ÖAW AUSTRIAN ACADEMY OF SCIENCES

RICAM
JOHANN·RADON·INSTITUTE FOR COMPUTATIONAL AND APPLIED MATHEMATICS

RICAM Special Semester on Optimization

Workshop 5
Feedback Control

Book of Abstracts

(c) Johann Steininger

Linz, Austria
November 28-30, 2019

Workshop Schedule

Thursday 28 November

9:00-9:20 **Registration**
9:20-9:30 **Welcome in Conference Room**
9:30-10:00 V. Barbu: *Asymptotic feedback controllability of Fokker-Planck equation.*
10:00-10:30 M. Herty: *Riccati Control for Particle Dynamics.*
10:30-11:00 **Coffee**
11:00-11:30 E. Cerpa: *Feedback designs for some linear infinite-dimensional systems.*
11:30-12:00 M. Tucsnak: *Polynomial stabilizability for a class of skew-adjoint systems describing water waves.*
12:00-12:30 S. Gomes: *Feedback control of falling liquid films.*
12:30-14:00 **Lunch**
14:00-14:30 C. Pignotti: *Stability estimates for a Korteweg-de-Vries-Burgers equation with feedback delay.*
14:30-15:00 M. Gugat: *The limits of stabilizability for networks of strings.*
15:00-15:30 C. Prieur: *Beam equation with saturating piezoelectric controls.*
15:30-16:00 **Coffee**
16:00-16:30 T. Meurer: *Flatness-based optimal and predictive control for PDEs.*
16:30-17:00 L. Pfeiffer: *Analysis of the Receding Horizon Control method for stabilization problems.*
17:00-17:30 L. Grüne: *Towards efficient discretizations in model predictive control of PDEs.*
18:30– **Fingerfood, drinks and posters**

Friday 29 November

9:30-10:00 M. Falcone: *Discrete-time Dynamic Programming on a tree structure for finite-horizon optimal control.*
10:00-10:30 L. Saluzzi: *A HJB-POD approach for the control of nonlinear PDEs on a tree structure.*
10:30-11:00 **Coffee**
11:00-11:30 S. Dolgov: *A tensor decomposition approach for high-dimensional Hamilton-Jacobi-Bellman equations.*
11:30-12:00 T. Breiten: *Nonlinear infinite-horizon control using generalized Lyapunov equations.*
12:00-12:30 G. Kirsten: *Order reduction methods for solving large-scale differential matrix Riccati equations.*
12:30-14:00 **Lunch**
14:00-14:30 J.-P.Raymond: *Robust boundary stabilization of fluid flows in the case of partial observation.*
14:30-15:00 P. Benner: *Numerical Computation of Robust Controllers for Incompressible Flow Problems.*
15:00-15:30 T. Takahashi: *Feedback boundary stabilization of a fluid-beam interaction system.*
15:30-16:00 **Coffee**
16:00-16:30 J.A. Burns: *Numerical Modeling for Feedback Control and Optimization of DPS.*
16:30-17:00 H. Zidani: *TBA*
17:00-17:30 B. Krämer: *LQR control for systems with uncertain parameters via online-adaptive reduced models.*
19:00– **Conference dinner**

Saturday 30 November

9:30-10:00 G. Pavliotis: *Spectral methods for linear and nonlinear Fokker-Planck equations.*
10:00-10:30 G. Albi: *The Boltzmann-Bellman approach for mean field control problems.*
10:30-11:00 **Coffee**
11:00-11:30 G. Marinoschi: *Feedback stabilization of a phase-field system with viscosity effects.*
11:30-12:00 A. Shirikyan: *Exponential mixing in terms of controllability and application to boundary-driven 2D Navier–Stokes.*
12:00-12:30 S. Rodrigues: *Semiglobal exponential stabilization of nonautonomous semilinear parabolic-like systems.*
12:00-12:31 **The End**

The Boltzmann-Bellman approach for mean field control problems

Giacomo Albi
University of Verona, Italy

Abstract

In this talk we will focus on the control of large systems of interacting agents. Starting from different motivating examples in the context of collective behavior, we will introduce a class of mean field optimal control problems, where the constrain is described by the evolution of a non-local PDE. Typically direct approaches for this problems fail to converge, due to the non-linearities and high-dimensionality of these problems.

