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Project-Team DISCO

Dynamical Interconnected Systems in COmplex Environments

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

RESEARCH CENTER
Saclay - Île-de-France

THEME
Optimization and control of dynamic systems

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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.

2.2. Highlights of the Year

Frédéric Mazenc in June 2013 for his presentation of the paper was awarded by the *IEEE Control Systems Society* the *Best Presentation of Session Presenter*.

Sorin Olaru got the Best paper award at the 17th International Conference on System Theory, Control and Computing .
BEST PAPERS AWARDS :
[55] **Robust Interval Observers for Discrete-time Systems of Luenberger type in ACC**. F. MAZENC, T. DINH, S.-I. NICULESCU.
[52] **A Nonlinear State Feedback Control Approach for a Pantograph-Catenary System in ICSTCC 2013**. C. KOITI IDE, S. OLARU, P. RODRIGUEZ-AYERBE, A. RACHID.

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], [89], [113], [91], [94].

- 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. [101]). 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], [106].

- 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. Software and Platforms

5.1. OreModules

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

The OREMODULES package [92], based on the commercial Maple package Ore_algebra [93], 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 [100], [102] 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) [109], [108], [91] 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/.

A Mathematica version of the OREMODULES package is in development. It is being developed by Maris Tõnso (Institute of Cybernetics, University of Tallinn), Thomas Cluzeau (ENSIL, University of Limoges) and A. Quadrat within the PHC Parrot project CASCAC. The Mathematica version of the OREMODULES package is based on the implementation of Gröbner bases over Ore algebras available in the Mathematica HolonomicFunctions package developed by Christoph Koutschan.

5.2. Stafford

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

The STAFFORD package of OREMODULES [92] contains an implementation of two constructive versions of Stafford's famous but difficult theorem [124] 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 [119] 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 [124] have recently been made constructive in [121] (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: Alban Quadrat [correspondent], Anna Fabiańska [Univ. Aachen].

The QUILLEN-SUSLIN package [96] contains an implementation of the famous Quillen-Suslin theorem [123], [125]. 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 [96] (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: Alban Quadrat [correspondent], Thomas Cluzeau [ENSIL, Univ. Limoges].

The OREMORPHISMS package [95] of OREMODULES [91] 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://www-sop.inria.fr/members/Alban.Quadrat/OreMorphisms/index.html.

A Mathematica version of the OREMORPHIMS package is in development. It is being developed by Maris Tõnso (Institute of Cybernetics, University of Tallinn), Thomas Cluzeau (ENSIL, University of Limoges) and Alban Quadrat within the PHC Parrot project CASCAC. The Mathematica version of the OREMORPHIMS package is based on the implementation of Gröbner bases over Ore algebras available in the Mathematica HolonomicFunctions package developed by Christoph Koutschan.

5.5. JanetMorphisms

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

The JANETMORPHISMS package is dedicated to a new mathematic approach to quasilinear systems of partial differential equations (e.g., Burger's equation, shalow water equations, Euler equations of a compressible fluid) based on algebraic analysis and differential algebra techniques [90]. This package computes symmetries, first integrals of motion, conservation laws, study Riemann invariants... The JANETMORPHISMS package is based on the `Janet` package (http://wwwb.math.rwth-aachen.de/Janet/).

5.6. PurityFiltration

Participant: Alban Quadrat [correspondent].

The PURITYFILTRATION package, built upon the OREMODULES package, is an implementation of a new effective algorithm obtained in [30] which computes the purity/grade filtration [86], [87] of linear functional systems (e.g., partial differential systems, differential time-delay systems, difference systems) and equivalent block-triangular matrices. See Section 6.1. 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. This package will soon be available.

5.7. AbelianSystems

Participants: Alban Quadrat [correspondent], Mohamed Barakat [Univ. Kaiserslautern].

The ABELIANSYSTEMS package is an implementation of an algorithm developed in [30] for the computation of the purity/grade filtration [86], [87] in the powerful `homalg` package of GAP 4 dedicated to constructive homological algebra methods, and developed by Barakat (University of Kaiserslautern) and his collaborators (http://homalg.math.rwth-aachen.de/). This package both supersedes the existing PURITYFILTRATION package which uses the non-efficient Maple Gröbner basis computation (see Section 5.6), and the original `homalg` procedure which computes purity filtration by means of time-consuming spectral sequences. Using the `homalg` package philosophy, the ABELIANSYSTEMS package can be used for the computation of the purity filtration of objects in different constructive abelian categories such as coherent sheaves over projective schemes as demonstrated in the `homag` package called `Sheaves` (see http://homalg.math.rwth-aachen.de/).

5.8. SystemTheory

Participants: Alban Quadrat [correspondent], Thomas Cluzeau [ENSIL, Univ. Limoges], Markus Lange-Hegermann [Univ. Aachen], Mohamed Barakat [Univ. Kaiserslautern].

