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WORKSHOP IN CONTROL THEORY & INVERSE PROBLEMS

This conference is focused in the control theory and inverse problems. The conference is composed of invited talks, short talks and posters.

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Program

Monday, May 06, 2024

- 9h - Reception of participants

Chairman: Sami Tliba

- 10h - 10h50: Pierre Gabriel (Tours)
- 10h50-11h10: Coffee break
- 11h10 - 12h: Kévin Le Balc'h (Paris)
- 12h - 12h25: Meriem Jakhoukh (Marrakech)
- 12h25 - 14h: Lunch break

Chairman: Pierre Gabriel

- 14h30 - 15h20: Karim Trabelsi (Paris)
- 15h20 - 15h45: Adil Brouri (Meknès)
- 15h45 - 16h15: Coffee break & Poster session
- 16h15 - 17h05: Akram Ben Aissa (Monastir)
- 17h05 - 17h30: Adnène Arbi (Carthage)

Tuesday, May 7, 2024

Chairman: Maatoug Hassine

- 9h - 9h50: Maria-Luisa Rapun (Madrid)
- 9h50 - 10h40: Alessandro Duca (Nancy)
- 10h40-11h10: Coffee break & Poster session
- 11h10 - 12h: Mohamed Ouzahra (Fès)
- 12h - 12h25: Hamadi Ammar (Tunis)
- 12h25 - 14h30: Lunch break

Chairman: Kévin Le Balc'h

- 14h30 - 15h20: Abdellatif Ben Makhlouf (Sfax)
- 15h20 - 15h45: Amal Nasri (Monastir)
- 15h45 - 16h15: Coffee break & Poster session
- 16h15 - 16h40: Badraddine Rjaibi (Tunis)
- 16h40 - 17h05: Ferid Hajji (Monastir)

Wednesday, May 8, 2024

Chairman: Mohamed Ouzahra

- 9h - 9h50: Fazia Bedouhene (Tizi-Ouzou)
- 9h50 - 10h15: Karim El Mufti (Manouba)

- 10h15-10h35: Coffee break & Poster session

- 10h35 - 11h: Ghazi Bel Mufti (Carthage)
- 11h - 11h25: Safouen Markou (Carthage)
- 11h25 - 12h15: Daouda Sangaré (Saint-Louis)

- 12h15: Closing and lunch

Plenary talks (50mn)

- Fazia Bedouhene (Tizi-Ouzou)
- Akram Ben Aissa (Monastir)
- Abdellatif Ben Makhlouf (Sfax)
- Alessandro Duca (Nancy)
- Pierre Gabriel (Tours)
- Kévin Le Balc'h (Paris)
- Mohamed Ouzahra (Fez)
- Maria-Luisa Rapun (Madrid)
- Daouda Sangaré (St-Louis)
- Karim Trabelsi (Paris)

Fazia Bedouhene [1]

Coexistence de valeurs spectrales rélles et leur effet sur la stabilité des systèmes à retard : Matrices de Vandermonde et décroissance exponentielle

Abstract. Des études récentes ont mis en évidence l'efficacité de la propriété de dominance induite par la multiplicité (MID), notamment pour décrire explicitement le taux de décroissance exponentielle des solutions d'une équation différentielle á retard (EDR). L'idée est d'attribuer à la fonction caractéristique (quasi-polynôme) du système une seule racine réelle s_0 avec une multiplicité maximale, et de montrer que, sous des conditions nécessaires et suffisantes, toute autre racine devrait avoir une partie réelle inférieure à l'abscisse spectrale s_0, conduisant ainsi à la stabilité exponentielle des solutions du système.

Cet exposé examine la propriété CRRID : Coexisting-Real-Root-Induced-Dominancy, dans laquelle un nombre maximal de zéros réels simples de la fonction caractéristique est attribué plutôt qu'un zéro multiple. Il présente également des propriétés structurelles de matrices de Vandermonde fonctionnelles, mettant en évidence des caractéristiques qualitatives d'une classe d'équations différentielles d'ordre n, autonomes linéaires, avec un terme source dépendant de la variable retardée.

Nous montrons comment cette approche peut être appliquée pour stabiliser des systèmes instables et améliorer le taux de décroissance exponentielle des solutions, offrant ainsi de nouvelles perspectives en théorie du contrôle.

Ces résultats découlent de travaux méthodologiques réalisés en collaboration avec Islam Boussaada (IPSA, (L2S) de l'Université Paris Saclay, France), Silviu Niculescu (L2S, Université Paris-Saclay), Timothée Schmoderer (PRISME, EA 4229, Université d'Orléans), Sami Tliba (L2S, Université Paris-Saclay), Amrane Souad (Univ. Tizi-Ouzou, Algérie).

