130].

4.4 Fourth axis: Geometric models for vision and sub-Riemannian geometry

Geometric control theory is not only a powerful framework to investigate control systems, but also a useful tool to model and study phenomena that are not *a priori* control-related. In particular, we use control theory to investigate the properties of sub-Riemannian structures, both for the sake of mathematical understanding and as a modeling tool for image and sound perception and processing . We recall that **sub-Riemannian geometry** is a geometric framework which is used to measure distances in nonholonomic contexts and which has a natural and powerful optimal control interpretation in terms control-linear systems with quadratic cost. Sub-Riemannian geometry turns out to be a powerful tool for studying **geometry of vision**, either from the perspective of the neurogeometrical model of the primary visual cortex inspired by Hubel and Wiesel [105] and proposed by Petitot, Citti and Sarti [119, 96, 121] or from the point of view of pattern matching in the group of diffeomorphisms [85]. Nonholonomic constraints are used in this setting to describe distortions of sets of interconnected objects (e.g., motions of organs in medical imaging).

4.5 Fifth axis: Magnetic confinement in stellarators

Another domain on which the team has been active since before the last evaluation is the **mathematics of magnetic confinement in stellarators**. The latter are toroidal devices whose goal is to achieve nuclear fusion, alternative to tokamaks. In stellarators, the twist in the confining magnetic fields is obtained without inducing any current (contrary to tokamaks), relying instead on a much more complex shape and magnetic field structure. While stellarators are expected to be easier to operate (they can in principle achieve steady-state operation), their design is considerably more challenging to realize. The design of stellarators still faces numerous problems, many of which are highly complex from a mathematical perspective [106]. Our goal is to improve the understanding of the dynamical properties of magnetic fields in toroidal domains at magneto-hydrodynamic equilibrium and to optimize the shape of stellarators in order to get magnetic fields with the best confining properties.

5 Social and environmental responsibility

5.1 Impact of research results

The collaboration with Renaissance Fusion on the topic of magnetic confinement has the objective of accelerating the development of stellarators, which have the potential of producing low-carbon energy with little radioactive waste and abundant fuel.

6 Highlights of the year

Emmanuel Trélat was invited to give a Frontiers in Mathematics Lecture, Hong Kong University, June 2025.

7 New results

7.1 Quantum control: new results

Participants: Ugo Boscain, Bettina Kazandjian, Kévin Le Balc'h, Ruikang Liang, Mario Sigalotti, Emmanuel Trélat.

Let us list here our new results in quantum control theory.

- The work [20], entitled *Good Lie Brackets for classical and quantum harmonic oscillators*, develops new structural results on the Lie algebra generated by harmonic-oscillator Hamiltonians. It identifies classes of “good” Lie brackets that play a central role in controllability analysis for both classical and quantum linear systems.

- The work [28], entitled *Schrödinger eigenfunctions sharing the same modulus and applications to the control of quantum systems*, investigates pairs of eigenfunctions with identical modulus and shows how such structures can be used to design control strategies for quantum dynamics, with implications for inverse problems and quantum identification.

- The work [65], entitled *A meaningful optimal control problem in quantum and classical physics*, proposes an optimal control formulation rooted in physical observability principles. The paper establishes well-posedness results and provides examples showing how meaningful performance criteria arise naturally in both quantum and classical settings.

- The work [34], entitled *Controllability of quantum systems having weakly conically connected spectrum*, proves controllability results for finite-dimensional quantum systems whose spectra satisfy a weak conical connectivity condition. This extends classical Lie-algebraic criteria and gives new tools for systems with spectral degeneracies.
- The work [35], entitled *Ensemble control of n-level quantum systems with a scalar control*, addresses the simultaneous control of a continuum of n-level quantum systems driven by a common scalar field. It provides constructive controllability results and discusses implications for robust manipulation of quantum ensembles.
- The work [71], entitled *Enhancing the controllability of quantum systems via a static field*, shows how adding a suitably chosen static Hamiltonian term can enlarge the effective Lie algebra and thereby improve the controllability of quantum systems. The article provides explicit conditions and illustrative examples.
- The work [45], entitled *Controllability and ensemble control design for quantum systems*, is a comprehensive study of controllability and ensemble-control methods for quantum dynamics. It combines Lie-algebraic criteria, adiabatic arguments, and constructive algorithms, with applications to multi-level systems and robust control.
- The work [41], entitled *An approach to control design for two-level quantum ensemble systems*, introduces a design methodology for controlling ensembles of two-level systems subject to inhomogeneities. The paper develops control laws ensuring uniform performance across the ensemble and analyzes their robustness.

7.2 Magnetic confinement in stellarators: new results

Participants: Ugo Boscain, Wadim Gerner.

Let us list here our new results on magnetic confinement in stellarators.

- The work [27], entitled *Charged particle motion in a strong magnetic field: Applications to plasma confinement*, provides a detailed analysis of charged-particle dynamics in the strong-field regime. By deriving accurate asymptotic models and characterizing effective drift motions, the paper contributes to a better understanding of confinement mechanisms in magnetized plasmas, with direct applications to the study and design of stellarators.
- The work [60], entitled *Kernel and image of the Biot-Savart operator and their applications in stellarator designs*, investigates the functional-analytic properties of the Biot–Savart operator relevant for magnetic-field generation. The characterization of its kernel and image leads to new insights into the degrees of freedom available in magnetic-field shaping, offering mathematical tools applicable to the optimization and geometric design of stellarators.

7.3 Stability and stabilization: new results

Participants: Kala Agbo Bidi, Jean-Michel Coron, Ihab Haidar, Kévin Le Balc'h, Rayane Mouhli, Mario Sigalotti, Emmanuel Trélat.