The SYSTEMTHEORY package is a `homalg` based package dedicated to mathematical systems. This package, still in development, will include the algorithms developed in the OREMODULES and OREMORPHISMS packages. It currently contains an implementation of the OREMORPHISMS procedures which handle the decomposition problem aiming at decomposing a module/system into direct sums of submodules/subsystems, and Serre's reduction problem aiming at finding an equivalent system defined by fewer unknowns and fewer equations.

5.9. YALTA

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

The YALTA toolbox is 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, [88] and [97]) and on classical continuation methods exploiting the particularities of the problem [98], [99]. 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/.

6. New Results

6.1. Equidimensional block-triangular representation of linear functional systems

Participant: Alban Quadrat.

In [30], it is shown that every linear functional system (e.g., PD systems, differential time-delay systems, difference systems) is equivalent to a linear functional system defined by an upper block-triangular matrix of functional operators: each diagonal block is respectively formed by a generating set of the elements of the system satisfying a purely i-codimensional system. Hence, the system can be integrated in cascade by successively solving (inhomogeneous) i-codimensional linear functional systems to get a Monge parametrization of its solution space [120]. The results are based on an explicit construction of the grade/purity filtration of the module associated with the linear functional system. This new approach does not use complex Grothendieck spectral sequence arguments as is done in the literature of modern algebra [86], [87]. To our knowledge, the algorithm obtained in [30] is the most efficient algorithm existing in the literature of non-commutative algebra. It was implemented in the PurityFiltration package developed in Maple (see Section 5.6) and in the `homalg` package of GAP 4 (see Section 5.7). Classes of overdetermined/underdetermined linear systems of partial differential equations which cannot be directly integrated by Maple can be solved using the PurityFiltration package.

6.2. Serre's reduction of linear functional systems and related problems

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

Given a linear multidimensional system (e.g., ordinary/partial differential systems, differential time-delay systems, difference systems), Serre's reduction aims at finding an equivalent linear multidimensional system which contains fewer equations and fewer unknowns. Finding Serre's reduction of a linear multidimensional system can generally simplify the study of structural properties and of different numerical analysis issues, and it can sometimes help solving the linear multidimensional system in closed form. The connection between Serre's reduction and the decomposition problem [94], which aims at finding an equivalent linear functional system which is defined by a block diagonal matrix of functional operators, is algorithmically studied in [41], [42]. Moreover, a characterization of isomorphic finitely presented modules in terms of certain inflations of their presentation matrices is obtained in [42]. This result yields a connection between a certain matrix completion problem and Serre's reduction [42].

6.3. Algorithmic study of linear PD systems and Stafford's theorems

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

In [121],[82], algorithmic versions of Stafford's results [124] (e.g., computation of unimodular elements, decomposition of modules, Serre's splitting-off theorem, Stafford's reduction, Bass' cancellation theorem, minimal number of generators) were obtained and implemented in the STAFFORD package [82]. In particular, we show how a determined/overdetermined linear system of partial differential equations with either polynomial, rational, formal power series or locally convergent power series coefficients is equivalent to a linear system of partial differential equations with at most two unknowns. This result is a large generalization of the cyclic vector theorem which plays an important role in the theory of linear ordinary differential equations.

6.4. Foundations of the behavioural approach

Participant: Alban Quadrat.

Within the algebraic analysis approach to behaviours [91], [113], in [34], we propose to consider a system not only as a behaviour $\mathrm{ext}^0_D(M, \mathcal{F})$ [107], where M is the finitely presented left D-module defined by the matrix defining the system and $\mathcal{F}$ the signal space, but as the set of all the $\mathrm{ext}^i_D(M, \mathcal{F})$'s, where $0 \leq i \leq n$, where n is the global dimension of D. In this new framework, using Yoneda product, the left D-homomorphims of M [94] and the internal symmetries of the behaviour $\mathrm{ext}^0_D(M, \mathcal{F})$ [94] are generalized to the full system $\{\mathrm{ext}^i_D(M, \mathcal{F})\}_{i=0,\ldots,n}$ In particular, a system-theoretic interpretation of the Yoneda product is given.

In [117], we study the construction of a double complex leading to a Grothendieck spectral sequence converging to the obstructions $\mathrm{tor}^i_D(N, \mathcal{F})$'s for the existence of a chain of successive parametrizations starting with the behaviour $\mathrm{ext}^0_D(M, \mathcal{F})$, where N is the Auslander transpose of M. These obstructions $\mathrm{tor}^i_D(N, \mathcal{F})$ can be studied by means of a long process starting with the $\mathcal{F}$-obstructions $\mathrm{ext}^j_D(\mathrm{ext}^k_D(N, D), \mathcal{F})$'s for the solvability of certain inhomogeneous linear systems defined by the algebraic obstructions $\mathrm{ext}^k_D(N, D)$'s measuring how far M is for being a projective left D-module. Hence, the algebraic properties of the left D-module M, defining the behaviour $\mathrm{ext}^0_D(M, \mathcal{F})$, and the functional properties of the signal space $\mathcal{F}$ can be simultaneously used to study the obstructions for the existence of a chain of successive parametrizations starting with the behaviour $\mathrm{ext}^0_D(M, \mathcal{F})$. These results can be used to find again the different situations studied in the literature (e.g., cases of an injective or a flat left D-module $\mathcal{F}$). Finally, setting $\mathcal{F} = D$, the above results can be used to find again the characterization of the grade/purity filtration of M by means of a Grothendieck spectral sequence. See Section 6.1 and [86], [87], [30].

