INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team NeCS

Networked Control Systems

Grenoble - Rhône-Alpes

Theme : Modeling, Optimization, and Control of Dynamic Systems

Activity Report

2009

Table of contents

NeCS is a joint project-team with GIPSA-lab (CNRS, INPG and UJF).

1. Team

Research Scientist

Carlos Canudas-de-Wit [Team Leader, DR CNRS, HdR]
Mazen Alamir [Part-time member, DR CNRS, HdR]
Nicolas Marchand [Part-time member, CR CNRS]
Daniel Simon [CR INRIA, HdR]
Alexandre Seuret [CR CNRS]

Faculty Member

Alain Kibangou [Assistant Professor UJF-CNRS Chair]
Olivier Sename [Part-time member, Professor Grenoble INP, HdR]
Cyrille Siclet [Part-time member, Assistant Professor UJF]

Technical Staff

Anne-Marie Alt [ARAVIS project engineer - from January 2008]
Florine Boudin [Young Engineer]
Jonathan Dumon [Research Engineer]

PhD Student

Carolina Albea-Sanchez [MENRT - 2007/2010, in coll with Univ. Sevilla]
Lara Briñón-Arranz [FeedNetBack project - 2008/2011]
Nicolas Cardoso de Castro [FeedNetBack project - 2009/2012]
Riccardo Ceccarelli [CIFRE-IFP-GIPSA-lab- 2007-2010]
Sylvain Durand [ARAVIS project - 2007/2010]
Jonathan Jaglin [MENRT - 2006/2009]
Luc Malrait [MENRT - 2007/2010]
Émilie Roche [FeedNetBack project - 2008/2011]
Gabriel Rodrigues de Campos [MENRT - 2009/2012]

Post-Doctoral Fellow

Denis Jacquet [Industrial post-doc]
Wenjuan Jiang [Institut Carnot- from November 2009]
Alain Kibangou [CONNECT project- from February to August 2009]
Brandon Moore [CONNECT project - until August 2009]
Katerina Stankova [INRIA- from February 2009]
Jiri Zikmund [CONNECT project - until October 2009]

Administrative Assistant

Myriam Etienne [Assistant]
Elodie Toihein [Assistant- from October 2009]

2. Overall Objectives

2.1. Introduction

The NeCS project-team goal is to develop a new control framework for assessing problems raised by the consideration of new technological low-cost and wireless components, the increase of systems complexity, and the distributed and dynamic location of sensors (sensor networks) and actuators. In this framework, control design is performed under general resources constraints including communication, computation, and energy. In that, the team targets an innovative step forward in the feedback design for networked controlled distributed systems by the development of combined control, computing & communication co-design. The project-team is bi-located at INRIA (Montbonnot) and at the GIPSA-LAB (at the Grenoble campus).

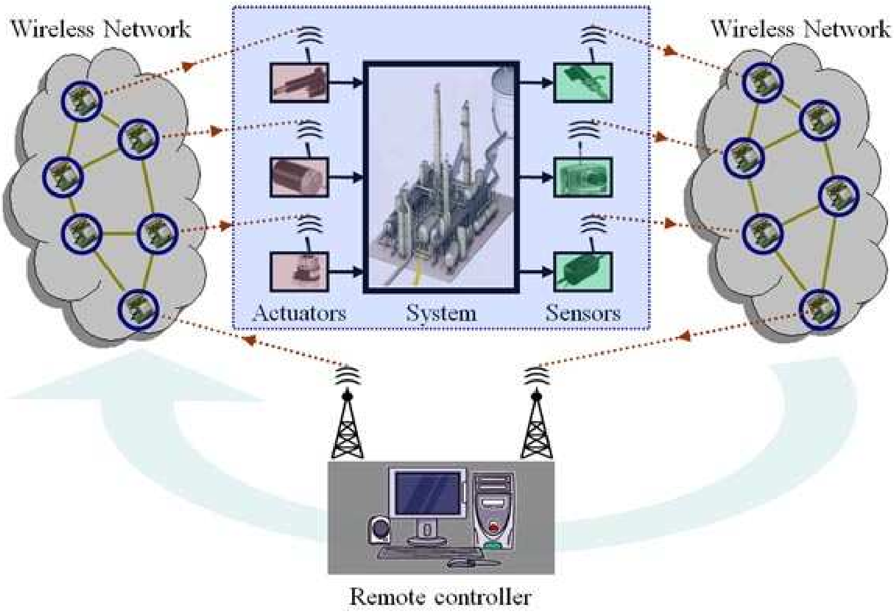

Figure 1. Overview of NeCS systems

The field of Networked Controlled Systems (NCS) refers to feedback systems controlled *over* networks, as shown in Fig 1. These systems result from the arrival of new control problems posed by the consideration of several factors, such as: new technological components (i.e. wireless sensors, RF communications, adhoc networks, etc.), increase of systems complexity (i.e. increase in vehicle components), the distributed location of sensor and actuator, and computations constraints imposed by their embedded nature (i.e. embedded systems, and systems on-chip). In this system class, the way that the information is transferred and processed (information constraints), and the manner in which the computation/energy resources are used (resources management), have a substantial impact in the resulting stability and performances properties of the feedback controlled systems. Inversely, the already designed feedback system, can be affected by the properties of the channel transmission (latency, fading, delay jitter, lost of data, etc.), and the way that the computational and energy resources are used.

2.2. Highlights of the year

The main new facts of the year are:

- the recruitment of a new researcher in the Team. Alain Kibangou has joined NeCS as Associate Professor within the UJF-CNRS chair framework, since September 2009;
- the organization of a workshop at Courchevel: "Cases-study definitions" for the European FeedNet-Back project (January 29-30, 2009);
- three patents have been deposed;
- a book on co-design approaches for networked control systems has been prepared [1]. It will be published on 2010;
- the recruitment of 2 new PhD students and of 3 PostDocs.

3. Scientific Foundations

3.1. Multi-disciplinary nature of the project

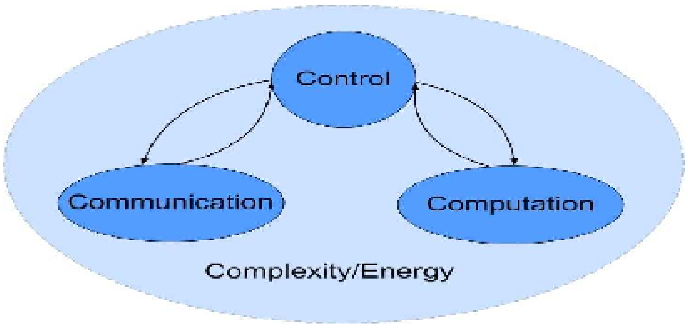

Figure 2. Relation of the NCS area with the fields of: Control, Communication, Computation.

The project propose to investigate problems in the area of NCS with the originality of integrated aspects on computation, communication and control. The combination of these three disciplines requires the interplay of the multi-disciplinary fields of: communication, real-time computation, and system theory (control). Figure 2, shows the natural interaction between disciplines that concern the NeCS project. The arrows describe the direction in which these areas interact, i.e.

(a) *Control in Communication*

(b) *Communication in Control*

(c) *Computation in Control*

(d) *Control in Computation*

Complexity and energy-management are additional features to be considered as well. Complexity here refers to the problems coming from: wireless networks with varying interconnection topologies, multi-agent systems coordination, scale of the number of sensors, etc. Energy management concerns aspect related to the efficient handling of energy in wireless sensors. That is the efficient way to send information, and perform computations.

3.1.1. (a) Control in Communication

This area concerns more control applications where control methods are used to solve problems found in the communication field. Examples are: the Power control in cell telephones, and the optimal routing of messages in communication networks (Internet, sensor networks).

3.1.2. (b) Communication in Control

This area concerns problems where communication and information theory interacts with system theory (control). A typical scheme of a networked controlled system (NECS) is shown in Fig. 3. As an example, of a classical paradigm we can mention the stabilization problem under channel (communications) constraints. A Key result here [74] was to show that it was generically impossible to stabilize a linear system in any reasonable sense, if the feedback channel's *Shannon classical capacity* C was smaller than the sum of the logarithms, base 2, of the unstable eigenvalues. In other words, in order to be able to cope with the stabilization problem under communication constraints, we need that

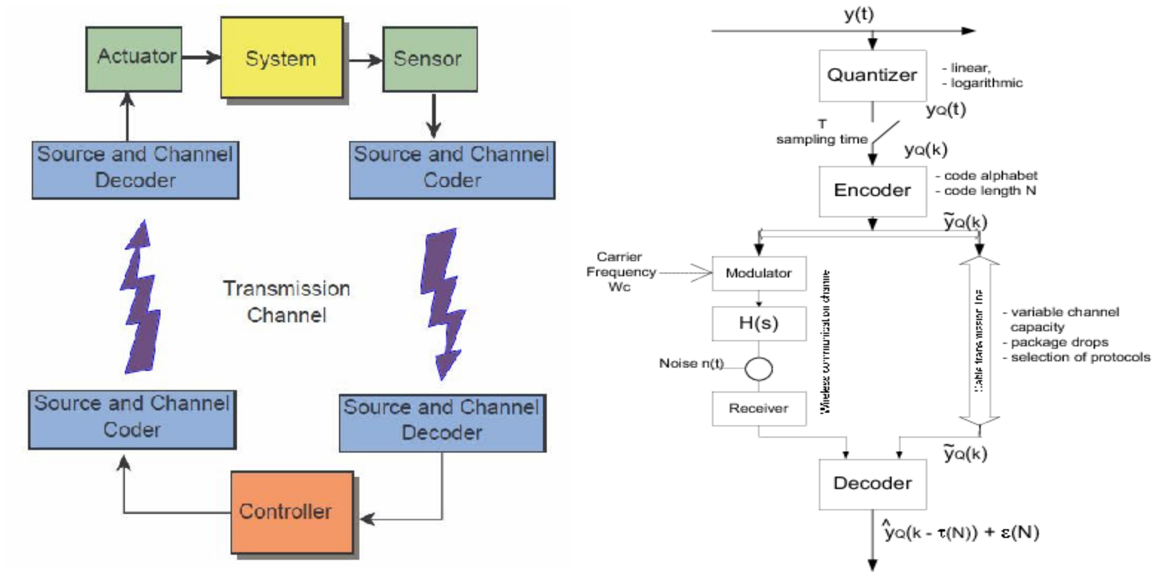

Figure 3. Block diagram of a networked controlled system. General closed loop configuration (left), details of the transmission path (right)

$$C > \sum_i \log_2 \lambda_i$$

where the $\lambda_i' s$ are unstable eigenvalue of the open loop system. Intuitively, this means that the rate of information production (for discrete-time linear systems, the intrinsic rate bits/time equals $\sum_i \log_2 \lambda_i$) should be smaller than the rate of information that can be transmitted throughout the channel. In that way, a potentially growing signal can be cached out, if the information of the signal is send via a channel with fast enough transmission rate. In relation to this, a problem of interest is the coding and control co-design. This issue is motivated by applications calling for data-compression algorithms aiming at reducing the amount of information that may be transmitted throughout the communication channel, and therefore allowing for a better resource allocation and/or for an improvement of the permissible closed loop system bandwidth (data-rate).

Networked control systems also constitute a new class of control systems including specific problems concerned by delays. In NCS, the communication between two agents leads unavoidably to transmission delays, discrete-time sending whereas the controlled processes evolves in continuous time, loss of information and data process. Our objectives concerns the stabilization of systems where the sensor, actuator and system are assumed to be remotely commissioned by a controller that interchanges measurements and control signals through a communication network. Additional dynamics are introduced due to time-varying communications delays, asynchronous samplings, packets losses or lake of synchronization. All those phenomena can be modelled as the introduction of time-delays in the closed loop system. Even if this time-delay approaches can be easily proposed, they require careful attention and more complex analysis. In general, the introduction of delays in a controlled loop leads to a reduction of the performances with respect to the non delay situation and could even makes the systems unstable. Our objective is to provide specific modelling of these phenomena and to develop dedicated tools to and methodologies to cope with stability and stabilization of such systems.

