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Activity Report 2015

Project-Team DISCO

Dynamical Interconnected Systems in COmplex Environments

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

RESEARCH CENTER
Saclay - Île-de-France

THEME
Optimization and control of dynamic systems

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Project-Team DISCO

Creation of the Team: 2010 January 01, updated into Project-Team: 2012 January 01

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Other Research Topics and Application Domains:
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1. Members

Research Scientists
Catherine Bonnet [Team leader, Inria, Senior Researcher, HdR]
Frederic Mazenc [Inria, Researcher, HdR]
Silviu-Iulian Niculescu [CNRS, Senior Researcher, HdR]
Alban Quadrat [Inria, Senior Researcher, until Oct 2015, HdR]

Faculty Members
Sorin Olaru [SUPELEC, HdR]
Guillaume Sandou [SUPELEC, HdR]

Engineer
Hugo Cavalera [Inria, until Nov 2015]

PhD Students
Walid Djema [Inria]
Guillaume Rance [SAGEM, granted by CIFRE]

Post-Doctoral Fellows
Mohamed Yacine Bouzidi [Inria, until Nov 2015]
Hakki Unal [Inria, from Sep 2015]

Visiting Scientists
Andre Fioravanti [UNIV Unicamp, until Jun 2015]
Yutaka Yamamoto [UNIV Kyoto, until Nov 2015]

Administrative Assistant
Maeva Jeannot [Inria]

Other
Xuemin Liu [SUPELEC, internship, from Apr 2015 until Sep 2015]

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. Modeling of complex environment

We want to model phenomena such as a temporary loss of connection (e.g. synchronisation of the movements through haptic interfaces), a nonhomogeneous environment (e.g. case of cryogenic systems) or the presence of the human factor in the control loop (e.g. grid systems) but also problems involved with technological constraints (e.g. range of the sensors). The mathematical models concerned include integro-differential, partial differential equations, algebraic inequalities with the presence of several time scales, whose variables and/or parameters must satisfy certain constraints (for instance, positivity).

3.2. Analysis of interconnected systems

- Algebraic analysis of linear systems

  Study of the structural properties of linear differential time-delay systems and linear infinite-dimensional systems (e.g. invariants, controllability, observability, flatness, reductions, decomposition, decoupling, equivalences) by means of constructive algebra, module theory, homological algebra, algebraic analysis and symbolic computation [8], [9], [79], [94], [80], [81].
- Robust stability of linear systems

  Within an interconnection context, lots of phenomena are modelled directly or after an approximation by delay systems. These systems might have fixed 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_∞-stability, BIBO-stablity, robust stability, robustness metrics) [1], [2], [5], [6], 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 [5], [6].

- 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 designing 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. [90]). 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 develpment of new robustness metrics in this biological context.

3.3. 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_∞-control since this parametrization allows one to rewrite the problem of finding the optimal stabilizing controllers for a certain norm such as H_∞ 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 [1], [2], [8], [9].

  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) [9]. Moreover, we investigate strongly stabilizable systems [9], 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

  The project aims at developing robust stabilization theory and methods for important classes of nonlinear systems that ensure good controllerperformance under uncertainty and time delays. The main techniques include techniques called backstepping and forwarding, contructions of strict Lyapunov functions through so-called "strictification" approaches [3] and construction of Lyapunov-Krasovskii functionals [4], [5], [6].

- Predictive control

  For highly complex systems described in the time-domain and which are submitted to constraints, predictive control seems to be well-adapted. This model based control method (MPC: Model Predictive Control) is founded on the determination of an optimal control sequence over a receding horizon. Due to its formulation in the time-domain, it is an effective tool for handling constraints and uncertainties which can be explicitly taken into account in the synthesis procedure [7]. The team considers how mutiparametric optimization can help to reduce the computational load of this method, allowing its effective use on real world constrained problems.

  The team also investigates stochastic optimization methods such as genetic algorithm, particle swarm optimization or ant colony [10] as they can be used to optimize any criterion and constraint whatever their mathematical structure is. The developed methodologies can be used by non specialists.

3.4. 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], [93].

- Predictive control

  The synthesis of predictive control laws is concerned with the solution of multiparametric optimization problems. Reduced order controller constraints can be viewed as non convex constraints in the synthesis procedure. Such constraints can be taken into account with stochastic algorithms.

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. Control of engineering systems

The team considers control problems in the aeronautic area and studies delay effects in automatic visual tracking on mobile carriers in collaboration with SAGEM.

4.2. Analysis and Control of life sciences systems

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

4.3. Energy Management

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

5. Highlights of the Year

5.1. Highlights of the Year

Dec. 2015 - Frédéric Mazenc is President of the "Commission Scientifique" Inria Saclay-Ile-de-France.

6. New Software and Platforms

6.1. OreAlgebraicAnalysis

FUNCTIONAL DESCRIPTION

OreAlgebraicAnalysis is a Mathematica implementation of algorithms available in the OreModules and the OreMorphisms packages (developed in Maple). OreAlgebraicAnalysis is based on the implementation of Grobner bases over Ore algebras available in the Mathematica HolonomicFunctions package developed by Christoph Koutschan (RICAM). OreAlgebraicAnalysis can handle larger classes of Ore algebras than the ones accessible in Maple, and thus we can study larger classes of linear functional systems. Finally, Mathematica internal design allows us to consider classes of systems which could not easily be considered in Maple such as generic linearizations of nonlinear functional systems defined by explicit nonlinear equations and systems containing transcendental functions (e.g., trigonometric functions, special functions). This package has been developed within the PHC Parrot project CASCAC.

- Participants: Alban Quadrat and Thomas Cluzeau
- Contact: Alban Quadrat
- URL: http://pages.saclay.inria.fr/alban.quadrat/OreAlgebraicAnalysis/index.html

6.2. OreModules

FUNCTIONAL DESCRIPTION

The OreModules package, based on the commercial Maple package Ore-algebra, is dedicated to the study of linear multidimensional systems defined over certain Ore algebras of functional operators (e.g., ordinary or partial differential systems, time-delay systems, discrete systems) and their applications in mathematical systems theory, control theory and mathematical physics.

- Participants: Frédéric Chyzak and Alban Quadrat
- Contact: Alban Quadrat
- URL: http://wwwb.math.rwth-aachen.de/OreModules/

6.3. OreMorphisms

FUNCTIONAL DESCRIPTION

The OreMorphisms package of OreModules is dedicated to the implementation of homological algebraic tools such as the computations of homomorphisms between two finitely presented modules over certain noncommutative polynomial algebras (Ore algebras), of kernel, coimage, image and cokernel of homomorphisms, Galois transformations of linear multidimensional systems and idempotents of endomorphism rings. Using the packages Stafford and Quillen-Suslin , the factorization, reduction and decomposition problems can be constructively studied for different classes of linear multidimensional systems. Many linear systems studied in engineering sciences, mathematical physics and control theory have been factorized, reduced and decomposed by means of the OreMorphisms package.

- Participants: Alban Quadrat and Thomas Cluzeau
- Contact: Alban Quadrat
- URL: http://pages.saclay.inria.fr/alban.quadrat/OreMorphisms/index.html

6.4. PurityFiltration

FUNCTIONAL DESCRIPTION

The PurityFiltration package, built upon the OreModules package, is an implementation of a new effective algorithm which computes the purity/grade filtration of linear functional systems (e.g., partial differential systems, differential time-delay systems, difference systems) and equivalent block-triangular matrices. This package is used to compute closed form solutions of over/underdetermined linear partial differential systems which cannot be integrated by the standard computer algebra systems such as Maple and Mathematica.

