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2025 *Activity Report*

RESEARCH CENTRE: **Inria Paris Centre at Sorbonne University**

IN PARTNERSHIP WITH: **CNRS, Sorbonne Université, Université Paris Cité**

Project-Team

OURAGAN

Tools for resolutions in algebra, geometry and their applications

In collaboration with Institut de Mathématiques de Jussieu - Paris Rive Gauche

Project-Team OURAGAN

Creation of the Project-Team: 2019 May 01

Each year, Inria research teams publish an Activity Report presenting their work and results over the reporting period. These reports follow a common structure, with some optional sections depending on the specific team. They typically begin by outlining the overall objectives and research programme, including the main research themes, goals, and methodological approaches. They also describe the application domains targeted by the team, highlighting the scientific or societal contexts in which their work is situated. The reports then present the highlights of the year, covering major scientific achievements, software developments, or teaching contributions. When relevant, they include sections on software, platforms, and open data, detailing the tools developed and how they are shared. A substantial part is dedicated to new results, where scientific contributions are described in detail, often with subsections specifying participants and associated keywords. Finally, the Activity Report addresses funding, contracts, partnerships, and collaborations at various levels, from industrial agreements to international cooperations. It also covers dissemination and teaching activities, such as participation in scientific events, outreach, and supervision. The document concludes with a presentation of scientific production, including major publications and those produced during the year.

Keywords

Computer sciences and digital sciences

A5.10.1. – Design

A5.10.4. – Robot control

A6.2.6. – Optimization

A6.2.8. – Computational geometry and meshes

A6.4.1. – Deterministic control

A6.4.3. – Observability and Controlability

A6.4.4. – Stability and Stabilization

A6.4.5. – Control of distributed parameter systems

A6.4.6. – Optimal control

A8.1. – Discrete mathematics, combinatorics

A8.3. – Geometry, Topology

A8.4. – Computer Algebra

A8.5. – Number theory

A8.10. – Computer arithmetic

Other research topics and application domains

B5.6. – Robotic systems

B9.5.1. – Computer science

B9.5.2. – Mathematics

Contents

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2 Overall objectives

OURAGAN focuses on the transfer of computational algebraic methods to related fields (computational geometry, topology, number theory, etc.) and to some carefully chosen application domains (robotics, control theory, evaluation of the security of cryptographic systems, etc.). This requires to devote our efforts equally on the use (modeling, know-how) and on the development of new algorithms. The latest breakthrough developments and applications, where algebraic methods are currently decisive, remain few and very targeted. We wish to contribute to the efforts to increase the impact of algebraic methods but also the number of domains where the use of computational algebraic methods represent a significant added value. This transfer-oriented positioning does not imply to stop working on the algorithms, it simply sets the priorities.

An original aspect of OURAGAN's directions is to blend into an environment of fundamental mathematics, at the Institut de Mathématiques de Jussieu – Paris Rive Gauche (IMJ-PRG, UMR CNRS 7586), and to be cross-functional to several teams (Algebraic Analysis, Complex Analysis and Geometry, Number Theory to name only the main ones); this serves as our first source of transfer of computational know-how. The success of this coupling maintains the strong theoretical basis of the team. It measures objectively our transfer activity in the direction of mathematicians (in geometry, topology, number theory, algebraic analysis, etc.). It also consolidates the presence of Inria in scientific areas among the most theoretical ones.

Structuration of the project-team: We are organized around five Research axes; two are transversal (Axis 1 and 5), three are thematic (Axis 2, 3 and 4):

- (Axis 1): *Computable objects*, see Section 2.1.1;
- (Axis 2): *Algebraic analysis, Algebraic topology and Group theory*, see Section 2.1.2;
- (Axis 3): *Algorithmic Number Theory*, see Section 2.1.3;
- (Axis 4): *Geometry and Topology in low dimension*, see Section 2.1.4;
- (Axis 5): *Applications*, see Section 2.1.5.

The following sections will explain precisely the goals and methods of these axes. We now describe the interactions between the transverse axes and the thematic ones.

Computable objects in interaction: The first axis hosts the study and development of a common set of core elements of **basic theory and algorithms in algebra and geometry**. It is a transverse activity, because the problem tackled are informed by the needs of the other axes and the solutions proposed find applications within the other axes.

This core activity is the development and study of fundamental algebraic algorithms and objects that can be grouped in two categories: algorithms designed to operate on finite fields and algorithms running on fields of characteristic 0. We develop and mix two types of computational strategies: exact computations on the one hand and the use of approximate arithmetic (but with certified results) on the other hand. The originality of the project team lies in the interaction between the different axes and the problems tackled at this core level.

This intertwining of the different axes can be described with two examples of shared *computable objects*:

- Elimination theory for functional systems (Axis 2) is deeply connected with elimination theory for polynomial systems, with direct links to Gröbner bases and rewriting. Those are applied to effective study of polynomial system, used in Axis 4 and 5. Moreover, on a theoretical level, they are linked to Garside theory and Koszul duality (Axis 2). This establishes a theoretical continuum between the effective methods studied in algebraic topology and group theory (Axis 2), in partial differential equations (Spencer theory, Axis 2), low dimensional geometry and topology (Axis 4) and some applications (Axis 5).
- Performing efficient basic arithmetic operations in number fields is also a key ingredient to most of our algorithms, in number theory (Axis 3) as well as in topology in small dimension (Axis 4) or, more generally, in the use of roots of polynomial systems (e.g. Axis 5). In particular, finding good representations of number fields leads to the same computational problems as working with roots of polynomial systems by means of triangular systems (towers of number fields) or rational parameterizations (unique number field). Making any progress in one direction will probably have direct consequences for almost all the problems we want to tackle.

Beyond sharing objects, we also share in our team computational strategies, sometimes applied similarly to apparently different situations. For example, we have spread in our team *computational strategies*. Several general low-level tools are also shared such as the use of approximate arithmetic to speed up certified computations. Sometimes these can also lead to improvement for a different purpose (for example computations over the rationals, deeply used in geometry, can often be performed in parallel by combining computations in finite fields together with fast Chinese remaindering and modular evaluations).

As a simple example of this sharing of strategies, the use of approximate arithmetic is common to the work on LLL (used in the evaluation of the security of cryptographic systems), resolutions of real-world algebraic systems (used in our applications in robotics, control theory, and signal theory), computations of signs of trigonometric expressions used in knot theory or to certified evaluations of dilogarithm functions on an algebraic variety for the computation of volumes of representations in our work in topology, numerical integration and computations of L-functions.

One goal of this structuration of the project-team is that the collection of shared computational objects and strategies foster *transversal research directions.* For example, the study of the topology of algebraic curves (Axis 4) is a central subject for OURAGAN. For real curves, one describe a graph isotopic to the curve. For real and complex curves, one would like to compute certified pictures (in the complex case those are called amoebas). OURAGAN's tools (Axis 1) are very well adapted to tackle this topics.

It becomes interesting for OURAGAN when we realize that this study of the topology of complex algebraic curves is central in the computation of periods of algebraic curves (Axis 3) but also in the study of character varieties (Axis 4) as well as in control theory (Axis 2 and 5). Very few computational tools exist for that purpose and they mostly translate the problem in terms of algebraic real varieties (Axis 1); we can then recycle our work in computational geometry (Axis 4).

Another example is the computation of the Mahler measure of a bivariate polynomial. It is both a challenging problem in number theory (Axis 3) and a new direction in topology (Axis 4). The basic formula requires the study of points of moduli 1 of the associated curve, as in stability problems in control theory (Axis 2), and certified numerical evaluations of non-algebraic functions at algebraic points, as in many computations for L-functions (Axis 2). The links with L-functions are also deep on the theoretical side.

Application and transfer activities: As described above, our work is application-driven in the sense that the first goal is to allow the three thematic axes to progress. Nevertheless, the tools and objects developed for research on algorithmic number theory as well as in computational geometry apply quite directly on some selected connected challenging topics: **Security of cryptographic systems, Control theory, Robotics, Signal processing**. These directions of transfer and application form Axis 5. It is transversal by design: when choosing application topics and working on transfer activity, we will use the tools and computational strategies already available in the team, usually developed in Axis 1 and already used in one or several other Axis.

On the other hand, Axis 5 generates also research subjects to be studied in other axes. To take a concrete example, we are working, within the framework of Axis 5, on system stability problems, with or without delays. In this context, a line of research consists of studying the topology of amoebae, thus joining the concerns of Axis 4 (geometry in small dimensions) and Axis 1 (certified evaluation of non-algebraic functions on algebraic varieties) sharing widely shared with Axis 3. For adaptation to delay systems, the same ingredients are necessary after reformulation of the problem by calling on the know-how of Axis 2.

From our point of view, these applications serve for the evaluation of the general tools we develop when used in a different context, in particular their capability to tackle state-of-the-art problems.

We will describe more precisely the different applications and their links with the other axes along the text and in particular in Section 2.1.5.

2.1 Scientific ground

2.1.1 Research axis 1: Computable objects

An important axis in our activities consists in identifying and (efficiently) describing the different computational objects that emanate from the other research directions of the group. Henceforth, we develop a mathematical and computational framework to manipulate computational objects, relying mainly on algebraic and geometric tools. This framework considers objects, algorithms, and theoretical and practical developments that we already know that are omnipresent or the bottleneck of various problems: for example advanced techniques for computing with (real) algebraic numbers, efficient algorithms for solving structured polynomial systems, certification of roots of polynomials and polynomial systems. We also focus on theoretical developments that are required to study algebraic and geometric algorithms, for precise bit complexity bounds real solving and resultant computations, separation and zero bounds for polynomials and polynomial systems, worst and average bounds for the condition numbers for non-linear problems. Lastly, we develop efficient general-purpose software for polynomial (systems) solving and geometric computations that supports our theoretical developments. However, our framework could be easily adapted to handle the various problems at hand, for example dedicated state-of-the-art algorithms for solving polynomial systems in two or three variables, new efficient techniques for algebraic elimination based on structure and sparsity, dedicated state-of-the-art algebraic and geometric algorithms for curve manipulation in small and higher dimensions, and dedicated algorithms for classical problems of non-linear computational geometry, like arrangement, sampling, and convex hull computations.

Our overall goal is to provide the best theoretical guarantees but also efficient implementations that solve practical problems.

2.1.2 Research axis 2: Algebraic Analysis, Algebraic Topology and Group Theory

Algebraic analysis is a mathematical theory that studies linear systems of partial differential equations by means of rings of differential operators, algebraic geometry, module theory, sheaf theory, homological theory, etc. It nowadays plays an important role in different branches of mathematics.

Motivated by applications of algebraic analysis to engineering sciences such as mathematical systems theory, control theory, and signal processing, as well as to mathematical physics, the OURAGAN project-team has been continuing to develop its expertise towards the development of effective algebraic analysis methods, extend them to other classes of linear functional systems (e.g., differential time-varying delay systems, integro-differential systems), develop dedicated computer algebra packages, and applications to the above-mentioned fields of applications.

More generally, the OURAGAN project-team works on algorithmic questions on *algebraic structures* from group theory (mainly braid monoids and some generalisations), algebraic topology (mainly associative algebras), rings of functional operators, module theory, and homological algebra. The *rewriting methods* and the construction of *explicit resolutions* of these objects are at the core of the approach developed within the OURAGAN project-team. In particular, the same methods are used to study questions arising from fundamental mathematics to engineering sciences.

Methods coming from Garside theory (originating in combinatorial group theory), mixed with rewriting, are developed to achieve results on more complex algebraic structures: generalisations and variants of braid monoids, and operads and their algebras. Algorithmic elimination theories are investigated such as an instrinsic differential elimination theory based on Spencer's theory of partial differential equations, and an ordinary integro-differential elimination theory based on the coherence property of rings of ordinary integro-differential operators.

2.1.3 Research axis 3: Algorithmic Number Theory

Algorithms and number theory have a long common history, as illustrated by Henri Cohen's book "A Course in Computational Algebraic Number Theory". Our work fits into this context and can be implemented in recognized tools such as Magma. On the other hand, it is also linked to fields such as cryptography. To give an overview of the topics we cover, we describe below the current links between cryptography and number theory.

The frontiers between computable objects, algorithms (above section), computational number theory and applications to security of cryptographic systems are very porous. This union of research fields is mainly driven by the algorithmic improvement to solve presumably hard problems relevant to cryptography, such as computation of discrete logarithms, resolution of hard subset-sum problems, decoding of random binary codes and search for close and short vectors in lattices. While factorization and discrete logarithm problems have a long history in cryptography, the recent post-quantum cryptosystems introduce a new variety of presumably hard problems/objects/algorithms with cryptographic relevance: the shortest vector problem (SVP), the closest vector problem (CVP) or the computation of isogenies between elliptic curves, especially in the supersingular case.