Let us list here our new results about stability and stabilization of control and hybrid systems.

- The work [72], entitled *Stabilizability with bounded feedback for analytic linear control systems*, establishes conditions guaranteeing stabilizability by bounded control laws in the analytic setting. The paper clarifies the relation between analytic structure, spectral constraints, and achievable closed-loop decay rates.

- The work [17], entitled *Global stabilization of a Sterile Insect Technique model by feedback laws*, analyzes a nonlinear population-dynamics model arising in Sterile Insect Technique strategies. It proposes explicit stabilizing feedback laws ensuring the eradication of the wild population under biologically meaningful assumptions.
- The work [48], entitled *Feedback stabilization for a spatial-dependent Sterile Insect Technique model with Allee Effect*, extends stabilization results to a spatially distributed PDE model incorporating an Allee effect. The article provides sufficient conditions and constructive feedback designs guaranteeing global asymptotic stabilization.
- The work [44], entitled *Feedback stabilisation of a sterile insect control system: Applications to mosquito-borne disease control*, offers a comprehensive study of feedback-based stabilization strategies for sterile insect models, combining PDE and ODE frameworks, with applications to mosquito population control and vector-borne disease mitigation.
- The work [23], entitled *Exponential stability of linear periodic difference-delay equations*, develops new criteria for exponential stability in linear systems combining periodicity and delay effects. The results allow for precise characterization of the spectral properties ensuring uniform decay.
- The work [42], entitled *Dynamics and Stability of Continuous-Time Switched Linear Systems*, provides a systematic analysis of stability properties for continuous-time switched linear systems. It characterizes dynamical behaviors under arbitrary, constrained, or optimized switching, with emphasis on Lyapunov and spectral criteria.
- The work [54], entitled *Stability characterization of impulsive linear switched systems*, studies linear systems subject to both switching and impulsive effects. It establishes conditions for stability and boundedness, revealing interactions between impulsive actions, switching signals, and system matrices.
- The work [61], entitled *Stability criteria for hybrid linear systems with singular perturbations*, examines hybrid systems involving multiple time scales and discontinuities. The article provides stability criteria capturing the combined influence of switching, fast–slow dynamics, and perturbation parameters.
- The work [40], entitled *Sampled-data global asymptotic stabilization of globally Lipschitz retarded switched systems*, derives stabilizing sampled-data feedback laws for a large class of switched systems with delays. The results guarantee global asymptotic stability under mild Lipschitz and switching assumptions.
- The work [69], entitled *Boundary output feedback stabilization of a cascade of N heat equations*, proposes an output-feedback law achieving exponential stabilization of a multi-equation heat cascade through boundary measurements only. The approach relies on tailored Lyapunov functionals and backstepping constructions.
- The work [66], entitled *Optimal dynamical stabilization*, introduces a framework for designing stabilizing controls that are optimal with respect to dynamical performance criteria. The article connects stabilization, optimality, and energy shaping through a unified variational perspective.
- The work [74], entitled *Decoupling actions of finite-dimensional groups of diffeomorphisms in the large deformation framework*, investigates stability and decoupling phenomena for group actions in large-deformation models. It provides structural and geometric insights relevant for stabilization in nonlinear shape analysis problems.
- The work [24], entitled *The usefulness of viscosity for the robustness of boundary feedback control of an unstable fluid flow system*, shows how adding viscosity terms enhances robustness properties of boundary-feedback controllers in fluid-flow models. The study quantifies the stabilizing effect of dissipative mechanisms.
- The work [22], entitled *Lyapunov Exponents of Linear Switched Systems*, analyzes the Lyapunov spectrum of linear switched systems under various switching rules. It provides new formulas and bounds for Lyapunov exponents, offering deeper insight into stability mechanisms for switched dynamics.

7.4 Controllability, observability, and motion planning: new results

Participants: Jean-Michel Coron, Bettina Kazandjian, Kévin Le Balc'h, Jingrui Niu, Mario Sigalotti, Emmanuel Trélat.

Let us list here our new results on controllability, observability, and motion planning.

- The work [77], entitled *Observability and controllability for Schrödinger equations in the semi-periodic setting*, develops new observability and controllability results for Schrödinger dynamics on semi-periodic domains. The analysis combines Fourier decomposition techniques with refined propagation estimates.
- The work [67], entitled *Geometric condition for the observability of electromagnetic Schrödinger operators on* $\mathbb{T}^2$, establishes a geometric condition ensuring observability for Schrödinger equations with electromagnetic potentials on the two-dimensional torus. The result extends classical geometric control principles to the magnetic setting.
- The work [59], entitled *Control of blow-up profiles for the mass-critical focusing nonlinear Schrödinger equation on bounded domains*, investigates how controls can influence blow-up dynamics in the mass-critical NLS. The article describes mechanisms allowing one to modify or steer blow-up profiles through appropriately chosen forcing.
- The work [33], entitled *Quantitative propagation of smallness and spectral estimates for the Schrödinger operator*, provides new quantitative results on propagation of smallness for Schrödinger eigenfunctions. These yield refined spectral estimates with implications for observability and control.
- The work [49], entitled *The Graph Geometric Control Condition*, introduces a graph-theoretic interpretation of geometric control conditions for PDEs. It provides a unified framework for understanding how geometric propagation interacts with control and observation regions.
- The work [29], entitled *Global controllability and stabilization of the wave maps equation from a circle to a sphere*, proves global controllability and stabilization results for the wave maps equation in a one-dimensional geometric setting. The analysis relies on the interplay between energy methods and geometric properties of the target manifold.
- The work [30], entitled *Global controllability to harmonic maps of the heat flow from a circle to a sphere*, establishes global controllability toward harmonic maps for the heat flow between the circle and the sphere. The result highlights how geometry influences the reachable set.
- The work [58], entitled *Wave maps from circle to Riemannian manifold: global controllability is equivalent to homotopy*, provides a characterization of global controllability in geometric wave-map systems, showing that controllability reduces to topological properties of homotopy classes.
- The work [70], entitled *Controllability and Stabilization of a Wave–Heat Cascade System*, analyzes a coupled wave–heat cascade and proves both controllability and stabilization results using boundary actions and appropriate energy estimates.
- The work [68], entitled *Boundary control of heat–heat cascades*, develops boundary control strategies for cascaded heat equations, providing explicit feedback constructions and demonstrating exponential stabilization.
- The work [76], entitled *Small-time local controllability of a KdV system for all critical lengths*, proves small-time local controllability for KdV dynamics at every critical length, resolving an open question and extending classical boundary-control results.
- The work [75], entitled *The periodic KdV with control on space-time measurable sets*, establishes controllability of periodic KdV equations with controls acting on general measurable subsets of space-time, using advanced observability and unique continuation arguments.

