IN PARTNERSHIP WITH:
CNRS

Ecole supérieure d'électricité

Activity Report 2012

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
Modeling, Optimization, and Control of Dynamic Systems

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Project-Team DISCO

Keywords: Computer Algebra, Control Theory, Dynamic Networks, Nonlinear Control, Numerical Methods, Robust Control

The Disco team is located in Supelec.

Creation of the Project-Team: January 01, 2012 .

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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 for consequence an increased complexity of the behavior of the "total" system both in the presence and absence of feedback control loops.

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, develop new algorithms and implementations dedicated to these techniques.

2.2. Highlights of the Year

With Anja Korporal and Markus Rosenkranz, G. Regensburger got the *Distinguished software presentation* award at ISSAC 2012 (International Symposium on Symbolic and Algebraic Computation) for the MAPLE packages `IntDiffOp` and `IntDiffOperations` (see [17]).

3. Scientific Foundations

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], [85], [106], [87], [90].

- 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. [98]). 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], [31].
- 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.

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).

4.3. Energy Management

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

5. Software

5.1. OreModules

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

The OREMODULES package [88], based on the commercial Maple package Ore_algebra [89], 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 [97], [99] 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) [102], [101], [87] 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 [88] contains an implementation of two constructive versions of Stafford's famous but difficult theorem [114] 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 [109] 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 [114] have recently been made constructive in [112] (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 [93] contains an implementation of the famous Quillen-Suslin theorem [113], [115]. 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 [93] (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 [91] of OREMODULES [87] 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.

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 [86]. 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 [108] which computes the purity/grade filtration [82], [83] 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 [34] for the computation of the purity/grade filtration [82], [83] 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 [correspondent], Catherine Bonnet, André Fioravanti [UNICAMP].

The YALTA package 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, [84] and [95]) and on classical continuation methods exploiting the particularities of the problem [96], [14]. We have included this year a Pade2 approximation scheme as well as H_∞-stability properties. The package is freely available at http://team.inria.fr/disco/fr/software/.

6. New Results

6.1. Algorithmic study of linear functional systems

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

In [108], 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 [110]. 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 involved spectral sequence arguments as is done in the literature of modern algebra [82], [83]. To our knowledge, the algorithm obtained in [34] 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.

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. In [13], Serre's reduction problem is studied for underdetermined linear systems of partial differential equations with either polynomial, formal power series or analytic coefficients and with holonomic adjoints in the sense of algebraic analysis [82], [83]. These linear partial differential systems are proved to be equivalent to a linear partial differential equation. In particular, an analytic linear ordinary differential system with at least one input is equivalent to a single ordinary differential equation. In the case of polynomial coefficients, we give an algorithm which computes the corresponding linear partial differential equation.

The connection between Serre's reduction and the decomposition problem [90], which aims at finding an equivalent linear functional system which is defined by a block diagonal matrix of functional operators, is algorithmically studied in [92].

In [111], algorithmic versions of Statford's results [114] (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. 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 equivalently to a linear system of partial differential in 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.

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

Participants: Alban Quadrat, Georg Regensburger.

In [61], 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 [81] 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. Finally, system-theoretic interpretations of these results are given and illustrated on integro-differential equations.

In [78], we develop linear algebra results needed for generalizing the composition of boundary problems to singular ones. We consider generalized inverses of linear operators and study the question when their product in reverse order is again a generalized inverse. This problem has been studied for various kinds of generalized inverses, especially for matrices. Motivated by our application to boundary problems, we use implicit representation of subspaces via "boundary conditions" from the dual space and this approach gives a new representation of the product of generalized inverses. Our results apply to arbitrary vector spaces and for Fredholm operators, the corresponding computations reduce to finite-dimensional problems, which is crucial for our implementation for boundary problem for linear ordinary differential equations.

In collaboration with Li Guo and Markus Rosenkranz [77], we study algebraic aspects of integro-differential algebras and their relation to so-called differential Rota-Baxter algebras. We generalize this concept to that of integro-differential algebras with weight. Based on free commutative Rota-Baxter algebras, we investigate the construction of free integro-differential algebras with weight generated by a regular differential algebra. The explicit construction is not only interesting from an algebraic point of view but is also an important step for algorithmic extensions of differential algebras to integro-differential algebras (compare with the related construction and the implementation of integro-differential polynomials in [72]). In this paper, we review also the construction of integro-differential operators, the algorithms for regular boundary problems and a prototype implementation in the Theorema system.