Within the algebraic analysis approach to behaviours [91], [113], in [116], we explain how the concept of inverse image of a finitely presented left D-module M, defining the behaviour $\mathrm{ext}^0_D(M, \mathcal{F})$ [107], can be used to study the problem of characterizing the restriction of the behaviour $\mathrm{ext}^0_D(M, \mathcal{F})$ to a non characteristic submanifold of $\mathbb{R}^n$. In particular, we detail the explict construction of inverse images of left D-modules for standard maps.

6.5. Boundary value problems for linear ordinary integro-differential equations

Participants: Alban Quadrat, Georg Regensburger.

In [35], we study algorithmic aspects of linear ordinary integro-differential operators with polynomial coefficients. Even though this algebra is not noetherian and has zero divisors, Bavula recently proved in [85] that it is coherent, which allows one to develop an algebraic systems theory. For an algorithmic approach to linear systems theory of integro-differential equations with boundary conditions, computing the kernel of matrices is a fundamental task. As a first step, we have to find annihilators, which is, in turn, related to polynomial solutions. We present an algorithmic approach for computing polynomial solutions and the index for a class of linear operators including integro-differential operators. A generating set for right annihilators can be constructed in terms of such polynomial solutions. For initial value problems, an involution of the algebra of integro-differential operators also allows us to compute left annihilators, which can be interpreted as compatibility conditions of integro-differential equations with boundary conditions. These results are implemented in MAPLE based on the `IntDiffOp` and `IntDiffOperations` packages.

6.6. Noncommutative geometry approach to infinite-dimensional systems

Participant: Alban Quadrat.

In [112], [111], [110], it was shown how the fractional representation approach to analysis and synthesis problems developed by Vidyasagar, Desoer, Callier, Francis, Zames..., could be recast into a modern algebraic analysis approach based on module theory (e.g., fractional ideals, algebraic lattices) and the theory of Banach algebras. This new approach successfully solved open questions in the literature. Basing ourselves on this new approach, we explain in [114], [115] why the non-commutative geometry developed by Alain Connes is a natural framework for the study of stabilizing problems of infinite-dimensional systems. Using the 1-dimensional quantized calculus developed in non-commutative geometry and results obtained in [112], [111], [110], we show that every stabilizable system and their stabilizing controllers naturally admit geometric structures such as connections, curvatures, Chern classes, ... These results developed in [114], [115] are the first steps toward the use of the natural geometry of the stabilizable systems and their stabilizing controllers in the study of the important H_∞ and H_2-problems.

6.7. Stability analysis of fractional neutral systems with commensurate delays

Participants: Le Ha Vy Nguyen, Catherine Bonnet.

Fractional neutral systems with commensurate delays have chains of poles aymptotic to vertical lines. The case where the imaginary axis is an asymptotic one is interesting. Indeed, if the system has some chains of poles asymptotic to the imaginary axis, then the fact that all poles lie in the open left half-plane does not guarantee the H_∞-stability of the system.

This kind of systems was studied in [97], [104]. In [97], systems with single chains of poles asymptotic to the imaginary axis was considered and necessary and sufficient conditions for H_∞-stability were derived. Some particular systems with multiple chains have been examined in [104]. We have extended this year this study to more general systems with multiple chains of poles approaching the imaginary axis.

6.8. Stabilization of fractional neutral systems with commensurate delays

Participants: Le Ha Vy Nguyen, Catherine Bonnet.

We consider fractional neutral systems with commensurate delays which may have chains of poles asymptotic to vertical lines lying in the open left half-plane and have chains clustering the imaginary axis. Due to the latter, the system may possess infinitely many poles in the right half-plane. We prove that a class of rational fractional controllers cannot stabilize this kind of systems in the sense of H_∞ except in a simple case. For this case, thanks to the fractional PI controller given in [1], a parametrization of stabilizing controllers is derived [105].

6.9. Stabilization of MISO fractional systems with delays

Participants: Le Ha Vy Nguyen, Catherine Bonnet.

In order to yield the set of all the stabilizing controllers of a class of MISO fractional systems with delays by mean of Youla-Kucera 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 [103]. We have continued this year to search for explicit expressions of right coprime factorizations for some classes of systems [63].

6.10. Interval Observer

Participants: Frédéric Mazenc [correspondent], Thach Ngoc Dinh, Silviu Iulian Niculescu.

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

1) In [18], we have shown how interval observers can be constructed for nonlinear (and not Lipschitz) systems possessing a special triangular system.

