IN PARTNERSHIP WITH:
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Activity Report 2016

Project-Team NON-A

Non-Asymptotic estimation for online systems

IN COLLABORATION WITH: Centre de Recherche en Informatique, Signal et Automatique de Lille

RESEARCH CENTER
Lille - Nord Europe

THEME
Optimization and control of dynamic systems

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Creation of the Team: 2011 January 01, updated into Project-Team: 2012 July 01

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2. Overall Objectives

2.1. Objectives

For engineers, a wide variety of information cannot be directly obtained through measurements. Some parameters (constants of an electrical actuator, delay in a transmission, etc.) or internal variables (robot's posture, torques applied to a robot, localization of a mobile robot, etc.) are unknown or unmeasured. In addition, usually the signals from sensors are distorted and tainted by measurement noises. In order to simulate, to control or to supervise processes, and to extract information conveyed by the signals, one has to estimate parameters or variables.

Estimation techniques are, under various guises, present in many parts of control, signal processing and applied mathematics. Such an important area gave rise to a huge international literature. From a general point of view, the performance of an estimation algorithm can be characterized by three indicators:

- The computation time (the time needed to obtain the estimation). Obviously, the estimation algorithms should have as small as possible computation time in order to provide fast, real-time, on-line estimations for processes with fast dynamics (for example, a challenging problem is to make an Atomic Force Microscope work at GHz rates).
- The algorithm complexity (the easiness of design and implementation). Estimation algorithms should have as low as possible algorithm complexity, in order to allow an embedded real-time estimation (for example, in networked robotics, the embedded computation power is limited and can be even more limited for small sensors/actuators devices). Another question about complexity is: can an engineer appropriate and apply the algorithms? For instance, an algorithm application is easier if the parameters have a physical meaning w.r.t. the process under study.
- The robustness. The estimation algorithms should exhibit as much as possible robustness with respect to a large class of measurement noises, parameter uncertainties, discretization steps and other issues of numerical implementation. A complementary point of view on robustness is to manage a compromise between existence of theoretical proofs versus universalism of the algorithm. In the first case, the performance is guaranteed in a particular case (a particular control designed for a particular model). In the second case, an algorithm can be directly applied in “most of the cases", but it may fail in few situations.

Within the very wide area of estimation, *Non-A* addresses 3 particular theoretical challenges (see the upper block “Theory” of Figure 1):

1) Design annihilators for some general class of perturbations;

2) Estimate on-line the derivatives of a signal;

3) Control without sophisticated models.

All of them are connected with the central idea of designing or exploiting algorithms with the finite-time convergence property. In particular, the *non-asymptotic* estimation techniques (numerical differentiation, finite-time differentiators or observers) constitute a central objective of the project, explaining the name *Non-Asymptotic estimation for on-line systems*. Below, these 3 challenges will be shortly described in relation to the above indicators.

The researches developed by *Non-A* are within the continuity of the project-team *ALIEN* in what concerns the *algebraic tools* that are developed for finite-time estimation purposes. However, *Non-A* also aims at developing complementary estimation techniques, still aiming at the finite-time performance but based on the so-called *higher-order sliding mode* algorithms, interval estimation techniques and, as well as, fixed-time algorithms.

Non-A also wants to confront these theoretical challenges with some application fields (shown on the bottom of Figure 1): Networked robots, Nano/macro machining, Multicell chopper, *i*-PID for industry. Today, most of our effort (*i.e.*, engineering staff) is devoted to the first item, according to the theme ‘Internet of Things’ promoted by Inria in its Strategic Plan for the Lille North-Europe research center. Indeed, WSNR (Wireless Sensor and Robot Networks) integrate mobile nodes (robots) that extends various aspects of the sensor network.

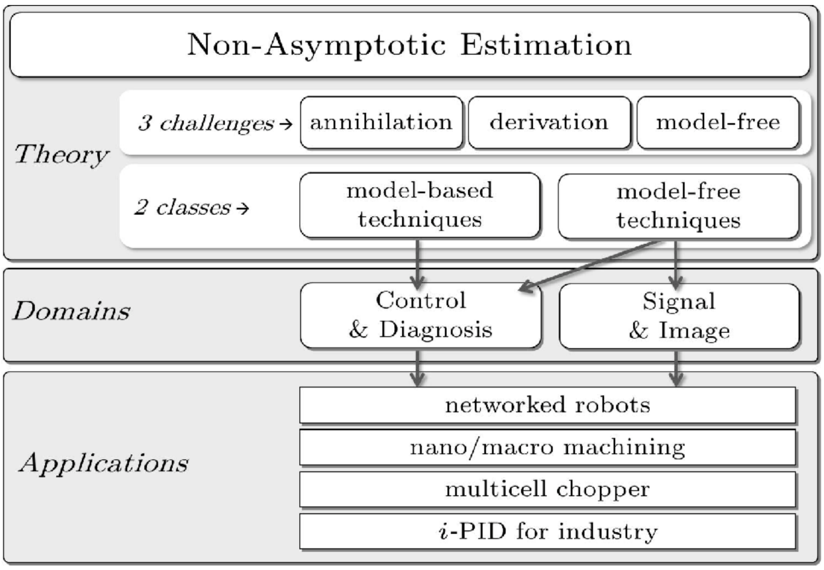

Figure 1. Non-A is a method-driven project, centered around non-asymptotic estimation techniques (i.e. providing estimates in finite-time), and connected to applications.

2.2. Members complementarity

The members of the Non-A project work in different places: Lille, Cergy, Reims and Nancy. They share a common algebraic tool and the non-asymptotic estimation goal, which constitute the natural kernel of the project. Each of them contributes to both theoretical and applied sides of the global project. The following table draws up a scheme of some of their specialities.

	Upstream Researches	*Application Fields*
Reims CReSTIC	Signal - Numerical analysis	De-noising - Demodulation - Biomedical signal processing
Cergy Quartz	Nonlinear observers - Hybrid systems	Cryptography - Multi-cell chopper/converter
Lille ENSAM	Applied mathematics	High performance machining - Precision sensors, AFM [1]
Lille CRIStAL	Delay systems - Nonlinear control - Observers (finite-time/unknown input)	Magnetic bearings - Friction estimation - Networked control - Robotics
Nancy CRAN	Diagnosis - Control - Signal	Industrial processes - Signal & image processing

3. Research Program

3.1. General annihilators

Estimation is quite easy in the absence of perturbations. It becomes challenging in more realistic situations, faced to measurement noises or other unknown inputs. In our works, as well as in the founding text of *Non-A*, we have shown how our estimation techniques can successfully get rid of perturbations of the so-called *structured* type, which means the ones that can be annihilated by some linear differential operator (called the annihilator). *ALIEN* already defined such operators by integral operators, but using more general convolution operators is an alternative to be analyzed, as well as defining the “best way to kill” perturbations. Open questions are:

OQ1) Does a normal form exist for such annihilators?

OQ2) Or, at least, does there exist an adequate basis representation of the annihilator in some adequate algebra?

OQ3) And lastly, can the annihilator parameters be derived from efficient tuning rules?

The two first questions will directly impact Indicators 1 (time) and 2 (complexity), whereas the last one will impact indicator 3 (robustness).

3.2. Numerical differentiation

Estimating the derivative of a (noisy) signal with a sufficient accuracy can be seen as a key problem in domains of control and diagnosis, as well as signal and image processing. At the present stage of our research, the estimation of the n-th order time derivatives of noisy signals (including noise filtering for $n = 0$) appears as a common area for the whole project, either as a research field, or as a tool that is used both for model-based and model-free techniques. *One of the open questions is about the robustness issues (Indicator 3) with respect to the annihilator, the parameters and the numerical implementation choices.*

Two classes of techniques are considered here (**Model-based** and **Model-free**), both of them aiming at non-asymptotic estimation.

[1] Atomic Force Microscope, for which fast filtering is required

In what we call *model-based techniques*, the derivative estimation is regarded as an observation problem, which means the software-based reconstruction of unmeasured variables and, more generally, a left inversion problem [2]. This involves linear/homogeneous/nonlinear state models, including ordinary equations, systems with delays, hybrid systems with impulses or switches [3], which still has to be exploited in the finite-time and fixed-time context. Power electronics is already one of the possible applications.

