Monday 2nd, Aula Magna, 9:00

Stability of transport equations on networks with intermittent damping

Mario Sigalotti, INRIA Saclay, France

We present the stabilizability problem for linear control systems with intermittent control action, under persistent excitation conditions. We present some conditions ensuring exponential and weak stability for general maximal-dissipative infinite-dimensional systems with intermittent damping. We conclude discussing some recent results, obtained in collaboration with Y. Chitour and G. Mazanti, concerning the special case of transport equations on networks.

Control of infinite dimensional closed quantum systems 2003-2013: a survey

Thomas Chambrion, Université de Lorraine, France

Quantum dynamics are frequently modelled, in a first approach, by evolution equations which are both linear with respect to the state and conservative.

Several difficulties prevent from easy control of such dynamics: the state often lies in an infinite dimensional space, some of the linear operators involved in the dynamics are not bounded and the dynamics is not linear in the control. Various teams, adopting different points of view and using different techniques, have addressed these issues from the beginning of the century.

This talk aims to expose some of the results obtained in the last decade and to present some of the many remaining open questions about this surprisingly rich problem.

Monday 2nd, Parallel Session A, Aula Magna, 11:10

Exact and Optimal control ability in scalar conservation laws

Adimurthi, TIFR CAM Bangalore, India

Necessary and sufficient conditions for the exact controlability for the one space dimension scalar conservation laws with strict convex flux will be discussed. Further more in the same context, using the backward construction, we give a complete solution for the Optimal control problem.

Control and stabilisation of the Benjamin-Ono equation

Camille Laurent, CNRS Paris, France

We prove the internal global controllability and stabilisation of the Benjamin-Ono equation on L^2 in periodic domain. The difficulty in the application of the compactness-uniqueness method consists in understanding the interaction between the gauge transform and the properties of propagation of compactness.

This is joint work with Felipe Linares and Lionel Rosier.

Monday 2nd, Parallel Session B, Room 128-129, 11:10

Some geometric problems related to the averaged Kepler controlled equation

B. Bonnard, Université de Bourgogne, France

In this talk we introduce the geometric framework related to the averaged optimal transfer between keplerian orbits in the energy and time minimal cases.

This leads to analyse Riemannian metric in the energy case vs Finsler metric in the time case.

We make a complete analysis for of coplanar transfer towards circular orbits.

This is a joint work with H. Henninger, J. Nemcova and J.-B. Pomet.

Sparse Control of Alignement models

Marco Caponigro, CNAM Paris, France

We focus on a general Cucker-Smale system, modeling self-organization and consensus emergence in a group of interacting agents. We show how it is possible to control this model in order to enforce or facilitate pattern formation or convergence to consensus. In particular, we are interested in designing control strategies that are "sparse" in the sense that they require a small amount of external intervention, and "time sparse" in the sense that such strategies are not chattering. These sparsity features are desirable in view of practical applications. We present a variational principle to design simple sparse feedback strategies steering the system to consensus. We then combine these results with local controllability properties to get global controllability results.

Monday 2nd, Parallel Session A, Aula Magna, 14:00

Exact controllability of networks of nonlinear strings and beams

Günter Leugering, University of Erlangen, Germany

We consider networks of nonlinear strings and Timoshenko beams, as well as Cosserat rods. We provide the modeling, analysis and controllability results based on the concept of semi-global solutions in the sense of Tastien Li.

Control problems in models of the interaction between a population and individuals

Nikolay Pogodaev

The talk is devoted to control problems arising in models of the interaction between a population and some individuals. Several specific situations can be considered: a shepherd dog leading a herd of sheep, several police officers trying to hold a crowd of protesters, a predator attacking a group of preys etc. There are two ways to describe such situations: one leads to a controlled differential inclusion, another to a controlled conservation law.

More precisely, let a map $\xi = \xi(t)$ describe the movement of the k individuals (e.g. the k shepherd dogs) in $\mathbb{R}^2$. Assume that the population is characterized by the region $K_\xi(t) \subset \mathbb{R}^2$ it occupies at time t. Then, $K_\xi(t)$ is the reachable set of the differential inclusion

$$\dot{x} \in v\,(x, \xi(t)) + B(0, c), \tag{1}$$

where $B(0, c)$ is the closed ball in $\mathbb{R}^2$ centered at 0 with radius c, c being the (maximal) wandering speed of the population's members. The vector field v is the drift speed due to the interaction between the k individuals and the population.

On the other hand, let the population be characterized by a density function $\rho = \rho(t, x)$ (the number of population's members per unit area). Then, ρ evolves according to the law of mass conservation

$$\rho_t + \mathrm{div}_x(\rho V) = 0. \tag{2}$$

Here $V = v(x, \xi) + v_{\mathrm{int}}(\rho)$ is the velocity of a population's member located at x.

In both models the function ξ can be considered as a strategy of the individuals, which they choose in order to achieve some goal. Thus, several control problems naturally arise: *the confinement problem* (find a strategy of the individuals that allows to hold the population inside a given set within a given period of time), *the steering problem* (find a strategy that allows to steer the population into a given set by a given time), *the optimal control problem* (find a strategy that minimizes some cost functional).

In the talk the recent results [1,2] concerning these control problems for model (1) will be presented. Some connections between models (1) and (2) will be discussed as well.

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Monday 2nd, Parallel Session B, Room 128-129, 14:00

Small time heat kernel asymptotics for (sub-)Riemannian manifolds at the cut locus

Grégoire Charlot, Université Joseph Fourier Grenoble, France

We provide the small-time heat kernel asymptotics at the cut locus for low-dimensional Riemannian manifolds and, close to the starting point, for generic 3D contact and 4D quasi-contact sub-Riemannian manifolds.

Singularities A3 and A5 happen to play a central role.