[1]Université Mouloud Mammeri Tizi-Ouzou, Algeria

Akram Ben Aissa [2]

On new concept in stability and stabilization of some PDEs: Old and recent results

Abstract. In this talk, we delve into the qualitative characteristics of various physical and mechanical systems governed by partial differential equations, encompassing waves, beam, and Kirchhoff equations. Our exploration extends to a range of techniques, including but not limited to well-posedness, controllability, observability, and stability. Before delving further, it is imperative to revisit fundamental concepts in the control and stabilization theory of both linear and nonlinear partial differential equations (PDEs). These foundational principles serve as a crucial groundwork, laying the foundation for the diverse set of techniques that was employed in the literature.

Abdellatif Ben Makhlouf [3]

On the stability of nonlinear fractional-order systems

Abstract. This talk presents a comprehensive investigation into the stability properties of nonlinear fractional-order systems which garnered significant attention due to their ability to model complex dynamics more accurately than integer-order systems. The study begins by introducing the concept of fractional calculus and its application to system dynamics. It then delves into the analysis of stability criteria for fractional-order systems, exploring both theoretical frameworks and numerical methods. Various approaches for assessing stability, including Lyapunov-based methods and frequency-domain techniques, are examined in the context of nonlinear fractional-order systems. Furthermore, the talk discusses recent advancements in stability analysis techniques, such as Lyapunov stability and finite time stability.

[2]University of Sousse, Tunisia
[3]University of Sfax, Tunisia

Alessandro Duca [4]

Scalar problems with sign-changing coefficients on networks

Abstract. We study the propagation of light/wave through a medium composed of materials with positive and negative conductivities. We assume that the medium is a network and focus our analysis on star and tadpole graphs. We start by discussing the well-posedness of the corresponding scalar problem under suitable assumptions on the edges' lengths, the conductivities' values, and boundary conditions. In the second part of the talk, we discuss two spectral representations via (pseudo-)eigenfunctions.

Pierre Gabriel [5]

On the principal eigenvalue problem for positive semigroups

Abstract. We revisit the Krein-Rutman theory for semigroups of positive operators, having in mind the application to linear PDEs which preserve positivity. We propose simple and applicable criteria for ensuring the existence, uniqueness, and (quantified) exponential stability of the principal eigentriplet made of the first eigenvalue and its associated primal and dual eigenvectors. The method can be applied to parabolic PDEs, kinetic transport equations, kinetic Fokker-Planck equations, growth-fragmentation equations, or purely integral equations. We will detail some of these examples.

[4]INRIA & University of Lorraine, France
[5]University of Tours, France

Kévin Le Balc'h [6]

Global stabilization of the cubic defocusing nonlinear Schrdinger equation on the torus

Abstract. In this talk, I will focus on the stabilization of defocusing nonlinear Schrdinger equations on manifolds, arising naturally as models of wave propagation in fiber optics. I will first recall local and semi-global results that have been obtained since the beginning of the 2000's. Then, I will introduce a method that I have developed in collaboration with Jmy Martin to prove the (uniform) global stabilization of the cubic defocusing nonlinear Schrdinger equation on the d-dimensional torus, d=1, 2 or 3.

Mohamed Ouzahra [7]

Finite-time stabilization of linear systems under observation assumptions

Abstract. The notion of stability constitutes an essential tool to guarantee the performance of time-evolution of dynamical systems. Roughly speaking, it enables us to describe the system's response to small perturbations on the initial conditions. While asymptotic stability implies convergence of the system trajectories to the equilibrium state over an infinite horizon, the finite time stability however, requires that the convergence to the equilibrium should be achieved in a finite time. Our goal here is to prove the finite-time stabilization of an abstract linear system under a weak observation assumption. The approach is based on the method of Lyapunov functions combined with the sliding mode techniques. The theoretical results are further applied to PDEs under locally distributed controls.

[6]INRIA & Sorbonne University, France
[7]Universitdi Mohamed Ben Abdellah Fez, Morocco

Maria-Luisa Rapún [8]

Non-invasive imaging by numerical methods based on topological derivatives

Abstract. The problem of determining the location, size and shape of objects embedded in a medium has attracted a lot of attention in recent years. The problem is of paramount interest in a variety of fields, including medical imaging, non-destructive testing of materials, and natural resources exploration. In this work we will focus on techniques that consist in electromagnetically, thermally or acoustically exciting a medium that has an unknown number of internal objects. The aim is to reconstruct these objects by processing measurements at a limited number of receivers. To do so, we will use different strategies based on the concept of the topological derivative. We will propose both one-step and iterative methods, which will provide an indicator function capable of classifying each point in the region of interest as belonging to the background medium or to an object, without any a priori assumption about the number, size, shape, or location of the objects. The performance of the methods in different applications, including acoustic, electromagnetic, and thermographic inspection will be shown.