2.1.4 Research axis 4: Geometry and Topology in low dimension

A structuring axis for our team revolves around applications in geometry and topology in low dimension. The aim of this axis is to leverage the shared computable object to obtain effective topological and geometric description of objects of mathematical interest. Following the application-oriented spirit of the team, we try and adapt the shared tools to contribute to the research around deep and interesting objects: general algebraic curves, knots, character varieties and geometric structures.

For a general algebraic curve, or more generally an algebraic variety, a very fundamental question is the description of the topology of its points: are there singularities? when trying to project the curve on a surface, what are the singularities of the projection? The answer to these questions then allows for certified approximated computations of the smooth part and a good understanding of the geometry of the curve. Several objects help answering these questions: amoebas for complex curves and varieties, discriminant subvarieties, construction of graphs isotopic to a curve, construction of meshes for algebraic varieties. A significant part of our work revolves around these fundamental objects. Applications of this work ranges from Robotics (see Research Axis 5) to computation of Mahler measures (see Research Axis 3). Among other cases, a specific attention has been given to polynomial knots, i.e. knots in $\mathbf{R}^3$ defined by the image of a polynomial embedding of $\mathbb{R}$.

Another long-standing field of work for our team is the computational study of character varieties and construction of geometric structures. The notion of a geometry carried by a manifold goes back almost two centuries. For example, it is known that a surface carries either the geometry of the sphere (the sphere itself) or of the plane (the torus) or of the hyperbolic plane (for higher genus surfaces). The modern notion of geometric structure has two faces. One is algebraic, through a representation of a surface group, the other one is geometric: the construction of the geometric structure compatible to the representation.

There is an existing and thriving international field of computational topology and hyperbolic geometry of 3-manifolds, with celebrated softwares as Regina and Snappy. The general approach to understanding the geometry carried by a 3-manifold consists in triangulating the manifold by tetrahedra; parametrize the algebraic object called the character variety; and for points in this character variety try to compatibly geometrize the triangulation (i.e. give shapes to the tetrahedra that glue together nicely).

In a continued effort for more than 10 years, members of our team contribute to the expansion of this field beyond the usual case of real hyperbolic geometry. It involves computational geometric tools for triangulations, algebraic tools such as those developed in our set of computable objects for describing the character variety, and theoretical geometric tools for the last step. Further study of the character varieties, such as the volume function defined on it, necessitates other tools shared by our team: certified numerical computations for example.

2.1.5 Research axis 5: Applications

We develop effective algebraic, and symbolic-numeric methods dedicated to problems studied in cryptography, robotics, control theory and signal processing. Our main keyword is *certification* : the methods must be conceptually infallible (able to solve the problem without unverifiable assumptions or returns a clear message) and able to keep track on uncertainty on the input (for example manufacturing errors).

In cryptography, applications are part of the theoretical problems to be studied and their description can directly be found in section 2.1.3.

In robotics, we follow some of the directions proposed by Jean-Pierre Merlet, in particular the use of interval analysis, and we combine them with pure algebraic objects such as discriminant varieties.

At the design level, we focus on parallel manipulators, which includes the study of direct and inverse kinematics problems, path planning, with and without parameters, with or without error considerations on the design parameters. At a second level, the study and use of such mechanisms for dedicated tasks meet our work on control theory.

For control theory and signal processing, we combine methods of algebraic analysis, algebraic geometry, and computer algebra to study analysis and synthesis problems such as the effective study of structural properties of linear functional systems, equivalence problems, symbolic-numeric methods for stability analysis and robust stabilization problems for multidimensional systems and infinite-dimensional systems (e.g., differential time-delay systems, partial differential systems), as well as for parameter estimation, demodulation problems, and geo-localization problem. The kernel of the methods used for this axis is the same as the one for robotics problems.

3 Research program

3.1 Research axis 1: Computable objects

This research axis must remain quite free to allow easy adaptations *on demand* to the needs expressed in the other axis.

However, the evaluation period was partially devoted to select and model several problems in order to find a formulation on which existing algorithms from computer algebra can act efficiently. In the next four years one of our goals will be to come back to the development of these tools keeping track of these numerous experiences. For example, we are currently working on new algorithms for solving zero-dimensional systems (general as well as for systems with particular properties).

Another objective is the consolidation and generalization of algorithms of general interest but used in a particular context in the evaluation period, such as those used in control theory for computing L^∞ norms as well as for the solvers dedicated to testing the stability of systems (with specific constraints on the roots). In particular, large efforts have been made during the evaluation period on continuation methods (for example for path planning in robotics) as well as for systems with uncertainties, these computational strategies for certified computations with uncertainties will be further developed in the next four years.

We will also concentrate on the (certified) evaluation of non algebraic function on algebraic varieties (physical quantities, amobeas, etc.). In particular, some collaborators of the project did make a strong link between the study of amobeas and stabilization problems in control theory and possibly the polydisk nullstellensatz.

Obviously some recent fundamental subjects such as solving univariate polynomials with coefficients in a multiple extensions will be further developed.

3.2 Research axis 2: Algebraic analysis, algebraic topology and group theory

In the direction of algebraic analysis, we want to further develop the effective study of rings of ordinary integro-differential and delay operators, produce a dedicated symbolic package, and study their applications to mathematical systems theory and control theory. Within the framework of C. Pinto's Ph.D, we plan to finish the development of an effective proof of the coherence property of the ring of integro-differential operators with polynomial coefficients. This proof will yield an algorithmic elimination theory, and thus, an effective algebraic analysis approach for integro-differential linear systems. We shall continue the algorithmic study of rings of integro-differential-delay operators, first with constant delay and then with time-varying delay, and their applications in control theory (e.g., system equivalences, predictors, stabilization). Finally, we shall further continue our effective sudy of Spencer's theory. The effective computation of Janet and Spencer sequences (two canonical resolutions) and Koszul-Tate resolutions will be studied and implemented.

These resolutions play a role in mathematical physics and engineering sciences [82, 83]. We shall develop a dedicated package to Spencer's approach and its applications to mathematical physics.

In the algebraic topology / group theory direction, we plan to continue the development of algorithmic tools for the computation of normal forms and resolutions of braid monoids and generalisations. Our motivation is to contribute, on the algorithmic side, to the progress around two important open problems in group theory: the word problem and the $K(\pi, 1)$ conjecture for Artin groups [74]. On the theoretical side, the main effort is a progressive generalisation of known normalisation tools (rewriting, Garside theory, multifractions, etc.) and known resolutions (mostly Anick [54], Garside [67] and Dehornoy-Lafont [68]) to new classes of examples: dual Artin monoids, dual monoids of well-generated complex reflection groups, submonoids of welded braids groups and surface braid groups (collaborations with Najib Idrissi and Muriel Livernet, IMJ-PRG, project with Owen Garnier, Amiens). On the practical side, we will progressively enhance the Julia library Garside.jl to include the new tools we develop (interaction with Jean Michel, IMJ-PRG). Other long-term objectives include: new applications to operads and their algebras (with Najib Idrissi); a new completion algorithm mixing rewriting and Garside theory (with Matthieu Picantin, IRIF); a better combinatorial understanding of the algebraic structure of strict higher categories (with Marcelo Fiore, Cambridge); an interpretation of known normal forms for quantum circuits using Garside theory (project with Julien Ross, Dalhousie).

Finally, to foster new connections inside the research axis (and beyond), we plan to create a working group on the different elimination/normalisation theories used within OURAGAN to study various algebraic structures: commutative and noncommutative Gröbner bases, Janet bases, Spencer theory, rewriting, Garside theory, collapsing schemes, etc.

3.3 Research axis 3: Algorithmic Number Theory

Cathy Swaenepoel joined OURAGAN in autumn 2023. She mainly studies the representation of prime numbers and other interesting sequences in number systems, with techniques coming essentially from Analytic Number Theory and Harmonic Analysis. She has obtained results both in the context of integers and in finite fields. For instance, she estimated the number of prime numbers with prescribed digits on a positive (explicit) proportion of positions in their digital expansion (in any base $b \geq 2$). Her results show that the digits of prime numbers "behave" like independent random variables, which may have implications in Cryptography. Besides theoretical results, she carried out some machine experiments and developed more efficient algorithms to count primes whose digits satisfy certain properties, which allowed us to contribute to the On-line Encyclopedia of Integer Sequences (OEIS).

The development of secure and efficient cryptographic systems leads to many questions about the representation of prime numbers in various number systems. Such questions arise, for example, in the study of polynomial modular number systems (PMNS), which are studied within the OURAGAN team, in particular by Jean Claude Bajard. Collaboration with Cathy Swaenepoel and other interested parties could provide answers and even open up new avenues. In addition, the techniques of analytic number theory and harmonic analysis can be very useful for studying the pseudo-random nature of sequences of a theoretical nature and for evaluating the complexity of algorithms.

We have also initiated fruitful collaborations with other IMJ-PRG members in the number theory team. Pascal Molin has been recently involved in a project around conjectures on modular forms with Loïc Merel, which raises interesting algorithmic issues and requires to push some computations on number fields and Galois representations beyond their current software limits. Also Pierre Charollois and Nicolas Bergeron seem to have unveiled a very explicit correspondance between degree 3 number fields and modular functions. This conjectural work asks for enormous computational verifications in many directions. Pierre Morain just started a PhD involving rigorous computation of transcendental functions analogous to theta quotients, a project directly inspired by these conjectures. We anticipate that this momentum will get stronger in the next years.

3.4 Research axis 4: Geometry and Topology in low dimension

A particular interesting tool to study the geometric structure is a notion of *generalized Hilbert metric*, that we introduced in [72]. This notion is a generalization to complex numbers of a classical notion of real projective geometry. This effort integrates, and even is central, in a newly funded ANR project HilbertXField, comprising mainly researchers at IMJ-PRG, Institut Fourier (Grenoble) and the Inria TROPICAL team at Saclay, especially researchers of our team or important collaborators (Deraux, Falbel, Guilloux, Will). The work around this project will be the major effort on the geometric structure side of our team. This represents a shift of focus: the notion of low dimension is less important, and new applications, e.g. to linear programming, are expected.

We plan to continue our work on (low dimensional) computational geometry by considering the computation of convex hull of curves in the space. Besides its theoretical importance, the problem has direct application in (convex) optimization in 2 and 3 variables. We aim for efficient algorithms to compute the convex hull but also for efficient representation of the output that will allows to perform further operations, e.g., membership, volume computations, etc. Such a study requires dedicated algorithms for manipulating (possible overdetermined) systems of polynomial equalities and inequalities in 2 and 3 variables. Partial results have already emerged from the work of C. Katsamaki, F. Rouillier, and E. Tsigaridas. Using our expertise in certified drawing of polynomial curves and knots, we intend to develop tools for certified drawing and identification of knot diagrams when given by a smooth polynomial curve, notably around P.V. Koseleff and E. Tsigaridas. Moreover, we intend to leverage these tools to develop certified algorithms for plotting and describing amoebas of complex curves and algebraic varieties. It should be mentioned that algorithms for these goals do exist, but are not certified and indeed may give flawed answers on some entries. Preliminary works have been done around A. Guilloux and F. Rouillier.

3.5 Research axis 5: Applications

OURAGAN's activities in control theory, robotics and geolocalization are all grouped in a subproject named PACE in collaboration with Safran Electronic and Defense. In practice, this means that a particular highlight will be set on these subjects in the future, with the help of new part-time collaborators from Safran Defense & Electronics and some recurrent specific help from Inria. In the direction of control theory, using methods of algebraic, projective and noncommutative geometries, we plan to develop (effective) geometrical interpretations and reformulations of the robust (H^∞) control theory. In the direction of signal processing, the study of geolocalization problems will be continued because it concerns one of the axes of the future collaboration with Safran Defense & Electronics. Finally, using our previous results, the study of the demodulation problems, appearing in gearbox vibration analysis − problems still of interest for Safran Tech − will be finalized by considering the underlying polynomial optimization problem.

4 Application domains

4.1 Security of cryptographic systems

The study of the security of asymmetric cryptographic systems comes as an application of the work carried out in algorithmic number theory and revolves around the development and the use of a small number of general purpose algorithms (lattice reduction, class groups in number fields, discrete logarithms in finite fields, . . .). For example, the computation of generators of principal ideals of cyclotomic fields can be seen as one of these applications since these are used in a number of recent public key cryptosystems.