Boundary Effect on Motility in Stokes Flow

Laetitia Giraldi, UMPA, ENS de Lyon, France

Swimming, i.e., being able to advance in absence of external forces by performing cyclic shape changes, is particularly demanding at low Reynolds numbers which is the regime of interest for micro-organisms and micro-robots. Since the sixties, experiments have proved that in confined geometries, microorganisms are attracted by the boundaries. Starting from these observations, the question that we want to address is how does boundary affect the motility of microswimmers ? Our work focuses on swimmers made of several balls linked by thin jacks: the so-called Three-sphere and Four-sphere swimmers. In this talk, we will analyze the effect of a plane wall and a rough wall on the controllability of these particular micro-swimmers.

First, we will recall controllability results got by F. Alouges, A. DeSimone, L. Heltai, A. Lefevbre and B. Merlet in [1] for these swimmers in the whole space. Then, we will analyze the effect of the presence of a plane wall on the controllability of these swimmers (see [2]). Finally, we will generalize our previous study by considering a rough wall (see [3]). We will show that boundary (plane wall and rough wall) does not affect the controllability of a controllable swimmer. On the contrary, we will prove that the presence of border increases the reachable set of a non fully controllable swimmer.

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Monday 2nd, Aula Magna, 15:50

Short Course: Stochastic equations and control theory

Arnaud Debussche, ENS Rennes, France

In these lectures, we introduce the basic theory for stochastic PDEs (SPDEs) driven by gaussian noise. We first define Wiener processes and explains on simple examples how to solve a SPDE.

Then, we show how the support of the law of a solution is related to a control problem and apply to obtain results on the blow-up of the solutions of super critical nonlinear Schrödinger equations.

Control problems also arise when one want to estimate probabilities when the noise is small. Indeed, large deviation theory give bounds on the probability that a solution does not behave like the deterministic solution when the intensity of the noise goes to zero. This bound is in term of the rate function which can be often estimated by control arguments.

Malliavin calculus is an extremely useful tool to prove qualitative properties on the solutions of SPDES: smoothness of the law, ergodicity ... It is another link between control theory and stochastic processes. For instance, the so-called Malliavin matrix associated to a stochastic equation is exactly the Gramm matrix. We will also explain how Malliavin calculus can be used to prove ergodicity for SPDEs and give a brief description of the recent method due Hairer and Mattingly to prove ergodicity for the stochastic Navier-Stokes equations.

Tuesday 3rd, Parallel Session A, Aula Magna, 9:00

Ferromagnetism modeling: from micro-scale to meso-scale

Stéphane Labbé, Université Joseph Fourier Grenoble, France

In this presentation we will focus on the link between the micro-scale and the meso-scale for ferromagnetic models. The micro-scale designates a model where atom kernels are assimilated to point-wise magnetic charges and the meso-scale is the model of micromagnetism. Starting from the micro-scale description, we will give a stochastic description of heat effects. In the following, we will expose the link between the micro and meso-scale.

Null controllability of hinged Thermoelastic Plates

Luz de Teresa, Universidad Nacional Autónoma. México

We present a null controllability result for hinged thermoelastic plates when the models account for rotational inertia.

For small values of a parameter we are able to control with a single control acting in the heat equation and with the support of the control been a proper open subset of the space. This work was done in collaboration with Carlos Castro.

Tuesday 3rd, Parallel Session B, Room 128-129, 9:00

A Runge-Walsh like theorem for the stationary Stokes equations, application to the lagrangian controllability of quasi-static Stokes fluids

Thierry Horsin, CNAM Paris, France

We present some results issued from a joint work in progress with O. Glass. We give a partial version of the famous Runge's approximation theorem, concerning analytical functions (and an extension for harmonic functions namely the Runge-Walsh 's theorem), for solutions of the stationary Stokes equations given on a bounded domain. As an application, we prove some approximate lagrangian controllability results for a fluid governed by the Stokes equations in quasi-static situations which, for example, occur when one neglects the inertial terms.

Inverse optimal control

Frédéric Jean, ENSTA ParisTech, France

An inverse optimal control problem is stated as follows. Assume that we are given a control system and a class L of cost function. With each cost function in L, one can associate the set of solutions of the corresponding optimal control problem. The inverse optimal control problem consists in determining an inverse of this mapping. These kind is of problem arises naturally in the study of human motor control, for determining which law governs a particular body movement, such as arm pointing motions or goal-oriented locomotion. Indeed, a nowadays widely accepted paradigm in neurophysiology is that, among all possible movements, the accomplished ones satisfy suitable optimality criteria. Once a dynamical model of the movements under consideration is given, as well as a set of recorded experimental data, one is then led to solve an inverse optimal control problem.

In this talk we will present the approach we have develop to study this problem in the case of movements of the arm and of goal-oriented human locomotion. We will discuss the well-posedness of this inverse problem, and see how the cost structure may be deduced from qualitative properties highlighted by the experimental data. We also show how this approach allow to determine the natural duration of some human motions.

Tuesday 3rd, Aula Magna, 11:10

Control and inverse problems for degenerate parabolic equations in dimension two

Piermarco Cannarsa, Università di Roma Tor Vergata, Italy

The behavior of degenerate parabolic operators, unlike uniformly parabolic ones, is not described by a comprehensive theory at least as far as controllability issues and stability estimates for inverse problems are concerned. There are, however, a few classes of degenerate parabolic operators for which a substantial body of results is now available. In this talk, we will focus on two such classes, namely operators that degenerate at the boundary of the space domain, and operators of Grushin type that degenerate in the interior. For the former class, we will discuss observability and controllability results commenting, in particular, on the blow-up of the observability constant as the degeneracy exponent approaches the noncontrollability threshold. For the latter, we will concentrate on the connections between observability and Lipschitz stability estimates for the reconstruction of source terms and coefficients. The common feature of our approach to these two different kinds of operators is represented by Carleman estimates which - though playing different roles - are decisive for our analysis.