In order to tame the computational cost induced by this setting we study first a reduced optimization problem for a binary interaction dynamics, deriving a class of feedback control laws via MPC, and dynamic programming techniques. Secondly, we embed such binary controlled dynamics in a Boltzmann-type model, and we develop a stochastic algorithm based on Monte-Carlo methods for kinetic equations, and whose computation requires a moderate numerical complexity and independent on the dimension. Finally, we show that under a proper scaling this method induces a hierarchy of feedback controls for the original mean-field dynamics.

Several numerical experiments will validate the theoretical findings, with applications to opinion formation, flocking and swarming dynamics.

This is a joint collaboration with: D. Kalise, M. Herty.

Asymptotic feedback controllability of Fokker-Planck equation

Viorel Barbu
Romanian Academy, Iasi, Romania

Abstract

One designs a nonlinear feedback controller which steers along the dynamics defined by the Fokker-Planck equation, the initial probability density to a final one in an infinite time. This result is used to the controllability in an infinite time of stochastic differential equations.

Numerical Computation of Robust Controllers for Incompressible Flow Problems

Peter Benner
Max Planck Institute for Dynamics of Complex Technical Systems, Magdeburg, Germany

Abstract

We consider the stabilization of incompressible fluid flow using linearized and spatially discretized models. In order to potentially work in applications, the designed controller must stabilize the discrete model with a robustness margin that covers linearization, discretization, and modeling errors. We show that a linearization error in the infinite-dimensional model amounts to a coprime factor uncertainty and show that H_∞-robust controllers can compensate this in the discrete approximation. To compute such controllers, standard software to solve algebraic Riccati equations cannot be used due to the potential indefiniteness of the Hessian. We report on an iterative scheme that overcomes this problem and can be applied to large-scale problems by emplyoing low-rank techniques. In numerical experiments, we quantify the robustness margins and show that the H_∞-robust controller, unlike the LQG-controller, is capable of stabilizing nonlinear incompressible Navier-Stokes equations with an inexact linearization.

This is joint work with Jan Heiland and Steffen Werner (MPI Magdeburg).

Nonlinear infinite-horizon control using generalized Lyapunov equations

Tobias Breiten
Institute of Mathematics and Scientific Computing
Karl-Franzens-Universität Graz Heinrichstraße 36 - A-8010 Graz

Abstract

It is well-known that the solution to the infinite-horizon linear-quadratic control problem is characterized by the algebraic Riccati equation. For nonlinear dynamics, one instead has to focus on the Hamilton-Jacobi-Bellman equation, a nonlinear PDE that suffers from the curse of dimensionality. This talk discusses approximation techniques for the HJB equation based on a series of generalized Lyapunov equations. Theoretical and numerical results as well as future challenges for these types of equations are presented. This is joint work with Karl Kunisch and Laurent Pfeiffer.

Numerical Modeling for Feedback Control and Optimization of DPS

John A. Burns
IInterdisciplinary Center for Applied Mathematics
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0531

Abstract

Currently there is considerable interest in model based engineering design (MBED) and using the concept of digital twins to enable this methodology. The basic idea is to develop "numerical models" of a system and to use these models in a design process. Most of the work in this area is focused on simulation based design and the numerical models are constructed with this as the goal. However, if one uses the model for other purposes such as control of optimization, then the numerical model may not be appropriate. Thus, the numerical modelling effort should always consider all possible uses of the model. In this presentation we consider higher order approximation schemes for developing numerical models suitable for both simulation and optimization. We focus on methods that are (a) convergent and (b) dual convergent / consistent. We discuss discontinuous Galerkin and finite element schemes and show that *hp* - finite element schemes can be employed to develop high order methods that satisfy (a) and (b). The problems are motivated by applications to industrial systems. Numerical examples involving systems governed by partial and delay differential equations are given to illustrate the method and ideas.

Feedback designs for some linear infinite-dimensional systems

Eduardo Cerpa
Universidad Técnica Federico Santa María, Chile

Abstract

In this talk we will be concerned with the boundary stabilization of two different infinite-dimensional systems: the linear Moore-Gibson-Thompson equation and one delayed parabolic-elliptic system. For the first equation we will show a feedback design built with the backstepping method. For the second system we use the Artstein transform to deal with the delay and the pole placement method to stabilize. More or less explicit feedback laws are obtained in each case.