2) The contributions [20] and [55] present a new major result for the design of interval observers for discete-time systems with input and output: it is explained how two classical Luenberger obsevers can be used, even in the absence of the positivity property as interval observer, provided two appropriate output, which compose the lower and the upper bound of the interval observer, are selected. In [19], coordinate transformations which change an arbitrary linear discrete-time system into a positive one and general nonlinear design of interval observers for nonlinear systems (satisfying a restricitive stability assumption) are proposed.

3) The paper [54] presents the first construction of continuous-discrete interval observer for linear continuous-time systems with discrete measurements. The importance in engineering applications of this result is clear: most of the time the measured variables are available at discrete instants only. The result relies on the design of changes of coordinates which transform a linear system into a nonnegative one, but the dynamic part of interval observers is not cooperative.

6.11. Reduction model approach: new advances

Participants: Frédéric Mazenc [correspondent], Michael Malisoff [Louisiana State University], Silviu Iulian Niculescu, Dorothé Normand-Cyrot [L2S, CNRS].

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 delay in the input.

1) We proposed in [25] a new construction of exponentially stabilizing sampled feedbacks for continuous-time linear time-invariant systems with an arbitrarily large constant pointwise delay in the inputs. Stability is guaranteed under an assumption on the size of the largest sampling interval. The proposed design is based on an adaptation of the reduction model approach. The stability of the closed loop systems is proved through a Lyapunov-Krasovskii functional of a new type, from which is derived a robustness result

2) The paper [59] presents several results pertaining to the stabilization with feedbacks given by an explicit formula of linear time varying systems in the case where there is a constant delay in the input. In addition, it establishes input-to-state stability with respect to additive uncertainties. As a particular case, we considered a large class of rapidly time varying systems and provided a lower bound on the admissible rapidness parameters. We illustrated our results using a pendulum model.

3) The paper [24], which is devoted to the original problem of stabilizing nonlinear systems with input with distributed delay, is actually not an extension of the reduction model approach, but it complements it and uses operators which have been inspired by those used in the classical context of the reduction model theory.

6.12. Neutral systems and integral equations

Participants: Frédéric Mazenc [correspondent], Hiroshi Ito [Kyushu Institute of Technology], Pierdomenico Pepe [Univ. of L'Aquila].

1) For nonlinear systems with delay of neutral type, we developped a new technique of stability and robustness analysis. It relies on the construction of functionals which make it possible to establish estimates of the solutions different from, but very similar to, estimates of ISS or iISS type. These functionals are themselves different from, but very similar to, ISS or iISS Lyapunov-Krasovskii functionals. The approach applies to systems which do not have a globally Lipschitz vector field and are not necessarily locally exponentially stable. We apply this technique to carry out a backstepping design of stabilizing control laws for a family of neutral nonlinear systems [21].

2) In a second paper [57], we extended the previous results to the problem of deriving stability and stabilizability conditions for nonlinear systems with delay interconnected with an integral equation via the construction of a Lyapunov-Krasovskii functional.

6.13. Nonlinear systems with delay

Participants: Frédéric Mazenc [correspondent], Michael Malisoff [Louisiana State University], Thach Ngoc Dinh.

We obtained new results on the robustness analysis of nonlinear systems belonging to a general family when they are globally stabilized by a state feedback corrupted by the presence of a delay and sampling [22], [58]. The result is based on the construction of a non-quadratic Lyapunov-Krasovskii functional.

In [23], a problem of state feedback stabilization of time-varying feedforward systems with a pointwise delay in the input is solved. The approach we adopted relies on a time-varying change of coordinates and Lyapunov-Krasovskii functionals. The result applies for any given constant delay, and provides uniformly globally asymptotically stabilizing controllers of arbitrarily small amplitude. The closed-loop systems enjoy input-to-state stability properties with respect to additive uncertainty on the controllers. The work was illustrated through a tracking problem for a model for high level formation flight of unmanned air vehicles.

6.14. Set theoretic fault detection and isolation

Participant: Sorin Olaru.

Fault-tolerant control theory is a well-studied topic but the use of the sets in detection, isolation and/or reconfiguration is rather tangential. Sorin Olaru together with his collaborators (and principally with F. Stoican) conducted a systematic analysis of the set-theoretic elements and devise approaches which exploit advanced elements within the field. The main idea is to translate fault detection and isolation conditions into those conditions involving sets. Furthermore, these are to be computed efficiently using positive invariance and reachability notions. Constraints imposed by exact fault control are used to define feasible references (which impose persistent excitation and, thus, non-convex feasible sets). Particular attention is given to the reciprocal influences between fault detection and isolation on the one hand, and control reconfiguration on the other. The recent results on this topic are gathered in the recent book [81].

A new result has been obtained by the use of controlled invariance for the separation of faulty/healthy invariant sets in the detection and isolation [32] based on the necessary and sufficent conditions of George Bitsoris.

In a series of recent papers [67], [68], [70], [69], the link between the interval observers and the invariant sets have been investigated by establishing a series of formal results on the limit behaviour with potential applications in the detection and isolation of actuators faults

6.15. Model Predictive Control: distributed formulations and collision avoidance problems

Participant: Sorin Olaru.