Control and mixing for nonlinear equations

Armen Shirikyan, Université de Cergy Pontoise, France

We discuss the interconnection between controllability properties of a dynamical system and large-time asymptotics of trajectories for the associated stochastic system. We begin with a result on the finite-dimensional case which applies to differential equations on a smooth Riemannian manifold. It will be proved that the approximate controllability to a given point and local solid controllability imply the uniqueness of a stationary measure and exponential mixing in the total variation distance. We next turn to problems in infinite dimension and derive a sufficient condition (in terms of controllability properties) for the exponential mixing in the Kantorovich-Wasserstein distance. This result applies, for instance, to the 2D Navier-Stokes system driven by a random force acting on the boundary. We conclude with some open problems on controllability properties of the Navier-Stokes system, which would have interesting applications in the ergodic theory of the associated random flow.

Tuesday 3rd, Parallel Session A, Aula Magna, 14:00

On the Approximation of the Controls for the Beam Equation

Sorin Micu, University of Craiova, Romania

We consider a finite difference semi-discrete scheme for the approximation of the boundary exact controls for the 1-D beam equation. Because of the high frequency spurious oscillations, it is known that the uniform (with respect to the mesh-size) controllability property of the semi-discrete model fails in the natural setting. We prove that this property is restored by adding a vanishing numerical viscosity.

Controllability of Fokker-Planck equations and the planning problem for Mean Field Games

Alessio Porretta, Università di Roma Tor Vergata, Italy

The planning problem in Mean Field Games theory is a kind of optimal transportation problem which consists in driving the distribution of the agents from an initial configuration to a final one following a strategy which is optimal for the agents' cost. We discuss one possible form of this problem, resulting into the exact controllability at time T of Fokker-Planck equations through the action of the drift, which plays the role of optimal feedback control for (the distribution law of) the associated stochastic process.

With PDE's methods, we prove existence and uniqueness of the optimal planning under suitable conditions for the cost functional and the initial/terminal distributions.

Tuesday 3rd, Parallel Session B, Room 128-129, 14:00

Stabilization of Persistently Excited Linear Systems by Delayed Feedback Laws

Guilherme Mazanti, CMAP, École Polytechnique, Palaiseau, France

This talk will consider the problem of stabilization by a linear feedback law of a linear system submitted to an intermittent control satisfying a condition of persistence of excitation, i.e., a system of the form

$$\dot{x} = Ax + \alpha(t)Bu$$

where α is a persistently exciting signal and u is taken under the form $u = -Kx$. The goal is to choose a matrix K such that the closed-loop system is asymptotically stable, uniformly with respect to a given class of persistently exciting signals.

We will first recall some existing results concerning this problem, mainly those presented in [1], before turning to the main question we consider: can we still obtain a stabilization result for this system if the linear feedback is not applied instantaneously, but only after a certain delay $\tau > 0$? We thus consider the feedback $u(t) = -Kx(t-\tau)$, and we are able to prove in this case that stabilization is indeed possible under certain assumptions on (A, B), which are the same as those for the non-delayed case presented in [2]. We shall explain the technique of the proof, which relies on a time-contraction argument and the study of a non-delayed limit system as the parameter of time contraction tends to infinity.

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Complexity for affine control systems

Dario Prandi, SISSA, Trieste, Italy

We present some results regarding the complexity of the motion planning problem for control-affine systems. Such complexities are already defined and rather well-understood in the particular case of non-holonomic (or driftless) systems. Our aim is to generalize these notions and results to systems with a drift. Accordingly, we present various definitions of complexity, as functions of the curve that is approximated, and of the precision of the approximation. Due to the lack of time-rescaling invariance of these systems, we consider geometric and parametrized curves separately. Then, we give some estimates for these quantities, both in situations where the path is generic with respect to the drift and where it is completely non-generic.

This is a joint work with F. Jean.

Spatio-temporal symmetries in control systems: an application to formation control

Luca Consolini, Università di Parma, Italy

With the aim of addressing the stabilization problem of periodic trajectories in systems composed of identical interconnected subsystems, we introduce the class of "spatio-temporally symmetric" nonlinear systems. We address in detail the linear, time-varying case and present conditions for the synthesis of a static and a dynamic stabilizing controller. We show that linear spatio temporally symmetric systems can be reduced to hybrid systems, described by a periodic linear system with periodic state jumps. As an application example, we present the stabilization of a formation of unicycle robots in cyclic pursuit.

On conjugate times of LQ optimal control problems

Luca Rizzi, SISSA, Italy

Motivated by the study of linear quadratic optimal control problems, we consider a dynamical system with a constant, quadratic Hamiltonian, and we characterize the number of conjugate times in terms of the spectrum of the Hamiltonian vector field . We prove the following dichotomy: the number of conjugate times is identically zero or grows to infinity. The latter case occurs if and only if has at least one Jordan block of odd dimension corresponding to a purely imaginary eigenvalue.

Tuesday 3rd, Aula Magna, 16:00

Short Course: Stochastic equations and control theory

Arnaud Debussche, ENS Rennes, France

Wednesday 4th, Parallel Session A, Aula Magna, 9:00

On some recent advances for under-controlled coupled PDE's and applications to insensitizing and simultaneous control

Fatiha Alabau-Boussouira, Université de Lorraine, France

Many applications in control theory are concerned with the controllability of coupled systems of PDE's. A topic which has recently emerged in this field is concerned with controllability issues for under-controlled coupled systems, characterized by the fact that the number of controls is strictly less than the number of equations. Such systems appear naturally when one wants to build robust controls for scalar equations, that is controls which are robust to small unknown perturbations of the initial data or when one wants to control simultaneously devices in parallel. They arise more generally in applications, whenever cost constraints or practical realizations, may require that the controls are activated only for some of the physical variables or for some of the equations.