Daouda Sangaré [9]

Exact controllability of wave equation and optimal control of a SIR model

Abstract. Control theory is approached in two ways in this talk. In the first part, we address the controllability of the wave equation by the H. U. M. method. We give the strong and weak solutions of the wave equation before the implementation of the H. U. M. method. An application of optimal control using Pontryagin's principle on an epidemiological model is considered in the second part. We expose the SIR model considered, apply the optimal control and give some numerical results.

[8]Polytechnical University of Madrid Madrid, Spain
[9]Université Gaston Berger, Saint-Louis, Senegal

Karim Trabelsi [10]

Multiplicity-induced-dominancy property for retarded and neutral second-order differential-difference equations

Abstract. This talk focuses on the characterization of a particular spectral property called Multiplicity-induced-dominancy (MID) applying for linear dynamical systems described by delay-differential equations with a single delay. More precisely, we characterize the property in the parametric second order retarded and neutral cases. In general, it is quite a challenge to establish conditions on the parameters of the system in order to guarantee such a stability. Recent works emphasized the link between maximal multiplicity and dominant roots. Indeed, conditions for a given multiple root to be necessarily dominant are investigated, this property is known as MID. Moreover, this strategy has the advantage of assigning the exponential decay rate. As an illustration, comprehensive examples shall be presented.

[10]Institut Polytechnique des Sciences Avancées, Ivry-sur-Seine, France

Invited talks (25mn)

- Hamadi Ammar (Tunis)
- Adnène Arbi (Carthage)
- Ghazi Bel Mufti (Carthage)
- Adil Brouri (Meknès)
- Karim El Mufi (Manouba)
- Ferid Hajji (Monastir)
- Mariem Jakhoukh (Marrakech)
- Safouen Markou (Carthage)
- Amal Nasri (Monastir)
- Badraddine Rjaibi (Tunis)

Hamadi Ammar [11]

Multidimensional optimization using adaptive filling curves. Estimation of the age-dependent viral hepatitis A infection force

Abstract. In this talk, we will present an interaction problem between mathematics and biology. In the first part, we are interested in solving multidimensional optimization problems defined as follows:

$$(P_n) \min_{x \in K \subset \mathbb{R}^n} f(x).$$

The basic idea that we present consists of defining a filling curve

$$\{H(t) = (h_1(t), ..., h_n(t)), t \in I \subset \mathbb{R}\},$$

so that, we convert the multidimensional (P_n) to a one-dimensional optimization problem:

$$(P_1) \min_{x \in K \subset \mathbb{R}} f^*(t) = f(h_1(t), ..., h_n(t)).$$

The solution of (P_1) provides an estimate of the minimum of (P_n) with a precision ε fixed in advance. The function f^* oscillates a lot, which slows down the minimum search algorithm. To overcome this handicap, we will define a sequence of filing functions which make it possible to iteratively reduce the feasible solutions set I of the objective function f^* by eliminating the subregions that cannot contain the minimum of f^*. This will allow us defining the dual problem of (P_1) which we solve using one of the branch and bound methods we developed in our previous work.

In the second part of this talk, we present work carried out with the Pasteur Institute of Tunis. It focuses on modeling the dynamics of a population within the virus of hepatitis A circulates. Our task consists of identifying its seroprevalence and infection force. We will establish a compartmental mathematical model to describe the dynamics of a population living in a place where the virus of hepatitis A (HAV) circulates. Each state of health of an individual with respect to the HAV is represented by a compartment. As the severity of the infection depends on age, each compartment is subdivided into sub-compartments according to the age of the individuals. For age group a_i where $i \in [[1; \textit{the greatest age}]]$, there is six compartments: (S) Susceptible, (E) Exposed, (I) Infectious, (R), Recovered, (D) Death. The compartment (I) is divided into two compartments: (Sy) Symptomatic and (Asy) Asymptomatic. Individuals flow between these compartments through two processes: the demographic processes (mortality and birth) and epidemiological processes.

The spread of the virus is governed by five a priori unknown parameters. To identify them, we minimized the least squares error between the experimental values and the theoretical values using the algorithm developed in the first part.

