Activity Report 2014

Project-Team DISCO

Dynamical Interconnected Systems in COmplex Environments

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

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Project-Team DISCO

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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], [71], [91], [72], [75].

- 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. [83]). 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 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 [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], [87].

- 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. New Software and Platforms

5.1. OreModules

Participants: Alban Quadrat [correspondent], Daniel Robertz [Univ. Aachen], Frédéric Chyzak [Inria Rocquencourt, Algorithms Project].

The OREMODULES package [73], based on the commercial Maple package Ore_algebra [74], 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. OREMODULES is original because it combines the recent developments of the Gröbner bases over some noncommutative polynomial rings [82], [84] and new algorithms of algebraic analysis in order to effectively check classical properties of module theory (e.g., existence of a non-trivial torsion submodule, torsion-freeness, reflexiveness, projectiveness, stably freeness, freeness), it gives their system-theoretical interpretations (existence of autonomous elements or successive parametrizations, existence of minimal/injective parametrizations or Bézout equations) [90], [89], [72] and it computes important tools of homological algebra (e.g., (minimal) free resolutions, split exact sequences, extension functors, projective or Krull dimensions, Hilbert power series). The abstract language of homological algebra used in the algebraic analysis approach carries over to the implementations in OREMODULES: up to the choice of the domain of functional operators which occurs in a given system, all algorithms are stated and implemented in sufficient generality such that linear systems defined over the Ore algebras developed in the Ore_algebra package are covered at the same time. Applications of the OREMODULES package to mathematical systems theory, control theory and mathematical physics are illustrated in a large library of examples. The binary of the package is freely available at http://wwwb.math.rwth-aachen.de/OreModules/.

5.2. Stafford

Participants: Alban Quadrat [correspondent], Daniel Robertz [Univ. Aachen].

The STAFFORD package of OREMODULES [73] contains an implementation of two constructive versions of Stafford's famous but difficult theorem [96] stating that every ideal over the Weyl algebra $A_n(k)$ (resp., $B_n(k)$) of partial differential operators with polynomial (resp., rational) coefficients over a field k of characteristic 0 (e.g., $k = \mathbb{Q}, \mathbb{R}$) can be generated by two generators. Based on this implementation and algorithmic results developed in [92] by the authors of the package, two algorithms which compute bases of free modules over the Weyl algebras $A_n(\mathbb{Q})$ and $B_n(\mathbb{Q})$ have been implemented. The rest of Stafford's results developed in [96] have recently been made constructive in [93] (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. The binary of the package is freely available at http://wwwb.math.rwth-aachen.de/OreModules/.

5.3. QuillenSuslin

Participants: Anna Fabiańska [Univ. Aachen], Alban Quadrat [correspondent].

The QUILLEN-SUSLIN package [78] contains an implementation of the famous Quillen-Suslin theorem [94], [97]. In particular, this implementation allows us to compute bases of free modules over a commutative polynomial ring with coefficients in a field (mainly $\mathbb{Q}$) and in a principal ideal domain (mainly $\mathbb{Z}$). The development of the QUILLEN-SUSLIN package was motivated by different constructive applications of the Quillen-Suslin theorem in multidimensional systems theory [78] (e.g., the Lin-Bose conjectures, the computation of (weakly) left/right/doubly coprime factorizations of rational transfer matrices, the computation of injective parametrizations of flat linear multidimensional systems with constant coefficients, the reduction and decomposition problems, Serre's reduction problem). To our knowledge, the QUILLEN-SUSLIN package is the only implementation of the Quillen-Suslin theorem nowadays available. The binary of the package is freely available at http://wwwb.math.rwth-aachen.de/QuillenSuslin.

5.4. OreMorphisms

Participants: Thomas Cluzeau [ENSIL, Univ. Limoges], Alban Quadrat [correspondent].

The OREMORPHISMS package [76] of OREMODULES [72] 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. The binary of the package is freely available at http://pages.saclay.inria.fr/alban.quadrat/OreMorphisms/index.html.

5.5. PurityFiltration

Participant: Alban Quadrat [correspondent].

The PURITYFILTRATION package, built upon the OREMODULES package, is an implementation of a new effective algorithm obtained in [24] which computes the purity/grade filtration [67], [68] 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. For more information, see http://pages.saclay.inria.fr/alban.quadrat/OreAlgebraicAnalysis/index.html.

5.6. OreAlgebraicAnalysis

Participants: Thomas Cluzeau [ENSIL, Univ. Limoges], Alban Quadrat [correspondent], Maris Tõnso [Institute of Cybernetics, Univ. Tallinn].

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 Gröbner 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.

5.7. YALTA

Participants: Catherine Bonnet [correspondent], Hugo Cavalera, André R. Fioravanti [UNICAMP], Jim Pioche [SciWorks Technologies].

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, [70] and [79]) and on classical continuation methods exploiting the particularities of the problem [80], [81].