We shall present some recent advances, based on a general macroscopic method: the multi-levels energy method, for the locally distributed and boundary control/observability of certain types of structured coupled hyperbolic systems, namely here cascade system. This method mixes different levels of energies of the components of the state vector according to the fact that they are observed or unobserved components. Further time invariance properties of these systems such as time-translation invariance, reversibility and conservation of some energies, play an important role. It allows us to deal with controllability/observability issues for such structured under-controlled coupled systems, in some "unified way". A further important concern is to obtain results for geometric situations in which the control and coupling regions do not intersect. In particular, we give a necessary and sufficient condition for the observability of the dual cascade system of two equations by a single observation. This condition, roughly speaking states that both the control and coupling region should satisfy the Geometric Control Condition. We further generalize this result to bi-diagonal cascade systems of n equations. These results are valid for sufficiently large control time. We then give applications to the existence of insensitizing and simultaneous locally distributed or boundary controls of scalar equations in a multi-dimensional framework and discuss some perspectives.

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Desensitizing control of the wave equation and related questions

Jérôme Le Rousseau, Université d'Orléans, France

Desensitizing control questions were introduced by J.-L. Lions. They lead to controllability issues for systems of coupled equation. We shall consider this setting in the case of the wave equation and provide a precise control time for such systems in connection with the underlying high-frequency geometry. This is joint work with B. Dehman (Faculté des Sciences de Tunis) and M. Léautaud (Université Paris-Diderot).In this presentation we will focus on the link between the micro-scale and the meso-scale for ferromagnetic models.

The micro-scale designates a model where atom kernels are assimilated to point-wise magnetic charges and the meso-scale is the model of micromagnetism. Starting from the micro-scale description, we will give a stochastic description of heat effects. In the following, we will expose the link between the micro and meso-scale.

Wednesday 4th, Parallel Session B, Room 128-129, 9:00

Properties of the extremal flow on Barabanov spheres

Paolo Mason, CNRS, LSS, France

The problem of uniform stability of (linear) switched systems can be reformulated as a problem of identification of the "most unstable trajectory" of the system. This problem can be easily solved for two-dimensional systems through the Jordan theorem, but turns out to be extremely difficult starting from dimension three. Thanks to Barabanov results the study of the most unstable dynamics is reduced to the study of certain dynamics on a manifold which is homeomorphic to a sphere (Barabanov sphere). In this talk I will discuss some results and open questions concerning such dynamics and the geometry of Barabanov spheres. In particular I will focus on recent results in the three-dimensional case with only two available modes, when the difference between the two corresponding matrices is a rank one matrix.

Curvature for affine optimal control problems

Davide Barilari, Université Paris Diderot, France

In this talk I will present a notion of curvature for an affine optimal control problem that is related with the asymptotic of the second derivative of the cost along a minimizing trajectory.

Moreover I will discuss some applications of this notion for drift-less systems with quadratic costs, i.e. control systems associated with the geodesic problem in (sub-)Riemannian geometry. In particular we will discuss an asymptotic formula for the sub-Laplacian of the distance squared along a geodesic and the notion of geodesic dimension. (Joint work with A. Agrachev and L. Rizzi)

Wednesday 4th, Aula Magna, 11:10

Stability and convergence results for an inverse problem for the waves

Sylvain Ervedoza, Université Toulouse 3, France

I will present some recent works with Lucie Baudouin and Axel Osses regarding the question of convergence of space semi-discrete inverse problems toward their continuous counterpart. More precisely, I will focus on the inverse problem consisting in recovering a potential in the wave equation from a measurement of the flux on the boundary. In the continuous setting, several uniqueness and stability results are available in the literature, and in particular a Lipschitz stability result under the multiplier condition obtained by Imanuvilov and Yamamoto, and a logarithmic stability result obtained by Bellassoued when no geometric condition is satisfied. In both situations, we will design a numerical process for which convergence results are proved. In both cases, our analysis is based on discrete Carleman estimates, either for the waves or for the elliptic operator, in which case we shall use the results of Boyer, Hubert and Le Rousseau.

Normal parabolic equations: structure of dynamical flow and nonlocal feedback stabilization

A.V.Fursikov, Moscow State University, Russia

As well-known, existence of weak solution for Navier-Stokes system is obtained with help of energy estimate. Absents of such bound in phase space H^1 in 3D case is serious obstacle to get nonlocal existence of smooth solutions.

Semilinear parabolic equation is called equation of normal type if its nonlinear term B satisfies the condition: $\forall v \in H^1$ $B(v)$ is collinear to v. Since the property $B(v) \perp v$ implies analog of energy estimate in H^1, equation of normal type does not satisfies energy estimate "in the most degree".

For 3D Helmholtz equations (that are analog of Navier-Stokes system where the curl of fluid velocity is given as unknown function) we derive corresponding normal parabolic equations (NPE). This means by definition that nonlinear term $B(v)$ of constructed NPE is orthogonal projection of nonlinear term $B_H(v)$ for Helmholtz system on the ray generated by v. It is turn out that there exists explicit formula for solution to NPE with periodic boundary conditions. This formula is used to study the structure of dynamical flow corresponding to NPE. We prove that its phase space V can be decomposed on the set of stability M_- (solutions with initial condition $\omega_0 \in M_-$ tends to zero with prescribed rate $e^{-\alpha t}$ as time $t \to \infty$), set of explosions M_+ (solutions with initial condition $\omega_0 \in M_+$ blow up during finite time), and set of growing M_G (norm of solutions with initial condition $\omega_0 \in M_G$ tends to infinity as time $t \to \infty$. The exact description of all these sets is given.

We hope to use obtained results to understand better questions connected with nonlocal solvability of 3D Helmholtz system.

All aforementioned results are true in the case of NPE corresponding to Burgers equation. Besides, in this case we construct nonlocal feedback stabilization of NPE solution by either starting or impulse or distributed control. In all cases we assume that this control is supported in an arbitrary fixed subdomain of the spatial domain.

