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Activity Report 2012

Project-Team NON-A

Non-Asymptotic estimation for online systems

RESEARCH CENTER
Lille - Nord Europe

THEME
Modeling, Optimization, and Control of Dynamic Systems

Table of contents

Project-Team NON-A

Keywords: Estimation, Numerical Differentiation, Control, Robotics

Non-A follows the research team ALIEN, which was stopped at the end of 2010.

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

1. Members

Research Scientists

Denis Efimov [Junior Researcher, Inria, HdR]
Thierry Floquet [Junior Researcher, CNRS, Laboratoire LAGIS UMR 8219, École Centrale de Lille, HdR]
Gang Zheng [Junior Researcher, Inria]

Faculty Members

Jean-Pierre Barbot [Professor, ENSEA Cergy-Pontoise, Laboratoire ECS EA3649, HdR]
Lotfi Belkoura [Professor, Université des Sciences et Technologies de Lille & Laboratoire LAGIS UMR 8219, HdR]
Olivier Gibaru [Professor, École Nationale Supérieure des Arts et Métiers, Lille, HdR]
Cédric Join [Associate professor, Université Henry Poincaré, Nancy, HdR]
Mamadou Mboup [Professor, Université de Reims-Champagne Ardenne & Laboratoire CReSTIC EA3804, HdR]
Wilfrid Perruquetti [**Permanent head**, Professor, École Centrale de Lille & Laboratoire LAGIS UMR 8219, HdR]
Samer Riachy [Associate professor, ENSEA Cergy-Pontoise, Laboratoire ECS EA3649]
Jean-Pierre Richard [**Team Leader**, Professor, École Centrale de Lille & Laboratoire LAGIS, CNRS UMR 8219, HdR]
Stéphane Thiery [Associate professor, École Nationale Supérieure des Arts et Métiers, Lille]
Rosane Ushirobira [Associate professor, Université de Bourgogne, HdR]

Engineers

Lucie Jacquelin [Engineer shared with POPS, till October 2012, Inria Lille-Nord Europe]
Rahma Yangui [Engineer, till January 2013, Inria Lille-Nord Europe]

PhD Students

Romain Delpoux [École Centrale de Lille, finished November 2012. Supervisor: T. Floquet. Subject: Fast identification and estimation of nonlinear systems via algebraic techniques. Support: French Ministry of Research]
Youssef EL Afou [Université des Sciences et Technologies de Lille, started October 2009. Supervisor: L. Belkoura, C. Join, A. Lachhab, B. Bouchikhi. Subject: Control strategies for greenhouse climate parameters. Support: EGIDE]
Matteo Guerra [École Centrale de Lille, started October 2012. Supervisors: W. Perruquetti and D. Efimov and G. Zheng. Subject: Supervisory control of collective motion of mobile robots. Support: French Ministry of Research]
Sonia Maalej [Université des Sciences et Technologies de Lille, from September 2011. Supervisors: A. Kruszewski and L. Belkoura. Subject: Algebraic estimation for robust control. Support: Contrat doctoral MESR]
Diego Mincarelli [Université des Sciences et Technologies de Lille, started September 2010. Supervisors: T. Floquet and L. Belkoura. Subject: Algebraic approach for observation of switched systems. Support: Inria CORDI-S]
Marouene Oueslati [ARTS ET METIERS ParisTech, started September 2009. Supervisor: Olivier GIBARU. Subject: Improving the accuracy of a 6-axis industrial robot for machining. Support: ENSAM-ANR]

Hugues Sert [Ecole Centrale de Lille, started September 2009, finished 01/2013. Supervisors: W. Perruquetti and A. M. Kökösy. Subject: Intelligent module decision for autonomous indoor navigation of wheelchair robot. Support: Norbert Ségard Fondation, ISEN]

Post-Doctoral Fellows

Antonio Estrada [CORDI-S, Inria]

Andrey Polyakov [CHASLIM, Inria]

Administrative Assistant

Corinne Jamroz [Secretary, Inria]

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 for obtaining the estimation). Obviously, the estimation algorithms should have as small as possible computation time in order to provide fast, real-time, online estimations for processes with fast dynamics (for example, a challenging problem is to make an Atomic Force Microspcope 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 the 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.

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	Denoising - Demodulation - Biomedical signal processing
Cergy ECS	Nonlinear observers - Hybrid systems	Cryptography - Multi-cell chopper/converter
Lille ENSAM	Applied mathematics	High performance machining - Precision sensors, AFM [1]
Lille LAGIS	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

2.3. Highlights of the Year

- The survey paper on delay systems [126] is the ScienceDirect TOP 1 hottest article of Automatica since July 2009;
- HdR of Join C. "Une approche algébrique pour la pratique de l'estimation, du diagnostic, de la commande et de la finance" [12], Université de Lorraine, June 2012;
- HdR of Efimov D. "Analysis, control and estimation of nonlinear oscillations" [11], Inria, November 2012;
- Patent pending (FR11/51604) on the control of traffic flow.

3. Scientific Foundations

3.1. Fast parametric estimation and its applications

Parametric estimation may often be formalized as follows:

$$y = F(x, \Theta) + n, \tag{1}$$

where:

- the measured signal y is a functional F of the "true" signal x, which depends on a set Θ of parameters,
- n is a noise corrupting the observation.

Finding a "good" approximation of the components of Θ has been the subject of a huge literature in various fields of applied mathematics. Most of those researches have been done in a probabilistic setting, which necessitates a good knowledge of the statistical properties of n. Our project is devoted to a new standpoint, which does not require this knowledge and which is based on the following tools, which are of algebraic flavor:

- differential algebra [2], which plays with respect to differential equations a similar role that the commutative algebra plays with respect to algebraic equations;
- module theory, i.e. linear algebra over rings, which are not necessarily commutative;
- operational calculus, which is the most classical tool among control and mechanical engineers [3].

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

[2] Differential algebra was introduced in nonlinear control theory by one of us almost twenty years ago for understanding some specific questions like input-output inversion. It allowed us to recast the whole of nonlinear control into a more realistic light. The best example is of course the discovery of *flat* systems, which are now quite popular in industry.

[3] Operational calculus is often formalized *via* the Laplace transform whereas the Fourier transform is today the cornerstone in estimation. Note that the one-sided Laplace transform is causal, but the Fourier transform over R is not.

3.1.1. Linear identifiability

In the most problems, which appear in linear control as well as in signal processing, the unknown parameters are *linearly identifiable*: standard elimination procedures are yielding the following matrix equation

$$P \begin{pmatrix} \theta_1 \\ \vdots \\ \theta_r \end{pmatrix} = Q, \tag{2}$$

where:

- θ_i, $1 \leq i \leq r$ represents unknown parameter,
- P is a $r \times r$ square matrix and Q is a $r \times 1$ column matrix,
- the entries of P and Q are finite linear combinations of terms of the form $t^\nu \frac{d^\mu \xi}{dt^\mu}$, $\mu, \nu \geq 0$, where ξ is an input or output signal,
- the matrix P is *generically* invertible, i.e., $\det(P) \neq 0$.

3.1.2. How to deal with perturbations and noises?

With noisy measurements equation (2) becomes:

$$P \begin{pmatrix} \theta_1 \\ \vdots \\ \theta_r \end{pmatrix} = Q + R, \tag{3}$$

where R is a $r \times 1$ column matrix, whose entries are finite linear combinations of terms of the form $t^\nu \frac{d^\mu \eta}{dt^\mu}$, $\mu, \nu \geq 0$, where η is a perturbation or a noise.

3.1.2.1. Structured perturbations

A perturbation π is said to be *structured* if, and only if, it can be annihilated by a linear differential operator of the form $\sum_{\text{finite}} a_k(t) \frac{d^k}{dt^k}$, where $a_k(t)$ is a rational function of t, i.e. $\left(\sum_{\text{finite}} a_k(t) \frac{d^k}{dt^k}\right) \pi = 0$. Note that many classical perturbations, like a constant bias, are annihilated by such an operator. An *unstructured* noise cannot be annihilated by a non-zero differential operator.

