Activity Report 2017

Project-Team NON-A

Non-Asymptotic estimation for online systems

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Project-Team NON-A

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Creation of the Team: 2011 January 01, updated into Project-Team: 2012 July 01, end of the Project-Team: 2017 December 31

Keywords:

<u>**Computer Science and Digital Science:**</u>

A5.1.1. - Engineering of interactive systems
A5.1.5. - Body-based interfaces
A5.9.1. - Sampling, acquisition
A5.9.2. - Estimation, modeling
A5.10.3. - Planning
A5.10.4. - Robot control
A5.10.6. - Swarm robotics
A6.1.1. - Continuous Modeling (PDE, ODE)
A6.4.1. - Deterministic control
A6.4.3. - Observability and Controlability
A6.4.4. - Stability and Stabilization

<u>**Other Research Topics and Application Domains:**</u>

B1.1.3. - Cellular biology
B3.4.3. - Pollution
B4.5. - Energy consumption
B5.6. - Robotic systems
B6.4. - Internet of things
B6.6. - Embedded systems
B7.1. - Traffic management
B7.1.2. - Road traffic
B7.2.1. - Smart vehicles

1. Personnel

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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.

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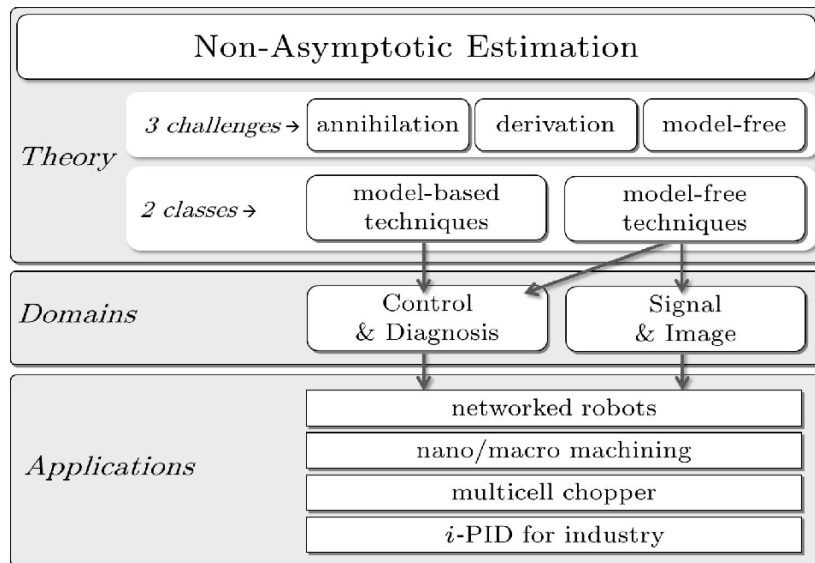
Figure 1. Non-A is a method-driven project, centered around non-asymptotic estimation techniques (i.e. providing estimates in finite-time), and connected to applications.

	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.

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[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.

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[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

5.1.1. Awards

- Maxime Feingesicht won The Creativity Prize of the FR CNRS TTM.
- Gabriele Perozzi won the Best Student Paper Award of the conference EUCASS 2017.
- The IPL COSY has been launched!
- Hafiz Ahmed won a CNRS PhD award by GDR MACS.

BEST PAPER AWARD:

[68]
G. PEROZZI, D. EFIMOV, J.-M. BIANNIC, L. PLANCKAERT, P. COTON. *Wind rejection via quasi-continuous sliding mode technique to control safely a mini drone*, in "7th European Conference for Aeronautics and Space Science", Milan, Italy, July 2017, https://hal.inria.fr/hal-01566857

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

6.2. 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: Jean-Pierre Richard

7. New Results

7.1. Research axis 1: General annihilators (tools: ALG)

- Integro-differential equations and integro-differential algebras were studied in [91], presenting new opportunities in nonlinear control theory.
- Algebraic estimation in partial derivatives systems were studied in [93].
- An effective version of the algebraic parameter estimation problem has recently been initiated in [73] based on algebraic analysis (module theory, homological algebra) and computer algebra (differential elimination techniques, Gröbner basis methods for noncommutative polynomial rings of ordinary differential operators with polynomial coefficients). The results of [73] have been implemented in the `Maple` package `NonA` built upon the package `OreModules`.