Wednesday 4th, Parallel Session A, Aula Magna, 14:00

Optimal shape and location of actuators or sensors in PDE models

Yannick Privat, CNRS Paris, France

We investigate the problem of optimizing the shape and location of actuators or sensors for evolution systems driven by a partial differential equation, like for instance a wave equation, a Schrödinger equation, or a parabolic system, on an arbitrary domain Omega, in arbitrary dimension, with boundary conditions if there is a boundary, which can be of Dirichlet, Neumann, mixed or Robin. This kind of problem is frequently encountered in applications where one aims, for instance, at maximizing the quality of reconstruction of the solution, using only a partial observation. From the mathematical point of view, using probabilistic considerations we model this problem as the problem of maximizing what we call a randomized observability constant, over all possible subdomains of Omega having a prescribed measure. The spectral analysis of this problem reveals intimate connections with the theory of quantum chaos. More precisely, if the domain Omega satisfies some quantum ergodic assumptions then we provide a solution to this problem. These works are in collaboration with Emmanuel Trélat (Univ. Paris 6) and Enrique Zuazua (BCAM Bilbao, Spain).

Numerical controllability of the wave equation using finite elements for a space-time discretization

Nicolae Cïndea, Université Blaise Pascal, Clermont-Ferrand, France

The aim of this talk is to present some recent results [1, 2] concerning the numerical approximation of exact boundary controls for the wave equation with a potential. The goal is to compute approximations of controls that drive the solution from a prescribed initial state to zero at a large enough controllability time. In this purpose we use primal and dual methods coupled with Carleman estimates and with an augmented Lagrangian method respectively.

The specificity of these two methods is that the boundary control and the controlled solution are obtained in terms of a new variable - the solution of a fourth-order elliptic problem defined in the space-time domain. For the primal method we prove that, for some specific weights determined by the global Carleman inequalities for the wave equation, this problem is well-posed. For the dual method, we prove a inf-sup condition which is sufficient for the existence and uniqueness of solutions for the corresponding elliptic problem. In both cases, in the framework of the finite element method, we introduce a family of finite dimensional approximate control problems and we prove a strong convergence result. Numerical experiments confirm the analysis.

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Wednesday 4th, Parallel Session B, Room 128-129, 14:00

Geometry and control of polygonal linkages

Giorgi Khimshiashvili, Ilia State University, Tbilisi, Georgia

We consider various numerical invariants of the shape spaces of polygonal and arachnoid linkages. For planar linkages, we present some applications of the Riemannian curvature of shape space to the kinematic singularities and stability of motion. For spatial linkages, we discuss similar issues regarding the symplectic volume of shape space.

We will also describe the critical points of several geometrically interesting Morse functions on the shape spaces of such linkages with a view toward applications to the control theory. As a typical application we will present in some detail a scenario for controlling the shape of polygonal linkage by means of the Coulomb potential of point charges placed at its vertices.

State Estimation Techniques for Nonlinear Stochastic Systems and Application to Continuous Glucose Monitoring Systems

Alexandros Charalampidis, EPFL, Switzerland

The first part of the talk will deal with the recursive state estimation of discrete time nonlinear stochastic systems. Some basic results will be presented with emphasis on the Kalman Filter and its nonlinear variants (EKF,UKF,GHKF). The possibility for heuristic modifications of nonlinear Kalman Filters will be illustrated, and then the talk will focus on the systems that consist of linear dynamical systems interconnected through static nonlinear characteristics. For them, it is possible to avoid integration on the space space, which may be of high order, reducing it to the solution of some linear systems and low-order integration. This way, more accurate calculations can be made. Additionally, a novel quadrature technique, alternative to the Gauss-Hermite quadrature, specially designed for nonlinear filters using norm minimization concepts will be presented. Finally, improvements for the Auxiliary Particle Filter and the Unscented Particle Filter will be presented briefly. The results of the comparison of the proposed techniques with the standard ones in suitable examples show that in some cases the improvement is drastic.

The second part will deal with the application of filters to data from a Continuous Glucose Monitoring System (CGMS). The importance of the CGMS in the construction of an Artificial Pancreas will be explained and the problems of CGMSs will be described. Filters based on the Kalman Filter and on the Particle Filter will be presented, designed using simple models of the system dynamics. The application of the filters to experimental data from ICU patients shows that the use of filters leads to significant reduction of the glucose estimation error.

1. A. C. Charalampidis and G. P. Papavassilopoulos, Computationally Efficient Kalman Filtering for a Class of Nonlinear Systems, IEEE Transactions on Automatic Control, vol. 56, no. 3, pp. 483–491, Mar. 2011.

2. ——, Kalman Filtering for a Generalized Class of Nonlinear Systems and a New Gaussian Quadrature Technique, IEEE Transactions on Automatic Control, vol. 57, no. 11, pp. 2967–2973, Nov. 2012.

3. ——, Development and Numerical Investigation of New Nonlinear Kalman Filter Variants, IET Control Theory and Applications, vol. 5, no. 10, pp. 1155–1166, 2011.

4. ——, Improved Auxiliary and Unscented Particle Filter Variants, in Proceedings of the 52nd Conference on Decision and Control, Firenze, Italy, December 2013 (to appear).

Wednesday 4th, Aula Magna, 15:50

Short Course: Stochastic equations and control theory

Arnaud Debussche, ENS Rennes, France

Thursday 5th, Aula Magna, 9:00

A controllability result for the the non-isentropic 1-D Euler equation

Olivier Glass, Université Paris Dauphine, France

We examine the question of the boundary controllability of the one-dimensional non-isentropic Euler equation for compressible polytropic gas, in the context of weak entropy solutions. We consider the system in Eulerian coordinates and the one in Lagrangian coordinates. For both systems a result of controllability toward constant states is obtained (with a limitation on the adiabatic constant for the Lagrangian system). Moreover the solutions that are constructed remain of small total variation in space for all time.