- Contact: Alban Quadrat
- URL: http://pages.saclay.inria.fr/alban.quadrat/OreAlgebraicAnalysis/index.html

6.5. QuillenSuslin

FUNCTIONAL DESCRIPTION

QuillenSuslin is a Maple implementation of a constructive version of the Quillen-Suslin Theorem. It provides an algorithm which computes a basis of a free module over a polynomial ring. In terms of matrices, this algorithm completes a unimodular rectangular matrix (e.g. a unimodular row) to an invertible matrix over the given polynomial ring with rational or integer coefficients. The package was also extended with Park's Algorithm to deal with unimodular rows over Laurent polynomial rings and with heuristic methods for localizations of polynomial rings.

- Participants: Alban Quadrat and Anna Fabiańska
- Contact: Alban Quadrat
- URL: http://wwwb.math.rwth-aachen.de/QuillenSuslin/

6.6. Stafford

FUNCTIONAL DESCRIPTION

The Stafford package of OreModules contains an implementation of two constructive versions of Stafford's famous but difficult theorem [96] stating that every ideal over the Weyl algebra An(k) (resp., Bn(k)) of partial differential operators with polynomial (resp., rational) coefficients over a field k of characteristic 0 (e.g., k=Q,R) can be generated by two generators. Based on this implementation and algorithmic results developed by the authors of the package, two algorithms which compute bases of free modules over the Weyl algebras An(Q) and Bn(Q) have been implemented. The rest of Stafford's results developed in [96] have recently been made constructive (e.g., computation of unimodular elements, decomposition of modules, Serre's splitting-off theorem, Stafford's reduction, Bass' cancellation theorem, minimal number of generators) and implemented in the Stafford package. The development of the Stafford package was motivated by applications to linear systems of partial differential equations with polynomial or rational coefficients (e.g., computation of injective parametrization, Monge problem, differential flatness, the reduction and decomposition problems and Serre's reduction problem). To our knowledge, the Stafford package is the only implementation of Stafford's theorems nowadays available.

- Participants: Alban Quadrat and Daniel Robertz
- Contact: Alban Quadrat
- URL: http://wwwb.math.rwth-aachen.de/OreModules/index_sub.html

6.7. YALTA

FUNCTIONAL DESCRIPTION

The YALTA toolbox is a Matlab 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. The corresponding algorithms are based on recent theoretical results and on classical continuation methods exploiting the particularities of the problem.

- Participants: Hugo Cavalera, Catherine Bonnet, Andre Fioravanti, Le Ha Vy Nguyen, Jim Pioche
- Contact: Catherine Bonnet
- URL: http://yalta-toolbox.gforge.inria.fr/

The YALTA toolbox is a Matlab 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. The corresponding algorithms are based on recent theoretical results (see, for instance, [78] and [85]) and on classical continuation methods exploiting the particularities of the problem [86], [87].

For classical delay systems, a Pade2 approximation scheme is available as well as a finite-dimensional approximation of the system.

Binaries are freely available at http://yalta-toolbox.gforge.inria.fr/.

The YALTA GUI (graphical user interface) is a graphical application developed in Python that interacts with the Matlab toolbox YALTA. User actions are performed through intuitive graphic elements (dialog boxes, icons, menus, scroll bars) in order to capitalize on the functionalities of YALTA. This software, still in development, is based on PyQt, a Python binding of the cross-platform GUI toolkit Qt (C++).

Recently, some features have been added. YALTA toolbox and YALTA GUI have been designed to support multi-languages settings (English and French languages currently available). Parallely, the implementation of the Pade2 approximation scheme has been improved. Finally, continuous integration processes and tools such as Jenkins Hudson have been configured and managed to ensure long-term software quality.

7. New Results

7.1. Algebraic Analysis Approach to Linear Functional Systems

Participants: Alban Quadrat [Disco], Rosane Ushirobira [Non-A].

7.1.1. Artstein's transformation of linear time-delay systems

Artstein's classical results show that a linear first-order differential time-delay system with delays in the input is equivalent to a linear first-order differential system without delays thanks to an invertible transform which includes integral and delay operators. Within a constructive algebraic approach, we show how Artstein's reduction can be found again and generalized as a particular isomorphism problem between the finitely presented modules defined by the two above linear systems over the ring of integro-differential time-delay operators. Moreover, we show that Artstein's reduction can be obtained in an automatic way by means of symbolic computation, and thus can be implemented in computer algebra systems.

7.1.2. Algebraic analysis for the Ore extension ring of differential time-varying delay operators

No algebraic (polynomial) approach seems to exist for the study of linear differential time-delay systems in the case of a (sufficiently regular) time-varying delay. Based on the concept of skew polynomial rings developed by Ore in the 30s, we construct the ring of differential time-delay operators as an Ore extension and to analyze its properties. A characterization of classical algebraic properties of this ring, such as noetherianity, its homological and Krull dimensions and the existence of Gröbner bases, are given in terms of the time-varying delay function. The algebraic analysis approach to linear systems theory allows us to study linear differential time-varying delay systems (e.g. existence of autonomous elements, controllability, parametrizability, flatness, behavioral approach) through methods coming from module theory, homological algebra and constructive algebra.

7.2. New Techniques for Robust Control of Linear Infinite-Dimensional Systems

Participants: Yacine Bouzidi [Disco], Petteri Laakkonen [Univ. Tampere], Adrien Poteaux [Lille 1], Alban Quadrat [Disco], Arnaud Quadrat [SAGEM], Guillaume Rance [SAGEM], Fabrice Rouillier [Ouragan].

7.2.1. Computer algebra methods for testing the structural stability of multidimensional systems

We present new computer algebra based methods for testing the structural stability of n-D discrete linear systems (with $n \geq 2$). More precisely, starting from the usual stability conditions which resumes to deciding if an hypersurface has points in the unit polydisc, we show that the problem is equivalent to deciding if an algebraic set has real points and use state-of-the-art algorithms for this purpose. Our strategy has been implemented in `Maple` and its relevance demonstrated through numerous experimentations.

Moreover, we also consider the specific case of two-dimensional systems and focus on the practical efficiency aspect. For such systems, the problem of testing the stability is reduced to that of deciding if a bivariate algebraic system with finitely many solutions has real ones. Our first contribution is an algorithm that answers this question while achieving practical efficiency. Our second contribution concerns the stability of two dimensional systems with parameters. More precisely, given a two-dimensional system depending on a set of parameters, we present a new algorithm that computes regions of the parameters space in which the considered system is structurally stable.

7.2.2. *Computer algebra methods for the stability analysis of differential systems with commensurate time-delays*

Within the frequency-domain approach, the asymptotic stability of of linear differential systems with commensurate delays is ensured by the condition that all the roots of the corresponding quasipolynomial have negative real parts. A classical approach for checking this condition consists in computing the set of critical zeros of the quasipolynomial, i.e., the roots (and the corresponding delays) of the quasipolynomial that lie on the imaginary axis, and then analyzing the variation of these roots with respect to the variation of the delay. Based on solving algebraic systems techniques, we propose a certified and efficient symbolic-numeric algorithm for computing the set of critical roots of a quasipolynomial. Moreover, using recent algorithmic results developed by the computer algebra community, we present an efficient algorithm for the computation of Puiseux series at a critical zero which allows us to finely analyze the stability of the system with respect to the variation of the delay

7.2.3. *A fractional ideal approach to the robust regulation problem*

We show how fractional ideal techniques developed in [8] can be used to obtain a general formulation of the internal model principle for stabilizable infinite-dimensional SISO plants which do not necessarily admit coprime factorization. This result is then used to obtain necessary and sufficient conditions for the robust regulation problem. In particular, we find again all the standard results obtained in the literature.

7.2.4. *Robust control as an application to the homological perturbation lemma:*

Within the lattice approach to transfer matrices developed in [8], we have recently shown how standard results on robust control can be obtained in a unified way and generalized when interpreted as a particular case of the so-called Homological Perturbation Lemma. This lemma plays a significant role in algebraic topology, homological algebra, algebraic and differential geometry, computer algebra .... Our results show that it is also central to robust control theory for infinite-dimensional linear systems.