[11]Carthage University, Tunisia

References

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2. Hamadi Ammar and Behcir Naffeti. A branch and bound algorithm for Holder bi-objective optimization. Implementation to multidimensional optimization. Mathematics and computers in simulation. August 2022.
3. Bechir Naffeti, Hamadi Ammar and Walid Ben Aribi. A Branch and Bound algorithm for multidimensional Holder optimization: Estimation of the age-dependent viral hepatitis A infection force. Mathematics and Computers in Simulation. 217 (2024). 311-326.

Adnène Arbi [12]

Neural network modeling approaches for model predictive control

Abstract. An overview of the recent developments of neural network modeling is presented along with its use in model predictive control (MPC). A nonlinear process example is introduced to demonstrate the application of various approaches based on neural networks and evaluate their performance in terms of closed-loop stability and prediction accuracy. Finally, the paper concludes with a proposal of future research directions on neural network modeling and its integration in theory of control.

[12]University of Carthage, Tunisia

Ghazi Bel Mufti [13]

Numerical results on some evolution equations using an LQR approach

Abstract. Initially, we address the heat and wave equations. Employing a wavelet-based Galerkin discretization in space, we reframe the problems into controlling ordinary differential equations. Subsequently, we develop a Q-learning approach for numerically controlling both equations. Later, we focus on the semi-linear Euler-Bernoulli model encompassing both finite and infinite interval scenarios.

For all these challenges, Linear Quadratic Regularization (LQR) ensures well-defined states and controls within a dynamic programming framework. To evaluate their efficiency and accuracy, numerical experiments are conducted, offering a comprehensive assessment of performance.

[13]Carthage University, Tunisia

Adil Brouri [14]

Identification et Modélisation des Systèmes Non-linéaires

Abstract. Le thème choisi s'inscrit dans le cadre de la modélisation et l'identification des systèmes non-linéaires. Les non-linéarités sont omniprésentes dans les systèmes réels et ne constituent pas l'exception. Dans cette présentation, un aperçu sur les types de modélisation des systèmes non-linéaires sera proposé. Les systèmes non-linéaires qui intéressent beaucoup le monde scientifique sont les systèmes structurés en blocs. Un système non-linéaire structuré en blocs est équivalent à l'association des blocs linèaires et non-linéaires en cascade ou en parallèle. Les systèmes non-linéaires les plus étudiés sont ceux basés sur des modèles de Hammerstein, Wiener, Wiener-Hammerstein et Hammerstein-Wiener. Une des étapes essentielles pour faire le contrôle est la procédure d'identification. Cette phase consiste à établir des méthodes et des algorithmes permettant la détermination des paramètres du système. L'objectif principal de cette présentation est de présenter d'une part la problématique générale de l'identification des systèmes non-linéaires. D'autre part, étant la mise en place d'une méthodologie d'identification des systèmes non-linéaires. Parmi les méthodes d'identification existantes, on trouve les méthodes stochastiques, les algorithmes récursifs et les méthodes fréquentielles. Plusieurs méthodes existantes se basent sur des approximations et des hypothèses trop restrictives. Une partie intéressante de cette présentation sera consacrée à la description de la méthode d'identification fréquentielle. Des exemples de simulation seront proposés à la fin de la présentation.

[14]Université Moulay Ismail Meknès, Morocco

Karim El Mufti [15]

Optimal control of the Euler-Bernoulli equation

Abstract. The well-posedness of the Euler-Bernoulli model is rigorously established, encompassing both the semi-linear case within finite intervals and the linear scenario across infinite intervals. Leveraging the Dynamic Programming Principle, we unveil that the optimal value function stands as the singular viscosity solution to the Hamilton-Jacobi-Bellman equation. Furthermore, we demonstrate the existence of an optimal control strategy across a judiciously defined space of admissible configurations, particularly emphasizing its applicability in scenarios characterized by linear quadratic costs. To assess the efficiency and accuracy, numerical experiments are done, providing a comprehensive evaluation of the performance.

Ferid Hajji [16]

Identification of a singular source in a time-fractional diffusion problem

Abstract. In this paper, we present a novel approach to reconstructing a singular time-dependent source function within a time-fractional diffusion problem. Our method leverages observational data acquired from a single boundary point and from within the domain. Notably, the source function we examine is represented by the Dirac delta function in time, adding depth to our analysis as the temporal aspect of the unknown source resides within a Sobolev space of negative order. We rigorously establish the uniqueness of the inverse problem under consideration in both scenarios. To achieve point-wise source reconstruction numerically, we employ topological derivatives, transforming the inverse source problem into an optimization framework. Specifically, we introduce a second-order non-iterative reconstruction algorithm designed to attain our objective efficiently. The effectiveness of our proposed approach is demonstrated through a variety of numerical examples, substantiating its practical utility and robustness.