In [11], we adapt our factorization technique for boundary problems to study ruin probabilities and related quantities in renewal risk theory. The analysis is based on boundary problems for linear ordinary differential equations (on the half bounded interval from zero to infinity) with variable coefficients and the corresponding factorization of Green's operators. With this approach, we obtain closed-form and asymptotic expressions for discounted penalty functions under the more realistic assumption that the premium income depends on the present surplus of the insurance portfolio.

6.3. Symbolic methods for developing new domain decomposition algorithms

Participants: Thomas Cluzeau [ENSIL, Univ. Limoges], Victorita Dolean [Univ. Nice - Sophia-Antipolis], Frédéric Nataf [CNRS, Paris 6], Alban Quadrat.

Some algorithmic aspects of systems of partial differential equations based simulations can be better clarified by means of symbolic computation techniques. This is very important since numerical simulations heavily rely on solving systems of partial differential equations. For the large-scale problems we deal with in today's standard applications, it is necessary to rely on iterative Krylov methods that are scalable (i.e., weakly dependent on the number of degrees on freedom and number of subdomains) and have limited memory requirements. They are preconditioned by domain decomposition methods, incomplete factorizations and multigrid preconditioners. These techniques are well understood and efficient for scalar symmetric equations (e.g., Laplacian, biLaplacian) and to some extent for non-symmetric equations (e.g., convection-diffusion). But they have poor performances and lack robustness when used for symmetric systems of partial differential equations, and even more so for non-symmetric complex systems (fluid mechanics, porous media, ...). As a general rule, the study of iterative solvers for systems of partial differential equations as opposed to scalar partial differential equations is an underdeveloped subject. In [76], we aim at building new robust and efficient solvers, such as domain decomposition methods and preconditioners for some linear and well-known systems of partial differential equations based on algebraic techniques (e.g., Smith normal forms, Gröbner basis techniques, D-modules).

6.4. Noncommutative geometry approach to infinite-dimensional systems

Participant: Alban Quadrat.

In [105], [104], [103], 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 [107] 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 [105], [104], [103], we show that every stabilizable system and their stabilizing controllers naturally admit geometric structures such as connections, curvatures, Chern classes, ... These results developed in [59] 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.

6.5. Stabilization of time-delay systems

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

In [60], we study the stabilization problem of a linear system formed by a simple integrator and a time-delay. We show that the stabilizing controllers of such a system can be be rewritten as the closed-loop system defined by the stabilizing controllers of the simple integrator and a distributed delay. This result is used to study tracking problems appearing in the study of inertially stabilized platforms for optical imaging systems.

6.6. Stabilization of MISO fractional systems with delays

Participants: Catherine Bonnet, Le Ha Vy Nguyen.

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 are derived in [51]. On the other hand, right coprime factorizations exist, and we have obtained explicit expressions for several particular cases of the studied systems.

6.7. Stability analysis of (fractional) neutral systems with commensurate delays

Participants: Catherine Bonnet, Andre Fioravanti [UNICAMP], Le Ha Vy Nguyen.

Neutral time-delay systems may have chains of poles asymptotic to the imaginary axis. As the chains approach the axis, some systems are H_∞-unstable even though all the poles are in the left-half plane. For a class of such systems, H_∞-stability conditions were presented in [84]. While systems with no more than one chain of poles asymptotic to a set of points on the imaginary axis were exhaustedly studied, only a particular case of systems with multiple chains were considered. We continue the stability analysis for more general cases of the latter systems. Primary results on pole locations are obtained [53], [52]. Based on these results, H_∞-stability conditions have also been derived.

6.8. Matrix Norm Approach for Control of Linear Time-Delay Systems

Participants: Catherine Bonnet, André Fioravanti [UNICAMP], José Claudio Geromel [UNICAMP], Silviu Niculescu.

In [94], we have treated the time-delay linear systems control design in the framework of complete and partial information. We were able to find linear controllers that increase the first stability window imposing at the same time that the delay-free system is stable using some properties about the norms of the state-space matrices. Our method treated the design problem by numeric routines based on Linear Matrix Inequalities (LMI) arisen from classical linear time invariant system theory coupled together with a unidimensional search. Both the state and output feedback design, were solved. We have this year tried our method on a 'high-dimensional' example for which no existing direct method would be computationnally feasible.