The cryptographic community is currently very actively assessing the threat coming for the development of quantum computers. Indeed, such computers would permit tremendous progress on many number theoretic problems such as factoring or discrete logarithm computations and would put the security of current cryptosystem under a major risk. For this reason, there is a large global research effort dedicated to finding alternative methods of securing data. For example, the US standardization agency called NIST has recently launched a standardization process around this issue. In this context, OURAGAN is part of the competition and has submitted a candidate (which has not been selected) [53]. This method is based on number-theoretic ideas involving a new presumably difficult problem concerning the Hamming distance of integers modulo large numbers of Mersenne.

4.2 Robotics

Algebraic computations have tremendously been used in Robotics, especially in kinematics, since the last quarter of the 20th century [75]. For example, one can find algebraic proofs for the 40 possible solutions to the direct kinematics problem [80] for steward platforms and companion experiments based on Gröbner basis computations [73]. On the one hand, hard general kinematics problems involve too many variables for pure algebraic methods to be used in place of existing numerical or semi-numerical methods everywhere and everytime, and on the other hand, global algebraic studies allow to propose exhaustive classifications that cannot be reached by other methods,for some quite large classes.

Robotics is a long-standing collaborative work with LS2N (Laboratory of Numerical Sciences of Nantes). Work has recently focused on the offline study of mechanisms, mostly parallel, their singularities or at least some types of singularities (cuspidals robots [89]).

For most parallel or serial manipulators, pose variables and joints variables are linked by algebraic equations and thus lie an algebraic variety. The two-kinematics problems (the direct kinematics problem - DKP- and the inverse kinematics problem - IKP) consist in studying the preimage of the projection of this algebraic variety onto a subset of unknowns. Solving the DKP remains to computing the possible positions for a given set of joint variables values while solving the IKP remains to computing the possible joints variables values for a given position. Algebraic methods have been deeply used in several situations for studying parallel and serial mechanisms, but finally their use stays quite confidential in the design process. Cylindrical Algebraic Decomposition coupled with variable's eliminations by means of Gröbner based computations can be used to model the workspace, the joint space and the computation of singularities. On the one hand, such methods suffer immediately when increasing the number of parameters or when working with imprecise data. On the other hand, when the problem can be handled, they might provide full and exhaustive classifications. The tools we use in that context [65, 64, 76, 78, 77] depend mainly on the resolution of parameter-based systems and therefore of study-dependent curves or flat algebraic surfaces (2 or 3 parameters), thus joining our thematic *Computational Geometry*.

4.3 Control theory

Certain problems studied in mathematical systems theory and control theory can be better understood and finely studied by means of algebraic structures and methods. Hence, the rich interplay between algebra, computer algebra, and control theory has a long history.

For instance, the first main paper on Gröbner bases written by their creators, Buchberger, was published in Bose's book [55] on control theory of multidimensional systems. Moreover, the differential algebra approach to nonlinear control theory (see [70, 69] and the references therein) was a major motivation for the algorithmic study of differential algebra [56, 71]. Finally, the behaviour approach to linear systems theory [90, 81] advocates for an algorithmic study of algebraic analysis. More generally, control theory is porous to computer algebra since one finds algebraic criteria of all kinds in the literature even if the control theory community has a very few knowledge in computer algebra.

OURAGAN has a strong interest in the computer algebra aspects of mathematical systems theory and control theory related to both functional and polynomial systems, particularly in the direction of robust stability analysis and robust stabilization problems for multidimensional systems [55, 81] and infinite-dimensional systems [66] (such as differential time-delay systems).

Let us shortly state a few points of our recent interests in this direction.

In control theory, stability analysis of linear time-invariant control systems is based on the famous Routh-Hurwitz criterion (late 19th century) and its relation with Sturm sequences and Cauchy index. Thus, stability tests were only involving tools for univariate polynomials [79]. While extending those tests to multidimensional systems or differential time-delay systems, one had to tackle multivariate problems recursively with respect to the variables [55]. Recent works use a mix of symbolic/numeric strategies, Linear Matrix Inequalities (LMI), sums of squares, etc. But still very few practical experiments are currently involving certified algebraic computations based on general solvers for polynomial equations. We have recently started to study certified stability tests for multidimensional systems or differential time-delay systems with an important observation: with a correct modelization, some recent algebraic methods – derived from our work in algorithmic geometry and shared with applications in robotics – can now handle previously impossible computations and lead to a better understanding of the problems to be solved [61, 62, 63]. The previous approaches seem to be blocked on a recursive use of one-variable methods, whereas our approach involves the direct processing of the problem for a larger number of variables.

The structural stability of n-D discrete linear systems (with $n \geq 2$) is a good source of problems of several kinds ranging from solving univariate polynomials to studying algebraic systems depending on parameters.

For instance, we show [57, 62, 63] that the standard characterization of the structural stability of a multivariate rational transfer function (namely, the denominator of the transfer function does not have solutions in the unit polydisc of $\mathbb{C}^n$) is equivalent to deciding whether or not a certain system of polynomial equations has real solutions. The use state-of-the-art computer algebra algorithms to check this last condition, and thus the structural stability of multidimensional systems has been validated in several situations from toy examples with parameters to state-of-the-art examples involving, e.g. the resolution of bivariate systems [60, 59].

The rich interplay between control theory, algebra, and computer algebra is also well illustrated with our recent work on robust stabilization problems for multidimensional and finite/infinite-dimensional systems [58, 84, 86, 85, 87, 88].

5 Social and environmental responsibility

The number of plane trips made by the team members is probably below the average of researchers in Computer Science, possibly a little above the average of researchers in fundamental mathematics.

The frequency of renewal of our machines respects the new rules imposed by Inria, we also have common utility servers.

6 Highlights of the year

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7 Latest software developments, platforms, open data

2025 was a year of intensive development for the new "PACE" library, implemented entirely in Julia mostly by Christina Kastamaki with the participation of Fabrice Rouillier.

The development is divided into several layers:

- Interfaces with existing C libraries (RS, AnewDesC, MPFI)
- New C libraries directly accessible from Julia (LACE), intended to eventually replace RS with more modern variants (multi-threading, SIMD, new algorithms)
- Julia libraries (DiscriminantVariety.jl, RationalUnivariateRepresentation.jl)
- Application libraries dedicated to robotics and control theory
- interfaces for Matlab and Maple

In 2025, Antonin Guilloux developped FAMEDexploration, a computational approach to verifying specific cases of longstanding conjecture in the realm of Quantum Invariants of Knots. For the specific version we explore, the Andersen-Kashaev volume conjecture, we are able to extend the proven cases of the conjecture from a few examples to 40 thousands. It is based on a combinatorial approach by Ben Aribi and Wong. It illustrates the pertinence of the choice of the team OURAGAN to sit firmly inside IMJ-PRG: Ben Aribi is a member of IMJ-PRG and this achievment has been possible because we were the go-to person to explore computational approaches to theoretical results. These experiments are used in a scientific contribution submitted for publication.

Pascal Molin is involved in a large computational effort to experiment on a web of new conjectures developped by Merel and Lecouturier (both in the number theory project team at IMJ-PRG), and which amounts to seek for algebraico-numerical invariants hidden in values of twisted L functions. Several computational limits related to modular forms, L functions and number field arithmetic have to be pushed in order to compute examples where the predicted phenomena should occur. The preprint https://hal.science/hal-05146892 is a first step in this direction: this work is also an achievement in the algorithmics of modular forms for it changes the complexity of the computation of their Fourier expansion from quadratic to quasi-linear. A striking fact is that when the modular forms correspond to elliptic curves of small conductor the implementation even beats those devised for cryptographic applications.

7.1 Latest software developments

7.1.1 A NewDsc

Name: A New Descartes

Keyword: Scientific computing

Functional Description: Computations of the real roots of univariate polynomials with rational coefficients.

URL: https://anewdsc.mpi-inf.mpg.de

Contact: Fabrice Rouillier

Partner: Max Planck Institute for Software Systems

7.1.2 Catex

Keywords: LaTeX, String diagram, Algebra

Functional Description: Catex is a Latex package and an external tool to typeset string diagrams easily from their algebraic expression. Catex works similarly to Bibtex.

URL: https://plmlab.math.cnrs.fr/guiraud/catex

Contact: Yves Guiraud

Participant: an anonymous participant

7.1.3 Cox

Keywords: Computer algebra system (CAS), Rewriting systems, Algebra

Functional Description: Cox is a Python library for the computation of coherent presentations of Artin monoids, with experimental features to compute the lower dimensions of the Salvetti complex.

URL: https://plmlab.math.cnrs.fr/guiraud/cox

Publications: hal-00682233, hal-00818253

Contact: Yves Guiraud

Participant: an anonymous participant

7.1.4 dCat

Keywords: Rewriting, Algebra, Termination, Complexity

Functional Description: dCat is a prototype for the automatic research of complexity bounds of polygraphic programs. It relies on the "termination by derivation" technique introduced in Termination orders for 3-dimensional rewriting and adapted to complexity analysis in Polygraphic programs and polynomial-time functions.

URL: https://plmlab.math.cnrs.fr/guiraud/dcat

Publications: tel-00006863, hal-00092196, hal-00092204, inria-00129391, inria-00122932

Contact: Yves Guiraud

Participant: 2 anonymous participants

7.1.5 Garside.jl

Keywords: Algebra, Garside, Computer algebra

Functional Description: Garside.jl is a Julia library for the explicit computation of a compact resolution (Dehornoy-Lafont resolution by lcms) of Garside monoids, including the classical and dual braid monoids in spherical type, and dual monoids of well-generated complex reflection groups. Garside.jl is replaced by a new extended version called Gauss.jl

URL: https://plmlab.math.cnrs.fr/guiraud/garside.jl

Contact: Yves Guiraud

Participant: Yves Guiraud

7.1.6 ISOTOP

Name: Topology and geometry of planar algebraic curves

Keywords: Topology, Curve plotting, Geometric computing

Functional Description: Isotop is a Maple software for computing the topology of an algebraic plane curve, that is, for computing an arrangement of polylines isotopic to the input curve. This problem is a necessary key step for computing arrangements of algebraic curves and has also applications for curve plotting. This software has been developed since 2007 in collaboration with F. Rouillier from Inria Paris - Rocquencourt.

URL: https://isotop.gamble.loria.fr/

Publications: hal-00809430, hal-00809425, inria-00329754, inria-00580431, hal-00992634, hal-01342211, inria-00425383, inria-00517175, hal-01468796, hal-00977671

Contact: Marc Pouget

Participant: 3 anonymous participants

7.1.7 MPFI

Name: Multiple Precision Floating-point Interval

Keyword: Arithmetic

Functional Description: MPFI is a C library based on MPFR and GMP for arbitrary precision interval arithmetic.

URL: https://gitlab.inria.fr/mpfi/mpfi

Contact: Nathalie Revol

7.1.8 OreAlgebraicAnalysis

Keywords: Algebra, Computer algebra, Gröbner bases, Linear system, Ordinary differential equations, Differential algebraic equations, Partial differential equation, Equations algebraic partial derivatives, Polynomial equations, Automatic control

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

URL: https://who.rocq.inria.fr/Alban.Quadrat/OreAlgebraicAnalysis/index.html

Contact: Alban Quadrat

Participant: 2 anonymous participants

7.1.9 OreMorphisms

Keywords: Algebra, Computer algebra, Gröbner bases, Linear system, Ordinary differential equations, Partial differential equation, Differential algebraic equations, Equations algebraic partial derivatives, Polynomial equations, Automatic control

Functional Description: The OreMorphisms package, based on OreModules, is dedicated to the implementation of homological algebra methods such as the computation 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 the endomorphism ring. Using the packages Stafford and Quillen-Suslin, the factorization, reduction and decomposition problems can be effectively studied for different classes of linear multidimensional systems. Many linear functional systems studied in engineering sciences, mathematical physics and control theory have been factorized, reduced and decomposed thanks to the OreMorphisms package.

URL: https://who.rocq.inria.fr/Alban.Quadrat/OreMorphisms/index.html

Contact: Alban Quadrat

Participant: 2 anonymous participants

7.1.10 OreModules

Keywords: Algebra, Computer algebra, Gröbner bases, Linear system, Ordinary differential equations, Differential algebraic equations, Partial differential equation, Equations algebraic partial derivatives, Polynomial equations, Automatic control

Functional Description: OreModules is a Maple package dedicated to module theory and homological algebra for finitely presented modules defined over an Ore algebra of functional operators (e.g., ordinary or partial differential operators, shift operators, time-delay operators, difference operators) available in the Maple package Ore_algebra, and to their applications in mathematical systems theory and mathematical physics.

URL: https://who.rocq.inria.fr/Alban.Quadrat/OreModules/index.html

Contact: Alban Quadrat

7.1.11 PTOPO

Name: Topology of Parametric Curves

Keywords: Parametric curve, 2D, 3D, Visualization, Computer algebra, Curve plotting, Topology

Functional Description: PTOPO computes (exactly) the topology and visualize parametric curves in 2D and in 3D.