In [78], the mixt integer techniques have been analysed in the distributed model predictive control context, underlining the dependence of collision avoidance mechanism on the obstacle modeling and susequently on their treatement inside optimization-based control techniques as MPC (model predictive control). On the same topic of adversary consraints, a geometrical conditions has been establised in [71] for the local stabilization of a linear dynamics on a boundary of a forbidden region in the state space.

The theoretical developments from the last two years on the MPC design for multi-agent control problem led to the succesful application of receding horizon flight control for trajectory tracking of autonomous aerial vehicles [28]. In the same line or research, the predictive control for trajectory tracking and decentralized navigation of multi-agent formations has been presented in [29].

In [66] a Characterization of the Relative Positioning of Mobile Agents for Full Sensorial Coverage in an Augmented Space with Obstacles is presented in view of a MPC control design.

A predictive control-based algorithm for path following of autonomous aerial vehicles has been proposed in [65] to improve the previous trajectory tracking mechanism. The ultimate goal oof both schemes is to avoid the real-time infeasibility problems in MPC.

The distributed predictive control mechanisms have been used for the control of a four interconnected tanks benchmark [48], proving the versatility of a nonlinear Distributed MPC technique previously proposed by A. Grancharova.

In [62] the distributed Model Predictive Control of Leader-Follower Systems has been studied using an interior point method with efficient computations leading to simple tuning mechanisms for the cost functions and the terminal sets of the local MPC sub-problems.

6.16. Invariant sets in control

Participant: Sorin Olaru.

The longstanding research interest on the positive invaraince of a set with respect to the trajectories of the dynamical systems allowed recently the statement of explicit invariant approximation of the maximal robust positive invariant ser for LTI dynamics with zonotopic disturbances [51].

In the class of hybrid dynamical systems, explicit robustness and fragility margins for discrete-time linear systems with PWA control has been established in [64] by means of positive invariance arguments.

In [37] a series of new results on the linear constrained regulation problem have been presented by completing the classical results with the case of active constraints for the equilibrium point.

6.17. Optimization of mu-analysis parameterization

Participant: Guillaume Sandou [correspondent].

The robustness against parametric uncertainties can be studied using the structured singular value mu. In that case, a normalization of the uncertain parameters is performed, and the mu analysis provides the larger parallelepiped centered in the nominal and included in the stability domain. However, results depend on the initial normalization. In this study, the normalization is optimized so as to get the largest guaranteed stability domain. The corresponding problem being highly nonlinear, a metaheuristic method, Particle Swarm Optimization, is used for that purpose. An academic and a real life example, namely the pendulum in the cart problem, have been used to prove the viability of the approach.

6.18. Optimal weight tuning in Hinfinity loop-shaping with PSO considering time constraints

Participants: Guillaume Sandou [correspondent], Gilles Duc [Supélec, E3S], Philippe Feyel [Sagem].

Hinfinity loop-shaping controllers have proven their efficiency to solve problems based on complex industrial specifications. However, the tuning of the weighting filters is a time consuming task. This work deals with the use of metaheuristics optimization for this weighting filter tuning. Whereas this topic has already been investigated in lot of works, all of them assume a particular pole/zero/damping/pulse expression for the searched transfer function. But choosing the best weight structure is not trivial and may lead to suboptimal solutions for the design process. That is why, we propose to enhance the weight selection problem by relaxing the structure constraints of transfer functions. The developed methodology is tested, using a real industrial example and leads to satisfactory results.

6.19. mu-synthesis with dynamic D-Scalings using Quantum Particle Swarm Optimization

Participants: Guillaume Sandou [correspondent], Gilles Duc [Supélec, E3S], Philippe Feyel [Sagem].

This study proposes to revisit the mu-synthesis problem with a recent and efficient meta-heuristic called Quantum Particle Swarm Optimization (QPSO). This algorithm allows us to optimizing dynamics (or static) D-scalings without fitting them which leads to robust performance controllers. This method has been applied to an industrial problem and has been proven to be better than the classical D-K iteration method.

6.20. Stabilization of time-delay systems

Participants: Alban Quadrat, Arnaud Quadrat [SAGEM, MASSY].

In [118], [122], we study the stabilization problem of a linear system formed by a simple integrator and a time-delay system. We show that the stabilizing controllers of such a system can be rewritten as the closed-loop system defined by the stabilizing controllers of the simple integrator and a distributed delay system. This result is used to study tracking problems appearing in the study of inertially stabilized platforms for optical imaging systems. Moreover, an elementary proof for the parametrization [111] of all stabilizing controllers of a stabilizable plant – which does not necessarily admits doubly coprime factorizations – is given in [122].

6.21. A Stabilization problem in chemostats

Participants: Frédéric Mazenc [correspondent], Jérôme Harmand [LBE INRA, EPI MODEMIC].