6.9. Interval observer

Participants: Frederic Mazenc, Silviu Niculescu, Thach Ngoc Dinh, Olivier Bernard [Inria - Sophia-Antipolis], Eric Walter [CNRS - L2S - Supelec], Michel Kieffer [CNRS - L2S - Supelec].

We made several progresses in the domain of the construction of state estimators called interval observers.
1) We presented the design of families of interval observers for continuous-time linear systems with a point-wise delay after showing that classical interval observers for systems without delays are not robust with respect to the presence of delays and that, in general, for linear systems with delay, the classical interval observers endowed with a point-wise delay are unstable. We proposed a new type of design of interval observers enabling to circumvent these obstacles. It incorporates distributed delay terms [26].

2) We considered a family of continuous-time systems that can be transformed through a change of coordinates into triangular systems. By extensively using this property, we constructed interval observers for nonlinear systems which are not cooperative and not globally Lipschitz. For a narrower family of systems, the interval observers possess the Input to State Stability property with respect to the bounds of the uncertainties [42], [21].

3) For the first time, we addressed in [44] the problem of constructing interval observers for discrete-time systems. Under a strong assumption, we proposed time-invariant interval observers for a very broad family of systems. In a second step, we have shown that, for any time-invariant exponentially stable discrete-time linear system with additive disturbances, time-varying exponentially stable discrete-time interval observers can be constructed. The latter result relies on the design of time-varying changes of coordinates which transform a linear system into a nonnegative one.

4) We considered continuous-time linear systems with additive disturbances and discrete-time measurements. First, we constructed a standard observer, which converges to the state trajectory of the linear system when the maximum time interval between two consecutive measurements is sufficiently small and there are no disturbances. Second, we constructed interval observers allowing to determine, for any solution, a set that is guaranteed to contain the actual state of the system when bounded disturbances are present [46].

6.10. New reduction model approach

Participants: Frederic Mazenc, Silviu Niculescu, Mounir Bekaik, Dorothee Normand-Cyrot [CNRS - L2S - Supelec], Claudio de Persis [Sapienza University of Rome], Miroslav Krstic [Univ. of California].

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

1) We proposed 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 [28], [50].

2) For linear systems with pointwise or distributed delays in the inputs which are stabilized through the reduction approach, we proposed a new technique of construction of Lyapunov-Krasovskii functionals. These functionals allow us to establish the ISS property of the closed-loop systems relative to additive disturbances [27], [49].

3) We proposed a solution to the problem of stabilizing nonlinear systems with input with a constant pointwise delay and state-dependent sampling. It relies on a recursive construction of the sampling instants and on a recent variant of the classical reduction model approach. The state feedbacks that are obtained do not incorporate distributed terms [43].

6.11. Analysis of neutral systems

Participants: Frederic Mazenc, Hiroshi Ito [Kyushu Institute of Technology].

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 [22], [45].

2) We extended the previous result to the problem of deriving the iISS property for dynamical networks with neutral, retarded and communication delay [41].

6.12. Hyperbolic systems

Participants: Frederic Mazenc, Christophe Prieur [GIPSA-Lab CNRS].

We considered a family of time-varying hyperbolic systems of balance laws. The partial differential equations of this family can be stabilized by selecting suitable boundary conditions. For the stabilized systems, the classical technique of construction of Lyapunov functions provides a function whose derivative along the trajectories of the systems may be not negative definite. In order to obtain a Lyapunov function with a negative definite derivative along the trajectories, we transform this function through a so-called "strictification" approach, which gives a time-varying strict Lyapunov function. It allows us to establish asymptotic stability in the general case and a robustness property with respect to additive disturbances of Input-to-State Stability type [32].

6.13. Time-varying systems with delay

Participants: Frederic Mazenc, Silviu Niculescu, Mounir Bekaik, Michael Malisoff [Departement of Mathematics - LSU].

1) We solved aproblem of state feedback stabilization of time-varying feedforward systems with a pointwise delay in the input. The approach 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 is illustrated through a tracking problem for a model for high level formation flight of unmanned air vehicles [48], [24].