Model-free techniques concern the works initiated by *ALIEN*, which rely on the only information contained in the output signal and its derivatives. The corresponding algorithms rely on our algebraic annihilation viewpoint. *One open question is: How to provide an objective comparison analysis between Model-based and Model-free estimation techniques? For this, we will only concentrate on Non-Asymptotic ones. This comparison will have to be based on the three Indicators 1 (time), 2 (complexity) and 3 (robustness).*

3.3. Model-free control

Industry is keen on simple and powerful controllers: the tuning simplicity of the classical PID controller explains its omnipresence in industrial control systems, although its performances drop when working conditions change. The last challenge we consider is to define control techniques which, instead of using sophisticated models (the development of which may be expensive), use the information contained in the output signal and its estimated derivatives, which can be regarded as "signal-based" controllers. *Such design should take into account the Indicators 1 (time), 2 (complexity) and 3 (robustness).*

3.4. Applications

Keeping in mind that we will remain focused at developing and applying fundamental methods for non-asymptotic estimation, we intend to deal with 4 main domains of application (see the lower part of Figure 1). The Lille context offers interesting opportunities in WSAN (wireless sensor and actuator networks and, more particularly, networked robots) at Inria, as well as nano/macro machining at ENSAM. A power electronics platform will be developed in ENSEA Cergy. Last, in contact with companies, several grants, patents and collaborations are expected from the applications of $i-$PID. Each of these four application domains was presented in the *Non-A* proposal:

- Networked robots, WSAN [Lille]
- Nano/macro machining [Lille]
- Multicell chopper [Lille and Cergy]
- i-PID for industry

In the present period, we choose to give a particular focus to the first item (Networked robots), which already received some development. It can be considered as the objective 4.

4. Application Domains

4.1. Robots and networked systems

Inria Lille and team FUN are hosting an "equipment of excellence", named FIT-IoT lab. It gives a remote access to thousands of wireless sensors to be connected with hundreds of mobile robots. Today, many sensor scenarios are available, with few robot testbeds.

[2] Left invertibility deals with the question of recovering the full state of a system ("observation") together with some of its inputs ("unknown input observers"), and also refers to algebraic structural conditions.

[3] Note that hybrid dynamical systems (HDS) constitute an important field of investigation since, in this case, the discrete state can be considered as an unknown input.

The package SLIM, developed by Non-A under ROS (Robot Operating System) with the support of an Inria ADT, aims at contributing to this environment. The self deployment of autonomous groups of mobile robots in an unknown and variable environment is a next step for IoT-lab, involving localization, path planning and robust control problems. Our ROS package SLIM aims at combining various algorithms developed by Non-A (localization, path planning, robust control). It should also offer a software library for multi-robot including: optimal local planner based on flatness; plugin for communication between different ROS cores; module Multi-Mapping for robot cooperation; plugin for YEI IMU.

4.2. Living systems: ecological monitoring, modelling, estimation and identification of biological systems, human-computer interaction

Modelling, estimation or detection for living is difficult because such systems cannot be isolated from external influences. Using our numerical differentiation tools, together with modelling techniques, we want to study the following four applications:

- *Biosensing*: Unlike classical approaches deploying physical sensors, biological systems can be used as living sensors. The marine biology lab EPOC (CNRS, Bordeaux) has developed underwater sensors for bivalve molluscs (such as oysters) measuring and sending through RGPS the opening gap between the two valves. We want to use it for water quality monitoring by either identifying oyster's rythm I/O models or by using our differentiation tools. Spawning detection is also considered (ANR WaQMoS).
- *Human-Computer Interaction*: Reduction of the latency between the human input and the system visual response in HCI (ANR TurboTouch). To do that, a simple forecasting algorithm for latency compensation in indirect interaction using a mouse has to be developed based on differentiators.
- *Smart bracelet*: Design a dynamical model for the GSR and for the development of an online algorithm making the GSR signal independent of the user movements. Most resulting computations should be embedded into the bracelet. Collaboration with NEOTROPE (start-up developing a bracelet intended for strong human emotion detection).
- *Microbial populations*: Real-time control of synthetic microbial communities (Inria Project Lab, COSY, under evaluation).

4.3. Turbulent flow control for aircrafts and vehicles

Non-A is active in a Regional consortium gathering micro-technologies (ONERA, IEMN, LAMIH, LML and PPrime lab, Univ. of Poitiers) which aims at developing methods for active control of separated flows (ContrATech subprogram of CPER ELSAT).

Aerodynamic losses are believed to be a major source of energy wastage for a vehicle at speeds higher than 50 km/h. Optimization of the vehicles shapes has reached its limit and such a passive control approach cannot deal with unsteady incoming flow. Similarly, in aeronautics, controlling boundary layer airflow could reduce stall drastically. In such contexts, active control strategies (air blowers, hot film sensors, etc.) are very attractive. But the natural phenomena ruling turbulent flows lead to highly nonlinear and infinite-dimension dynamics. Till now, researchers use either nonlinear PDEs (Navier-Stokes equations) allowing for analysis but improper for control design or unrealistic linear finite-dimension models for classical − but non robust − control. Non-A first wants to propose a model with intermediate complexity (bilinear with time delays, "grey-box" identification on experimental data) and then develop model-based sliding mode and optimal control algorithms.

4.4. Industry and society: i-PID for industry and society, mechatronics (Safran)

- Industry is keen on simple and powerful controllers. The tuning simplicity of the classical PID controller explains its omnipresence in industrial control systems, although its performances drop when the working conditions change. AL.I.E.N SAS was created in 2011 as a spin-off of the Inria project ALIEN, which gave rise to Non-A, working on algebraic estimation and i-PID controller (i.e., using algebraic estimation of the perturbations and apply a simple PID control on some “ultra-local” model). These control technique uses the information contained in the output signal and its estimated derivatives, which can be regarded as “signal-based” controllers. Model-free control technique has been applied in many different domains (electronics, hydroelectric power, etc.).

  Recent research is focused on traffic control and biology. The quality of traffic control laws depends on a good knowledge of the highway characteristics, especially the critical density and the free-flow speed, which are unfortunately most difficult to estimate in real time. Therefore, we aim at developing an algorithm which shows the possibility to control the traffic without the knowledge of density and free-flow speed.
- A collaboration with the Safran Electronics & Defense company has been developed (CIFRE PhD thesis) on the parametric stabilization of gyrostabilized platforms. To do that, we first aim at developing new symbolic-numeric methods for the standard H_∞-loop shaping design problem for models of gyrostabilized platforms in terms of the physical parameters (masses, inertia, etc.) considered as unknown/slowly varying parameters. Using Non-A techniques for the estimation of the physical parameters, we then want to develop new embeddable and adaptive controllers for the robust stabilization of gyrostabilized platforms.

5. Highlights of the Year

5.1. Highlights of the Year

UCoCoS

The H2020 project UCoCoS (Understanding and Controlling of Complex Systems, supervisors: W. Michiels, J.-P. Richard, H. Nijmeijer, 2016-2020) has started effectively this year: kick-off meeting in Eindhoven in March and, at the end of this year, recruitment of the 6 PhD students (including 4 jointly with Lille: H. Silm, J. Thomas, D. Dileep, Q. Voortman) in the 3 hosting institutions.

5.1.1. Awards

D. Efimov is Outstanding IEEE TAC reviewer.

6. New Software and Platforms

6.1. Blimp

FUNCTIONAL DESCRIPTION

Scientific research and development on the control of autonomous airship have shown a significant growth in recent years. New applications appear in the areas such as freight carrier, advertising, monitoring, surveillance, transportation, military and scientific research. The control of autonomous airship is a very important problem for the aerial robots research.

The development of Blimp by Non-A is used for experimentation and demonstration of controlling algorithms. The blimp is required to provide some environment information and status of itself, such as surveillance video of surrounding environment, gesture of blimp, altitude of blimp. With these basic information, one could localize blimp with certain algorithm (visual SLAM for example) or implement one controller in order to improve the stability and maneuverability of blimp.

- Contact: Jean-Pierre Richard
- URL: https://bil.inria.fr/fr/software/view/2279/tab

6.2. ControlHub

The driving idea is to interconnect a group of actors (researchers, engineers, etc.) around a control problem and grant them remote access to existing experimental facilities, thus allowing them to verify their theoretical results online, and finally share them with the project members.