By well-known properties of the non-commutative ring of differential operators, we can multiply both sides of equation (3) by a suitable differential operator Δ such that equation (3) becomes:

$$\Delta P \begin{pmatrix} \theta_1 \\ \vdots \\ \theta_r \end{pmatrix} = \Delta Q + R', \tag{4}$$

where the entries of the $r \times 1$ column matrix R' are unstructured noises.

3.1.2.2. Attenuating unstructured noises

Unstructured noises are usually dealt with stochastic processes like white Gaussian noises. They are considered here as highly fluctuating phenomena, which may therefore be attenuated *via* low pass filters. Note that no precise knowledge of the statistical properties of the noises is required.

3.1.2.3. Comments

Although the previous noise attenuation procedure [4] may be fully explained *via* formula (4), its theoretical comparison [5] with today's literature [6] has yet to be done. It will require a complete resetting of the notions of noises and perturbations. Besides some connections with physics, it might lead to quite new "epistemological" issues [101].

3.1.3. Some hints on the calculations

The time derivatives of the input and output signals appearing in equations (2), (3), (4) can be suppressed in the two following ways which might be combined:

- integrate both sides of the equation a sufficient number of times,
- take the convolution product of both sides by a suitable low pass filter.

The numerical values of the unknown parameters $\Theta = (\theta_1, \cdots, \theta_r)$ can be obtained by integrating both sides of the modified equation (4) during a very short time interval.

3.1.4. A first, very simple example

Let us illustrate on a very basic example, the grounding ideas of the algebraic approach. For this purpose consider the first order linear system:

$$\dot{y}(t) = ay(t) + u(t) + \gamma_0, \tag{5}$$

where a is an unknown parameter to be identified and γ_0 is an unknown constant perturbation. With the notations of operational calculus and $y_0 = y(0)$, equation (5) reads:

$$s\widehat{y}(s) = a\widehat{y}(s) + \widehat{u}(s) + y_0 + \frac{\gamma_0}{s} \tag{6}$$

where $\widehat{y}(s)$ represents the Laplace transform of $y(t)$.

In order to eliminate the term γ_0, multiply first the both hand-sides of this equation by s and next take their derivatives with respect to s:

$$\frac{d}{ds}\left[s\left\{s\widehat{y}(s) = a\widehat{y}(s) + \widehat{u}(s) + y_0 + \frac{\gamma_0}{s}\right\}\right] \tag{7}$$

$$\Rightarrow 2s\widehat{y}(s) + s^2\widehat{y}'(s) = a\left(s\widehat{y}'(s) + \widehat{y}(s)\right) + s\widehat{u}'(s) + \widehat{u}(s) + y_0. \tag{8}$$

Recall that $\widehat{y}'(s) \triangleq \frac{d\widehat{y}(s)}{ds}$ corresponds to $-ty(t)$. Assume $y_0 = 0$ for simplicity of presentation [7]. Then for any $\nu > 0$,

$$s^{-\nu}\left[2s\widehat{y}(s) + s^2\widehat{y}'(s)\right] = s^{-\nu}\left[a(s\widehat{y}'(s) + \widehat{y}(s)) + s\widehat{u}'(s) + \widehat{u}(s)\right]. \tag{9}$$

For $\nu = 3$, we obtained the estimated value a:

[4] It is reminiscent to that the most practitioners in electronics are doing.

[5] Let us stress again that many computer simulations and several laboratory experiments have been already successfully achieved and can be quite favorably compared with the existing techniques.

[6] Especially in signal processing.

[7] If $y_0 \neq 0$ one has to take above derivatives of order 2 with respect to s, in order to eliminate the initial condition.

$$a = \frac{2\int_0^T d\lambda \int_0^\lambda y(t)dt - \int_0^T ty(t)dt + \int_0^T d\lambda \int_0^\lambda tu(t)dt - \int_0^T d\lambda \int_0^\lambda d\sigma \int_0^\sigma u(t)dt}{\int_0^T d\lambda \int_0^\lambda d\sigma \int_0^\sigma y(t)dt - \int_0^T d\lambda \int_0^\lambda ty(t)dt} \quad (10)$$

Since $T > 0$ can be very small, estimation *via* (10) is very fast.

Note that equation (10) represents an on-line algorithm, which involves only two kinds of operations on u and y: (1) multiplications by t, and (2) integrations over a pre-selected time interval.

If we now consider an additional noise of zero mean in (5), say:

$$\dot{y}(t) = ay(t) + u(t) + \gamma_0 + n(t), \quad (11)$$

it can be considered as a fast fluctuating signal. The order ν in (9) determines the order of iterations in the integrals (3 integrals in (10)). Those iterated integrals are low-pass filters which are attenuating the fluctuations.

This example, even simple, clearly demonstrates how algebraic techniques proceed:

- they are algebraic: operations on s-functions;
- they are non-asymptotic: parameter a is obtained from (10) in a finite time;
- they are deterministic: no knowledge of the statistical properties of the noise n is required.

3.1.5. A second simple example, with delay

Consider the first order, linear system with constant input delay [8]:

$$\dot{y}(t) + ay(t) = y(0)\delta + \gamma_0 H + bu(t-\tau). \quad (12)$$

Here we use a distributional-like notation, where δ denotes the Dirac impulse and H is its integral, i.e. the Heaviside function (unit step) [9]. Still for simplicity, we suppose that the parameter a is known. The parameter to be identified is now the delay τ. As previously, γ_0 is a constant perturbation, a, b, and τ are constant parameters. Consider also a step input $u = u_0 H$. A first order derivation yields:

$$\ddot{y} + a\dot{y} = \varphi_0 + \gamma_0\,\delta + b\,u_0\,\delta_\tau, \quad (13)$$

where δ_τ denotes the delayed Dirac impulse and $\varphi_0 = (\dot{y}(0) + ay(0))\,\delta + y(0)\,\delta^{(1)}$, of order 1 and support $\{0\}$, contains the contributions of the initial conditions. According to Schwartz theorem, multiplication by a function α such that $\alpha(0) = \alpha'(0) = 0$, $\alpha(\tau) = 0$ yields interesting simplifications. For instance, choosing $\alpha(t) = t^3 - \tau\,t^2$ leads to the following equalities (to be understood in the distributional framework):

$$\begin{array}{rcl} t^3\,[\ddot{y} + a\dot{y}] & = & \tau\,t^2\,[\ddot{y} + a\dot{y}], \\ bu_0\,t^3\delta_\tau & = & bu_0\,\tau\,t^2\delta_\tau. \end{array} \quad (14)$$

The delay τ becomes available from $k \geq 1$ successive integrations (represented by the operator H), as follows:

[8] This example is taken from [93]. For further details, we suggest the reader to refer to it.

[9] In this document, for the sake of simplicity, we make an abuse of the language since we merge in a single notation the Heaviside function H and the integration operator. To be rigorous, the iterated integration (k times) corresponds, in the operational domain, to a division by s^k, whereas the convolution with H (k times) corresponds to a division by $s^k/(k-1)!$. For $k = 0$, there is no difference and $H * y$ realizes the integration of y. More generally, since we will always apply these operations to complete equations (left-and right-hand sides), the factor $(k-1)!$ makes no difference.

$$\tau = \frac{H^k(w_0 + a\,w_3)}{H^k(w_1 + a\,w_2)}, \qquad t > \tau, \tag{15}$$

where the w_i are defined using the notation $z_i = t^i\,y$ by:

$$\begin{aligned} w_0 &= t^3\,y^{(2)} = -6\,z_1 + 6\,z_2^{(1)} - z_3^{(2)}, \\ w_1 &= t^2\,y^{(2)} = -2\,z_0 + 4\,z_1^{(1)} - z_2^{(2)}, \\ w_2 &= t^2\,y^{(1)} = 2\,z_1 - z_2^{(1)}, \\ w_3 &= t^3\,y^{(1)} = 3\,z_2 - z_3^{(1)}. \end{aligned}$$

These coefficients show that $k \geq 2$ integrations avoid any derivation in the delay identification.