2) We addressed the problem of stabilizing systems belonging to a family of time-varying nonlinear systems with distributed input delay through state feedbacks without retarded term. The approach we adopted is based on a new technique that is inspired by the reduction model technique. The control laws we obtained are nonlinear and time-varying. They globally uniformly exponentially stabilize the origin of the considered system. We illustrate the construction with a networked control system [25].

6.14. Positive invariance for time delay systems

Participants: Sorin Olaru [correspondent], Silviu Niculescu [CNRS (LSS)], Georges Bitsoris [University of Patras, Greece].

A new concept of positive invariance has been established in the original state space for discrete time dynamical systems. Furthermore, the necessary and sufficient algebraic condition for such properties have been derived allowing a direct test using basic linear programming arguments. In a recent work, the rigid positive invariance has been relaxed toward a cyclic invariant concept [18].

6.15. Predictive control for networked control systems

Participants: Sorin Olaru [correspondent], Silviu Niculescu [CNRS (LSS)], Warody Lombardi [INSA Lyon].

The work on the networked control system modeling lead to the establishement of a solid framework based on linear difference inclusion. Subsequently via set invariance and optimization based techniques, a design procedure has been proposed to deal with the real time constrained feedback control. Is worth to be mentioned that the robust feasibility and control performances are enforced via inverse optimality principles [19].

6.16. Reduced order H_∞-controllers synthesis with explicit constraints handling

Participants: Guillaume Sandou [correspondent], Gilles Duc [Suplec (E3S), Control Department], Mohamed Yagoubi [Ecole des Mines de Nantes].

Efficient dedicated methods have been developed for Hinfinity controller synthesis. However, such methods require translating the design objectives using weighting filters, whose tuning is not easy; in addition they lead to high order controllers which have to be reduced. Previous works have dealt with these two problems separately with the help of Particle Swarm Optimization: optimization of filter tunings for a full order synthesis and reduced order synthesis with fixed filters. In recent works, we have considered the solution to both problems in one shot. The constraints of the problem are explicitly taken into account in the synthesis problem, thanks to the use of Particle swarm optimization which does not require any specific expression for costs and constraints [63].

6.17. Robust optimization for energy management

Participants: Guillaume Sandou [correspondent], Philippe Dessante [Suplec (E3S), Energy Department], Marc Petit [Suplec (E3S), Energy Department].

The optimization of energy networks and the solution to Unit Commitment problems are one of the main collaborations between the Control and Energy Departments of Supelec. Robust optimization has been used to take into account the uncertainties which are observed on the consumer demand, the cost function, and the maximum capacity [66], [73].

6.18. Firefly optimization for the synthesis of controllers and the identification of systems

Participants: Guillaume Sandou [correspondent], Alfonso Goches Sanchez [Suplec (E3S), Control Department].

Firefly optimization is a new optimization algorithm which has appeared in 2009. This algorithm belongs to the class of metaheuristic algorithms. As such algorithms can optimized any cost and functions, firefly optimization has been tested for the optimization of PID controllers (with no reformulations of specifications) and the identification of nonlinear systems.

6.19. Receding horizon based controllers for the energy management in complex systems

Participants: Guillaume Sandou [correspondent], Sorin Olaru, Silviu Niculescu, Emmanuel Witrant [Gips-Lab, Grenoble].

The use of receding horizon based controllers is a good trend to extend the optimization results of a complex system in a closed loop framework. To prove the viability and the efficiency of the approach, several real life examples have been tested. Among them are the district heating networks and the mining ventilation system.

6.20. Particle Swarm Optimization for the optimization of feasibility domain volumes

Participants: Guillaume Sandou [correspondent], Mohamad-Taki Asghar [Suplec (E3S), Control Department].

It is a well-known fact that using mu-analysis for the computation of a guaranteed stability domain gives the largest hyper-rectangle included in the real stability domain (which is impossible to compute). However, the results strongly depend on the choice which has been made for the nominal system and the parameterization of the uncertainties. In this study, these choices are considered as optimization variables. The goal is now to find the best parameterization of the problem to get the largest stability domain. The optimization has been done using Particle Swarm Optimization.

6.21. Model of reaction networks

Participants: Georg Regensburger, Stefan Müller [RICAM, Linz].