- The work [31], entitled *Controlling the rates of a chain of harmonic oscillators with a point Langevin thermostat*, analyzes controllability properties in chains of harmonic oscillators coupled to a thermostat. It characterizes how localized stochastic forcing influences the global energy distribution.
- The work [32], entitled *Internal control of the transition kernel for stochastic lattice dynamics*, studies internal control mechanisms for stochastic lattice systems. It provides results on how controls shape the transition kernel and long-term behavior of the system.
- The work [39], entitled *On the dimension of observable sets for the heat equation*, investigates how the size and geometry of observation sets influence observability for the heat equation, providing new bounds on the minimal dimension of sets enabling full observation.
- The work [21], entitled *Generic controllability of equivariant systems and applications to particle systems and neural networks*, establishes generic controllability results for systems with symmetry. Applications include controlled particle systems and models of neural dynamics exhibiting equivariance.
- The work [64], entitled *Orbits and attainable Hamiltonian diffeomorphisms of mechanical Liouville equations*, characterizes the reachable sets and attainable Hamiltonian diffeomorphisms associated with mechanical Liouville equations. The results clarify how geometric constraints shape controllability in Hamiltonian systems.

7.5 Optimization, optimal control, and sub-Riemannian models: new results

Participants: Barbara Gris, Ugo Boscain, Bettina Kazandjian, Xiangyu Ma, Rayane Mouhli, Mario Sigalotti, Alessandro Socionovo, Lucia Tessarolo, Emmanuel Trélat.

Let us list here our new results on optimization, optimal control, and sub-Riemannian models.

- The work [36], entitled *Turnpike property of linear quadratic control problems with unbounded control operators*, establishes turnpike phenomena for infinite-dimensional LQ problems involving unbounded control operators. The result identifies conditions ensuring exponential attraction to steady-state optimal profiles.
- The work [38], entitled *The exponential turnpike property for periodic linear quadratic optimal control problems in infinite dimension*, demonstrates exponential turnpike behavior in periodic infinite-dimensional LQ settings. The article provides precise estimates for the convergence rate toward periodic optimal trajectories.
- The work [80], entitled *Turnpike in optimal control and beyond: a survey*, offers a comprehensive survey of turnpike theory across finite- and infinite-dimensional optimal control. It highlights general mechanisms, frameworks, and recent applications.
- The work [19], entitled *Optimal Control for Linear Systems with L^1-norm Cost*, studies optimal control problems with L^1-type performance criteria. It characterizes optimal solutions, their sparsity properties, and the geometry of associated Hamiltonian flows.
- The work [50], entitled *Numerical solving of an optimal control problem in large time horizon: the aerial vehicle guidance*, develops numerical methods for long-horizon optimal control with an application to aerial-vehicle trajectory planning. The approach combines shooting, continuation, and sensitivity tools.
- The work [43], entitled *PDE-constrained optimization within FreeFEM*, presents algorithms and software tools for PDE-constrained optimization implemented in FreeFEM. It illustrates the methodology through applications in shape optimization and inverse problems.

- The work [79], entitled *Probabilistic algorithm for computing all local minimizers of Morse functions on a compact domain*, proposes a probabilistic algorithm capable of detecting all local minima of Morse functions. The method has potential applications in global optimization and parameter-estimation problems.

- The work [56], entitled *Not all sub-Riemannian minimizing geodesics are smooth*, provides examples showing that minimizing geodesics in sub-Riemannian manifolds may lack smoothness. This sheds light on the subtleties of regularity in optimal control and geometric analysis.

- The work [63], entitled *A note on pliability and the openness of the multiexponential map in Carnot groups*, studies the multiexponential map in Carnot groups and introduces new insights on pliability and openness properties relevant to controllability and geometric flows.

- The work [74], entitled *Decoupling actions of finite-dimensional groups of diffeomorphisms in the large deformation framework*, analyzes the geometry of large-deformation models and provides decoupling results for group actions, with implications for shape analysis and geometric optimal control.

- The work [46], entitled *Schrödinger evolution on surfaces in 3D contact sub-Riemannian manifolds*, investigates Schrödinger dynamics on submanifolds embedded in contact sub-Riemannian structures. It provides geometric insights into propagation and controllability phenomena in degenerate settings.

- The work [25], entitled *Embedding the Grushin Cylinder in* $\mathbf{R}^3$ *and Schroedinger evolution*, studies embeddings of the Grushin cylinder into Euclidean space and analyzes associated Schrödinger equations. The work connects geometric degeneracies with quantum propagation properties.

