RESEARCH CENTRE

**Inria Saclay Centre**
**at Université Paris-Saclay**

**IN PARTNERSHIP WITH:**

**CNRS, Université Paris-Saclay**

# 2023
# ACTIVITY REPORT

## Project-Team
## DISCO

## Dynamical Interconnected Systems in COmplex Environments

**IN COLLABORATION WITH: Laboratoire des signaux et systèmes (L2S)**

### DOMAIN

**Applied Mathematics, Computation and Simulation**

### THEME

**Optimization and control of dynamic systems**

# Contents

# Project-Team DISCO

*Creation of the Project-Team: 2012 January 01*


## Keywords

### Computer sciences and digital sciences

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

A6.1.2. – Stochastic Modeling

A6.1.3. – Discrete Modeling (multi-agent, people centered)

A6.2.1. – Numerical analysis of PDE and ODE

A6.2.6. – Optimization

A6.3.4. – Model reduction

A6.4.1. – Deterministic control

A6.4.2. – Stochastic control

A6.4.3. – Observability and Controlability

A6.4.4. – Stability and Stabilization

A6.4.6. – Optimal control

A8.2.1. – Operations research

A8.11. – Game Theory

A9.2. – Machine learning

### Other research topics and application domains

B1.1.8. – Mathematical biology

B1.1.10. – Systems and synthetic biology

B2.5. – Handicap and personal assistances

B3.6. – Ecology

B4. – Energy

B5.2.3. – Aviation

B5.10. – Biotechnology

B7.2.1. – Smart vehicles

# 1 Team members, visitors, external collaborators

## Research Scientists

- Catherine Bonnet [Team leader, INRIA, Senior Researcher, HDR]
- Joseph Frederic Bonnans [INRIA, Senior Researcher, HDR]
- Ziad Kobeissi [INRIA, ISFP, from Oct 2023]
- Guilherme Mazanti [INRIA, ISFP]
- Frederic Mazenc [INRIA, Senior Researcher, HDR]
- Silviu-Iulian Niculescu [CNRS, Senior Researcher, HDR]
- Laurent Pfeiffer [INRIA, Researcher]

## Faculty Members

- Islam Boussaada [IPSA, convention with CENTRALESUPELEC, Professor, HDR]
- Giorgio Valmorbida [CENTRALESUPELEC, Associate Professor]

## Post-Doctoral Fellows

- Mathieu Bajodek [CNRS, Post-Doctoral Fellow, until Sep 2023]
- Arthur Bottois [INRIA, Post-Doctoral Fellow, from Sep 2023]
- Timothee Schmoderer [INRIA, Post-Doctoral Fellow, until May 2023]
- Cyprien Tamekue [ECOLE POLY PALAISEAU, from Oct 2023]

## PhD Students

- Omonwoumi Balogoun [CENTRALESUPELEC, from Oct 2023]
- Kang Liu [LIX, until Aug 2023]
- Thibault Moquet [CENTRALESUPELEC]
- Jeanne Redaud [CENTRALESUPELEC, until Oct 2023]
- Juan Diego Torres Garcia [CENTRALESUPELEC, (joint doctorate UPSaclay-UASLP San Luis Potosi, Mexico)]
- Can Kutlu Yuksel [CentraleSupélec, (joint doctorate UPSaclay-CTU Prague, Czech Republic)]

## Interns and Apprentices

- Xinyu Huang [INRIA, Intern, from Mar 2023 until Sep 2023]

## Administrative Assistants

- Melanie Da Silva [INRIA, from Dec 2023]
- Melanie Da Silva [INRIA, from May 2023 until Nov 2023, On secondment from FPT]

## External Collaborator

- Ali Zemouche [UL, HDR]

# 2 Overall objectives

## 2.1 Objectives

The goal of the project is to better understand and well formalize the effects of complex environments on the dynamics of the interconnections, as well as to develop new methods and techniques for the analysis and control of such systems.

It is well-known that the interconnection of dynamic systems has as consequence an increased complexity of the behavior of the total system.

In a simplified way, as the concept of dynamics is well-understood, the interconnections can be seen as associations (by connections of materials or information flows) of distinct systems to ensure a pooling of the resources with the aim of obtaining a better operation with the constraint of continuity of the service in the event of a fault. In this context, the environment can be seen as a collection of elements, structures or systems, natural or artificial constituting the neighborhood of a given system. The development of interactive games through communication networks, control from distance (e.g. remote surgical operations) or in hostile environment (e.g. robots, drones), as well as the current trend of large scale integration of distribution (and/or transport and/or decision) and open information systems with systems of production, lead to new modeling schemes in problems where the dynamics of the environment have to be taken into account.

In order to tackle the control problems arising in the above examples, the team investigates new theoretical methods, develops new algorithms and implementations dedicated to these techniques.

# 3 Research program

## 3.1 Analysis of interconnected systems

The major questions considered are those of the characterization of the stability (also including the problems of sensitivity compared to the variations of the parameters) and the determination of stabilizing controllers of interconnected dynamic systems. In many situations, the dynamics of the interconnections can be naturally modelled by systems with delays (constant, distributed or time-varying delays) possibly of fractional order. In other cases, partial differential equations (PDE) models can be better represented or approximated by using systems with delays. Our expertise on this subject, on both time and frequency domain methods, allows us to challenge difficult problems (e.g. systems with an infinite number of unstable poles).

- Robust stability of linear systems

  Within an interconnection context, several phenomena are modelled directly or after an approximation by delay systems. These systems may have constant delays, time-varying delays, distributed delays.

  For various infinite-dimensional systems, particularly delay and fractional systems, input-output and time-domain methods are jointly developed in the team to characterize stability. This research is developed at four levels: analytic approaches ($H_\infty$-stability, BIBO-stablity, robust stability, robustness metrics) [3, 2, 10, 11], symbolic computation approaches (SOS methods are used for determining easy-to-check conditions which guarantee that the poles of a given linear system are not in the closed right half-plane, certified CAD techniques), numerical approaches (root-loci, continuation methods) and by means of softwares developed in the team [10, 11].

- Robustness/fragility of biological systems

  Deterministic biological models describing, for instance, species interactions, are frequently composed of equations with important disturbances and poorly known parameters. To evaluate the impact of the uncertainties, we use the techniques of design of global strict Lyapunov functions or functional developed in the team.

However, for other biological systems, the notion of robustness may be different and this question is still in its infancy (see, e.g. [89]). Unlike engineering problems where a major issue is to maintain stability in the presence of disturbances, a main issue here is to maintain the system response in the presence of disturbances. For instance, a biological network is required to keep its functioning in case of a failure of one of the nodes in the network. The team, which has a strong expertise in robustness for engineering problems, aims at contributing at the development of new robustness metrics in this biological context.

### 3.2 Stabilization of interconnected systems

- Linear systems: Analytic and algebraic approaches are considered for infinite-dimensional linear systems studied within the input-output framework.

  In the recent years, the Youla-Kučera parametrization (which gives the set of all stabilizing controllers of a system in terms of its coprime factorizations) has been the cornerstone of the success of the $H_\infty$-control since this parametrization allows one to rewrite the problem of finding the optimal stabilizing controllers for a certain norm such as $H_\infty$ or $H_2$ as affine, and thus, convex problem.

  A central issue studied in the team is the computation of such factorizations for a given infinite-dimensional linear system as well as establishing the links between stabilizability of a system for a certain norm and the existence of coprime factorizations for this system. These questions are fundamental for robust stabilization problems [3, 2].

  We also consider simultaneous stabilization since it plays an important role in the study of reliable stabilization, i.e. in the design of controllers which stabilize a finite family of plants describing a system during normal operating conditions and various failed modes (e.g. loss of sensors or actuators, changes in operating points). Moreover, we investigate strongly stabilizable systems, namely systems which can be stabilized by stable controllers, since they have a good ability to track reference inputs and, in practice, engineers are reluctant to use unstable controllers especially when the system is stable.

- Nonlinear systems

  In any physical systems a feedback control law has to account for limitation stemming from safety, physical or technological constraints. Therefore, any realistic control system analysis and design have to account for constraints appearing mainly from sensors and actuators nonlinearities and from the regions of safe operation in the state space. This motivates the study of linear systems with more realistic, thus complex, models of actuators accounting for saturation and quantization at the inputs of the system [16], [12], [17].

  The project aims at developing robust stabilization theory and methods for important classes of nonlinear systems that ensure good controller performance under uncertainty and time delays. The main techniques include techniques called backstepping and forwarding, contructions of strict Lyapunov functions through so-called "strictification" approaches [8] and construction of Lyapunov-Krasovskii functionals [9, 10, 11] or or Lyapunov functionals for PDE systems [15].

### 3.3 Synthesis of reduced complexity controllers

- PID controllers

  Even though the synthesis of control laws of a given complexity is not a new problem, it is still open, even for finite-dimensional linear systems. Our purpose is to search for good families of “simple” (e.g. low order) controllers for infinite-dimensional dynamical systems. Within our approach, PID candidates are first considered in the team [2], [91].

  For interconnected systems appearing in teleoperation applications, such as the steer-by-wire, Proportional-Derivative laws are simple control strategies allowing to reproduce the efforts in both ends of the teleoperation system. However, due to delays introduced in the communication channels these strategies may result in loss of closed loop stability or in performance degradation when compared to the system with a mechanical link (no communication channel). In this context we search for non-linear proportional and derivative gains to improve performance [6, 5]. This is assessed in terms of reduction of overshoot and guaranteed convergence rates.

- Delayed feedback

  Control systems often operate in the presence of delays, primarily due to the time it takes to acquire the information needed for decision-making, to create control decisions and to execute these decisions. Commonly, such a time delay induces desynchronizing and/or destabilizing effects on the dynamics. However, some recent studies have emphasized that the delay may have a stabilizing effect in the control design. In particular, the closed-loop stability may be guaranteed precisely by the existence of the delay. The interest of considering such control laws lies in the simplicity of the controller as well as in its easy practical implementation. It is intended by the team members to provide a unified approach for the design of such stabilizing control laws for finite and infinite dimensional plants [4, 13].

- Finite Time and Interval Observers for nonlinear systems

  We aim to develop techniques of construction of output feedbacks relying on the design of observers. The objectives pertain to the design of robust control laws which converge in finite time, the construction of intervals observers which ensure that the solutions belong to guaranteed intervals, continuous/discrete observers for systems with discrete measurements and observers for systems with switches.

Finally, the development of algorithms based on both symbolic computation and numerical methods, and their implementations in dedicated Scilab/Matlab/Maple toolboxes are important issues in the project.