7.2.5. *A symbolic-numeric method for the parametric H_∞ loop-shaping design problem*

We develop a symbolic-numeric method for solving the H_∞ loop-shaping design problem for a low order single-input single-output system with parameters. Due to the system parameters, no purely numerical algorithm can indeed solve the problem. Using Gröbner basis techniques and the rational univariate representation of zero-dimensional algebraic varieties, we first give a parametrization of all the solutions of the two algebraic Riccati equations associated with the H_∞ control problem. Then, using results on the spectral factorization problem, a certified symbolic-numeric algorithm is obtained for the computations of the positive definite solutions of these two algebraic Riccati equations. Finally, we present a certified symbolic-numeric algorithm which solves the H_∞ loop-shaping design problem for the above class of systems.

7.3. Improved algorithm for computing separating linear forms for bivariate systems

Participants: Yacine Bouzidi [Disco], Sylvain Lazard [Vegas], Guillaume Moroz [Vegas], Marc Pouget [Vegas], Fabrice Rouillier [Ouragan].

We present new algorithms for computing linear separating forms, RUR decompositions and isolating boxes of the solutions. We show that these three algorithms have worst-case bit complexity $\widetilde{O}_B(d^6 + d^5\tau)$, where $\widetilde{O}$ refers to the complexity where polylogarithmic factors are omitted and O_B refers to the bit complexity. We also present probabilistic Las-Vegas variants of our two first algorithms, which have expected bit complecity $\widetilde{O}_B(d^5 + d^4\tau)$. A key ingredient of our proofs of complexity is an amortized analysis of the triangular decomposition algorithm via subresultants, which is of independent interest.

7.4. Stable H_∞ Controller for Infinite-dimensional systems

The controllers, besides the stabilization, are often designed to achieve some performance and robustness objectives by minimizing H_∞ norm of some cost functions. The resulting controller may be stable or unstable. The unstable controllers, however, are more sensitive to sensor/actuator faults, or nonlinearities. It is not an easy task to design a stable controller for systems having infinitely many zeros and poles in the right-half-plane. By using the similar idea in [88], stable H_∞ controller design method will be presented for a certain class of infinite-dimensional plants. The plants may have infinitely many unstable zeros, however, it is assumed that these zeros are *unformly separated*. Under some certain assumptions, first, a sufficient condition will be presented to construct a real unit function, which satisfies certain interpolation conditions at the right-half-plane zeros of the plant and some H_∞ norm constraints. Then, by utilizing this result, stable H_∞ controller design method are presented.

7.5. Multiplicity and Stable Varieties of Time-delay Systems: A Missing Link

Multiple spectral values in dynamical systems are often at the origin of complex behaviors as well as unstable solutions. In this work, an unexpected property of multiple spectral values is emphasized. It has been shown that the variety corresponding to such a multiple root defines a stable variety for the steady state. Under mild assumptions, for the reduced examples we show that such a multiple spectral value is nothing else than the spectral abscissa.

7.6. Delay effect in chemical reactions

Belousov-Zhabotinskii (BZ) reaction, which is a very complicated reaction, has been widely studied in bio-science and chemistry, since its dynamic behaviour is similar to real biological oscillators [89]. For certain type of chemical reactions, the use of the law of mass-action kinetics may lead to some simple models expressed by ordinary differential equations. The main feature of BZ reaction, oscillatory behaviour, has been represented by a simple mechanism and the model of this mechanism can be described by ordinary differential equations. However, delayed mass-actions kinetics lead to more accurate models by conserving the simplicity and a relative reduced number of parameters. In [83], [95], [96], [82], some delay-differential models are proposed for Belousov-Zhabotinskii (BZ) reaction with a fewer of concentrations compared to the models obtained by ordinary differential equations. However, in most of these works, the delay, which occurs due to the required time to provide sufficient energy, has not been taken into account. Recently, we consider a more realistic Belousov-Zhabotinskii model, which includes two independent delays. The novelty of the proposed model with respect to the existing ones in the literature can be summarized as follows; one of these delays is introduced to reproduce qualitatively the behavior of the model proposed by [84] with a less number of concentrations as in [95]. Second, the remaining delay appears naturally since the reactants do not react suddenly in the chemical reactions, i.e. the delay stems from the needed time for the occurence of reaction, called “delayed concentration”.

7.7. H_∞-stability analysis of neutral systems with commensurate delays

Participants: Catherine Bonnet, Le Ha Vy Nguyen.

We have analyzed [32] the H_∞-stability of neutral systems with commensurate delays and multiple chains of poles asymptotic to a same set of points on the imaginary axis. First, by approximation, the location of poles of large modulus is determined. This analysis requires to consider several subclasses of systems where poles of high modulus exhibit various patterns. Second, we derive necessary and sufficient conditions for H_∞-stability which are easy to check as expressed in terms of the degrees of the polynomials involved in the numerator and denominator of the transfer function.

7.8. H_∞-Stabilization of neutral delay systems

Participants: Catherine Bonnet, Yutaka Yamamoto [Kyoto University].

We have considered two particular neutral delay systems with one delay having a chain of poles clustering the imaginary axis from left or right. For these systems the existence of coprime factorizations have been investigated. The extension to more general systems is still in progress.

7.9. Interval Observer of a new type

Participants: Frederic Mazenc [Disco], Emilia Fridman [Tel-Aviv University].

In [19], we addressed the fundamental problem of constructing for nonlinear systems observers that converge in finite time and, at the same time, provided with upper and lower bounds for the solutions when disturbances are present. This new technique of estimation relies on the use of past values of the output, as done to construct some already known observers which converge in finite time, and on a recent technical result pertaining to the theory of the monotone systems The result applies to systems with additive disturbances and disturbances in the output. The nonlinear terms are not supposed to be globally Lipschitz, but it is requested that they depend only on the input and output variables. The fundamental advantage over classical interval observer techniques is that no information on the initial conditions of the solutions of the studied system are needed.

7.10. Trajectory based approach

Participants: Frederic Mazenc [Disco], Silviu Niculescu [Disco], Michael Malisoff [LSU].

In the work [22], we provided a new stability analysis technique, which is based on the study of the behaviors of the solutions over any interval $[t-T, T]$, where t represents the time and T is an appropriately chosen constant. Thus trajectory-based approach is completely new in the sense that it neither reply on Lyapunov functions nor on the small gain theorem. One of its most striking feature is that it applies to a broad number of systems (systems with delay, continuous/discrete systems, ODE coupled with difference equations).

In [30] and [55] we provided several significant applications of the main result of [22]. In [30] in two results, we use a Lyapunov function for a corresponding undelayed system to provide a new method to prove stability of linear continuous-time time-varying systems with bounded time-varying delays. We allow uncertainties in the coefficient matrices of the systems. Our main results use upper bounds on an integral average involving the delay. The results establish input-to-state stability with respect to disturbances. We also provided in [55] a novel reduction model approach that ensures global exponential stabilization of linear systems with a time-varying pointwise delay in the input, which allows the delay to be discontinuous and uncertain. Finally, we provided an alternative to the reduction model method, based on a different dynamic extension.

7.11. Positive Systems Approach

Participants: Frederic Mazenc [Disco], Michael Malisoff [LSU].

We presented new methods to prove stability of time-varying systems with delays by taking advantage of the theory of the positive and cooperative systems [24], [23]. We used linear time-varying Lyapunov functionals, operators with integral terms, and positive systems, and we provided robustness of the stability with respect to multiplicative uncertainty in the vector fields. We allowed cases where the delay may be unknown, and where the vector fields defining the systems are not necessarily bounded. The results apply to neutral time-varying systems but are very distinct from those of the paper [69].

7.12. Attitude dynamics, control and observation

Participants: Frederic Mazenc [Disco], Maruthi Akella [Univ of Texas], Divya Thakur [Univ of Texas], Sunpil Yang [Univ of Texas].