- The work [78], entitled *Universal approximations of quasilinear PDEs by finite distinguishable particle systems*, shows how quasilinear PDEs can be approximated by interacting particle systems. It establishes convergence results and explores implications for numerical simulation and control.

- The work [0], entitled *Infinite-wise interactions: mean-field and graph limits for multiple-wise distinguishable agent systems*, analyzes systems with higher-order interactions and proves propagation-of-chaos results. The macroscopic limits obtained have applications in collective dynamics and optimal control.

- The work [37], entitled *Existence of surfaces optimizing geometric and PDE shape functionals under reach constraint*, establishes existence results for shape-optimization problems under reach constraints. The work blends geometric measure theory with PDE-based optimization.

- The work [51], entitled *A solution to the mystery of the sub-harmonic combination tone via a linear mathematical model of the cochlea*, proposes a linear cochlear model explaining the emergence of sub-harmonic combination tones. The analysis uses geometric and dynamical tools relevant to sub-Riemannian auditory models.

8 Bilateral contracts and grants with industry

8.1 Bilateral contracts with industry

Participants: Emmanuel Trélat.

Grant by AFOSR (Air Force Office of Scientific Research), 2025–2028, coordinated by Emmanuel Trélat. The focus of the project was on optimization and optimal control problems having an algebraic structure, involving for instance polynomial or semi-algebraic dynamics and cost functionals, or switches between polynomial models. Motion planning under obstacles is one of the main targeted problems.

9 Partnerships and cooperations

9.1 International initiatives

Participants: Emmanuel Trélat, Kévin Le Balc'h.

9.1.1 Participation in other International Programs

In 2025 we began a 3-years project funded by the Indo-French Centre for the Promotion of Advanced Research (IFCPAR/CEFIPRA) on the topic *Control of PDEs: Constraints, Coupling and New Challenges*. The Indian partner is the Indian Institute of Science Education and Research Kolkata (IISERKOL).

IISERKOL members of the project: Shirshendu Chowdhury and Rajib Dutta.

CAGE members of the project: Kévin Le Balc'h and Emmanuel Trélat.

9.2 National initiatives

9.2.1 ANR

Participants: Emmanuel Trélat, Kévin Le Balc'h, Ugo Boscain, Mario Sigalotti, Tommaso Rossi.

- ANR TRECOS, for *New Trends in Control and Stabilization: Constraints and non-local terms*, coordinated by Sylvain Ervedoza, University of Bordeaux, 2021–2025. TRECOS' focus is on control theory for partial differential equations, and in particular models from ecology and biology. Kévin Le Balc'h and Emmanuel Trélat are member of TRECOS.
- ANR/DFG CoRoMo for *Efficient quantum control of molecular rotations – time and controllability*, 2023–2025. The grant is co-coordinated by Ugo Boscain (CAGE) and Christiane Koch (Berlin). In this project, we seek to elucidate the role of time in quantum control, using the important benchmark of molecular rotations as testbed. We will leverage controllability analysis to tackle the role of time in quantum control, combining physical intuition from the control of molecular rotations with recent advances of mathematical methods. Ugo Boscain, Tommaso Rossi, and Mario Sigalotti are member of CoRoMo.
- ANR EINSTEIN-PPF for *Contraintes d'Einstein : passé', présent et futur*, coordinated by Philippe Lefloch, since 2023. Relying on a close collaboration between analysts and geometers, the ANR project is aimed at advancing our knowledge of the analytic and geometric properties of Einstein spacetimes, especially when the metrics under consideration have low regularity. Emmanuel Trélat is member of EINSTEIN-PPF.

9.2.2 Other national initatives

Participants: Kévin Le Balc'h.

- Inria Exploratory Action BANG (Building Appropriate controls using the Nonlinearity and blowinG up solutions). The AEx BANG aims to explore the deep links between control theory and blow-up theory. This includes, for example, establishing how certain blow-up results can be deduced from controllability properties, or conversely, using blow-up techniques to demonstrate positive or negative results regarding controllability.
  Members of BANG from the team CAGE: Kévin Le Balc'h.

9.3 Regional initiatives

Participants: Barbara Gris, Rayane Mouhli.

The Bourse Emergence(s) de la Ville de Paris “Morphométrie sous contrainte pour l’analyse de données biologiques : un nouvel outil pour la communauté scientifique”, 2022–2025, coordinated by Barbara Gris. Members for CAGE: Barbara Gris and Rayane Mouhli.

9.4 Public policy support

Participants: Emmanel Trélat.

Emmanel Trélat is **member of the scientific committee CERT at CNES**, headed by Sébastien Candel (Académie des Sciences).

10 Dissemination

10.1 Promoting scientific activities

10.1.1 Scientific events: organisation

- Emmanuel Trélat was member of the scientific committee of the IFAC Workshop on Control of Systems Governed by Partial Differential Equations (CPDE), Beijing, China, June 2025.
- Emmanuel Trélat was member of the organizing committee of the “Workshop on Functional Inequalities”, Paris-Dauphine, June 2025.
- Emmanuel Trélat was member of the organizing committee of the workshop “Round meanfield IV”, Venise, Italy, September 2025.
- Ugo Boscain was member of the organizing committee of the “Colloque Energie du CNRS”, Paris, March 2025.
- Ugo Boscain and Mario Sigalotti were members of the organizing committee of the workshop “CoRoMo: Quantum control of rotational dynamics”, Paris, September 2025.
- Mario Sigalotti was member of the organizing committee of the “Grand séminaire MACS Apprentissage et systèmes dynamiques”, Paris, October 2025.