In [100], we propose a notion of generalized mass action systems that could serve as a more realistic model for reaction networks in intracellular environments; classical mass action systems capture chemical reaction networks in homogeneous and dilute solutions. We show that several results of chemical reaction network theory carry over to the case of generalized mass action kinetics. Our main result gives conditions for the existence of a unique positive steady state for arbitrary initial conditions and independent of rate constants in this generalized setting. The conditions are formulated in terms of sign vectors (oriented matroids) of the stoichiometric and kinetic-order subspace and face lattices of related cones. We also give necessary and sufficient conditions for multistationarity, which is an important property in many applications, for example, in connection with cell differentiation.

6.22. Control of aircraft dynamics

Participants: Frederic Mazenc, Michael Malisoff [Departement of Mathematics - LSU], Aleksandra Gruszka [Departement of Mathematics - LSU].

We have worked on several models describing physical devices.

1) We studied a kinematic model that is suitable for control design for high level formation flight of UAVs [16], [40]. We designed controllers that give robust global tracking for a wide class of reference trajectories in the sense of input-to-state stability while satisfying amplitude and rate constraints on the inputs.

2) We studied feedback tracking problems for the planar vertical takeoff and landing (PVTOL) aircraft dynamics, which is a benchmark model in aerospace engineering. We provided a survey of the literature on the model. Then we constructed new feedback stabilizers for the PVTOL tracking dynamics. The novelty of our work is in the boundedness of our feedback controllers and their applicability to cases where the velocity measurements may not be available, coupled with the uniform global asymptotic stability and uniform local exponential stability of the closed loop tracking dynamics, and the input-to-state stable performance of the closed loop tracking dynamics with respect to actuator errors [15].

3) We solved a stabilization problem for an important class of feedback controllers that arise in curve tracking problems for robotics. Previous experimental results suggested the robust performance of the control laws under perturbations. Consequently, we used input-to-state stability to prove predictable tolerance and safety bounds that ensure robust performance under perturbations and time delays. Our proofs are based on an invariant polygon argument and a new strict Lyapunov function design [20].

6.23. Study of chemostat models

Participants: Frederic Mazenc, Michael Malisoff [Departement of Mathematics - LSU].

We provided a study of chemostat models in which two or more species compete for two or more limiting nutrients. First we considered the case where the nutrient flow and species removal rates and input nutrient concentrations are all given positive constants. In that case, we used Brouwer fixed point theory to give conditions guaranteeing that the models admit globally asymptotically stable componentwise positive equilibrium points. For cases where the dilution rate and input nutrient concentrations can be selected as controls, we used Lyapunov methods to prove that many different possible componentwise positive equilibria can be made globally asymptotically stable. We demonstrated our methods in simulations [23].

6.24. Modeling and control of Acute Myeloid Leukemia

Participants: José Luis Avila Alonso, 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 Niculescu, Hitay Özbay [Bilkent University, Ankara, Turkey], Ruoping Tang [INSERM Paris (Team18 of UMR 872) Cordeliers Research Centre and St. Antoine Hospital, Paris].

We have continued this year our work on modeling healthy and pathological hematopoiesis [36]. A. Ballesta has performed some experiments on patient fresh cell cultures in order to identify parameters of our model of acute myeloblastic leukemia (AML). To evaluate therapies, she also considered patient fresh cell cultures under anticancer drugs.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

As a part of his research actions in the Control Department of Supélec, Guillaume Sandou has numerous collaborations with Industry (Renault, Astrium, Sagem, Valeo). This may lead to relevant opportunities for the DISCO project.

Guillaume Sandou is in particular the head of the RISEGrid Institute (Resaerch Institut for Smarter Electric Grids), joint institute between Supelec and EDF R&D.

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, observateurs par intervalles, et systèmes à retard
Decembre 2011 - Decembre 2014
Coordinator: Frédéric Mazenc
Other partners: organisme, labo (pays) L2S, France, Mines-ParisTech, France.
Abstract: MOISYR is concerned with the creation of 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 setp, we shall extend our result to discrete time systems and to a specific class of continuous/discrete systems called Networked Control Systems.

8.2. National Initiatives

8.2.1. Competitivity Clusters

C. Bonnet and S. Olaru are members of the Multimodal Transportation section of the IRT SystemX

8.3. European Initiatives

8.3.1. Collaborations with Major European Organizations

Partner 1: Patras University, Greece

Constrained control systems (analysis and design)

Partner 2: Leeds University, United Kingdom

Analysis of delay systems

Partner 3: Bilkent University, Turkey

Modelling of cell dynamics

Partner 4: RWTH Aachen University, Germany

Mathematical systems theory, control theory, symbolic computation.