We addressed several problems pertaining to the control of fully actuated rigid-body attitude dynamics. The fundamental tool we used is the adaptation of the so called strictification approach to the features of the attitude dynamics (see [3] for an introduction to the 'strictifiation' paradigm). In particular

1) The contribution [31] output feedback stabilization of fully actuated rigid-body attitude dynamics in the presence of unknown point-wise time-delay in the input torque. Specifically, rate-gyros are unavailable here and only the attitude state represented by the unit quaternion is assumed to be measured. It is worth mentioning that the presence of unknown time-delay in the measured variables, imposes formidable technical challenges for the output-feedback attitude stabilization problem on hand. One of the central difficulties stems from the availability of only a weak Lyapunov-like function for the passivity based dynamic output feedback controller in the absence of delay. This obstacle is circumvented in this contribution by a novel process of partially strictifying the underlying weak Lyapunov-like function.

2) In [57], we considered stabilization of fully actuated rigid-body attitude dynamics in the absence of angular velocity measurements and presents new robustness results to bounded unknown external disturbance torques. In particular, it is assumed that only body orientation is measured in the form of a unit-quaternion signal. It is well known that the passivity properties of the dynamics allows design of velocity-free controllers using a first-order stable filter driven by measured states. When external disturbance torques are taken into account, however, the robustness properties of these passivity-based output feedback controllers cannot be readily analyzed because the Lyapunov-like function from which the controller is derived has a time-derivative that is only negative semidefinite, and therefore non-strict. This obstacle is circumvented through a new partial-strictification approach which ultimately allows the characterization of robustness properties for this closed-loop system.

3) In [18], we proposed a smooth angular velocity observer for the attitude tracking control of a rigid body in the absence of angular velocity measurements. The observer design ensures asymptotic convergence of angular velocity state estimation errors irrespective of the control torque or the initial attitude state of the spacecraft. Unlike existing rate observer formulations that attain estimation error convergence by imposing certain switching conditions or hybrid-logic, the proposed observer has a smooth structure that ensures continuity of all estimated states.Lyaounov strictification is again the key technical result making us to establish the results.

7.13. Introduction of artificial delays for control and observation

Participants: Frederic Mazenc [Disco], Silviu Niculescu [Disco], Michael Malisoff [LSU], Nikolaos Bekiaris-Liberis [Tech. Univ. of Crete].

It is well-known that, in some cases, control or observation problems for systems with or without inherent delay can be solved by artificially introducing delays. We obtained in this field of reseach two distinct new results.

1) In [56] and [54], we have considered a family of linear time-varying systems with an input, an output and delays in the input. We have shown that, under classical stabilizability and detectability assumptions, all the systems of this family can be exponentially stabilized through a time-varying feedback depending on past values of the output and the input and this without the use of observers or dynamic extensions. Hence, the simplicity of the design and the determination of the value of the solutions in finite time are the main features of the new approach.

2) In [54], we provided a new backstepping result for time-varying systems with input delays. The novelty of the contribution is in the bounds on the controls, and the facts that (i) one does not need to compute any Lie derivatives to apply our controls, (ii) the controls have no distributed terms, and (iii) no differentiability conditions on the available controls for the subsystems are needed. The result is obtained by the introduction

of constant pointwise delay in the input. Thus this result is significantly different for backstepping results for systems with delay in the input as presented for instance in [70].

7.14. Continuous-discrete observers

Participants: Frederic Mazenc [Disco], Emilia Fridman [Tel-Aviv University], Michael Malisoff [LSU], Vincent Andrieu [LAGEP].

We solved several problems of observer design pertaining to the fundamental and difficult case where the measurements are available at discrete instants only.

1) We considered the problem of stabilizing a linear continuous-time system with discrete-time measurements and a sampled input with a pointwise constant delay [20]. In a first part, we designed a continuous-discrete observer which converges when the maximum time interval between two consecutive measurements is sufficiently small. In a second part, we constructed a dynamic output feedback by using a technique which is strongly reminiscent of the reduction model approach. It stabilizes the system when the maximal time between two consecutive sampling instants is sufficiently small. No limitation on the size of the delay is imposed and an ISS property with respect to additive disturbances is established.

2) The problem of designing continuous-discrete observers for a large class of continuous time nonlinear time-varying systems with discrete time measurements has been addressed in several contributions: [12], [17] and [53]. Some technical obstacle encountered in [12] were overcome in [17] by using the notion of cooperative systems, which led to results consisting in explicit expressions of the largest sampling interval under which the observers converge to the solutions of the original system

7.15. Sensor faults: detectability and distributed Fault Diagnosis. A positive invariance based approach.

Participants: Sorin Olaru [correspondent], Vasso Reppa [L2S], Abid Kodakkadan [L2S], Marios Polycarpou [University of Cyprus].

The paper [62] introduces the performance analysis of local monitoring modules of a distributed diagnosis scheme tailored to detect multiple sensor faults in a class of nonlinear systems. The local modules monitor the healthy operation of subsets of sensors (local sensor sets). Every module is designed to detect the occurrence of faults in the local sensor sets when some analytical redundancy relations (ARRs) are violated. The set of ARRs is formulated using structured residuals and adaptive thresholds based on a nonlinear observer. In order to characterize the sensitivity of every monitoring module to local sensor faults, we obtain structural fault detectability conditions based on adaptive thresholds, and strong fault detectability conditions based on ultimate robust positively invariant sets. These conditions correspond to explicit relationships between the local sensor faults, the worst-case bounds on modeling uncertainties and the design parameters of the local monitoring module.

In a recent paper [44], we considered the abnormal functioning of sensors (measurement channels) deployed for monitoring and control of discrete linear time invariant systems affected by additive uncertainties. The main objective was to analyze the sensor fault detectability via a robust positive invariance based technique. The analysis relies on the categorization of detectable faults and leads to certain conditions for guaranteed nondetectability, guaranteed detectability and implicit detectability.

As a support to this line of research, in the paper [73] we presented a methodology for computing robust positively invariant sets for linear, discrete time-invariant systems that are affected by additive disturbances, with the particularity that these disturbances are subject to state-dependent bounds. The proposed methodology requires less restrictive assumptions compared to similar established techniques, while it provides the framework for determining the state-dependent (parameterized) ultimate bounds for several classes of disturbances. The added value of the proposed approach is illustrated by an optimization-based problem for detecting the mode of functioning of a switching system.

7.16. Fault tolerant control design for multi-sensor networked control systems

Participants: Sorin Olaru [correspondent], Nikola Stankovic [L2S], Silviu Niculescu [L2S], Florin Stoican [Univ. Politehnica, Bucharest].

In the paper [27], we consider a multi-sensor networked control configuration with linear plant which is affected by a bounded additive disturbance. Shared network is used for the communication between sensors and controller. It is assumed that the sensors are prone to abrupt faults, while the controller's input may be updated with a varying time-delay. In order to identify and isolate the sensor(s) providing faulty information, we equip the controller with a set-based detection and isolation routine. Furthermore, in the case when the network induces time-delays, control is performed based on the knowledge we have on the mathematical model of the plant. In the presence of model inaccuracies or disturbance, such a control action may not guarantee satisfying performance of the system. Therefore, a stabilising controller with delay compensation has been designed.

7.17. Constrained Control of Uncertain, Time-varying Linear Discrete-Time Systems Subject to Bounded Disturbances

Participants: Sorin Olaru [correspondent], Nam Nguyen [Technion, Israel], Per-Olof Gutman [Technion, Israel], Morten Hovd [NTNU, Trondheim, Norway].

In the paper [26], robust invariance for ellipsoidal sets with respect to uncertain and/or time-varying linear discrete-time systems with bounded additive disturbances is revisited. We provide an extension of an existing invariance condition and propose a novel robust interpolation based control design involving several local unconstrained robust optimal controls. It is shown that at each time instant a quadratic programming problem is solved on-line for the implementation. Proofs of recursive feasibility and input-to-state stability are provided to support the theoretical foundation.