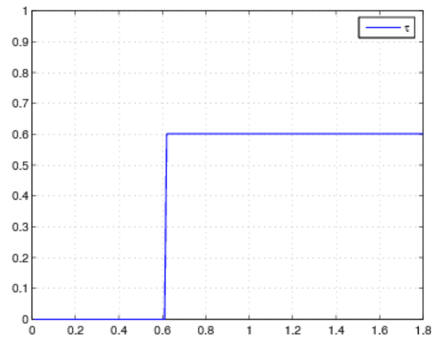

Figure 1. Delay τ identification from algorithm (15)

Figure 1 gives a numerical simulation with $k = 2$ integrations and $a = 2, b = 1, \tau = 0.6$, $y(0) = 0.3, \gamma_0 = 2, u_0 = 1$. Due to the non identifiability over $(0, \tau)$, the delay τ is set to zero until the numerator or the denominator in the right hand side of (15) reaches a significant nonzero value.

Again, note the realization algorithm (15) involves two kinds of operators: (1) integrations and (2) multiplications by t. It relies on the measurement of y and on the knowledge of a. If a is also unknown, the same approach can be utilized for a simultaneous identification of a and τ. The following relation is derived from (14):

$$\tau(H^k w_1) + a\,\tau(H^k w_2) - a\,(H^k w_3) = H^k w_0, \tag{16}$$

and a linear system with unknown parameters $(\tau, a\,\tau, a)$ is obtained by using different integration orders:

$$\begin{pmatrix} H^2 w_1 & H^2 w_2 & H^2 w_3 \\ H^3 w_1 & H^3 w_2 & H^3 w_3 \\ H^4 w_1 & H^4 w_2 & H^4 w_3 \end{pmatrix} \begin{pmatrix} \widehat{\tau} \\ \widehat{a\tau} \\ -\widehat{a} \end{pmatrix} = \begin{pmatrix} H^2 w_0 \\ H^3 w_0 \\ H^4 w_0 \end{pmatrix}.$$

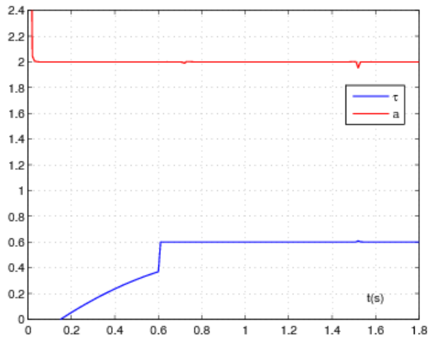

Figure 2. Simultaneous identification of a and τ from algorithm (16)

The resulting numerical simulations are shown in Figure 2. For identifiability reasons, the obtained linear system may be not consistent for $t < \tau$.

3.2. Finite time estimation of derivatives

Numerical differentiation, i.e. determining the time derivatives of various orders of a noisy time signal, is an important but difficult ill-posed theoretical problem. This fundamental issue has attracted a lot of attention in many fields of engineering and applied mathematics (see, e.g. in the recent control literature [94], [95], [109], [108], [115], [116], and the references therein).

3.2.1. Model-free techniques for numerical differentiation

A common way of estimating the derivatives of a signal is to resort to a least squares fitting and then take the derivatives of the resulting function. In [119], [117] this problem was revised through our algebraic approach. The approach can be briefly explained as follows:

- The coefficients of a polynomial time function are linearly identifiable. Their estimation can therefore be achieved as above. Indeed, consider a real-valued polynomial function $x_N(t) = \sum_{\nu=0}^{N} x^{(\nu)}(0)\frac{t^\nu}{\nu!} \in \mathbb{R}[t],\ t \geq 0$, of degree N. Rewrite it in the well-known notations of operational calculus:

$$X_N(s) = \sum_{\nu=0}^{N} \frac{x^{(\nu)}(0)}{s^{\nu+1}}.$$

Here we use $\frac{d}{ds}$, which corresponds in the time domain to the multiplication by $-t$. Multiply both sides by $\frac{d^\alpha}{ds^\alpha}s^{N+1}$, $\alpha = 0, 1, \cdots, N$. The quantities $x^{(\nu)}(0)$, $\nu = 0, 1, \cdots, N$ are given by the triangular system of linear equations:

$$\frac{d^\alpha s^{N+1} X_N}{ds^\alpha} = \frac{d^\alpha}{ds^\alpha}\left(\sum_{\nu=0}^{N} x^{(\nu)}(0)s^{N-\nu}\right). \tag{17}$$

The time derivatives, i.e. $s^{\mu}\frac{d^{\iota}X_N}{ds^{\iota}}$, $\mu = 1, \cdots, N$, $0 \leq \iota \leq N$ are removed by multiplying both sides of Equation (17) by $s^{-\overline{N}}$, $\overline{N} > N$.

- For an arbitrary analytic time function, let us apply the preceding calculations to a suitable truncated Taylor expansion. Consider a real-valued analytic time function defined by the convergent power series $x(t) = \sum_{\nu=0}^{\infty} x^{(\nu)}(0)\frac{t^{\nu}}{\nu!}$, where $0 \leq t < \rho$. Approximate $x(t)$ in the interval $(0, \varepsilon)$, $0 < \varepsilon \leq \rho$ by its truncated Taylor expansion $x_N(t) = \sum_{\nu=0}^{N} x^{(\nu)}(0)\frac{t^{\nu}}{\nu!}$ of order N. Introduce the operational analogue of $x(t)$, i.e. $X(s) = \sum_{\nu \geq 0}\frac{x^{(\nu)}(0)}{s^{\nu+1}}$. Denote by $[x^{(\nu)}(0)]_{e_N}(t)$, $0 \leq \nu \leq N$, the numerical estimate of $x^{(\nu)}(0)$, which is obtained by replacing $X_N(s)$ by $X(s)$ in Eq. (17). It can be shown [104] that a good estimate is obtained in this way.

Thus using elementary differential algebraic operations, we derive an explicit formulae yielding point-wise derivative estimation for each given order. Interesting enough, it turns out that the Jacobi orthogonal polynomials [129] are inherently connected with the developed algebraic numerical differentiators. A least-squares interpretation then naturally follows [118], [119] and this leads to a key result: the algebraic numerical differentiation is as efficient as an appropriately chosen time delay. Though, such a delay may not be tolerable in some real-time applications. Moreover, instability generally occurs when introducing delayed signals in a control loop. Note however that since the delay is known *a priori*, it is always possible to derive a control law, which compensates for its effects (see [127]). A second key feature of the algebraic numerical differentiators is its very low complexity which allows for a real-time implementation. Indeed, the n^{th} order derivative estimate (that can be directly managed for $n \geq 2$, without using n cascaded estimators) is expressed as the output of the linear time-invariant filter, with finite support impulse response $h_{\kappa,\mu,n,r}(\cdot)$. Implementing such a stable and causal filter is easy and simple. This is achieved either in continuous-time or in discrete-time when only discrete-time samples of the observation are available. In the latter case, we obtain a tapped delay line digital filter by considering any numerical integration method with equally-spaced abscissas.

3.2.2. Model-based estimation of derivatives

If we assume that the derivatives to be estimated are unmeasured states of a process that generates the signal, then the differentiation techniques can be considered as left invertibility algorithms. In this sense, the previous algebraic estimation achieves a “model-free” left inversion. Now, when such a model is available, the *finite-time observers* relying on higher order sliding modes [123] and homogeneity properties [124], [120] also represent possible non-asymptotic algorithms for differentiation [10]. Using such model-based techniques appears to be complementary[11]. The left-inversion results have been already obtained for several classes of models: linear systems [106], nonlinear systems [92], delay systems [2] and hybrid systems [114].