3.1.3. (c) Computation in Control

This area concerns the problem of redesigning the control law such as to account for variations due to the resource allocation constraints. Computation tasks having different levels of priority may be handled by asynchronous time executions. Hence controllers need to be re-designed as to account for non-uniform sampling times resulting in this framework. Questions on how to redesign the control laws while preserving its stability properties are in order. This category of problems can arise in embedded systems with low computation capacity or low level resolution.

3.1.4. (d) Control in Computation

The use of control methods to solve or to optimize the use of computational resources is the key problem in this area. This problem is also known as a scheduling control. The resource allocations are decided by the controller that try to regulate the total computation load to a prefixed value. Here, the "system" to be regulate is the process that generate and use the resources, and not any physical system. Hence, internal states are computational tasks, the control signal is the resource allocation, and the output is the period allowed to each task.

3.1.5. (c + d) Integrated control/scheduling co-design

Control and Computation co-design describes the possibility to study the interaction or coupling between the flows (c) and (d). It is possible, as shown in Figure 4, to re-frame both problems as a single one, or to interpret such an interconnection as the cascade connection between a computational system, and a physical system.

In our framework the feedback scheduling is designed w.r.t a QoC (Quality of Control) measure. The QoC criterion captures the control performance requirements, and the problem can be stated as QoC optimization under constraint of available computing resources. However, preliminary studies suggest that a direct synthesis of the scheduling regulator as an optimal control problem leads, when it is tractable, to a solution too costly to be implemented in real-time [55]. Practical solutions will be found in the currently available control theory and tools or in enhancements and adaptation of current control theory. We propose in Figure 4 a hierarchical control structure : besides the usual process control loops we add an outer control loop which goal is to manage the execution of the real-time application through the control of the scheduling parameters of the inner loops. Together with the outer loop (working on a periodic sampled time scale) we also need a scheduling manager working on a discrete events time scale to process exception handling and admission control.

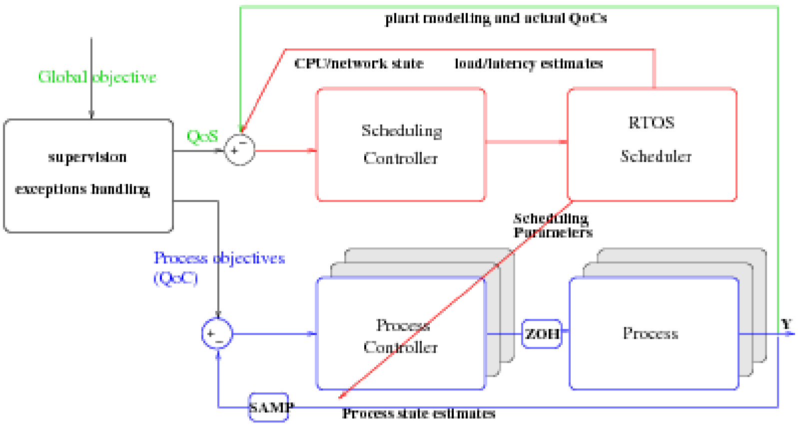

Figure 4. Hierarchical control structure.

The task periods directly affect the computing load, they have been chosen as actuators. They can be implemented through software variable clocks. As timing uncertainties cannot be avoided and are difficult to model or measure, we currently design robust control algorithms using the H_∞ control theory, which have been successfully simulated and experimentally validated [72].

This methodology is supported by ORCCAD (see Section 5.1) where a run-time library for multi-rate multitasking has been developed and integrated. It will be further improved using a QoS-based management of the timing constraints to fully benefit from the intrinsic robustness of closed loop controllers w.r.t. timing uncertainties.

3.2. Main Research Directions

The main objective of the project is to develop a unified control, communication, computing co-design methodology explicitly accounting for all the components involved in the system controlled over a network. This includes quantifier properties, scheduling parameters, encoder/decoder, alphabet length, bandwidth of the transmission media (wire or wireless), delays, resource allocation, jitter, etc.

These components, including the control laws, should be designed so as to optimize performance/stability trade-offs resulting from the ceiling of the computing resources, the channel capacity limitations and the quality of the send/received information protocols.

In short the project is centered along the following 3 main axes:

1. **Control under Communications Constraints.** One well established topic along this axis concerns the coding and control co-design. That is, the design of new code alphabets simultaneously than the design of the control law. Or equivalently, the ability of designing codes containing information pertained to the system model and the control law. The objective being the improvements of the overall closed loop performances. Besides this matter, additional improvements pertain to the field of the information theory are also in order.
2. **Control under Computational resources constraints.** The main objective here is the design of control loops by explicitly accounting for the network and/or the computing resources. Dynamic allocation of such resources depends on the desired controlled systems specifications. Keys aspects to be considered are: the design of controllers with variable sampling time, the robustness with respect to time uncertainties such as the input/output latencies, the global control of resources and its impact over the performance and the robustness of the system to be controlled. We aim to provide an *integrated control and scheduling co-design* approach [73].
3. **Controlling Complexity** Design and control of partially cooperative networked (possible also multi-agent) systems subject to communication and computational constraints. Here, a large number of entities (agents), having each its own goal share limited common resources. In this context, if there is no minimum coordination, dramatic consequences may follow, on the other hand, total coordination would be impossible because of the lack of exhaustive, reliable and synchronous information. Finally, a local "network of strategies" that are based on worst-case assumptions is clearly far from being realistic for a well designed system. The aim of this topic is to properly define key concepts and the relevant variables associated to the above problem (sub-system, partial objective, constraints on the exchanged data and computational resources, level of locally shared knowledge, key parameters for the central level, etc).

4. Application Domains

4.1. Polling the domain

Closing feedback loops around Wireless sensor networks offers new challenges and new opportunities for the area of control. Several new application areas can be enabled, or enhanced if systematic methods are developed for the design of NCS. Examples include:

- Intelligent buildings, where sensor information on CO_2 concentration, temperature, room occupancy, etc. can be used to control the heating, ventilation and air conditioning (HVAC) system under multi-objective considerations of comfort, air quality, and energy consumption.
- Intelligent transportation systems, where traffic flow or density can be measured using novel wireless technologies and used to determine control inputs such as on-ramp metering schemes and variable message signs.
- Disaster relief operations, where data collected by sensor networks can be used to guide the actions of rescue crews and operate automated rescue equipment.
- Surveillance using swarms of Uninhabited Aerial Vehicles (UAVs), where sensor information (from sensors on the ground and/or on-board the vehicles) can be used to guide the UAVs to accomplish their mission.
- Environmental monitoring and exploration using schools of Autonomous Underwater Vehicles (AUVs), where underwater sensors and communication are used to guide the AUVs.
- Infrastructure security and protection using smart camera networks, where the images collected are shared among the cameras and used to control the cameras themselves (pan-tilt-zoom) and ensure tracking of potential threat.

In particular, the team is already involved in the areas described in detail below :

4.2. Vehicular transportation systems

4.2.1. Car industry

Car industry has been already identified as a potential homeland application for NCS [60], as the evolution of micro-electronics paved the way for introducing distributed control in vehicles. In addition, automotive control systems are becoming the more complex and iterative, as more on-board sensors and actuators are made available through technology innovations. The increasing number of subsystems, coupled with overwhelming information made available through on-board and off-board sensors and communication systems, rises new and interesting challenges to achieve optimal performance while maintaining the safety and the robustness of the total system. Causes of such an increase of complexity/difficulties are diverse: interaction between several control sub-systems (ABS, TCS, ESP, etc.), loose of synchrony between sub-systems, limitations in the computation capabilities of each dedicate processor, etc. The team had several past collaborations with the car industry (Renault since 1992, and Ford), and has recently initiate a new collaboration on observer design and fault diagnostics design for multi-sensor systems in Homogeneous Charge Diesel engines, in collaboration with the IFP. In addition, a new ANR project, named VOLHAND, has been started in collaboration with INRETS, JTEKT, Fondation Hopale, LAMIH, CHRU. It aims at developing a new generation of electrical power-assisted steering specifically designed for disabled and aged persons.

4.2.2. Intelligent transportation systems

Throughout the world, roadways are notorious for their congestion, from dense urban network to large freeway systems. This situation tends to get worse over time due to the continuous increase of transportation demand whereas public investments are decreasing and space is lacking to build new infrastructures. The most obvious impact of traffic congestion for citizens is the increase of travel times and fuel consumption. Another critical effect is that infrastructures are not operated at their capacity during congestion, implying that fewer vehicles are served than the amount they were designed for. Using macroscopic fluid-like models, the NeCS team has initiated new researches to develop innovative traffic management policies able to improve the infrastructure operations. This activity is currently focused on automatic model calibration and traffic prediction, two important items to implement efficient Intelligent Transportation Systems (ITS) such as traffic responsive ramp metering and varying speed limit as well as producing relevant user information. The team is currently setting up a consortium with local authorities involved in traffic management to build to a demonstrator called GTL (Grenoble Traffic Lab). One target of this activity is to transfer part of the developed technology to a start-up currently incubated at GRAIN (Grenoble incubator for high tech start-ups) named Karrus.

4.3. Underwater systems

Underwater systems, as presently used or intended by the offshore industry and marine research, are subject to severe technological constraints. In AUVs, the on-board power is limited and calls for both control and computing optimization. The links between the master and slave nodes use ultrasonic devices, which have a very low bandwidth and are subject to frequent transient loss, thus calling for sharing the decisional process among the nodes and for a robust implementation of the distributed control, taking into account the communication network features. These constraints together with the potential cost of failures make these systems good candidates for safe and flexible control, communication and computing co-design. The team already got a significant experience in this domain with a past collaboration with IFREMER and other EU projects. Currently, the projects CONNECT and FEEDNETBACK deal with this type of problems (see Sections 8.1.2 and 8.2).

4.4. Systems on chip

Achieving a good compromise between computing power and energy consumption is one of the challenge in embedded architecture of the future. This management is especially difficult for 45nm or 32nm known to be at the limit of the scalability. Automatic control loops have therefore to be designed in order to make the performance fit the requirement in order to minimize the energy loss in a context of highly unknown performance of the chip. The main objective is to control the computing power and the consumption using the voltage and frequency automatically according to the requirements of the OS. For this, appropriate sensors must be implemented on the chip and a high-performance repartition between hardware and software implementation must be made.

4.5. Computer systems

Server systems (Internet, database, news, etc.) is a very active industry in the communication area. Tuning servers is currently done with the experience and the feeling of human operators with potential problems like under-optimality or even trashing phenomena in case of bad tuning. The NeCS team has started research on that subject in collaboration with the INRIA-Sardes team for using control theory tools in closed loop server systems and especially for controlling their admission. This goes in the direction to fully autonomous servers in completely heterogeneous aggregation of servers.

5. Software

5.1. Orccad

Participants: S. Arias [SED], R. Pissard-Gibollet [SED], F. Boudin, D. Simon [contact person].

ORCCAD [1] is a software environment that allows the design and implementation of the discrete and continuous components of complex control systems, e.g. robotics systems which provided it first ground [52]. It also allows the specification and validation of missions to be realized by this system. It is mainly intended for critical real-time applications, in which automatic control aspects (*servo loops*) have to interact narrowly with the handling of discrete events (*exception handling*). ORCCAD offers a complete and coherent vertical solution, ranging from the high level specification to real-time code generation. ORCCAD is supported by the *Support Expérimentations & Développement (SED)* service of INRIA-Rhône-Alpes. ORCCAD is used by the experimental robotics platforms of INRIA-Rhône-Alpes and by the SAFE_NECS ANR project in a real-time simulator of a X4 drone. New functionalities and updates are developed jointly by the *SED* service and researchers of the NECS and SARDES teams.