7.18. Explicit robust constrained control for linear systems : analysis, implementation and design based on optimization

Participants: Sorin Olaru [correspondent], Ngoc Anh Nguyen [L2S], Pedro Rodriguez Ayerbe [L2S], Martin Gulan [STUBA, Bratislava].

Piecewise affine (PWA) feedback control laws is relevant for the control of constrained systems, hybrid systems; equally for the approximation of nonlinear control. However, they are associated with serious implementation issues. Motivated from the interest in this class of particular controllers, the thesis of Ngoc Anh Nguyen is mostly related to their analysis and design. The first part of this thesis aims to compute the robustness and fragility margins for a given PWA control law and a linear discrete-time system. More precisely, the robustness margin was defined as the set of linear time-varying systems such that the given PWA control law keeps the trajectories inside a given feasible set. On a different perspective, the fragility margin contains all the admissible variations of the control law coefficients such that the positive invariance of the given feasible set is still guaranteed. The second part of this thesis focuses on inverse optimality problem for the class of PWA controllers. Namely, the goal is to construct an optimization problem whose optimal solution is equivalent to the given PWA function. The methodologyis based on convex lifting [33]: an auxiliary 1-dimensional variable which enhances the convexity characterization into recovered optimization problem. Accordingly, if the given PWA function is continuous [35], the optimal solution to this reconstructed optimization problem will be shown to be unique. Otherwise, if the continuity of this given PWA function is not fulfilled, this function will be shown to be one optimal solution to the recovered problem [36]. In view of applications in linear model predictive control (MPC), it was shown that any continuous PWA control law can be obtained by a linear MPC problem with the prediction horizon at most equal to 2 prediction steps [65]. Aside from the theoretical meaning, this result can also be of help to facilitate implementation of PWA control laws by avoiding storing state space partition [66]. Another utility of convex liftings [34] will be shown in the last part of this thesis to be a control Lyapunov function. Accordingly, this convex lifting will be deployed in the so-called robust control design based on convex liftings for linear system affected by bounded additive disturbances and polytopic uncertainties [60]. Both implicit and explicit controllers can be obtained. This method can also guarantee the recursive feasibility and robust stability. However, this control Lyapunov function is only defined over the maximal λ-contractive set for a given subunitary λ which is known to be smaller than the maximal controllable set. Therefore, an extension of the above method to the N-steps controllable set will be presented. This method is based on a cascade of convex liftings where an auxiliary variable will be used to emulate a Lyapunov function. Namely, this variable will be shown to be non-negative, to strictly decrease for N first steps and to stay at 0 afterwards. Accordingly, robust stability is sought.

7.19. Predictive Control for multi-agent (multi-vehicle) systems

Participants: Sorin Olaru [correspondent], Ionela Prodan [LCIS], Minh Tri Nguyen [L2S], Cristina Stoica [L2S], Silviu Niculescu [L2S], Fernando Fontes [FEUP U. Porto], Joao Sousa [FEUP U. Porto], Fernando Lobo Pereira [FEUP U. Porto], Alexandra Grancharova [U. Sofia, Bulgaria].

We continued a mature line of research on the tracking problems for multi-agent systems. In [75] we presented a series of developments on predictive control for path following via a priori generated trajectory for autonomous aerial vehicles. The strategy partitions itself into offline and runtime procedures with the assumed goal of moving the computationally expensive part into the offline phase and of leaving only tracking decisions to the runtime. First, it will be recalled that differential flatness represents a well-suited tool for generating feasible reference trajectory. Next, an optimization-based control problem which minimizes the tracking error for the nonholonomic system is formulated and further enhanced via path following mechanisms. Finally, possible changes of the selection of sampling times along the path and their impact on the predictive control formulation will be discussed in detail.

On a relatively different frameowrk, in [71] we investigate multiple agents evolving in the same environment with the objective of preservation of a predefined formation. This formation aims to reinforce the safety of the global system and further lighten the supervision task. One of the major issues for this objective is the task assignment problem, which can be formulated in terms of an optimization problem by employing set-theoretic methods. In real time the agents will be steered into the defined formation via task (re)allocation and classical feedback mechanisms. The task assignment calculation is often performed in an offline design stage, without considering the possible variation of the number of agents in the global system. These changes (i.e., including/excluding an agent from a formation) can be regarded as a typical fault, due to some serious damages on the components or due to the operator decision. In this context, our work proposes a new algorithm for the dynamical task assignment formulation of multi-agent systems in view of real-time optimization by including fault detection and isolation capabilities. This algorithm allows to detect whether there is a fault in the global multi-agent system, to isolate the faulty agent and to integrate a recovered/healthy agent. The proposed methods will be illustrated by means of a numerical example with connections to multi-vehicle systems.

7.20. Invariant sets for time-delay systems

Participants: Sorin Olaru [correspondent], Mohammed Laraba [L2S], Silviu Niculescu [L2S].

The characterization of invaraint sets for dynamical systems affected by time-delays is a long standing research topic in our group and this year new results have been obtained [52], [51] towards construction of invariant sets in the original state space (also called D-invariant sets) by exploiting the forward mappings. As novelties, the present paper contains a sufficient condition for the existence of ellipsoidal D-contractive sets for dDDEs, and a necessary and sufficient condition for the existence of D-invariant sets in relation to time-varying dDDE stability. Another contribution is the clarification of the relationship between convexity (convex hull operation) and D-invariance. In short, this shown that the convex hull of two D-invariant sets is not D-invariant but the convex hull of a non-convex D-invariant set is D-invariant.

7.21. Biochemical system modelized through a PDE

Participants: Frédéric Mazenc, Abdou Dramé [City Univ. of New York], Peter Wolenski [LSU].

We studied a model of chemostat relying on a Partial Differential Equation. More precisely, we studied in [13] the stability of periodic solutions of distributed parameters biochemical system with periodic input $S_{in}(t)$ (which respresent the substrate input concentration). We established that if the function $S_{in}(t)$ is periodic then the system has a periodic solution that possess the robust stability property called input to state stability and this when sufficiently small perturbations are acting on $S_{in}(t)$.

7.22. Modelling of cell dynamics in Acute Myeloid Leukemia

Participants: Catherine Bonnet, Jean Clairambault [BANG project-team], François Delhommeau [INSERM Paris (Team18 of UMR 872) Cordeliers Research Centre and St. Antoine Hospital, Paris], Walid Djema, Emilia Fridman [Tel-Aviv University], Pierre Hirsch [INSERM Paris (Team18 of UMR 872) Cordeliers Research Centre and St. Antoine Hospital, Paris], Frédéric Mazenc.

Modelling of Acute Myeloid Leukemia strated a few years ago. Starting from a PDE model of hematopoiesis given in [77], we have derived several models of healthy or cancer cell dynamics in hematopoiesis which according to some conditions admit one or two equilibrium points. Often taking profit of the positivity of the system we have derived this year several sufficient (or necessary and sufficient) conditions which ensure stability properties ranging from local symptotic stability to global exponential stability and obtained, when appropriate, an estimation of a subset of the bassin of attraction [14], [40].

7.23. Observability analysis of AC electric machines

Participants: Mohamad Koteich [CentraleSupelec, L2S, Renault], Guillaume Sandou [correspondent], Gilles Duc [CentraleSupelec, L2S], Abdelmalek Maloum [Renault].

High-performance control of electric drives requires an accurate knowledge of the rotor position and/or speed. These mechanical variables are traditionally measured using sensors, which increases the cost and reduces both the robustness and the reliability of the system. This emphasizes the importance of electric drives control without shaft sensors, often referred to as sensorless control : it consists of replacing sensors with a state observer algorithm, that estimates the desired mechanical variables from currents and voltages sensing and based on the system's model. Nevertheless, before designing a state observer, the observability of the system should be examined, that is, it should be checked whether the states to be estimated can be reconstructed, unambiguously, from the input/output signals of the system.