4. Application Domains

4.1. Application domains

Unlike the traditional methods, the estimators we defined are "non-asymptotic": solutions are provided by an explicit formulae. They result in relatively simple and fast algorithms. In this sense, rather than being a project linked to a specific domain of application, we can say that the project Non-A is method-driven. However, one must not forget that applicability remains a guideline in all our researches. As it has been noted, estimation is a huge area, which touches a variety of possible application fields, which our new methods address. Figure 3 illustrates the connections between our techniques and the possible applications.

[10] Usually, observer design yields asymptotic convergence of the estimation error dynamics. The main advantages of such a technique in the case of linear systems are simplicity of design, estimation with a filtering action and global stability property. Nevertheless, the filtering property is not ensured for nonlinear systems and the stability property is generally obtained only locally. For these reasons, in the case of nonlinear systems, finite-time observers and estimators have been proposed in the literature [116], [124], [125], [105]...

[11] The choice between the two approaches will be done after comparison with respect to the indicators 1–3, and taking into account the application (for instance, the system bandwidth, system dimension), the kind of discontinuity, the observer in the control loop or not...

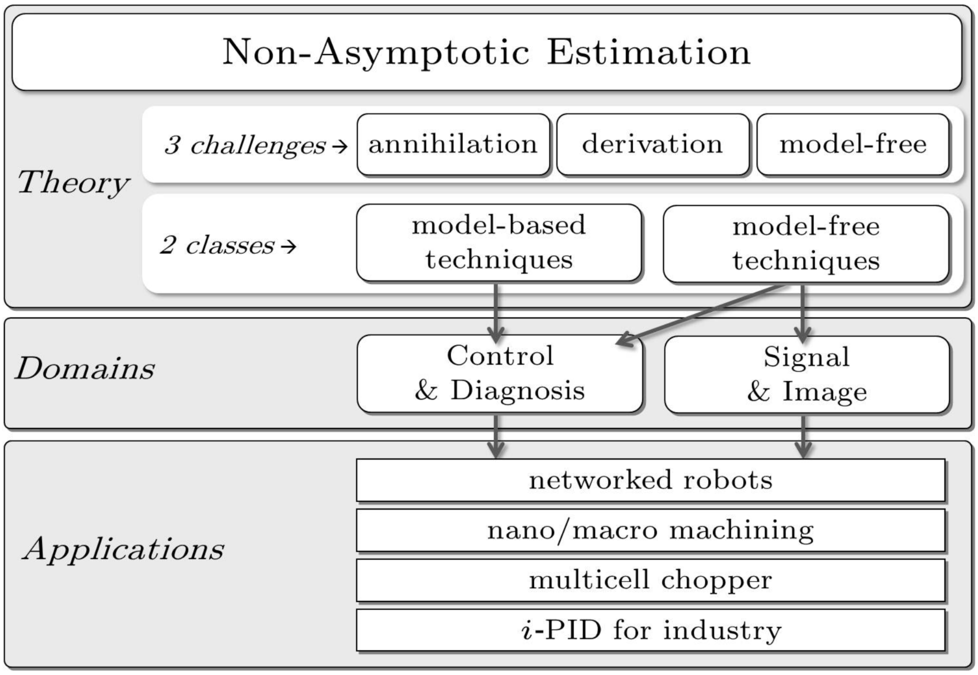

Figure 3. Non-A is a method-driven project, centered around non-asymptotic estimation techniques (i.e., providing estimates in finite-time), and connected to applications.

During these few years, our techniques have already generated 3 patents [98], [100], [99]. It shows their efficiency in various industrial domains, including (see the previous reports):

- Vehicle control (engine throttle [112], lateral and longitudinal velocities [96], stop-and-go [131], tire/road contact condition [134]) with PSA, APEDGE, Mines-ParisTech, Inria IMARA, Universidad Carlos III (Madrid), Université Paris Sud, spark ignition engine control with GM [28];
- Hydroelectric power plants [111], [110] with EDF-CIH (patent pending FR0858532);
- Shape memory actuators [107] with Université de Bretagne Occidentale and ANR MAFESMA;
- Magnetic actuators with Univ. des Saarlandes;
- Power Electronics [121] with Univ. du Québec à Trois-Rivières;
- Aircraft identification [130] with ONERA DCSD;
- Secured communications (chaos-based cryptography [128], [136], [135], CPM demodulation [122]) with CINVESTAV Mexico, Math.Dept. Tlemcen Univ. Algeria and PRISME ENSI-Bourges.
- Image and video processing (denoising [102], edge detection [113]) with Inria QGAR, compression [103], compressive sensing [132], [133] with CINVESTAV Mexico and Whuan Univ., China;
- Financial engineering [97] with MEREOR Investment Management and Advisory SAS;
- Neural signal processing [35], [83];
- Stabilization of a ball & beam system through saturated control [91], [81]
- Control of a new class of power converters [48], [49];
- Power management of a hydrogen fuel cell system combined with super capacitors [69];
- Sensorless parameter identification for permanent magnet stepper motors [60], [58], [59];
- A flexible robot joint control [78];
- Localization of mobile robots [82];
- Teleoperation [46], [44], [45];
- Oscillatory failure case (OFC) detection for aircraft [38].

5. New Results

5.1. Model-free control

Participants: Cédric Join, Samer Riachy.

The achievements obtained in 2012 are as follows:

- The model-free control approach is applied to a complex nonlinear model describing the dynamics of a traffic flow in [24]. The robustness with respect to external disturbances is shown by numerical simulations.
- Model-free control is applied to a magnetic bearing in [56], which is a quite important industrial device. The experimental results are compared to those obtained via other control techniques.
- ”Model-free” control and the related ”intelligent” proportional-integral controllers are successfully applied to freeway ramp metering control in [47]. Implementing the proposed control strategy is straightforward. Numerical simulations need the identification of quite complex quantities like the free flow speed and the critical density. This is achieved due to new estimation techniques, where the differentiation of noisy signals plays a key role.

5.2. Algebraic technique for estimation, differentiation and its applications

Participants: Cédric Join, Mamadou Mboup, Wilfrid Perruquetti, Rosane Ushirobira, Olivier Gibaru.

Elementary techniques from operational calculus, differential algebra, and noncommutative algebra lead to a new algebraic approach for estimation and detection. It is investigated in various areas of applied sciences and engineering. The following lists only some applications:

- The paper [30] proposes an algebraic method to fault diagnosis for uncertain linear systems. The main advantage of this new approach is to realize fault diagnosis only from knowledge of input and output measurements without identifying explicitly model parameters. Using tools and results of algebraic identification and pseudospectra analysis, the issues of robustness of the proposed approach compared to the model order and noise measurement are examined.
- The aim of [79], [84] is to develop an algebraic approach to estimate human posture in the sagittal plane using inertial measurement unit providing accelerations and angular velocities. For this purpose the issue of the estimation of the amplitude, frequency and phase is addressed for a biased and noisy sum of three sinusoidal waveform signals on a moving time horizon. Since the length of the time window is small, the estimation must be done within a fraction of the signal's period. The problem is solved via algebraic techniques.
- An application of algebraic estimation approach for estimation of option pricing and dynamic hedging is given in [66].
- A model-based online fault-diagnosis scheme for an electromagnetically supported plate is presented in [73] as an example of a nonlinear and open-loop unstable system. First, residuals for sensor as well as for actuator faults are generated using algebraic derivative estimators. Then, the robust detection and isolation of step-like sensor and actuator faults is presented.
- The paper [57] uses the extreme value theory for threshold selection in a previously proposed algebraic spike detection method. The algebraic method characterizes the occurrence of a spike by an irregularity in the neural signal and devises a nonlinear (Volterra) filter which enhances the presence of such irregularities.
- The papers [39], [40] generalize the algebraic method from the integer order to the fractional order for estimating the fractional order derivatives of noisy signals. The proposed fractional order differentiator is deduced from the Jacobi orthogonal polynomial filter and the Riemann-Liouville fractional order derivative definition. Exact and simple formula for this differentiator is given where an integral formula involving Jacobi polynomials and the noisy signal is used without complex mathematical deduction. Hence, it can be used both for continuous-time and discrete-time models. The comparison between our differentiator and the recently introduced digital fractional order Savitzky-Golay differentiator is given in numerical simulations so as to show its accuracy and robustness with respect to corrupting noises.