[1] http://sed.inrialpes.fr/Orccad/

Although it has been developed years ago, the basic concepts upon which the ORCCAD architecture relies still appear to be solid in the field of software development for robot control [71], and compares well with other tools dedicated for real-time control implementation [75]. However the ORCCAD V3 software was designed with proprietary tools that moreover are now becoming obsolete. ORCCAD V4 is currently deeply re-engineered to be compliant with open-source and free software tools (Java/Eclipse). Current targets are Linux (Posix threads) and Xenomai, a real-time development framework cooperating with the Linux kernel (http://www.xenomai.org).

5.2. Connectsim

Participants: J. Dumon [contact person], P. Bellemain [GIPSA-Lab], S. Nicolas [PROLEXIA], N. Maciol [PROLEXIA], F. Martinez [ROBOSOFT], J. Caquas [ROBOSOFT].

CONNECTSIM [2] is a shared platform having as main goal the validation of the fundamental principles developed in the CONNECT project. It integrates agent's models, communication media including their limitations, heterogeneous network, and all the variants of the multi-agent control strategies. Besides the models and simulation engine, the simulator is complemented with an interactive graphical interface which is used to visualise and interpret the state of the multi-agent control system in one direction and to send high or low-level controls to the agents. The validation scenario is a real-size application complex enough to enforce the pertinence of our results. It will be further used as an open research tool for various applications in the field of multi-agents networked systems.

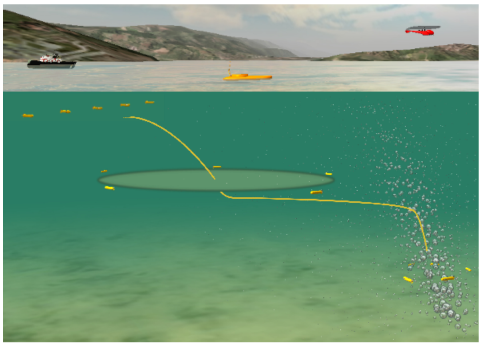

Figure 5. A scenario's view obtained with Connectsim

6. New Results

6.1. Stability and control design of asynchronous interconnected systems

6.1.1. Passivity design for asynchronous feedback-interconnected systems

Participants: C. Canudas de Wit [Contact person], F. Rubio, M. Lopez-Matinez [University of Sevilla].

In this topic we have studied the passivity properties of asynchronously non-uniformly sampled systems. The idea of studying these systems comes from the necessity of developing theoretical tools for the analysis of systems that are asynchronously interconnected. Imposing certain passivity properties to each sub-system it is possible to design a local controller for each sub-system disregarding the particular characteristic of the other system (modular design).

[2] http://www.lag.ensieg.inpg.fr/connect/simulator.php

Further studies consider systems that are either Input/Output Strictly passive (IOSP), or systems which have bounded L_2-gains less than one. The analysis is performed by using the concept of MAximum Sampling time preserving Dissipation (MASD), for each interconnected system. We investigate the impact of using the scattering transformation in the computation of the MASD, and we provide a numerical algorithm (based on a set of LMI's) that allows to choose the most suitable configuration for the interconnection (see [32])

6.1.2. Stability of sampled-data systems: an input delay approach

Participant: A. Seuret.

NCS are controlled systems containing several distributed plants which are connected through a communication network. In such applications, a heavy temporary load of computation in a processor can corrupt the sampling period of a certain controller. The variations of the sampling period will affect the stability properties. It is now reasonable to design controllers which guarantee the robustness of the solutions of the closed loop system under periodic samplings. However the case of asynchronous samplings still leads to several open problems such that the guarantee of stability whatever the sampling period lying in an interval. In [38], we propose a novel approach to obtain sufficient asymptotic and exponential stability conditions of linear time-varying systems. Those conditions are based on the continuous-time approach, [56], and the stability of impulsive systems [66]. The proposed theorems provide larger upper-bounds of the allowable sampling period than the existing ones (based on the continuous time approach).

6.1.3. Event-based control design

Participants: N. Marchand [Contact person], S. Durand.

Asynchronicity is becoming more and more meaningful in modern control architectures and some new control strategies are being developed by some research teams in the world. The principle of these control laws is to compute a new control signal only when some event occur, where an event characterizes a change in the system and therefore a need for a new control. These approaches are supposed to reduce the number of times the control signal is computed and to remove the real-time hard constraint on the computational system. In this domain, our contribution is twice. First, based on previous result from Nicolas Marchand [5], we proposed a fully asynchronous control scheme (without any time information) for chain of integrators that insures the global stability of the system with only measures when the states cross an *a priori* defined level. This work was presented at the IFAC world congress in Korea [6]. Secondly, we removed the safety limit condition introduced by K-E. Årzén in his event-based PID controller [77]. This safety limit was added to prevent the system to be sampled less than what Shannon theorem requires but we showed that the Shannon sampling condition is no more consistent in the context of event based systems. This work led to two papers [29], [18].

6.2. Communication and control co-design in feedback systems

6.2.1. Differential coding for networked controlled systems

Participants: C. Canudas-de-Wit [contact person], C. Siclet, J. Jaglin.

We have devised several methods for differential modulation in NCS: gain scheduling 2-bit coding [65], Delta modulation for MIMO systems in [58]. In [57] authors have presented a quantization method based on a one-bit-adaptive Δ modulation. Extensions to Adaptive Delta modulation, and extension to multi-variable adaptive are also studied. We have introduced a new adaptive Delta modulation variant called D-ZIZO (Dwell Time Zoom In Zoom Out). The objective of our work published in [12] is specifically to treat aspects related to the energy management, in relation with the particular code to be used.

In [11] we have investigated the closed loop properties of the differential coding scheme known as Delta Modulation (DM) when used in feedback loops within the context of feedback controlled systems. We propose a new modified scheme of the original form of the DM algorithm which is better suited for applications where the sensed information is used in feedback. A state feedback controller is implemented with the state estimated by a predictorbased differential decoder. Stability of the resulting closed loop systems (controller-coder-decoder) are studied. These properties (stability and performance) depend on the quantization parameter, which is assumed constant in the first part of our work. In a further step, this parameter is made adaptive, by defining an adaptation law exclusively in terms of information available at both the transmitter and receiver side. With this approach both stability and performance are improved.

Current studies addresses new adaptive differential coding algorithms over a limited channel rate. Adaptive coding is preferred over fixed quantizers as these only can reach local practical stability, at its best. The new proposed adaptive algorithm provides global exponential stability for noiseless MIMO system, and Input-to State Stability otherwise. Two of main advantages of the algorithm are that firstly it provides robustness against disturbances, and that secondly it reaches rate theoretical limits. Indeed, the algorithm is coded with the minimum number of possible bits, for both scalar and multi-variable systems. The robustness is achieved thanks to the introduction of a new state namely dwell-time state in addition to the zoom-in and zoom-out ones. The dwell-time mechanism introduces a hysteretic effect that smoothes out the periodic and oscillatory behavior observed in previous ZIZO[3] quantifiers. Because of this behavior, the algorithm is named dwell-time zoom-in/zoom-out (D-ZIZO).

6.2.2. *Energy-aware and entropy coding in NCS*

Participants: C. Canudas-de-Wit [Contact person], J. Jaglin, N. Cardoso.

New thesis form Nicolas Cardoso (relation with the FeedNetBack project)

Wireless low-cost sensor networks are an expanded technology in many new and varied areas such as: traffic monitoring and control (urban, highways), undersea monitoring/exploration, environment sensing (forest, farms, etc.), building services, large instruments with distributed sensing and actuators (Tokamak, telescopes), etc.

In this context, future generation of this type of sensors are expected to be packaged together with communication protocols, RF electronics, and energy management systems. Therefore, the development of such integrated sensors will be driven by constraints like: low cost, ease of replacement, low energy consumption, and energy-efficient communication links. In turn, these constraints bring new problems to be considered in the exploitation of this information. For instance, low cost will induce sensors with low resolution (binary sensors, at the extreme) advocating for minimum bit coding strategies, low consumption will impose issues on efficient sensor energy management (sleep and wake-up modes, differentiation of stand-still event), ease of replacement will imply the system ability to keep safe operation in a failure of one or several sensors, and finally communication links and protocols should be designed to account for energy savings, information loss, and varying fading characteristics.

Energy-aware and entropy coding for Networked Controlled Linear Systems has been investigated in [12]. Here we address issues on coding design in the context of control of systems equipped with low-energy sensors networks. We particularly focus on issues concerning minimum bit and energy-aware coding. To this aim, we devise a coding strategy with the ability to quantify and to differentiate stand-still signal events from changes in the source (level crossing detector). Coding is effectuated by defining at least 3-valued alphabet for the minimum bit case, and $(2L + 1)$-valued alphabet for a general case with a precision depending on L. Energy saves are studied in two different scenarios; (1) in the word-by-word transmission case, the stand-still signal event is modulated with a low power transmission mechanisms, whereas the changes of levels will be modulated with high-power, (2) in the package-based transmission case, an entropy variable length coding is added to the previous encoding process. Entropy coding assigns some probability distribution to the events, so that the mean transmission energy can be substantially improved for systems where the stand-still events have

[3] Zoom In Zoom Out

higher probability to arise (i.e. stable systems). The paper studies the stability properties needed for this type of coding to operate properly, and quantify the energy saves for each of the considered scenarios.

6.2.3. Stabilization under Communication Networks: A Time-Delay Approach

Participants: A. Seuret [Contact person], J.-P. Richard [LAGIS], E. Fridman [Univ. Tel Aviv], J. Gomès Da Silva Jr. [Univ. Federal do Rio Grande do Sul], K.H. Johansson [KTH].

A first contribution consists in developing novel type of tools able to assess stability of time-delay systems. In [22] and [37], we develop a new type of Lyapunov-Krasovskii functional whose parameters are defined using an arbitrary linear differential equation. In [13], we propose a method to design a memoryless state feedback control law which stabilizes neutral and delayed systems with saturated input. Concerning the stability of NCS under communication delays, we proposed in [10], [76] and [21], to use a time-varying horizon predictor to design a stabilizing control law that sets the poles of the closed loop system. The computation of the horizon of the predictor is investigated and the proposed control law takes into account the average delay dynamics explicitly. The resulting closed loop system robustness with respect to some uncertainties on the delay model is also considered. Tele-operation subject to time-varying delays has been considered in [7]. In [69] and [70], we also proposed an observer-based controller to ensure the stabilization of networked controlled systems. The main interest of such a controller concerns the potential to take into account the additional dynamics induced by the networks cited above. Further developments will take into account the quantification and the coding of the transmitted data packets.

6.2.4. Collaborative behavior of a fleet of AUVs

Participants: A. Seuret, C. Canudas-de-Wit [contact person], L. Briñón-Arranz, B. Moore.

An effort has been devoted to the problem of controlling a set of agents, cooperating under communication constraints. Formation control of multi-agent systems is also considered and we focus on the translation control and uniform distribution of the agents in a moving circle.