# 4 Application domains

## 4.1 Analysis and Control of life sciences systems

The team is involved in life sciences applications. The two main lines are the analysis of bioreactors models (microorganisms; bacteria, microalgae, yeast, etc..) and the modeling of cell dynamics in Acute Myeloblastic Leukemias (AML) in collaboration with St Antoine Hospital in Paris.

## 4.2 Energy Management

The team is interested in Energy management and considers control problems in energy networks.

## 4.3 Transportation Systems

The team is interested in control applications in transportation systems. In particular, the problem of collision avoidance of autonomous vehicels has been investigated under the framework of Time Varying systems. The goal is to obtain closed-loop control laws that guarantee the execution of a trajectory under uncertainties such as road and vehicle conditions.

## 4.4 Mechanical engineering

The team is interested in vibration control (in link with the so-called multiplicity-induced-dominancy, MID and partial pole placement) and in developing advanced delay algorithms for compensating and tracking periodic signals (related to the repetitive control).

# 5 Highlights of the year

- Silviu-Iulian Niculescu received the title of Doctor Honoris Causa (DHC) of the University Dunărea de Jos, Galaţi, Romania (June 12ve, 2023).

- Silviu-Iulian Niculescu was the General Co-Chair of the Organizing Committee of the 21st European Control Conference, Bucharest, Romania, June 13-16th ECC 2023: : 982 authors, 362 contributions accepted (acceptance rate: 68%).

# 6 New software, platforms, open data

## 6.1 New software

### 6.1.1 P3$\delta$

**Name:** Partial pole placement via delay action

**Keywords:** Delay systems, Control design, Automatic control

**Functional Description:** A Python implementation of recent methods for the stability analysis and stabilization of linear time-delay systems exploiting the delay action. Its control design strategy is based on properties of the spectral distribution of the time-delay system.

**Release Contributions:** Generic and control-oriented MID

**URL:** https://iboussaa.gitlabpages.inria.fr/partial-pole-placement-via-delay-action/P3d-Home.html

**Authors:** Guilherme Mazanti, Islam Boussaada, Silviu-Iulian Niculescu, Julien Huynh, Adrien Leclerc, Max Perraudin, Jayvir Raj, Franck Sim, Matthieu Thomas, Yoann Audet, Ayrton Hammoumou, Pierre-henry Poret

**Contact:** Islam Boussaada

**Partners:** Cyb'Air-IPSA, ICODE, CentraleSupélec

### 6.1.2 YALTAPy

**Keywords:** Linear system, Delay systems, Stability, Fractional system

**Scientific Description:** YALTAPy is a Python Toolbox dedicated to the stability analysis of (fractional) delay systems given by their transfer function.

The delays are supposed to be commensurate.

In the case of retarded systems or of neutral systems with asymptotic axes in the left half-plane, YALTAPy gives: – For a given delay , the number and the position of unstable poles. – For which values of the delay the system is stable, – For a set of values of the delay, the position of unstable poles (root locus).

**Functional Description:** The YALTAPy toolbox is a Python toolbox dedicated to the study of classical and fractional systems with delay in the frequency-domain. Its objective is to provide basic but important information such as, for instance, the position of the neutral chains of poles and unstable poles, as well as the root locus with respect to the delay of the system.

YALTAPy_Online is an online version of YALTAPy

**Publication:** hal-00766550

**Authors:** Catherine Bonnet, Guilherme Mazanti, Hugo Cavalera

**Contact:** Catherine Bonnet

#### 6.1.3 YaltaPy Online

**Keywords:** Linear system, Delay systems, Stability, Fractional system

**Scientific Description:** YALTAPy_Online is an online version of YALTAPy

**Functional Description:** YALTAPy_Online is an online version of YALTAPy

**Authors:** Catherine Bonnet, Guilherme Mazanti, Jayvir Raj

**Contact:** Catherine Bonnet

# 7 New results

## 7.1 Averaging for time-varying systems

**Participants:** Rami Katz *(Tel Aviv Univ)*, Frédéric Mazenc, Emilia Fridman *(Tel Aviv Univ)*.

In two works, we have have developed a new avaraging technique for fast-varying continuous-time systems.

In [54], we studied linear systems with fast-varying almost periodic coefficients. We presented a novel transformation of the fast varying coefficients. This transformation enabled us to perform averaging over multiple time-scales for systems with constant delays, where the value of delay is not small (i.e. arbitrarily large with respect to the small parameter). We carried out stability analysis by employing time-varying Lyapunov functions (or functionals for the delayed case). The analysis leads to LMI conditions that are always feasible for small enough parameters.

The paper [53] is devoted to the problem of establishing input-to-state stability (ISS) for linear systems with multiple time-scales. The considered systems contain rapidly-varying, piecewise continuous and almost periodic coefficients with small parameters. The stability analysis relies on a novel system transformation, leading to a new system whose ISS guarantees the ISS of the original one. In this work, we unified this transformation with a new superposition-based system presentation. We employed time-varying Lyapunov functions for ISS analysis, where the novel system presentation plays a crucial role in deriving essentially less conservative compensating upper bounds. The analysis yields conditions of LMI type for ISS, leading to explicit bounds on the small parameters, decay rate and ISS gains. The LMIs are accompanied by suitable feasibility guarantees.

## 7.2 Event-triggered control

**Participants:** Frédéric Mazenc, Michael Malisoff *(LSU)*, Corina Barbalata *(LSU)*.

Event-triggered control has the advantage that it can reduce computational burdens of implementing feedback controls, by only changing control values when a significant enough event occurs. In order to decrease the number of needed switches of the control laws, we developed results relying on the theory of the positive systems and comparison systems called interval observers. In the papers [37] and [56], we provided a new input-to-state stabilizing event-triggered feedback design for linear systems with unknown input delays, unknown measurement delays, and unknown additive disturbances. We used the theory of positive systems, interval observers, and a vector version of Halanay's inequality. We illustrated our method using a marine robotic model.

### 7.3 Discrete-time trajectory-based approach

**Participants:** Frédéric Mazenc, Michael Malisoff *(LSU)*, Jackson Knox *(LSU)*.

In contribution [39], to help the analysis of the stability properties of discrete-time systems, we provided a discrete-time vector valued analog of recently developed continuous-time trajectory-based estimates. We used it to provide a discrete-time version of the celebrate Halanay's inequality. We combined the results with interval observers to prove exponential stability properties for discrete-time linear systems with uncertainties whose arbitrarily long input delays are compensated for by reduction model controls, and a robust global exponential stability result for observers for discrete-time linear systems.

### 7.4 Advanced observers design: estimation of parameters and state variables

**Participants:** Frédéric Mazenc, Michael Malisoff *(LSU)*, Laurent Burlion *(Rutgers Univ.)*.

In the papers [38] and [57], we provided new observer designs to simultaneously identify parameters and states of systems whose non-linearities have order two near the origin, which include cubic terms arising in the study of jump phenomena, process control, and bistable models of aerospace systems. This yields local exponential convergence of the state estimation error to zero, basin of attraction estimates, and fixed time parameter identification. We illustrated our result using Duffing's equation, whose cubic term puts it outside the scope of prior methods

### 7.5 Local Stability Analysis of Piecewise affine systems

**Participants:** Giorgio Valmorbida, Joao Manoel Gomes da Silva Jr *(Universidade Federal do Rio Grande do Sul)*, Leonardo Cabral *(Universidade Federal do Rio Grande do Sul)*.

Piece-wise affine systems appear when linear dynamics are defined in different partitions of the state space. This type of systems naturally appears whenever actuators have different stages or saturate or whenever non-linear control laws are obtained as the solution to a parameterised optimization problem as, for instance for systems with feedback laws based on the so-called explicit Model Predictive Control. Even though the dynamics is simple to describe, the stability analysis, performance assessment and robustness analysis are difficult to perform since, due to the often used explicit representation, the Lyapunov stability and dissipation tests are often described in terms of a number of inequalities that increases exponentially on the number of sets in the partition since they are based on the enumeration of the partition transitions. Moreover regional stability and uncertainties corresponding to modification on the partition are difficult to study in this scenario.

To overcome these difficulties we have proposed an implicit representation for this class of systems in terms of ramp functions. The main advantage of such a representation lies on the fact that the ramp function can be exactly characterized in terms of linear inequalities and a quadratic equation, namely a linear complementarity condition. Thanks to the characterization of the ramp function and the implicit description of the PWA system, the verification of Lyapunov inequalities related to piecewise quadratic functions can be formulated as a semidefine programming whenever some co-positivity constraints are relaxed.

We have applied the results to the local analysis and synthesis of PWA control laws. Such a local formulation is based on local conditions for co-positivity of matrices. The proposed results encompass regional stability analysis formulations in the literature.

The stability conditions rely on the solution via convex optimization of piecewise quadratic inequalities in an implicit form, which can also be used to compute lower bounds to the minimum of non-convex and discontinuous functions.

## 7.6 Solution to Quadratic and Linear Programming problems arising in Model Predictive Control

**Participants:** Giorgio Valmorbida, Morten Hovd *(NTNU)*.

A novel method is proposed for solving quadratic programming problems arising in model predictive control. The method is based on an implicit representation of the Karush–Kuhn–Tucker conditions using ramp functions. The method is shown to be highly efficient on both small and fairly large Quadratic Program problems, can be implemented using simple computer code, and has modest memory requirements. The proposed algorithm shows a performance improvement mainly for large dimension optimization problems whenever few constraints are active in the optimal solution.

## 7.7 Controllability of one-dimensional hyperbolic systems

**Participants:** Yacine Chitour *(L2S, Univ. Paris-Saclay)*, Sébastien Fueyo *(School of Electrical Engineering, Tel Aviv University)*, Guilherme Mazanti *(DISCO)*, Mario Sigalotti *(Inria & LJLL, Sorbonne Université)*.

One-dimensional hyperbolic systems are useful models for a wide range of natural phenomena, in particular those involving the propagation of some physical quantities, such as the propagation of electricity along a transmission line, of laser signals in optical fibers, of water in open channels, of water or gaz in ridig pipes, of vehicles in a road system, of vibrations on mechanical structures, of living organisms in the presence of certain chemicals, among many others [84]. These numerous applications have motivated many recent works on the analysis of these kinds of systems, such as [83, 84], which address questions such as their stability, stabilizability, and controllability.