5.3. Observability and observer design for nonlinear systems

Participants: Jean-Pierre Barbot, Wilfrid Perruquetti, Gang Zheng, Denis Efimov.

Observability analysis and observer design are important issues in the field of control theory. Some recent results are listed below:

- The problem of observer design for fault detection in a class of nonlinear systems subject to parametric and signal uncertainties is studied in [22]. The design procedure includes formalized optimization of observer free parameters in terms of trade-offs for fault detection performance and robustness to external disturbances and model uncertainties. The technique makes use of some monotonicity conditions imposed on the estimation error dynamics. Efficiency of the proposed approach is demonstrated through the Oscillatory Failure Case in aircraft control surface servo-loops.
- An algorithm for the frequency and bias identification of a harmonic signal is presented in [14], [15]. The solution is based on an adaptive observer technique and the hybrid systems method.

- An influence of a singular manifold of non observable states on reconstruction of chaotic attractors is analysed in [25]. The probability of visits of the observability singularity manifold and the relative time spent in the observability singularity manifold are introduced.
- In [36], the cluster structured sparse signals are investigated. Under the framework of Bayesian compressive sensing, a hierarchical Bayesian model is employed to model both the sparse prior and cluster prior, then Markov Chain Monte Carlo (MCMC) sampling is implemented for the inference. Unlike the state-of-the-art algorithms, which are also taking into account the cluster prior, the proposed in [36] algorithm solves the inverse problem automatically–prior information on the number of clusters and the size of each cluster is unknown.
- The papers [54], [86], [87] present 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.
- The paper [85] investigates the observer design problem of for linear switched system with disturbance jumps. Detection of active sub-system and finite time estimation of states are respectively discussed. A switched finite time observer is proposed to guarantee the finite time convergence independent of the disturbance jumps.
- The paper [71], [72] proposes a new observer scheme for chaotic and hyperchaotic systems. Firstly, a classical impulsive observer is investigated for Lorenz chaotic system. This approach is based on sufficient conditions for stability of impulsive dynamical systems. After, an hybrid observer is proposed for hypoerchaotic systems. In the paper [70], a new method of strange attractor identification, under sparse measurement, is proposed this method is based on the concept of compressive sensing. For this, some particular impulsive observers have been presented with a decision scheme linked to diagnosis method, the identification of the strange attractor and state observation are done.
- The problem of state reconstruction for nonlinear differential-algebraic systems with unknown inputs is studied in [51].
- In the paper [26] the design of observers for nonlinear systems with unknown, time-varying, bounded delays, on both state and input for a class of nonlinear systems is proposed. Furthermore, the feasibility of the proposed strategy is illustrated by a numerical example.

5.4. Sliding mode control estimation

Participants: Jean-Pierre Barbot, Wilfrid Perruquetti, Denis Efimov, Thierry Floquet.

Sliding mode algorithms are very popular for finite-time estimation and regulation. The recent results obtained by the group are as follows:

- The issues of a higher order sliding mode controller realization under actuator saturation and quantization have been analysed in [37]. The zig-zag solutions are introduced and analysed.
- The problem of design of interval observers for linear-parameter-varying systems, containing non detectable or non strongly observable parts, is addressed in [18], [63], [62] applying the higher order sliding mode algorithms. Application of sliding mode observers leads to accuracy improvement in the system.
- In [32] an anomaly signal detection in communication networks is studied by control theory techniques. Several classes of sliding mode observers are proposed for a fluid flow model of the transmission control protocol (TCP)/internet protocol network. Comparative simulations via network simulator NS-2 show the enhancement brought by a higher order sliding mode observer. The efficiency of this observer opens the way toward observing traffics with real TCP flow characteristics.

- In [80], [42], [41] the problem of continuous and discrete state estimation for a class of linear switched systems is studied. The class of systems under study can contain non-minimum phase zeros in some of their "operating modes". The conditions for exact reconstruction of the discrete state are given using structural properties of the switched system. The state-space is decomposed into the strongly observable part, the nonstrongly observable part and the unobservable part, to analyze the effect of the unknown inputs. A state observer based on high-order sliding-mode and Luenberger-like observers is proposed. For the case when the exact reconstruction of the state cannot be achieved, the ultimate bounds on the estimation errors are provided. In [41] this technique has been applied to fault detection in switched systems.
- The paper [55] aims, firstly to highlight the possibility of recovering a message included in a chaotic continuous time delay system, secondly to show that it is possible to use the third order sliding mode in order to recover directly all the states and the unknown input (message), thirdly to illustrate the robustness of the proposed observer with respect to a noisy signal. This work is based on the concept of left invertibility and recent advances in sliding mode observers.
- The problem of estimation of discrete and continuous states for switched systems applying higher order sliding mode observers and projection is investigated in the papers [68], [67].

5.5. Non-linear, Sampled and Time-delay systems

Participants: Jean-Pierre Richard, Lotfi Belkoura, Gang Zheng, Denis Efimov, Wilfrid Perruquetti.

Nonlinearities, sampling, quantization and time-delays cause serious obstructions for control and observer design in many fields of techniques and engineering (e.g. networked and internet systems, distributed systems etc.). The proposed by the team algebraic approach suits well for estimation and regulation in such a type of systems. The recent results are listed below:

- A new type of stability is introduced and its equivalent Lyapunov characterization is presented in [16]. The problem of global stability for the compact set composed of all invariant solutions of a nonlinear system (several equilibriums, for instance) is studied. It is shown that several well-known multi-stable systems satisfy this new stability property.
- A new state-dependent sampling control is proposed in [23], [65], which enlarges the sampling intervals of state feedback control. The case of linear time invariant systems with time delays is considered that guarantees the exponential stability of the system origin for a chosen decay rate. The approach is based on LMIs obtained from the sufficient Lyapunov-Razumikhin stability conditions.
- Nonlinear feedback design for fixed-time stabilization of linear control systems is studied in [31]. Nonlinear control algorithms of two types are presented for uncertain linear plants. Controllers of the first type are stabilizing polynomial feedbacks that allow to adjust a guaranteed convergence time of system trajectories into selected neighborhood of the origin independently on initial conditions. Controllers of the second type are modifications of the second order sliding mode control algorithms. They provide global finite-time stability of the closed-loop system and allow to adjust a guaranteed settling time independently on initial conditions. Control algorithms are presented for both single-input and multi-input systems.
- The problem of natural wave control is addressed in [17], which involves steering a lattice of oscillators towards a desired natural (i.e. zero-input) assignment of energy and phase across the lattice. This problem is formulated and solved for lattices of linear oscillators via a passivity-based approach.
- The verification problems for transition systems enriched with a metric structure is analysed in [27]. The main novelty compared to an algorithm presented recently by Lerda et al. [2008] consists in introducing a tuning parameter, which improves the performance drastically. A procedure that allows one to prove unbounded safety from the result of the bounded safety algorithm via a refinement step is also established. The algorithm to handle bounded liveness verification is adapted.