The platform architecture relies on three key principles:

- Problem centric: The control problem to be solved is the core project, whereas the software resources, tools and online experiments are web services available to support experimental verification of the solutions.
- Separation of concerns: setup and maintenance of experiment facilities, installation of software tools, problem formulation and theoretical analysis, etc.
- Resource sharing: software packages, experimental facilities, open problems.
- Contact: R. Dagher, A. Polyakov, J.-P. Richard
- URL: https://bil.inria.fr/fr/software/view/2830/tab

6.3. SLIM

FUNCTIONAL DESCRIPTION

Multi-robots cooperation can be found as an application in many domains of science and technology: manufacturing, medical robotics, personal assistance, military/security and spatial robots. The market of robots is quickly developing and its capacity is continuously growing. Concerning cooperation of mobile multi-robots, 3 key issues have to be studied: Localization, path planning and robust control, for which Non-A team has worked and proposed new algorithms. Due to the ADT SLIM, we implement our algorithms (localization, path planning and robust control) and integrate them into ROS (Robotic Operating System) as a package, named SLIM.

- Contact: G. Zheng
- URL: https://bil.inria.fr/fr/software/view/2278/tab

7. New Results

7.1. Homogeneity Theory

Homogeneity is one of the tools we develop for finite-time convergence analysis. In 2016 this concept has received various improvements:

- Frequency domain approach to analysis of homogeneous nonlinear systems [85], [46]:

  Analysis of feedback sensitivity functions for implicit Lyapunov function-based control system is developed. The Gang of Four and loop transfer function are considered for practical implementation of the control via frequency domain control design. The effectiveness of this control scheme is demonstrated on an illustrative example of roll control for a vectored thrust aircraft.
- Homogeneous distributed parameter systems [72], [32]:

A geometric homogeneity is introduced for evolution equations in a Banach space. Scalability property of solutions of homogeneous evolution equations is proven. Some qualitative characteristics of stability of trivial solution are also provided. In particular, finite-time stability of homogeneous evolution equations is studied. Classical theorems on existence and uniqueness of solutions of nonlinear evolution equations are revised. A universal homogeneous feedback control for a finite-time stabilization of linear evolution equation in a Hilbert space is designed using homogeneity concept. The design scheme is demonstrated for distributed finite-time control of heat and wave equations.

- Robustness of Homogenous Systems:
  - [93], [36] The problem of stability robustness with respect to time-varying perturbations of a given frequency spectrum is studied applying homogeneity framework. The notion of finite-time stability over time intervals of finite length, i.e. short-finite-time stability, is introduced and used for that purpose. The results are applied to demonstrate some robustness properties of the three-tank system.
  - The uniform stability notion for a class of nonlinear time-varying systems is studied in [35] using the homogeneity framework. It is assumed that the system is weighted homogeneous considering the time variable as a constant parameter, then several conditions of uniform stability for such a class of systems are formulated. The results are applied to the problem of adaptive estimation for a linear system.
  - Robustness with respect to delays is discussed in [84], [45] for homogeneous systems with negative degree. It is shown that if homogeneous system with negative degree is globally asymptotically stable at the origin in the delay-free case then the system is globally asymptotically stable with respect to a compact set containing the origin independently of delay. The possibility of applying the result for local analysis of stability for not necessary homogeneous systems is analyzed. The theoretical results are supported by numerical examples.
- Finite-time and Fixed-time Control and Estimation:
  - [61], [46] A switched supervisory algorithm is proposed, which ensures fixed-time convergence by commutation of finite-time or exponentially stable homogeneous systems of a special class, and a finite-time convergence to the origin by orchestrating among asymptotically stable systems. A particular attention is paid to the case of exponentially stable systems. Finite-time and fixed-time observation problem of linear multiple input multiple output (MIMO) control systems is studied. The nonlinear dynamic observers , which guarantee convergence of the observer states to the original system state in a finite and a fixed (defined a priori) time, are studied. Algorithms for the observers parameters tuning are also developed.
  - [16] This paper focuses on the design of fixed-time consensus for multiple unicycle-type mobile agents. A distributed switched strategy, based on local information, is proposed to solve the leader-follower consensus problem for multiple nonholonomic agents in chained form. The switching times and the prescribed convergence time are explicitly given regardless of the initial conditions. Simulation results highlight the efficiency of the proposed method.
- Discretization of Homogeneous Systems:
  - [63] Sufficient conditions for the existence and convergence to zero of numeric approximations to solutions of asymptotically stable homogeneous systems are obtained for the explicit and implicit Euler integration schemes. It is shown that the explicit Euler method has certain drawbacks for the global approximation of homogeneous systems with non-zero degrees, whereas the implicit Euler scheme ensures convergence of the approximating solutions to zero.

  - [69] The known results on asymptotic stability of homogeneous differential inclusions with negative homogeneity degrees and their accuracy in the presence of noises and delays are extended to arbitrary homogeneity degrees. Discretization issues are considered, which include explicit and implicit Euler integration schemes. Computer simulation illustrates the theoretical results.
- Multi-Homogeneity and differential inclusions:
  - The notion of homogeneity in the bi-limit from is extended in [21] to local homogeneity and then to homogeneity in the multi-limit. The converse Lyapunov/Chetaev theorems on (homogeneous) system instability are obtained. The problem of oscillation detection for nonlinear systems is addressed. The sufficient conditions of oscillation existence for systems homogeneous in the multi-limit are formulated. The proposed approach estimates the number of oscillating modes and the regions of their location. Efficiency of the technique is demonstrated on several examples.
  - In [94], the notion of geometric homogeneity is extended for differential inclusions. This kind of homogeneity provides the most advanced coordinate-free framework for analysis and synthesis of nonlinear discontinuous systems. The main qualitative properties of continuous homogeneous systems are extended to the discontinuous setting: the equivalence of the global asymptotic stability and the existence of a homogeneous Lyapunov function; the link between finite-time stability and negative degree of homogeneity; the equivalence between attractivity and asymptotic stability are among the proved results.

7.2. Algebraic Technique For Estimation

- Time parameter estimation for a sum of sinusoidal waveform signals [39]:

  A novel algebraic method is proposed to estimate amplitudes, frequencies, and phases of a biased and noisy sum of complex exponential sinusoidal signals. The resulting parameter estimates are given by original closed formulas, constructed as integrals acting as time-varying filters of the noisy measured signal. The proposed algebraic method provides faster and more robust results, compared with usual procedures. Some computer simulations illustrate the efficiency of our method.
- Algebraic estimation via orthogonal polynomials [80]:

  Many important problems in signal processing and control engineering concern the reconstitution of a noisy biased signal. For this issue, we consider the signal written as an orthogonal polynomial series expansion and we provide an algebraic estimation of its coefficients. We specialize in Hermite polynomials. On the other hand, the dynamical system described by the noisy biased signal may be given by an ordinary differential equation associated with classical orthogonal polynomials. The signal may be recovered through the coefficients identification. As an example, we illustrate our algebraic method on the parameter estimation in the case of Hermite polynomials.
- An effective study of the algebraic parameter estimation problem [105]:

  Within the algebraic analysis approach, we first give a general formulation of the algebraic parameter estimation for signals which are defined by ordinary differential equations with polynomial coefficients such as the standard orthogonal polynomials (Chebyshev, Jacobi, Legendre, Laguerre, Hermite, ... polynomials). We then show that the algebraic parameter estimation problem for a truncated expansion of a function into an orthogonal basis of L^2 defined by orthogonal polynomials can be studied similarly. Then, using symbolic computation methods such as Gröbner basis techniques for (noncommutative) polynomial rings, we first show how to compute ordinary differential operators which annihilate a given polynomial and which contain only certain parameters in their coefficients. Then, we explain how to compute the intersection of the annihilator ideals of two polynomials and characterize the ordinary differential operators which annihilate a first polynomial but not a second one. These results are implemented in the NON-A package built upon the OREMODULES software.