7.2. Research axis 2: Numerical differentiation and finite-time estimation (tools: HOM)

- Algorithms of finite-time and fixed-time observer design have been developed for linear plants based on Implicit Lyapunov function method and homogeneity [30].
- In [23], 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 nonzero degrees, whereas the implicit Euler scheme ensures convergence of the approximating solutions to zero. Properties of absolute and relative errors of the respective discretizations are investigated.
- In [34], the problem of time-varying parameter identification is studied. To this aim, two identification algorithms are developed in order to identify time-varying parameters in a finite-time or prescribed time (fixed-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-based approach. The results are obtained under injectivity of the regressor term, which is related to the classical identifiability condition. The case of bounded disturbances (noise of measurements) is analyzed for both algorithms. Simulation results illustrate the feasibility of the proposed algorithms.

- [36] contributes to the stability analysis for nonlinear impulsive dynamical systems based on a vector Lyapunov function and its divergence operator. The new method relies on a 2D time domain representation. Different types of stability notions for a class of nonlinear impulsive systems are studied using a vector Lyapunov function approach. The results are applied to analyze the stability of a class of Lipschitz nonlinear impulsive systems based on Linear Matrix Inequalities. Some numerical examples illustrate the feasibility of the proposed approach.

- [21] 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.

- [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.

- Delay estimation algorithms based on sliding mode methodology have been presented in [44].

- A nonlinear distributed observer was proposed in [81] for the problem of distributed estimation in a linear large-scale system.

- In [15], we analyze the observability for linear singular systems with delays, and the corresponding observer design technique has been proposed in [42]. For nonlinear singular system without delay, we propose in [43] a nonlinear Luenberger-like observer. For systems with delays, in [44], we investigate the identifiability of time-delay, and use a sliding mode technique and a classical Newton method to estimate the delay.

7.3. Research axis 3: Control without sophisticated models (tools: ALG-HOM-SET)

- Topological equivalence between quadratically stable and homogeneous asymptotically stable systems have been proven in [72].

- Boundary finite-time control for heat system have been developed in [69], but hyper-exponential control for state delay linear systems have been developed in [70].

7.4. Research axis 4: Applications (tools: ALG-HOM-SET)

- Robust set-point tracking control and optimal control algorithms for turbulent flows have been developed in [26] and tested in Wind Tunnel L1 of ONERA, Lille. (https://www.youtube.com/watch?v=b5NnAV2qeno) The set-point tacking control have been patented, FR 1755440, "Dispositif de contrôle actif du recollement d'un écoulement sur un profil".

- In [75], [77], the development of a robust (H_∞) control for parametric systems has been initiated. A general framework based on symbolic computation techniques was proposed. In these two papers, the general approach has been applied to the case of linear systems of order up to four and illustrated with the two mass-spring system with damping. In particular, closed forms for the robust controllers and for the robustness radius were obtained. Finally, the robust stabilization of the line of sight of a stabilized mirror system, modeled by a time-delay fourth order system, was studied in [76].

- Within a collaboration with *Safran Tech Laboratory* and *Safran Electronics & Defense*, in [98], we propose a symbolic method for the explicit computation of certain invariant observers studied in navigation theory.

- An experimental synchronization of a family of a recently proposed oscillator model (i.e. the Brockett oscillator) was studied and implemented in [12].

- In [13], high frequency measurements of various water characteristics and nutrients information of the Marel-Carnot sea monitoring station (Boulogne-sur-Mer, France) have been used to identify a physiological model for phytoplankton bloom through the fluorescence signal. An auto-regressive-moving-average with exogenous inputs (ARMAX) model is designed and tested based on the dataset. It was demonstrated that the developed dynamical model can be used for estimating the fluorescence level and for predicting the various states of phytoplankton bloom. Thus, the developed model can be used for monitoring phytoplankton biomass in the water which in turn might give information about unbalanced ecosystem or change in water quality.

- The problem of latency reduction in direct human-computer interaction was considered in [50] and formulated as a trajectory prediction problem. The predictor was constructed as a frequency-domain approximation of the non-casual ideal predictor. This approximation can be computed analytically, or obtained as an optimization task. An adaptive modification of the forecasting algorithm was proposed taking into account possible variations in user behavior.

- In [24], 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 and it complements the ISS theory of multistable dynamics for periodic systems. The efficiency of the proposed approach is illustrated via the global analysis of a nonlinear pendulum with constant persistent input.

- Conditions for almost global stability of an operating point of a realistic model of a synchronous generator with constant field current connected to an infinite bus are derived in [38]. The analysis is conducted by employing the recently proposed concept of input-to-state stability (ISS)–Leonov functions, which is an extension of the powerful cell structure principle developed by Leonov and Noldus to the ISS framework. Compared with the original ideas of Leonov and Noldus, the ISS–Leonov approach has the advantage of providing additional robustness guarantees. The efficiency of the derived sufficient conditions is illustrated via numerical experiments. This article is part of the themed issue 'Energy management: flexibility, risk and optimization'.

