Analysis of a fluid-structure interactive PDE model

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Results of wellposedness and stability are presented for a partial differential equation (PDE) model which has been used to model certain biological and physical fluid-structure interactions. The coupling between the fluid and structural equations occurs across the boundary interface. A key feature in the analysis is the novel method of eliminating the associated pressure of the system. This is joint work with Roberto Triggiani.

Latest developments in the control of shells modelled by intrinsic geometric models

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In this presentation we will present the latest developments in the use of Partial Differential Equations within the context of coordinate-free intrinsic shell models. The aim of the method, introduced by Michel Delfour and Jean-Paul Zolésio, is to produce a coordinate free version of the shell equations, in contrast to the classical equations which require explicit representation of the nonconstant coefficients. With the intrinsic approach, one can exploit the underlying geometry of the shell to derive equations in which the nonconstant coefficients are written in the form of tangential operators. This enables us to better modify and apply known techniques that were developed for use in the constant-coefficient case (flat plate models). This work continues the development of the model introduced so far. We will present an improved modeling which improved the way the curvature is taken into account.

Optimal decay rate estimates for viscoelastic dissipative

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The linear viscoelastic equation is considered:

\[
\begin{align*}
    y_{tt} - \Delta y + h * \Delta y &= 0 \quad \text{in } \Omega \times (0, \infty) \\
    y &= 0 \quad \text{on } \Gamma_0 \times (0, \infty) \\
    \partial_n y - h * \partial_n y + g(y_t) &= 0 \quad \text{on } \Gamma_1 \times (0, \infty)
\end{align*}
\]

where \( \Omega \) is a bounded domain of \( \mathbb{R}^n, n \geq 1 \), with a smooth boundary \( \Gamma = \Gamma_0 \cup \Gamma_1 \). Here, \( \Gamma_0 \) and \( \Gamma_1 \) are closed, non-empty and disjoint and \( \nu \) represents the unit outward normal to \( \Gamma \). We prove uniform decay rates of the energy by assuming a nonlinear feedback acting on the boundary, without imposing any growth assumption on the damping term near the origin and strongly weakening the usual assumptions on the domains, namely, star-shaped ones, when \( -h' \leq 0 \) is bounded from below by a positive constant and improving the usual assumptions on the kernels. Our estimate depends both on the behavior of the damping term near zero and on the behavior of the relaxation function at infinity.

D.L. Russell’s Controllability via Stabilizability Principle and the associated entropy change

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For a linear control system admitting forward and backward feedbacks with uniformly exponential stability, D.L. Russell’s controllability via stabilizability principle has offered the most elegant results for exact controllability of the system. In principle, such a control scheme may generate zero entropy in the process as at every instant the system is reversible. However, in reality, various couplings with the ambient reservoir causes the entropy of the coupled system to rise, and the amount is dependent on the control scheme used. In this talk, we will address some of such issues for this particular controllability via stabilizability principle, with concrete examples.
Mathematical analysis of the dimensional scaling method in quantum mechanics

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The dimensional scaling method was proposed by Witten and Herschbach in 1980’s to compute the ground state energy of the few-electron systems in chemical physics. Since then, this method has been applied to various systems for estimating the ground and excited state energies in physics literatures. This is a nonstandard method handling the eigenvalue problems of the Schrodinger equation with Coulomb potential. There has been no mathematical justification of this method in the literature. In this talk, we present some preliminary results on mathematical analysis of the dimensional scaling method.

Asymptotic stability of the wave equation on compact surfaces - a sharp result

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Marcelo Cavalcanti and Ryuichi Fukuoka

This paper is concerned with the study of the wave equation on compact surfaces and locally distributed damping, described by

\[ u_{tt} - \Delta_M u + a(x) g(u_t) = 0 \quad \text{on} \quad M \times [0, \infty[ , \]

where \( M \subset \mathbb{R}^3 \) is a smooth oriented embedded compact surface without boundary. Denote the Riemannian metric induced on \( M \) by \( \mathbb{R}^3 \) by \( g \). First of all we prove that for \( \epsilon > 0 \), there exist an open subset \( V \subset M \) and a smooth function \( f : M \to \mathbb{R} \) such that \( \text{meas}(V) \geq \text{meas}(M) - \epsilon \) and \( \text{Hess} f \approx g \) on \( V \). Finally we prove that if \( a(x) \geq a_0 > 0 \) on an open subset \( M^* \subset M \) that contains \( M \setminus V \) and if \( g \) is a monotonic increasing function such that \( k|s| \leq |g(s)| \leq K|s| \) for all \( |s| \geq 1 \), then uniform and optimal decay rates of the energy hold.