7.3. Set-Theoretic Methods of Control, Observer Design and Estimation

- Interval Observers:
  - [19] New design of interval observers for continuous-time systems with discrete-time measurements is proposed. For this purpose new conditions of positivity for linear systems with sampled feedbacks are obtained. A sampled-data stabilizing control is synthesized based on provided interval estimates. Efficiency of the obtained solution is demonstrated on examples.
  - [66] The problem of interval state estimation is studied for systems described by parabolic Partial Differential Equations (PDEs). The proposed solution is based on a finite-element approximation of PDE, with posterior design of an interval observer for the obtained ordinary differential equation. The interval inclusion of the state function of PDE is obtained using the estimates on the error of discretization. The results are illustrated by numerical experiments with an academic example.
  - [18] New interval observers are designed for linear systems with time-varying delays in the case of delayed measurements. Interval observers employ positivity and stability analysis of the estimation error system, which in the case of delayed measurements should be delay-dependent. New delay-dependent conditions of positivity for linear systems with time-varying delays are introduced. Efficiency of the obtained solution is demonstrated on examples.
  - [22] Interval state observers provide an estimate on the set of admissible values of the state vector at each instant of time. Ideally, the size of the evaluated set is proportional to the model uncertainty, thus interval observers generate the state estimates with estimation error bounds, similarly to Kalman filters, but in the deterministic framework. Main tools and techniques for design of interval observers are reviewed in this tutorial for continuous-time, discrete-time and time-delayed systems.
  - [43] investigates the problem of observer design for a general class of linear singular time-delay systems, in which the time delays are involved in the state, the output and the known input (if there exists). The involvement of the delay could be multiple which however is rarely studied in the literature. Sufficient conditions are proposed which guarantees the existence of a Luenberger-like observer for the general system.
  - In [90] an interval observer is proposed for on-line estimation of differentiation errors in some class of high-order differentiators (like a high-gain differentiator, or homogeneous nonlinear differentiator, or super-twisting differentiator). The results are verified and validated on the telescopic link of a robotic arm for forestry applications in which the mentioned approaches are used to estimate the extension velocity while the interval observer gives bounds to this estimation.
  - The problem of interval observer design is studied in [87] for a class of linear hybrid systems. Several observers are designed oriented on different conditions of positivity and stability for estimation error dynamics. Efficiency of the proposed approach is demonstrated by computer experiments for academic and bouncing ball systems.
  - The problem of estimation of sequestered parasites Plasmodium falciparum in malaria, based on measurements of circulating parasites, is addressed in [60]. It is assumed that all (death, transition, recruitment and infection) rates in the model of a patient are uncertain (just intervals of admissible values are given) and the measurements are subject to a bounded noise, then an interval observer is designed. Stability of the observer can be verified by a solution of LMI. The efficiency of the observer is demonstrated in simulation.
- Observer design:

  - [81] presents a new approach for observer design for a class of nonlinear singular systems which can be transformed into a special normal form. The interest of the proposed form is to facilitate the observer synthesis for the studied nonlinear singular systems. Necessary and sufficient geometrical conditions are deduced in order to guarantee the existence of a diffeomorphism which transforms the studied nonlinear singular systems into the proposed normal form.
  - In [38], we investigate the estimation problem for a class of partially observable nonlinear systems. For the proposed Partial Observer Normal Form (PONF), necessary and sufficient conditions are deduced to guarantee the existence of a change of coordinates which can transform the studied system into the proposed PONF. Examples are provided to illustrate the effectiveness of the proposed results.
  - [71] deals with the problem of finite-time and fixed-time observation of linear multiple input multiple output (MIMO) control systems. The nonlinear dynamic observers , which guarantee convergence of the observer states to the original system state in a finite and a fixed (defined a priori) time, are studied. Algorithms for the observers parameters tuning are also developed. The theoretical results are illustrated by numerical examples.
  - [44] Sliding mode control design for linear systems with incomplete and noisy measurements of the output and additive/multiplicative exogenous disturbances is studied. A linear minimax observer estimating the system's state with minimal worst-case error is designed. An algorithm, generating continuous and discontinuous feedbacks, which steers the state as close as possible to a given sliding hyperplane in finite time, is presented. The optimality (sub-optimality) of the designed feedbacks is proven for the case of bounded noises and additive (multiplicative) disturbances of L_2-class.
  - [37] deals with the design of a robust control for linear systems with external disturbances using a homogeneous differentiator-based observer based on a implicit Lyapunov function approach. Sufficient conditions for stability of the closed-loop system in the presence of external disturbances are obtained and represented by linear matrix inequalities. The parameter tuning for both controller and observer is formulated as a semi-definite programming problem with linear matrix inequalities constraints. Simulation results illustrate the feasibility of the proposed approach and some improvements with respect to the classic linear observer approach.
  - The problem studied in [17] is one of improving the performance of a class of adaptive observer in the presence of exogenous disturbances. The H^∞ gains of both a conventional and the newly proposed sliding-mode adaptive observer are evaluated, to assess the effect of disturbances on the estimation errors. It is shown that if the disturbance is "matched" in the plant equations, then including an additional sliding-mode feedback injection term, dependent on the plant output, improves the accuracy of observation.
  - In [95], we consider the classical reaching problem of sliding mode control design, that is to find a control law which steers the state of a Linear Time-Invariant (LTI) system towards a given hyperplane in a finite time. Since the LTI system is subject to unknown but bounded disturbances we apply the minimax observer which provides the best possible estimate of the system's state. The reaching problem is then solved in observer's state space by constructing a feedback control law. The cases of discontinuous and continuous admissible feedbacks are studied. The theoretical results are illustrated by numerical simulations.

- Estimation and Identification:
  - The problem of output control for linear uncertain system with external perturbations is studied in [77]. It is assumed that the output available for measurements is the higher order derivative of the state only (acceleration for a second order plant), which is also corrupted by noise. Then via series of integration an identification algorithm is proposed for identification of values of all parameters and unknown initial conditions for the state vector.

Finally, two control algorithms are developed, adaptive and robust, providing boundedness of trajectories for the system. Efficiency of the obtained solutions is demonstrated by numerical experiments.

– [24] focuses on the problem of velocity and position estimation. A solution is presented for a class of oscillating systems in which position, velocity and acceleration are zero mean signals. The proposed scheme considers that the dynamic model of the system is unknown. Only noisy acceleration measurements, that may be contaminated by zero mean noise and constant bias, are considered to be available. The proposal uses the periodic nature of the signals obtaining finite-time estimations while tackling integration drift accumulation.

– In [41], we investigate the problem of simultaneous state and parameter estimation for a class of nonlinear systems which can be transformed into an output depending normal form. A new and simple adaptive observer for such class of systems is presented. Sufficient condition for the existence of the proposed observer is derived. A concrete application is given in order to highlight the effectiveness of the proposed result.

– In [75], the problem of time-varying parameter identification is studied. To this aim, an identification algorithm is developed in order to identify time-varying parameters in a finite-time. The convergence proofs are based on a notion of finite-time stability over finite intervals of time, i.e. Short-finite-time stability; homogeneity for time-varying systems; and Lyapunov function approach. The algorithm asks for a condition over the regressor term which is related to the classic identifiability condition corresponding to the injectivity of such a term. Simulation results illustrate the feasibility of the proposed algorithm.

7.4. Stability, Stabilization, Synchronization

- Input-to-state stability:
  – Supported by a novel field definition and recent control theory results, a new method to avoid local minima is proposed in [25]. It is formally shown that the system has an attracting equilibrium at the target point, repelling equilibriums in the obstacles centers and saddle points on the borders. Those unstable equilibriums are avoided capitalizing on the established Input-to-State Stability (ISS) property of this multistable system. The proposed modification of the PF method is shown to be effective by simulation for a two variables integrator and then applied to an unicycle-like wheeled mobile robots which is subject to additive input disturbances.
  – [62] Motivated by the problem of phase-locking in droop-controlled inverter-based microgrids with delays, the recently developed theory of input-to-state stability (ISS) for multistable systems is extended to the case of multistable systems with delayed dynamics. Sufficient conditions for ISS of delayed systems are presented using Lyapunov-Razumikhin functions. It is shown that ISS multistable systems are robust with respect to delays in a feedback. The derived theory is applied to two examples. First, the ISS property is established for the model of a nonlinear pendulum and delay-dependent ro-bustness conditions are derived. Second, it is shown that, under certain assumptions, the problem of phase-locking analysis in droop-controlled inverter-based microgrids with delays can be reduced to the stability investigation of the nonlinear pendulum. For this case, corresponding delay-dependent conditions for asymptotic phase-locking are given.
  – [103] A necessary and sufficient criterion to establish input-to-state stability (ISS) of nonlinear dynamical systems, the dynamics of which are periodic with respect to certain state variables and which possess multiple invariant solutions (equilibria, limit cycles, etc.), is provided. Unlike standard Lyapunov approaches, the condition is relaxed and formulated via a sign-indefinite function with sign-definite derivative, and by taking the system's periodicity explicitly into account. The new result is established by using the framework of cell structure introduced in [24] and it complements the methods developed in [3], [4]

for periodic systems. The efficiency of the proposed approach is illustrated via the global analysis of a nonlinear pendulum with constant persistent input.