In the recent work [74], we have obtained criteria for exact and approximate controllability of linear one-dimensional hyperbolic systems in $L^p$ spaces, $p \in [1, +\infty)$, under the form of Hautus-type conditions expressed in the frequency domain. The strategy of this work relies on classical transformations of hyperbolic systems into difference equations (see, e.g., [84, 88]), whose solutions can be expressed under the form of a suitable representation formula, the latter being useful for providing upper bounds on the minimal controllability times. The main controllability results of [74] are obtained by expressing the difference equations under consideration as input/output infinite-dimensional systems, which allows one to make use of the formalism developped by Y. Yamamoto in [94, 95, 93], similarly to what was previously done in [27] for the approximate and exact controllability of difference equations.

Finally, [74] considers the special case of flows in networks, identifying a topological obstruction for controllability and deducing Hautus-type controllability criteria for these systems, which reduce to Kalman criteria in the case where the delays of the corresponding difference equation are commensurate.

## 7.8 Partial differential equations with different time scales

**Participants:** Gonzalo Arias *(Facultad de Matematicas, Pontificia Universidad Catolica de Chile)*, Swann Marx *(LS2N, École Centrale de Nantes & CNRS)*, Guilherme Mazanti *(DISCO)*.

The dynamics of systems in which phenomena of different nature are present may contain different time scales. This is the case, for instance, of electric motors, in which the electrical time scale is typically much faster than the mechanical one. A natural question in these situations, which is the basis of the singular perturbation theory, is whether one can approximate the fastest time scale by an instantaneous process. For finite-dimensional systems, its answer is given by Tikhonov's theorem, which states roughly that such an approximation is valid as soon as the dynamics of the fastest time scale is stable [90].

However, many systems in practice involving propagative, diffusive, or reactive phenomena are naturally modeled as infinite-dimensional systems. Singular perturbation in infinite dimension has attracted much interest from researchers in recent years, and it was highlighted in particular that classical results for finite-dimensional systems may fail to hold true in general in such a context, according to which system evolves in a fast time scale (see, e.g., [92]). Most works in the literature on singular perturbation for infinite-dimensional systms deal only with specific systems, showing approximation properties, when they hold, through the use of Lyapunov functions, as done in [92].

In order to get a better understanding of when singular perturbation methods work well for infinite-dimensional systems, we have revisited, in the recent work [50], the system considered in [92] made of a slow ODE coupled with a fast one-dimensional transport PDE. By adopting a spectral point of view of the problem, we have obtained sharper conditions under which approximation properties hold true, improving the results of [92]. In addition, the spectral methods used in [50] have provided valuable insight on the behavior of singularly perturbed systems in infinite dimension, which might be used to address more general systems than the one from that reference.

### 7.9 Multiplicity-induced-dominancy for classes of time-delay systems

**Participants:** Amina Benarab *(DISCO)*, Islam Boussaada *(DISCO)*, Yacine Chitour *(L2S, Univ. Paris-Saclay, France)*, Sébastien Fueyo *(School of Electrical Engineering, Tel Aviv University)*, Guilherme Mazanti *(DISCO)*, Wim Michiels *(Department of Computer Science, KU Leuven)*, Silviu-Iulian Niculescu *(DISCO)*, Karim Trabelsi *(IPSA)*.

Since the seminal works [86, 87], it has been known that spectral values of some families of time-delay systems of large multiplicity are often dominant (i.e., they attain the spectral abcissa of the system, and determine thus its asymptotic behavior), a property which came to be known as the *multiplicity-induced-dominancy* (MID) property. The validity of this property has an important impact in the stabilization of time-delay systems, since, when it holds, one may stabilize a system by selecting its free parameters in order to ensure that it admits a spectral value of large multiplicity which is dominant and has negative real part, ensuring stability.

In [73], we have studied the MID property for a family of delay-differential equations with a single delay when considering spectral values of multiplicity equal to $n+1$, where $n$ is the largest order of derivation appearing in the equation. In addition to several characterizations of spectral values with this multiplicity, [73] provides sufficient conditons for dominance and studies in more details the case of a chain of $n$ integrators, for which more precise results can be provided, together with links between multiple spectral values and the optimization of the spectral abscissa. The derived results show how the delay can be further exploited as a control parameter and are applied to some problems of stabilization of standard benchmarks with prescribed exponential decay.

The work [72] extends the results of [73] to roots of multiplicity larger than or equal to $n+1$, providing extensive characterizations of such roots. Many configurations are considered according to which coefficients of the system are assumed to be fixed and which ones are assumed to be available for choice, with a special attention paid to the so-called *control-oriented* configuration, in which the coefficients of highest order of the non-delayed part of the system are fixed, and all others are free. Sufficient conditions for dominance, similar to those of [73], are also provided in [72], together with a detailed analysis of two examples.

For instance, in [19], we characterize the MID property in the scalar neutral case with respect to the system parameters. Particular attention is paid to the so-called over-order multiplicities corresponding to real double and triple characteristic roots.

While most results on the MID property consider only systems with a single delay, the work [31] has addressed a first-order system with two delays. By considering the ratio between the smallest and the largest delay as a parameter, [31] provides a careful analysis of the behavior of the spectrum of the system with respect to this parameter, which is used to establish the MID property for roots of maximal multiplicity of such a class of systems. As a consequence, [31] also establishes that the inclusion of a second delay may help in stabilizing time-delay systems with constraints on their coefficients, with respect to a classical proportional-delayed controller. As an extension of the methodology of the latter, [59] characterizes the MID property for second-order systems controlled by a two-delay "block". As an application of which, the problem of stabilization of the classical pendulum with exclusive access to the delayed position is treated.

### 7.10 Coexistent-real-roots-induced-dominancy for time-delay systems

**Participants:** Islam Boussaada *(DISCO)*, Silviu-Iulian Niculescu *(DISCO)*, Timothée Schmoderer *(DISCO)*.

In recent years, the Team highligted an extension of the MID property called *coexistent-real-roots-induced-dominancy* (CRRID), see for instance [85, 82] applying for LTI functional differential equations of retarded type. The CRRID property consists in conditions on an LTI functional dynamical system's parameters guaranteeing the dominancy of coexistence of real spectral values. In [44], we extend such a property to a class of neutral systems, and exploit it in the boundary control of the standard transport equation. Namely, by using the CRRID property, we show that one can arbitrarily and robustly prescribe the exponential decay of the closed-loop transport solution, yielding the prospect of applying the CRRID partial poles placement methodology to hyperbolic PDE's.

### 7.11 Well-posedness of the shooting algorithm for control-affine problems for a scalar state constraint

**Participants:** Frédéric Bonnans *(DISCO)*, Soledad Aronna *(FGV, Rio de Janeiro, Brazil)*, Bean San Goh *(Curtin U., Perth)*.

We deal in [18] with a control-affine problem with scalar control subject to bounds, a scalar state constraint and endpoint constraints of equality type. For the numerical solution of this problem, we propose a shooting algorithm and provide a sufficient condition for its local convergence. We exhibit an example that illustrates the theory.

### 7.12 Numerical analysis for mean field optimization problems

**Participants:** Kang Liu, Laurent Pfeiffer.

We investigate in [75] the convergence of the Generalized Frank-Wolfe (GFW) algorithm for the resolution of potential and convex second-order mean field games. In a previous work [34], we had established some rates of convergence for this method, at the continuous level. We analyze here the impact of the discretization of the mean-field-game system on the effectiveness of the GFW algorithm. The article focuses on the theta-scheme, which we introduced in [25]. A sublinear and a linear rate of convergence are obtained, for two different choices of stepsizes. These rates have the mesh-independence property: the underlying convergence constants are independent of the discretization parameters.

In the preprint [76], we formulate and investigate a mean field optimization (MFO) problem over a set of probability distributions $\mu$ with a prescribed marginal $m$. The cost function depends on an aggregate term, which is the expectation of $\mu$ with respect to a contribution function. This problem is of particular interest in the context of Lagrangian potential mean field games (MFGs) and their discretization. We provide a first-order optimality condition and prove strong duality. We investigate stability properties of the MFO problem with respect to the prescribed marginal, from both primal and dual perspectives. In our stability analysis, we propose a method for recovering an approximate solution to an MFO problem with the help of an approximate solution to an MFO with a different marginal $m$, typically an empirical distribution. We combine this method with the stochastic Frank-Wolfe algorithm, which we had introduced in [23], to derive a complete resolution method.

### 7.13 Study of SIR models

**Participants:** Frédéric Mazenc, Michael Malisoff *(LSU)*, Hiroshi Ito *(Kyushu Institute)*.

In the paper [32], we derived feedback control laws for isolation, contact regulation, and vaccination for infectious diseases, using a strict Lyapunov function. We use an SIQR (Susceptible, Infected, Quarantined, Recovered individuals) epidemic model describing transmission, isolation via quarantine, and vaccination for diseases to which immunity is long-lasting. Assuming that mass vaccination is not available to completely eliminate the disease in a time horizon of interest, we provided feedback control laws that drive the disease to a small endemic equilibrium. We prove the ISS robustness property on the entire state space, when the immigration perturbation is viewed as the uncertainty. We use an ISS Lyapunov function to construct the feedback control laws. A key ingredient in our analysis is that all compartment variables are present not only in the Lyapunov function, but also in a negative definite upper bound on its time derivative. We illustrate the efficacy of our method through simulations. Since the control laws are feedback, their values are updated based on data acquired in real time. We also discussed the degradation caused by the delayed data acquisition occurring in practical implementations, and we derive bounds on the delays under which the ISS property is maintained when delays are present.

### 7.14 Harmonic disturbance compensation of a system with long dead-time, design and experimental validation

**Participants:** Can Kutlu Yuksel, Jaroslav Busek, Milan Anderle, Tomas Vyhlidal, Silviu-Iulian Niculescu.

An internal model control scheme is proposed in [49] to compensate both a long dead-time of a system and a harmonic disturbance. The controller is based on an inversion of the first-order model used to approximate the system dynamics together with an input delay. Two other components of the controller consist of a filter and an additional delay by which the harmonic modes are targeted via adjusting the control loop gain and phase shift. The design of the filter-delay pair is fully analytical and the implementation of the scheme is straightforward. The main attention is paid to the complete compensation of a single harmonic disturbance. Besides, an extension of the scheme is proposed to target a double harmonic disturbance. Increased attention is paid to the robustness aspects of the schemes. Outstanding performance in terms of harmonic disturbance compensation of the proposed schemes is demonstrated on a series of laboratory experiments.