10.1.2 Journal

Member of the editorial boards

- Ugo Boscain is Associate editor of SIAM Journal of Control and Optimization
- Ugo Boscain is Managing editor of Journal of Dynamical and Control Systems
- Jean-Michel Coron is Editor-in-chief of Advances in Differential Equations
- Jean-Michel Coron is Associate editor of Applied Mathematics Research Express
- Jean-Michel Coron is Associate editor of Mathematics of Control, Signals, and Systems
- Mario Sigalotti is Associate editor of SIAM Journal on Control and Optimization
- Mario Sigalotti is Associate editor of ESAIM: Control, Optimisation and Calculus of Variations

- Mario Sigalotti is Associate editor of Journal on Dynamical and Control Systems
- Emmanuel Trélat is Associate editor of SIAM Review
- Emmanuel Trélat is Associate editor of Systems & Control Letters
- Emmanuel Trélat is Associate editor of Journal on Dynamical and Control Systems
- Emmanuel Trélat is Associate editor of Bollettino dell'Unione Matematica Italiana
- Emmanuel Trélat is Associate editor of ESAIM: Mathematical Modelling and Numerical Analysis
- Emmanuel Trélat is Editor of BCAM Springer Briefs
- Emmanuel Trélat is Associate editor of IEEE Transactions on Automatic Control
- Emmanuel Trélat is Associate editor of Journal of Optimization Theory and Applications
- Emmanuel Trélat is Associate editor of Mathematical Control & Related Fields
- Emmanuel Trélat is Associate editor of Mathematics of Control, Signals, and Systems
- Emmanuel Trélat is Associate editor of Optimal Control Applications and Methods
- Emmanuel Trélat is Associate editor of Advances in Continuous and Discrete Models: Theory and Modern Applications
- Emmanuel Trélat is Associate editor of Comptes Rendus Mathématique

10.1.3 Invited talks

- Ugo Boscain was invited speaker at the 2025 International Workshop on Operator Theory and its Applications, University of Twente, the Netherlands.
- Kévin Le Balc'h was invited speaker at the seminar *Mathematical Physics and PDEs*, Paris Nord.
- Kévin Le Balc'h was invited speaker at the conference Control of PDEs and Related Fields, Toulouse.
- Mario Sigalotti was invited speaker at the seminar Problèmes Spectraux en Physique Mathématique, IHP, Paris.
- Mario Sigalotti was invited speaker at the workshop Quantum Lo : contrôle quantique en Lorraine, Nancy.
- Emmanuel Trélat was invited speaker at the Frontiers in Mathematics Lecture, Hong Kong University.
- Emmanuel Trélat was invited speaker at the Colloquium of Univ. Potsdam.
- Emmanuel Trélat was invited speaker at the conference Journées franco-chiliennes d'optimisation, Rouen.
- Emmanuel Trélat was invited speaker at the conference Control of PDEs and related topics, Toulouse.
- Emmanuel Trélat was invited speaker at the Congrès de la SMF 2025.
- Emmanuel Trélat was invited speaker at the conference Equations Cinétiques et Turbulence, 85ème anniversaire de C. Bardos.
- Emmanuel Trélat was invited speaker at the seminar of the Chinese Academy of Sciences.
- Emmanuel Trélat was invited speaker at the seminar of the Chengdu University.

10.1.4 Leadership within the scientific community

- Ugo Boscain is Délégué Scientifique at INSMI in charge of interdisciplinarity and member of the *Comité de pilotage* of the *Mission pour les initiatives transverses et interdisciplinaires* (MITI).
- Jean-Michel Coron is member of the *Académie des sciences* and of the *Academia Europaea*.
- Emmanuel Trélat is head of the *Laboratoire Jacques-Louis Lions*.
- Emmanuel Trélat is member of the *Academia Europaea*.

10.1.5 Scientific expertise

- Emmanuel Trélat is member of the conseil scientifique de la Fédération de Mathématiques de CentraleSupelec.
- Emmanuel Trélat is member of the Advisory Board of the Department of Data Science, FAU (Erlangen), Germany.

10.1.6 Research administration

- Kévin Le Balc'h is SMAI correspondent for the Laboratoire Jacques-Louis Lions.
- Emmanuel Trélat is member of the Bureau de comité des équipes-projets, Inria Paris center.

10.2 Teaching - Supervision - Juries - Educational and pedagogical outreach

- Ugo Boscain and Mario Sigalotti taught "Geometric control theory" to M2 students at Sorbonne Université (15h *équivalent TD* each).
- Kévin Le Balc'h taught "Agrégation (analyse, probabilités)" to M2 students at Sorbonne Université (16h *équivalent TD*).
- Kévin Le Balc'h taught "Oraux blancs analyse probabilités" to M2 students at Sorbonne Université (20h *équivalent TD*).
- Kévin Le Balc'h taught "Optimisation, Contrôle, Données" to M2 students at Sorbonne Université (24h *équivalent TD*).
- Mario Sigalotti taught "Introduction to Geometric Control Theory" to PhD students at SISSA, Trieste, Italy (30h *équivalent TD*).
- Emmanuel Trélat taught "Contrôle en dimension finie et infinie" to M2 students at Sorbonne Université (36h *équivalent TD*).
- Emmanuel Trélat taught "Optimisation numérique et sciences des données" to M1 students at Sorbonne Université (36h *équivalent TD*).

10.2.1 Supervision

- PhD: Kala Agbo Bidi, "Feedback stabilisation of a sterile insect control system: Applications to mosquito-borne disease control". Supervisors: Luis Almeida and Jean-Michel Coron.
- PhD: Ruikang Liang, "Contrôlabilité et conception du contrôle d'ensemble pour les systèmes quantiques". Supervisors: Ugo Boscain and Mario Sigalotti.
- PhD in progress: Vincent Boulard, "F-equivalence and sub-Riemannian geometric analysis for the stabilization and control of partial differential equations", started in 2025. Supervisors: Amaury Hayat and Emmanuel Trélat.