  - In [53] we revisit the problem of stabilizing a triple integrator using a control that depends on the signs of the state variables. For a more general class of linear systems it is shown that the stabilization by sign feedback is possible, depending on some properties of the system's matrix. The conditions for the stability are established by means of linear matrix inequalities. For the triple integrator, the domain of stability is evaluated. Also, the control law is augmented by a linear feedback and the stability properties for this case, checked. The results are illustrated by numerical experiments for a chain of integrators of third order.

- Stabilization:
  - A solution to the problem of global fixed-time output stabilization of a chain of integrators is proposed in [70]. A nonlinear state feedback and a dynamic observer are designed in order to guarantee both fixed-time estimation and fixed-time control. Robustness with respect to exogenous disturbances and measurement noises is established. The performance of the obtained control and estimation algorithms are illustrated by numeric experiments.
  - In [20], the rate of convergence to the origin for a chain of integrators stabilized by homogeneous feedback is accelerated by a supervisory switching of control parameters. The proposed acceleration algorithm ensures a fixed-time convergence for otherwise exponentially or finite-time stable homogeneous closed-loop systems. Bounded disturbances are taken into account. The results are especially useful in the case of exponentially stable systems widespread in the practice. The proposed switching strategy is illustrated by computer simulation.
  - [33] The problem of robust finite-time stabilization of perturbed multi-input linear system by means of generalized relay feedback is considered. A new control design procedure, which combines convex embedding technique with Implicit Lyapunov Function (ILF) method, is developed. The sufficient conditions for both local and global finite-time stabilization are provided. The issues of practical implementation of the obtained implicit relay feedback are discussed. Our theoretical result is supported by numerical simulation for a Buck converter.
  - [100] contributes to the stability analysis for impulsive dynamical systems based on a vector Lyapunov function and its divergence operator. The new method relies on a 2D time domain representation. The result is illustrated for the exponential stability of linear impulsive systems based on LMIs. The obtained results provide some notions of minimum and maximum dwell-time. Some examples illustrate the feasibility of the proposed approach.
  - The Universal Integral Control, introduced in H.K. Khalil, is revisited in [34] by employing mollifiers instead of a high-gain observer for the differentiation of the output signal. The closed loop system is a classical functional differential equation with distributed delays on which standard Lyapunov arguments are applied to study the stability. Low-pass filtering capability of mollifiers is demonstrated for a high amplitude and rapidly oscillating noise. The controller is supported by numerical simulations.

- Synchronization:
  - In [12], we study a robust synchronization problem for multistable systems evolving on manifolds within an Input-to-State Stability (ISS) framework. Based on a recent generalization of the classical ISS theory to multistable systems, a robust synchronization protocol is designed with respect to a compact invariant set of the unperturbed system. The invariant set is assumed to admit a decomposition without cycles, that is, with neither homoclinic nor heteroclinic orbits. Numerical simulation examples illustrate our theoretical results.

– In [51], [96], motivated by a recent work of R. Brockett Brockett (2013), we study a robust synchronization problem for multistable Brockett oscillators within an Input-to-State Stability (ISS) framework. Based on a recent generalization of the classical ISS theory to multistable systems and its application to the synchronization of multistable systems, a synchronization protocol is designed with respect to compact invariant sets of the unperturbed Brockett oscillator. The invariant sets are assumed to admit a decomposition without cycles (i.e. with neither homoclinic nor heteroclinic orbits). Contrarily to the local analysis of Brockett (2013), the conditions obtained in our work are global and applicable for family of non-identical oscillators. Numerical simulation examples illustrate our theoretical results.

7.5. Non-Linear, Sampled-Data And Time-Delay Systems

- Time-delay systems:
  – The problem of delay estimation for a class of nonlinear time-delay systems is considered in [82]. The theory of non-commutative rings is used to analyze the identifiability. Sliding mode technique is utilized in order to estimate the delay showing the possibility to have a local (or global) delay estimation for periodic (or aperiodic) delay signals.
  – In [14] we give sufficient conditions guaranteeing the observability of singular linear systems with commensurable delays affected by unknown inputs appearing in both the state equation and the output equation. These conditions allow for the reconstruction of the entire state vector using past and actual values of the system output. The obtained conditions coincide with known necessary and sufficient conditions of singular linear systems without delays.
  – [67] presents a finite-time observer for linear time-delay systems. In contrast to many observers, which normally estimate the system state in an asymptotic fashion, this observer estimates the exact system state in predetermined finite time. The finite-time observer proposed is achieved by updating the observer state based on actual and pass data of the observer. Simulation results are also presented to illustrate the convergence behavior of the finite-time observer.
  – The backward observability (BO) of a part of the vector of trajectories of the system state is tackled in [57] for a general class of linear time-delay descriptor systems with unknown inputs. By following a recursive algorithm, we present easy testable sufficient conditions ensuring the BO of descriptor time-delay systems.
  – Motivated by the problem of phase-locking in droop-controlled inverter-based microgrids with delays, in [23], the recently developed theory of input-to-state stability (ISS) for multistable systems is extended to the case of multistable systems with delayed dynamics. Sufficient conditions for ISS of delayed systems are presented using Lyapunov-Razumikhin functions. It is shown that ISS multistable systems are robust with respect to delays in a feedback. The derived theory is applied to two examples. First, the ISS property is established for the model of a nonlinear pendulum and delay-dependent robustness conditions are derived. Second, it is shown that, under certain assumptions, the problem of phase-locking analysis in droop-controlled inverter-based microgrids with delays can be reduced to the stability investigation of the nonlinear pendulum. For this case, corresponding delay-dependent conditions for asymptotic phase-locking are given.
  – Causal and non-causal observability are discussed in [68] for nonlinear time- delay systems. By extending the Lie derivative for time-delay systems in the algebraic framework introduced by Xia et al. (2002), we present a canonical form and give sufficient condition in order to deal with causal and non-causal observations of state and unknown inputs of time-delay systems.

- [83] presents a finite-time observer for linear time-delay systems with commensurate delay. Unlike the existing observers in the literature which converges asymptotically, the proposed observer provides a finite-time estimation. This is realized by using the well-known sliding mode technique. Simulation results are also presented in order to illustrate the feasibility of the proposed method.

- Sampled-Data systems:
  - [104] presents basic concepts and recent research directions about the stability of sampled-data systems with aperiodic sampling. We focus mainly on the stability problem for systems with arbitrary time-varying sampling intervals which has been addressed in several areas of research in Control Theory. Systems with aperiodic sampling can be seen as time-delay systems, hybrid systems, Input/Output interconnections, discrete-time systems with time-varying parameters, etc. The goal of the article is to provide a structural overview of the progress made on the stability analysis problem. Without being exhaustive, which would be neither possible nor useful, we try to bring together results from diverse communities and present them in a unified manner. For each of the existing approaches, the basic concepts, fundamental results, converse stability theorems (when available), and relations with the other approaches are discussed in detail. Results concerning extensions of Lyapunov and frequency domain methods for systems with aperiodic sampling are recalled, as they allow to derive constructive stability conditions. Furthermore, numerical criteria are presented while indicating the sources of conservatism, the problems that remain open and the possible directions of improvement. At last, some emerging research directions, such as the design of stabilizing sampling sequences, are briefly discussed.
  - In [31] we investigate the stability analysis of nonlinear sampled-data systems, which are affine in the input. We assume that a stabilizing controller is designed using the emulation technique. We intend to provide sufficient stability conditions for the resulting sampled-data system. This allows to find an estimate of the upper bound on the asynchronous sampling intervals, for which stability is ensured. The main idea of the paper is to address the stability problem in a new framework inspired by the dissipativity theory. Furthermore, the result is shown to be constructive. Numerically tractable criteria are derived using linear matrix inequality for polytopic systems and using sum of squares technique for the class of polynomial systems.
  - [76] deals with the sampled-data control problem based on state estimation for linear sampled-data systems. An impulsive system approach is proposed based on a vector Lyapunov function method. Observer-based control design conditions are expressed in terms of LMIs. Some examples illustrate the feasibility of the proposed approach.