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

Recently, some optimizations and features have been added. For instance, the main software function has been split into several procedures, allowing some calculus such as finding the position of the neutral chains to be processed independently of more computationnally expensive ones (for instance determining the root locus with respect to the delay of the system). In parallel, software documentation has been rewritten.

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 5.7. 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++).

6. New Results

6.1. Zero-parameter mono and multi objective methods for the tuning of controllers

The synthesis of controllers for any kind of system is the main point in Automatic Control. The traditional approach is to use a simplified model of the system to control and/or use some reformulations of the

specifications to tune an often efficient but suboptimal controller. In a more and more competitive industrial context, the design of high performances controllers has emerged as a crucial point to enhance the global productivity. However, the design of optimal controllers supposes the solution of non-convex and non-differentiable optimization problems, for which deterministic and (often) local search algorithm fail in the solution. In this work, Particle Swarm Optimization is used to solve the problem, and tested to define some controllers for a magnetic levitation. The use of standard settings and penalization terms leads to a zero-parameter and reformulation free method. Results are much than satisfactory and show that Evolutionary Computation could be of great interest in the Automatic Control field.

6.2. Fixed-structure H_∞ synthesis for multiple plants

This work proposes an efficient evolutionary approach to the fixed-order and structured H_∞ control design problem extended to the multiple plants case. By testing it on the classical example of a flexible plant, this evolutionary approach proves to be very efficient compared with other recent tools, especially in the case of a high number of plants; it can then be considered as an interesting alternative for such problems.

6.3. Fixed-Structure Mu-Synthesis

This work proposes to shed a new light on the Mu-synthesis problem using the differential evolution algorithm. This algorithm allows optimizing simultaneously the structured controller and the dynamic (or static) D-scalings, which leads to robust performance controllers. This method has been applied successfully to a classical flexible plant control problem. After a comparison between the evolutionary approach and the non-smooth optimization one has envisaged proving the high potential of the proposed method.

6.4. Algebraic Analysis Approach to Linear Functional Systems

6.4.1. *Serre's reduction problem*

The purpose of this work is to study the connections existing between Serre's reduction of linear functional systems - which aims at finding an equivalent system defined by fewer equations and fewer unknowns - and the decomposition problem - which aims at finding an equivalent system having a diagonal block structure - in which one of the diagonal blocks is assumed to be the identity matrix. In order to do that, in [62], we further develop results on Serre's reduction problem and on the decomposition problem. Finally, we show how these techniques can be used to analyze the decomposability problem of standard linear systems of partial differential equations studied in hydrodynamics such as Stokes equations, Oseen equations and the movement of an incompressible fluid rotating with a small velocity around a vertical axis.

6.4.2. *A spectral sequence central in the behaviour approach*

Within the algebraic analysis approach to multidimensional systems, the behavioural approach developed by J. C. Willems can be understood as a dual approach to the module-theoretic approach. This duality is exact when the signal space is an injective cogenerator module over the ring of differential operators. In particular, the obstruction to the existence of a parametrization of a multidimensional system is characterized by the existence of autonomous elements of the multidimensional system. In [52], we consider the case of a general signal space and investigate the connection between the algebraic properties of the differential module defining the multidimensional system and the obstruction to the existence of parametrizations of the multidimensional system. To do so, we investigate a certain Grothendieck spectral sequence connecting the obstructions to the existence of parametrizations to the obstructions to the differential module - defining the multidimensional system - to be torsion-free, reflexive ...projective.

6.4.3. *Restrictions of n-D systems and inverse images of $\mathcal{D}$-modules*

The problem of characterizing the restriction of the solutions of a n-D system to a subvector space of $\mathbb{R}^n$ has recently been investigated in the literature of multidimensional systems theory. For instance, this problem plays an important role in the stability analysis and in stabilization problems of multidimensional systems. In this work, we characterize the restriction of a n-D behaviour to an algebraic or analytic submanifold of $\mathbb{R}^n$. In [51], within the algebraic analysis approach to multidimensional systems, we show that the restriction of a n-D behaviour to an algebraic or analytic submanifold can be characterized in terms of the inverse image of the differential module defining the behaviour. Explicit characterization of inverse images of differential modules is investigated. Finally, we explain Kashiwara's extension of the Cauchy-Kowalevsky theorem for general n-D behaviours and non-characteristic algebraic or analytic submanifolds.

6.4.4. *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.

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

6.5.1. *Robust stabilization of a flexible rod moving in rotation and translation*

We develop a hierarchy of models for a flexible rod moving in rotation and translation from a nonlinear partial differential model (generalization of the Euler-Bernoulli equation) to a linear partial differential equation and finite-dimensional models via approximations. We study the stability of those models as well as their robust stabilizations. This work is an extension of the results obtained in [61]. This work will be pursued within the framework of a CIFRE PhD thesis developed in collaboration with SAGEM (2015).