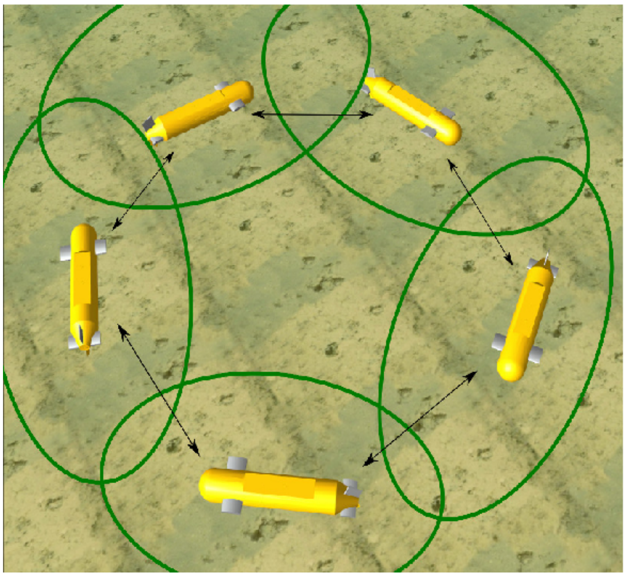

Figure 6. View of a fleet of AUVs with their communication range as displayed by Connectsim

In [25] we propose a control algorithm to stabilize a circular formation of AUVs tracking a circle with a time-varying center and a time varying radius [53]. We also consider the problem of uniform distribution of all the agents along the circle from two approaches: all-to-all and limited communication. We tackle this communication constraint using a cooperative control which includes the Laplacian matrix of the communication graph (fixed or distance-dependent). Based on those preliminary results, we developed a gradient search algorithm The objective for this agent to reach a circular formation whose center is located a the maximum of a potential function.

A version of decentralized formation control for multiple mobile agents was analyzed based on a concept of alignment error and the optimization thereof. This resulted in the development of a type of consensus algorithm for which the total alignment error of the formation is monotonically decreasing [35]. Current research is focused on source seeking behavior for a fleet of AUVs. One part focuses on centralized continuous time outer-loop control for steering a circular formation of AUVs and another on discrete time decentralized control with information delays.

6.2.5. Consensus algorithm under communication delay

Participants: A. Seuret[Contact person], G. Rodrigues de Campos, D.V. Dimarogonas [MIT], K.H. Johansson [KTH].

Another effort has been devoted to the problem of controlling a set of agents cooperating under communication constraints. It is well-known that introducing a delay generally leads to a reduce of the performance or to instability. Thus, investigating the impact of time-delays in the consensus problem is an important issue. In our research, we assume that each agent receives instantaneously its own output information but receives the information from its neighbors after a constant delay τ. The setup we considered leads to study the following equation $\dot{x}(t) = -\mu x(t) + Ax(t-\tau)$, where $\mu > 0$ and A is the classical adjacency matrix. These corresponds to a more realistic setup than the one usually considered in the literature [67]. More especially, in [9], [20], we investigate the influence of the communication on the location of the agreement point and on the convergence rate, which is not straightforward when delays appear in the network. First, we proved that whatever the delay and whatever the graph, the set of agents will reach a consensus. The consensus equilibrium depends on the delay and on the initial conditions taken in an interval given by:

$$x_{eq} = U_2 \left(\lim_{s \to 0} s \frac{x(0) + \mu e^{-\tau s} \int_{-\tau}^{0} x(u) e^{-us} du}{s + \mu(1 - e^{-\tau s})} \right) \vec{1}.$$

where U_2 is a vector depending on the communication graph. Then, based on Lyapunov-Krasovskii techniques and LMI representation, an estimate of the convergence rate is provided. Figure 7 shows the examples of four communications graphs and Figure 8 shows the corresponding convergence rate.

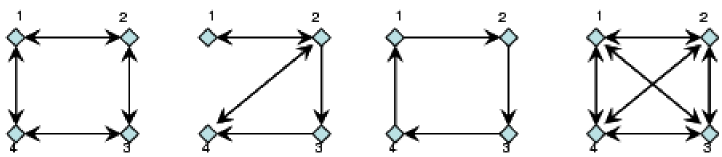

Figure 7. Four agents connected through various communication graphs

It can be seen that the convergence rate strongly depends on the connection. Note that an interesting phenomena concerning the full connected network is pointed out. It is now well known that for some systems, delays could improve the performance and even lead to stability [16]. It thus appears that a set of full connected agents is one of those systems.

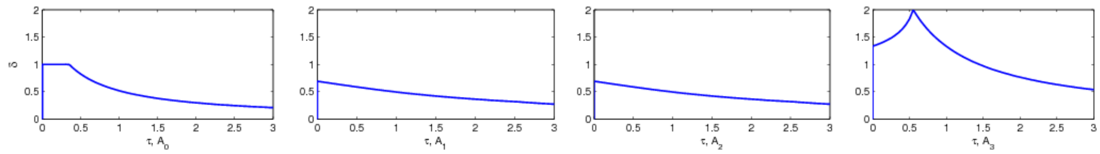

Figure 8. Evolution of the convergence rate δ with respect to the delay τ for various communication graphs

6.2.6. AUVs formation control using relative position information

Participants: M. Alamir [contact person], J. Zikmund.

In this work, a novel observer-based relative positioning method is proposed. It makes it possible to maintain a "solid" and predefined configuration between a leader and a set of followers in a fleet of AUVs. The scheme is based on dynamic observer in which the leader sends its level as well as the module of its own velocity to the followers. Each of the latter dynamically deduces the state of the leader in its own reference frame. This makes it possible for each follower to regulate its own position in a pre-defined formation structure. A particular feature in the proposed solution is that the success of the estimation algorithm does depend on the control being applied. The control and the observation algorithm are intimately linked and need to cooperate towards the success of the overall task.

6.2.7. Adaptive Observer Design under Low Data Rate Transmission with Applications to Oil Well Drill-string

Participants: C. Canudas-de-Wit [Contact person], R. Barreto Jijón, S.-I. Niculescu [LSS].

In oil well drilling operations, one of the important problem to deal with is represented by the necessity of suppressing harmful stick-slip oscillations. A control law named D-OSKIL mechanism uses the weight-on-the-bit force as a control variable to extinguish limit cycles. It uses the value of the bit angular velocity that is found through an unknown parameter observer by means of the measure of the table rotary angular speed.

Since the physics effects occurring downhole have no strong influence at surface due to the attenuation along the drill string, the measurement does not effectively reflect them. This means that the signal to noise ratio is small and it affects the quality of estimation. We are to improve the observer's behavior, using some coarse information of the bit angular velocity coming from the drilling toll equipped with a new embedded sensor. There are mainly two types of sensor technologies : telemetry signals send along the drilling fluid often referred to as mud-pressure pulses, and acoustic waves send along the drillstring. These technological constraints induce the presence of a *transmission delay*. The work in [51] concerns linear-time varying systems with a delayed output feedback. It extends the works done by Q. Zhang, on Adaptive observer for MIMO linear time varying systems, to linear time-varying systems.

6.2.8. Tele-operated system

Participants: C. Canudas de Wit [Contact person], O. Sename, W. Jiang, J. Dumon.

NecsCar is an electrical vehicle (scale 1/3) to be used as an experimental platform to study improvement of new control architectures. The vehicle is designed to be remotely tele-operated from our active steering wheel platform, ant it is equipped of a 3D vision system to provide the operator with stereo vision capabilities. Bilateral teleoperation can be performed using wheel contact torque measurements, feedback for force deflection. Wireless connection will allow us to test coding algorithms, resource sharing, and robustness against transmission delays. The vehicle was redesigned this year to lower the center of gravity. New experiments were conducted this summer and a demo is available at http://necs.inrialpes.fr/pages/setups-software/setups.php.

Figure 9. NeCScar

6.3. Underwater acoustic communications

Participants: A. Kibangou [contact person], C. Siclet, L. Ros, G. Gomez.

Nowadays, a great interest is dedicated to study fleets of AUVs working together to reach a common objective such as a gradient search for source detection; that is the overall goal of the CONNECT project. For this purpose derivation of distributed, multi-vehicle co-ordination schemes and development of efficient underwater acoustic communication protocols are needed. Current underwater acoustic modems are based on very classical single-carrier modulation with a very low bit rate. For achieving high data rate and large system capacity, Orthogonal Frequency Division Multiplexing (OFDM) has been claimed to be an efficient communication technology. It allows designing low complexity receivers to deal with highly dispersive channels. This fact motivates the use of OFDM in underwater environments.

Underwater acoustic channels are wideband in nature due to the small ratio of carrier frequency to the signal bandwidth, which introduces frequency-dependent Doppler shifts [64]. They also exhibit several propagation paths.

In order to adequately recover the transmitted information, algorithms at the receiver must include estimation and compensation of the Doppler scaling factor, channel estimation, and information symbols estimation. Several approaches have been suggested in the literature for estimating the Doppler scaling factor. They are based on the use of preamble and postamble of a packet consisting of multiple OFDM blocks [64] or by exploiting correlation induced by the cyclic prefix [63]. Then, the received signal is resampled by using a sampling period related to the estimated Doppler scaling factor. It is also necessary to estimate and compensate for the residual carrier frequency offset (CFO) since the Doppler can vary between consecutive OFDM blocks inside a given packet.

In our studies, the received data are processed block-by-block. We make use of high resolution harmonic estimation methods to estimate both Doppler scaling factor and channel parameters (path gains and delays) [61]. The advantage of the proposed scheme is to avoid data resampling and residual CFO estimation and compensation. The estimated channel parameters and Doppler are then used to build a channel matrix that is used for estimating the informative symbols following a zero forcing scheme [62].

This work can be easily extended to the multiple access channel technique called OFDMA (Orthogonal Frequency Division Multiplex Access), which can significantly reduce the latency induced by TDMA (Time Division Multiplex Access) based protocols currently used. We also investigate transmitter/receiver using tensor algebra tools. We have indeed recently developed new algorithms [30] and applications on nonlinear system identification [31], [14] based on multilinear algebra.

6.4. Traffic prediction for fluid traffic models

Participants: C. Canudas de Wit [contact person], K. Staňková.

In this work, the linear switched model for traffic state estimation/prediction based on the so-called Lighthill-Whitham-Richards (LWR) traffic flow model was developed. This model uses real traffic data as inputs and the dynamics of the model switching is given by a nondeterministic finite automata. The model performance was validated with respect to the performance of the original LWR traffic flow model as well as with respect to the performance of the microscopic traffic models (with use of the traffic simulator Aimsun 6). Various traffic state estimation/observation methods for the model have been tested. The so-called particle filtering seems to be a very efficient method for the problem, as it combines high observation/prediction accuracy with high computational speed. Fast and accurate traffic state estimation/prediction is important for use of suitable controls, such as dynamic tolls, on which we elaborated in [17], [39].

6.5. Modeling and control of web servers

Participants: N. Marchand [contact person], L. Malrait, S. Bouchenak [SARDES].

This work focuses on the design of a server model, the design of admission control laws that allow the server to satisfy different Service Level Objectives, and the implementation of the latter. This work is in collaboration with SARDES team at INRIA.

The first part of the work consists in designing a continuous time model using a fluid flow approach. Inherent non-linearities of such systems are taken into account. We validate model with different experimental data sets, under different conditions. Results show the relevancy of the model, which is accurate on a wide range of load.

Then it is used for control purposes. We build theoretical admission control laws that ensure a compromise between performance and availability of the system. We implemented them on a real system which is supposed to emulate an e-business environment [33],[34]. Fig. 10 show the behaviour of the closed loop system when a sudden increase of the workload amount occurs. The control law implemented here was designed to prevent the average latency of the requests from exceeding a given L_{max} while maximizing the availability of the system. This work is under patent [50].