### 7.15 A distributed delay based controller for simultaneous periodic disturbance rejection and input-delay compensation

**Participants:** Can Kutlu Yuksel, Jaroslav Busek, Milan Anderle, Tomas Vyhlidal, Silviu-Iulian Niculescu.

The paper [48] presents a controller design for systems suffering from multi-harmonic periodic disturbance and substantial input time-delay. It forms an alternative approach to Repetitive Control where the goal is to stabilize a closed-loop that encapsulates an explicit time-delay model of the periodic signal. The proposed controller design is based on the Internal Model Control (IMC) framework, and it consists of the inverse system model and an appropriate distributed delay with an overall length related to the period of the disturbance. The properness of the controller can be ensured by utilizing a low-pass filter, however, such a component is shown to be unnecessary when the relative order of the system model is one. This fact makes the alternative approach especially suitable for systems approximated by a first-order model with input time-delay, leading to a straightforward controller design thanks to its simple structure and attainable conditions. Stability of the configuration is guaranteed by an ideal IMC framework. For further performance and robustness requirements for the non-ideal case the tuning of the controller is posed as a weighted-$H_\infty$ optimization problem where frequency-, spectral-and time-domain requirements are formulated as constraints. The overall control design is experimentally verified on a laboratory setup that has high-order dynamics approximated by a first-order model with input delay.

### 7.16 A practical cell density stabilization technique through drug infusions

**Participants:** Catherine Bonnet, Walid Djema, Frédéric Mazenc, Hitay Özbay.

Following our project on the modeling and analysis of healthy and unhealthy cell population dynamics in leukemia, we have considered a nonlinear system with distributed delays where the parameters depend on growth-factor concentrations. Here, a change in one of the growth factor concentrations may lead to a switch in the corresponding model parameter. We have achieved a network representation of the switching system involving nodes and edges. Each node stands for a full-fledged nonlinear system with distributed delays where the parameters are constant. For each node, a stable positive steady state may exist. In this network framework, a change in the growth-factor concentration is interpreted as a transition from one node to another. We have proposed a method which provides a (sub)optimal therapeutic strategy, guiding the density of cells from an abnormal state towards a healthy one, through multiple drug infusions.

# 8 Partnerships and cooperations

## 8.1 International initiatives

#### 8.1.1 STIC/MATH/CLIMAT AmSud projects

**Participants:** G. Valmorbida, S. Tarbouriech, A. Girard, P.L.D. Peres, J.M. Gomes da Silva, D. Sbárbaro H., D. Munoz C..

**Title:** project SticAmsud (22-STIC-09) NetConHybSDP - Networked control of hybrid systems by semi-definite programming with applications in industry 4.0.

**Partner Institution(s):**
- UNICAMP, UFRGS, CEFET-MG, Brazil
- Universidad de O'Higgins, Universidad de Concepcion, Universidad de Talca, Chile

## 8.2 International research visitors

#### 8.2.1 Visits of international scientists

- Prof. Diego Munoz Carpintero (Universidad O'Higgins), 2 visits of 2 weeks (February and December 2023)
- Aditya Mahajan (McGill University, Canada): sabbatical year, July 2023-June 2024; visit financially supported by McGill, DATA IA (4 months), d'Alembert program (6 months), RTE CentraleSupélec Chair (1 month).

- Kaïs Ammari (University of Monastir), 2 weeks stay June and September 2023.
- Prof. Valter Leite (CEFET-MG), 1 week stay (October 2023).
- Prof. Hitay Özbay (Bilkent University) 5-9 December 2023.
- Prof. Pedro L. D. Peres (UNICAMP), 1 week stay (october 2023), 1 month stay (November-December 2023).

**Gonzalo Arias**

**Status:** PhD

**Institution of origin:** Pontificia Universidad Católica de Chile

**Country:** Chile

**Dates:** November 27 – December 11, 2023

**Context of the visit:** Collaboration with G. Mazanti on partial differential equations with different time scales, as part of the project "Control of propagation phenomena: from hyperbolic partial differential equations to time-delay systems" funded by H-CODE.

**Mobility program/type of mobility:** Research stay

#### 8.2.2 Visits to international teams

**Research stays abroad**

**Guilherme Mazanti**

**Visited institution:** Universidade de Brasília

**Country:** Brazil

**Dates:** October 16–19, 2023

**Context of the visit:** Collaboration with Jaqueline Godoy Mesquita and Felipe Gonçalves Netto on difference equations with varying delays, as part of the project "Control of propagation phenomena: from hyperbolic partial differential equations to time-delay systems" funded by H-CODE.

**Mobility program/type of mobility:** Research stay

**Giorgio Valmorbida**

**Visited institution:** UNICAMP, Campinas

**Country:** Brazil

**Dates:** 1-31 August, 2023

**Context of the visit:** program Franco-Brazilian Chairs of the state of São Paulo.

**Mobility program/type of mobility:** Research stay

### 8.3 National initiatives

- C. Bonnet is member of the ANR Dreamy

  From September 2021 - September 2025

  A key advantage of biological computing devices is their ability to sense, compute, and especially to respond to their biological environment, e.g., bacteria can be programmed to act as autonomous robots within the human body. Local presence of certain molecules in the environment allows sensing of neighboring cell types and acting accordingly, e.g., by activating an immune response. Current designs of synthetic circuits in bacteria, however, face severe resource limitations: each genetic part added to the cell imposes an additional burden, becoming progressively toxic for the cell. The most common design techniques for biological logic gates rely on gene regulation via DNA-binding proteins, nucleic acid (DNA/RNA) interactions, or more recently the CRISPR machinery. Each comes with its own constraints: like limited availability of orthogonal signals for use within the cell (DNA-binding), small dynamic range (RNA-based), or reduced growth rates (the CRISPR machinery). This has led to recent efforts to distribute circuits among several cells to reduce the resource load per cell, taking the formative steps towards distributed bacterial circuits. The DREAMY research project seeks to develop innovative solutions to the problem of building distributed circuits in bacteria from an algorithmic, theoretical perspective that contributes to real-world implementable solutions.

  Involved groups: LMF (FR), LISN (FR), DISCO (FR), ALGO group (University of Geneva, CH), Micalis (INRAE, FR), L2S (FR)

### 8.4 Regional initiatives

- Laurent Pfeiffer chairs the PGMO (programme d'optimisation Gaspard Monge) project "Large-scale and non-convex multi-agent optimization for energy management" (other DISCO participants: Frédéric Bonnans, Kang Liu, and Thibault Moquet). Industrial partners: Nadia Oudjane (EDF R&D) and Cheng Wan (EDF R&D). Funding in 2023: 7000 euros.

## 9 Dissemination

### 9.1 Promoting scientific activities

S-I Niculescu is the Founding Editor and the Editor-in-Chief of the Springer-Nature book series « Advances in delays and dynamics » since its creation in 2012.

#### 9.1.1 Scientific events: organisation

**General chair, scientific chair** S-I Niculescu was the General Co-Chair of the 21st European Control Conference, Bucharest, Romania, June 13-16th, 2023 (ECC 2023: ).

**Member of the organizing committees**

- I. Boussaada was an organizer of the conference Control Theory and Inverse Problems (CTIP) 2023 , held in Monastir, Tunisia, May, 8-10, 2023.
- G. Mazanti was an organizer of the workshop "EDP, commande et observation des systèmes (EDP-COSy)", held in Toulouse, France, October 17–20, 2023.
- G. Mazanti is an organizer of the "Séminaire d'Automatique du Plateau de Saclay".

**Minisymposium organization**

- C. Bonnet co-organized a tutorial session at ECC 2023.
- G. Mazanti and L. Pfeiffer organized a minisymposium on mean-field games and control during the PGMO days (November 2023, EDF-Lab).

#### 9.1.2 Scientific events: selection

- C. Bonnet was SIAM Associate Editor of the 2023 American Control Conference, held in May 31 - June 2, 2023, San Diego, CA, USA.
- I. Boussaada and F. Mazenc were Associate Editor for ECC 2023.
- S-I Niculescu was an Associate Editor (as an IFAC Technical Committee Chair) and C. Bonnet was a Technical Associate Editor of the 22nd IFAC World Congress, Yokohama, Japan, July 9-14th, 2023 IFAC World Congress.

**Member of the conference program committees**

- C. Bonnet was member of the international program committee of the IFAC World Congress 2023, 9-14 July 2023, Yokohama, Japan.

**Reviewer** Members of the team have reviewed papers for several journals covering the topics of the team, including the European Control Conference and the IFAC World Congress.

#### 9.1.3 Journal

**Member of the editorial boards**

- F. Mazenc is Editor of the Asian Journal of Control, Associate Editor of Automatica and IEEE Control Systems Letters.
- S-I Niculescu is an Associate Editor of IMA Journal of Mathematical Control and Information (since 2011), IFAC PapersOnLine (2020-2023),Journal of Numerical Analysis and Approximation Theory (since 2022).
- G. Valmorbida is a member of the conference editorial board of the Control Systems Society 2023.
- G. Mazanti is an associate editor of Matemática Contemporânea.

**Reviewer - reviewing activities** Members of the team have reviewed papers for several journals covering the topics of the team, including Acta Applicandae Mathematicae, Applied Mathematics and Optimization, Automatica, Communications in Contemporary Mathematics, IEEE Transactions on Automatic Control, IMA Journal of Mathematical Control and Information, Journal of Optimization Theory and Applications, and Systems & Control Letters

#### 9.1.4 Invited talks

- C. Bonnet gave a talk at the Operator Theory and Spaces of Analytic Functions Workshop at King's College London, 3-5 May, 2023.
- I. Boussaada gave a talk at the control Seminar of Laboratoire Jacques-Louis Lions (LJLL), Sorbonne Université, France, June, 16, 2023, a talk at the Seminar of the Laboratory of Analysis and Control of Partial Differential Equations (ACPDE) , University of Monastir, Tunisia, March, 8, 2023, a talk at the workshop , "EDP, commande et observation des systèmes (EDP-COSy)" held in Toulouse, France, October 17–20, 2023, a talk at the Seminar of the "laboratoire de Mathématiques Pures et Appliquées" (LMPA)université Mouloud Mammeri de Tizi-Ouzou, Algeria, November 23, 2023.
- G. Mazanti gave talks in seminars at the Laboratoire des Sciences du Numérique de Nantes (LS2N), France, and at the Analysis Seminar of University of Brasília. He was also an invited speaker at the conference "Control Theory & Inverse Problems (CTIP 2023)" held in Monastir, Tunisia.
- F. Mazenc gave a talk in the Gipsa-Lab, Grenoble (June 2023). Title of the talk: A stability analysis technique called trajectory-based approach.