- The problem of finite-time output stabilization of the double integrator is addressed in [52] applying the homogeneity approach. A homogeneous controller and a homogeneous observer are designed (for different degree of homogeneity) ensuring the finite-time stabilization. Their combination under mild conditions is shown to stay homogeneous and finite-time stable as well.
- The notes [76], [77] are dedicated to the stability analysis of bilinear sampled-data systems, controlled via a linear state feedback static controller. A zero order hold device is used. The purpose is to find a constructive way to calculate the maximum allowable sampling period (MASP) that guarantees the local stability of the system. The proposed stability conditions are formulated as linear matrix inequalities (LMI).
- The works [75], [74] concern the adaptation of sampling times for linear time invariant systems controlled by state feedback. Complementary to various works that guarantee stabilization independently of changes in the sampling rate, there the conditions to design stabilizing sequences of sampling instants is provided. In order to reduce the number of these sampling instants, a dynamic scheduling algorithm optimizes, over a given sampling horizon, a sampling sequence depending on the system state value. The proofs are inspired on switched system techniques combining Lyapunov functions and LMI optimization.
- The mechanism of entrainment to natural oscillations in a class of (bio)mechanical systems described by linear models is investigated in [61]. A nonlinear control strategy (based on the speed gradient control algorithm) is analyzed providing the system oscillation in resonance mode with a natural frequency. It ensures an energy-optimal entrainment performance robustly against perturbations in system parameters in a finite time.
- The paper [29] considers a networked control loop, where the plant is a "slave" part, and the remote controller and observer constitute the "master". Since the performance of Networked Control Systems (NCS) depends on the Quality of Service (QoS) available from the network, a controller is designed that takes into account qualitative information on the QoS in real time.
- In the paper [50], the theory of non-commutative rings allows determining whether or not there exists an equation called algebraically essential in order to estimate the delay on a nonlinear system. From this equation, it is shown that this equation is generally not enough to guarantee the delay estimation, thus the notion of persistent signal with respect to delay estimation is introduced. Furthermore, based on the definitions of algebraically essential equation and of persistent signal, a delay estimation algorithm is proposed. Some simulation results have been presented in order to highlight the robustness (with respect to measurement noise) of the proposed algorithm.
- The problem of algebraic identifiability for linear and nonlinear dynamical systems is considered in [88].

5.6. Interval control and estimation

Participants: Denis Efimov, Wilfrid Perruquetti.

In many cases due to parametric and/or signal uncertainties presented in a plant model it is not possible to design a conventional observer, which provides a point-wise estimate of state in a finite time or asymptotically. In this case it is still frequently possible to apply the interval observer techniques, which generate an estimate on the interval of the admissible values of the state at the current instant of time. The recent results are listed below:

- The problem of output stabilization of a class of nonlinear systems subject to parametric and signal uncertainties is studied in [20], [21]. First, an interval observer is designed estimating the set of admissible values for the state. Next, it is proposed to design a control algorithm for the interval observer providing convergence of interval variables to zero, that implies a similar convergence of the state for the original nonlinear system. An application of the proposed technique shows that a robust stabilization can be performed for linear time-varying and linear-parameter-varying systems without assumption that the vector of scheduling parameters is available for measurements.

- The problem of interval observer design for a class of observable nonlinear systems is studied in [33]. It is shown that under some mild conditions a Hurwitz matrix can be transformed to a Hurwitz and Metzler one using a real similarity transformation.
- The work [64] is devoted to interval observer design for Linear Time Varying (LTV) systems and a class of nonlinear time-varying systems in the output canonical form. An interval observer design is feasible if it is possible to calculate the observer gains making the estimation error dynamics cooperative and stable. It has been shown that under some mild conditions the cooperativity of an LTV system can be ensured by a static linear transformation of coordinates. The case of a time-varying transformation for periodic systems is considered in the work [64].
- The problem of actuator fault detection for flat systems using the sliding-mode differentiation and the interval constraint satisfaction technique has been analysed in [43].

5.7. Applications

Participants: Jean-Pierre Richard, Jean-Pierre Barbot, Mamadou Mboup, Gang Zheng, Denis Efimov, Wilfrid Perruquetti, Olivier Gibaru, Samer Riachy.

As it was mentioned, Non-A is a kind of "method-driven" project, which deals with different aspects of finite-time estimation and control. Thus different applications are possible, ones touched this year are as follows:

- The global stabilization of a ball & beam through saturated control, which imposes restrictions on the reactivity of the closed loop, is studied in [91], [81]. A modified design for the classical ball & beam system is presented. The beam is driven by two actuators. In comparison to the classical system, this design offers an additional degree of freedom, which is the vertical motion of the beam. We show that the new design offers the possibility to get rid of the closed loop low reactivity restriction. Two nonlinear controllers to steer the trajectories of the system towards a final desired position are proposed.
- In papers [48], [49] a new class of power converters is studied (Parallel Multicell Chopper). The topology of these chopper is based on a combination of n switching cells interconnected via independent inductors. This type of choppers is a new DC/DC static power converter which has an output current equals to n times the source current where n is the number of cells . After recalling the dynamical equations of the converter, its hybrid dynamical behavior and properties are highlighted. This particular hybrid system induces new and difficult control problems, such problem can be tackled by a new control concept based on Petri net.
- The paper [69] addresses the problem of power management of a hydrogen fuel cell system combined with super capacitors under high load variations in an electric vehicle. The singular perturbation theory is used for the control and coordination of two converters. The Lyapunov theory is used for analysis.
- Combined feedforward/feedback control algorithm for highly nonlinear systems was proposed on the basis of the approximating hybrid model in [28]. The designed MIMO controller enables simultaneous control of the air-to-fuel ratio and torque for injector automobile engines. The theoretical results were validated experimentally with physical cars.
- A spike sorting method for multi-channel recordings is proposed in [35]. The proposed method uses an iterative application of Independent Component Analysis (ICA) algorithm and a deflation technique in two nested loops. The results suggest that the proposed solution significantly improves the performance of ICA in spike sorting.
- In the paper [83] an algorithm for a particular change-point detection problem is proposed, where the frequency band of the signal changes at some points in the time axis. Apart from detecting the change-points, the proposed algorithm is also able to estimate the frequency bands. The main idea of the algorithm is to consider a simple local bandlimited model to represent the input signal in each sliding time window.

- The papers [60], [58], [59] present a new sensorless parameter identification method for permanent magnet stepper motors. Current sensors are assumed available, but position and velocity sensors are not. Data is obtained with open-loop voltage commands at multiple speeds. A new reference frame is proposed that presents advantages similar to the standard $d-q$ frame, but without the need for a position sensor. The method exploits carefully derived linear parameterizations and a least-squares algorithm. In one case, overparameterization is resolved using elimination theory. Overall, the parameters identified using the new procedure are found to be very close to those obtained with position sensors. The approach is potentially applicable to other types of synchronous motors as well.
- In the paper [78], an improvement of the dynamic accuracy of a flexible robot joint is addressed. Based on the observation of the measured axis deformation, a simplified elastic joint model is deduced. In the first step, the non-linear model component's is analyzed and identified in the cases of the gravity bias and the friction term. In the second step, a non asymptotically algebraic fast identification of the oscillatory behavior of the robot axis is introduced. Finally, the performances of the identification approach are exploited in order to improve the dynamic accuracy of a flexible robot axis. This is done experimentally by the combination of the adaptation of the jerk time profile to reduce the end-point vibration and the model-based precompensation of the end-point tracking error.
- Localizability of unicycle mobiles robots is analysed in [82] from an algebraic point of view. A sensibility study leads to a new fusion algorithm in the multi landmark case using as a basis the posture differentiation based estimator.
- The problem of early detection of oscillatory failures for aircrafts is addressed in [38]. The proposed solution is based on a finite-time sliding-mode differentiator and a hybrid optimization scheme.
- The H_∞ control design under time-varying delays and uncertainties, which ensures the stability and performance (synchronization/transparency) between the master and slave manipulators, is proposed in [46], [44], [45]. The design of the controller based on a proposed control scheme, which is performed by using LMI optimization based on Lyapunov-Krasovskii functionals and H_∞ control theory.