This work addresses the modeling and the observability analysis of electric drives in the view of mechanical sensors removal. Firstly, electrical machines models are elaborated, and it is shown that a unified modeling of alternating current machines is feasible, for the purpose of designing unified control and estimation strategies. The observability of the machines' models is next studied in the view of sensorless control. The local instantaneous observability theory is applied, which enables us to formulate physically insightful analytic conditions that can be easily interpreted and tested in real time. The validity of the observability conditions is confirmed by numerical simulations and experimental data, using an extended Kalman observer. This work contributes to novel outlooks on the sensorless alternating current drives and to a deeper understanding of its properties, in order to develop higher performance estimation techniques in the critical operating conditions (mainly at standstill and/or zerostator-frequency). The concepts introduced throughout this work, such as the equivalent flux and the observability vector, with the obtained results, open new horizons in a domain that seems to become mature enough [48], [76], [46], [49], [45], [15], [16], [91], [92], [47].

7.24. Optimization of Line of Sight controller based on high-level optronic criterion

Participants: Sophie Frasnedo [CentraleSupelec, L2S, Sagem], Guillaume Sandou [correspondent], Gilles Duc [CentraleSupelec, L2S], Philippe Feyel [Sagem], Cédric Chapuis [Sagem].

A method to tune the parameters of the controller of an inertially stabilized platform is proposed. This platform carries an electro-optical system. The image quality is obviously influenced by the movements of the platform: the Line of Sight (LoS) of the imager has to remain fixed in an inertial frame. The more the LoS controller manages to counter the movement of the platform, the better the image quality will be. The motion Modulation Transfer Function (motion MTF) measures the amount of blur brought into the image by the motion of the platform. It represents the contrast over spatial frequencies. Up to now, it has mostly been used as a validation tool for controllers already tuned from derived low level and conservative considerations. The proposed methodology aims to tune LoS controllers using directly the motion MTF as a criterion in the design procedure [42].

7.25. Optimization of controller using bayesian optimization

Participants: Sophie Frasnedo [CentraleSupelec, L2S, Sagem], Julien Bect [CentraleSupelec, L2S], Gilles Duc [CentraleSupelec, L2S], Guillaume Sandou [correspondent], Philippe Feyel [Sagem], Cédric Chapuis [Sagem].

A method to globally optimize the parameters of the controller of an inertially stabilized platform is presented. This platform carries an electro-optical system. The quality of the produced image is obviously influenced by the capacity of the controller to compensate for the unwanted motion of the platform. The motion Modulation Transfer Function (motion MTF) measures the amount of blur brought into the image by those parasite movements. The controller is tuned by minimizing a criterion which includes the motion MTF. However, evaluating this criterion is time-consuming. Using an optimization method that needs numerous evaluations of the criterion is not compatible with industrial constraints. Bayesian optimization methods consist in combining prior information about the criterion and previous evaluation results in order to choose efficiently new evaluation points and reach the global minimizer within a reasonable time. In this paper, a Bayesian approach is used to optimize the motion MTF-based criterion. The results are compared with a local optimization of the same MTF-based criterion, initialized with an acceptable initial point. Similar performances are achieved by the proposed methodology, without requiring an initialization point [41].

7.26. Particle Swarm Optimization based Approach for Model Predictive Control Tuning

Participants: Mohamed Lotfi Derouiche [CentraleSupelec, L2S, Ecole Nationale d'Ingénieur de Tunis], Guillaume Sandou [correspondent], Soufiene Bouallegue [Ecole Nationale d'Ingénieur de Tunis], Joseph Haggège [Ecole Nationale d'Ingénieur de Tunis].

In this work, a new Model Predictive Controller (MPC) parameters tuning strategy is proposed using a perturbed Particle Swarm Optimization (pPSO) approach. This original LabVIEW implementation of this metaheuristic algorithm is firstly validated on some test functions in order to show its efficiency and validity. The optimization results are compared with the standard PSO as well as a LabVIEW implemented Genetic Algorithm (GA) approaches. The parameters tuning problem, i.e. the weighting factors on the output error and input increments of the MPC algorithm, is after that formulated and systematically resolved, using the proposed LabVIEW pPSO algorithm. The case of a Magnetic Levitation (MAGLEV) system is investigated to illustrate the robustness and superiority of the proposed pPSO-based tuning MPC approach. All obtained simulation results, as well as the statistical analysis tests, are compared and discussed in order to improve the effectiveness of the proposed pPSO-based MPC tuning methodology.

7.27. Traffic rescheduling for CBTC train system running in a mixed traffic

Participants: Juliette Pochet [CentraleSupelec, L2S, SNCF], Guillaume Sandou [correspondent], Sylvain Baro [SNCF].

Railway companies need to achieve higher capacities on existing infrastructures such as high density suburban mainlines. Communication based train control (CBTC) systems have been widely deployed on dedicated subway lines. However, deployment on shared rail infrastructure, where CBTC and non CBTC trains run, leads to a mixed positioning and controlling system with different precision levels and restrictions. New performance and complexity issues are to arise. In this work, a method for traffic rescheduling, adapted to a CBTC system running in a mixed traffic, is introduced. A genetic algorithm solves the problem to optimize the cost function. It determines the dwell times and running times of CBTC-equipped trains, taking into account the non-equipped trains planning and fixed-block localization. In addition, reordering can be allowed by modifying the problem constraints. The work is supported by a new simulation tool developed by SNCF and adapted to mixed traffic study. The approach is illustrated with a case study based on a part of an East/West line in Paris region network, proving the ability of the method to find good feasible solutions when delays occur in the traffic.

7.28. Combined Feedback Linearization and MPC for Wind Turbine Power Tracking

Participants: Nicolo Gionfra [CentraleSupelec, L2S], Guillaume Sandou [correspondent], Houria Siguerdidjane [CentraleSupelec, L2S], Damien Faille [EDF], Philippe Loevenbruck [EDF].

The problem of controlling a variable-speed-variable-pitch wind turbine in non conventional operating points is addressed.We aim to provide a control architecture for a general active power tracking problem for the turbine's entire operating envelope. The presented control enables to cope with system non linearities while handling state and input constraints, and avoiding singular points. Simulations are carried out based on the CART turbine parameters. Comparatives results show that the proposed controller outperforms the classic PI regulator.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

A collaboration with SAGEM Défense Sécurité on the robust stabilization of the lines of sight for pointing systems is developed through the PhD thesis of G. Rance (CIFRE).

A CIFRE PhD with Renault is currently undergoing in collaboration with Univ. d'Orleans (Nicoleta Stroe as PhD student).

9. Partnerships and Cooperations

9.1. Regional Initiatives

DIGITEO Project (DIM LSC) ALMA3

Project title: Mathematical Analysis of Acute Myeloid Leukemia (AML) and its treatments

September 2014 - August 2017

Coordinator: Catherine Bonnet

Other partners: Inria Paris-Rocquencourt, France, L2S, France, UPMC, St Antoine Hospital Paris

Abstract: this project follows the regional projects ALMA (2010-2014) and ALMA2 (2011-2013). Starting from the work of J. L. Avila Alonso's PhD thesis in ALMA the aim of this project is to provide a refined coupled model of healthy and cancer cell dynamics in AML whose (stability) analysis will enable evaluation of polychemiotherapies delivered in the case of AML which have a high level of Flt-3 duplication (Flt-3-ITD).

9.2. National Initiatives

9.2.1. ANR

An ANR Blanc SIMI 3 *Multidimensional Systems: Digression On Stabilities* (MSDOS) has started at the beginning of 2014. Its main goal is to constructively study stabilities and stabilization problems of (nonlinear) multidimensional systems. For more details, see http://www.lias-lab.fr/perso/nimayeganefar/doku.php. Alban Quadrat is the local leader for Inria Saclay.