6.5.2. *Noncommutative geometric approach to infinite-dimensional systems theory:*

This new field of research aims at showing that noncommutative geometric structures such as connections and curvatures exist on internally stabilizable infinite-dimensional linear systems and on their stabilizing controllers. To see this new geometry, using the noncommutative geometry developed by Connes, we have to replace the standard differential calculus by the quantized differential calculus and classical vector bundles by projective modules. In [50], we give an explicit description of the connections on an internally stabilizable system and on its stabilizing controllers in terms of the projectors of the closed-loop system classically used in robust control. Their curvatures are explicitly computed. These connections aim at studying the variations of the signals in the closed-loop system in response to a disturbance or a change of the reference. The study of these connections are useful to understand how techniques of (noncommutative) differential geometry can be used in the study of H^∞ control theory.

6.5.3. *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.

6.5.4. 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.

6.6. Set invariance for discrete-time delay systems

We studied the existence of positively invariant sets for linear delay-difference equations. In particular, we regarded two strong stability notions: robust (with respect to delay parameter) asymptotic stability for the discrete-time case and delay-independent stability for the continuous-time case. The correlation between these stability concepts is also considered. Furthermore, for the delay-difference equations with two delay parameters, we provided a computationally efficient numerical routine which is necessary to guarantee the existence of contractive sets of Lyapunov–Razumikhin type. This condition also appears to be necessary and sufficient for the delay-independent stability and sufficient for the robust asymptotic stability. The results are published in [25].

We proposed a new perspective on the structural properties of invariant sets for time delay systems via set factorization. This novel perspective describes, in a unified framework, different existing notions of invariant sets [60]. Additionally, it is shown that the (possible non-minimal) state space representation is a key element in the description of low complexity invariant sets.

6.7. Low complexity constrained control

On one side, we proposed an explicit (piecewise affine feedback) control obtained via interpolation for constrained linear systems [23]. On another side, we studied the Linear Constrained Regulation problem for Continuous-Time Systems in the presence of non-convex constraints [32]. This might prove to be useful for the multi-agent dynamical systems operating under collision avoidance constraints.

6.8. Fault detection based on set theoretic methods and connexions with fault tolerant control

We proposed a set-theoretic fault detection mechanism for multisensor systems with a classification of possible functioning according to the use in the feedback mechanism. The healthy, faulty and under-recovery class are characterized via set descriptions in the residual space and as such can be monitored via on-line mechanisms [26]. Furthermore, the robust detection has been enhanced with an interval observer mechanism for the monitorig during the transients [28].

6.9. Interval Observer

We made several progresses in the domain of the construction of state estimators called interval observers.

1) In [16], we have shown how interval observers can be constructed for nonlinear (and not Lipschitz) systems possessing a special triangular system. These systems are not cooperative and not globally Lipschitz and have a rather general structure which may result from a change of coordinates or an output injection. Besides, under additional assumptions, input to state stability (ISS) properties are derived. We illustrated the constructions by designing a framer and an ISS interval observer for two models of bioreactors.

2) The contributions [17] and [18] present major results for the design of interval observers for discete-time systems. In [18], coordinate transformations which change an arbitrary linear discrete-time system into a positive one and general nonlinear designs of interval observers for nonlinear systems (satisfying a restricitive stability assumption) are proposed. In [17], it is explained how two classical Luenberger observers can be used, (even in the absence of the positivity property of the studied system or the error equations) as interval observer, provided two appropriate outputs, which compose the lower and the upper bound of the interval observer, are selected.

3) In [33], we present a new type of interval observers for nonlinear systems that are affine in the unmeasured part of the state.They are composed of two copies of classical observers and upper and lower bounds which are designed by taking advantage of positivity properties of the error equations when written in appropriate coordinates.

6.10. Reduction model approach: new advances

We solved several distinct problems entailing to the celebrated reduction model approach. Let us recall that this technique makes it possible to stabilize systems with arbitrarily large pointwise or distributed delays in the input.

1) In [46], solutions to the problem of globally exponentially stabilizing linear systems with an arbitrarily long pointwise delay with sampled feedbacks are presented. The main result of a contribution by F. Mazenc and D. Normand-Cyrot is recalled and compared with other results available in the literature.

2) We considered in [41] a stabilization problem for continuous-time linear systems with discrete-time measurements and a sampled input with a pointwise constant delay. In a first step, we constructed a continuous-discrete observer which converges when the maximum time interval between two consecutive measurements is sufficiently small. We also constructed a dynamic output feedback through 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 was imposed.

3) In [43], we studied a general class of nonlinear systems with input delays of arbitrary size. We adapted the reduction model approach to prove local asymptotic stability of the closed loop input delayed systems, using feedbacks that may be nonlinear. We determined estimates of the basins of attraction for the closed loop systems using Lyapunov-Krasovskii functionals.

4) The contribution [21] is devoted to stabilization problems for time-varying linear systems with constant input delays. The reduction model approach we proposed ensures a robustness property (input-to-state stability) with respect to additive uncertainties, under arbitrarily long delays. It applies to rapidly time-varying systems, and gives a lower bound on the admissible rapidness parameters. We also covered slowly time-varying systems, including upper bounds on the allowable slowness parameters. We illustrated our work using a pendulum model.