Alban

8.4. International Initiatives

8.4.1. Inria 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

8.4.2. Participation In International Programs

A. Quadrat has developed a strong collaboration with the members of the Lehrstuhl B für Mathematik and particularly with Daniel Robertz and Mohamed Barakat. He is a member of a PHC Procope developed in collaboration with the University of Limoges (XLIM) and the Lehrstuhl B für Mathematik, RWTH Aachen University (2011-2012) which aims at developing computer algebra aspects to mathematical systems theory and control theory.

A. Quadrat is developing a new collaboration with the team of Ülle Kotta, Control Systems Department, Tallinn University, Estonia, on symbolic computation and control theory. A PHC Parrot has just been accepted (2013-2015).

8.5. International Research Visitors

8.5.1. Visits of International Scientists

Mohamed Barakat (University of Kaiserslautern), Daniel Robertz (University of Aachen), and Thomas Cluzeau (University of Limoges) visited A. Quadrat within a PHC Procope.

George Bitsoris (University Patras, Greece), 1 Octobre - 30 Novembre 2012.

Hiroshi Ito, Kyushu Institute of Technology, Japan, 26 September - 8 October 2012.

Hitay Ozbay, Bilkent University, Turkey, 19 November - 23 November 2012.

9. Dissemination

9.1. Scientific Animation

+ C. Bonnet is a member of the IFAC Technical Committee 2.5 on Robust Control. She is also in the boards of the association *Femmes et Mathématiques* and of the consortium Cap'Maths. She was a member of the Program Committee of the Septième Conférence Internationale Francophone d'Automatique, CIFA 2012, Grenoble. She has been co-organizing the International Workshop 'Low-Order Controllers for Dynamical Systems' November 20th to November 22nd 2012, Supelec/L2S, Paris, France. She is co-chair of the NOC of the first IFAC Workshop on Control of Systems Modeled by Partial Differential Equations, Paris September 2013 and is co-organizing the workshop Modeling and Analysis of Cancer Cells Dynamics, Paris June 2013. She is co-organizer of the "Séminaire du Plateau de Saclay". She has been an evaluator for the French National Research Agency (ANR).
+ Frédéric Mazenc was Associate Editor for the conferences 2013 American Control Conference, Washington, 51th IEEE Conference On Decision and Control, Maui, Hawaii, USA, Septième Conférence Internationale Francophone d'Automatique, CIFA 2012, Grenoble. The 54th Chinese Control and Decision Conference, May 23-25, Taiyuan, China. He is a Member of the Mathematical Control and Related Fields editorial board. He is co-organizer of the 'Séminaire du Plateau de Saclay'. He was an invited speaker at the Workshop 'Observers and Controllers for Complex Dynamical Systems', November 20th to November 22nd 2012, Supelec/L2S, Paris, France. He is evaluator for the National Agency for the Italian Evaluation of Universities and Research Institutes (ANVUR). He is evaluator for Partnership Programme - Joint Applied Research Projects - PCCA of the Romanian National Council for Development and Innovation.
+ S. Olaru is a member of the program committee of the International Conference on System Theory, Control and Computing (2011, 2012) et CIFA 2012.

  He is also member of the IFAC Technical Committee 2.5 on Robust Control.
+ A. Quadrat is an Associate Editor of the journal "Multidimensional Systems and Signal Processing" (Springer). With Georg Regensburger, he organized an invited session "Algebraic and symbolic methods in mathematical systems theory" at the forthcoming "5th Symposium on System Structure and Control" (Grenoble, 4-6/02/2013). With Mohamed Barakat and Thierry Coquand, he also organized a forthcoming mini-workshop at Oberwolfach (12-18/5/2013). He proposed a PHC Parrot with the team of Ülle Kotta, Control Systems Department, Tallinn University, Estonia, which has just been accepted. He was invited to the seminar of the Equipe Calcul algébriques et systèmes dynamiques (CASYS), Laboratory of Jean Kuntzmann, University of Grenoble, 09/02, at the Sultan Qaboos University of Oman (10-18/06) where he gave a talk, at RWTH Aachen University (17-21/09), and at RICAM, Linz (16-18/12). Finally, with Hugues Mounier (University of Orsay, L2S) and Sette Diop (CNRS, L2S), he organized a seminar on algebraic systems theory at L2S (http://pages.saclay.inria.fr/alban.quadrat/Seminar.html).
+ G. Regensburger co-organized the session AADIOS (Algebraic and Algorithmic Aspects of Differential and Integral Operators Session) at ACA'12 (Sofia, 25-28/06). He was also a program committee of ADG 2012 (Edinburgh, 17-19/09) and publicity chair and web master of MACIS 2011 (Beijing, 19-21/10).