We have considered the classical model of the chemostat (which is a bio-reactor) with one substrate, one species and a Haldane type growth rate function is considered. The input substrate concentration is supposed to be constant and the dilution rate is considered as the control. The problem of globally asymptotically stabilizing a positive equilibrium point of this system in the case where the measured concentrations are delayed and piecewise constant with a piecewise constant control is addressed. The result relies on the introduction of a dynamic extension of a new type. [56].

6.22. Control design for UAVs

Participants: Frédéric Mazenc [correspondent], Michael Malisoff [Louisiana State University].

In [14], we studied a kinematic model that is suitable for control design for high level formation flight of UAVs (Unmanned Aerial Vehicles). We designed controllers that give robust global tracking for a wide class of reference trajectories in the sense of the robustness notion called input-to-state stability. The control laws satisfy amplitude and rate constraints.

6.23. Modeling and control of Acute Myeloid Leukemia

Participants: José Luis Avila Alonso [correspondent], Annabelle Ballesta [BANG project-team], Frédéric Bonnans [COMMANDS project-team], Catherine Bonnet, Jean Clairambault [BANG project-team], Xavier Dupuis [COMMANDS project-team], Pierre Hirsch [INSERM Paris (Team18 of UMR 872) Cordeliers Research Centre and St. Antoine Hospital, Paris], Jean-Pierre Marie [INSERM Paris (Team18 of UMR 872) Cordeliers Research Centre and St. Antoine Hospital, Paris], Faten Merhi [INSERM Paris (Team18 of UMR 872) Cordeliers Research Centre and St. Antoine Hospital, Paris], Silviu Iulian Niculescu, Hitay Özbay [Bilkent University, Ankara, Turkey], Ruoping Tang [INSERM Paris (Team18 of UMR 872) Cordeliers Research Centre and St. Antoine Hospital, Paris].

In [75] we propose 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. The dynamics of the cell populations are governed by transport partial differential equations structured in age and by using the method of characteristics, we obtain that the dynamical system of equation can be reduced to two coupled nonlinear equations with four internal sub-systems involving distributed delays. Local stability conditions for a particular equilibrium point, corresponding to a positive cells, are derived in terms of a set of inequalities involving the parameters of the mathematical model. A parameter estimation of our model is being performed using biological data (Annabelle Ballesta).

We have also studied a coupled 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. The cell dynamics are modelled by nonlinear partial differential equations. The interconnection phenomenon between the healthy and cancer cells takes place on the re-introduction functions leaving the resting compartments to the proliferating compartments of both populations of cells at the first stage. For a particular healthy equilibrium point, locally stability conditions involving the parameters of the mathematical model are obtained [83], [84].

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 contract made by Alban Quadrat, Silviu Iulian Niculescu and Hugues Mounier (L2S, University Paris Sud).

8. Partnerships and Cooperations

8.1. Regional Initiatives

- DIGITEO Project (DIM LSC) ALMA

  Project title: Mathematical Analysis of Acute Myeloid Leukemia

  Decembrer 2010 - December 2013

  Coordinator: Catherine Bonnet

  Other partners: Inria Paris-Rocquencourt, France, L2S, France, INSERM, Cordeliers Research Center, France.

  Abstract: this project studies a model of leukaemia based on previous works by M. Adimy and F. Crauste (Lyon), with theoretical model design adjustments and analysis in J. L. Avila Alonso's Ph D thesis and experimental parameter identification initiated by F. Merhi, postdoc of Bang (Dec. 2010-Nov. 2011), working at St. Antoine Hospital (Paris) on biological experiments on leukaemic cells.
- DIGITEO Project (DIM Cancéropôle) ALMA2

  Project title: Mathematical Analysis of Acute Myeloid Leukemia - 2

  October 2011 - March 2013

  Coordinator: Jean Clairambault (Inria Paris-Rocquencourt)

  Other partners: Inria Saclay-Île-de-France, France, L2S, France, INSERM, Cordeliers Research Center, France.

  Abstract: This project has taken over the experimental identification part in St. Antoine Hospital, together with further model design with the postdoc of A. Ballesta (BANG). With this postdoc project have also been developed the theoretical and experimental - in leukaemic cell cultures - study of combined therapies by classical cytotoxics (anthracyclins, aracytin) and recently available targeted therapies (anti-Flt-3).
- 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) was submitted in 2013 and accepted. It will start in 2014 for a period of 4 years. Alban Quadrat is the local leader for Inria Saclay. For more details, see http://www.lias-lab.fr/perso/nimayeganefar/doku.php. Its main goal is to constructively study stabilities and stabilization problems of (nonlinear) multidimensional systems.

8.3. European Initiatives

8.3.1. Collaborations in European Programs, except FP7

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.