Symmetric hyperbolic systems with boundary conditions that do not satisfy the Kreiss-Sakamoto condition

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Symmetric hyperbolic systems with a class of non-homogeneous boundary conditions that does not satisfy the Kreiss-Sakamoto condition (or uniform Lopatinskii condition) are discussed. The boundary conditions are of conservative type. An energy estimate which provides interior and boundary regularity for weak solutions to the system is proved. The results are valid for operators with rough coefficients. As an example the anisotropic Maxwell system is considered.

A reaction-diffusion system with higher-order nonlinearity

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In this talk, we present some recent results on a nonlinear reaction-diffusion system which is used as a model for animal and insect dispersal. Applying the qualitative theory of planar dynamical systems and the Lie symmetry method, we find that under certain parametric conditions the system admits one-parameter Lie groups of transformations, which lead to two independent first integrals.

On the Fourier series method in control theory

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We present various generalizations of Ingham’s classical extension of Parseval’s equality, and we illustrate their usefulness in control theory by several applications. Most of the results presented in the talk were obtained in collaboration with C. Baiocchi and P. Loreti.

The Balayage method : Boundary control of a thermo-elastic plate

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Walter Littman and Stephen Taylor

We discuss the null boundary controllability of a linear thermo-elastic plate. The method employs a smoothing property of the system of PDEs which allows the boundary controls to be calculated directly by solving two Cauchy problems.

Semi-discrete Ingham type inequalities

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In this talk we briefly recall the harmonic analysis approach to observability problems of linear distributed systems. Then we discuss some results in the semi-discrete setting.

Existence and uniqueness for general nonlinear diffusion equations via a Wasserstein metric variational method

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We discuss a new method based on the Wasserstein metric to obtain results of existence and uniqueness for some general nonlinear diffusion equations. In particular we study nonhomogeneous equations (of Fokker-Planck type) with time dependent coefficients. Solutions to the main nonlinear general problem are obtained through the minimizing movements approach. We construct weak solutions as limits of time-interpolants of minimizers of an implicit variational scheme. Some applications to optimal control problems with Dirac data will also be discussed.

Exact controllability of bending-torsion vibration model

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We present exact and approximate controllability results for bending-torsion vibration model which is extremely popular in various branches of engineering sciences. The model is governed by a coupled system of Euler-Bernoulli and Timoshenko beam equations. To prove controllability we use spectral decomposition method and solvability of the corresponding moment problem.

Instability of viscous flow in channel with flexible walls

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We consider a viscous fluid flow governed by Navier-Stokes equations in a channel bounded by elastic flexible walls. Our results deal with a rigorous proof of flow instability for high Reynolds numbers.

Shape optimization problems for compressible Navier-Stokes equations

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Topological derivatives for variational inequalities

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We present a framework for topological sensitivity analysis of elliptic variational inequalities. We combine the domain decomposition technique with the compound asymptotic expansions in singularly perturbed geometrical domains. The frictionless contact problems on the boundary of elastic body as well as on the interior cracks are considered. We derive the form of topological derivatives for the energy shape functional in two and three spatial dimensions. Material derivatives of the solutions to the associated variational inequalities are obtained. Some numerical results are presented and confirms the theoretical findings. The results are used in shape and topology optimization in structural mechanics. Some open problems are presented.

Locally distributed desensitizing controls for the wave equation

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We consider the wave equation with partially known initial data in a bounded domain. For this system, we construct locally distributed controls that desensitize a certain norm of the state. This result is new in space dimensions greater than one. The method of proof combines a judicious application of the Carleman estimate, and a localization technique.

The critical case of clamped thermoelastic systems with interior point control: optimal interior and boundary regularity

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The critical case for clamped thermoelastic equations is the 2-d case, which offers genuine difficulties over the case d=3 and d=1. We shall provide optimal interior and boundary regularity regularity

Radar network scanning coordination based on ensemble transform Kalman filtering variance optimization

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In this work the variance of the error of analyzed wind fields obtained from an ensemble Kalman filter is used as a criterion with which to optimize radar network scanning strategies. The measurement equation in the Kalman filter approach is obtained from variational wind retrieval and, thus, is a function of the retrieval scanning parameters. It is shown that the mapping from radar parameters to the variance of the error is differentiable. The ensemble transform is introduced to facilitate the computational effort. The approach presented in principle may be used to optimize the scanning strategy in a network with any number of radars. Numerical examples are presented with networks consisting of two, four and nine radars using a quasi monte carlo optimization scheme. Error estimates for the approximation of the optimal strategies are discussed.