- L. Pfeiffer was invited speaker at the "Optimization and Control in Burgundy" workshop (Dijon, may 2023), at the "Journées Ateliers FIME" (EDF Lab, September 2023), and a plenary speaker at the "Journées annuelles du GDR MOA" (Perpignan, October 2023).

- G. Valmorbida delivered talks at USP, USP São Carlos, UNICAMP, Brésil (August 2023). Title of the talks: Stability Analysis of Piecewise-Affine Systems in Implicit Form and Evaluation of Piecewise-Linear Functions. G. Valmorbida delivered a talk at the IFAC World Congress Workshop : A Showcase of LMI-Based Methods for Analysis, Control and Estimation of PDEs. Verification methods for the Lyapunov-Krasovskii functional inequalities 9 July 2023, Yokohama, Japan.

### 9.1.5 Leadership within the scientific community

S-I Niculescu was the Chair of the IFAC Technical Committee Linear Control Systems (TC 2.2; 2017-2023; 171 members).

### 9.1.6 Scientific expertise

- C. Bonnet was a member of the Inria Evaluation Committee until August 2023. She is a member of the Scientific Council of CentraleSupélec since December 2021 and of the board of directors of the Gaspard Monge Program for Optimization since October 2023. She also was an invited expert member of COMEVAL, université Gustave Eiffel in January 2023.

- I. Boussaada is a member of the Scientific Council of IPSA Engineering school (11/2016-01/2023), Scientific Council of Tésa collaborative Laboratory (Since 06/2021), Skills Development Council of Sup'Biotech Engineering school (Since 03/2019).

- I. Boussaada was Jury member of the Best PhD Thesis award of the GdR MACS, the Automatic section of the EEA Club and SAGIP.

- F. Mazenc is member of the Commission de Développement Technologique du CRI Saclay.

- Silviu-Iulian Niculescu is a Scientific Expert for L'Oréal foundation (« prix L'Oréal UNESCO »: For Women in Science, program « Jeunes Talents »).

### 9.1.7 Research administration

- C. Bonnet is a member of the : - Bureau du Comité des Equipes Projets du CRI Saclay-Ile-de-France. - Coordination committee of the Mentoring Program of Inria Saclay-Île-de-France. - Council of L2S. She is the co-President of the Parity Committee at Inria since January 2022. She is the Parity Referent at L2S for CNRS since its creation in November 2020.

- I. Boussaada is a member of the Administration Council of SAGIP association (since 06/2019).

- Silviu-Iulian Niculescu was a member of the Scientific Council of the CNRS Institute INS2I (2022-2023)

- Silviu-Iulian Niculescu is a member of the Scientific Council of the University of Craiova (Romania, since 2020)

- Silviu-Iulian Niculescu is a member of the Local Committee of Pascal Institute, University Paris-Saclay (since 2018)

- L. Pfeiffer is member of the board of the Fédération de Mathématiques of CentraleSupélec, since November 2023. L. Pfeiffer is correspondent for the hiring mission (mission recrutement) at Inria-Saclay.

- G. Valmorbida is a member of the : - Council of L2S.

## 9.2 Teaching - Supervision - Juries

### 9.2.1 Teaching

- Licence: Islam Boussaada, *Complex and harmonic analysis*, 127h, 3rd year, IPSA, France.
- Licence: Ziad Kobeissi, *Convergence, Integration and Probability*, 16.5h, 1st year, CentraleSupelec, Université Paris-Saclay.
- Licence: Ziad Kobeissi, *Partial Differential Equation*, 15h, 1st year, CentraleSupelec, Université Paris-Saclay.
- Licence: Guilherme Mazanti, *Partial differential equations*, 16.5h, 1st year, CentraleSupélec, Université Paris-Saclay.
- Licence: Silviu Niculescu, *Mathematics*, 15h, 1st year, ENSMP Paris, France.
- Licence: Silviu Niculescu, *Introduction to optimization*, 30h, 1st year, ESIEE Paris, France.
- Licence: Giorgio Valmorbida, *Signal Processing*, 1st year, 43h CentraleSupélec Université Paris-Saclay.
- Master: Silviu Niculescu, *Signals and Systems*, 12h, ESIEE Paris, France.
- Master: Giorgio Valmorbida, *Stability of Dynamical Systems*, Master ATSI (M2), Université Paris-Saclay.
- Master: Guilherme Mazanti, *Optimization*, 46h, 2nd year, CentraleSupélec, Université Paris-Saclay.
- Master: Laurent Pfeiffer, *Optimal control of ordinary differential equations*, 15h, Optimization Master, Université Paris-Saclay and Ensta-Paris.
- Master: Laurent Pfeiffer, *Continuous optimization*, 18h, Energy Master, Institut Polytechnique de Paris and Ensta-Paris.
- Master: Laurent Pfeiffer, *Optimization project*, 18h, Energy Master, Institut Polytechnique de Paris and Ensta-Paris.
- Master: Giorgio Valmorbida, *Optimization*, 2nd year, 43h CentraleSupélec Université Paris-Saclay.
- Master: Giorgio Valmorbida, *Hybrid Systems*, 3rd year, 18h CentraleSupélec Université Paris-Saclay.
- Master: Giorgio Valmorbida, *Projects and Internship supervision*, 2nd and 3rd years, 81h, CentraleSupélec Université Paris-Saclay.
- Master: Giorgio Valmorbida, *Introduction aux systèmes asservis*, 3h, CentraleSupélec Executive Education, Université Paris-Saclay.
- Doctorat: Silviu Niculescu, *Controlling Delayed Dynamics: Advances in Theory, Methods and Applications*, 7h, CISM Udine, Italy.

### 9.2.2 Supervision

**PhD defenses**

- Kang Liu defended his PhD thesis on October 5 at Ecole Polytechnique, entitled "Numerical analysis and methods for mean-field type optimization problems". He was supervized by L. Pfeiffer and co-supervized by F. Bonnans. He was funded by an AMX fellowship of Ecole Polytechnique.
- Ricardo Falcon Prado defended his PhD thesis on June 7th at CentraleSupelec, entitled "Active vibration control of flexible structures under input saturation through delay-based controllers and anti-windup compensators". He was supervized by I. Boussaada and co-supervized by S. Tliba. He was funded by CONACYT.

**Master theses**

- L. Pfeiffer supervized the master thesis of Xinyu Huang (Computer Science Master, Sorbonne Université). The intership was co-supervized with Guilhem Dupuis, research engineer at EDF R&D. New methods for the resolution of aggregative multi-agent problems, extending our work [23], were developed and tested on a problem concerning the smart charging of a fleet of electrical vehicles.

### 9.2.3 Juries

- C. Bonnet was a member of several recruiting committees at Inria (Grenoble young researchers competition, young researchers with disabilities competition, Senior researcher competition).
- C. Bonnet was a member of the PhD committees of:

  - Z. Wang, 18 Januray 2023, INSA Val de Loire. Title of the thesis: Modulating function-based non-asymptotic and robust estimations for fractional-order systems.

  - A. Diab 18 April 2023, Centralesupelec. Title of the thesis: Stability analysis and control design for time-delay systems with applications to automotive steering systems.

  - H. Li, 28 June 2023, Université de Lille. Title of the thesis: Cosserat-Based Modeling and Control of Slender Soft Robots.

  - K. Saidi, 29 September 2023, Université de Lorraine. Title of the thesis: Stabilisation d'une classe d'EDPs non linéaires. Application à l'équation de Vlasov-Poisson.

  - E. Paiva, 20 December 2023, Mines Paris PSL. Title of the thesis: Wind Velocity Estimation for Wind Farms.

  - S. Mohite, 20 December 2023, Université de Lorraine. Title of the thesis: Observer Design for Nonlinear Systems using LMI Relaxation Techniques.

  She also was a member of the Habilitation committee of M. Di Loreto, 5 October 2023, INSA de Lyon. Title of the habilitation thesis: Propriétés structurelles des systèmes dynamiques pour le contrôle.
- I. Boussaada was a member of the recruting committee of an Associate Professor in Bioprocesses at Sup'Biotech Engineering school.
- I. Boussaada was a Thesis evaluation member of B. Caiazzo, March 2023, University of Napoli, Federico II. Title of the PhD: Distributed control of Cyber-Physical Energy Systems: Towards the Energy Transition
- L. Pfeiffer was examiner in the PhD committee of Hubert Ménou, January 2023, École des Mines de Paris - Université PSL. Title of the thesis: Hierarchical Emergency Guidance Optimization for reusable Tossback vehicle landing.
- F. Mazenc was member ('rapporteur') of the PhD committe of S. Zekraoui, October 2023, Centrale Lille. Title of the PhD: Finite-time control and estimation of some classes of PDEs.

## 9.3 Popularization

### 9.3.1 Internal or external Inria responsibilities

S-I Niculescu participated in the launch of the « Cahiers de l'Institut Pascal »(published by EDP Sciences Paris) and he is one of the Associate Editors. This is an initiative launched at the University of Paris-Saclay - a collection of white papers (free access) from thematic programs (2 per year) organized at the institute. The first issue (Physics) was published in 2023, and the evaluation of second one (devoted to « urban mobility ») was finalized November 2023.

### 9.3.2 Interventions

- G. Mazanti gave a popular science talk about the mathematical modelling of pedestrians and vehicles at an event organized by the group "Pesquisadores e universitários brasileiros em Paris".

# 10 Scientific production

## 10.1 Major publications

[1] A. L. Bertolin, R. C. Oliveira, G. Valmorbida and P. L. Peres. 'Output feedback control of discrete-time Lur'e systems through FIR Zames-Falb multipliers'. In: IFAC World Congress 2023. Vol. 56. 2. Yokohama, France, 2023, pp. 9528–9533. DOI: 10.1016/j.ifacol.2023.10.252. URL: https://hal.science/hal-04363973.

[2] C. Bonnet and J. Partington. 'Stabilization of some fractional delay systems of neutral type'. In: *Automatica* 43 (2007), pp. 2047–2053.

[3] C. Bonnet, A. R. Fioravanti and J. R. Partington. 'Stability of Neutral Systems with Commensurate Delays and Poles Asymptotic to the Imaginary Axis'. In: *SIAM Journal on Control and Optimization* 49.2 (Mar. 2011), pp. 498–516. URL: https://hal.inria.fr/hal-00782325.

[4] I. Boussaada, I.-C. Morarescu and S.-I. Niculescu. 'Inverted pendulum stabilization: characterization of codimension-three triple zero bifurcation via multiple delayed proportional gains'. In: *Systems Control Lett.* 82 (2015), pp. 1–9.