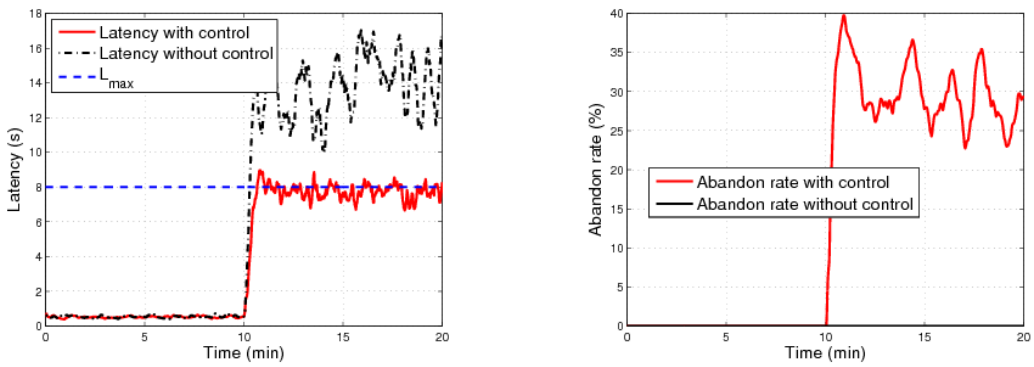

Figure 10. System behavior upon sudden workload amount variation – controlled system vs. non-controlled system a) Performance - Latency – b) Availability - Abandon rate

6.6. Observers design for multi-sensor systems: application to HDI engines

Participants: C. Canudas-de-Wit [contact person], R. Ceccarelli.

Research activity in vehicle industry targets pollutant emission reduction. Homogeneous charge compression engine ignition (HCCI) is an interesting alternative to this problem. New European community laws impose new stringer constraints to pollution, and as a consequence, forces the car industry to realize on board diagnosis system in order to detect engine failures that may result in an increase in the engine pollution. The control of pollutant emission, in diesel engine, is ensured by exhaust gas recirculation system (EGR). Its functioning is very important and a fault detection and isolation system (FDI) is necessary in order to ensure good performances and poor emissions. Exhaust gas could be taken before or after compressor: respectively called high and low pressure EGR.

In this project carried out in collaboration with the IFP (Institut Français du Pétrole), we aim at developing model-based observer allowing to identify several types of engine failures, like: gas leakage in the low and high pressure recirculation circuits, ill functioning of some of the sensors, and actuators (valves).

First year has been dedicated to system modeling with respect to leakage detection and estimation. In a first phase, leakage in intake receiver has been studied by the mean of two different nonlinear adaptive observers. The observers have been tested on a experimental engine testbed. For this first application, no differences come out from the use of this two observers [26].The second part of the work is dedicated to the design of a variable threshold in order to be less conservative and avoid false alarms. For this purpose, we are investigating a study of possible causes (modeling and measures error) whose effect drive leakage estimation away from the correct value [27].

The second year has been devoted to the application of the previously proposed approach to a different part of the Diesel air-path system: the turbocharger. The aim was the detection of the turbine efficiency loss in order to guarantee the correct amount of air needed to the combustion. A complete sensitivity study has been carried on the turbocharger subsystem to generate a variable threshold and determine working points where the detection is insensitive to possible measurement biases. The system has been successfully tested in simulation along the standard european car cycle [54].

6.7. Energy-aware control for systems on-chip

The NECS team is involved in the ARAVIS project (see 7.1 at http://www.minalogic.com/posters/aravis.pdf) : the high level of integration in future chips will lead to heterogeneity in the performance of the various integrated components. It appears that introducing control loops at different levels of these chips will be necessary to be compliant with heterogeneous circuits.

6.7.1. Energy-Aware Control Design for Voltage Scaling Converters

Participants: C. Canudas-de-Wit [contact person], C. Albea-Sanchez.

In low-power electronics, achieving high energy efficiency has great relevance. Global Asynchronous Local Synchronous Systems enables to use a Local Dynamic Voltage Scaling architecture, this technique allows to achieve a high energy efficiency. Moreover, Local Dynamic Voltage Scaling can be implemented using different approaches. One of them is Vdd-Hopping technique.

We have continued our researches in the context of the ARAVIS project. An energy-aware controller has been designed for a Vdd-Hopping system dealing with current peak constraints. It improves considerably the system efficiency (transistor losses during the switching phases) and achieves fast time responses. The stability of this controller has been studied in [23]. Further studies, concerning the control implementation and more specifically the control parameters tuning accounting for the delay associated to the critical gate transmission, have been performed.

This controller named (ENARC: Energy-Aware Control) has been patented [47].

6.7.2. Energy aware computing power control

Participants: N. Marchand [contact person], S. Durand.

Achieving a good tradeoff between computing power and energy consumption is one of the challenges in embedded architectures of the future. This management is especially difficult for 45nm or 32nm known to be at the limit of the scalability, i.e. with a high process variability. Automatic control loops have therefore to be designed in order to make the performance fit the requirement in order to minimize the energy loss in a context of highly unknown performance of the chip. The main objective is to dynamically control the computing power and the consumption using the voltage and the frequency according to the requirements of the OS. In this way, a robust control law was developed [19] in order to minimize the high voltage running time with predictive technique, i.e. to minimize the energy consumption. Results are shown on figure 11 where the robustness is illustrated for 10% and 20% of process variability.

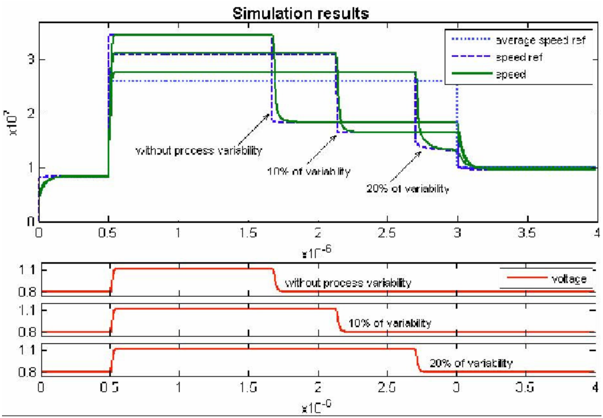

Figure 11. Energy controller simulation results

This control was done for one node (i.e. a processor) but in ARAVIS SoC, the chip is composed of several clusters with several nodes each (see figure 12). Thus, the energy controller has to manage the voltage level (one voltage domain by cluster) and the frequency for all nodes: a maximal frequency is performed for critical node and then a ratio of this frequency could be apply to the other nodes. Thus, a multicore control strategy with low computational needs was proposed [28].

Two patents have been deposed: the first one for the monocore energy control [48] and the second one for the multicore energy control [49].

6.7.3. QoS control

Participants: D. Simon [Contact person], A.-M. Alt.

An application software deployment based on a static and worst case point of view is no longer effective for such heterogeneous chips and more flexible designs must be used. It appears that closed loop control can be integrated at several hardware and software levels of the chips to provide both adaptivity to the operation conditions and robustness w.r.t. variability.

On top of the clusters power control and computing speed control layers, the outer application layer will include a feedback controller for the application quality of service (QoS) under constraints of computing and energy resources availability. This loop uses the scheduling parameters provided by the operating system to control the application's QoS. In the context of ARAVIS the computing speed of each integrated node is a controllable scheduling parameter.

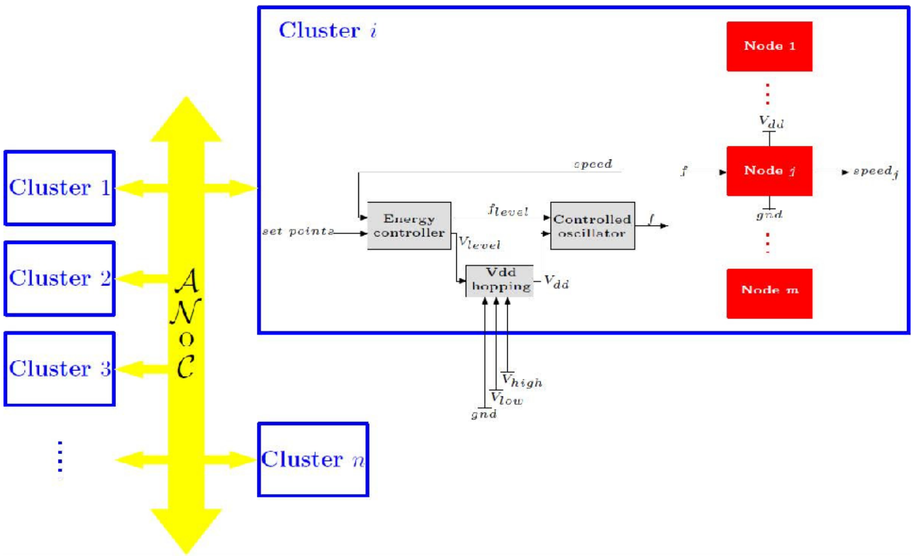

Figure 12. ARAVIS SoC architecture

Current work is focusing on the analysis and control of a H264/SVC video decoder. First the possible sensors and control variable must be defined. The SVC (Scalable Video Coding) extension of the H264 protocol [68] provides several profiles to scale the video decoding quality. Experiments using the JSVM reference software of H264/SVC, running on Linux, has shown that the image resolution and quantization step have both an impact on the computing load and on the decoded image quality measured by the Peak Noise to Signal Ratio (PSNR) between the original and decoded images. Moreover the observed relationships between the used decoding parameters and computing load look like affine functions, so that simple control stategies are expected to provide effective results [45].

As the Aravis chip will use clusters of computing nodes, a parallel version of the decoding algorithm is currently under development using the event-based programming model and associated tools provided by the SARDES team.

6.8. Control and scheduling co-design

Participants: D. Simon [contact person], O. Sename, E. Roche, M. Ben Gaid [IFP].

Control and real-time computing have been associated for a long time, for the control of industrial plants and in embedded or mobile systems, e.g. automotive and robotics [41]. However both parts, control and computing, are often designed with poor interaction and mutual understanding. We propose here an *Integrated control and scheduling co-design* approach, where closing the loop between the control performance and the computing activity is promising for both adaptivity and robustness issues ([46], [40]).

6.8.1. Control with adaptive variable sampling

In the past years we developed a variable sampling control methodology based on the LPV (Linear Parameter Varying) framework and H_∞ control synthesis ([42]), where the sampling interval is used as a known and controlled variable. Few assumptions about sampling are needed for this control design : the main point is that the control interval is known and lies between the predefined bounds $[h_{min}; h_{max}]$, whatever the origin of the control interval variations, its speed and its frequency, e.g. Figure 14a which simulates data dropping due to a (m,k)-firm sensing policy. Within the timing schemes of Figure 13 two cases may be considered :

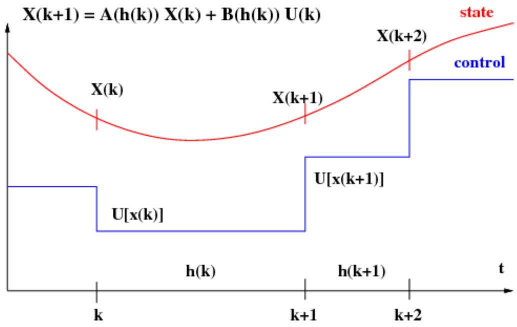

Figure 13. Scheduled varying sampling scheme

- the control interval is a control variable which can be used by a feedback scheduler to manage the CPU load share : in that case the desired control interval is computed by a scheduling controller and sent to the real-time scheduler which manages the control tasks execution ;
- the control interval variations may be due to sensor scheduling, e.g. induced by a communication channel between the sensor and controller nodes : in that case the interval between the successive expected appearance of data at the controller input are delivered by the scheduling policy controller, as it may be the case inside a swarm of underwater vehicles.

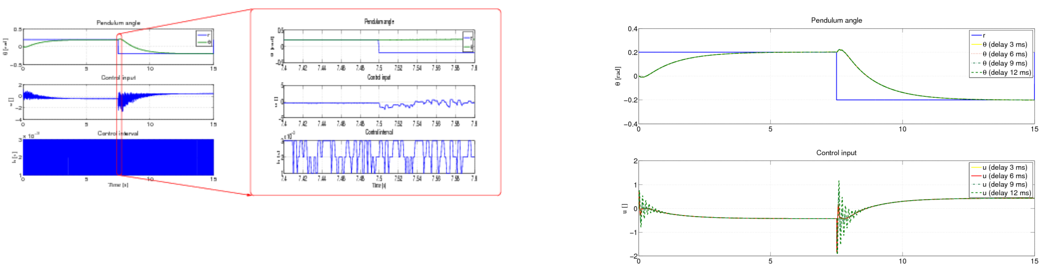

Figure 14. LPV with :a) (1-3)-firm input scheduling – b) unmodeled output delay

The approach has been cleaned in [8]. Beyond the initial goal, where the control interval is assumed to be controlled and known, case studies simulations (e.g. Figure 14b) show that the method has a good robustness w.r.t. to unmodelled delays, such as latencies due to networking, computing and preemption activities. Further work plans to specifically analyse, understand and exploit this robustness.