7.6. Effective algebraic systems theory

- Algebraic analysis approach:
  - The purpose of [97] is to present a survey on the effective algebraic analysis approach to linear systems theory with applications to control theory and mathematical physics. In particular, we show how the combination of effective methods of computer algebra – based on Gröbner basis techniques over a class of noncommutative polynomial rings of functional operators called Ore algebras – and constructive aspects of module theory and homological algebra enables the characterization of structural properties of linear functional systems. Algorithms are given and a dedicated implementation, called ORE-ALGEBRAICANALYSIS, based on the Mathematica package HOLONOMICFUNCTIONS, is demonstrated.
  - As far as we know, there is no algebraic (polynomial) approach for the study of linear differential time-delay systems in the case of a (sufficiently regular) time-varying delay. Based on the concept of skew polynomial rings developed by Ore in the 30s, the purpose

of [73] is to construct the ring of differential time-delay operators as an Ore extension and to analyze its properties. Classical algebraic properties of this ring, such as noetherianity, its homological and Krull dimensions and the existence of Gröbner bases, are characterized in terms of the time-varying delay function. In conclusion, the algebraic analysis approach to linear systems theory allows us to study linear differential time-varying delay systems (e.g. existence of autonomous elements, controllability, parametrizability, flatness, behavioral approach) through methods coming from module theory, homological algebra and constructive algebra.

  - Within the algebraic analysis approach to linear systems theory, in [98], we investigate the equivalence problem of linear functional systems, i.e., the problem of characterizing when all the solutions of two linear functional systems are in a one-to-one correspondence. To do that, we first provide a new characterization of isomorphic finitely presented modules in terms of inflations of their presentation matrices. We then prove several isomorphisms which are consequences of the unimodular completion problem. We then use these isomorphisms to complete and refine existing results concerning Serre's reduction problem. Finally, different consequences of these results are given. All the results obtained are algorithmic for rings for which Gröbner basis techniques exist and the computations can be performed by the Maple packages OREMODULES and OREMORPHISMS.
  - In [99], we study algorithmic aspects of the algebra of linear ordinary integro-differential operators with polynomial coefficients. Even though this algebra is not Noetherian and has zero divisors, Bavula recently proved that it is coherent, which allows one to develop an algebraic systems theory over this algebra. For an algorithmic approach to linear systems of integro-differential equations with boundary conditions, computing the kernel of matrices with entries in this algebra is a fundamental task. As a first step, we have to find annihilators of integro-differential operators, which, in turn, is related to the computation of polynomial solutions of such operators. For a class of linear operators including integro-differential operators, we present an algorithmic approach for computing polynomial solutions and the index. A generating set for right annihilators can be constructed in terms of such polynomial solutions. For initial value problems, an involution of the algebra of integro-differential operators then allows us to compute left annihilators, which can be interpreted as compatibility conditions of integro-differential equations with boundary conditions.
  - Recent progress in computer algebra has opened new opportunities for the parameter estimation problem in nonlinear control theory, by means of integro-differential input-output equations. In [102], we recall the origin of integro-differential equations. We present new opportunities in nonlinear control theory. Finally, we review related recent theoretical approaches on integro-differential algebras, illustrating what an integro-differential elimination method might be and what benefits the parameter estimation problem would gain from it.

- Computational real algebraic geometric approach:
  - In [74], we present a symbolic-numeric method for solving the H_∞ loop-shaping design problem for low order single-input single-output systems with parameters. Due to the system parameters, no purely numerical algorithm can indeed solve the problem. Using Gröbner basis techniques and the Rational Univariate Representation of zero-dimensional algebraic varieties, we first give a parametrization of all the solutions of the two Algebraic Riccati Equations associated with the H_∞ control problem. Then, following some works on the spectral factorization problem, a certified symbolic-numeric algorithm is obtained for the computation of the positive definite solutions of these two Algebraic Riccati Equations. Finally, we present a certified symbolic-numeric algorithm which solves the H_∞ loop-shaping design problem for the above class of systems.
  - In [58], the asymptotic stability of linear differential systems with commensurate delays

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

– In [59], we present new computer algebra based methods for testing the structural stability of n-D discrete linear systems (with $n \geq 2$). More precisely, we show 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 fact that a certain system of polynomials does not have real solutions. We then use state-of-the-art algorithms of the computer algebra community to check this last condition, and thus the structural stability of multidimensional systems.

7.7. Applications

- A fault detection method for an automatic detection of spawning in oysters [13]:

  Using measurements of valve activity (i.e. the distance between the two valves) in populations of bivalves under natural environmental condition (16 oysters in the Bay of Arcachon, France, in 2007, 2013 and 2014), an algorithm for an automatic detection of the spawning period of oysters is proposed in this paper. Spawning observations are important in aquaculture and biological studies, and until now, such a detection is done through visual analysis by an expert. The algorithm is based on the fault detection approach and it works through the estimation of velocity of valve movement activity, that can be obtained by calculating the time derivative of the valve distance. A summarized description of the methods used for the derivative estimation is provided, followed by the associated signal processing and decision making algorithm to determine spawning from the velocity signal. A protection from false spawning detection is also considered by analyzing the simultaneity in spawning. Through this study, it is shown that spawning in a population of oysters living in their natural habitat (i.e. in the sea) can be automatically detected without any human expertise saving time and resources. The fault detection method presented in the paper can also be used to detect complex oscillatory behavior which is of interest to control engineering community.

- Robust synchronization of genetic oscillators [52]:

  Cell division introduces discontinuities in the dynamics of genetic oscillators (circadian clocks, synthetic oscillators, etc.) causing phase drift. This paper considers the problem of phase synchronization for a population of genetic oscillators that undergoes cell division and with a common entraining input in the population. Inspired by stochastic simulation, this paper proposes analytical conditions that guarantee phase synchronization. This analytical conditions are derived based on Phase Response Curve (PRC) model of an oscillator (the first order reduced model obtained for the linearized system and inputs with sufficiently small amplitude). Cell division introduces state resetting in the model (or phase resetting in the case of phase model), placing it in the class of hybrid systems. It is shown through numerical experiments for a motivating example that without common entraining input in all oscillators, the cell division acts as a disturbance causing phase drift, while the presence of entrainment guarantees boundedness of synchronization phase errors in the population. Theoretical developments proposed in the paper are demonstrated through numerical simulations for two different genetic oscillator models (Goodwin oscillator and Van der Pol oscillator).

- Modeling pointing tasks in mouse-based human-computer interactions [54]:

Pointing is a basic gesture performed by any user during human-computer interaction. It consists in covering a distance to select a target via the cursor in a graphical user interface (e.g. a computer mouse movement to select a menu element). In this work, a dynamic model is proposed to describe the cursor motion during the pointing task. The model design is based on experimental data for pointing with a mouse. The obtained model has switched dynamics, which corresponds well to the state of the art accepted in the human-computer interaction community. The conditions of the model stability are established. The presented model can be further used for the improvement of user performance during pointing tasks.

- Modeling and control of turbulent flows [64]:

  The model-based closed-loop control of a separated flow can be studied based on the model described by Navier-Stokes equation. However, such a model still rises difficult issues for control practice. An alternative bilinear and delayed model has been developed tested on the experiments allowing its identification. The identification technique combines least-square technique with a Mesh Adaptive Direct Search (MADS) algorithm.

- Practical design considerations for successful industrial application of model-based fault detection techniques to aircraft systems [47]:

  This paper discusses some key factors which may arise for successful application of model-based Fault Detection(FD) techniques to aircraft systems. The paper reports on the results and the lessons learned during flight V & V(Validation & Verification) activities, implementation in the A380 Flight Control Computer(FCC) and A380 flight tests at Airbus(Toulouse, France).The paper does not focus on new theoretical materials, but rather on a number of practical design considerations to provide viable technological solutions and mechanization schemes. The selected case studies are taken from past and on-going research actions between Airbus and the University of Bordeaux (France). One of the presented solutions has received final certification on new generation Airbus A350 aircraft and is flying (first commercial flight: January 15,2015)

- Finite-time obstacle avoidance for unicycle-like robot [26]:

  The problem of avoiding obstacles while navigating within an environment for a Unicycle-like Wheeled Mobile Robot (WMR) is of prime importance in robotics; the aim of this work is to solve such a problem proposing a perturbed version of the standard kinematic model able to compensate for the neglected dynamics of the robot. The disturbances are considered additive on the inputs and the solution is based on the supervisory control framework, finite-time stability and a robust multi-output regulation. The effectiveness of the solution is proved, supported by experiments and finally compared with the Dynamic Window Approach (DWA) to show how the proposed method can perform better than standard methods.