9.2.2. Industrial-Academic Institute

Guillaume Sandou is the head of the RISEGrid Institute. The Institute is dedicated to the study, modelling and simulation of smart electric distribution grids and their interactions with the whole electric power system. It is located in Supélec and gathers about 20 people (academic and industrial researchers, PhD students, post-doctoral researchers).

9.3. European Initiatives

9.3.1. FP7 & H2020 Projects

Sorin Olaru is coordinator of the European project FUTURUSM in the IEF scheme (Dr. Vasso Reppa as postdoctoral fellow).

Sorin Olaru is Principal investigator of the TEMPO ITN (Mohammed Laraba, Rajesh Koduri and Iris Ballesteros as PhD students financed by this training network within L2S).

9.3.2. Collaborations in European Programs, except FP7 & H2020

Program: GDRI (European research network founded by CNRS)

Project acronym: DelSys

Project title: Delay Systems

Duration: 2011-2015

Coordinator: Silviu Iulian Niculescu

Other partners: GIPSA-Lab and LAAS France, Ancona University Italy, Czech Technical University in Prague Czech Republic, Kent University Great-Britain, KTH Stockholm Sweden and KU Leuven Belgium.

Abstract: the aim of this GDRI is to bring together the main European teams which work in the fiels of Delay systems. This network meets once a year.

9.3.3. Collaborations with Major European Organizations

University of l'Aquila, Department of Electrical and Information Engineering (Italy)

Study of nonlinear systems with delay, (notably differential equations interconnected with difference equations) via Lyapunov-Krasovskii functionals.

Tel Aviv University, (Israel)

Stability analysis of nonlinear Partial Differential Equations, construction of observers (continuous/discrete obsevers for systems with delay, observers with convergence in finite time).

9.4. International Initiatives

Sorin Olaru is member of the LIA between several universities in Montreal Canada and Laboratoire des Signaux et Systèmes (L2S).

9.4.1. Inria International Partners

9.4.1.1. Informal International Partners

- Kyushu Institute of Technology, Iizuka, Fukuoka and University of Kyoto, Kyoto, Japan.

- Louisiana State University, Baton Rouge, USA

- School of Electrical Engineering at the Tel-Aviv University

- Unicamp, Campinas, Brazil

- The University of Texas at Austn, Dept. of Aerospace Engineering & Engineering Mechanics

- University of Leeds, UK

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- S. Boatto, Feder. University Rio de Janeiro, Brazil, 20/06-07/10.
- G. Bitsoris, Univ of Patras, Greece.
- A. Fioravanti, UNICAMP Campinas, Brazil, 24/05-10/06.
- E. Fridman, University of Tel-Aviv, IsraÃ«l, 07/07-13/07.
- M. Hovd, NTNU Trondheim, 01/09-31/12.
- Y. Yamamoto, University of Kyoto, Japan, 03/09-11/11.

9.5.1.1. Internships

- Licence: Q. Renvoise, *Lemme de perturbation homologique et ses applications en théorie du contrôle*, 03-06, Ecole Normale Supérieure de Rennes. Supervisor: A. Quadrat.
- Master 2: Liu Xuemin, *control of models of bioreactors with delay and piecewise constant feedbacks*, University Paris-Sud/CentraleSupelec. Financial support: iCODE. Supervisor : Frédéric Mazenc.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific events organisation

10.1.1.1. General chair, scientific chair

- Catherine Bonnet was co-chair of the Organizing Committee of SIAM CT15 which will held 8-10 July in Paris.

- Catherine Bonnet is together with Alexandre Chapoutot and Paolo Mason the organizer of the Working Group Shy of Digicosme on the Plateau de Saclay.

10.1.1.2. Member of the organizing committees

- Catherine Bonnet was with Maurice Robin (DIGITEO) the co-Local Conference Organizer of SIAM CT15 which will held 8-10 July in Paris.

- Catherine Bonnet was a member of th organizing Committee of IFIP 2015, June 29-July 3rd 2015, Sophia-Antipolis, France.

10.1.2. Scientific events selection

10.1.2.1. Member of the conference program committees

Catherine Bonnet is a member of the IPC of the IFAC TDS16 Conference, Istambul, june 2016.

Hakkı Unal is a Member of National Programme Committee of Turkish Automatic Control Meeting in 2016. Frédéric Mazenc a member of the scientific committee of SIAM on Control and Its Applications CT15, (Paris, France, July 2015), http://www.siam.org/meetings/ct15/

Sorin Olaru was member of the IPC for ICSTCC 2015.

Guillaume Sandou was a member of the program committee of the 2015 IEEE Symposium on Computational Intelligence in Production and Logistics Systems, Cape Town, South Africa.

10.1.2.2. Reviewer

The team reviewed many papers for international conferences e.g IEEE Conference on Decision and Control, American Control Conference, European Control Conference, the power systems computation conference (PSCC)

10.1.3. Journal

10.1.3.1. Member of the editorial boards

Frédéric Mazenc is Member of the Mathematical Control and Related Fields editorial board.

Frédéric Mazenc is Member of the European Journal of Control editorial board.

Frédéric Mazenc is Associate Editor for the Asian Journal of control.

Frédéric Mazenc is Associate Editor for the Journal of Control and Decision.

Frédéric Mazenc is Associate Editor for IEEE Transactions on Automatic Control.

Frédéric Mazenc was Associate Editor for the conferences 2016 American Control Conference, Boston, USA and the 54th IEEE Conference on Decision and Control, Osaka, Japan, (2015).

A. Quadrat is an associate editor of the journal *Multidimensional Systems and Signal Processing*, Springer.

Sorin Olaru is an associate editor for IMA Journal of Mathematical Control and Information

10.1.3.2. Reviewer - Reviewing activities

The team reviewed many papers for international journals of mathematics, control Theory and symbolic computation e.g European Journal of Control, Automatica, IEEE Trans. Aut. Contr., IEEE Trans. on Control Systems Technology, IMA Journal of Mathematical Control and Information, Journal of Process Control, Asian Journal of Control, transactions on control systems and technology journal and for a book for Springer.

10.1.4. Invited talks

Y. Bouzidi was an invited speaker at the conference ANR GeoLIM, Jussieu 22-24/06 and at the Cadi Ayyad university, Marrakesh, Morocco (17/12), and gave a talk at the seminar of the Vegas team, Inria Nancy Grand Est (30/06).

Frédéric Mazenc was a plenary speaker of 12th International Multi-Conference on Systems, Signals and Devices, SDD'15, http://www.ssd-conf.org/ssd15/. March 16-19, 2015, Mahdia, Tunisia. Title of his talk: *Stabilization of Time-Varying and Nonlinear Systems with Pointwise and Distributed Delays Through the Reduction Model Approach.*

Frédéric Mazenc gave a talk entitled "*Interval Observer: recent advances*" for the Journée Analyse et Synthèse dâobservateur pour les systèmes complexes, INSA Centre Val de Loire, Campus de Bourges, 17 juin 2015, http://www.ensea.fr/webecs/New-SYNC/

Frédéric Mazenc gave a talk entitled "*Continuous-Discrete Observers for Time-Varying Nonlinear Systems: A Tutorial on Recent Results*" for the workshop entitled "Praly's fest" in July, 27-28th 2015, Mines ParisTech, Paris, http://cas.ensmp.fr/ petit/LP/

A. Quadrat was an invited speaker at 7th Functional Equations in LIMoges (FELIM), Limoges, 23-25/03, at the conference ANR GeoLIM, Jussieu 22-24/06, and at the 4th DelSys conference (25-27/11). He gave a talk at the GT Systèmes à Retards (SAR) (04/06) and at the seminar of the Non-A team, Inria Lille - Nord Europe (06/02) and of the SpecFun team, Inria Saclay (15/06).