6.8.2. Robust control of underwater vehicles

In the framework of the Connect and FeedNetBack projects, the $\mathcal{H}_\infty$/LPV approach has been applied to an AUV ([36]). The 3D coordinated control of an autonomous underwater vehicle is not straightforward : indeed the model of the vehicle has important non-linearities and several poorly known parameters which lead up to robust control. Moreover the limited capabilities of underwater acoustic links and limited embedded computing power and on-board energy induced serious timing disturbances and scheduling constraints. These problems make AUVs good testbeds for control/computing co-design.

In this preliminary work, the H_∞ approach is chosen for the control of the whole vehicle. The method requires the linearization of the vehicle model, but has the advantage to guarantee good robustness margins with respect to the nominal plant. The control of the vehicle is separated according the 3 axes of the referential (Ox, Oy and Oz). So the control of the whole vehicle involves the synthesis of 3 different controllers.

The first controller is computed for the control of the longitudinal speed of the vehicle by the propeller. The second one addresses the control of the altitude z. A constraint on the pitch angle is added to enforce the vehicle to climb up the slope parallel to the roof (this constraint allows a more effective control by limiting the drag effort). The third controller concerns the yaw angle. Some problems due to the use of fins by two controllers have been solved by choosing different weights for shared fins (small) than for devoted ones (high). (For example, the considered AUV has tree fins at the tail of the vehicle, one horizontal and the two others inclined by angle plus or minus 120 degree. The horizontal fin is only used by the yaw angle controller, whereas the others fins are also used by the altitude controller).

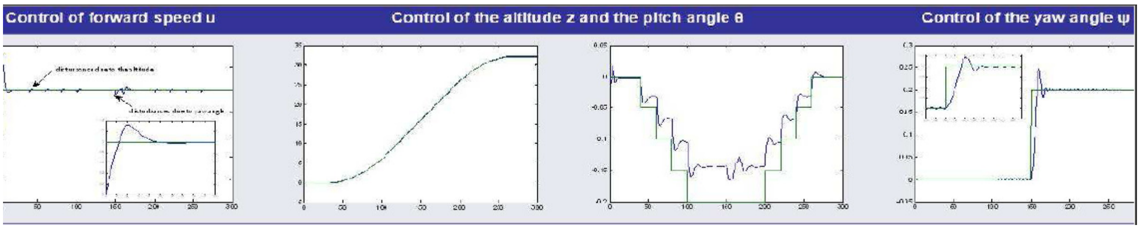

Figure 15. AUV robust control in bottom following mode

The discretization of the controllers has been done using classical tool, with constant sampling period. As the measure of the distance with respect to sea bottom is not know at constant period (due to different altitude or loose of data), this controller can be seen as a periodic controller with variable sampling time.

These first results foster ongoing research to better understand how the LPV approach can be used to efficiently and robustly control such autonomous vehicle, subject to timing uncertainties. In particular it is intended to combine several uncertain parameters, including computing and communication resources related disturbances like computing and networking induces delays.

6.8.3. Hardware-in-the-loop simulation of a quadrotor drone

In the framework of the SafeNECS project (see 8.1.1), a hardware-in-the-loop experiments using ORCCAD has been set up to provide a safe environment for both algorithms and software validation, prior to experiment with the real (expensive and fragile) quadrotor.

Figure 16 describes the control and diagnostic setup used for testing purpose [24]. In this block-diagram the blue boxes represent the user-provided modules (i.e. functions) interconnected by their input/output ports (respectively blue/red). From the real-time point of view, each module is implemented by a real-time task possessing its own programmable timer. Therefore all the modules can be run asynchronously at their own (possibly varying) sampling frequency. In this diagram one of the modules implements a feedback scheduler: it monitors the controller's real-time activity and may react by setting on-the-fly the tasks and messages scheduling parameters, e.g. their firing intervals or priority. For example it may be used to implement a (m,k)-firm dropping policy ([59]) or hybrid priority schemes over the CAN bus [43], [44].

To set up a "hardware-in-the-loop" real-time simulator, the multitasks controller running on the embedded target is connected via a Can (or Ethernet) link running a numerical integrator, calling a model of the drone, of its sensors and of its actuators. This setup allows for ultimate tuning of the control algorithms before launching the real and fragile system. Daemons are also added to simulate various kind of failures and evaluate

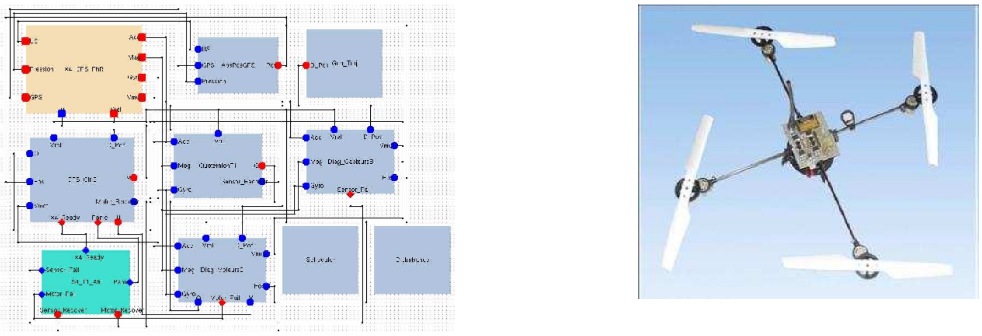

Figure 16. Control and diagnosis block-diagram

fault detection filters and fault tolerant control recovery efficiency. Finally the Orccad controller has been succesfully integrated in the real drone, and the preliminary experiments are coherent with those from the real-time simulator.

7. Contracts and Grants with Industry

7.1. Pôle de compétitivité Minalogic/ARAVIS

ARAVIS (Architecture reconfigurable et asynchrone intégrée sur puce) is a project sponsored by the Minalogic Pole, started for 3 years in October 2007 (http://www.minalogic.com/posters/aravis.pdf). The project has been extended to december 2011. It will investigate innovative solutions needed by the integration of 22 nano-meter scale future chips. It is headed by STMicroelectronics, the other partners are CEA-Leti, TIMA laboratory and the SARDES and NECS teams at INRIA.

7.2. IFP

Accompanying contract with IFP (Institut Français du Pétrole), in the framework of the CIFRE PhD grant of Riccardo Ceccarelli (2007-2010). The goal sought with the Control Engine Dept. of IFP is the development of a model-based observer allowing to identify several types of engine failures. First year has been dedicated to system modeling with respect to leakage detection and estimation. In a first phase, leakage in intake receiver has been studied by the mean of two types of nonlinear adaptive observers. The observers have been tested on a AMEsim - Simulink co-simulation environment. For this first application, no differences come out from the use of this two observers. The second part of the work (current task) is dedicated to the design of a variable threshold in order to be less conservative and avoid false alarms. For this purpose we are investigating the possible causes (modeling and measurement error) whose effects drive leakage estimation away from the correct value.

7.3. Patents

- "Dispositif de commande d'alimentation d'un calculateur". S. Durand and N. Marchand. Co-propriété (INRIA et CNRS). No. 09/004686, October 1st, 2009.
- "Dispositif de commande d'alimentation d'un calculateur". S. Durand and N. Marchand. Co-propriété (INRIA et CNRS). No. 09/01576, March 31th, 2009.

- "Dispositif de commande d'admission pour un serveur". L. Malrait, N. Marchand, and S. Bouchenak. Copropriété (CNRS et Grenoble INP, UJF). Patent 09/02551, May 27th, 2009.
- "Dispositive de Commande numérique pour un tableau de transistors PMOS en parrallèle". C. Canudas De Wit and C. Albea-Sanchez. Co-propriété (INRIA et CNRS). No. 08/007342.

7.4. Technology transfer towards start-up creation Karrus and GTL

The NeCS team is continuing its activity in road traffic modeling and control. The expected scientific contribution of NeCS in this field concerns the development of new estimation prediction and identification algorithms based on the measurements collected through sensor networks installed on freeways. The team study also the problems of time-to destination and control algorithms for ramp metering. The team is currently setting up a consortium with local authorities involved in traffic management to build to demonstrator called GTL for Grenoble Traffic Lab. One target of this activity is to transfer part of the developed technology to a start-up currently incubated at GRAIN (Grenoble incubator for high tech start-ups) named Karrus and leaded by Denis Jacquet.

8. Other Grants and Activities

8.1. National actions

8.1.1. ARA-SSIA Safe_NECS

SAFE_NECS is an « Action de Recherche Amont - Sécurité, Systèmes embarqués et Intelligence Ambiante » funded by the ANR and started in December 2005 http://safe-necs.cran.uhp-nancy.fr/. The research topic is fault tolerant control of distributed process and the project focuses on both diagnosis and robust control under execution resources constraints. It gathers teams from CRAN and LORIA (Nancy), LAAS (Toulouse), and GIPSA-LAB and NECS (Grenoble). The project finished in September 2009 with the edition of a book to appear in 2010 [1].

8.1.2. ANR PsiRob CONNECT

The CONNECT proposal (**CON**trol of **NE**tworked **C**ooperative sys**T**ems) deals with the problem of controlling multi-agent systems, i.e. systems composed of several sub-systems interconnected between them by an *heterogeneous* communication network. The control of a cluster of agents composed of autonomous underwater vehicles, marine surface vessels, and possibly aerial drones will be used as a support example all along the proposal. The partners are the NECS team, Ifremer robotics lab. and the ROBOSOFT and Prolexia companies. It started for 3 years in May 2007 (http://www.lag.ensieg.inpg.fr/connect/).

8.1.3. ANR VOLHAND

C. Canudas de Wit, in collaboration with Violaine Cahouët (from the biomechanical team of GIPSA-Lab). A new project named VOLHAND fund by the ANR has been started in Oct 2009. The project aims at developing a new generation of Electrical power-assisted steering specifically designed for disabled and aged people. Our contribution is to work out new assisted laws that accomodate to the specific mechanical characteristics of this particular driver population. The consortium is composed by: LAMIH, CHRU, Fondation Hopale, GIPSA-Lab, INRETS and JTEKT. This project is in collaboration with the biomechanical team of GIPSA-Lab.

8.1.4. Collaborations inside Inria

The development of Orccad raises collaborations between NECS, SARDES and SED. Support about its use is provided to the TRIO team at Nancy in the framework of the SafeNecs project.

8.1.5. Cooperations with other laboratories

Long term collaboration does exist with the University of Sevilla along several different topics including: coding and control co-design, Power control in NCS, energy-aware control in SoC, and control of CD and AC converters. Scientific collaborations inside the IST FeedNetBack project have been initialized with ETH Zurich and University of Sevilla about the integration of control and scheduling on distributed architectures, in particular focusing on the robustness and predictive control point of views. The ANR SafeNecs project provided support and collaboration along the three past years with teams from both the computing side (LORIA Trio team about control and (m,k)-firm scheduling) and from the fault tolerant control side (CRAN Nancy and Gipsa-lab, about the integration of real-time control, diagnosis and flexible scheduling).