These ongoing works are in collaboration with C. Lizama (Santiago), C. Roman (Bessancon), S. Zamorano (Santiago), H. Parada (Santiago) and K. Morris (Waterloo).

A tensor decomposition approach for high-dimensional Hamilton-Jacobi-Bellman equations

Sergey Dolgov
University of Bath, United Kingdom

Abstract

Joint work with Dante Kalise and Karl Kunisch.

It was dynamic programming that motivated Richard Bellman to coin the term "curse of dimensionality", referring to an exponential growth of the number of unknowns in a numerical solution with the number of independent coordinates in a system. Specifically, we consider optimal feedback control of a dynamical system, assuming no knowledge of the initial state. This is useful when certain objectives (e.g. stabilisation) must be achieved for a system subject to stochastic perturbation. Optimal control for any current state of the system can be produced from the value function, which satisfies the Hamilton-Jacobi-Bellman (HJB) equation. However, the latter is a high-dimensional PDE with the number of coordinates being equal to the state dimension of the original dynamical system. Straightforward numerical discretization of the HJB equation can thus go out of memory for fewer than ten dimensions.

Traditional approach to the optimal feedback control problem relies on a linear approximation of a system, solution of a (low-dimensional) Riccati equation for the so-called Linear Quadratic Regulator (LQR), and higher-order nonlinear perturbations where necessary (T. Breiten et al., 2018). Recently a polynomial ansatz with a bounded total degree was used successfully for a direct numerical solution of a moderate dimensional HJB equation (D. Kalise et al., 2018). However, it still suffers from a rapid growth of complexity for larger systems.

In this talk, I will discuss our alternative approach of applying low-rank tensor decompositions to a high-dimensional HJB equation for optimal feedback control of a PDE system. For linear systems, low ranks of the value tensor can be backed up by low mosaic ranks of the Riccati solution. However, numerical evidence suggests that some strongly nonlinear PDEs admit also a low-rank value function, which can be approximated efficiently by low-rank tensor algorithms, and which can deliver a much lower running cost than LQR.

A discrete time Dynamic Programming approach on a tree structure for finite horizon optimal control problems

Maurizio Falcone
Dipartimento di Matematica
Università di Roma La Sapienza

Abstract

The classical Dynamic Programming (DP) approach to optimal control problems is based on the characterization of the value function as the unique viscosity solution of a Hamilton-Jacobi-Bellman (HJB) equation. The DP scheme for the numerical approximation of viscosity solutions of those equations is typically based on a time discretization which is projected on a fixed space triangulation of the numerical domain. The time discretization can be done by a one-step scheme for the dynamics and the projection on the grid typically uses a polynomial interpolation. This approach, which allows to get information on optimal controls in feedback form, works in any dimension although its practical application has been limited to rather low dimensional problems. Several methods have been proposed to mitigate the curse of dimensionality of DP schemes, e.g. static and dynamic domain decomposition, fast-marching and fast-sweeping methods and discrete representation formulas.
We will discuss a new approach for finite horizon optimal control problems where we compute the value function on a tree structure constructed directly by the time discrete dynamics and we do not use a space discretization to solve the HJB equation. This allows to drop the cost of space interpolation, moreover the tree will guarantee a perfect matching with the discrete dynamics. We prove convergence and a-priori error estimates. In the simple case, we discretize the dynamics with an Euler scheme and we will prove first order convergence to the value function in the framework of viscosity solutions. We will also discuss how this approach

can be extended to high-order schemes, show some examples of second order approximation schemes and applications to the control of evolutive PDEs.

Based on joint works with Alessandro Alla (PUC, Rio de Janeiro) and Luca Saluzzi (Gran Sasso Science Institute, L'Aquila, Italy).