[15]Université la Manouba Manouba, Tunisia
[16]University of Monastir

Mariem Jakhoukh [17]

Kalman Condition For Null Controllability For Parabolic Systems With Dynamic Boundary Conditions

Abstract. In this talk, we study the null controllability of systems of ncoupled parabolic equations with dynamic boundary conditions, where the coupling and control matrices A and B are constant in time and space. Being different to the case of static boundary conditions, we will show that the Kalman rank condition $rank[B, AB, ..., A^{n?1}B] = n$ is a sufficient condition, we also show that it is necessary for the null controlability under an extra assumption on the boundary coupling. The null controlability result will be proved by proving Carleman and observability inequalities for the corresponding adjoint problem.

Safouen Markou [18]

Multiagent Reinforcement Learning for Traffic Signal Control

Abstract. Traffic congestion occurs when there are too many vehicles trying to use the same infrastructure simultaneously. Several studies have explored dynamic control strategies for traffic signal durations using reinforcement learning. The primary objective is to alleviate traffic congestion and enhance traffic light control systems. Reinforcement Learning operates on the principle that an agent, typically an AI, learns from its environment through interaction, receiving rewards (either positive or negative) as feedback for its actions. In this context, we evaluate different reinforcement learning approaches for urban intersection traffic signal control, specifically employing Proximal Policy Optimization (PPO) and Advantage Actor Critic (A2C) algorithms to tackle the complexities of traffic signal management. The state space is defined by real-time traffic data, including information such as vehicle position, direction, and speed. The action space encompasses various traffic signal phases, which are crucial for developing effective and realistic control mechanisms. Experiments are conducted using a microscopic traffic simulator, namely SUMO (Simulation of Urban MObility), in conjunction with a Python package called SUMO-RL. These experiments yield promising results, notably significant reductions in vehicle waiting times.

[17]Cadi Ayyad University Marrakech, Morocco
[18]Carthage University

Amal Nasri [19]

A new family of discontinuous finite element methods for elliptic problems in the whole space

Abstract. We investigate a new hybrid method we call the discontinuous Glerkin inverted finite element method (DGIFEM) to approximate the solution of elliptic problems in $\mathbb{R}^n$, especially when the growth or the decay of the solution is very slow. On the basis of both the discontinuous Galerkin discretization and the inverted finite element method, the DGIFEM keeps part of the domain bounded and maps the other infinite extent into a bounded region via a suitable polygonal inversion. The numerical solution is then constructed in an appropriate subspace of weighted Sobolev spaces, where the weights allow the control of the growth or the decay of functions at infinity. A careful study of the convergence of the DGIFEM is carried out and shows that the optimal order of convergence can always be reached. Finally some numerical results are given as illustration of the good performance of the proposed method.

Badreddine Rjaibi [20]

X-ray tomographic image reconstruction from missing data with topological gradient techniques

Abstract. A novel technique for reconstructing x-ray tomography images is presented. This method is based on the first and second order topological gradient approach for computed tomography problem. The use of the topological asymptotic analysis enables the detection of crucial geometric data, reducing the present noise during the inversion of the x-ray transform. The experimental results obtained from inpainted sinograms and truncated data illustrate the effectiveness of this promising approach.

[19]University of Monastir
[20]University of Tunis El Manar Tunis, Tunisia

Posters

Mama Abdelli
Djillali Liabes University of Sidi Bel Abbes, Algeria

Global existence and general decay estimates of solution for the wave equation with a localized nonlinear strong damping

Wafa Ahmedi
University of Sousse

Stabilization of a locally transmission problems of two strongly-weakly coupled wave systems

Hamza Bibi
University Mouloud Mammeri, Tizi-Ouzou, Algeria

Static Output Stabilization of Linear Systems with Parameter Uncertainties. Enhanced LMI Conditions

Amina Boukhatem
University of Laghouat, Algeria

Almost periodicity and stability for solutions to networks of beams with structural damping

Khadidja Fekirini
Djillali Liabes University, Algeria

Decay Solutions of Coupled Schrödinger Equation with Internal Fractional Damping

Houssem Lihiou
University of Monastir, Tunisia

Identification of small anisotropic electromagnetic anomalies from dynamic boundary measurements

Naima Mehenaoui
Bejaia University, Algeria

Nonlinear Klein Gordon Equation on a Network

Marwa Ragoubi
University of Monastir, Tunisia

Spectral analysis and stabilization of one dimensional wave equation with variables coefficients