6.11. Nonlinear systems with delay

1) In [45], we developed a new technique for stability analysis for nonlinear dynamical systems with delays and possible discontinuities. In contrast with Lyapunov based approaches, the trajectory based approach we proposed involves verifying certain inequalities along solutions of auxiliary systems. It applies to a wide range of systems, notably time-varying systems with time-varying delay, ODE coupled with difference equations, and networked control systems with delay. It relies on the input-to-state stability notion, and yields input-to-state stability with respect to uncertainty.

2) In [39], to address various types of delays including the neutral-type arising in dynamical networks, we dealt with coupled delay differential and continuous-time difference equations and proposed stability and robustness criteria. In these criteria, differential equation parts do not necessarily exhibit unbounded dissipation rate. Subsystems described by differential equations are not required to be input-to-state stable either. No assumptions on network topology are made. To handle such a general case, we construct explicit Lyapunov-type functionals. We established stability and robustness of the overall networks.

3) In [22], [42] and [44], stability results for several families of systems with delay are established. The key ingredient of these contributions is the use of comparison systems of a new type, the theory of the positive systems and linear Lyapunov functionals. 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. We illustrate our work using a chain of integrators and other examples.

6.12. Strictification

In [40], the problem of stabilizing rigid-body attitude dynamics in the presence of pointwise time-delay for the input torque is considered. A quaternion-based linear state feedback controller is shown to achieve local stability in addition to the characterization of sufficient condition that depends only on the magnitude of the initial angular rates. More specifically, no restrictions are imposed on the body initial orientation which is a significant contrast with other results from recent literature that adopt three-dimensional representations for the attitude kinematics. Using the quaternion-based linear feedback structure, the closed-loop system is shown to never admit the possibility for finite-time escapes. While the actual magnitude of the time-delay can be unknown, an upper bound on the delay is assumed to be known. The proof relies on the construction of a functional which does not belong to the family of the strict Lyapunov-Krasovskii functionals, but shares important features with the functionals of this family. The stability conditions and results are illustrated through numerical simulations.

6.13. Stability analysis of fractional and classical neutral systems with commensurate delays

Fractional and classical neutral systems with commensurate delays have chains of poles asymptotic to vertical lines (see [66] for classical systems). The delicate case where system have some chains of poles asymptotic to the imaginary axis is interesting as the absence of poles in the open left half-plane does not guarantee the H_∞-stability of the system.

Stability analysis of classical or fractional neutral systems with one single chain of poles asymptotic to the imaginary axis has been investigated in [88], [70], [2], [69], where the asymptotic location of poles of neutral chains was given and necessary and sufficient conditions for H_∞-stability were derived.

We have performed a full analysis of classical and fractional systems with multiple chains of poles approaching a set of points on the imaginary axis. Moreover, a unified method to analyze the stability of fractional and classical systems has been derived.

6.14. Stabilization of fractional neutral systems with commensurate delays

We consider strictly proper fractional neutral systems with one delay and one chain of poles asymptotic to the imaginary axis including the case where this chain may approach the axis from the right side. Thus the system may possess infinitely many poles in the right half-plane. For these systems, a Youla-Kučera parametrization regarding H_∞-stability of all stabilizing controllers has been obtained in [59]. Having in mind the robustness of the closed-loop relative to parameter uncertainties, we wish to find controllers which are able to provide a closed-loop free of chain of poles asymptotic to the imaginary axis. However, we prove that a large class of realizable stabilizing controllers cannot achieve this. [47].

6.15. Stabilization of MISO fractional systems with I/O delays

In order to yield the set of all the stabilizing controllers of a class of MISO fractional systems with delays by mean of Youla-Kučera parametrization regarding H_∞-stability, we are interested in determining coprime factorizations of the transfer function. Explicit expressions of left coprime factorizations and left Bézout factors have been derived in [85]. Explicit expressions of right coprime factorizations and right Bézout factors for some classes of systems have also been derived in [86]. Recently, we obtain right factors for a more general class of systems. Furthermore, we present these right factors in the minimal form, i.e. factors with the minimal number of coefficients to be determined and with the lowest degree. We also obtain left factors in the minimal form.

6.16. Modeling and control of Acute Myeloid Leukemia

Starting from a PDE model of hematopoiesis given in [64], we have derived several models of healthy or cancer cell dynamics in hematopoiesis and performed several stability analyses.

We have proposed in [58] a new mathematical model of the cell dynamics in Acute Myeloid Leukemia (AML) which takes into account the four different phases of the proliferating compartment as well the fast self-renewal phenomenon frequently observed in AML. As was the case in [58] this model is transformed into a distributed delay system and was analyzed here with input-output techniques. Local stability conditions for an equilibrium point of interest are derived in terms of a set of inequalities involving the parameters of the mathematical model.

We have also studied a coupled delay model for healthy and cancer cell dynamics in Acute Myeloid Leukemia consisting of two stages of maturation for cancer cells and three stages of maturation for healthy cells. For a particular healthy equilibrium point, locally stability conditions involving the parameters of the mathematical model have been obtained [30], [31].