Feedback control of falling liquid films

Susana Gomes
University of Warwick

Abstract

The flow of a thin film down an inclined plane is an important physical phenomenon appearing in many industrial applications, such as coating (where it is desirable to maintain the fluid interface flat) or heat transfer (where a larger interfacial area is beneficial). These applications lead to the need of reliably manipulating the flow in order to obtain a desired interfacial shape. The interface of such thin films can be described by a number of models, each of them exhibiting instabilities for certain parameter regimes. In this talk, we propose a feedback control methodology based on same-fluid blowing and suction. We use the Kuramoto–Sivashinsky (KS) equation to model interface perturbations and to derive the controls. We show that we can use a finite number of point-actuated controls based on observations of the interface to stabilise both the flat solution and any chosen nontrivial solution of the KS equation. Furthermore, we investigate the robustness of the designed controls to uncertain observations and parameter values, and we study the effect of the controls across a hierarchy of models for the interface, which include the KS equation, (nonlinear) long-wave models and the Navier–Stokes equations.

Towards efficient discretizations in model predictive control of PDEs

Lars Grüne
Chair of Applied Mathematics, University of Bayreuth, Germany

Abstract

Model predictive control (MPC) is a popular control method, in which a feedback control is computed from the successive numerical solution of optimal control problems. For large scale systems including numerically discretized PDEs this method is computationally challenging, because the optimal control problems must be solved within one sampling period, i.e., in a potentially relatively short time.

A particular feature of MPC is that typically the optimal control problems are solved on overlapping horizons, implying that only a small portion of the computed optimal control function is actually used. This suggests that an adapted discretization in time and/or space may offer a large benefit for MPC of PDEs. In this talk we first explain the theoretical justification of this approach based on novel sensitivity results for the optimal control of general evolution equations. Then the efficiency of the proposed method is illustrated by numerical experiments.

The talk is based on joint work with Manuel Schaller and Anton Schiela (both University of Bayreuth).

The limits of stabilizability for networks of strings

Martin Gugat
Friedrich-Alexander-Universität Erlangen-Nürnberg
Department of Mathematics
Chair in Applied Analysis (Alexander von Humboldt-Professorship)

Abstract

Many systems in engineering can be modeled as boundary control system with system dynamics defined on a graph where on each edge, the evolution is governed by a hyperbolic equation.

Often, there exist feedback loops that stabilize the system exponentially fast. However, this requires certain assumptions on the data. In particular, if the edges are too long, sometimes boundary stabilization is impossible. In this talk, this phenomenon is illustrated for networks of vibrating strings that are governed by the wave equation with a certain source term. For certain source term, the system cannot be stabilized if the total length of the strings is too large.

Riccati Control for Particle Dynamics

Michael Herty
RWTH Aachen University

Abstract

We survey recent results on controlled particle systems. The control aspect introduces new challenges in the discussion of properties and suitable mean field limits. Some of the aspects are highlighted in a detailed discussion of a particular controlled particle dynamics. The applied techniques are shown on this simple problem to illustrate the basic methods. Computational results confirming the theoretical findings are presented and further particle models are discussed.

LQR control for systems with uncertain parameters via online-adaptive reduced models

Boris Krämer
University of California San Diego
Department of Mechanical and Aerospace Engineering

Abstract

We present a online-adaptive reduced-order modeling strategy for controlling large-scale linear systems with uncertain, time-varying parameters. The approach follows an offline-online decomposition. During the offline phase, we use a high-fidelity model to compute a library of LQR feedback control gains over a sampled set of parameter values. Then, during the online phase, in which the uncertain parameter changes over time, we learn a reduced-order model (ROM) from system data. The learned ROM is employed within an optimization routine to update the feedback control throughout the online phase. Since the system data naturally reflects the uncertain parameter, the data-driven updating of the controller gains is achieved without an explicit parameter estimation step. We consider two numerical test problems in the form of partial differential equations: a convectiondiffusion system, and a model for flow through a porous medium. We demonstrate on those models that the proposed method successfully stabilizes the system model in the presence of process noise.

Feedback stabilization of a phase-field system with viscosity effects

Gabriela Marinoschi
Gheorghe Mihoc-Caius Iacob Institute of Mathematical Statistics and Applied Mathematics of the Romanian Academy, Calea 13 Septembrie 13, Bucharest, Romania

Abstract

We discuss the internal feedback stabilization of a phase field system of Cahn-Hilliard type with viscosity effects in the equation for the phase, by using a feedback controller with support in a subset of the domain. The technique is based on the design of the controller as a linear combination of the unstable modes of the corresponding linearized system, followed by its representation in a feedback form by means of an optimization method. Results are provided both for a regular potential involved in the phase field equation (the double-well potential) and for a singular potential of logarithmic type. At the end, the limit case as the viscosity tends to zero is discussed.