[5] A. Diab, W. Pasillas-Lépine and G. Valmorbida. 'A Steer-by-Wire Control Architecture Robust to High Assistance Gains and Large Transmission Delays'. In: *Proceeding of the 15th International Symposium on Advanced Vehicle Control.* The 15th International Symposium on Advanced Vehicle Control. Proceeding of the 15th International Symposium on Advanced Vehicle Control. Kanagawa, Japan: Society of Automotive Engineers of Japan, 12th Sept. 2022. URL: https://centralesupelec.hal.science/hal-03798214.

[6] A. Diab, G. Valmorbida and W. Pasillas-Lépine. 'Linear assistance filter design for electric power steering systems with improved delay margin'. In: *International Journal of Control* (27th Apr. 2023), pp. 1–18. DOI: 10.1080/00207179.2023.2201648. URL: https://hal.science/hal-04363969.

[7] M. Hovd and G. Valmorbida. 'Solving LP-MPC problems using ramp functions*'. In: 2023 IEEE Conference on Control Technology and Applications (CCTA). Bridgetown, France: IEEE, 16th Aug. 2023, pp. 445–450. DOI: 10.1109/CCTA54093.2023.10252720. URL: https://hal.science/hal-04363933.

[8] M. Malisoff and F. Mazenc. *Constructions of Strict Lyapunov Functions.* Communications and Control Engineering Series. Springer-Verlag London Ltd., 2009.

[9] F. Mazenc, M. Malisoff and S.-I. Niculescu. 'Reduction Model Approach for Linear Time-Varying Systems with Delays'. In: *IEEE Transactions on Automatic Control* 59.8 (2014), pp. 2068–2014.

[10] W. Michiels and S.-I. Niculescu. *Stability, Control, and Computation for Time-Delay Systems.* Ed. by S.-I. Niculescu and W. Michiels. Philadelphia, PA: Society for Industrial and Applied Mathematics, 2014.

[11] S.-I. Niculescu. *Delay Effects on Stability: a Robust Control Approach.* Vol. 269. Lecture Notes in Control and Information Sciences. Springer, 2001.

[12] I. Queinnec, S. Tarbouriech, G. Valmorbida and L. Zaccarian. 'Design of Saturating State-Feedback with Sign-Indefinite Quadratic Forms'. In: *IEEE Transactions on Automatic Control* (2021). DOI: 10.1109/TAC.2021.3106878. URL: https://hal.laas.fr/hal-03353776.

[13] M. B. Saldivar, I. Boussaada, H. Mounier and S.-I. Niculescu. *Analysis and Control of Oilwell Drilling Vibrations.* Springer International Publishing, May 2015. URL: https://hal.archives-ouvertes.fr/hal-01123773.

[14] M. G. Titton, J. M. Gomes da Silva Jr., G. Valmorbida and M. Jungers. 'Stability analysis of Lure systems under aperiodic sampled-data control'. In: *International Journal of Robust and Nonlinear Control* 33.12 (Aug. 2023), pp. 7130–7153. DOI: 10.1002/rnc.6744. URL: https://hal.science/hal-04239552.

[15] G. Valmorbida, M. Ahmadi and A. Papachristodoulou. 'Stability Analysis for a Class of Partial Differential Equations via Semidefinite Programming'. In: *IEEE Transactions on Automatic Control* 61.6 (June 2016), pp. 1649–1654.

[16] G. Valmorbida, S. Tarbouriech and G. Garcia. 'Design of Polynomial Control Laws for Polynomial Systems Subject to Actuator Saturation'. In: *IEEE Transactions on Automatic Control* 58.7 (July 2013), pp. 1758–1770.

[17] G. Valmorbida and F. Ferrante. 'On Quantization in Discrete-Time Control Systems: Stability Analysis of Ternary Controllers'. In: *CDC 2020 - 59th IEEE Conference on Decision and Control*. IEEE. Jeju Island (virtual), South Korea, Dec. 2020. URL: https://hal.archives-ouvertes.fr/hal-03092417.

## 10.2 Publications of the year

### International journals

[18] M. S. Aronna, J. F. Bonnans and B. S. Goh. 'Well-posedness of the shooting algorithm for control-affine problems with a scalar state constraint'. In: *Journal of Computational and Applied Mathematics* (19th June 2023). DOI: 10.1007/s40314-023-02346-2. URL: https://inria.hal.science/hal-04134841.

[19] A. Benarab, I. Boussaada, S.-I. Niculescu and K. Trabelsi. 'Multiplicity-induced-dominancy for delay systems: Comprehensive examples in the scalar neutral case'. In: *European Journal of Control* (June 2023), p. 100835. DOI: 10.1016/j.ejcon.2023.100835. URL: https://centralesupelec.hal.science/hal-04196450.

[20] A. Benarab, I. Boussaada, K. Trabelsi and C. Bonnet. 'Multiplicity-Induced-Dominancy property for second-order neutral differential equations with application in oscillation damping'. In: *European Journal of Control* 69 (1st Jan. 2023). DOI: 10.1016/j.ejcon.2022.100721. URL: https://hal.science/hal-03626756.

[21] J. F. Bonnans, J. Gianatti and L. Pfeiffer. 'A Lagrangian approach for aggregative mean field games of controls with mixed and final constraints'. In: *SIAM Journal on Control and Optimization* 61.1 (15th Feb. 2023), pp. 105–134. DOI: 10.1137/21M1407720. URL: https://inria.hal.science/hal-03174167.

[22] J. F. Bonnans, P. Lavigne and L. Pfeiffer. 'Discrete potential mean field games: duality and numerical resolution'. In: *Mathematical Programming* 202.1-2 (28th Mar. 2023), pp. 241–278. DOI: 10.1007/s10107-023-01934-8. URL: https://inria.hal.science/hal-03260057.

[23] J. F. Bonnans, K. Liu, N. Oudjane, L. Pfeiffer and C. Wan. 'Large-scale nonconvex optimization: randomization, gap estimation, and numerical resolution'. In: *SIAM Journal on Optimization* 33.4 (10th Nov. 2023), pp. 3083–3113. DOI: 10.1137/22M1488892. URL: https://hal.science/hal-03631702.

[24] J. F. Bonnans, G. Bonnet and J.-M. Mirebeau. 'Monotone discretization of anisotropic differential operators using Voronoi's first reduction'. In: *Constructive Approximation* (1st Dec. 2023). DOI: 10.1007/s00365-023-09672-y. URL: https://hal.science/hal-03855267.

[25] J. F. Bonnans, K. Liu and L. Pfeiffer. 'Error estimates of a theta-scheme for second-order mean field games'. In: *ESAIM: Mathematical Modelling and Numerical Analysis* 57.4 (July 2023), pp. 2493–2528. DOI: 10.1051/m2an/2023059. URL: https://hal.science/hal-04175251.

[26] L. Broering Groff, G. Valmorbida and J. M. Gomes da Silva. 'An implicit representation for the analysis of piecewise affine discrete-time systems'. In: *Automatica* 147 (Jan. 2023), p. 110730. DOI: 10.1016/j.automatica.2022.110730. URL: https://hal.science/hal-03946015.

[27] Y. Chitour, S. Fueyo, G. Mazanti and M. Sigalotti. 'Hautus-Yamamoto criteria for approximate and exact controllability of linear difference delay equations'. In: *Discrete and Continuous Dynamical Systems - Series A* 43.9 (Sept. 2023), pp. 3306–3337. DOI: 10.3934/dcds.2023049. URL: https://hal.science/hal-03827918.

[28] Y. Chitour, G. Mazanti, P. Monmarché and M. Sigalotti. 'On the gap between deterministic and probabilistic Lyapunov exponents for continuous-time linear systems'. In: *Electronic Journal of Probability* 28 (2023), Paper No. 43, 39 pp. DOI: 10.1214/23-EJP932. URL: https://hal.science/hal-03478271.

[29] A. Diab, G. Valmorbida and W. Pasillas-Lépine. 'Linear assistance filter design for electric power steering systems with improved delay margin'. In: *International Journal of Control* (27th Apr. 2023), pp. 1–18. DOI: 10.1080/00207179.2023.2201648. URL: https://hal.science/hal-04363969.

[30] R. Drummond and G. Valmorbida. 'Generalised Lyapunov functions for discrete-time Lurie systems with slope-restricted nonlinearities'. In: *IEEE Transactions on Automatic Control* (2023). DOI: 10.1109/TAC.2022.3233540. URL: https://hal.science/hal-03946093.

[31] S. Fueyo, G. Mazanti, I. Boussaada, Y. Chitour and S.-I. Niculescu. 'On the pole placement of scalar linear delay systems with two delays'. In: *IMA Journal of Mathematical Control and Information* 40.1 (17th Feb. 2023), pp. 81–105. DOI: 10.1093/imamci/dnad001. URL: https://hal.science/hal-03669644.

[32] H. Ito, M. Malisoff and F. Mazenc. 'Feedback control of isolation and contact for SIQR epidemic model via strict Lyapunov function'. In: *Mathematical Control and Related Fields* 13.4 (2023), pp. 1438–1465. DOI: 10.3934/mcrf.2022043. URL: https://inria.hal.science/hal-04337733.

[33] M. Kuře, J. Bušek, I. Boussaada, W. Michiels, S.-I. Niculescu and T. Vyhlídal. 'Robust delayed resonator with acceleration feedback – design by double root assignment and experimental validation'. In: *Journal of Sound and Vibration* (Jan. 2024), p. 118261. DOI: 10.1016/j.jsv.2024.118261. URL: https://hal.science/hal-04409473.

[34] P. Lavigne and L. Pfeiffer. 'Generalized conditional gradient and learning in potential mean field games'. In: *Applied Mathematics and Optimization* 88 (24th Oct. 2023). DOI: 10.1007/s00245-023-10056-8. URL: https://hal.science/hal-03341776.

[35] D. Lunz, J. F. Bonnans and J. Ruess. 'Optimal control of bioproduction in the presence of population heterogeneity'. In: *Journal of Mathematical Biology* 86.3 (6th Feb. 2023), p. 43. DOI: 10.1007/s00285-023-01876-x. URL: https://inria.hal.science/hal-03445175.

[36] D. Lunz and J. F. Bonnans. 'Modelling and optimal control of a two-species bioproducing microbial consortium'. In: *SIAM Journal on Applied Mathematics* 83.1 (13th Feb. 2023), pp. 144–171. DOI: 10.1137/22M1476113. URL: https://inria.hal.science/hal-03479385.