URL: https://webusers.imj-prg.fr/~christina.katsamaki/ptopo/

Contact: Elias Tsigaridas

7.1.12 PurityFiltration

Keywords: Symbolic computation, Partial differential equation

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

URL: https://who.rocq.inria.fr/Alban.Quadrat/PurityFiltration.html

Contact: Alban Quadrat

7.1.13 Rewr

Name: Rewriting methods in algebra

Keywords: Computer algebra system (CAS), Rewriting systems, Algebra

Functional Description: Rewr is a prototype of computer algebra system, using rewriting methods to compute resolutions and homotopical invariants of monoids. The library implements various classical constructions of rewriting theory (such as completion), improved by experimental features coming from Garside theory, and allows homotopical algebra computations based on Squier theory. Specific functionalities have been developed for usual classes of monoids, such as Artin monoids and plactic monoids.

URL: https://plmlab.math.cnrs.fr/guiraud/rewr

Publications: hal-00326974, hal-00531242, hal-00682233, hal-00818253, hal-00932845, hal-01141226

Contact: Yves Guiraud

Participant: 2 anonymous participants

7.1.14 RS

Functional Description: Real Roots isolation for algebraic systems with rational coefficients with a finite number of Complex Roots

URL: https://team.inria.fr/ouragan/software/

Contact: Fabrice Rouillier

Participant: an anonymous participant

7.1.15 SIROPA

Keywords: Robotics, Kinematics

Functional Description: Library of functions for certified computations of the properties of articulated mechanisms, particularly the study of their singularities

URL: http://siropa.gforge.inria.fr/

Contact: Guillaume Moroz

Partner: LS2N

7.1.16 SLV

Keywords: Univariate polynomial, Real solving

Functional Description: SLV is a software package in C that provides routines for isolating (and subsequently refine) the real roots of univariate polynomials with integer or rational coefficients based on subdivision algorithms and on the continued fraction expansion of real numbers. Special attention is given so that the package can handle polynomials that have degree several thousands and size of coefficients hundrends of Megabytes. Currently the code consists of approx. 5000 lines.

URL: https://who.paris.inria.fr/Elias.Tsigaridas/soft.html

Contact: Elias Tsigaridas

7.1.17 Stafford

Keywords: Symbolic computation, Partial differential equation

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

URL: https://who.rocq.inria.fr/Alban.Quadrat/OreModules/stafford.html

Contact: Alban Quadrat

Participant: 2 anonymous participants

7.1.18 Gauss.jl

Keywords: Algebra, Garside, Computer algebra

Functional Description: Garside.jl is a Julia library for the explicit computation of a compact resolutions of Garside monoids, including the classical and dual braid monoids in spherical type, and dual monoids of well-generated complex reflection groups. Gauss.jl reimplements in a more effective way the lcm resolution of Dehornoy-Lafont from Garside.jl, and adds several enhanced versions of that construction.

URL: https://plmlab.math.cnrs.fr/guiraud/gauss.jl

Contact: Yves Guiraud

Participant: Yves Guiraud

7.1.19 PACE

Keywords: Robotics, Control, Geolocation, Modelization and numerical simulations, Symbolic computation, Scientific computing

Functional Description: PACE is a software designed to provide solutions to problems in robotics, control theory and geolocation, using effective algebraic and symbolic-numeric methods

Contact: Christina Katsamaki

7.1.20 RankFactorizationProblem

Name: RankFactorizationProblem

Keywords: Computer algebra system (CAS), Polynomial equations, Algebra

Scientific Description: Vibration analysis aims to identify a rotating machinery's potential failures by monitoring its vibration levels, i.e., by measuring the vibrations and comparing them to known failure vibration signals. New demodulation methods have recently been introduced in acoustic and signal processing to diagnose gears. This new approach put forward the mathematical problem of decomposing a given complex matrix M as M = D_1 u v_1 + . . . + D_r u v_r, where D_1, . . . , D_r are fixed matrices and u (resp., v_1, . . . , v_r) a row vector (resp., column vectors) to be determined. This problem is equivalent to factoring M as M = (D_1 u . . . D_r u) (v_1T̂ . . . v_rT̂)T̂, where the integer r is larger than or equal to the rank of M . Using methods of algebraic geometry, module theory, homological algebra, and computer algebra, the general solutions of the corresponding polynomial systems can be effectively characterized. The symbolic package RankFactorization is developed to effectively study the rank factorization problem and the corresponding demodulation problems.

Functional Description: RankFactorizationProblem is a Maple package containing the implementation of algorithms, described in Inria Report 9438, for the study of the rank factorization problem (appearing in demodulation problems useful for gear fault detection).

URL: https://who.rocq.inria.fr/Alban.Quadrat/RankFactorizationProblem/index.html

Contact: Alban Quadrat

7.1.21 ANewDsc

Name: A New Descartes

Keyword: Scientific computing

Functional Description: Computation of the real roots of univariate polynomials with rational coefficients

Contact: Fabrice Rouillier

8 New results

8.1 Axis 1 : Computable objects

Solving bihomogeneous polynomial systems with a zero-dimensional projection. In [28], we study bihomogeneous systems defining, non-zero dimensional, biprojective varieties for which the projection onto the first group of variables results in a finite set of points. To compute (with) the 0-dimensional projection and the corresponding quotient ring, we introduce linear maps that greatly extend the classical multiplication maps for zero-dimensional systems, but are not those associated to the elimination ideal; we also call them multiplication maps. We construct them using linear algebra on the restriction of the ideal to a carefully chosen bidegree or, if available, from an arbitrary Gröbner bases. The multiplication maps allow us to compute the elimination ideal of the projection, by generalizing FGLM algorithm to bihomogenous, non-zero dimensional, varieties. We also study their properties, like their minimal polynomials and the multiplicities of their eigenvalues, and show that we can use the eigenvalues to compute numerical approximations of the zero-dimensional projection. Finally, we establish a single exponential complexity bound for computing multiplication maps and Gröbner bases, that we express in terms of the bidegrees of the generators of the corresponding bihomogeneous ideal.

8.2 Axis 2: Algebraic analysis of functional systems, algebraic topology and group theory

A reference book on higher-dimensional rewriting. Polygraphs are a higher-dimensional generalization of the notion of directed graph. Based on those as unifying concept, the reference book [38] on polygraphs revisits the theory of rewriting in the context of strict higher categories, adopting the abstract point of view offered by homotopical algebra. The first half explores the theory of polygraphs in low dimensions and its applications to the computation of the coherence of algebraic structures. It is meant to be progressive, with little requirements on the background of the reader, apart from basic category theory, and is illustrated with algorithmic computations on algebraic structures. The second half introduces and studies the general notion of n-polygraph, dealing with the homotopy theory of those. It constructs the folk model structure on the category of strict higher categories and exhibits polygraphs as cofibrant objects. This allows extending to higher dimensional structures the coherence results developed in the first half.

On a general robust stability test based on the homological perturbation lemma. Within the lattice approach to synthesis problems, in [26], we show how a general unstructured robust stability test can be obtained directly by applying the homological perturbation lemma, a standard method developed in algebraic topology and homological algebra. This robust stability test generalizes and unifies various results from the robust control literature.

An algorithmic proof of the coherence of the ring of polynomial ordinary integro-differential operators. Bavula proved that the ring I_1 of polynomial ordinary integro-differential operators over a field k of characteristic zero is coherent in the sense that the left/right kernel of any rectangular matrix with entries in I_1 is a finitely generated left/right I_1 -module. Unfortunately, his proof is not algorithmic. The contribution of [30] is to give an algorithmic proof of the coherence property of I_1 . We show that the kernel computation can be reduced to a kernel computation in a certain ring of skew Laurent polynomials and the computation of polynomial solutions of linear polynomial integrodifferential systems. These two problems are shown to be effective. The algorithmic proof of the coherence of I_1 allows us to develop an algorithmic elimination theory for linear systems of polynomial integro-differential equations with separable polynomial kernels. Finally, the algorithms presented in the paper are implemented in the freely available `Maple` package Bavula.

Polynomial solutions for general linear polynomial ordinary integro-differential systems. In [31], we consider the problem of computing polynomial solutions of general linear systems of ordinary integro-differential equations with polynomial coefficients. This algorithmic problem is a key step for many computations with matrices having linear integro-differential operator entries such as the computation of left/right syzygies, left/right inverses, left/right factorizations, and thus, for the development of an effective algebraic analysis approach for linear systems of ordinary integro-differential systems using effective elimination methods and effective homological algebra. The linear systems that appear in the above problems are generally rectangular and inhomogeneous. The contribution of this paper is to provide the first algorithm for computing polynomial solutions of inhomogeneous rectangular systems of linear integro-differential equations with polynomial coefficients. Our algorithm is implemented in the freely available `Maple` package BAVULA.

Formal integrability of partial differential systems: implementation and applications. The contribution [29] aims to review a recent development of an algorithmic approach to the theory of formal integrability of linear systems of partial differential equations. In particular, effective tests for the 2-acyclicity and involutivity properties, as well as a procedure for bringing a linear system of partial differential equations into involutivity, are recalled and illustrated with explicit examples handled by the `Maple` package SPENCER.

Discretization of differential time-delay systems and the inverse image functor. The contribution [33] aims to develop the connections between the discretization schemes of continuous linear differential time-delay systems and the inverse image functor (which has been well-studied in algebraic geometry, topology, and algebraic analysis). Using methods from module theory and homological algebra, we first introduce a mathematical framework to study how discretization schemes preserve or lose structural properties of linear differential time-delay systems. We then show how this problem of torsion-free controllability advocates for a future algorithmic study of the composition of two standard functors (duality and torsion product) and the so-called Grothendieck's spectral sequence associated with this functor composition.

8.3 Axis 3: Algorithmic number theory, rigorous numerical computations.

Squares with a positive proportion of preassigned digits. The aim of [27] is to provide, in any given base $g \geq 2$, an asymptotic formula for the number of squares with a proportion $c > 0$ of preassigned digits, together with explicit admissible values of c depending on g. Our proof involves the circle method using the strategy first developed by Bourgain for primes with preassigned digits in base 2, which we refined and generalised to any base. However, squares are much sparser than prime numbers, which leads us to overcome new substantial difficulties. Our method combines techniques from harmonic analysis together with arithmetic properties of squares and bounds for quadratic Weyl sums

8.4 Axis 4: Geometry and Topology in small dimension

Reductions of path structures and classification of homogeneous structures in dimension three In [22] we show that if a path structure has non-vanishing curvature at a point then it has a canonical reduction to a Z/2Z-structure at a neighbourhood of that point (in many cases it has a canonical parallelism). A simple implication of this result is that the automorphism group of a non-flat path structure is of maximal dimension three (a result by Tresse of 1896). We also classify the invariant path structures on three-dimensional Lie groups.

volesti: A C++ library for sampling and volume computation on convex bodies. Sampling from (constrained) high-dimensional distributions and volume approximation of convex bodies are fundamental operations that appear in optimization, finance, engineering, artificial intelligence, and machine learning.

In [20], we present volesti, a C++ library that delivers efficient implementations of state-of-the-art, mainly randomized, algorithms to sample from general logarithmically concave (or log-concave) distributions. Based on these routines, we can estimate the volume of convex bodies in high dimensions, round them, and compute multidimensional integrals over them. The backbone of our library consists of Monte Carlo algorithms, which are randomized algorithms, the output of which can be incorrect with (usually very small) error probability; thus, we also provide several high-dimensional statistical tests to certify and verify the output. The focus of volesti is scalability in high dimensions, that, depending on the problem at hand, could range from hundreds to thousands of dimensions. Another novelty is the ability to handle a variety of different inputs for the constrained support of the various distributions. volesti supports three different types of polyhedra (Ziegler, 1995), spectrahedra (Ramana & Goldman, 1999), and general non-linear convex objects. volesti relies on Eigen library (Guennebaud et al., 2010) for linear algebra but also supports MKL optimizations (Intel Math Kernel Library (Intel MKL), 2024). There are R (Chalkis & Fisikopoulos, 2021) and Python (Chalkis, Fisikopoulos, Tsigaridas, et al., 2023) interfaces available.

A global invariant for path structures and second order differential equations. In [23], we study a global invariant for path structures. The invariant is obtained as a secondary invariant from a Cartan connection on a canonical bundle associated to a path structure. It is computed in examples which are defined in terms of reductions of the path structure. In particular we give a formula for this global invariant for second order differential equations defined on a torus.