Flatness-based optimal and predictive control for PDEs

Thomas Meurer
Chair of Automatic Control, Kiel University, Kaiserstr. 2, 24143 Kiel, Germany, email: tm@tf.uni-kiel.de

Abstract

The concept of (differential) flatness in general refers to the determination of the state and the input parametrization by means of a so-called flat output and its derivatives. The flatness property can be in particular for finite-dimensional systems immediately exploited to solve trajectory planning and tracking control problems. In recent years different approaches have been presented to extend this concept to systems governed by partial differential equations (PDEs) eventually leading to a systematic solution of the trajectory planning and feedforward control problems. However, the flatness concept does not immediately allow to incorporate input and state constraints or to include optimization criteria such as energy or time optimality. In this contribution, a twofold extension of the flatness approach for PDEs is proposed.

At first, flatness-based optimal control for PDEs is considered to efficiently address input and state constraints as well as the minimization of cost functionals. In particular, a constrained dynamic optimization problem is formulated based on an integrator chain representing the flat output trajectory and its derivatives. Herein, the highest derivative serves as the decision variable and input to the integrator chain. By using a discrete time formulation the dynamic optimization problem is transferred to a static problem, which can be efficiently solved using, e.g., interior-point methods. Taking into account the state and input parametrization, that is computed for the system under consideration prior to the optimization, this results in a flatness-based constrained optimal control approach, which does not require to solve any PDE.

These results are at second extended to a model predictive control (MPC) setup to achieve closed-loop optimal control and stabilization. For this the constrained optimal control problem expressed in terms of the integrator chain representing the flat output and the obtained state and input parametrizations is solved on a receding horizon. The integrator chain is in addition used to develop an observer to estimate the successive flat output derivatives based on the output from the PDE model to update the MPC.

Simulation results are presented for different scenarios involving open-loop stable and unstable diffusion-convection-reaction systems to illustrate the performance of the proposed design approaches.

Spectral methods for linear and nonlinear Fokker-Planck equations with applications to optimal control

Grigorios A. Pavliotis
Department of Mathematics, Imperial College London

Abstract

In this talk I will present some recent results on spectral numerical methods for the numerical solution on Fokker-Planck equations. We consider both linear and nonlocal/nonlinear, McKean-Vlasov PDEs, that arise in the mean field limit of weakly interacting diffusions. A main feature of the spectral numerical method is that no gradient structure is required. We illustrate the performance of our method by studying phase transitions for mean field models of interacting diffusions with collored noise. We then show how this numerical method can be used to study optimal control problems for diffusion processes and their associated Fokker-Planck equation. This is joint work with Susana Gomes (Warwick), Dante Kalise (Nottingham) and Urbain Vaes (Imperial College London).

Analysis of the Receding Horizon Control method for stabilization problems

Laurent Pfeiffer
Inria-Saclay and Ecole Polytechnique

Abstract

This talk is dedicated to the analysis of the Receding Horizon Control (RHC) algorithm. The method aims at approximating the solution to optimal control problems on large time-horizons. As it is well-known, it consists in solving a sequence of truncated problems with a small prediction horizon. A control is generated by concatenation of the obtained solutions, each solution being restricted to a sampling time.

The analysis will focus on a class of infinite-horizon stabilization problems of partial differential equations. An error estimate, bringing out the effect of the prediction horizon and the sampling time, will be provided for the distance of the generated control to the optimal one. The use of a terminal cost for the truncated problems will also be discussed.

Based on joint works with Tobias Breiten (University of Graz) and Karl Kunisch (University of Graz).

References:

- Karl Kunisch and Laurent Pfeiffer. The effect of the Terminal Penalty in Receding Horizon Control for a Class of Stabilization Problems. ArXiv preprint, 2018.
- Tobias Breiten and Laurent Pfeiffer. On the Turnpike Property and the Receding-Horizon Method for Linear-Quadratic Optimal Control Problems. ESAIM Control Optim. Calc. Var., to appear.