Sorin Olaru delivered an IEEE talk in Montreal, Canada in 2015. Details at: https://meetings.vtools.ieee.org/m/34673

10.1.5. Leadership within the scientific community

Frédéric Mazenc was Co-Editor of "Recent Results on Nonlinear Delay Control Systems, Springer", Advances in Delays and Dynamics, Volume 4 2016, Editors: Michael Malisoff, Pierdomenico Pepe, Frédéric Mazenc, Iasson Karafyllis,

ISBN: 978-3-319-18071-7 (Print) 978-3-319-18072-4 (Online).

10.1.6. Scientific expertise

Catherine Bonnet is a member of the Evaluation Committee of Inria since September 2015.

Catherine Bonnet has been an expert for ANR.

Since 2014, Frédéric Mazenc is an expert for the FNRS (Belgium). His mission consists in evaluating research projects funded by this institution.

Since 2012, Frédéric Mazenc is a, expert for the ANVUR (National Agency for the Evaluation of Universities and Research Institutes, Italy). His mission consists in evaluating the contribution of Italian scientists.

Since 2011, Frédéric Mazenc is a, expert for the Romanian National Council for Development and Innovation (Romania). His mission consists in evaluating research projects funded by the this institution.

10.1.7. Research administration

Catherine Bonnet is in the board of Directors of the consortium Cap'Maths.

She is also involved in the Inria Parity Committee created in 2015.

Frédéric Mazenc and Sorin Olaru are members of the Conseil du Laboratoire of Laboratoire des Signaux et Systèmes (L2S).

Frédéric Mazenc is president of the commission scientifique du CRI Saclay-Ile-de-France.

Frédéric Mazenc is member of the Bureau du Comité des Projets du CRI Saclay - Ile-de-France

A. Quadrat was in charge for Inria Saclay of the ANR MDOS.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Master: A. Quadrat gave a course on constructive algebra (30 hours) at AIMS Structured Master's Mathematical Sciences, African Institute for Mathematical Sciences, South Africa, 23/02-13/03/2015.

Licence : Guillaume Sandou, Signals and Systems, 87h, L3, CentraleSupélec

Licence : Guillaume Sandou, Mathematics and programming, 18h, L3, CentraleSupélec

Master : Guillaume Sandou, Automatic Control, 8h, M1, CentraleSupélec

Master : Guillaume Sandou, Numerical methods and optimization, 28h, M1 and M2, CentraleSupélec

Master : Guillaume Sandou, Modelling and system stability analysis, 21h, M2, CentraleSupélec

Master : Guillaume Sandou, Control of energy systems, 22h, M2, CentraleSupélec

Master : Guillaume Sandou, Robust control and mu-analysis, 9h, M2, CentraleSupélec

Master : Guillaume Sandou, Systems identification, 32h, M2, ENSTA

Master : Guillaume Sandou, System Analysis, 22h, M2, Ecole des Mines de Nantes

10.2.2. Supervision

- PhD in progress : Mohamed Lotfi Derouiche, Sur l'optimisation par métaheuristiques avancées de lois de commande prédictive non linéaire. Supervisor: Soufienne Bouallegue, Joseph Haggége et Guillaume Sandou.
- PhD in progress Walid Djema, Analysis of an AML model enabling evaluation of polychemiotherapies delivered in the case of AML which have a high level of Flt-3 duplication (Flt-3-ITD). Supervisor : Catherine Bonnet. Co-supervisors : Jean Clairambault and Frédéric Mazenc.

- PhD : Philippe Feyel, Optimisation des correcteurs par les métaheuristiques et application à la stabilisation inertielle de ligne de visée, soutenue le 16 juin 2015.
- PhD in progress : Sophie Frasnedo, Optimisation globale des lois de commande des autodirecteurs sur critére optronique : application à un autodirecteur à double phase de stabilisation. Supervisors : Gilles Duc et Guillaume Sandou.
- PhD in progress : Nicolo Gionfra, Optimisation du pilotage d'un parc d'énergies renouvelables avec stockage et du réseau de distribution sous-jacent. Supervisors: Houria Siguerdidjane et Guillaume Sandou.
- PhD in progress : Mohamad Koteich, Modélisation et Observabilité des Machines Electriques en vue de la commande sans capteur mécanique. Supervisors: Gilles Duc et Guillaume Sandou.
- PhD in progress : Juliette Pochet, Analyse de performance et de résilience d'une ligne de type RER équipée d'un automatisme CBTC. Supervisors: Guillaume Sandou.
- PhD: G. Rance, *Stabilisation paramétrique de systèmes flexibles à retard et applications aux viseurs*, SAGEM Défense Sécurité, CIFRE. Supervisors: A. Quadrat and H. Mounier.
- Postdoc: Y. Bouzidi, *Constructive study of analysis and synthesis problems of multidimensional systems*, Inria Saclay - Île-de-France, ANR MSDOS. Supervisor: A. Quadrat.

10.2.3. Juries

Catherine Bonnet was the President of the Jury of the Junior Researcher (CR2) Competition of the Saclay-Ile-de-France Inria center in 2015.

She was the external examiner of the thesis of Aolo Bashar Abusaksakar entitled "*Properties of Delay Systems and Diffusive Systems*", School of Mathematics, University of Leeds, UK, 29 June 2015.

Frédéric Mazenc was a reviewer of the PhD thesis of Vincent Léchappé, entitled "*Predictive control and estimation of uncertain systems with an input delay*", (Université de Nantes Angers Le Mans, ECN, December 7, 2015).

A. Quadrat was a reviewer of the PhD thesis of S. Damak, "Approximation de systèmes à paramètres répartis : Analyse, simulation et commande", INSA Lyon, 31/03.

Sorin Olaru was member of the PhD defense committee of Juan Manuel Grosso Perez at Universitat Politecnica de Catalunya.

Guillaume Sandou was a member of the following PhD theses committees:

+ Yujun He, Contribution au réglage de la tension sur un réseau HTA avec producteurs. Apport de la flexibilité de la demande, 5 mars 2015.
+ Rodrigo Mena, Risk based Modeling, Simulation and Optimization for the Integration of Renewable Distributed Generation into Electric Power Networks, 30 juin 2015.

11. Bibliography

Major publications by the team in recent years

[1] C. Bonnet, J. Partington. *Analysis of fractional delay systems of retarded and neutral type*, in "Automatica", 2002, vol. 38, pp. 1133–1138

[2] C. Bonnet, J. Partington. *Stabilization of some fractional delay systems of neutral type*, in "Automatica", 2007, vol. 43, pp. 2047–2053

[3] M. MALISOFF, F. MAZENC. *Constructions of Strict Lyapunov Functions*, Communications and Control Engineering Series, Springer-Verlag London Ltd., 2009

[4] F. MAZENC, P. BLIMAN. *Backstepping design for time-delay nonlinear systems*, in "IEEE Transactions on Automatic Control", January 2006, vol. 51, n° 1, pp. 149–154

[5] W. MICHIELS, S.-I. NICULESCU. *Stability and Stabilization of Time-Delay Systems. An Eigenvalue-Based Approach*, Advances in Design and Control, SIAM: Philadelphia, 2007, vol. 12

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

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[10] G. SANDOU. *Particle swarm optimization: an efficient tool for the design of automatic control law*, in "European Control Conference", Budapest, Hungary, August 23rd-26th 2009

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Articles in International Peer-Reviewed Journals

[11] T. CLUZEAU, A. QUADRAT. *A new insight into Serre's reduction problem*, in "Linear Algebra and its Applications", 2015, vol. 483, pp. 40-100, https://hal-centralesupelec.archives-ouvertes.fr/hal-01259834

[12] T. N. DINH, V. ANDRIEU, M. NADRI, U. SERRES. *Continuous-discrete time observer design for Lipschitz systems with sampled measurements*, in "IEEE Transactions on Automatic Control", March 2015, vol. 60, n° 3, pp. 787 - 792 [*DOI :* 10.1109/TAC.2014.2329211], https://hal.archives-ouvertes.fr/hal-01018716

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