- Carlos Canudas-de-Wit has collaborations with University of Sevilla (F. Gomez-Estern, F. R. Rubio, F. Gordillo, J. Aracil), University of New Mexico (C.T. Abdallah), and Lund Control system department (K.J. Astrom)
- A. Seuret has collaborations with LAGIS (J.-P. Richard), Leicester University (C. Edwards), University of Kent (S.K. Spurgeon), Tel Aviv University (E. Fridman), UFRGS (J.M. Gomes da Silva Jr.), with KTH (K.H. Johansson), MIT (D.V. Dimarogonas)
- C. Siclet has collaborations with L. Ros, C. Baras and J-M. Brossier at Gipsa-lab, and with P. Siohan at Orange Lab in Rennes.
- A. Kibangou has collaborations with I3S (G. Favier), Universidade Federal do Ceara (A.L.F. de Almeida), and ENIG (K. Abderrahim).
- Strong collaborations have been established with KTK (Stockolm), ETH (Zurich), University of Sevilla and Padova as core partners of the FeedNetBack European project.

8.2. European actions

8.2.1. FeedNetBack

The FEEDNETBACK proposal has been accepted as a STREP project at the FP7-ICT-2007-2 call in October 2007. It is coordinated by Carlos Canudas-de-Wit and gathers researchers from academia (INRIA-NeCS, ETH Zurich, Universidad de Sevilla, KTH Stockholm, Universita di Padova) and from industry (Ifremer, Vodera, Vitamib, Intellio and OMG).

The main objective of the FeedNetBack project is to generate a rigorous co-design framework that integrates architectural constraints and performance trade-offs from control, communication, computation, complexity and energy management. The goal is to master complexity, temporal and spatial uncertainties such as delays and bandwidth in communications and node availability. This approach will enable the development of more efficient, robust and affordable networked control systems that scale and adapt with changing application demands. The project will extend the current scientific state-of-the-art in networked control and develop a set of software tools to support the co-design framework. To demonstrate the potential and limitations of the new technology, FeedNetBack will apply it on two industrial test cases of realistic complexity and scale: underwater inspection systems based on fleets of Autonomous Underwater Vehicles (AUVs), and surveillance systems using a network of smart cameras. The control component is essential in both test cases as they require cooperation of distributed objects to achieve a common goal (http://feednetback.eu/). Specific issues that will be addressed in the project include:

- Heterogeneity: The sensor hardware and the communication means may be of different natures (different noises, bandwidths, resolution characteristics, etc.).
- Mobility: Sensor location may not be fixed. Dynamic location of sensors will lead to varying topologies.
- Resource management: The energy and computation capabilities of each node are generally limited.
- Scalability: Wireless sensor networks may comprise hundreds or thousands of nodes. It is therefore crucial that the complexity of the design procedures and the resulting controllers scale slowly with the number of nodes.
- Asynchrony: Information exchange between sensor/control units may not be synchronous in time.

Since in NCS the goal is to ensure satisfactory performance of the overall closed loop system, these problems are treated holistically through sets of performance constraints.

The co-design framework aims at controlling more complex systems with a fraction of the effort, while increasing availability and reliability. The framework will enable application developers, programmers and systems integrators to fully use the potential of networked control in a wide set of industrial domains. Examples of areas where an impact is expected are the fields of factory automation, public infrastructure safety and security, transport and building maintenance.

FeedNetBack will go beyond developing new technologies, but will also apply these technologies to areas of society where they protect the environment and improve people's safety, security and ultimately quality of life.

9. Dissemination

9.1. Scientific community

- Carlos Canudas-de-Wit was the program chair of the IEEE Conference on Control Applications 2009, in Saint-Petersburg Russia. He participated to several concertation meetings in the CORDIS reseach program at the ITC-department in the EU. He also participated in the "International Workshop on the Impact of Control: Past, Present, and Future" at Berchtesgaden, Germany in Oct. 2009.(http://workshop-impact-control-2009.lsr.ei.tum.de/). The Workshop is being sponsored by the Institute for Advanced Study (IAS) at the Technische Universität München, the IEEE Control Systems Society, and our FeedNetBAck EU project. This report will be available on the CSS and IAS Websites and we expect to publish a version in IEEE Control Systems Magazine. He was participated as evaluator (Dec. 2009) in the FP7 program "Factories of the Future": FP7-2010-NMP-ICT-FoF, and as reviewer of EU projects in the FP6 program on Embedded Systems and Control (June 2009).

  He was member of program committees at the IFAC Workshop NeCSYS 2009 in Venice. He is a member of the COST (Inria). He was Guest editor of the two-part special issue of the International journal of Robust & Nonlinear Control on "Control with Limited Information". Issue Edited by Ivan Lopez Hurtado, C. T. Abdallah, and C. Canudas-de-Wit (Volume 19 Issue 16 - 10 November 2009 (1767-1870) Special Issue : Control under limited information: Special issue (Part I) and Volume 19 Issue 18 - December 2009 (1973-2080) Special Issue : Control under limited information: Special issue (part II)). He has been reviewer and examiner for the PhD thesis of Rémy Nouailletas (Grenoble INP-Essisar)
- M. Alamir is a member of the "Nonlinear Systems" IFAC technical committee and served as co-animator of the "Nonlinear Predictive Control" group of GDR-MACS during the period 2002-2007. He is Associated Editor for the IFAC World Congress (South Korea, 2008), the international symposium on Dynamics and control of process systems (Leuven, 2010) and editor of a Special issue of International Journal on Robust and Nonlinear Control. He serves as member of the selection committee of the ANR-ARPEGE call for proposals.
- N. Marchand is co-animator of the "Nonlinear Predictive Control" group of GDR-MACS. He is member of the scientific committee of the IEEE ASME Advanced Intelligent Mechatronics (AIM).
- D. Simon is member of the RTNS'09 (international conference on Real Time and Network Systems) program committee and of the NecSys'10 (Estimation and Control of Networked Systems) IFAC workshop. He was reviewer for the PhD thesis of Ning Jia, Loria, Nancy, in January 2009 and examiner for the PhD defense of Cédric Berbra, Gipsa-lab, Grenoble, in November 2009. Reviewer for the IEEE Trans. in Industrial Informatics, IEEE Trans. on on Industrial Electronics, European Journal of Control, and Control Engineering Practice journals. Member of the local working group about software evaluation (Grolon).

- O. Sename is member of the IFAC Technical committees 'Linear systems'and 'Automotive control'. He is Associated Editor of the European Control Conference 2009. He was reviewer of the PhD Thesis of Wilfried Gilbert (Toulouse), Matteo Corno (Politecnico di Milano), and of the HDR of Nicolas Langlois (Univ. Rouen). He is responsible of the Master and PhD programs in Automatic Control.
- A. Seuret is co-animator of the "Time-delay System" group (GDR SAR) since March 2008. He, with Karl H. Johansson from KTH (Sweden), organized an invited session in the 8th IFAC Workshop on Time-Delay Systems (TDS'09) about networked control systems with delays. He is leader of a Workpackage of the European Project FeedNetBack. He is member of the International Program Committee of the IEEE Conference on Control and Application (CCA'09) and of the IFAC Workshop on Time-delay Systems (TDS'10). He is also reviewer for the major Journals and Conferences of the field. Among them, there are journals (IEEE Trans. on Automatic Control, Automatica, System Control and Letter, International Journal of Systems Science), conferences (Conference on Decision and Control (CDC), American Control Conference (ACC), IFAC Workshops on Robust Control (ROCOND) and on Time Delay Systems (TDS)).
- A. Kibangou was a member of the Technical Program Committee of the European Signal Processing Conference (EUSIPCO) 2009. He serves as a reviewer for the following international journals: IET Signal Processing, Signal Image and Video Processing, Electronics Letters, Int. J. Modelling, Identification and Control. He also served as reviewer for IFAC symposium on System Identification (SYSID 2009) and as committee member of the EECI PhD Award on Networked and Embedded Control.

9.2. Teaching

9.2.1. Courses

- Olivier Sename and Cyrille Siclet teach several courses in control and signal processing inside Grenoble INP schools and IUT 1 Grenoble, UJF; O. Sename teaches Robust Control (20h) in the M2R Automatique Master at Grenoble INP; Olivier Sename is responsible of the 2-years engineering program in Automatic Control, Systems and Information Technology.
- Nicolas Marchand : *Nonlinear control systems*, Master PSPI, Université Joseph Fourier. *Control of Embedded systems*, Filiere SLE, ENSIMAG, Grenoble-INP.
- Alain Kibangou teaches Mathematics and Automatic control at IUT 1 Grenoble, UJF.

9.2.2. Advising

Post-docs:

- Wenjuan Jiang (Institut Carnot, from October 2009), co-advised by C. Canudas de Wit and O. Sename.
- Katerina Stankova (INRIA, from February 2009), advised by C. Canudas de Wit.
- Alain Kibangou (CONNECT project, from February to August 2009), co-advised by C. Siclet and L. Ros.
- Brandon Moore (CONNECT project - until August 2009), PostDoc advised by C. Canudas de Wit
- Jiri Zikmund (CONNECT project - until October 2009), co-advised by M. Alamir and D. Simon.

PhDs:

- Nicolas Cardoso de Castro, advised by C. Canudas de Wit, INRIA, FeedNetBack project-2009/2012,
- Gabriel Rodrigues de Campos, co-advised by A. Seuret and C. Canudas de Wit,Grenoble INP, 2009/2012,

- Lara Briñón-Arranz co-advised by C. Canudas de Wit and A. Seuret, INRIA, FeedNetBack project - 2008/2011,
- Émilie Roche, co-advised by O. Sename and D. Simon, INRIA, FeedNetBack project - 2008/2011,
- Carolina Albea-Sanchez, co-advised by C. Canudas and F. Gordillo (Univ. Sevilla), 2007/2010
- Riccardo Ceccarelli, co-advised by C. Canudas and A Sciaretta (IFP), 2007/2010
- Sylvain Durand, co-advised by N. Marchand and D. Simon, Grenoble INP, 2007/2010.
- Luc Malrait, co-advised by N. Marchand and S. Bouchenak (SARDES), Grenoble INP, 2007/2010.
- Jonathan Jaglin, co-advised by C. Canudas and C. Siclet, Grenoble INP, 2006/2009

Masters:

- Rafael Barreto Jijòn, advised by C. Canudas de Wit, M2R EEATS, Grenoble-INP
- Gorka Gomez Garnika (University of Pamplona), co-advised by C. Siclet and L. Ros.

10. Bibliography

Major publications by the team in recent years

[1] C. AUBRUN, D. SIMON, Y.-Q. SONG (editors). *Co-design approaches for dependable networked control systems*, ISTE-Wiley, 2010, to appear.

[2] C. ALBEA-SANCHEZ, C. CANUDAS-DE-WIT, F. GORDILLO ALVAREZ. *Advanced Control Design for Voltage Scaling Converters*, in "in Proc. IEEE Industrial Electronics (IECON), Orlando (USA)", november 2008 ES .

[3] C. CANUDAS-DE-WIT, F. RUBIO, J. FORNES, F. GOMEZ-ESTERN. *Differential coding in networked controlled linear systems*, in "American Control Conference", 14-16 June 2006, DOI 10.1109/ACC.2006.1657374 ES ES .

[4] F. GOMEZ-ESTERN, C. CANUDAS-DE-WIT, F. RUBIO, J. FORNES. *Adaptive Delta-modulation coding in networked controlled systems*, in "American Control Conference, New York, USA USA", June 2007 ES .

[5] N. MARCHAND, H. HABLY, A. CHEMORI. *Global stabilization with low computational cost of the discrete time chain of integrators by means of bounded controls*, in "IEEE Transactions on Automatic Control", vol. 52, n^o 5, 2007, p. 948-952.

[6] N. MARCHAND. *Stabilization of Lebesgues sampled systems with bounded controls: the chain of integrators case*, in "IFAC World Congress", 2008.