- Almost global attractivity of a synchronous generator connected to an infinite bus [56]:

  The problem of deriving verifiable conditions for stability of the equilibria of a realistic model of a synchronous generator with constant field current connected to an infinite bus is studied in the paper. Necessary and sufficient conditions for existence and uniqueness of equilibrium points are provided. Furthermore, sufficient conditions for almost global attractivity are given. To carry out this analysis a new Lyapunov–like function is proposed to establish convergence of bounded trajectories, while the latter is proven using the powerful theoretical framework of cell structures pioneered by Leonov and Noldus.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

Contract with Neotrope (Tourcoing, France), Technologies & Augmented Human UX. Subject: De-correlation of GSR measurements with acceleration, from March 2016 to September 2016, D. Efimov, R. Ushirobira.

8.2. Bilateral Grants with Industry

Project of Autonomous control of clinic table with La Maison Attentive, 2016.

8.3. Bilateral Grants with Industry

Collaboration with Safran Electronics & Defense (Massy-Palaiseau) in the framework of the CIFRE PhD thesis of Guillaume Rance on robust stabilization of gyrostabilized platforms (2014-2018).

9. Partnerships and Cooperations

9.1. Regional Initiatives

- Project ARCIR ESTIREZ “Estimation distribuée de systèmes dynamiques en réseaux”, coordinators: D. Efimov, M. Petreczky, 2013-2017.
- CPER DATA 2016-2020 (involved in two projects: “FIT” related to the wireless robots and sensors network and “DATA”, related to platform). FIT includes our robotic activity and DATA corresponds to our computation need in fluid mechanics as well as possible security issues in the ControlHub development platform.
- ELSAT20202 (Ecomobilité, Logistique, Sécurité, Adaptabilité dans les Transports) is a Regional consortium gathering aeronautics (ONERA), micro/nano technologies (IEMN), control sciences (Non-A) and fluid mechanics (LAMIH, LML) and working on technologies and methods for the active control of separated flows.

9.2. National Initiatives

- ANR project Finite4SoS (Finite time control and estimation for Systems of Systems), coordinator: W. Perruquetti, 2015-2020.
- ANR project WaQMoS (Coastal waters quality surveillance using bivalve mollusk-based sensors), coordinator: D. Efimov, 2015-2019.
- ANR project TurboTouch (High-performance touch interactions), coordinator: G. Casiez (MJOLNIR team, Inria), 2014-2018.
- ANR project ROCC-SYS (Robust Control of Cyber-Physical Systems), coordinator: L. Hetel (CNRS, EC de Lille), 2013-2018.
- ANR project MSDOS (Multidimentional System: Digression on Stability), coordinator: Nima Yeganefar (Poitiers University), 2014-2018.
- We are also involved in several technical groups of the GDR MACS (CNRS, "Modélisation, Analyse de Conduite des Systèmes dynamiques", see http://www.univ-valenciennes.fr/GDR-MACS), in particular: Technical Groups "Identification", "Time Delay Systems", "Hybrid Systems", "Complex Systems, Biological Systems and Automatic Control," and "Control in Electrical Engineering".
- Model-free control: collaborations with the startup ALIEN SAS (created by C. Join and M. Fliess).

9.3. European Initiatives

9.3.1. Collaborations with Major European Organizations

Partner 1: KULeuven, labo 1 (Belgium)

Supervisor: W. Michiels

Partner 2: TU/Eindhoven, labo 1 (The Netherlands)

Supervisor: H. Nijmeijer

Partner 3: Centrale Lille, labo 1 (France)

Supervisor: J.-P. Richard

H2020 project UCoCoS ("Understanding and Controlling of Complex Systems", 2016-2020) is a European Joint Doctorate aiming at creating a framework for complex systems, and at defining a common language, common methods, tools and software for the complexity scientist. It strongly relies on a control theory point of view. Six ESR (early stage researchers) perform a cutting-edge project, strongly relying on the complementary expertise of the 3 academic beneficiaries and benefiting from training by 4 non-academic partners from different sectors. ESR1: Analytical and numerical bifurcation analysis of delay-coupled systems; ESR2: Estimation in complex systems; ESR3: Grip on partial synchronization in delay-coupled networks; ESR4: Reduced modelling of large-scale networks ; ESR5: Network design for decentralized control ; ESR6: Networks with event triggered computing. Non-A is firstly invested on ESR 2 (Haik Silm), 4 (Quentin Voortman), 5 (Deesh Dileep), 6 (Jijju Thomas).

9.4. International Initiatives

9.4.1. Inria Associate Teams Not Involved in an Inria International Labs

HoTSMoCE "Homogeneity Tools for Sliding Mode Control and Estimation", project with UNAM (Mexico), supervisor: D. Efimov, 2015-2018.

9.4.2. Inria International Partners

9.4.2.1. Declared Inria International Partners

Arie Levant, Tel Aviv University, Israel (Invited Professor, 4 months, 2015-2016).

9.4.2.2. Informal International Partners

- Emilia Fridman, Tel Aviv University, Israel
- Leonid Fridman, UNAM, Mexico
- Jaime Moreno, UNAM, Mexico
- Johannes Schiffer, Leeds University, UK
- ITMO University, Saint-Petersburg, Russia
- Eva Zerz, Aachen University, Germany

9.4.3. Participation in Other International Programs

- "Robust and Reliable Control of Aerial Syste"', Beihang University, China, 2016, in charge: G. Zheng
- PHC Amadeus "Computer Algebra and Functional Equations", 2016-2017, with the University of Limoges (XLIM) and the University of Linz (Austria).

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Leonid Fridman, UNAM, Mexico, 10/07/2016-22/07/2016, "Stability analysis of a sliding-mode control algorithm of second order with time delays".
- Emilia Fridman, Tel Aviv University, Israel, 27/06/2016-11/07/2016, "Design of interval observers for distributed-parameters systems".
- Jaime Alberto Moreno Pérez, UNAM, Mexico, 27/06/2016-08/07/2016, "Recursive design of Lyapunov functions for finite-time stable systems".
- Tonametl Sanchez Ramirez, UNAM, Mexico, 24/10/2016-18/11/2016, "Homogeneity for discrete-time systems".

- Juan Gustavo Rueda Escobedo, UNAM, Mexico, 24/10/2016-18/11/2016, “Finite-time and fixed-time identification of parameters”.
- Konstantin Zimenko, ITMO, Russia, 26/09/2016-28/10/2016, “Delay independent stabilization via implicit Lyapunov function approach”.
- Damiano Rotondo, NTNU, Norway, 17/10/2016-21/10/2016, “Fault detection for LPV systems using interval observers”.

9.5.1.1. Internships

- Paul Lesur, “Robust control of blimp”, 05-07/2016 , supervisor: G. Zheng
- Baihui Du, “Robust control of fast dynamical systems”, 05-07/2016, supervisor: G. Zheng

9.5.2. Visits to International Teams

G. Zheng visited Beihang University (China) for two weeks in July 2016.

9.5.2.1. Explorer programme

COSY (under evaluation) Real-time Control of Synthetic microbial communities. While some precursory work has appeared in recent years, the control of microbial communities remains largely unexplored. This proposal aims at exploiting the potential of state-of-art biological modelling, control techniques, synthetic biology and experimental equipment to achieve a paradigm shift in control of microbial communities. Lead by E. Cinquemani as a collaboration of 4 Inria teams IBIS, BIOCORE, COMMANDS, Non-A), the Inria Exploratory Action INBIO and external partners BIOP (CNRS), MaIAge (INRA), and YoukLAB (TU Delft).

9.5.2.2. Research Stays Abroad

G. Zheng held a visiting professor position in Nanjing University of Science and Technology (China) for two months stay in August 2016.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organisation

10.1.1.1. General Chair, Scientific Chair

- W. Perruquetti is the chairman of the IFAC Technical Committee “Social Impact of Automation”, International Federation of Automatic Control, TC 9.2, and a member of the IFAC Technical Committees “Nonlinear Control Systems”, TC 2.3, and “Discrete Event and Hybrid Systems”, TC 1.3.
- A. Quadrat is a member of the IFAC Technical Committee “Linear Control Systems”, International Federation of Automatic Control, TC2.2
- J.-P. Richard is a member of the IFAC Technical Committee “Linear Control Systems”, International Federation of Automatic Control, TC2.2
- G. Zheng is a member of the IFAC Technical Committee “Social Impact of Automation”, International Federation of Automatic Control, TC9.2
- G. Zheng is co-chair of the working group “Commande et pilotage en environnement incertain” of GRAISYHM

10.1.1.2. Member of the Organizing Committees

C. Jamroz, A. Quadrat, J.-P. Richard and G. Zheng were members of the organizing committee of “JAMACS’16 : Journées Automatique du GDR MACS 2016”, Villeneuve d’Ascq, 15-16/11/2016.