Optimality in Robot Motion

Jean-Paul Laumond, CNRS Toulouse, France

The talk emphasizes on the distinction between an optimal robot motion and a robot motion resulting from the application of optimization techniques. Most of the time, optimal motions do not exist and when they exist they are difficult to compute. The goal of the talk is to introduce a clear distinction between optimal motion planning and motion optimization. To do so we overview three key points of view that come from different communities (robotics, differential geometry, control, computer science, numerical analysis). They all address optimality in robot motion, but they are rarely gathered into a single presentation. They deal with

1. robot motion planning and control,

2. motion generation for humanoid robots, and

3. inverse optimal control, respectively.

Degenerate parabolic operators of Kolmogorov type with a geometric control condition

Karine Beauchard, Ecole Polytechnique, France

We consider Kolmogorov-type equations on a rectangle domain $(x, v) \in \Omega = \mathbb{T} \times (-1, 1)$, that combine diffusion in variable v and transport in variable x at speed v^γ, $\gamma \in \mathbb{N}^*$, with Dirichlet boundary conditions in v. We study the null controllability of this equation with a distributed control as source term, localized on a subset ω of Ω,

$$\begin{cases} \left(\partial_t - v^\gamma \partial_x - \partial_v^2\right) f(t,x,v) = u(t,x,v) 1_\omega(x,v)\,, & (t,x,v) \in (0,T) \times \mathbb{T} \times (-1,1)\,, \\ f(t,x,\pm 1) = 0\,, & (t,x) \in (0,T) \times \mathbb{T}\,. \end{cases}$$

Thanks to the interplay between diffusion in v and transport in x, the equation diffuses both in variables v and x (contrarily to equation $(\partial_t - \partial_v^2)g(t,x,v) = 0$) but, in a weaker way than the $2D$ heat equation (i.e. $(\partial_t - \partial_x^2 - \partial_v^2)g(t,x,v) = 0$). Thus, natural questions are the following ones.

Question 1: Is the diffusion in variable v strong enough for observability to hold when the control acts on a horizontal strip $\omega = \mathbb{T} \times (a, b)$ with $0 < a < b < 1$, whatever $\gamma \in \mathbb{N}^*$ is? (i.e. as for equation $(\partial_t - \partial_v^2)g = 0$, $(t, x, v) \in (0, T) \times \mathbb{T} \times (-1, 1)$)

Question 2: Is the diffusion in variable x sufficient for null controllability to hold when the control acts on a vertical strip $\omega = \omega_1 \times (-1, 1)$ where $\omega_1 \subset\subset \mathbb{T}$? (i.e. as for the 2D heat equation)

When the control acts on a horizontal strip $\omega = \mathbb{T} \times (a, b)$ with $0 < a < b < 1$, then the system is null controllable in any time $T > 0$ when $\gamma = 1$, and only in large time $T > T_{min} > 0$ when $\gamma = 2$: a finite speed of propagation occurs (see [1]). When $\gamma > 3$, the system is not null controllable (whatever T is) in this configuration, even if unique continuation holds (see [2]). Thus, the first order term $v^\gamma \partial_x$ weakens strongly the diffusion in variable v when $\gamma \geqslant 3$. These results answer **Question 1**.

When the control acts on a vertical strip $\omega = \omega_1 \times (-1, 1)$ with $\overline{\omega_1} \subset \mathbb{T}$, we investigate the null controllability on a toy model, where $(\partial_x, x \in \mathbb{T})$ is replaced by $((-\Delta)^{1/2}, x \in \Omega_1)$, and Ω_1 is an open subset of $\mathbb{R}^N$. As the original system, this toy model satisfies the controllability properties listed above. We prove that, for $\gamma = 1, 2$ and for appropriate domains (Ω_1, ω_1), then null controllability does not hold (whatever $T > 0$ is), when the control acts on a vertical strip $\omega = \omega_1 \times (-1, 1)$ with $\overline{\omega_1} \subset \Omega_1$ (see [2]). Thus, a geometric control condition is required for the null controllability of this toy model. It indicates that a geometric control condition may be necessary for the original model too. This is a conjecture about the answer of **Question 2**.

References

1. K. Beauchard, Null controllability of Kolmogorov-type equations, *Mathematics of Control, Signals, and Systems* (to appear), 2013.
2. K. Beauchard, B. Helffer, R. Henry, L. Robbiano, *Degenerate parabolic operators of Kolmogorov type with a geometric control condition*, preprint, 2013.

Design and stability of quantum filters with measurement imperfections: discrete-time and continuous-time cases

Pierre Rouchon, Mines ParisTech, France

This talk starts with a detailed description of the discrete-time quantum filter used at Laboratoire Kastler Brossel (LKB) for nonlinear state feedbacks stabilizing photon-number states. This filter provides a real-time estimation of the density matrix of the photons trapped inside a cavity. This filter combines quantum probability and the usual Bayes law. It takes into account measurement imperfections, delays and also decoherence. Such kind of filters are shown to be always stable and tend to forget their initial conditions.

Since the seminal contributions of Belavkin, quantum filtering is usually developed in continuous time. We propose here a suggestive and direct path from discrete-time towards continuous-time filters. This path has been used in the thesis of Hadis Amini to derive a new set of continuous time filters driven simultaneously by Wiener and Poisson processes. Similarly to the discrete-time case, such continuous-time filters take into account measurement imperfections and decoherence. They are shown to be stable but their convergence analysis remains an open-problem.

Thursday 5th, Parallel Session A, Aula Magna, 14:00

Finite-time stabilization of hyperbolic systems on tree-shaped networks

Lionel Rosier, Université de Lorraine, France

We investigate the finite-time boundary stabilization of a 1-D first order quasilinear hyperbolic system of diagonal form on $[0,1]$. The dynamics of both boundary controls are governed by a finite-time stable ODE. The solutions of the closed-loop system issuing from small initial data in $Lip([0,1])$ are shown to exist for all times and to reach the null equilibrium state in finite time. When only one boundary feedback law is available, a finite-time stabilization is shown to occur roughly in a twice longer time. The above feedback strategy is then applied to the Saint-Venant system for the regulation of water flows in a network of canals.