8.5 Axis 5 : Applications

Certified Kinematic Tools for the Design and Control of Parallel Robots. In [25], we present a methodology for the design and control of Parallel Kinematic Robots (PKRs). First, one focuses on the problematics of design. In particular, given a parallel mechanism defined by its design parameters and its kinematic modeling as well as its prescribed workspace, the idea is to certify the absence of any numerical instabilities (computational and physical singularities) that may jeopardize the integrity of the robot. This is achieved through two complementary approaches: a global method using symbolic computation and a local one based on continuation techniques and interval calculus, accounting for uncertainties in the design. The methodology is then applied to real PKR examples. Secondly, the paper proposes a control strategy that limits the active joint velocities to ensure the robot remains within its certified workspace. It will be applied to a special class of parallel robots: Spherical Parallel Manipulators (SPM) with coaxial input shafts (CoSPM).

Semidefinite network games: multiplayer minimax and complementarity problems. Network games provide a powerful framework for modeling agent interactions in networked systems, where players are represented by nodes in a graph and their payoffs depend on the actions taken by their neighbors. Extending the framework of network games, we introduce and study semidefinite network games. In this model, each player selects a positive semidefinite matrix with trace equal to one, known as a density matrix, to engage in a two-player game with every neighboring node. The player's payoff is the cumulative payoff acquired from these edge games. Initially, we focus on the zero-sum setting, where the sum of all players' payoffs is equal to zero. We establish that, in this class of games, Nash equilibria can be characterized as the projection of a spectrahedron. Furthermore, we show that determining whether a semidefinite network game is a zero-sum game is equivalent to deciding if the value of a semidefinite program is zero. Beyond the zero-sum case, we characterize Nash equilibria as the solutions of a semidefinite linear complementarity problem.

General solutions of demodulation problems arizing in gearbox vibration analysis. Combining methods from linear algebra, algebraic geometry, computer algebra, module theory, and homological algebra, in [37], we characterize the general solutions of ideal demodulation problems arising in gearbox vibration analysis. More precisely, within the frequency domain, the separation of the toothed gearbox vibration from the measured signal raises the problem of finding a centrohermitian column vector u and r centrohermitian row vectors $v_1, \ldots, v_r$ which minimize the Frobenius norm $|| \sum_{i=1}^{r} D_i\, u\, v_i - M||_{\mathrm{Frob}}$, where M is a centrohermitian matrix defined by the measurement and the D_i's are fixed centrohermitian matrices which depend on the demodulation problem under-study. To study this polynomial optimal problem, in a series of papers, the rank factorization problem corresponding to solving the ideal case, i.e., to finding u and $v_1, \ldots, v_r$ satisfying $\sum_{i=1}^{r} D_i\, u\, v_i = M$, was investigated. Partial characterizations of the solutions were obtained. This paper aims at characterizing the general solutions to the rank factorization problem. The results obtained are implemented in the dedicated `Maple` package RankFactorizationProblem.

Projective geometry in robust stabilization problems Part I: Projective lines. The paper [34] aims to highlight connections between projective geometry and stabilization problems. Within the fractional representation approach, we introduce the definition of the projective line $\mathbb{P}(A)$ over a ring A of proper and stable transfer functions and the definition of the projective line $\mathbb{P}(K)$ over the quotient field K of A. We show that the groups of homographies of these projective lines correspond to the Möbius transformations defined over A or K. We generalize the definitions of a well-posed system and internal stabilizability to consider plants defined over $\mathbb{P}(K)$. The vanishing of the denominator of a plant or controller is no longer considered a pathological case, and the Youla-Kučera parameterization of all stabilizing controllers is always well-defined. Finally, we show that the points of $\mathbb{P}(A)$ can be interpreted as transfer functions with coprime factorizations. Concepts of projective geometry, such as distant relation and distant graph on $\mathbb{P}(A)$, are introduced, and their system-theoretic interpretations are given.

Projective geometry in robust stabilization problems Part II: Möbius transformations. Within the fractional representation approach, a fractional ideal can naturally be attached to a linear system defined by a transfer function. System properties are then reflected in the algebraic properties of this fractional ideal. Therefore, standard algebraic methods can be used to study system properties in detail. The contribution [35] studies the equivalence of systems corresponding to isomorphic associated fractional ideals. These natural equivalences bijectively transform a system into systems sharing the structural properties. This paper proves that these equivalences are defined by two kinds of Möbius transformations. Finally, this result is used to show how a stabilizing controller or a (weakly) coprime factorization is transformed by the application of these Möbius transformations.

Some Computational Tools for Solving a Selection of Problems in Control Theory. The paper [32] demonstrates how certified computational tools can be used to address various problems in control theory. In particular, we introduce PACE.jl, a Julia package that implements symbolic elimination techniques, including (among others) discriminant varieties and Rational Univariate Representation, while also supporting multi-precision interval computations. We showcase its applications to key control theory problems, including identification, stability analysis, and optimization, for both parameter-dependent and parameter-free systems.

Symbolic and Numerical Tools for L∞-Norm Calculation. The computation of the L_∞-norm is an important issue in H_∞ control, particularly for analyzing system stability and robustness. This paper focuses on symbolic computation methods for determining the L_∞ -norm of finite-dimensional linear systems, highlighting their advantages in achieving exact solutions where numerical methods often encounter limitations. In [36], key techniques such as Sturm-Habicht sequences, Rational Univariate Representations (RUR), and Cylindrical Algebraic Decomposition (CAD) are surveyed, with an emphasis on their theoretical foundations, practical implementations, and specific applicability to L_∞-norm computation. A comparative analysis is conducted between symbolic and conventional numerical approaches, underscoring scenarios in which symbolic computation provides superior accuracy, particularly in parametric cases. Benchmark evaluations reveal the strengths and limitations of both approaches, offering insights into the trade-offs involved. Finally, the discussion addresses the challenges of symbolic computation and explores future opportunities for its integration into control theory, particularly for robust and stable system analysis.

9 Bilateral contracts and grants with industry

Participants: Christina Katsamaki, Alban Quadrat, Fabrice Rouillier.

9.1 Bilateral contracts with industry

9.1.1 WATERLOO MAPLE INC

The objective of our Agrement with WATERLOO MAPLE INC. is to promote software developments to which we actively contribute.

On the one hand, WMI provides manpower, software licenses, technical support (development, documentation and testing) for an inclusion of our developments in their commercial products. On the other hand, OURAGAN offers perpetual licenses for the use of the concerned source code.

As past results of this agreement one can cite our C-Library *RS* for the computations of the real solutions zero-dimensional systems or also our collaborative development around the Maple package *DV* for solving parametric systems of equations.

For this term, the agreement covers algorithms developed in areas including but not limited to: 1) solving of systems of polynomial equations, 2) validated numerical polynomial root finding, 3) computational geometry, 4) curves and surfaces topology, 5) parametric algebraic systems, 6) cylindrical algebraic decompositions, 7) robotics applications.

In particular, it covers our collaborative work with some of our partners, especially the Gamble Project-Team - Inria Nancy Grand Est.

9.1.2 Safran Electronics and Defense

A five-year renewable contract has been signed with Safran Electronics and Defense.

This contract commits us to all of OURAGAN's application work, except for that concerning algorithmic number theory: Robotics, Control Theory, and Geolocation.

A joint laboratory called PACE embodies this collaboration, with a balanced participation of engineers from Safran and researchers from OURAGAN.

It should be noted that the PACE laboratory covers all of OURAGAN's operating costs and also funds five doctoral scholarships and likely several postdoctoral positions.

10 Partnerships and cooperations

10.1 International research visitors

10.1.1 Visits of international scientists

Jeremy Kaminsky from Holon Institute of Technology visited us in April and October for a collaboration with Pierre-Vincent Koseleff.

Thorsten Theobald from Institut für Mathematik Goethe-Universität, Frankfurt, visited us from 14–19 September 2025.

Máté L. Telek from Leipzig University visited us from 12–17 October 2025.

Josué Tonelli-Cueto from John Hopkins University visited us from 17–24 January 2025.

10.2 European initiatives

10.2.1 Other european programs/initiatives

A bilateral program Partenariat Hubert Curien (PHC), PHC Procope, is running from 2025-2027 with Institut für Mathematik, Goethe-Universität, Germany. The local PI is Elias Tsigaridas and the PI on the german side is Thorsten Theobald. The project is on "Quantum games and polynomial optimization".

10.3 National initiatives

10.3.1 ANR

- ANR JCJC SHoCoS (Structure and Homotopy of Configuration Spaces)

  Coordinator: Najib Idrissi (Univ. Paris Cité, IMJ-PRG)

  Participant: Yves Guiraud

  Duration: 2022 – 2026

  This is a project of fundamental research in mathematics, specifically algebraic topology, homotopical algebra, and quantum algebra. It is concerned with configuration spaces, which consist in finite sequences of pairwise distinct points in a manifold. Over the past couple of decades, strides have been made in the study and computation of the homotopy types of configuration spaces, i.e., their shape up to continuous deformation. These advances were possible thanks to the rich structure of configuration spaces, which comes from the theory of operads. Moreover, a new theory, factorization homology, allowed the use of configuration spaces to compute topological field theories, topological invariants of manifolds inspired by physics. Our purpose is to exploit the full operadic structure of configuration spaces to obtain new kinds of stabilizations in the homotopy types of configuration spaces, and to use this stability to effectively compute topological field theories from deformation quantization.

- ANR HilbertxField (Géométries de Hilbert sur les corps valués)

  Coordinator Antonin Guilloux

  Duration: Sept 2023 - Aug 2027

  A Hilbert geometry is defined on any convex body in a real affine space. This notion is the source of numerous examples of metric spaces and has had many applications in various fields since its definition in 1895 by Hilbert. The participants in this project contribute to different generalizations of this notion and these applications in contexts where the basic body is no longer the body of realities.

  This project has three main objectives: - develop a unified approach to these generalizations: unified definitions, common generalization of the results of Benzécri and the notion of volume; - explore the interactions between the different generalization contexts, using numerous families of examples; - obtain important applications in each case study.

  These applications are expected in different projects including:

  – the study of minimum entropy metrics on symmetric spaces;
  – the geometric study of degenerations of convex projective structures on surfaces;
  – the study of the boundary of Anosov representations, especially in the context of complex hyperbolic geometry;
  – the development of new linear programming algorithms, with Smale's 9th problem in focus.

- ANR StratMesh

  Coordinator : Guillaume Moroz (Gamble project-team - Centre Inria de l'Université de Lorraine)

  Coordinator for OURAGAN (partner) : Alban Quadrat

  Participants : Christina Katsamaki, Fabrice Rouillier, Elias Tsigaridas

  Duration: Apr. 2024 - Apr. 2028

  StratMesh aims to develop provably-correct triangulation algorithms for stratified spaces. Our focus is on stratified spaces that are the projection of smooth manifolds, which arise in many applications such as robotics, control theory, and medial axis computation for learning from geometric data.

  – Develop provably-correct triangulation algorithms
  – Focus on hypersurfaces or low dimensional manifolds
  – Handle singularities in both small and high dimensions
  – Create practical applications in robotics and control theory

10.3.2 Inria Exploratory actions

- LOCUS (non-Linear geOmetriC compUting at Scale) Inria Exploratory Action

  Coordinator: Elias Tsigaridas

  Duration 2022 - 2025

  Summary : LOCUS shapes a novel theoretical, algorithmic, and computational framework at the intersection of computational algebra, high dimensional geometric and statistical computing, and optimization. It focuses on sampling and integrating in convex bodies, algorithms for convex optimization, and applications in structural biology. It aims to deliver effective theoretical algorithms and efficient open source software for the problems of interest.

- Réal (Réécriture algébrique) Inria Exploratory Action

  Coordinator : Yves Guiraud

  Duration : 2022-2025

  Summary : Rewriting is a branch of computer algebra consisting in transforming mathematical expressions according to admissible rules. Examples range from elementary situations, such as a remarkable identity $(a+b)^2 = a^2 + 2ab + b^2$ in a ring, to calculations in complex algebraic structures, such as the Jacobi relation [[x,y],z] = [x,[y,z]] - [[x,z],y] in a Lie algebra.

  The Réal project proposes to explore the connections between rewriting and algebra. The aim is to understand the algebraic foundations of rewriting, to integrate similar calculation mechanisms known in algebra, and to develop new calculation tools with a view to applications in three areas of mathematics: combinatorial and higher algebra, theory groups and representations, study of algebraic systems and varieties.

11 Dissemination

11.1 Promoting scientific activities

11.1.1 Scientific events: organisation

- Pascal Molin organized the conference "Atelier Pari/GP", 6-10 january 2025 at Institut Pascal, Orsay. 50 participants attended this event.