[37] M. Malisoff, F. Mazenc and C. Barbalata. 'Event-Triggered Control under Unknown Input and Unknown Measurement Delays using Interval Observers'. In: *IEEE Control Systems Letters* 7 (2023), p. 6. DOI: 10.1109/LCSYS.2022.3220502. URL: https://inria.hal.science/hal-04337725.

[38] F. Mazenc, M. Malisoff and L. Burlion. 'Almost Fixed Time Observers for Parameters and for State Variables of Nonlinear Systems'. In: *IEEE Control Systems Letters* 7 (2023), p. 6. DOI: 10.1109/LCSYS.2022.3214237. URL: https://inria.hal.science/hal-04017818.

[39] F. Mazenc, M. Malisoff and J. Knox. 'Discrete-Time Trajectory-Based Stabilization Approach using Interval Observer'. In: *IEEE Control Systems Letters* (2023). DOI: 10.1109/LCSYS.2023.3298068. URL: https://inria.hal.science/hal-04169026.

[40] F. Mazenc, G. Robledo and D. Sepulveda. 'A Stability Aanalysis of a Time-Varying Chemostat with Pointwise Delay'. In: *Mathematical Biosciences and Engineering* 21.2 (2024), p. 38. DOI: 10.3934/mbe.2024119. URL: https://inria.hal.science/hal-04412087.

[41] W. Michiels, S.-I. Niculescu and I. Boussaada. 'A Complete Characterization of Minima of the Spectral Abscissa and Rightmost Roots of Second-Order Systems with Input Delay'. In: *IMA Journal of Mathematical Control and Information* (21st June 2023). DOI: 10.1093/imamci/dnad020. URL: https://centralesupelec.hal.science/hal-04196433.

[42] J. Redaud, J. Auriol and F. Bribiesca Argomedo. 'Output Regulation and Tracking for Linear ODE-Hyperbolic PDE-ODE systems'. In: *Automatica* (2023). DOI: 10.1016/j.automatica.2023.111503. URL: https://hal.science/hal-04315507.

[43] J. Redaud, J. Auriol and Y. Le Gorrec. 'In domain dissipation assignment of boundary controlled Port-Hamiltonian systems using backstepping'. In: *Systems and Control Letters* (11th Jan. 2024). URL: https://hal.science/hal-04389143.

[44] T. Schmoderer, I. Boussaada and S.-I. Niculescu. 'On Boundary Control of the Transport Equation. Assigning Real Spectra & Exponential Decay'. In: *IEEE Control Systems Letters* 7 (29th Nov. 2023), pp. 3591–3596. DOI: 10.1109/LCSYS.2023.3337591. URL: https://hal.science/hal-04194365.

[45] T. Schmoderer, I. Boussaada, S.-I. Niculescu and F. Bedouhene. 'Insights on equidistributed real spectral values in second-order delay systems: perspectives in partial pole placement'. In: *Systems and Control Letters* 185 (22nd Jan. 2024), p. 105728. DOI: 10.1016/j.sysconle.2024.105728. URL: https://hal.science/hal-04145041.

[46] A. Seguret, C. Alasseur, J. F. Bonnans, A. de Paola, N. Oudjane and V. Trovato. 'Decomposition of convex high dimensional aggregative stochastic control problems'. In: *Applied Mathematics and Optimization* 88.8 (10th Apr. 2023), p. 35. DOI: 10.1007/s00245-023-09977-1. URL: https://inria.hal.science/hal-02917014.

[47] G. Valmorbida and M. Hovd. 'Quadratic programming with ramp functions and fast online QP-MPC solutions'. In: *Automatica* 153 (July 2023), p. 111011. DOI: 10.1016/j.automatica.2023.111011. URL: https://hal.science/hal-04363951.

[48] C. K. Yuksel, J. Bušek, M. Anderle, T. Vyhlídal and S.-I. Niculescu. 'A distributed delay based controller for simultaneous periodic disturbance rejection and input-delay compensation'. In: *Mechanical Systems and Signal Processing* 197 (2023), p. 110364. DOI: 10.1016/j.ymssp.2023.110364. URL: https://hal.science/hal-04175929.

[49] C. K. Yüksel, T. Vyhlídal, J. Bušek, M. Anderle and S.-I. Niculescu. 'Harmonic disturbance compensation of a system with long dead-time, design and experimental validation'. In: *IEEE/ASME Transactions on Mechatronics* (2023), pp. 1–12. DOI: 10.1109/TMECH.2023.3253727. URL: https://hal.science/hal-04071873.

**International peer-reviewed conferences**

[50] G. Arias, S. Marx and G. Mazanti. 'Frequency domain approach for the stability analysis of a fast hyperbolic PDE coupled with a slow ODE'. In: *Proceedings of the 2023 62nd IEEE Conference on Decision and Control*. 62nd IEEE Conference on Decision and Control. Singapore, Singapore, 31st Dec. 2023. DOI: 10.1109/cdc49753.2023.10383213. URL: https://hal.science/hal-04059956.

[51] A. Benarab, I. Boussaada, S.-I. Niculescu and K. Trabelsi. 'On the Spectrum Distribution of Parametric Second-Order Delay Differential Equations: Perspectives in Partial Pole Placement'. In: *Part of the Trends in Mathematics book series (TM)*. CIP 2022: Control and Inverse Problems. Trends in Mathematics. Monastir, Tunisia: Springer Nature Switzerland, 31st May 2023, pp. 49–75. DOI: 10.1007/978-3-031-35675-9_4. URL: https://hal.science/hal-04423767.

[52] W. Djema, C. Bonnet, H. Ozbay and F. Mazenc. 'A practical cell density stabilization technique through drug infusions: a simple pathfinding approach'. In: *IEEE Xplore*. 2023 European Control Conference (ECC 2023). 2023 European Control Conference (ECC). Bucharest, Romania, 13th June 2023. DOI: 10.23919/ECC57647.2023.10178254. URL: https://inria.hal.science/hal-04379210.

[53] R. Katz, F. Mazenc and E. Fridman. 'ISS of rapidly time-varying systems via a novel superposition-based presentation'. In: 62nd IEEE Conference on Decision and Control (CDC 2023). Singapour city, Singapore, 2023. DOI: 10.1109/cdc49753.2023.10383953. URL: https://inria.hal.science/hal-04337778.

[54] R. Katz, F. Mazenc and E. Fridman. 'Stability by averaging via time-varying Lyapunov functions'. In: 22nd World Congress of the International Federation of Automatic Control (IFAC 2023). Yokohama, Japan, 2023. DOI: 10.1016/j.ifacol.2023.10.1569. URL: https://inria.hal.science/hal-04337744.

[55] K. Liu, N. Oudjane and L. Pfeiffer. 'Decomposed resolution of finite-state aggregative optimal control problems'. In: 2023 Proceedings of the Conference on Control and its Applications (CT). Philadelphie (USA), United States: Society for Industrial, Applied Mathematics; Society for Industrial and Applied Mathematics, 10th Jan. 2023, pp. 56–63. DOI: 10.1137/1.9781611977745.8. URL: https://hal.science/hal-03642127.

[56] M. Malisoff, F. Mazenc and C. Barbalata. 'Event-Triggered Control under Unknown Input and Unknown Measurement Delays using Interval Observers'. In: American Control Conference (ACC2023). San Diego, United States, 31st May 2023. URL: https://inria.hal.science/hal-04337859.

[57] F. Mazenc and M. Malisoff. 'Local Observer for Parameters and for State Variables of Nonlinear Systems'. In: American Control Conference (ACC2023). San Diego, United States, 2023. DOI: 10.23919/acc55779.2023.10156653. URL: https://inria.hal.science/hal-04337848.

[58] J. Redaud and J. Auriol. 'Backstepping stabilization of a clamped string with actuation inside the domain'. In: 22nd World Congress of the International Federation of Automatic Control (IFAC 2023). Yokohama, Japan, 9th July 2023. DOI: 10.1016/j.ifacol.2023.10.692. URL: https://hal.science/hal-04054149.

[59] A. Remadna, I. Boussaada, F. Bedouhene, S.-I. Niculescu and A. Benchettah. 'Some Remarks on the Pendulum Stabilization. Multiple Delays & Decay Rate Assignment'. In: *IEEE Xplore*. 27th International Conference on System Theory, Control and Computing. Timisoara, Romania, 11th Oct. 2023. DOI: 10.1109/icstcc59206.2023.10308493. URL: https://centralesupelec.hal.science/hal-04213496.

[60] A. Sassi, I. Boussaada and S.-I. Niculescu. 'Reduced-Order Observer Design for Time-Delay Systems using Partial Pole Placement'. In: ICSC 2023 - 11th International Conference on Systems and Control. Sousse, Tunisia, 18th Dec. 2023. URL: https://hal.science/hal-04381790.

[61] D. Torres-García, J.-A. Hernández-Gallardo, C.-f. Méndez-barrios and S.-I. Niculescu. 'Exploring Delay-Based Controllers. A Comparative Study for Stabilizing Angular Positioning'. In: LACAR 2023 - Latin American Congress on Automation and Robotics. San Salvador, El Salvador, 15th Nov. 2023. URL: https://centralesupelec.hal.science/hal-04262544.


#### National peer-reviewed Conferences


[62] C. E. Dórea, S. Olaru and S.-I. Niculescu. 'Delay-Dependent Invariance of Polyhedral Sets for Discrete-Time Linear Systems'. In: *IFAC-PapersOnLine*. 22nd World Congress of the International Federation of Automatic Control (IFAC 2023). Vol. 56. 2. Yokohama, Japan, 2023, pp. 3259–3264. DOI: 10.1016/j.ifacol.2023.10.1466. URL: https://centralesupelec.hal.science/hal-04310993.


#### Conferences without proceedings


[63] L. Cabral, G. Valmorbida and J. M. Gomes da Silva. 'Robust stability analysis of continuous PWA systems'. In: 22nd World Congress of the International Federation of Automatic Control (IFAC 2023). Vol. 56. 2. Yokohama, Japan, 2023, pp. 556–561. DOI: 10.1016/j.ifacol.2023.10.1626. URL: https://hal.science/hal-04363976.

[64] M. Hovd and G. Valmorbida. 'Solving LP-MPC problems using ramp functions*'. In: CCTA 2023 - 7th IEEE Conference on Control Technology and Applications. Bridgetown, Barbados: IEEE, 16th Aug. 2023, pp. 445–450. DOI: 10.1109/CCTA54093.2023.10252720. URL: https://hal.science/hal-04363933.