This is a joint work with Vincent Perrollaz (University of Tours).

Stabilization of some fluid-structure models

J.-P. Raymond, Université Paul Sabatier Toulouse III, France

We shall address the problem of stabilizing systems coupling the incompressible Navier-Stokes equations with damped elastic models. We are mainly interested in the case when the control acts only in the structure equations. We shall consider two dimensional domains with a damped an Euler-Bernoulli beam located at the boundary of the fluid domain and three dimensional domains with a damped plate located at the boundary of the fluid domain. The case when the structure is governed by the linear elasticity equations with damping will also be considered. These results extend previous results already published in SIAM J. Control and Optim. (Feedback stabilization of a fluid-structure model. SIAM J. Control Optim. 48 (2010), no. 8, 5398–5443).

Thursday 5th, Parallel Session B, Room 128-129, 14:00

Simultaneous global exact controllability of an arbitrary number of 1D bilinear Schrödinger equations

Morgan Morancey, Ecole Polytechnique, Palaiseau, France

This talk deals with simultaneous global exact controllability of an arbitrary (finite) number of 1D bilinear Schrödinger equations

$$\begin{cases} i\partial_t \psi^j = \big(-\partial^2_{xx} + V(x)\big)\psi^j - u(t)\mu(x)\psi^j, & (t,x) \in (0,T)\times(0,1),\, j\in\{1,\dots,N\}, \\ \psi^j(t,0) = \psi^j(t,1) = 0, & t\in(0,T),\, j\in\{1,\dots,N\}. \end{cases} \tag{3}$$

This is a joint work with Vahagn Nersesyan [3].

In this setting we have N identical equations controlled by a single control u. This control is the amplitude of the external field applied on the particles. Our controllability result holds for an arbitrary potential V with generic assumptions on the dipole moment μ.

From the local exact controllability around the ground state in $H^3_{(0)}$ obtained by K. Beauchard and C. Laurent [1] and the global approximate controllability towards the ground state obtained by V. Nersesyan [4], global exact controllability was known for the case of a single equation with $V = 0$.

Our proof combines three steps. Using Lyapunov-like ideas we prove global approximate controllability towards vectors that are finite sums of eigenvectors.

The simultaneous local exact controllability is obtained thanks to the return method introduced by J.-M. Coron. As in [2] the reference trajectory is designed using partial control results. The controllability of the linearized system around this reference trajectory relies on suitable Riesz basis properties.

Simultaneous global exact controllability is then obtained by connectedness and compactness arguments.

Finally, this result is extended to arbitrary potentials using translations on the controls.

References

1. K. Beauchard and C. Laurent. Local controllability of 1D linear and nonlinear Schrödinger equations with bilinear control. J. Math. Pures Appl. (9), 94(5):520?554, 2010.

2. M. Morancey. Simultaneous local exact controllability of 1D bilinear Schrödinger equations. Ann. Inst. H. Poincaré Anal. Non Linéaire, 2013. DOI : 10.1016/j.anihpc.2013.05.001.

3. M. Morancey and V. Nersesyan. Simultaneous global exact controllability of an arbitrary number of 1D bilinear Schrödinger equations. preprint, arXiv:1306.5851, 2013.

4. V. Nersesyan. Global approximate controllability for Schrödinger equation in higher Sobolev norms and applications. Ann. Inst. H. Poincaré Anal. Non Linéaire, 27(3):901?915, 2010.

Making irrational pedestrian behave as rational: A challenge in control of PDEs

Fabio S. Priuli, University Roma Tor Vergata, Italy

In this talk we present a new mathematical model for pedestrians moving in a large built environment. The model allows one to switch on and off the rational and predictive abilities of pedestrians. We assume that poorly rational pedestrians just move following signs and perform basic short–range interactions with the others. On the contrary, highly rational pedestrians are assumed to know the environment they move in and to optimize their path based on a perfect prevision of the movements of the others, thus minimizing the time to reach their destinations.

From the mathematical point of view, the pedestrian flow in the environment is described by a 2D continuity equation with nonlocal flux, in the spirit of multiscale model approach presented in [1], where the desired velocity of the pedestrian is either assigned at start (poorly rational behavior) or deduced by solving at each time an Hamilton–Jacobi equation to obtain the optimal path to the target (highly rational behavior), along the lines of [2,3].

The final goal of our research is to "optimize" the shape of the environment, by adding barriers and obstacles, in such a way that the solution corresponding to poor rationality is as close as possible to the target solution corresponding to high rationality, so to get a "good" behavior of the pedestrians even in the case of incomplete information and limited predictive capabilities.

Numerical simulations will be presented to illustrate the different behaviors of pedestrian and the effect of the shape of the domain on the dynamics.

Joint work with A. Tosin & E. Cristiani, CNR IAC Roma

[1] E. Cristiani, B. Piccoli, A. Tosin, *Multiscale modeling of granular flows with application to crowd dynamics,* Multiscale Model. Simul., **9**(1),155–182, 2011

[2] R. L. Hughes, *A continuum theory for the flow of pedestrians,* Transportation Res. B, **36**, 507–535, 2002.

[3] S. P. Hoogendoorn, P. H. L. Bovy, *Simulation of pedestrian flows by optimal control and differential games,* Optimal Control Appl. Methods, **24**, 153–172, 2003.