- Fabrice Rouillier and Elias Tsigaridas organized a special session on Symbolic–Numeric Computation at the ACA 2025 Conference.

- Elias Tsigaridas co-organized a session at PGMO days 2025.

Chair of conference program committees

- Alban Quadrat was the Program co-editor of the 9th IFAC Symposium on Systems Structure and Control, Paris Saclay, France. See [39].

Member of the editorial boards

- Elisha Falbel is a member of the editorial board of São Paulo Journal of Mathematical Sciences - Springer.

- Elisha Falbel is a member of the editorial board of Moduli - Foundation Compositio Mathematica.

- Alban Quadrat is an associated editor of *Multidimensional Systems and Signal Processing*

- Alban Quadrat is an associated editor of *Maple Transactions*.

- Elias Tsigaridas is member of the editorial board of *Journal of Symbolic Computation*.

- Elias Tsigaridas is member of the editorial board of *Applied & Computational Topology & Geometry*.

- Fabrice Rouillier is a member of the editorial board of Journal of Symbolic Computation.

- Fabrice Rouillier is a member of the editorial board of Maple Transactions.

11.1.2 Invited talks

- Antonin Guilloux has been invited to present his work in seminars at Grenoble, Cergy, IHES
- Fabrice Rouillier was invited speaker at the Chinese Academy of Science in Beijin (January 2025)
- Pierre-Vincent Koseleff with Moshe Cohen (SU New-York Paltz) and Marina Ville (Université Paris-Est) : Project on computing polynomial invariants (Casson invariants) for some distributions of knots.
- Cathy Swaenepoel was invited to present her work at
  - Séminaire de Théorie des Nombres, LMNO, Caen.
  - Séminaire AFRIMath en Théorie des Nombres et Théorie de l'Information (online)
  - Rencontres de théorie analytique et élémentaire des nombres, IHP, Paris
  - Séminaire Ernest, I2M, Marseille
  - Purdue Analytic Number Theory and Harmonic Analysis Seminar (online)
  - Number Theory Seminar, IndAM, Rome
  - Number Theory Seminar, Warwick
  - Analytic Number Theory workshop, Saint-Étienne
- Elias Tsigaridas was invited to present his wok at
  - *Real algebraic geometry and interactions* workshop at Nice.
  - *16th Viennese Conference on Optimal Control and Dynamic Games* at TU Wien.
  - *Discrete mathematics seminar* at Institut für Mathematik,Goethe-Universität, Frankfurt.
  - *Geometry and machine learning* workshop, Paris.

11.1.3 Leadership within the scientific community

- Alban Quadrat is a member of the Technical Committee on Linear Systems of the International Federation of Automatic Control (IFAC).

11.1.4 Scientific expertise

- Yves Guiraud was an elected member of the Comité National de la Recherche Scientifique (the evaluation body of the CNRS), section 41 (mathematics), from 2021 to 2025.
- Yves Guiraud was a member of the HCERES evaluation committee of the MICS Laboratory (math-info of CentraleSupélec) and the Fédération de Mathématiques of CentraleSupélec in April 2025.
- Fabrice Rouillier is the scientific contact for the strategic agreement between Inria and Safran.

11.1.5 Research administration

- Yves Guiraud is an elected member of the IMJ-PRG laboratory council since 2021.
- Yves Guiraud was an elected member of the Comité de Centre INRIA of Paris, from 2019 to 2025.
- Fabrice Rouillier is the co-chair of the PACE joint Laboratory Inria-Safran.
- Elias Tsigaridas is an elected member of the Commission d'évaluation d'Inria (CE) since 2019.

11.2 Teaching - Supervision - Juries - Educational and pedagogical outreach

11.2.1 Teaching

- Antonin Guilloux, Alban Quadrat, Elias Tsigaridas , Master 1, Effective Linear Algebra and Polynomials. (24h course + 36h exercises).
- Antonin Guilloux, Fabrice Rouillier, João Rafael De Melo Ruiz, Master 1, Introduction to Algebraic geometry (24h course + 36h exercises).
- Antonin Guilloux, Pierre-Vincent Koseleffand Fabrice Rouillier take part to the "agrégation de mathématiques - option C" at Sorbonne Université
- Christina Katsamaki: TP Initiation à Python - Préparation à l'Agrégation Externe de Mathématiques (4h), Sorbonne Université.
- Pierre-Vincent Koseleff: Master 1 Maths - Sorbonne Université : Algebraic Cryptography (36H) at Sorbonne Université
- Pierre-Vincent Koseleff: Master 2 EducFellow in Maths - Computer Algebra (120H) at Sorbonne Université
- Pierre-Vincent Koseleff: License 3 Maths - Sorbonne Université : Algebraic Structures (36H) at Sorbonne Université.
- Pascal Molin: Master 2 pure math : course "explicit method in number theory"
- Pascal Molin:Master 1 crypto and data science : course "information theory"
- Pascal Molin:Master 1 crypto : supervision of 4 student groups (homomorphic encryption, NTRU, LWE, LLL for cryptanalysis)
- Cathy Swaenepoel, "Codes et Cryptographie", Master 1 MATH-INFO, Université Paris Cité
- Elias Tsigaridas, 24h "Algebraic and geometric techniques in optimation", Master 2 Mathématiques fondamentales, Sorbonne Université.
- Elias Tsigaridas: Introduction to Programming. 28h TD. Bachelor program at the Department of Informatics (LIX), École Polytechnique, France.
- Elias Tsigaridas : Algorithms and Competitive Programming, Ingénieur 2A, modal. 15h lectures and 45h TD. Department of Informatics (LIX), École Polytechnique, France.

11.2.2 Supervision

- PhD
  - Antonin Guilloux supervises (in collaboration with Pierre Charollois) the PhD of Pierre Morrain.
  - Antonin Guilloux co-supervises Damien Domenget (50% shared with Elisha Falbel) and Baptiste Dugué (50% with Gilles Courtois - IMJ-PRG)
  - Antonin Guilloux co-supervided Arielle Marc-Zwecker with Pierre Will (Université Grenoble Alpes)
  - Alban Quadrat co-supervises the Ph.D. thesis of Antoine Courteau, *Conception de lois de commande d'un télescope actif*, CIFRE PhD in collaboration with Safran Electronics & Defense.
  - Fabrice Rouillier supervises the Ph.D. thesis of Joao Ruiz.
  - Fabrice Rouillier supervises the Ph.D. thesis of Florent Corniquel.
  - Fabrice Rouillier co-supervises (50%) the Ph.D. thesis of Alexandre Loustric (CIFRE in Collaboration with Safran Electronics & Defense).
  - Elias Tsigaridas supervises (90%) the PhD of Chaoping Zhu since 09/2023.

  - Elias Tsigaridas supervises (90%) the PhD of Jules Tsukahara since 09/2024.
  - Elias Tsigaridas (80%) and Antonin Guilloux (20%) supervise the PhD of Ennio Grammatica since 11/2024.

- Master
  - Yves Guiraud supervised the M2 internship of Emir Melliti (M2 mathématiques fondamentales Paris), March-June 2025.
  - Yves Guiraud co-supervises the ENS 4th year internship of Emir Melliti, with Hoel Queffelec (Montpellier-Camberra), 2025-2026.
  - Cathy Swaenepoel supervised the Master 2 internship of Hugo Lecointre.
  - Elias Tsigaridas supervised the M2 internship of Alexander Zenkovich (ENS Paris) April-September 2025.

11.2.3 Juries

- Alexandre Lê successfully defended his Ph.D. thesis, *Design and control of parallel robots for the inertial stabilization of sighting devices*[40], Sorbonne University, Inria Paris, 23/10.
- Camille Pinto successfully defended her Ph.D. thesis, *Elimination theory for linear integro-differential systems*[41], Sorbonne University, Inria Paris, 23/10.
- Alban Quadrat was a rapporteur of the Ph.D. thesis of Maxime Bridoux, *Automated Generation of Proofs of the Nonexistence of Darboux Polynomials*, Université de Rennes, IRISA.
- Alban Quadrat was a rapporteur of the Ph.D. thesis of Hadrien Brochet, *Efficient Algorithms for Creative Telescoping using Reductions*, Université Paris-Saclay, Inria Saclay.
- Fabrice Rouillier was a referee for the PhD Thesis of Arthur IGNAZI *Box atlas, une approche ensembliste des variétés : Applications en robotique.*Université d'Angers.

11.3 Popularization

11.3.1 Specific official responsibilities in science outreach structures

- Antonin Guilloux is member of the national coordination comitee of Maths C pour L since 2025 and the local organization comitee of Maths C pour L Paris since 2022. The initiative Maths C pour L is inspired by Math C2+ and proposes to female Licence students, especially from non-privileged social background, a week of initiation to research, through research projects and meetings of numerous female mathematicians.
- Fabrice Rouillier is the president of the association Animath.
- Fabrice Rouillier is the scientific referent for scientific popularization at Inria Paris center.
- Fabrice Rouillier is in charge of defining the outlines of a national platform for the shared management of mediation resources for the DCIS (Direction de la Culture et de l'Information Scientifique).
- Fabrice Rouillier is the representative from Inria in the Jury of National Mathematical Olympiads.

11.3.2 Participation in Live events

- Florent Corniquel gave two presentations as part of the *Chiche* initiative at the Inria center in Paris.
- Florent Corniquel animated an activity to initiate young (high school) girls to reach activities.
- Christina Katsamaki gave a talk on parametrized curves in dimensions 2 and 3 and their applications, as part of the high-school internship « Courbes et Surfaces » held at Sorbonne Université.

- Fabrice Rouillier shared the supervision of 4 observation placements of first-year high school students with Anne Canteaut (COSMIQ project-team).
- Fabrice Rouillier participated to the "observation week" at Inria Paris center for middle school students.
- Cathy Swaenepoel :
  - Leading two workshops on numbers at the Rendez-vous des jeunes mathematiciennes et informatiqueiennes (RJMI) in Caen on January 31 and February 1, 2025.
  - Presentation "Fascinating Prime Numbers" at the Normandy Popularization Seminar on January 31, 2025, in Caen.
  - Presentation "Pseudo-randomness of Prime Number Digits" at the Mathematics in Motion day organized by the FSMP on November 15, 2025, at the Henri Poincaré Institute.

12 Scientific production

12.1 Major publications

[1] Y. Bouzidi, S. Lazard, G. Moroz, M. Pouget, F. Rouillier and M. Sagraloff. 'Solving bivariate systems using Rational Univariate Representations'. In: *Journal of Complexity* 37 (2016), pp. 34–75. DOI: 10.1016/j.jco.2016.07.002. URL: https://hal.inria.fr/hal-01342211.

[2] E. Brugallé, P.-V. Koseleff and D. Pecker. 'On the lexicographic degree of two-bridge knots'. In: *Journal Of Knot Theory And Its Ramifications (JKTR)* 25.7 (June 2016). 14p., 21 figs. DOI: 10.1142/S0218216516500449. URL: https://hal.archives-ouvertes.fr/hal-01084472.

[3] E. Brugallé, P.-V. Koseleff and D. Pecker. 'The lexicographic degree of the first two-bridge knots'. In: *Annales de la Faculté des Sciences de Toulouse. Mathématiques.* 29.4 (Dec. 2020), pp. 761–793. DOI: 10.5802/afst.1645. URL: https://hal.science/hal-01108678.

[4] E. Brugallé, P.-V. Koseleff and D. Pecker. 'Untangling trigonal diagrams'. In: *Journal Of Knot Theory And Its Ramifications (JKTR)* 25.7 (June 2016). 10p., 24 figs. DOI: 10.1142/S0218216516500437. URL: https://hal.archives-ouvertes.fr/hal-01084463.

[5] F. Chyzak, A. Quadrat and D. Robertz. 'Effective algorithms for parametrizing linear control systems over Ore algebras'. In: *Applicable Algebra in Engineering, Communications and Computing* 16 (2005), pp. 319–376.

[6] T. Cluzeau and A. Quadrat. 'Factoring and decomposing a class of linear functional systems'. In: *Linear Algebra and Its Applications* 428 (2008), pp. 324–381.

[7] E. Falbel and A. Guilloux. 'Dimension of character varieties for 3-manifolds'. In: *Proceedings of the American Mathematical Society* (2016). DOI: 10.1090/proc/13394. URL: https://hal.archives-ouvertes.fr/hal-01370284.

[8] E. Falbel, A. Guilloux, P.-V. Koseleff, F. Rouillier and M. Thistlethwaite. 'Character Varieties For SL(3,C): The Figure Eight Knot'. In: *Experimental Mathematics* 25.2 (2016), p. 17. DOI: 10.1080/10586458.2015.1068249. URL: https://hal.inria.fr/hal-01362208.