We have performed in [29] a stability analysis of both the PDE model of healthy hematopoiesis and a coupled PDE model of healthy and cancer cell dynamics. The stability conditions obtained here in the time domain strengthen the idea that fast self-renewal plays an important role in AML.

A time-domain stability analysis by means of Lyapunov-Krasovskii functionals has been performed on the delay system modeling healthy hematopoiesis for a strictly positive equilibrium point of interest.

6.17. Algebraic geometry techniques for polynomial systems

6.17.1. *Testing the structural stability of N-d discrete linear systems*

The goal of this work is to propose new computer algebra based methods for testing the structural stability of N-d discrete linear systems. Recall that a discrete linear system given by its transfer function $G(z_1, ..., z_n) = N(z_1, ..., z_n)/D(z_1, ..., z_n)$ is said to be stable if and only if the denominator $D(z_1, ..., z_n)$ is devoid from zero inside the unit complex poly-disc. This fundamental problem in the analysis of N-d systems has been extensively studied these last decades. At the end of the seventies, DeCarlo et al [77] show that testing the previous condition is equivalent to testing the existence of complex zeros on each face of the poly-disc i.e. $D(1, ..., z_i, ..., 1)$ for $i = 1...n$ as well as testing the existence of complex zero on the poly-circle i.e. the zeros of $D(z_1, ..., z_n)$ when $|z_1| = ... = |z_n| = 1$.

Starting from the conditions of DeCarlo et al, we propose a new approach that transform the last condition, that is, the non-existence of complex zeros on the unit poly-circle to a condition on the existence of real solutions inside a region of R^n. More precisely we propose two type of transformations. The first one reduces the problem to looking for real solutions inside the unit box while the second one reduces the problem to looking for real solutions in the whole space R^n. In order to check the existence of real solutions, we use classical computer algebra algorithms for solving systems of polynomial equations. In the case of one or two variables, the appearing systems are generally zero-dimensional. To count or locate the real solutions of such systems, we compute a rational univariate representation [95], that is a one to one mapping between the solutions of the system and the roots of a univariate polynomial, thus the problem is reduced to a univariate problem. When the number of variables is larger than two, the systems that stem from the conditions above are no longer zero-dimensional. In such case, we use critical points method that allow to compute solutions in each real connected component of the zeros of the systems [65].

We implemented the previous approach on maple using the external library Raglib [63] which provides routines for testing the existence of real solutions of an algebraic system. Preliminary tests show the relevance of our approach.

This work is supported by the ANR MSDOS grant.

6.17.2. *Efficient algorihtms for solving bivariate algebraic systems*

This work addresses the problem of solving a bivariate algebraic system (i.e computing certified numerical approximation of the solutions) via the computation or a rational univariate representation. Such a representation is useful since it allows to turn many queries on the system into queries on univariate polynomials. Given two coprime polynomials P and Q in $Z[x, y]$ of degree bounded by d and bitsize bounded by τ we present new

algorithms for computing rational univariate representation of the system $\{P, Q\}$ and from this representation, isolating the real solutions of $\{P, Q\}$. The cost analysis of these algorithms show that they have a worst-case bit complexity in $sOB(d^6 + d^5\tau)$ which improves by a factor d the state-of-the-art complexity.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

A collaboration with SAGEM Défense Sécurité, Etablissement de Massy, has been developed on the effect of time-delay in inertially stabilized platforms for optical imaging systems. This collaboration led to research contracts made by Alban Quadrat, Silviu Niculescu and Hugues Mounier (L2S, University Paris Sud).

8. Partnerships and Cooperations

8.1. 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).

- DIGITEO Project (DIM LSC) MOISYR

  Project title: Monotonie, observaterus par intervalles et systèmes à retard.

  Dedember 2011- December 2014

  Coordinator: Frédéric Mazenc

  Other partners: L2S, France, Mines-ParisTech, France

  Abstract: MOISYR is concerned with the problem of extending the theory of monotone systems to the main families of continuous time systems with delay along with the application of this theory to the design of observers and interval observers. In particular, nonlinear systems with pointwise and distributed delays and stabilizable systems with delay in the input shall be considered. In a second step, we extend our result to discrete time systems and to a specific class of continuous/discrete systems calles Networked Control Systems.

8.2. National Initiatives

8.2.1. 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.

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).

Frédéric Mazenc is member of the Conseil du Laboratoire of Laboratoire des Signaux et Systèmes (L2S).

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

8.3. European Initiatives

8.3.1. *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.