Program: PHC Aurora (Norway)

Project acronym: 28920SB

Project title: Connections between constrained control law synthesis and theory of positive dynamical systems

Duration: 2013

Coordinator: Sorin Olaru (French leader), Morten Hovd (Norwegian leader)

Other partners: NTNU Trondheim

Abstract: The project is constructed with two main scientific objectives: a) The (controlled) invariant set computation and their use in the stability analysis The main objective is the construction of invariant sets of reduced complexity in terms of generators (for example vertices in polyhedral/zonotopic sets). Such invariant sets are related to the positivity by the invariance of the positive orthant of a dual (comparison) state space. The existence of invariant sets will be subsequently linked through this comparison systems with the stability analysis of complex (large scale, interconnected, hybrid, delay-affected or nonlinear) dynamics. The results will be compared with the state of the art methods as for example those related to the feasible set description in Model Predictive Control related problems. b) Control design for constrained dynamical systems Once the invariance tools with manageable complexity are available, the respective set will be employed in the synthesis procedure as Lyapunov level sets. Practically this will lead to polyhedral Lyapunov functions type of constructions for which interpolation based techniques have recently been shown to be effective. Further, the robustness and the performance of the resulting closed-loop dynamics need to be adjusted in accordance with the choice of the interpolation factor. These control design degrees of freedom need to be adjusted with respect to positiveness or monotonicity requirements.

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

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

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).

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, Italy

Nonlinear delay systems interconnected with a differential-difference equation.

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 Initiatives

8.4.1. Inria International Partners

8.4.1.1. Informal International Partners

- UNICAMP, Sao Paulo, Brazil

- Kyushu Institute of Technology, Iizuka, Fukuoka, Japan

- Louisiana State University, Baton Rouge, USA

- University of California, San Diego, CA, USA

8.5. International Research Visitors

8.5.1. Visits of International Scientists

Within the PHC Parrot (Inria Saclay - Institute of Cybernetics, University of Tallinn), Ülle Kotta, Maris Tõnso and Juri Belikov visited the DISCO project (twice for a week).

Within the invited Professor Program of DIGITEO, Prof. Georges BiTSORIS visited the DISCO project and Supélec from January-July 2013 and Emilia Fridman visited the DISCO project in September 2013.

8.5.2. Visits to International Teams

Alban Quadrat was invited by the Mathematics department of the Universidad Nacional de Colombia Bogotá (Colombia) for two weeks, and at the Tempere University of Technology (Finland).

9. Dissemination

9.1. Scientific Animation

- Catherine Bonnet is a member of the IFAC Technical Committee 2.5 on Robust Control and of the IFAC Technical Committee 2.6 on Distributed Parameter Systems. She is also in the boards of the association *Femmes et Mathématiques* and of the consortium Cap'Maths. She has been the co-chair of the NOC and a member of IPC of the first IFAC Workshop on Control of Systems Modeled by Partial Differential Equations, Paris September 2013 and has co-organized the workshop Modeling and Analysis of Cancer Cells Dynamics, Paris June 2013 (ISSSMA 2013). She is a member of the organizing committee of the *Colloque en l'honneur d'Abdelhad El Jai* to be held 29-30 May 2014 in Ifrane, Marocco. She is a co-Editor of the book "Low Complexity Controllers for Time-Delay Systems" of the Springer Series *Advances in Dynamics and Delays*. She is co-organizer of the "Séminaire du Plateau de Saclay". She has co-organized with K. Morris (Univ of Waterloo) the session *Analysis and Control of Infinite-Dimensional Systems* at the SIAM CT13 Conference.