[9] E. Falbel and J. Wang. 'Branched spherical CR structures on the complement of the figure-eight knot'. In: *Michigan Mathematical Journal* 63 (2014), pp. 635–667. URL: https://hal.archives-ouvertes.fr/hal-01374789.

[10] S. Gaussent, Y. Guiraud and P. Malbos. 'Coherent presentations of Artin monoids'. In: *Compositio Mathematica* 151.5 (2015), pp. 957–998. DOI: 10.1112/S0010437X14007842. URL: https://hal.archives-ouvertes.fr/hal-00682233.

[11] Y. Guiraud, E. Hoffbeck and P. Malbos. 'Convergent presentations and polygraphic resolutions of associative algebras'. In: *Mathematische Zeitschrift* 293.1-2 (2019), pp. 113–179. DOI: 10.1007/s00209-018-2185-z. URL: https://hal.archives-ouvertes.fr/hal-01006220.

[12] Y. Guiraud and P. Malbos. 'Higher-dimensional normalisation strategies for acyclicity'. In: *Advances in Mathematics* 231.3-4 (2012), pp. 2294–2351. DOI: 10.1016/j.aim.2012.05.010. URL: https://hal.archives-ouvertes.fr/hal-00531242.

[13] A. Joux. 'A one round protocol for tripartite Diffie-Hellman'. In: *J. Cryptology* 17.4 (2004), pp. 263–276.

[14] A. Joux and R. Lercier. 'Improvements to the general number field sieve for discrete logarithms in prime fields. A comparison with the gaussian integer method'. In: *Math. Comput.* 72.242 (2003), pp. 953–967.

[15] D. Lazard and F. Rouillier. 'Solving Parametric Polynomial Systems'. In: *Journal of Symbolic Computation* 42 (June 2007), pp. 636–667.

[16] A. Quadrat and D. Robertz. 'Computation of bases of free modules over the Weyl algebras'. In: *Journal of Symbolic Computation* 42 (2007), pp. 1113–1141.

[17] F. Rouillier. 'Solving zero-dimensional systems through the rational univariate representation'. In: *Journal of Applicable Algebra in Engineering, Communication and Computing* 9.5 (1999), pp. 433–461.

[18] F. Rouillier and P. Zimmermann. 'Efficient Isolation of Polynomial Real Roots'. In: *Journal of Computational and Applied Mathematics* 162.1 (2003), pp. 33–50.

12.2 Publications of the year

International journals

[19] M. R. Bender, L. Busé, C. Checa and E. Tsigaridas. 'Bigraded Castelnuovo-Mumford regularity and Groebner bases'. In: *Journal of Symbolic Computation* 133 (Mar. 2026), p. 26. DOI: 10.1016/j.jsc.2025.102487. URL: https://hal.science/hal-04909467.

[20] A. Chalkis, V. Fisikopoulos, M. Papachristou and E. Tsigaridas. 'volesti: A C++ library for sampling and volume computation on convex bodies'. In: *Journal of Open Source Software* 10.108 (11th Apr. 2025), p. 7886. DOI: 10.21105/joss.07886. URL: https://inria.hal.science/hal-05471783 (cit. on p. 22).

[21] B. El Hilany, M. Helmer and E. Tsigaridas. 'Stratification of projection maps from toric varieties'. In: *Journal of Symbolic Computation* 135 (July 2026), p. 102547. DOI: 10.1016/j.jsc.2025.102547. URL: https://inria.hal.science/hal-05440865.

[22] E. Falbel, M. Mion-Mouton and J. M. Veloso. 'Reductions of path structures and classification of homogeneous structures in dimension three'. In: *Transformation Groups* (25th Nov. 2025). DOI: 10.1007/s00031-025-09937-9. URL: https://hal.science/hal-04612815 (cit. on p. 22).

[23] E. Falbel and J. Veloso. 'A global invariant for path structures and second order differential equations'. In: *Differential Geometry and its Applications* 98 (Feb. 2025), p. 102224. DOI: 10.1016/j.difgeo.2024.102224. URL: https://hal.science/hal-04121036 (cit. on p. 23).

[24] C. Ickstadt, T. Theobald, E. Tsigaridas and A. Varvitsiotis. 'Semidefinite network games: multiplayer minimax and complementarity problems'. In: *Journal of Optimization Theory and Applications* (2025). URL: https://inria.hal.science/hal-05466813. In press.

[25] A. Lê, F. Rouillier, G. Rance and D. Chablat. 'Certified Kinematic Tools for the Design and Control of Parallel Robots'. In: *Mechanism and Machine Theory* 205 (Mar. 2025), p. 105865. DOI: 10.1016/j.mechmachtheory.2024.105865. URL: https://hal.science/hal-04821252 (cit. on p. 23).

[26] A. Quadrat. 'On a general robust stability test based on the homological perturbation lemma'. In: *Mathematics of Control, Signals, and Systems* 37 (5th June 2025), pp. 697–735. URL: https://hal.science/hal-05472350 (cit. on p. 21).

[27] C. Swaenepoel. 'Squares with a positive proportion of preassigned digits'. In: *Mathematische Annalen* (2nd Sept. 2025). DOI: 10.1007/s00208-025-03253-z. URL: https://hal.science/hal-05236556 (cit. on p. 22).

International peer-reviewed conferences

[28] M. R. Bender, L. Busé, C. Checa and E. Tsigaridas. 'Solving bihomogeneous polynomial systems with a zero-dimensional projection'. In: ISSAC '25: International Symposium on Symbolic and Algebraic Computation. Guanajuato Mexico, Mexico: ACM; ACM, 2025, pp. 206–214. DOI: 10.1145/3747199.3747563. URL: https://hal.science/hal-04909457 (cit. on p. 20).

[29] C. Chenavier, T. Cluzeau and A. Quadrat. 'Formal integrability of partial differential systems: implementation and applications'. In: *IFAC-PapersOnLine*. SSSC 2025 - 9th IFAC Symposium on System Structure and Control. Vol. 59. 12. Gif-sur-Yvette, France: Elsevier, 1st July 2025, pp. 79–84. URL: https://hal.science/hal-05471962 (cit. on p. 22).

[30] T. Cluzeau, C. Pinto and A. Quadrat. 'An algorithmic proof of the coherence of the ring of polynomial ordinary integro-differential operators'. In: ISSAC 2025 - 50th International Symposium on Symbolic and Algebraic Computation. Vol. ISSAC '25: Proceedings of the 2025 International Symposium on Symbolic and Algebraic Computati. Guanajuato, Mexico: ACM, 1st Aug. 2025, pp. 178–187. DOI: 10.1145/3747199.3747560. URL: https://hal.science/hal-05472194 (cit. on p. 21).

[31] T. Cluzeau, C. Pinto and A. Quadrat. 'Polynomial solutions for general linear polynomial ordinary integro-differential systems'. In: ISSAC 2025 - 50th International Symposium on Symbolic and Algebraic Computation. Vol. ISSAC '25: Proceedings of the 2025 International Symposium on Symbolic and Algebraic Computati. Guanajuato, Mexico: ACM, 1st Aug. 2025, pp. 178–187. URL: https://hal.science/hal-05472131 (cit. on p. 21).

[32] A. Demin, C. Katsamaki and F. Rouillier. 'Some Computational Tools for Solving a Selection of Problems in Control Theory'. In: SSSC 2025 - 9th IFAC Symposium on System Structure and Control. Vol. 59. Gif -sur-Yvette, France, 2025, pp. 73–78. DOI: 10.1016/j.ifacol.2025.09.570. URL: https://inria.hal.science/hal-05362405 (cit. on p. 24).

[33] H. Mounier and A. Quadrat. 'Discretization of differential time-delay systems and the inverse image functor'. In: *IFAC-PapersOnLine*. TDS 2025 - 19th IFAC Workshop on Time Delay Systems. Vol. 59. 13. Gif-sur-Yvette, France: Elsevier, 1st July 2025, pp. 261–266. URL: https://hal.science/hal-05471910 (cit. on p. 22).

[34] A. Quadrat and A. Quadrat. 'Projective geometry in robust stabilization problems Part I: Projective lines'. In: *IFAC-PapersOnLine*. TDS 2025 - 19th IFAC Workshop on Time Delay Systems. Vol. 59. 13. Gif-sur-Yvette, France: Elsever, 1st July 2025, pp. 243–248. URL: https://hal.science/hal-05471864 (cit. on p. 23).

[35] A. Quadrat and A. Quadrat. 'Projective geometry in robust stabilization problems Part II: Möbius transformations'. In: *IFAC-PapersOnLine*. TDS 2025 - 19th IFAC Workshop on Time Delay Systems. Vol. 59. 13. Gif-sur-Yvette, France: Elsevier, 1st July 2025, pp. 249–254. URL: https://hal.science/hal-05471887 (cit. on p. 24).

[36] G. Younes, A. Quadrat and F. Rouillier. 'Symbolic and Numerical Tools for L∞-Norm Calculation'. In: SSSC 2025 - 9th IFAC Symposium on System Structure and Control. Vol. 59. Gif -sur-Yvette, France, 2025, pp. 202–207. DOI: 10.1016/j.ifacol.2025.09.592. URL: https://inria.hal.science/hal-05362416 (cit. on p. 24).

Conferences without proceedings

[37] E. Hubert and A. Quadrat. 'General Solutions of Demodulation Problems Arizing in Gearbox Vibration Analysis'. In: SSSC 2025 - 9th IFAC Symposium on System Structure and Control. Gif-sur-Yvette, France, 30th June 2025. URL: https://hal.science/hal-05472072 (cit. on p. 23).

Scientific books

[38] D. Ara, A. Burroni, Y. Guiraud, P. Malbos, F. Métayer and S. Mimram. *Polygraphs: From Rewriting to Higher Categories*. Vol. 495. London Mathematical Society Lecture Note Series. Cambridge University Press, 2025, pp. xx+648. URL: https://hal.science/hal-04322821 (cit. on p. 21).

[39] J. Jacques Loiseau and A. Quadrat, eds. *Proceedings 9th IFAC Symposium on System Structure and Control SSSC 2025*. July 2025. URL: https://hal.science/hal-05344290 (cit. on p. 27).

Doctoral dissertations and habilitation theses

[40] A. Lê. 'Design and control of parallel robots for the inertial stabilization of sighting devices'. Sorbonne Université, 15th Oct. 2025. URL: https://theses.hal.science/tel-05462259 (cit. on p. 30).

[41] C. Pinto. 'Elimination theory for linear systems of integro-differential equations'. Sorbonne Université, 23rd Oct. 2025. URL: https://theses.hal.science/tel-05394996 (cit. on p. 30).

Reports & preprints

[42] F. B. Aribi, A. Guilloux and K. H. Wong. *FAMED by computer: proving the Andersen-Kashaev volume conjecture for 42,000 knots*. 19th Dec. 2025. URL: https://hal.science/hal-05441024.

[43] M. Bender, P. Di Dio and E. Tsigaridas. *Positive Univariate Polynomials: SOS certificates, algorithms, bit complexity, and T-systems*. 19th Sept. 2025. URL: https://inria.hal.science/hal-05269445.

[44] M. Bender, E. Tsigaridas and C. Zhu. *Certificates of nonnegativity of multivariate polynomials with zero-dimensional gradient ideal and infimum attained*. 26th Nov. 2025. URL: https://inria.hal.science/hal-05382946.

[45] M. R. Bender, K. Kozhasov, E. Tsigaridas and C. Zhu. *Certificates for nonnegativity of multivariate integer polynomials under perturbations*. 9th Dec. 2025. URL: https://inria.hal.science/hal-05407890.

[46] E. Falbel. *Self-adjoint extensions of singular Sturm-Liouville operators on graphs and Weyl's law*. 20th Nov. 2025. URL: https://hal.science/hal-05322387.

[47] P. Molin. *Computing Euler products and coefficients of classical modular forms for twisted L-functions*. 7th July 2025. URL: https://hal.science/hal-05146892.

[48] P. L. L. Morain. *Computations of higher elliptic units*. 17th Jan. 2026. URL: https://hal.science/hal-05473431.

[49] P. L. L. Morain. *Geometric families of multiple elliptic Gamma functions and arithmetic applications, I*. 18th Oct. 2025. URL: https://hal.science/hal-05424130.

[50] G. Sergeant-Perthuis and L. Boitel. *Minima and Critical Points of the Bethe Free Energy Are Invariant Under Deformation Retractions of Factor Graphs*. 5th Oct. 2025. URL: https://hal.science/hal-05297954.