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Program: **PHC Pessoa (Portugal)**

Project acronym: 28750QA

Project title: Robust Distributed Model Predictive Control of Medium- and Large- Scale Systems

Duration: 2013-2014

Coordinator: Cristina Stoica (French leader), Fernando Lobo Perreira (Portuguese leader)

Other partners: Sorin Olaru

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Program:**PHC Brancusi (Romania)**

Project acronym: 28705PF

Project title: Adaptive and predictive control of bioprocesses (modelling, identification and control of interconnected bioprocesses)

Duration: 2013-2014

Coordinator: Sihem Tebbani (French leader), Dan Selisteanu (Romanain leader)

Other partners: Sorin Olaru

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Program:**PHC Parrot**

Project acronym: CASCAC

Project title: Computer Algebra, Symbolic Computation, and Automatic Control

Duration: 2013 - 2014

Coordinator: Alban Quadrat (French leader), Maris Tõnso (Estonian leader)

Other partners: Institute of Cybernetics, University of Tallinn

Abstract: The CASCAC project is at the interfaces of control theory, computer algebra and software engineering. The goals of the project are: 1. Develop new theoretical results on nonlinear control systems defined by functional equations (e.g., ordinary differential equations, partial differential equations, differential time-delay equations, partial difference equations). 2. Implement them on dedicated softwares developed in the computer algebra system Mathematica. In particular, Mathematica versions of the OREMODULES and OREMORPHISMS packages will be developed. 3. Develop an interface between the C library BLAD (http://www.lifl.fr/~boulier/pmwiki/pmwiki.php?n=Main.BLAD) − dedicated to differential algebra techniques − and Mathematica. This interface will allow one to have access to differential elimination techniques in Mathematica and to use them in decision methods for nonlinear control theory. 4. Co-supervise the Master thesis of Kristina Halturina with Prof. Ülle Kotta on constructive aspects of differential flatness and its applications to control theory (e.g., tracking, motion planning).

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Program:**PHC GALILEE 2014**

Project acronym: SeTASDelSys - 30188PK

Project title: Set theoretic analysis of switched and time delay systems with application to fault tolerant control systems

Duration: January 2014 - December 2014

Coordinator: Sorin Olaru (France), Stefano Miani (Italy)

Other partners: Dipartimento di Ingegneria Elettrica, Gestionale e Meccanica, Universita' degli Studi di Udine, Italy

Abstract: The present Galileo project intends to initiate a collaborative research relationship based on the common interest of the French and Italian teams in the set-theoretic analysis of switched and delay time dynamics. On a broad perspective, the results on these topics can be extended to different aspects of the control design (as fault tolerance, constraints handling or robustness with respect to communication uncertainties). The scientific objective is to address two main open problems : i) the construction of (positive) invariant sets for switched dynamical systems; ii) the definition of the appropriate concepts of set invariance for delay time systems and their algorithmic construction.

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Program: **PHC Rila (Bulgaria)**

Project acronym: 29401YJ

Project title: Robust Distributed Model Predictive Control of Medium- and Large- Scale Systems

Duration: 2013-2014

Coordinator: Sorin Olaru (French leader), Alexandra Grancharova (Bulgarian leader)

Other partners: Bulgarian Academy of Science

Abstract: The project intends to address the control design of large scale dynamical systems with an emphasis on distributed predictive control strategies. There are two points of view with respect to the control synthesis in this framework: a. avoid the use of a global prediction model in the receding horizon optimal control of the subsystems and privilege the use of a coordination level in the decision process; b. consider the distributed synthesis for a network of discrete-time constrained linear systems without central coordinator. In the present project we intend to contribute to both of these directions by: a. Prediction of the interactions in between subsystems in a decomposition-coordination scheme. This can be done by imposing a reduced set of constraints for the MPC problems at the lower levels. b. With respect to the MPC design in the absence of coordination one of the issues will be the definition of appropriate terminal sets, ensuring invariance properties or at least recursive feasibility for the global functioning. We will investigate the construction of terminal set for a stabilizing centralized MPC decomposable in the form of a cross product of sets in each subsystem state space. An interesting idea on this direction was presented recently by the participants in this project.

8.3.2. *Collaborations with Major European Organizations*

Partner 1: University of L'Aquila, Department of Electrical and Information Engineering (Italy)

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

Partner 2: RWTH Aachen University, Germany

Mathematical systems theory, control theory, symbolic computation

Partner 3: Bilkent University, Turkey

Control of linear and nonlinear systems with delays, medical applications

Partner 4: Tel Aviv University, Israel

Stability analysis of nonlinear Partial Differential Equations

8.4. International Research Visitors

8.4.1. *Visits of International Scientists*

- E. Acchab, University of El Jadida, Marocco, 01-15/11.
- M. Barakat, University of Kaiserslautern, Germany, 31/04-01/05.
- Y. Belikov, University of Tallinn, Estonia, 26-30/05.
- E. Fridman, University of Tel-Aviv, Israël, 22/09-22/10.
- U. Kotta, University of Tallinn, Estonia, 26-30/05.
- P. Laakkonen, University of Tampere, Finland, 09-17/06.
- G. Regensburger, RICAM, Linz, Austria, 06/03.
- D. Robertz, University of Plymouth, United Kingdom, 02-05/06.
- M. Tõnso, University of Tallinn, Estonia, 26-30/05, 17-21/11.
- Y. Yamamoto, University of Kyoto, Japan, 15-30/04.