6. Bilateral Contracts and Grants with Industry

6.1. Projects

- Project SYSIASS http://www.sysiass.eu/;
  - Subject: Autonomous and Intelligent Healthcare System;
  - Partners: ISEN de Lille, Ecole Centrale de Lille, University of Kent, University of Essex, East Kent Hospitals University NHS Foundation Trust, Groupement Hospitalier de l'Institut Catholique de Lille;
  - Duration: 2010 - 2013;
  - Support: FEDER;
- Project CHASLIM http://chaslim.gforge.inria.fr/;
  - Subject: Sliding mode control;
  - Partners: Inria Grenoble-Rhône Alpes, Inria Lille-Nord Europe, Ecole Centrale de Nantes;
  - Duration: 2011-2014;
  - Support: ANR;
- Project HYCON2 http://www.hycon2.eu/;
  - Subject: Networked control systems;

  - Partners: See http://www.hycon2.eu/?page=5&PHPSESSID=c185e278a6cab0a35c8dea0970c5723d
  - Duration: 2010-2015;
  - Support: FP7;
- Project SENSAS http://sensas.gforge.inria.fr/wiki/doku.php;
  - Subject: Sensor network Applications;
  - Partners: Inria Grenoble-Rhône Alpes, Inria Lille-Nord Europe, Inria Sophia Antipolis-Méditerranée, Inria Nancy-Grand Est;
  - Duration: 2010-2014;
  - Support: ANR;
- Project SLIM
  - Subject: Software library for multi-robots cooperation;
  - Duration: 2012-2014;
  - Support: Inria ADT;
- Project FP7 ERRICS http://cordis.europa.eu/projects/index.cfm?fuseaction=app.details&TXT=ERRIC&FRM=1&STP=10
  - Subject: ERRIC-Empowering Romanian Research on Intelligent Information Technologies;
  - Partners: UNIVERSITATEA POLITEHNICA DIN BUCURESTI;
  - Duration: 2010-2013;
  - Support: EU FP7 Capacities Programme.

7. Partnerships and Cooperations

7.1. National Initiatives

- We are 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" and "Control in Electrical Engineering".
- Model-free control: collaborations with Professor Brigitte D'Andréa-Novel at Mines ParisTech and Professor Emmanuel Delaleau at ENIB (Brest).
- Atomic Force Microscope (AFM): application of new algebraic methods in tapping mode for AFM, collaboration with the National Laboratory of Metrology (LNE) located at Trappes.

7.2. European Initiatives

- Collaboration with Sarah Spurgeon of University of Kent on Sliding mode control;
- Collaboration with Emmanuel Brousseau of Cardiff University for the project: "on nano mechanical machining of 3D nano structures by AFM".

7.3. International Initiatives

- Collaboration with Professors Tulay Adali (University of Baltimore, USA) and Daniel Alpay (University of Ben Gurion, Israel) on signal processing.
- Collaboration with Professors Emilia Fridman (Tel Aviv University) and Joao Manoel Gomes da Silva (UFRGS, Porto Allegre, Brasil) on time-delay systems.

- Collaborations with Professor Guiseppe Fedele from University of Calabria, Italy, on "Model-free control".
- Programme Hubert Curien GALILEE for scientific exchange between LAGIS and University of Cagliari, Italy;
- Programme Hubert Curien VOLUBILIS (Maroc, Integrated Action MA/09/211) between LAGIS (Université Lille1), Non-A/Inria and Laboratory of Electronic, Information and Biotechnology of Department of Science at University Moulay Ismail of Meknès;
- Programme Hubert Curien COGITO for scientific exchange between University of Reims Champagne Ardenne, Non-A and University of Zagreb.
- Collaboration and scientific exchanges with Saint-Petersburg National Research University ITMO, Russia, on interval estimation of linear-parameter-varying systems and on spark ignition engine control.
- Collaboration and scientific exchanges with Universidad Nacional Autónoma de México (UNAM) (Prof. L. Fridman) and Autonomous University of Nuevo Leon (Prof. M. Basin), Mexico, on estimation of linear-parameter-varying systems and sliding-mode control.

7.4. International Research Visitors

7.4.1. Visits of international scientists

- Emilia Fridman, Professor of Tel Aviv University, Israel, June 2012, supported by École Centrale de Lille;
- Marc Bodson, Professor of University of Utah, USA, June 2012, supported by École Centrale de Lille;
- Michael Basin, Professor of Autonomous University of Nuevo Leon, Mexico, June 2012, supported by a bilateral CNRS project.
- Hebertt Sira Ramírez, Professor of CINVESTAV IPN, Mexico, November 2012, supported by École Centrale de Lille.

7.4.2. Internships

- Stanislav Chebotarev, PhD student of National Research University ITMO, Russia, June 2012, "Interval estimation of LPV systems", supported by ITMO;
- Hector Rios, PhD student of UNAM, Mexico, September–November 2012, "Discrete state estimation for switched LPV systems", supported by UNAM.

8. Dissemination

8.1. Scientific Animation

8.1.1. Editorial boards

- Jean-Pierre Richard is currently Associate Editor of *Int. J. of Systems Science*.
- Mamadou Mboup is currently Editor-In-Chief (from December 2012) *African Diaspora Journal of Mathematics* and Associate Editor of *EURASIP Journal on Advances in Signal Processing*.
- Thierry Floquet is currently Associate Editor of *Nonlinear Analysis : Hybrid Systems* and *e-sta*.

8.1.2. Program Committees

- IFAC Technical Committees: The members of Non-A are participating to several technical committees of the IFAC (International Federation of Automatic Control, see the TC list on http://www.ifac-control.org/areas): TC 1.2 - Adaptive and Learning Systems, TC 1.3 - Discrete Event and Hybrid Systems, TC 1.5 Networked Systems, TC 2.2 Linear Control Systems, TC 2.3 Nonlinear Control Systems, TC 2.5 Robust Control, TC 9.2 Control for Society.
- Jean-Pierre Richard was the president of the International Program Committee of the 1st Int. Conf. on Systems & Computer Science, 2012, Lille.
- Mamadou Mboup was in the International Program committee of 22nd IEEE Workshop on Machine Learning for Signal Processing 2012 and 1st International Conference Systems and Computer Science 2012;
- Jean-Pierre Barbot was in the organizing committee of the MECATRONICS congress (France-Japan and Europe-Asia) and REM workshop November 21 – 23, 2012 – Supméca, Paris (France);
- Wilfrid Perruquetti and Lotfi Belkoura were in International Program committee of 7eme Conférence Internationale Francophone d'Automatique, Grenoble, France, 2012;
- Lotfi Belkoura was the NOC Chair and organizer of 1st Int. Conf. on Systems & Computer Science, 2012, Lille (IEEE Technical co-sponsorship);
- Wilfrid Perruquetti was in the International Program committee of 12th International IEEE Workshop on Variable Structure Systems (VSS), 2012, Bombay, India;
- Wilfrid Perruquetti was in the International Program committee of 1st Int. Conf. on Systems & Computer Science, 2012, Lille;
- Jean-Pierre Richard was in the International Program committee of 20th IEEE Mediterranean Conference on Control and Automation, 2012, Barcelone; 10th Workshop on Time Delay Systems, 2012, Boston; 2nd Int. Conf. on Communications, Computing and Control Applications, 2012, Marseilles; 3rd IEEE International Workshop on SmArt COmmunications in NEtwork Technologies, 2012, Canada.