- Frédéric Mazenc was Associate Editor for the conferences 2014 American Control Conference, Portland, USA. and 52th IEEE Conference on Decision and Control, Florence, Italy, (2013). He is member of the Mathematical Control and Related Fields editorial board, member of the European Journal of Control editorial board and Associate Editor for the Asian Journal of control. He was member of the national organizing committee of 1st IFAC Worshop on Control of Systems Modeled by Partial Differential Equation, Paris 2013. He was member of the international program committee of the 2014 European Control Conference, Strasbourg, France, the 2013 IFAC Nolcos, Toulouse, France and the 5th IFAC International Workshop on Periodic Control Systems, Caen, France, 2013. He is evaluator for the National Agency for the Italian Evaluation of Universities and Research Institutes (ANVUR). He is evaluator for Partnershio Programme - Joint Applied Research Projects - PCCA of the Roumanian National Council for Development and Innovation. He was invited to the seminar of the Laboratoire d'Automatique, Ecole polytechnique Fédérale de Lausanne, Lausanne, Switzerland (13/03/2013 - 21/03/2013). He was invited to the seminar of the LAGEP, Université Claude Bernard, Lyon 1 in December 2013 (17/12/2013 - 20/12/2013).
- Alban Quadrat is an Associate Editor of the journal "Multidimensional Systems and Signal Processing", Springer. With Eva Zerz, he organized a special issue "Symbolic Methods in Multidimensional Systems Theory" for this journal (to appear in 2014). With Georg Regensburger, he organized an invited session "Algebraic and symbolic methods in mathematical systems theory" at the 5th Symposium on System Structure and Control (Grenoble, 4-6/02/2013). With Eva Zerz, he organized an invited session "Algebraic and behavioural approaches to multidimensional system theory" at the 8th International Workshop on Multidimensional Systems (nDS13), Erlangen, Germany (9-11/09/13). Moreover, they have also proposed two invited sessions "Algebraic methods and symbolic-numeric computation in systems theory" at the forthcoming 21st International Symposium on Mathematical Theory of Networks and Systems (MTNS), Groningen, the Netherlands (7-11/07/14). With Mohamed Barakat and Thierry Coquand, he organized a mini-workshop "Constructive homological algebra with applications to coherent sheaves and control theory" at Oberwolfach (12-18/5/2013). He was an International Programm Commitee member of the 8th International Workshop on Multidimensional (nD) Systems (nDS13), Erlangen (Germany) (9-11/09/13), and a National Organizing Commitee member of the 1st IFAC Workshop on Control Systems Modeled by Partial Differential Equations, IHP, Paris (France) (25-27/09/13). Finally, with Hugues Mounier (University of Orsay, L2S) and Sette Diop (CNRS, L2S), he organizes a seminar on algebraic systems theory at L2S (http://pages.saclay.inria.fr/alban.quadrat/Seminar.html).
- Alban Quadrat was a plenary speaker at the 5th International Workshop on Differential Algebra and Related Topics (DART V), Lille, France (24-26/06/13) and a semi-plenary speaker at the Colombian Congress of Mathematics, Barranquilla, Colombia (15-19/07/13). He was invited to give a talk at the University of Versailles (23/04/13), at the Centre Automatique et Systèmes (CAS), Mines ParisTech (20/06/13), at the Institute of Cybernetics of the University of Tallinn, Estonia (01/10/13), and at the Tampere University of Technology, Finland (24/10/13). Finally, he participated to the workshop Geometry and algebra of linear matrix inequalities, CIRM, Luminy (12-16/11/13).

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence : Le Ha Vy Nguyen, Applied Informatics in Physics, 16h, L2, Paris-Sud University

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

Licence : Sorin Olaru, Numerical Methods and Optimization, 24h, L2, SUPELEC, France

Licence : Sorin Olaru, Hybrid Dynamical Systems, 18h, L3, SUPELEC, France

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

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

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

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

Master : Guillaume Sandou, Multivariable control, 12h, M2, Evry University

9.2.2. Supervision

- PhD in progress José Luis Avila Alonso, Mathematical Analysis of Acute Myeloid Leukemia, December 31st 2011. University Paris-Sud, STITS. Supervisor : Catherine Bonnet. Co-supervisors : Jean Clairambault and Silviu Iulian Niculescu.
- PhD in progress: Thach Ngoc Dinh, Interval Observers and Delay Systems, December 2011. University Paris-Sud STITS. Supervisor: Frédéric Mazenc. Co-Supervisor: Silviu Iulian Niculescu, Silvère Bonnabel.
- PhD in progress Le Ha Vy Nguyen, H_∞ Stability and control of fractional delay systems, September 15th 2011. University Paris-Sud, STITS. Supervisor: Catherine Bonnet.
- PhD in progress Nikola Stankovic, Set-based control methods for systems affected by time-varying delay, September 30th 2010, University Paris-Sud, STITS. Defense: 20 November 2013. Supervisor: Sorin Olaru Co-Supervisor: Silviu Iulian Niculescu

9.2.3. Juries

Catherine Bonnet was an examiner member and President of the jury of the PhD Thesis of Hao Lu entitled ”Approximation and Applications of Distributed Delays”, INSA Lyon, 1st October 2013; and an examiner member of the jury of the PhD Thesis of Julien Chaudenson entitled ”Analyse de robustesse par contraintes intégrales quadratiques, application aux lanceurs spatiaux”, Supélec, 4 December 2013.

She was a member of the Recruiting Committee of the *Chargé de Recherche de 2ème classe* competition of Inria Saclay-Ile-de-France and in the Recruiting Committee of the *Maître de Conférences* competition at University Paris-Sud.

Alban Quadrat was the opponent of the PhD thesis “Robust Regulation for Infinite-Dimensional Systems and Signals in Frequency Domain” by Petteri Laakkonen, Tampere University of Technology, Finland (25/11/13), and the reviewer of the PhD thesis “Ring and Module Theoretic Properties of σ- PBW Extensions” by Milton Reyes Armando Villamil, Universidad Nacional de Colombia, Colombia (23/07/13).

9.3. Popularization

Catherine Bonnet spoke at the ”Cérémonie de remise des prix des Olympiades de Mathématiques, Ministère de l’éducation nationale, juin 2013. She gave a talk and met high school students groups at the event ”Sciences au Carrée” in the context of Fête de la Sciences, CNES, October 2013.

Alban Quadrat was invited to give a popularization talk on the development of ideas in mathematics and physics at the conference “Lieux de passage en Science-Fiction”, University of La Rochelle (France), Lettres, Langues, Arts et Sciences Humaines (FLASH), 11-13/04/13.

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