[65] T. Schmoderer, I. Boussaada, S.-I. Niculescu, F. Bedouhene and A. Remadna. 'On Quasipolynomials Real Roots Coexistence: Effect on Stability of Time-Delay Systems with Perspectives in Partial Pole Placement'. In: 2023 European Control Conference (ECC 2023). Bucharest, Romania, 13th June 2023. URL: https://hal.science/hal-04028886.

[66] D. Torres-García, C. F. Méndez Barrios and S.-I. Niculescu. 'Some Remarks on the Implementation of a Derivative Action via a Delay-Difference Approximation'. In: 2023 European Control Conference (ECC 2023). Bucarest, Romania, 13th June 2023. URL: https://centralesupelec.hal.science/hal-04130834.

[67] C. K. Yuksel, T. Vyhlídal and S.-I. Niculescu. 'A Spectrum-based Filter Design for Periodic Output Regulation of Systems with Dead-Time'. In: 22nd World Congress of the International Federation of Automatic Control (IFAC 2023). Yokohama, Japan, 9th July 2023. DOI: 10.1016/j.ifacol.2023.10.1682. URL: https://hal.science/hal-04071852.

### Scientific book chapters

[68] A. Benarab, I. Boussaada, S.-I. Niculescu and K. Trabelsi. 'On the Spectrum Distribution of Parametric Second-order Delay Differential Equations. Perspectives in Partial Pole Placement'. In: *Control and Inverse ProblemsThe 2022 Spring Workshop in Monastir, Tunisia.* 23rd Oct. 2023. DOI: 10.1007/978-3-031-35675-9_4. URL: https://centralesupelec.hal.science/hal-04213259.

### Doctoral dissertations and habilitation theses

[69] J. Redaud. 'Robust control of linear hyperbolic partial differential equations systems interconnected in a chain'. Université Paris Saclay, 16th Nov. 2023. URL: https://hal.science/tel-04313615.

### Reports & preprints

[70] K. Ammari, I. Boussaada, S.-I. Niculescu and S. Tliba. *Multiplicity manifolds as an opening to prescribe exponential decay : auto-regressive boundary feedback in wave equation stabilization.* 8th May 2023. URL: https://hal.science/hal-04094238.

[71] I. Boussaada, G. Mazanti and S.-I. Niculescu. *Confluent hypergeometric functions reduced to iterated integrals of an exponential kernel.* 26th Jan. 2024. URL: https://hal.science/hal-04420553.

[72] I. Boussaada, G. Mazanti and S.-I. Niculescu. *Over-order Multiplicities and their Application in Controlling Delay Dynamics. On Zeros' Distribution of Linear Combinations of Kummer Hypergeometric Functions.* 31st Oct. 2023. URL: https://hal.science/hal-04266392.

[73] I. Boussaada, G. Mazanti, S.-I. Niculescu and W. Michiels. *Decay Rate Assignment through Multiple Spectral Values in Delay Systems.* 31st Oct. 2023. URL: https://hal.science/hal-04266228.

[74] Y. Chitour, S. Fueyo, G. Mazanti and M. Sigalotti. *Approximate and exact controllability criteria for linear one-dimensional hyperbolic systems.* 4th Oct. 2023. URL: https://inria.hal.science/hal-04228797.

[75] K. Liu and L. Pfeiffer. *A mesh-independent method for second-order potential mean field games.* 3rd Nov. 2023. URL: https://inria.hal.science/hal-04269396.

[76] K. Liu and L. Pfeiffer. *Mean Field Optimization problems: stability results and Lagrangian discretization.* 3rd Nov. 2023. URL: https://inria.hal.science/hal-04269378.

[77] T. Schmoderer and W. Respondek. *Trivialisable control-affine systems revisited.* 2nd Feb. 2023. URL: https://hal.science/hal-03971788.

[78] D. Torres-García, S.-I. Niculescu and C. F. Méndez Barrios. *Delay-Difference Approximations of PD-Controllers. Improperly-posed Systems in Multiple Delays Case.* 2023. URL: https://hal.science/hal-04172009.

## 10.3 Other

### Softwares


[79] [SW] C. Bonnet, G. Mazanti and H. Cavalera, *Yet Another LTI TDS Algorithm (YALTAPy)*, 8th Jan. 2024. LIC: GNU General Public License v3.0 or later. HAL: ⟨hal-04362068⟩, URL: https://hal.science/hal-04362068, VCS: https://gitlab.inria.fr/disco/yaltapy-public, SWHID: ⟨swh:1:dir:5bc875f3c10faa08340df73026e930230581a2f1;origin=https://hal.archives-ouvertes.fr/hal-04362068;visit=swh:1:snp:565b2dfe96de74a9f8801e69743ebc921f66526d;anchor=swh:1:rel:0d90811ca11242387dbb7ae9e7eda29844f57725;path=/⟩.

[80] [SW] C. Bonnet, G. Mazanti and J. Raj, *Yet Another LTI TDS Algorithm — Online (YALTAPy_Online)*, 8th Jan. 2024. LIC: GNU General Public License v3.0 or later. HAL: ⟨hal-04362092⟩, URL: https://hal.science/hal-04362092, VCS: https://gitlab.inria.fr/disco/YALTAPy_Online, SWHID: ⟨swh:1:dir:d14b5ebec4f7d20f4bec3237b41d8c11370d1844;origin=https://hal.archives-ouvertes.fr/hal-04362092;visit=swh:1:snp:a6dc48cc7ce635b464cde61bfe52eee39b3741d5;anchor=swh:1:rel:f61b53729f07136b63bc2b309e43fb168836f21f;path=/⟩.

[81] [SW] I. Boussaada, G. Mazanti, S.-I. Niculescu, J. Huynh, A. Leclerc, M. Perraudin, J. Raj, F. Sim, M. Thomas, Y. Audet, A. Hammoumou and P.-H. Poret, *Partial pole placement via delay action*, 13th Dec. 2023. LIC: GNU General Public License v3.0 or later. HAL: ⟨hal-04342601⟩, URL: https://hal.science/hal-04342601, VCS: https://github.com/ECChew/MIDPython.


## 10.4 Cited publications


[82] S. Amrane, F. Bedouhene, I. Boussaada and S.-I. Niculescu. 'On Qualitative Properties of Low-Degree Quasipolynomials: Further remarks on the spectral abscissa and rightmost-roots assignment'. In: *Bulletin mathématique de la Société des Sciences mathématiques de Roumanie* 61 (2018), pp. 361–381. URL: https://centralesupelec.hal.science/hal-01969066.

[83] J. Auriol and D. Bresch Pietri. 'Robust state-feedback stabilization of an underactuated network of interconnected $n+m$ hyperbolic PDE systems'. In: *Automatica J. IFAC* 136 (2022), Paper No. 110040, 13. DOI: 10.1016/j.automatica.2021.110040. URL: https://doi.org/10.1016/j.automatica.2021.110040.

[84] G. Bastin and J.-M. Coron. *Stability and boundary stabilization of 1-D hyperbolic systems*. Vol. 88. Progress in Nonlinear Differential Equations and their Applications. Subseries in Control. Birkhäuser/Springer, [Cham], 2016, pp. xiv+307. DOI: 10.1007/978-3-319-32062-5. URL: https://doi.org/10.1007/978-3-319-32062-5.

[85] F. Bedouhene, I. Boussaada and S.-I. Niculescu. 'Real spectral values coexistence and their effect on the stability of time-delay systems: Vandermonde matrices and exponential decay'. In: *Comptes Rendus. Mathématique* 358.9-10 (Sept. 2020), pp. 1011–1032. DOI: 10.5802/crmath.112. URL: https://hal.science/hal-02476403.

[86] I. Boussaada and S.-I. Niculescu. 'Characterizing the codimension of zero singularities for time-delay systems: a link with Vandermonde and Birkhoff incidence matrices'. In: *Acta Appl. Math.* 145 (2016), pp. 47–88. DOI: 10.1007/s10440-016-0050-9. URL: https://doi-org.ezproxy.universite-paris-saclay.fr/10.1007/s10440-016-0050-9.

[87] I. Boussaada, H. U. Unal and S.-I. Niculescu. 'Multiplicity and stable varieties of time-delay systems: A missing link'. In: *22nd International Symposium on Mathematical Theory of Networks and Systems (MTNS)*. 2016.

[88] Y. Chitour, G. Mazanti and M. Sigalotti. 'Stability of non-autonomous difference equations with applications to transport and wave propagation on networks'. In: *Netw. Heterog. Media* 11.4 (2016), pp. 563–601. DOI: 10.3934/nhm.2016010. URL: https://doi.org/10.3934/nhm.2016010.

[89] H. Kitano. 'Biological robustness'. In: *Nature* 5 (2004), pp. 826–837.

[90] P. Kokotović, H. K. Khalil and J. O'Reilly. *Singular perturbation methods in control. Analysis and design*. Vol. 25. Classics in Applied Mathematics. Society for Industrial and Applied Mathematics (SIAM), Philadelphia, PA, 1999, pp. xvi+371. DOI: 10.1137/1.9781611971118. URL: https://doi.org/10.1137/1.9781611971118.

[91] H. Ozbay, C. Bonnet and A. Fioravanti. 'PID Controller Design for Fractional-Order Systems with Time Delays'. Anglais. In: *Systems and Control Letters* 61.1 (Jan. 2012), pp. 18–23. URL: http://hal.inria.fr/hal-00766062.

[92] Y. Tang and G. Mazanti. 'Stability analysis of coupled linear ODE-hyperbolic PDE systems with two time scales'. In: *Automatica J. IFAC* 85 (2017), pp. 386–396. DOI: 10.1016/j.automatica.2017.07.052. URL: https://doi.org/10.1016/j.automatica.2017.07.052.

[93] Y. Yamamoto. 'Realization theory of infinite-dimensional linear systems'. PhD Thesis. Florida, United States: University of Florida, 1978. URL: http://ufdcimages.uflib.ufl.edu/UF/00/09/82/85/00001/realizationtheor00yama.pdf.

[94] Y. Yamamoto. 'Realization theory of infinite-dimensional linear systems. I'. In: *Math. Systems Theory* 15.1 (1981), pp. 55–77. DOI: 10.1007/BF01786973. URL: https://doi.org/10.1007/BF01786973.

[95] Y. Yamamoto. 'Realization theory of infinite-dimensional linear systems. II'. In: *Math. Systems Theory* 15.2 (1981), pp. 169–190. DOI: 10.1007/BF01786978. URL: https://doi.org/10.1007/BF01786978.