National scientists who gave a talk at the seminar *Théorie Algébrique des Systèmes* (http://pages.saclay.inria.fr/alban.quadrat/Seminar.html): F. Boulier (University of Lille I, 27/05), Y. Bouzidi (Inria Nancy, VEGAS, 30/06), T. Cluzeau (University of Limoges, 19-20/11), J.-A. Weil (University of Limoges, 20/01, 03/02).

8.4.1.1. Internships

- Master thesis: W. Djema, *Etude de la stabilité d'un modèle de leucémie aiguë myëloblastique*, Ecole Nationale Polytechnique d'Alger (Algeria), 17/06/2014, C. Bonnet et F. Mazenc.
- Master thesis: K. Halturina, *Constructive study of differential flatness and its applications in control theory*, University of Tallinn (Estonia), grant of the French governement (3 months), 15/05/2014, Alban Quadrat.
- Master thesis: N. Ribard, *Etude constructive des théorèmes de Warfield sur l'équivalence des systèmes fonctionnels linéaires*, University of Versailles (France), 15/09/2014, Alban Quadrat.

8.4.2. *Visits to International Teams*

Alban Quadrat visited the department of mathematics of the University of SUNY Cortland, New York (USA), 09/2014.

8.5. International Initiatives

8.5.1. *Inria International Partners*

8.5.1.1. Informal International Partners

- UNICAMP, Sao Paulo, Brazil.

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

- Louisiana State University, Baton Rouge, USA.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific events organisation

With E. Zerz (RWTH Aachen University), Alban Quadrat co-organized two invited invited sessions at the *21th International Symposium on Mathematical Theory of Networks and Systems* (MTNS), Groningen (The Netherlands), 07-11/07/2014. The contributions of these invited sessions will appear as extended chapters of the book *Algebraic and Symbolic Computation Methods in Dynamical Systems*, Springer series ADD@S, Springer, 2015 (A. Quadrat, G. Regensburger, E. Zerz eds.).

With E. Zerz (RWTH Aachen University), Alban Quadrat co-organized a special issue for the international journal *Multidimensional Systems and Signal Processing* (Springer), entitled *Symbolic Methods in Multidimensional Systems Theory*. This issue will appear at the beginning of 2015.

9.1.1.1. General chair, Scientific chair

Catherine Bonnet is co-chair of the Organizing Committee of SIAM CT15 which will held 8-10 July in Paris. She is also with Maurice Robin (DIGITEO) the Local Conference Organizer.

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

Alban Quadrat is a scientific committee member of the *Journées Nationales de Calcul Formel* (JNCF), http://www.lifl.fr/jncf2014/index.html.

9.1.1.2. Member of the organizing committee

Catherine Bonnet was a member of the organizing committee of the *Symposium in honor of Professor Abdelhaq El Jai* 29-30 May 2014 in Ifrane, Marocco.

Frédéric Mazenc was a member of the organizing committee of the *2014 European Control Conference*, July, Strasbourg, France.

9.1.2. Scientific events selection

Catherine Bonnet is in the board of directors of Cap'maths.

Sorin Olaru wax the Scientific organizer of the Workshop "Interpolation-based techniques for constrained control: from improved vertex control to robust model predictive control alternatives." at ECC 2014.

Alban Quadrat was an inviter speaker at the conference *Homological Perturbation Lemma*, Galway (Ireland), 01-05/12, and at the conference *DelSys' 2014*, Grenoble (France), 12-14/11, and gave a talk at the department of mathematics, SUNY Cortland, New York (USA), 16/09, and at the seminar of the University of Versailles, 17/12. He also attended the *Journées Nationales de Calcul Formel*, CIRM, Luminy (France), 03-07/11.

9.1.2.1. Member of the conference program committee

Catherine Bonnet was a member of the scientific committee of the *Symposium in honor of Professor Abdelhaq El Jai* 29-30 May 2014 in Ifrane, Marocco.

Sorin Olaru was a member of the program committees of the European Control Conference 2014, 18th International Conference on System Theory, Control and Computing - ICSTCC 2014.

Guillaume Sandou was a member of the Programm Committee of the 2014 IEEE Symposium on Computational Intelligence in Production and Logistics Systems (CIPLS'14), Orlando, USA, December 2014.

9.1.3. Journal

9.1.3.1. Member of the editorial board

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 *2015 American Control Conference*, Chicago, USA and the *53th IEEE Conference on Decision and Control*, Los Angeles, USA, (2014).

Sorin Olaru is a memeber of the editorial board of *IMA Journal of Mathematical Control and Information*.