Decomposition, Potential-based Realization, and Stabilization of Nonlinear Systems

Nicolas Hudon, Universite Catholique de Louvain, Belgium

This contribution considers the problem of representing a sufficiently smooth nonlinear dynamical system as a structured potential-driven system and to exploit the obtained structure for the design of nonlinear state feedback stabilizing controllers. The problem has been studied in recent years for systems modeled as structured potential-driven systems, for example gradient systems, generalized Hamiltonian systems and systems given in Brayton–Moser form. To recover the advantages of those representations for the stabilization of general nonlinear systems, the present note proposes a geometric decomposition technique to re-express a given vector field into a desired potential-driven form. The decomposition method is based on the Hodge decomposition theorem, where a one-form associated to the given vector field is decomposed into its exact, co-exact, and harmonic parts. In particular, it is shown that the combination of the homotopy and the dual homotopy operators provides a general decomposition of the nonlinear system as a potential-driven system. Using the identified structure, it is then possible to design a stabilizing damping state feedback controller and ensure stability of desired isolated equilibria of the control system.

Sparse Stabilization of dynamical systems driven by attraction and avoidance forces

Mattia Bongini, Technische Universität München, Germany

In this talk we address dynamical systems of agents driven by attraction and repulsion forces, modelling cohesion and collision avoidance. When the total energy, which is composed of a kinetic part and a geometrical part describing the balance between attraction and repulsion forces, is below a certain threshold, then it is known that the agents will converge to a dynamics where mutual space confinement is guaranteed. In this paper we question the construction of a stabilization strategy, which requires the minimal amount of external intervention for nevertheless inducing space confinement, also when the initial energy threshold is violated. Our main result establishes that if the initial energy exceeds the threshold mainly because of its kinetic component, then a sparse control instantaneously applied with enough strength on the most rowdy agent, i.e., the one with maximal speed, will be able to steer in finite time the system to an energy level under the threshold.

Thursday 5th, Aula Magna, 16:00

Short Course: Stochastic equations and control theory

Arnaud Debussche, ENS Rennes, France

Friday 6th, Parallel Session A, Aula Magna, 9:00

Boundary null controllability of parabolic systems

Assia Benabdallah, Aix-Marseille University, France

In this lecture we will focus on the boundary controllability of parabolic systems. The particularity is that the control is exerted on some of the components. With respect with parabolic control problems, we will see new phenomena such as conditions on the time control and geometric conditions on the location of the control.

Geometric control theory and Microswimmers

François Alouges, CMAP-Ecole Polytechnique, France

The talk will give an overview of the locomotion problem in a fluid at low Reynolds number and recent mathematical results obtained for such problems. We will show in particular how modelization principles can rephrase the problem as a control problem linear in the controls without drift, and where the controls are given by the rate of shape changes. Borrowing results from Geometric control theory permits then to show the controllability of model swimmers and understand in a whole most of the known results in the physics literature.

Most of this work is in collaboration with several people around A. DeSimone at SISSA and myself at the Ecole Polytechnique.

Friday 6th, Parallel Session B, Room 128-129, 9:00

Observer convergence from the Riemannian point of view

Laurent Praly, Mines ParisTech, France

An observer whose state lives in a copy of the given system's space and which guarantees the property that a Riemannian distance between system and observer solutions is nonincreasing is such that that the Lie derivative of the Riemannian metric along the system vector field is negative in the space tangent to the output function level sets. Also, if the observer has an infinite gain margin then the level sets of the output function are geodesically convex.

Conversely, if these two properties are satisfied, then there exists an observer with an infinite gain margin.

The existence of a Riemannian metric satisfying these two properties is guaranteed for systems that are strongly differentially observable.

The existence of a Riemannian metric satisfying the inequality on its Lie is also guaranteed when the time-varying linear systems resulting from the linearization along solutions to the system satisfy an observability property. On the other hand, the fact that it makes the output level sets geodesically convex is equivalent to the existence of a reduced order observer.

Path planing for Kinematic systems : a conjecture

Nicolas Boizot, LSIS Toulon, France

This talk presents the main ideas of a theory of path planning for kinematic systems. In particular this theory deals with ε-approximations of highly non-admissible paths by admissible ones in a certain optimal sense.

Up to now, the solution trajectories obtained for kinematic systems with flag of distributions of type $(2, 3)$, $(2, 3, 4)$, $(2, 3, 5)$ and $(2, 3, 5, 6)$ displays a behavior that opens up a nice conjecture. The academic system of the "ball with a trailer rolling on a plane", which is a system of flag $(2, 3, 5, 6)$, will serve as an illustrative example to the method.

Friday 6th, Aula Magna, 11:10

Recent advances in the approximation of optimal control problems via dynamic programming

Maurizio Falcone, SAPIENZA - Università di Roma, Italy

The approximation of optimal control problems and games via the solution of the Hamilton–Jacobi–Bellman or Isaacs equation is a well known technique. The advantage of this method is that it stands on solid mathematical grounds, the drawback is the difficulty to use it for large scale problems due to the curse of dimensionality.

I will present some recent advances trying to develop new algorithms for the solutions of equations in rather high dimension ($n \leq 10$). Among these techniques we will discuss efficient algorithms in high dimension and their application to dynamic programming equations, fast marching schemes and adaptive domain decomposition. The methods will be illustrated by several examples giving some hints on their efficiency, accuracy and implementation.

Some recent advances on time optimal control problems for infinite dimensional systems

Marius Tucsnak, University of Lorraine, France

We consider the time optimal control problem, with a point target, for a class of infinite dimensional systems with a dynamics governed by an abstract heat or Schrödinger type equation. The main results establish a Pontryagyn type maximum principle (for the Schrö dinger case) and give sufficient conditions for the bang-bang property of optimal controls (for both types of systems). The results are then applied to some systems governed by partial differential equations. The paper ends by a discussion of possible extensions and by stating some open problems. The main part of the presented results have been obtained [1] and [2].

References

1. S. Micu, I. Roventa and M. Tucsnak, Time optimal boundary controls for the heat equation, Journal of Fuctional Analysis 262 (2012), 25-49.

2. J. Lobéac and M. Tucsnak, Maximum principle and bang-bang property of time optimal controls for Schrö dinger type systems, to appear in SIAM Journal on Control.