10.1.2. Scientific Events Selection

10.1.2.1. Member of the Conference Program Committees

W. Perruquetti is a member of the steering committee of IFAC CPHS'16 (7-9 December 2016, Florianopolis, Brazil), an IPC member of IEEE VSS'16 (1-4 June 2016, Nanjing, Jiangsu, China) and of IFAC HMS'16 (August 30-September 2 2016, Kyoto, Japan) and an Associate Editor of the 20th IFAC World Congress (10-14 July 2017, Toulouse, France).

W. Perruquetti and J.-P. Richard are members of the Advisory panel (NOC) of 20th IFAC World Congress, Toulouse, France, 10-14 July 2017.

10.1.2.2. Reviewer

The members of NON-A team are reviewers and contributors of all top-ranked conferences in the field of automatic control (IEEE Conference on Decision and Control, IFAC World Congress, European Control Conference, American Control Conference, etc.).

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

- A. Polyakov: International Journal of Robust and Nonlinear Control
- A. Polyakov: Journal of Optimization Theory and Applications (JOTA)
- A. Polyakov: Automation and Remote Control
- A. Quadrat: Multidimensional Systems and Signal Processing (MSSP)

10.1.3.2. Reviewer - Reviewing Activities

The members of NON-A team are reviewers of all top-ranked journals in the field of automatic control (IEEE Transactions on Automatic Control, Automatica, SIAM Journal of Control and Optimization, International Journal of Robust and Nonlinear Control, etc.).

10.1.4. Invited Talks

D. Efimov gave a plenary talk at the conference "JAMACS'16 : Journées Automatique du GDR MACS 2016", Villeneuve d'Ascq, France, 15-16/11/2016.

10.1.5. Leadership within the Scientific Community

The NON-A team is the leader in the field of non-asymptotic control and estimation using homogeneity framework.

Moreover, the NON-A team is also leader in algebraic systems theory. In particular, two invited sessions "Algebraic methods and symbolic-numeric computation in systems theory" were organized at the 22nd International Symposium on Mathematical Theory of Networks and Systems (MTNS 2016), University of Minnesota, USA, 12-15/07/2016. Moreover, a mini-workshop "New trends on multidimensional systems and their applications in control theory and signal processing" was organized at Centre International de Rencontres Mathématiques (CIRM), Luminy, France, 03-07/10/2016.

10.1.6. Scientific Expertise

A. Quadrat was a member of the "jury d'admission des concours Inria CR2 & CR1". He was also a member of the "Commission des Emplois de Recherche", Inria Lille, and a member of the "Authorité de déchiffrement" for the local elections.

10.1.7. Research Administration

- W. Perruquetti is Vice-deputy of INS2I CNRS.
- J.-P. Richard is an Expert for the French Ministry of Research, MENESR/MEIRIES.
- R. Ushirobira was a Member (nominated) of the “Comité du Centre” of Inria Lille (Dec. 2013 - Sept. 2016) and a Member of the “Commission de Développement Technologique” (CDT).

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Licence: D. Efimov, Laboratory works in automatics, 20 h, EC de Lille.

Licence: D. Efimov, Practical works in automatics, 28 h, ISEN, Lille.

Licence: D. Efimov, Laboratory works in discrete systems, 20 h, ENSAM, Lille.

Licence: R. Ushirobira, Travaux Pratiques en Automatique, 8 h, U. Lille 1, France.

Licence: R. Ushirobira, Travaux Pratiques en Automatique, 24 h, EC-Lille, France.

Licence: R. Ushirobira, Travaux dirigés/Travaux Pratiques en Automatique, 12 h+9 h, U. Lille 1.

Master: D. Efimov, Analysis of dynamical systems, 24 h, U. Lille 1.

Master: R. Ushirobira, Travaux Pratiques en Automatique, 32 h, U. Lille 1.

Master: G. Zheng, Robotic, 20 h, U. Lille 1.

Master: G. Zheng, Automatic control, 24 h, U. Lille 1.

10.2.2. Supervision

PhD: Hafiz Ahmed, “Modeling and synchronization of biological rhythms: from cells to oyster behavior”, 2013-2016, supervisors: D. Efimov, R. Ushirobira and D. Tran

PhD: Zilong Shao, “Oscilatory control of robot manipulator”, EC Lille, 2012-2016, supervisors: D. Efimov, W. Perruquetti, G. Zheng

PhD in progress: Haik Jan Davtjan, “Estimation in complex systems”, EC Lille, 2016, UCoCoS EU project, supervisors: D. Efimov, J.-P. Richard

PhD in progress: Maxime Feingesicht, “Dynamic Observers for Control of Separeted Flows”, Ecole Centrale de Lille, 2015, supervisors: J.-P. Richard, F. Kerherve, A. Polyakov

PhD in progress: Nadhynee Martinez Fonseca, “Non-asymptotic control and estimation problems in robotic system designed for manipulation of micro-organisms”, National Polytechnic Institute of Mexico, 2015-now, supervisors: I. Chairez-Oria, A. Polyakov

PhD in progress: Tatiana Kharkovskaya, “Interval Observers for Distributed Parametr Systems”, ITMO University-EC Lille, 2015, supervisors: D. Efimov, J.-P. Richard and A. Kremlev

PhD in progress: Langueh Désiré Kokou, “Inversion a gauche, singularités d’inversion, immersion et formes normales pour les systèmes dynamiques”, 2015, supervisors: T. Floquet, G. Zheng

PhD in progress: Gabriele Perozzi, “Save exploration of aerodynamic field by microdron”, Onera-Region, 2015, supervisors: D. Efimov, J.-M. Biannic and L. Planckaert

PhD in progress: Francisco Lopez-Ramirez, “Control and estimation via implicit homogeneous Lyapunov function”, Inria, 2015, supervisors: D. Efimov, W. Perruquetti and A. Polyakov

PhD in progress: Guillaume Rance, “Asservissement paramétrique de systèmes flexibles à retard et application aux viseurs”, CIFRE Safran Electronics & Defense, 2014, supervisors: A. Quadrat, A. Quadrat, H. Mounier

PhD in progress: Haik-Jan Silm, “Estimation in complex systems”, 2016, supervisors: D. Efimov, R. Ushirobira, W. Michels, J.-P. Richard

PhD in progress: Yue Wang, “Development of a blimp robot for indoor operation”, EC Lille, 2016, supervisors: D. Efimov, W. Perruquetti, G. Zheng

Master: Boussad Abci, EC Lille, 2015-2016, supervisors: D. Efimov, J.-P. Richard

Master: Rabehi Djahid, EC Lille, 2015-2016, supervisors: D. Efimov, J.-P. Richard

10.2.3. Juries

- A. Quadrat was an Examiner Member of the PhD Thesis of Mohamed Belhocine, “Modélisation et analyse structurelle du fonctionnement dynamique des systèmes électriques”, ENS Cachan. He was also a Member of Recruiting Committee for a MCF CNU 26-27 position at the University of Limoges.
- J.-P. Richard was an Examiner Member of the PhD Thesis of Arvo Kaldmae (Estonia), “Design of discrete-time and delayed nonlinear systems”, of Lucien Etienne (Italy), “Elements of observation and estimation for networked control systems”, and of Zilong Shao (Centrale Lille) “Identification and control of position-controlled robot arm in the presence of joint flexibility”.
- R. Ushirobira was a Member of Recruiting Committee for a MCF CNU 61 position at CNAM (Paris) and for a MCF CNU 61 position at ENSAE (Cergy).

10.3. Popularization

- Mediation: Scientific baccalaureate students. Meeting on the Inria platform EuraTechnologies (23/03/2016, Lille): “SN Lille Académie : À la découverte des sciences numériques !”.
- Mediation: BeyondLab community. A co-working night event within BeyondLabon using “Living sensor” for water quality monitoring, featuring our PhD student Hafiz Ahmed (Lille, 16/03/2016).
- Contribution to the prospective report “Systems & Control for the Future of Humanity” coordinated by F. Lamnabhi-Lagarrigue, Research Agenda Task Force (to appear, special issue of Annual Reviews in Control to be distributed during the IFAC 2017).
- The book “Mathématiques pour l'ingénieur” (2009, ISBN : 978-9973-0-0852-7 (ATAN, 385 pages)) has been downloaded more than 65000 times.

11. Bibliography

Major publications by the team in recent years

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