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

9.1.3.2. Reviewer

The team reviewed many papers for international journals (European Journal of Control, Automatica, IEEE Trans. Aut Contr, IEEE Trans. on Control Systems Technology, IMA Journal of Mathematical Control and Information, Information Sciences, IEEE Symposium Series on Computational Intelligence, SICON, Journal of Process Control, Journal of Franklin Institute, Transactions on Cybernetics, Asian Journal of Control) and conferences (IEEE Conference on Decision and Control, American Control Conference, European Control Conference, IFAC World Congress 2014) and for a book for Springer.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence : Le Ha Vy Nguyen, Signals and Systems, 28h, L3, Paris-Sud University

Master : Le Ha Vy Nguyen, Information Processing and Source Coding, 12h, M1, Paris-Sud University

Master : Le Ha Vy Nguyen, Numerical Methods for Physics, 12h, M1, Paris-Sud University

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

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

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

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

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

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

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

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

Master : Guillaume Sandou, Embedded Systems, 18h, M2, Ecole Centrale Paris

Master : Guillaume Sandou, Automatic control, 23h, M2, Ecole Centrale Paris

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

Licence : Sorin Olaru, Numerical methods and Optimization, 24h, niveau M1, SUPELEC, France

Licence : Sorin Olaru, Hybrid systems, 16h, niveau M2, SUPELEC, France

Licence : Sorin Olaru, Automatic Control, 8h , niveau M1, SUPELEC, France

Licence : Sorin Olaru, Signals and systems, 8h , niveau L3, SUPELEC, France

Licence : Sorin Olaru, Embedded systems, 8h , niveau M1, Centrale Paris, France

9.2.2. Supervision

- Postdoc: Y. Bouzidi, *Constructive study of analysis and synthesis problems of multidimensional systems*, Inria Saclay - Île-de-France, ANR MSDOS, 2014-2015, A. Quadrat.

- PhD : Thach Ngoc Dinh, Interval Observers and Delay Systems, University Paris-Sud, December 2011. Date of the defence: 24 Nov., 2014. Supervisor: Frédéric Mazenc. Co-Supervisor: Silviu I. Niculescu, Silvère Bonnabel.

- PhD José Luis Avila Alonso, Leucémie Aigue Myéloblastique : Modélisation et Analyse de Stabilité, Defended July 2nd 2014. University Paris-Sud, STITS. Supervisor : Catherine Bonnet. Co-supervisors : Jean Clairambault and Silviu I. Niculescu.

- PhD in progress Walid Djema, Analysis of an AML model enabling evaluation of polychemio-therapies 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 Le Ha Vy Nguyen, H_∞ Stabilité et Stabilisation de diverses classes de systèmes fractionnaires et à retards, Defended December 9th 2014. University Paris-Sud, STITS. Supervisor: Catherine Bonnet.

9.2.3. *Juries*

- Catherine Bonnet was a rewiever of the Habilitation thesis of Lucie Beaudoin entitled 'Problèmes inverses et commande robuste de quelques équations aux dérivées partielles, Université Toulouse 3 Paul Sabatier, France, June 20th 2014.

- Frédéric Mazenc was a reviewer of the PhD thesis of Houda Thabet, entitled "Détection de défauts des systèmes non linéaires à incertitudes bornées continus", (Univerté de Bordeaux, December 2014).

- Frédéric Mazenc was a reviewer of the PhD thesis of Hassan Omran, entitled "Contribution à la commande de systèmes non linéaires sous échantillonnage apériodique", (Ecole Centrale de Lille, March 2014).

- Frédéric Mazenc was an invited member of the PhD thesis of José Avial, entitled "Leucémie Aigue Myéoblastique : Modélisation et Analyse de Stabilité", (université Paris-Sud soutenue au L2S, CNRS, July 2014).

- Sorin Olaru was a reviewer for John Anderson Sandoval Moreno's PhD thesis. The thesis was defended in November 2014, Gipsa-Lab, Univ. Joseph Fourier Grenoble.

9.3. Popularization

Catherine Bonnet has been a portrait in the exhibition *'Infinités Plurielles', Marie-Hélène Le Ny*

Alban Quadrat gave a scientific popularization talk entitled *Une sience du contrôle ou Qu'appelle-t-on théorie du contrôle en science ?* at the conference *Contrôle et Contrainte en Science-Fiction*, University of Picardie Jules Verne, Beauvais (France), organized by the department of Lettres, Langues, Arts et Sciences Humaines (FLASH), 23-25/04/2014.

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

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[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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[8] A. QUADRAT. *The fractional representation approach to synthesis problems: an algebraic analysis viewpoint. Part I: (Weakly) doubly coprime factorizations, Part II: Internal stabilization*, in "SIAM J. Control & Optimization", 2003, vol. 42, n° 1, pp. 266–299, 300–320

[9] A. QUADRAT. *On a general structure of the stabilizing controllers based on stable range*, in "SIAM J. Control & Optimization", 2004, vol. 42, n° 6, pp. 2264–2285

[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

Publications of the year

Doctoral Dissertations and Habilitation Theses

[11] L. H. V. NGUYEN. *Stability and stabilization of several classes of fractional systems with delays*, Paris-Sud XI, December 2014, https://hal.inria.fr/tel-01113945

Articles in International Peer-Reviewed Journals

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