- PhD in progress: Armen Chahmirian, "Contrôlabilité unilatérale de systèmes de réaction-diffusion par des formes", started in 2025. Supervisors: Kévin Le Balc'h and Emmanuel Trélat.
- PhD in progress: Angelina Jammart, "Comportement en temps long et limite de grande population de systèmes de particules non échangeables", started in 2025. Supervisors: Benoît Bonnet-Weill, Nastassia Pouradier Duteil, and Mario Sigalotti.
- PhD in progress: Bettina Kazandjian, "Small-time controllability of bilinear partial differential equations via Lie bracket methods", started in 2024. Supervisors: Ugo Boscain, Eugenio Pozzoli, and Mario Sigalotti.
- PhD in progress: Xiangyu Ma, "A bio-inspired geometric model for speech sound reconstruction", started in 2023. Supervisors: Ugo Boscain, Dario Prandi, and Giuseppina Turco.
- PhD in progress: Rayane Mouhli, "L'ontogénèse par grandes déformations", started in 2023. Supervisors: Barbara Gris and Irène Kaltenmark.
- PhD in progress: Lia Sela, "Modélisation de la divergence phénotypique cellulaire dans la carcinogénèse orale pour améliorer la prévention et le traitement des cancers de la cavité buccale", started in 2024. Supervisors: Jean Clairambault, Jean-Philippe Foy, and Emmanuel Trélat.
- PhD in progress: Lucia Tessarolo, "Sub-Riemannian geometry and pinwheels", started in 2023. Supervisor: Ugo Boscain.

10.2.2 Juries

- Ugo Boscain was member of the PhD jury of Thiziri Aissaoui, Sorbonne Université.
- Ugo Boscain was member of the HDR jury of Nataliya Shcherbakova, ENSIACET, Toulouse.

  Barbara Gris was member of the PhD jury of Thomas Pierron ENS Saclay. Barbara Gris was member of the PhD jury of Siwan Boufadene Université Gustave Eiffel. Barbara Gris was member of the PhD jury of Abbas Kabalan, ENPC.
- Mario Sigalotti was member of the HDR jury of Nataliya Shcherbakova, ENSIACET, Toulouse.
- Emmanuel Trélat was referee and member of the HDR jury of Lamberto Dell'Elce, Univ. Nice.
- Emmanuel Trélat was member of the HDR jury of Swann Marx, Univ. Nantes.
- Emmanuel Trélat was member of the HDR jury of Paolo Mason, Univ. Paris-Saclay.

  Emmanuel Trélat was referee and member of the HDR jury of Laurent Pfeiffer, Univ. Paris-Saclay.

  Emmanuel Trélat was referee and member of the PhD jury of T. Caleb, ISAE, Toulouse.

  Emmanuel Trélat was member of the PhD jury of G. Le Ruz, Inria Paris.

  Emmanuel Trélat was referee and member of the PhD jury of M. Ayamou, Univ. Lille.

  Emmanuel Trélat was member of the PhD jury of J. Labatut, ONERA.

  Emmanuel Trélat was member of the PhD jury of J. Wang, Sorbonne Univ.

  Emmanuel Trélat was referee and member of the PhD jury of R. Chenevat, Univ. Montpellier.

  Emmanuel Trélat was president of the PhD jury of K. Agbo, Sorbonne Université.

  Emmanuel Trélat was president of the PhD jury of A. Saibi, Sorbonne Université.

  Emmanuel Trélat was referee and member of the PhD jury of Y. Wang. Univ. Bordeaux.

10.3 Popularization

10.3.1 Specific official responsibilities in science outreach structures

Emmanuel Trélat is member of the *Comité d'Honneur du Salon des Jeux et Culture Mathématique*.

10.3.2 Participation in Live events

- Ugo Boscain gave a presentation on *Sur la perception des sous-harmoniques* at the annual meeting of the *Association des Collectionneurs d'Instruments de Musique à Vent (ACIMV)*, La Couture-Boussey, 2025.
- Ugo Boscain gave a presentation *Témoignage de chercheur* at the *Journée des chercheuses et chercheurs à + 6, 7 ans*, PMA Paris, 2025.
- Emmanuel Trélat gave a presentation at the Lycée Français International de Pékin, China.

11 Scientific production

11.1 Major publications

[1] D. Barilari, U. Boscain, D. Cannarsa and K. Habermann. 'Stochastic processes on surfaces in three-dimensional contact sub-Riemannian manifolds'. In: *Annales de l'Institut Henri Poincaré (B) Probabilités et Statistiques* (2021). 25 pages, 2 figures. DOI: `10.1214/20-AIHP1124`. URL: `https://hal.archives-ouvertes.fr/hal-02557862`.

[2] D. Barilari, Y. Chitour, F. Jean, D. Prandi and M. Sigalotti. 'On the regularity of abnormal minimizers for rank 2 sub-Riemannian structures'. In: *Journal de Mathématiques Pures et Appliquées* 133 (2020), pp. 118–138. DOI: `10.1016/j.matpur.2019.04.008`. URL: `https://hal.archives-ouvertes.fr/hal-01757343`.

[3] M. Bertalmio, L. Calatroni, V. Franceschi, B. Franceschiello and D. Prandi. 'Cortical-inspired Wilson-Cowan-type equations for orientation-dependent contrast perception modelling'. In: *Journal of Mathematical Imaging and Vision* (June 2020). DOI: `10.1007/s10851-020-00960-x`. URL: `https://hal.archives-ouvertes.fr/hal-02316989`.