8.1.3. Scientific and administrative responsibilities

- Jean-Pierre Richard is president of the GRAISyHM, federation from the French government. He is an expert for the evaluation of projects submitted to ANR, CNRS, DGRI and AERES. He is a member of the Scientific Committee of the GdR MACS, CNRS.
- Wilfrid Perruquetti is the scientific head of ANR program Blanc SIMI3, and is heading the 3rd year professional training "ISD: Information System and Decision" of the École Centrale de Lille; He is an expert for ANR, AERES and ARC (Australian Research Council);
- Mamadou Mboup is heading the group SYSCOM - CReSTIC, University of Reims Champagne-Ardenne;
- Lotfi Belkoura is heading the Master "AG2i: Automatique, Génie Informatique et Image", University of Lille 1 and École Centrale de Lille. This Master, after a national evaluation (A), is presently "SMaRT: Systèmes, Machines autonomes et Réseaux de Terrain";
- Thierry Floquet is an expert for the evaluation of projects submitted to ANR and Israel Science Foundation, and a member of Conseil National des Universités, 61ème Section. He is as well the head of the groupe SyNeR of LAGIS laboratory;
- Lotfi Belkoura is an expert of "National Council for Research and Development" (Roumanie)www.ue1Cscdi-direct.ro
- Gang Zheng is a member of Conseil National des Universités, 61ème Section.
- Cédric Join is heading the AII-ASRI, IUT Nancy-Brabois.
- Jean-Pierre Barbot is the heading of the ECS-Lab EA 3649.

8.2. Teaching - Supervision - Juries

8.2.1. Teaching

The members of the team teach at different level in universities and engineering schools and, in particular, at Master Thesis level:

Licence : Samer Riachy; Systèmes linéaires (36h), Asservissements (48h), Introduction à la thermodynamique (32h), Echantillonnage et systèmes discrets (36h), Conversion d'énergie (48h); L3; Ecole Nationale Supérieure de l'Electronique et de ses Applications; France

Licence : Jean-Pierre Richard; Automatique et Intelligence ambiante (12h); L2; EC-Lille; France

Licence : Jean-Pierre Richard; Systèmes dynamiques (30h), Métiers de la recherche (4h), Modélisation des systèmes complexes(12h), Commande et observation (12h), Séminaire episteme (24h); L3; EC-Lille; France

Licence : Lotfi Belkoura; Initiation à l'Automatique (20h), Régulation Industrielle (60h); L3; Lille 1; France

Master : Jean-Pierre Richard; Systèmes dynamiques non linéaires et à retards (30h); M2; Lille 1 – EC-Lille, France

Master : Lotfi Belkoura; Systèmes automatisés (60h); M1; Lille 1; France

Master : Lotfi Belkoura; Distributions (8h); M2; Lille 1; France

General responsibility:

- Jean-Pierre Richard is in charge of the professional training "Research" of Ecole Centrale de Lille since 2003 (training for last-year students of EC Lille who are preparing a research career). (http://www.ec-lille.fr/85787934/0/fiche___pagelibre/).
- Wilfrid Perruquetti is in charge of the professional training "ISD: Information System and Decision" of Ecole Centrale de Lille since 2010 (http://www.ec-lille.fr/syst_auto/0/fiche___formation/).
- Lotfi Belkoura is in charge of the SMART Master Thesis training in control of University of Lille 1 and Ecole Centrale de Lille.

8.2.2. Supervision

PhD & HdR :

HdR : Join C., "Une approche algébrique pour la pratique de l'estimation, du diagnostic, de la commande et de la finance", Université de Lorraine, June 2012

HdR : Efimov D., "Analysis, control and estimation of nonlinear oscillations", Inria, November 2012

PhD : Delpoux R., "Fast identification and estimation of nonlinear systems via algebraic techniques", École Centrale de Lille, November 2012, Supervisor: T. Floquet

PhD : Fiter C., "Contribution to the control of systems with time-varying and state-dependent sampling", École Centrale de Lille, September 2012, Supervisors: J.P. Richard, W. Perruquetti, L. Hetel

PhD : Zhang B., "New control schemes for bilateral teleoperation under asymmetric communication channels: Stabilization and performance under variable time delays", École Centrale de Lille, July 2012, Supervisors: J.P. Richard, A. Kruszewski

PhD in progress : EL Afou Y., "Control strategies for greenhouse climate parameters", Université des Sciences et Technologies de Lille, started 2009, Supervisors: L. Belkoura, C. Join, A. Lachhab, B. Bouchikhi

PhD in progress : Guerra M., "Supervisory control of collective motion of mobile robots", started 2012, Supervisors: W. Perruquetti, D. Efimov, G. Zheng

PhD in progress : Maalej S., "Algebraic estimation for robust control", started 2011, Supervisors: A. Kruszewski and L. Belkoura

PhD in progress : Oueslati M., "Improving the accuracy of a 6-axis industrial robot for machining", started 2009, Supervisor: O. Gibaru

PhD in progress : Sert H., "Intelligent module decision for autonomous indoor navigation of wheelchair robot", started 2012, Supervisors: W. Perruquetti and A. M. Kökösy

PhD in progress : Mincarelli D., "Algebraic approach for observation of switched systems", started 2010, Supervisors: T. Floquet and L. Belkoura

8.2.3. Juries

The team members are also involved in numerous examination committees of Theses and Habilitations, in France and abroad.

8.3. Popularization

8.3.1. Participation to conferences

- European Signal Processing Conference, Bucharest, Romania, August 2012 (Mamadou Mboup);
- 22nd IEEE Workshop on Machine Learning for Signal Processing, Santander, Spain, September 2012 (Mamadou Mboup);
- 1st International Conference Systems and Computer Science, Lille, France, August 2012 (Lotfi Belkoura, Jean-Pierre Richard, Wilfrid Perruquetti, Mamadou Mboup, Gang Zheng, Denis Efimov, Andrey Polyakov, Diego Mincarelli);
- 16th IFAC Symposium on System Identification, Brussels, July 2012 (Wilfrid Perruquetti, Mamadou Mboup, Rosane Ushirobira);
- IEEE Conference on Decision and Control, 2012, USA (Jean-Pierre Richard, Wilfrid Perruquetti, Jean-Pierre Barbot, Denis Efimov, Diego Mincarelli);
- IEEE Chinese Conference on Control and Decision, 2012, China (Gang Zheng);
- ASME 11th Biennial Conference on engineering systems design and analysis, 2012, France (Samer Riachy);
- IFAC Conference on Time-delay systems (TDS), June 2012, USA (Jean-Pierre Richard, Thierry Floquet);
- IFAC Robust Control symposium (ROCOND), 2012, Denmark (Jean-Pierre Richard);
- IFAC ADHS, 2012, Netherlands (Jean-Pierre Richard, Denis Efimov, Diego Mincarelli)
- IEEE 20th Mediterranean Conference on Control and Automation, 2012, Barcelona (Jean-Pierre Richard);
- IEEE CIFA, 2012, France (Jean-Pierre Richard, Jean-Pierre Barbot, Wilfrid Perruquetti, Gang Zheng);
- IFAC Conference on analysis and control of chaotic systems (CHAOS), 2012, Mexico (Jean-Pierre Barbot).

8.3.2. Reviews

The members of Non-A are reviewers for most of the journal of the control and signal communities: IEEE Transactions on Automatic Control, IEEE Transactions on Systems and Control Technologies, IEEE Transactions on Industrial Electronics, IEEE Transactions on Signal Processing, Automatica, SIAM Journal on Control and Optimization, Journal of Computation and Applied Mathematics, Systems & Control Letters, International Journal of Control, International Journal of Robust and Nonlinear Control, International Journal of Systems Science, Journal Européen des Systèmes Automatisés, IET Control Theory & Applications, Fuzzy Sets and Systems, Mathematics and Computers in Simulation, International Journal of Modeling and Simulation, Journal of the Franklin Institute, ...

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[12] C. JOIN. *Une approche algébrique pour la pratique de l'estimation, du diagnostic, de la commande et de la finance*, Université de Lorraine, June 2012, HDR, http://tel.archives-ouvertes.fr/tel-00759370.

Articles in International Peer-Reviewed Journals

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