Stability estimates for a Korteweg-de-Vries-Burgers equation with feedback delay

Cristina Pignotti
Università di L'Aquila

Abstract

We consider a KdV-Burgers equation with indefinite damping and time delay in the whole real line. Under appropriate conditions on the damping mechanism and the time delay feedback, global well-posedness and exponential decay estimates are established for the linearized equation and the nonlinear model. Joint work with V. Komornik (Université de Strasbourg).

Beam equation with saturating piezoelectric controls
Christophe Prieur
Univ. Grenoble Alpes, CNRS, France

Abstract

A beam with a piezo-electric actuator is considered in this talk. The input is subject to magnitude saturation. A partial differential equation describes the dynamics of the deflection of the beam with respect to the rest position. The input is the voltage applied on an actuator located in a given interval of the space domain. Two kinds of control are considered: a static controller and a dynamical one. In both cases, a saturated control is applied to the beam equation. By closing the loop with such a nonlinear control, it is obtained a nonlinear partial differential equation, which is the generalization of the classical beam equation. The well-posedness is proven by using nonlinear semigroups techniques. Considering a generalized sector condition to tackle the control nonlinearity, the semi-global asymptotic stabilization system is proven by Lyapunov-based arguments.

Robust boundary stabilization of fluid flows in the case of partial observation
Jean-Pierre Raymond
Institut de Mathématiques de Toulouse, Université Paul Sabatier Toulouse III, France

Abstract

We have recently developed new numerical strategies, based on spectral projections, for the boundary stabilization of fluid flows (or for fluid-structure interaction systems) [1, 2, 3]. These strategies have been adapted to the case of partial observation in [**?**]. The goal of this talk is to present strategies for the robustification of these feedback and filtering gains, based on variants of the standard H^∞-optimal control problem [5]. This is a joint work with Gilles Tissot (Inria Rennes).

References

[1] C. Airiau, J.-M. Buchot, R. K. Dubey, M. Fournié, J.-P. Raymond, J. Weller-Calvo, Stabilization and best actuator location for the Navier-Stokes equations. SIAM J. Sci. Comput. 39 (2017), B993-B1020.

[2] M. Fournié, M. Ndiaye, and J.-P. Raymond, Feedback Stabilization of a Two-Dimensional Fluid-Structure Interaction System with Mixed Boundary Conditions. SIAM J. Control Optim. 57 (2019), 3322-3359.

[3] M. Fournié, M. Ndiaye, and J.-P. Raymond, Numerical stabilization of a fluid-structure interaction system, 2019.

[4] J.-M. Buchot and J.-P. Raymond, Dynamic output stabilizer for the Navier-Stokes equations with boundary pressure measurements, in preparation.

[5] A. Bensoussan, P. Bernhard, On the standard problem of H_∞-optimal control for infinite-dimensional systems. Identification and control in systems governed by partial differential equations, 117-140, SIAM, Philadelphia, PA, 1993

Semiglobal exponential stabilization of nonautonomous semilinear parabolic-like systems

Séergio S. Rodrigues
RICAM

Abstract

It is shown that an explicit oblique projection nonlinear feedback controller is able to stabilize semilinear parabolic equations, with time-dependent dynamics and with a polynomial nonlinearity. The actuators are typically modeled by a finite number of indicator functions of small subdomains.

No constraint is imposed on the sign of the polynomial nonlinearity. The norm of the initial condition can be arbitrarily large, and the total volume covered by the actuators can be arbitrarily small.

The number of actuators depends on the operator norm of the oblique projection, on the polynomial degree of the nonlinearity, on the norm of the initial condition, and on the total volume covered by the actuators.

The range of the feedback controller coincides with the range of the oblique projection, which is the linear span of the actuators. The oblique projection is performed along the orthogonal complement of a subspace spanned by a suitable finite number of eigenfunctions of the diffusion operator. For rectangular domains, it is possible to explicitly construct/place the actuators so that the stability of the closed-loop system is guaranteed.

Results of simulations are presented, which show the semiglobal stabilizing performance of the nonlinear feedback.