+ Guillaume Sandou is a member of the program committee of the 2013 IEEE Symposium on Computational Intelligence in Production and Logistics Systems, as a part of the 2013 IEEE Symposium Series on Computational Intelligence (Singapore)

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence : Le Ha Vy Nguyen, Applied Informatics in Physics, 16h, Universit Paris-sud

Licence : Le Ha Vy Nguyen,Ssignals, Systems, and Control, 38h, L3, Universit Paris-sud

Licence : Sorin Olaru, Numerical methods and optimization, 38heqTD, niveau L3, Suplec

Licence : Sorin Olaru, Signals and Systems, 12heqTD, niveau L3, Suplec

Licence : Guillaume Sandou, Signals and Systems, 63h, L3, Suplec

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

Master : Le Ha Vy Nguyen, Information Processing and Source coding, 12h M1, Universit Paris-sud

Master : Sorin Olaru, Hybrid Systems, 32heqTD, niveau M1, Suplec

Master : Sorin Olaru, Automatic Control, 55heqTD, niveau M1, Suplec

Master : Sorin Olaru, Embedded Systems, 18heqTD, niveau M2, Ecole Centrale Paris

Master : Guillaume Sandou, Automatic Control, 55h, M1, Suplec

Master : Guillaume Sandou, Numerical methods, 28h, M2, Suplec

Master : Guillaume Sandou, Optimization, 18h, M2, Suplec

Master : Guillaume Sandou, Modelling and system stability analysis, 6h, 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, NonLinear systems, 11h, M2, Ecole des Mines de Nantes

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. Supervisors : C. Bonnet, J. Clairambault and S.I. Niculescu.

PhD Mounir Bekaik, Commande des systèmes non linéaires à retard, October 2010-December 2012. University Paris-Sud, STITS. Supervisor: Frédéric Mazenc. Co-Supervisors: Silviu I. Niculescu Defence: 19 December 2012.

PhD in progress Thach Ngoc Dinh, Monotony, Interval Observers and Delays Systems, December 2011 . University Paris-Sud, STITS. Supervisor: Frédéric Mazenc. Co-Supervisors: Silviu I. 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: C. Bonnet.

PhD in progress Nikola Stankovic, Commande tolérante aux défauts pour systèmes à retard, September 30th 2010, University Paris-Sud, STITS. Supervisor: Sorin Olaru Co-Supervisor: Silviu I. Niculescu

HdR : Guillaume Sandou, Contribution au développement de méthodologies pour l'Automatique fondées sur l'optimisation, Universit Paris-Sud, June 2012

9.2.3. Juries

C. Bonnet was a member of the jury of Nadia Maï's HDR entitled "De la dimension infinie la dimension prospective : variations autour du paradigme d'optimalit", Universit de Nice, july 2012.

A. Quadrat was a referee of Debasattam Pal's PhD thesis entitled “Algebro-geometric analysis of multidimensional (n-D) systems”, IIT Bombay, and of Anja Korporal's PhD thesis entitled “Symbolic methods for generalized Green's operators and boundary problems”, University of Linz. Moreover, he was a member of the jury of Alexandre Benoit's PhD thesis entitled “Algorithmique semi-numérique rapide des séries de Tchebychev”, Ecole Polytechnique.

S. Olaru was a referee of Jennifer ZARATE FLOREZ's PhD thesis entitled ‘Etudes de commande par dcomposition-coordination pour l?optimisation de la conduite de valles hydro-lectriques ", GIPSA-LAB and of Mohamed Yacine LAMOUDI's PhD thesis entitled “Distributed model predictive control for energy management in building",GIPSA-LAB.

10. Bibliography

Major publications by the team in recent years

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Publications of the year

Articles in International Peer-Reviewed Journals

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