- Conditions for existence and global attractivity of the equilibria of a realistic model of a synchronous generator with constant field current connected to an infinite bus are derived in [14]. First, necessary and sufficient conditions for existence and uniqueness of equilibrium points are provided. Then, sufficient conditions for local asymptotic stability and almost global attractivity of one of these equilibria are given. The analysis is carried out by employing a new Lyapunov–like function to establish convergence of bounded trajectories, while the latter is proven using the powerful theoretical framework of cell structures pioneered by Leonov and Noldus. The efficiency of the derived sufficient conditions is illustrated via extensive numerical experiments based on two benchmark examples taken from the literature.

- In [96], we propose a new approach for testing the stability of nD systems. The standard stability conditions are transformed into algebraic conditions and then checked by means of computer algebra techniques for solving algebraic systems such as Gröbner bases, univariate representations and discriminant varieties. The corresponding results were implemented in `Maple`.

- In [17], we address the problem of computing stabilizing controllers for a specific class of multidimensional SISO systems. This problem, which was an open problem (i.e., no effective methods were existing for the computation of stabilizing controllers), has been solved using techniques from computer algebra. As a result, an effective test of stabilizability as well as an algorithm for computing stabilizing controllers were developed.

- We have recently proposed a new method for the *anchor position self-calibration problem*, a rather well-known problem in the signal processing community. In essence, given two sets of wireless communicating devices, i.e. sources and sensors lying in the three dimensional space, the self-calibration algorithm estimates the position of the devices by only using the source–sensor distance measurements. We have first reformulated the problem in terms of certain matrix equalities. They can then be studied in detail by means of computer algebra methods such as Gröbner basis techniques and the package `OreModules`. Coupling symbolic methods with standard linear algebra techniques, we obtain a general solution in all dimensions. In particular, for a space of dimension three, very compact closed-form solutions are obtained in a particular reference frame. Thanks to these closed-form solutions, the noise effect can then be characterized yielding the synthesis of realtime filtering to mitigate the effect of the measurement noise. Finally, the resulting implementation is rather straightforward and based on real-time operations. Additionally, the underlying numerical tools are standard (least-squares, low-rank factorization, matrix calculus) and well-known. The result of this work is being transferred to a patent. A software prototype `AutoCal` (https://bil.inria.fr/fr/search/query?terms=AutoCal in the BIL) is available on the server `Autocalibrationserver` (https://allgo.inria.fr/webapps/166) under the Inria platform `AllGO`, which allows the user to test the implemented algorithm on his own dataset.

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 (MJOL-NIR 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 (Multidimensional 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

9.4.1.1. HoTSMoCE

Title: Homogeneity Tools for Sliding Mode Control and Estimation

International Partner (Institution - Laboratory - Researcher):

UNAM (Mexico), Departamento de Ingeniería de Control y Robótica, Leonid Fridman

Start year: 2016

See also: https://team.inria.fr/non-a/asso-team-hotsmoce/

The team Non-A is developing an estimation theory, built around differential algebra and operational calculation on the one hand, and high gain algorithms (such as sliding mode) on the other hand. The Mexican partner team comes from "Sliding Mode Control" laboratory of UNAM. There exists a strong intersection of interests of both teams (application of homogeneity for design of sliding mode control and estimation algorithms, and analysis of finite-time stability). That is why there exists a long history of collaboration between these two teams. The goal of the project is development of control and estimation algorithms converging in fixed or in finite time by applying the last generation sliding mode techniques and the homogeneity theory. The project realization is planned in the form of short-time visits of permanent staff and visits of PhD students for a long period of stay. Such visits are very important for young scientists, and also help Non-A team to prepare and find good PhDs/post-docs for future.

9.4.2. Inria International Partners

9.4.2.1. 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

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
- Petteri Laakkonen, Tampere University of Technology, Finland, 11–14/12/2017

9.5.2. Visits to International Teams

G. Zheng visited two weeks at Wuhan University (China) in July 2017.

9.5.2.1. Research Stays Abroad

G. Zheng held a visiting professor position in Nanjing University of Science and Technology (China) for one month stay in August 2017.

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

A. Quadrat is a member of the organization committee of the Journées Nationales de Calcul Formel (JNCF), Luminy, France, 22–26/01/2018.

J.-P. Richard is associate editor of the conferences EUCA-IEEE ECC 2018, Limassol, Cyprus (16th European Control Conference), 12–15/06/2018, IFAC TDS 2018, Budapest, Hungary (14th IFAC Workshop on Time Delay Systems), 28–30/06/2018, and IEEE MED 2017, Valletta, Malta (25th IEEE Mediterranean Conference on Control and Automation), 3–6/06/2017.

10.1.2. Scientific Events Selection

J.-P. Richard was the coordinator of the Inria Evaluation Seminar of the theme "Optimization and control of dynamical systems" à Rungis, 13–17/03/2017.