[51] G. Sergeant-Perthuis, T. St Clere Smithe and L. Boitel. *On the Functoriality of Belief Propagation Algorithms on Finite Partially Ordered Sets*. 18th Mar. 2025. URL: https://hal.sorbonne-universite.fr/hal-04995548.

[52] G. Younes, A. Quadrat and F. Rouillier. *Symbolic and Numerical Tools for L_∞-Norm Calculation*. 2025. URL: https://hal.science/hal-05198345.

12.3 Cited publications

[53] D. Aggarwal, A. Joux, A. Prakash and M. Santha. 'A New Public-Key Cryptosystem via Mersenne Numbers'. In: *Advances in Cryptology - CRYPTO 2018 - 38th Annual International Cryptology Conference, Santa Barbara, CA, USA, August 19-23, 2018, Proceedings, Part III*. 2018, pp. 459–482. DOI: 10.1007/978-3-319-96878-0_16. URL: https://doi.org/10.1007/978-3-319-96878-0%5C_16 (cit. on p. 12).

[54] D. J. Anick. 'On the Homology of Associative Algebras'. In: *Trans. Amer. Math. Soc.* 296.2 (1986), pp. 641–659 (cit. on p. 11).

[55] N. Bose. *Multidimensional Systems Theory: Progress, Directions and Open Problems in Multidimensional Systems*. Mathematics and Its Applications. Springer Netherlands, 2001 (cit. on p. 13).

[56] F. Boulier, D. Lazard, F. Ollivier and M. Petitot. 'Computing representations for radicals of finitely generated differential ideals'. In: *Applicable Algebra in Engineering, Communication and Computing* 20 (2009), pp. 73–121 (cit. on p. 13).

[57] Y. Bouzidi, A. Quadrat and F. Rouillier. 'Computer algebra methods for testing the structural stability of multidimensional systems'. In: *IEEE 9th International Workshop on Multidimensional (nD) Systems (IEEE nDS 2015)*. Proceedings of the IEEE 9th International Workshop on Multidimensional (nD) Systems (IEEE nDS 2015). Vila Real, Portugal, Sept. 2015. URL: https://hal-centralesupelec.archives-ouvertes.fr/hal-01259968 (cit. on p. 14).

[58] Y. Bouzidi, T. Cluzeau, G. Moroz and A. Quadrat. 'Computing effectively stabilizing controllers for a class of *n*D systems'. In: *The 20th World Congress of the International Federation of Automatic Control*. Vol. 50. 1. Toulouse, France, July 2017, pp. 1847–1852. DOI: 10.1016/j.ifacol.2017.08.200. URL: https://hal.archives-ouvertes.fr/hal-01667161 (cit. on p. 14).

[59] Y. Bouzidi, S. Lazard, G. Moroz, M. Pouget, F. Rouillier and M. Sagraloff. 'Solving bivariate systems using Rational Univariate Representations'. In: *Journal of Complexity* 37 (2016), pp. 34–75. DOI: 10.1016/j.jco.2016.07.002. URL: https://hal.inria.fr/hal-01342211 (cit. on p. 14).

[60] Y. Bouzidi, S. Lazard, M. Pouget and F. Rouillier. 'Separating linear forms and Rational Univariate Representations of bivariate systems'. In: *Journal of Symbolic Computation* 68.0 (May 2015), pp. 84–119. DOI: 10.1016/j.jsc.2014.08.009. URL: https://hal.inria.fr/hal-00977671 (cit. on p. 14).

[61] Y. Bouzidi, A. Poteaux and A. Quadrat. 'A symbolic computation approach to the asymptotic stability analysis of differential systems with commensurate delays'. In: *Delays and Interconnections: Methodology, Algorithms and Applications*. Advances on Delays and Dynamics at Springer. Springer Verlag, Mar. 2017. URL: https://hal.inria.fr/hal-01485536 (cit. on p. 13).

[62] Y. Bouzidi, A. Quadrat and F. Rouillier. 'Certified Non-conservative Tests for the Structural Stability of Multidimensional Systems'. Research Report. To appear in Multidimensional Systems and Signal Processing, https://link.springer.com/article/10.1007/s11045-018-0596-y. Aug. 2017. URL: https://hal.inria.fr/hal-01571230 (cit. on pp. 13, 14).

[63] Y. Bouzidi and F. Rouillier. 'Certified Algorithms for proving the structural stability of two dimensional systems possibly with parameters'. In: *MNTS 2016 - 22nd International Symposium on Mathematical Theory of Networks and Systems*. Proceedings of the 22nd International Symposium on Mathematical Theory of Networks and Systems. Minneapolis, United States, July 2016. URL: https://hal.inria.fr/hal-01366202 (cit. on pp. 13, 14).

[64] D. Chablat, R. Jha, F. Rouillier and G. Moroz. 'Non-singular assembly mode changing trajectories in the workspace for the 3-RPS parallel robot'. In: *14th International Symposium on Advances in Robot Kinematics*. Ljubljana, Slovenia, June 2014, pp. 149–159. URL: https://hal.archives-ouvertes.fr/hal-00956325 (cit. on p. 13).

[65] D. Chablat, R. Jha, F. Rouillier and G. Moroz. 'Workspace and joint space analysis of the 3-RPS parallel robot'. In: *ASME 2013 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference*. Vol. Volume 5A. Buffalo, United States, Aug. 2014, pp. 1–10. URL: https://hal.archives-ouvertes.fr/hal-01006614 (cit. on p. 13).

[66] R. Curtain and H. Zwart. *An Introduction to Infinite-Dimensional Linear Systems Theory*. Texts in Applied Mathematics. Springer New York, 2012 (cit. on p. 13).

[67] P. Dehornoy, F. Digne, E. Godelle, D. Krammer and J. Michel. *Foundations of Garside theory*. Vol. 22. EMS Tracts in Mathematics. Author name on title page: Daan Kramer. European Mathematical Society (EMS), Zürich, 2015, pp. xviii+691. DOI: 10.4171/139. URL: https://doi.org/10.4171/139 (cit. on p. 11).

[68] P. Dehornoy and Y. Lafont. 'Homology of Gaussian groups'. In: *Ann. Inst. Fourier (Grenoble)* 53.2 (2003), pp. 489–540 (cit. on p. 11).

[69] S. Diop. 'Differential-algebraic decision methods and some applications to system theory'. In: *Theoret. Comput. Sci.* 98 (1992), pp. 137–161 (cit. on p. 13).

[70] S. Diop. 'Elimination in control theory'. In: *Math. Control Signals Systems* 4 (1991), pp. 17–32 (cit. on p. 13).

[71] H. Evelyne. 'Notes on Triangular Sets and Triangulation-Decomposition Algorithms II: Differential Systems'. In: *Symbolic and Numerical Scientific Computation*. Ed. by F. Winkler and U. Langer. Lecture Notes in Computer Science 2630. Springer, 2003, pp. 40–87 (cit. on p. 13).

[72] E. Falbel, A. Guilloux and P. Will. 'Hilbert metric, beyond convexity'. working paper or preprint. 2018. URL: https://hal.archives-ouvertes.fr/hal-01768400 (cit. on p. 11).

[73] J. Faugère and D. Lazard. 'Combinatorial classes of parallel manipulators'. In: *Mechanism and Machine Theory* 30.6 (1995), pp. 765–776. DOI: https://doi.org/10.1016/0094-114X(94)00069-W. URL: http://www.sciencedirect.com/science/article/pii/0094114X9400069W (cit. on p. 13).

[74] E. Godelle and L. Paris. 'Basic questions on Artin-Tits groups'. In: *Configuration spaces*. Vol. 14. CRM Series. Ed. Norm., Pisa, 2012, pp. 299–311. DOI: 10.1007/978-88-7642-431-1_13. URL: https://doi.org/10.1007/978-88-7642-431-1_13 (cit. on p. 11).

[75] M. L. Husty and H.-P. Schröcker. 'Algebraic Geometry and Kinematics'. In: *Nonlinear Computational Geometry*. Ed. by I. Z. Emiris, F. Sottile and T. Theobald. New York, NY: Springer New York, 2010, pp. 85–107 (cit. on p. 12).

[76] R. Jha, D. Chablat, L. Baron, F. Rouillier and G. Moroz. 'Workspace, Joint space and Singularities of a family of Delta-Like Robot'. In: *Mechanism and Machine Theory* 127 (Sept. 2018), pp. 73–95. DOI: 10.1016/j.mechmachtheory.2018.05.004. URL: https://hal.archives-ouvertes.fr/hal-01796066 (cit. on p. 13).

[77] R. Jha, D. Chablat, F. Rouillier and G. Moroz. 'An algebraic method to check the singularity-free paths for parallel robots'. In: *International Design Engineering Technical Conferences & Computers and Information in Engineering Conference*. ASME. Boston, United States, Aug. 2015. URL: https://hal.archives-ouvertes.fr/hal-01142989 (cit. on p. 13).

[78] R. Jha, D. Chablat, F. Rouillier and G. Moroz. 'Workspace and Singularity analysis of a Delta like family robot'. In: *4th IFTOMM International Symposium on Robotics and Mechatronics*. Poitiers, France, June 2015. URL: https://hal.archives-ouvertes.fr/hal-01142465 (cit. on p. 13).

[79] T. Kailath. *Linear Systems*. Prentice-Hall, 1980 (cit. on p. 13).

[80] B. Mourrain. 'The 40 Generic Positions of a Parallel Robot'. In: *Proceedings of the 1993 International Symposium on Symbolic and Algebraic Computation*. ISSAC '93. Kiev, Ukraine: ACM, 1993, pp. 173–182. DOI: 10.1145/164081.164120. URL: http://doi.acm.org/10.1145/164081.164120 (cit. on p. 13).

[81] U. Oberst. 'Multidimensional constant linear systems'. In: *Acta Appl. Math.* 20 (1990), pp. 1–175 (cit. on p. 13).

[82] F. Paugam. *Towards the mathematics of quantum field theory*. Vol. 59. Ergebnisse der Mathematik und ihrer Grenzgebiete. 3. Folge. A Series of Modern Surveys in Mathematics [Results in Mathematics and Related Areas. 3rd Series. A Series of Modern Surveys in Mathematics]. Springer, Cham, 2014, pp. xvi+487. DOI: 10.1007/978-3-319-04564-1. URL: https://doi.org/10.1007/978-3-319-04564-1 (cit. on p. 11).

[83] J.-F. Pommaret. *Partial differential equations and group theory*. Vol. 293. Mathematics and its Applications. New perspectives for applications. Kluwer Academic Publishers Group, Dordrecht, 1994, pp. x+473. DOI: 10.1007/978-94-017-2539-2. URL: https://doi.org/10.1007/978-94-017-2539-2 (cit. on p. 11).

[84] A. Quadrat. 'Noncommutative geometric structures on stabilizable infinite-dimensional linear systems'. In: *ECC 2014*. Strasbourg, France, June 2014, pp. 2460–2465. DOI: 10.1109/ECC.2014.6862563. URL: https://hal-supelec.archives-ouvertes.fr/hal-01108019 (cit. on p. 14).

[85] G. Rance. 'Parametric H_∞ control and its application to gyrostabilized sights'. Theses. Université Paris-Saclay, July 2018. URL: https://tel.archives-ouvertes.fr/tel-01904086 (cit. on p. 14).

[86] G. Rance, Y. Bouzidi, A. Quadrat and A. Quadrat. 'A symbolic-numeric method for the parametric H∞ loop-shaping design problem'. In: *22nd International Symposium on Mathematical Theory of Networks and Systems (MTNS)*. Minneapolis, United States, July 2016, p. 8. URL: https://hal.inria.fr/hal-01415294 (cit. on p. 14).

[87] G. Rance, Y. Bouzidi, A. Quadrat and A. Quadrat. 'Explicit H∞ controllers for 1st to 3rd order single-input single-output systems with parameters'. In: *IFAC 2017 Workshop Congress*. Toulouse, France, July 2017. URL: https://hal.inria.fr/hal-01667410 (cit. on p. 14).

[88] G. Rance, Y. Bouzidi, A. Quadrat, A. Quadrat and F. Rouillier. 'Explicit H∞ controllers for 4th order single-input single-output systems with parameters and their applications to the two mass-spring system with damping'. In: *IFAC 2017 Workshop Congress*. Toulouse, France, July 2017. URL: https://hal.inria.fr/hal-01667368 (cit. on p. 14).

[89] P. Wenger. 'A new general formalism for the kinematic analysis of all nonredundant manipulators'. In: *ICRA*. 1992 (cit. on p. 13).

[90] J. Willems and J. Polderman. *Introduction to Mathematical Systems Theory: A Behavioral Approach*. Texts in Applied Mathematics. Springer New York, 2013 (cit. on p. 13).