A HJB-POD approach for the control of nonlinear PDEs on a tree structure

Luca Saluzzi
GSSI, Italy

Abstract

The Dynamic Programming approach allows to compute a feedback control for nonlinear problems, but suffers from the *curse of dimensionality*. The computation of feedback optimal controls is based on the approximation of a nonlinear PDE, the Hamilton-Jacobi-Bellman equation in a space with the same dimension of the original dynamics. Recently, a new numerical method to compute the value function on a tree structure has been introduced, allowing to work without a space grid thus avoiding any space interpolation.

In this talk, we aim to apply the algorithm for nonlinear two dimensional PDEs coupling it with model order reduction, e.g. Proper Orthogonal Decomposition (POD). This technique allows to project the problem onto a low-dimensional one and to decrease the computational complexity of the tree. Furthermore, we provide error estimates for the coupling between POD and the tree structure.

We will also discuss how this approach can be extended to high-order schemes and provide an example with second order approximation schemes. Finally, we show efficiency of the method through numerical tests.

Exponential mixing in terms of controllability and application to boundary driven 2D Navier–Stokes equations

Armen Shirikyan
Department of Mathematics, University of Cergy-Pontoise, 2 avenue Adolphe Chauvin, 95302 Cergy-Pontoise, France

Abstract

We describe a general criterion ensuring the uniqueness and stability of a stationary distribution for a class of Markovian random dynamical systems. Our main result proves that the global approximate controllability to a point and a local stabilisation property are sufficient for the exponential mixing of a random flow driven by a non-degenerate noise. We next discuss an application of this result to the 2D Navier–Stokes system perturbed by a stochastic boundary forcing.

Order reduction methods for solving large-scale differential matrix Riccati equations

Gerhard Kirsten
Università di Bologna

Abstract

We consider the numerical solution of large-scale symmetric differential matrix Riccati equations. Under certain hypotheses on the data, reduced order methods have recently arisen as a promising class of solution strategies, by forming low-rank approximations to the sought after solution at selected timesteps. We show that great computational and memory savings are obtained by a reduction process onto rational Krylov subspaces, as opposed to current approaches. By specifically addressing the solution of the reduced differential equation and reliable stopping criteria, we are able to obtain accurate final approximations at low memory and computational requirements. This is obtained by employing a two-phase strategy that separately enhances the accuracy of the algebraic approximation and the time integration. The new method allows us to numerically solve much larger problems than in the current literature. Numerical experiments on benchmark problems illustrate the effectiveness of the procedure with respect to existing solvers.

This is joint work with Gerhard Kirsten, Università di Bologna.

Feedback boundary stabilization of a fluid-beam interaction system

Takéo Takahashi
Inria Nancy

Abstract

Our aim is to stabilize a fluid-structure interaction system composed by an incompressible viscous fluid and a deformable structure located at the boundary of the fluid domain. The fluid is modeled by the Navier-Stokes system and the structure by a damped beam equation. We consider only the 2D case in order to deal with weak solutions.

We obtain the feedback stabilization of the corresponding system by acting on a part of the boundary of the fluid domain outside the beam. More precisely, we can stabilize the position and the velocity of the structure and the velocity of the fluid around a stationary state and our control is with values in a finite dimensional space.

Our method is based on general arguments for stabilization of nonlinear parabolic systems combined with a change of variables to handle the fact that the fluid domain of the stationary state and of the stabilized solution are different.

In the case where the beam is not damped, the corresponding fluid-structure system is no more parabolic but we can show the well-posedness of strong solutions.

This is a joint work with Mehdi Badra (Université de Toulouse).

Polynomial stabilizability for a class of skew-adjoint systems describing water waves

Marius Tucsnak
Université de Bordeaux, France

Abstract

We consider the stabilization of a class of infinite dimensional systems with skew-adjoint generator and collocated actuators and sensors. The main novelty is that the spectrum of the generator is not satisfying the gap conditions which are usually assumed for exponential or polynomial stabilization of this type of problems. In particular, the systems may be not approximately observable in any finite time. The main motivation for studying this class comes from the stabilization of small amplitude water waves model in gravity and gravity-capillary cases. However, the presented results are of more general interest, as illustrated by simple applications to the fractional Schrödinger and wave equations.