10.1.2.1. Member of the Conference Program Committees

A. Quadrat was a member of the Program Committee of the 10th International Workshop on Multidimensional (nD) Systems (nDS 2017), University of Zielona Góra, Poland, 13-15/09/2017.

J.-P. Richard was a member of the Program Committee of the conference IARA VEHICULAR 2017, Nice, France (6th Int. Conf. on Advances in Vehicular Systems, Technol. & Appl.), 23-27/06/2017. He will also be a member of the Program Committee of IARA VEHICULAR 2018, Venice, Italy (7th Int. Conf. on Advances in Vehicular Systems, Technol. & Appl.), 24-28/06/2018.

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

D. Efimov is associate editor of:

- Associate editor, IFAC Journal on Nonlinear Analysis: Hybrid Systems
- Associate editor, Asian Journal of Control

He was also guest editor of two special issues on differentiators and on interval and set-membership estimation for International Journal of Control.

A. Polyakov is associate editor of:

- International Journal of Robust and Nonlinear Control
- Journal of Optimization Theory and Applications
- Automation and Remote Control

A. Quadrat is associate editor of Multidimensional Systems and Signal Processing.

10.1.3.2. Reviewer - Reviewing Activities

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.).

10.1.4. Invited Talks

A. Quadrat was invited to give a talk at the conference "Questions algorithmiques en algèbre, analyse, géométrie et topologie", I.H.E.T, Tunis, Tunisia, 24–26/10/2017, and at the "1st DECOD Workshop – Delays and Constraints on Distributed Parameter Systems", CentraleSupélec, Gif-sur-Yvette, France, 22–24/11/2017.

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" and "New Results in Multidimensional Systems Theory" were organized at the IFAC 2017 World Congress, Toulouse (France), 09-14/07/2017. Finally, the book "Algebraic and Symbolic Computation Methods in Dynamical Systems" was edited by A. Quadrat and E. Zerz (RWTH Aachen, Germany) for the collection "Advances in Delays and Dynamics" (ADD), volume 9, Springer, and will appear in 2018.

10.1.6. Scientific Expertise

Since 2016, R. Ushirobira and D. Efimov have been working with the start-up Neotrope (Tourcoing). Following a first contract (2016) on the treatment of electro-dermal signals from their connected bracelet, a second part of the collaboration is underway for the filtering of the heart rate signal (HR). A second contract should be implemented in the coming months.

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.
- A. Quadrat is a member of the "Bureau du Comité des Equipes-Projets" (BCEP) and of the "Commission des Emplois de Recherche", Inria Lille.
- R. Ushirobira continues to participate in our local commissions: technological development (CDT, since January 2012); IT users (CUMI, since March 2016); sustainable development (CLDD since September 2016). Since 2013, she has been leading the "30 minutes of science" cycle (monthly seminar for the center's scientific staff).

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

From September 2016 to June 2017, Y. Bouzidi was ATER at Ecole Central de Lille. He completed 192 hours of computer science courses/TD, as well as algorithmic courses, for students in L3 and M1.

Since February 2017, R. Ushirobira has completed 24 hours of Linear Algebra course / TD at Polytech'Lille, 8 h of Automatic TP in L3 at the University of Lille1 and 38 h TD of Mathematics in Mathematics. 1st year at Centrale Lille. She supervises this year students in 4th and 3rd grades of Arthur Rimbaud College Villeneuve d'Ascq, as part of 'Math in Jeans'.

10.2.2. Supervision

PhD: Maxime Feingesicht, "Dynamic Observers for Control of Separeted Flows", Ecole Centrale de Lille, 11/12/2017, supervisors: J.-P. Richard, F. Kerherve, A. Polyakov

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: Nadhynee Martinez Fonseca, "Non-asymptotic control and estimation problems in robotic system designed for manipulation of micro-organisms", National Polytechnic Institute of Mexico, 2015, 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 à gauche, singularités d'inversion, immersion et formes normales pour les systèmes dynamiques", 2015, supervisors: Thierry Floquet, Gang 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", 2016, supervisors: Wilfrid Perruquetti, Denis Efimov, Gang Zheng

PhD in progress: Siyuan Wang, "Robust control of quadrotors", 2017, supervisors: Andrey Polyakov, Gang Zheng

10.2.3. Juries

- A. Quadrat was member of a selection committee for a MCF position (CNU 15-17), University of Limoges.
- R. Ushirobira was a jury member of the CR2 Inria 2017 competition for the Lille - Nord Europe center. She was also invited to participate in 3 selection committees for MCF positions (CNU 61, ENSEA and CNAM in May, Ecole Centrale de Nantes in September).

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