[4] R. Bonalli, B. Hérissé and E. Trélat. 'Optimal Control of Endo-Atmospheric Launch Vehicle Systems: Geometric and Computational Issues'. In: *IEEE Transactions on Automatic Control* 65.6 (2020), pp. 2418–2433. DOI: `10.1109/tac.2019.2929099`. URL: `https://hal.archives-ouvertes.fr/hal-01626869`.

[5] U. Boscain, E. Pozzoli and M. Sigalotti. 'Classical and quantum controllability of a rotating 3D symmetric molecule'. In: *SIAM Journal on Control and Optimization* (2020). URL: `https://hal.inria.fr/hal-02421593`.

[6] Y. Colin de Verdière, L. Hillairet and E. Trélat. *Spectral asymptotics for sub-Riemannian Laplacians*. 5th Dec. 2022. URL: `https://hal.archives-ouvertes.fr/hal-03885610`.

[7] J.-M. Coron, A. Hayat, S. Xiang and C. Zhang. 'Stabilization of the linearized water tank system'. In: *Archive for Rational Mechanics and Analysis* 244.3 (2022), pp. 1019–1097. URL: `https://hal.archives-ouvertes.fr/hal-03161523`.

[8] J.-M. Coron, F. Marbach and F. Sueur. 'Small-time global exact controllability of the Navier-Stokes equation with Navier slip-with-friction boundary conditions'. In: *Journal of the European Mathematical Society* 22.5 (May 2020), pp. 1625–1673. DOI: `10.4171/JEMS/952`. URL: `https://hal.archives-ouvertes.fr/hal-01422161`.

[9] J.-M. Coron and H.-M. Nguyen. 'Finite-time stabilization in optimal time of homogeneous quasilinear hyperbolic systems in one dimensional space'. In: *ESAIM: Control, Optimisation and Calculus of Variations* 26 (2020), p. 119. DOI: `10.1051/cocv/2020061`. URL: `https://hal.archives-ouvertes.fr/hal-03080852`.

[10] J.-M. Coron and H.-M. Nguyen. 'Optimal time for the controllability of linear hyperbolic systems in one dimensional space'. In: *SIAM Journal on Control and Optimization* 57.2 (5th Apr. 2019), pp. 1127–1156. DOI: `10.1137/18M1185600`. URL: `https://hal.archives-ouvertes.fr/hal-01952134`.

[11] S. Ervedoza, K. Le Balc'h and M. Tucsnak. 'Reachability results for perturbed heat equations'. In: *Journal of Functional Analysis* 283.10 (15th Nov. 2022). URL: https://hal.science/hal-03380745.

[12] M. Leibscher, E. Pozzoli, C. Pérez, M. Schnell, M. Sigalotti, U. Boscain and C. P. Koch. 'Full quantum control of enantiomer-selective state transfer in chiral molecules despite degeneracy'. In: *Communications Physics* (6th May 2022). DOI: 10.1038/s42005-022-00883-6. URL: https://hal.inria.fr/hal-02972059.

[13] J. Lohéac, E. Trélat and E. Zuazua. 'Nonnegative control of finite-dimensional linear systems'. In: *Annales de l'Institut Henri Poincaré (C) Non Linear Analysis* 38 (2021), pp. 301–346. DOI: 10.1016/j.anihpc.2020.07.004. URL: https://hal.archives-ouvertes.fr/hal-02335968.

[14] O. Öktem, B. Gris and C. Chen. 'Image reconstruction through metamorphosis'. In: *Inverse Problems* 36 (2020). DOI: 10.1088/1361-6420/ab5832. URL: https://hal.archives-ouvertes.fr/hal-01773633.

[15] Y. Privat, R. Robin and M. Sigalotti. 'Optimal shape of stellarators for magnetic confinement fusion'. In: *Journal de Mathématiques Pures et Appliquées* (2022). DOI: 10.1016/j.matpur.2022.05.005. URL: https://hal.inria.fr/hal-03472623.

[16] R. Robin, N. Augier, U. Boscain and M. Sigalotti. 'Ensemble qubit controllability with a single control via adiabatic and rotating wave approximations'. In: *Journal of Differential Equations* 318 (5th May 2022). DOI: 10.1016/j.jde.2022.02.042. URL: https://hal.archives-ouvertes.fr/hal-02504532.

11.2 Publications of the year

International journals

[17] K. Agbo Bidi, L. Almeida and J.-M. Coron. 'Global stabilization of a Sterile Insect Technique model by feedback laws'. In: *Journal of Optimization Theory and Applications* 204 (2025). URL: https://hal.science/hal-04777957 (cit. on p. 12).

[18] K. Agbo Bidi, J.-M. Coron, A. Hayat and N. Lichtlé. 'A novel approach to feedback control with deep reinforcement learning'. In: *Systems and Control Letters* 202 (Aug. 2025), p. 106102. DOI: 10.1016/j.sysconle.2025.106102. URL: https://hal.science/hal-05339948.

[19] A. Agrachev and B. Kazandjian. 'Optimal Control for Linear Systems with L^1-norm Cost'. In: *Journal of Optimization Theory and Applications* 204.3 (2025). URL: https://inria.hal.science/hal-04546593 (cit. on p. 14).

[20] A. Agrachev, B. Kazandjian and E. Pozzoli. 'Good Lie Brackets for classical and quantum harmonic oscillators'. In: *Systems and Control Letters* 205 (2025), p. 106233. DOI: 10.1016/j.sysconle.2025.106233. URL: https://hal.science/hal-04991273 (cit. on p. 10).

[21] A. Agrachev and C. Letrouit. 'Generic controllability of equivariant systems and applications to particle systems and neural networks'. In: *Annales de l'Institut Henri Poincaré (C), Analyse non linéaire* (2025). URL: https://hal.science/hal-04542990. In press (cit. on p. 14).

[22] A. A. Agrachev and M. Motta. 'Lyapunov Exponents of Linear Switched Systems'. In: *Regular and Chaotic Dynamics* (2025). URL: https://inria.hal.science/hal-04353841 (cit. on p. 12).

[23] L. Baratchart, S. Fueyo and J.-B. Pomet. 'Exponential stability of linear periodic difference-delay equations'. In: *SIAM Journal on Mathematical Analysis* 57 (2025), pp. 3110–3145. DOI: 10.1137/23M160133X. URL: https://inria.hal.science/hal-03500720 (cit. on p. 12).

[24] G. Bastin, J.-M. Coron and A. Hayat. 'The usefulness of viscosity for the robustness of boundary feedback control of an unstable fluid flow system'. In: *Automatica* (2025), p. 112048. URL: https://hal.science/hal-04360354 (cit. on p. 12).

[25] I. Beschastnyi, U. Boscain, D. Cannarsa and E. Pozzoli. 'Embedding the Grushin Cylinder in $\mathbf{R}^3$ and Schroedinger evolution'. In: *Contemporary mathematics* 809 (2025). DOI: 10.1090/conm/809. URL: https://hal.science/hal-04668482 (cit. on p. 15).

[26] S. Borza, M. Magnabosco, T. Rossi and K. Tashiro. 'Curvature Exponent of Sub-Finsler Heisenberg Groups'. In: *SIAM Journal on Mathematical Analysis* 57.4 (2nd July 2025), pp. 3561–3586. DOI: `10.1137/24M1690692`. URL: `https://hal.science/hal-05429282`.

[27] U. Boscain and W. Gerner. 'Charged particle motion in a strong magnetic field: Applications to plasma confinement'. In: *Nonlinearity* 38 (2025). DOI: `10.48550/arXiv.2504.04165`. URL: `https://hal.science/hal-05025567` (cit. on p. 11).

[28] U. Boscain, K. Le Balc'h and M. Sigalotti. 'Schrödinger eigenfunctions sharing the same modulus and applications to the control of quantum systems'. In: *Mathematics of Control, Signals, and Systems* 37 (2025), pp. 415–449. URL: `https://inria.hal.science/hal-04496433` (cit. on p. 10).

[29] J.-M. Coron, J. Krieger and S. Xiang. 'Global controllability and stabilization of the wave maps equation from a circle to a sphere'. In: *Calculus of Variations and Partial Differential Equations* 64.4 (24th Mar. 2025), p. 108. DOI: `10.1007/s00526-025-02961-3`. URL: `https://inria.hal.science/hal-05339960` (cit. on p. 13).

[30] J.-M. Coron and S. Xiang. 'Global controllability to harmonic maps of the heat flow from a circle to a sphere'. In: *Journal de Mathématiques Pures et Appliquées* 204 (2025). URL: `https://hal.science/hal-04432880` (cit. on p. 13).

[31] A. Hannani, M. N. Phung, M.-B. Tran and E. Trélat. 'Controlling the rates of a chain of harmonic oscillators with a point Langevin thermostat'. In: *Journal of Differential Equations* 426 (2025), pp. 253–316. URL: `https://hal.science/hal-04507495` (cit. on p. 14).

[32] A. Hannani, M. N. Phung, M.-B. Tran and E. Trélat. 'Internal control of the transition kernel for stochastic lattice dynamics'. In: *Journal of Differential Equations* Part 1 (2026), p. 113798. URL: `https://hal.science/hal-04717306` (cit. on p. 14).

[33] K. Le Balc'h and J. Martin. 'Quantitative propagation of smallness and spectral estimates for the Schrödinger operator'. In: *Journal of Spectral Theory* (2025). DOI: `10.4171/JST/543`. URL: `https://hal.science/hal-04625215` (cit. on p. 13).

[34] R. Liang, U. Boscain and M. Sigalotti. 'Controllability of quantum systems having weakly conically connected spectrum'. In: *SIAM Journal on Control and Optimization* 63 (2025), S175–S199. URL: `https://hal.science/hal-04174206` (cit. on p. 11).

[35] R. Liang, U. Boscain and M. Sigalotti. 'Ensemble control of n-level quantum systems with a scalar control'. In: *Automatica* (2025). URL: `https://hal.science/hal-04819595`. In press (cit. on p. 11).

[36] H.-M. Nguyen and E. Trélat. 'Turnpike property of linear quadratic control problems with unbounded control operators'. In: *Advances in Differential Equations* 31.3-4 (2026), pp. 219–252. URL: `https://hal.science/hal-05093587` (cit. on p. 14).

[37] Y. Privat, R. Robin and M. Sigalotti. 'Existence of surfaces optimizing geometric and PDE shape functionals under reach constraint'. In: *Interfaces and Free Boundaries : Mathematical Analysis, Computation and Applications* 27.1 (2025), pp. 65–90. DOI: `10.4171/IFB/523`. URL: `https://inria.hal.science/hal-03690069` (cit. on p. 15).

[38] E. Trélat, X. Zeng and C. Zhang. 'The exponential turnpike property for periodic linear quadratic optimal control problems in infinite dimension'. In: *SIAM Journal on Control and Optimization* 63.4 (2025), pp. 2524–2546. URL: `https://hal.science/hal-04433814` (cit. on p. 14).

[39] A. Walton Green, K. Le Balc'h, J. Martin and M.-A. Orsoni. 'On the dimension of observable sets for the heat equation'. In: *Pure and Applied Analysis* (2025). DOI: `10.2140/paa.2025.7.639`. URL: `https://hal.science/hal-04666012` (cit. on p. 14).

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