[7] Y.-J. PAN, C. CANUDAS-DE-WIT, O. SENAME. *A new predictive approach for bilateral teleoperation with applications to drive-by-wire systems*, in "IEEE Transaction on Robotics", vol. Vol. 22, n^o No. 6, December 2006, p. 1146-1162.

[8] D. ROBERT, O. SENAME, D. SIMON. *An H_∞ LPV design for sampling varying controllers : experimentation with a T inverted pendulum*, in "IEEE Transactions on Control Systems Technology", 2009, http://ieeexplore.ieee.org/search/wrapper.jsp?arnumber=5208376, DOI 10.1109/TCST.2009.2026179.

[9] A. SEURET, D. V. DIMAROGONAS, K. H. JOHANSSON. *Consensus under communication delays*, in "Proceedings of the 47th IEEE Conference on Decision and Control, CDC 2008, Cancun Mexique", December 2008, http://hal.archives-ouvertes.fr/hal-00386104/en/USSE.

[10] E. WITRANT, C. CANUDAS-DE-WIT, D. GEORGES, M. ALAMIR. *Remote Stabilization via Communication Networks with a Distributed Control Law*, in "IEEE Transactions on Automatic Control", vol. 52, No.8, august 2007, p. 1480-1486, http://hal.archives-ouvertes.fr/hal-00201790/en/.

Year Publications

Articles in International Peer-Reviewed Journal

[11] C. CANUDAS-DE-WIT, F. GOMEZ-ESTERN, F. RUBIO. *Delta-Modulation Coding Redesign for Feedback-Controlled Systems*, in "IEEE Transactions on Industrial Electronics", vol. 56, n^{o} 7, 2009, p. 1-20, http://hal.archives-ouvertes.fr/hal-00394981/en/ES.

[12] C. CANUDAS-DE-WIT, J. JAGLIN. *Energy-aware and entropy coding for Networked Controlled Linear Systems*, in "International Journal of Robust and Nonlinear Control", vol. 19, n^{o} 16, 2009, p. 1851–1870, http://hal.archives-ouvertes.fr/hal-00344234/en/.

[13] J. M. GOMES DA SILVA, A. SEURET, E. FRIDMAN, J.-P. RICHARD. *Stabilization of Neutral Systems with Saturating Control Inputs*, in "International Journal of Systems Science", 2010, http://hal.archives-ouvertes.fr/hal-00421351/en/, To appearBRILGB.

[14] A. KIBANGOU, G. FAVIER. *Tensor analysis for model structure determination and parameter estimation of block-oriented nonlinear systems.*, in "IEEE Journal of Selected Topics in Signal Processing", June 2010, http://hal.archives-ouvertes.fr/hal-00417815/en/.

[15] D. ROBERT, O. SENAME, D. SIMON. *An H_∞ LPV design for sampling varying controllers : experimentation with a T inverted pendulum*, in "IEEE Transactions on Control Systems Technology", 2009, http://ieeexplore.ieee.org/search/wrapper.jsp?arnumber=5208376, DOI 10.1109/TCST.2009.2026179.

[16] A. SEURET, C. EDWARDS, S. SPURGEON, E. FRIDMAN. *Static output feedback sliding mode control design via an artificial stabilizing delay*, in "IEEE Transactions on Automatic Control", vol. 54, n^{o} 2, 2009, p. 256 - 265, http://hal.archives-ouvertes.fr/hal-00385893/en/GBIL.

[17] K. STANKOVA, G. J. OLSDER, M. BLIEMER. *Comparison of Different Toll Policies in the Dynamic Second-best Optimal Toll Design Problem: Case study on a Three-link network*, in "European Journal of Transport and Infrastructure Research", vol. 9, n^{o} 4, 2009, p. 331-346 NL .

Invited Conferences

[18] S. DURAND, N. MARCHAND. *An Event-Based PID Controller With Low Computational Cost*, in "8th International Conference on Sampling Theory and Applications, France Marseille", 2009, http://hal.archives-ouvertes.fr/hal-00393031/en/.

[19] S. DURAND, N. MARCHAND. *Fast Predictive Control of Micro Controller's Energy-Performance Tradeoff*, in "3rd IEEE Multi-conference on Systems and Control, 18th IEEE International Conference on Control Applications, Russie Saint Petersburg", 2009, http://hal.archives-ouvertes.fr/hal-00391988/en/.

[20] A. SEURET, D. V. DIMAROGONAS, K. H. JOHANSSON. *Consensus of double integrator multi-agents under communication delay*, in "8th IFAC Workshop on Time Delay Systems, Roumanie Sinaia", 2009, http://hal.archives-ouvertes.fr/hal-00391651/en/SEUS.

[21] A. SEURET, K. H. JOHANSSON. *Networked control under time-synchronization errors*, in "8th IFAC Workshop on Time Delay systems, Roumanie Sinaia", 2009, http://hal.archives-ouvertes.fr/hal-00391611/en/SE.

[22] A. SEURET. *Lyapunov-Krasovskii Functionals Parameterized with Polynomials*, in "ROCOND'09, Israël Haifa", 2009, http://hal.archives-ouvertes.fr/hal-00386275/en/.

International Peer-Reviewed Conference/Proceedings

[23] C. ALBEA-SANCHEZ, C. CANUDAS-DE-WIT, F. GORDILLO ALVAREZ. *Control and Stability Analysis for the Vdd-hopping Mechanism*, in "IEEE MSC, Conference on Control and Applications, Russie Saint-Petersburg", 2009, http://hal.archives-ouvertes.fr/hal-00399972/en/ES.

[24] C. BERBRA, D. SIMON, S. GENTIL, S. LESECQ. *Hardware in the loop networked diagnosis of a quadrotor drone*, in "7th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes SafeProcess'09", july 2009.

[25] L. BRIÑÓN-ARRANZ, A. SEURET, C. CANUDAS-DE-WIT. *Translation Control of a Fleet Circular Formation of AUVs under Finite Communication Range*, in "48th IEEE Conference on Decision and Control, CDC 2009, Chine Shanghai", 2009, http://hal.archives-ouvertes.fr/hal-00403253/en/.

[26] R. CECCARELLI, C. CANUDAS-DE-WIT, P. MOULIN, A. SCIARRETTA. *Model-based Adaptive Observers for Intake Leakage Detection in Diesel Engins*, in "American Control Conference, IEEE ACC'09, Saint Louis, Missouri, USA", 2009, http://hal.archives-ouvertes.fr/hal-00394982/en/.

[27] R. CECCARELLI, P. MOULIN, C. CANUDAS-DE-WIT. *Robust Strategy for Intake Leakage Detection in Diesel Engines*, in "Proc. of IEEE Application Control Conference, MSC, Russie Saint Petersbourg", 2009, http://hal.archives-ouvertes.fr/hal-00394983/en/.

[28] S. DURAND, N. MARCHAND. *Dynamic Voltage and Frequency Scaling of Multicore System with Energy-Performance Tradeoff*, in "48th IEEE Conference on Decision and Control, CDC 2009, Chine Shanghai", 2009, http://hal.archives-ouvertes.fr/hal-00404053/en/.

[29] S. DURAND, N. MARCHAND. *Further Results on Event-Based PID Controller*, in "European Control Conference, ECC'09, Hongrie Budapest", 2009, http://hal.archives-ouvertes.fr/hal-00368535/en/.

[30] A. KIBANGOU, G. FAVIER. *Non-iterative solution for PARAFAC with a Toeplitz matrix factor*, in "17th European Signal Processing Conference, EUSIPCO-2009, Royaume-Uni Glasgow", 2009, 5, http://hal.archives-ouvertes.fr/hal-00397808/en/.

[31] A. KIBANGOU, G. FAVIER. *Tensor-based Identification of the Structure of Block-Oriented Nonlinear Systems*, in "15th IFAC Symposium on System Identification, SYSID 2009, France Saint-Malo", 2009, 6, http://hal.archives-ouvertes.fr/hal-00397802/en/.

[32] M. LOPEZ-MARTINEZ, C. CANUDAS-DE-WIT, F. RUBIO. *Stability of Asynchronous Feedback-Interconnected Dissipative Systems*, in "Europeen Control Conference, Hongrie budapest", 2009, http://hal.archives-ouvertes.fr/hal-00438818/en/ES.

[33] L. MALRAIT, S. BOUCHENAK, N. MARCHAND. *Fluid Modeling and Control for Server System Performance and Availability*, in "39th annual IEEE/IFIP International Conference on Dependable Systems and Networks, Portugal Estoril", 2009, http://hal.inria.fr/inria-00367666/en/.

[34] L. MALRAIT, N. MARCHAND, S. BOUCHENAK. *Average Delay Guarantee in Server Systems Using Admission Control*, in "8th Workshop on time delay systems, Roumanie Sinaia", 2009, -, http://hal.archives-ouvertes.fr/hal-00404404/en/.

[35] B. MOORE, C. CANUDAS-DE-WIT. *Formation Control via Distributed Optimization of Alignment Error*, in "48th IEEE Conference on Decision and Control, CDC 2009, Chine Shanghai", 2009, unknown, http://hal.archives-ouvertes.fr/hal-00404480/en/.

[36] E. ROCHE, O. SENAME, D. SIMON. *LPV/$\mathcal{H}_\infty$ control of an Autonomous Underwater Vehicle (AUV)*, in "European Control Conference ECC'09, Budapest, Hungary", august 2009.

[37] A. SEURET, K. H. JOHANSSON. *Stabilization of time-delay systems through linear differential equations using a descriptor representation*, in "European Control Conference, ECC'09, Hungary Budapest", 2009, http://hal.inria.fr/inria-00391311/en/SE.

[38] A. SEURET. *Stability analysis for sampled-data systems with a time-varying period*, in "48th IEEE Conference on Decision and Control, CDC 2009, China Shanghai", 2009, 6, http://hal.archives-ouvertes.fr/hal-00403252/en/.

[39] K. STANKOVA. *On Dynamic Optimal Toll Design Problem with Traffic-flow Dependent Tolls and Drivers' Joint Route and Departure Time Choices*, in "3rd IEEE Multi-conference on Systems and Control, 18th IEEE International Conference on Control Applications, St. Petersburg, Russia", 2009, p. 1–6, CD.

Scientific Books (or Scientific Book chapters)

[40] C. AUBRUN, D. SIMON, Y.-Q. SONG. *chap. 1 : Preliminary notions and state of the art*, in "Co-design approaches for dependable networked control systems", ISTE-Wiley, 2010, to appear.

[41] C. AUBRUN, D. SIMON, Y.-Q. SONG. *chap. 0 : Introduction and Problem Statement*, in "Co-design approaches for dependable networked control systems", ISTE-Wiley, 2010, to appear.

[42] M. BEN GAID, D. ROBERT, O. SENAME, A. SEURET, D. SIMON. *chap. 2 : Computing aware control*, in "Co-design approaches for dependable networked control systems", ISTE-Wiley, 2010, to appear.

[43] M. BEN GAID, D. ROBERT, O. SENAME, D. SIMON. *chap. 4 : Plant state based feedback scheduling*, in "Co-design approaches for dependable networked control systems", ISTE-Wiley, 2010, to appear.

[44] C. BERBRA, S. GENTIL, S. LESECQ, D. SIMON. *chap. 7 : Implementation: Control and Diagnosis for an Unmanned Aerial Vehicle*, in "Co-design approaches for dependable networked control systems", ISTE-Wiley, 2010, to appear.

Research Reports

[45] ANNE-MARIE. ALT. *Rapport d´avancement : Codesign commande/ordonnancement/énergie*, Projet Aravis, october 2009, Technical report.

[46] D. SIMON, A. SEURET, P. HOKAYEM, J. LYGEROS, E. CAMACHO. *State of the art in control/computing co-design*, n° deliverable D04-01, FeedNetBack IST project, march 2009, Technical report.

Patents and standards

[47] C. CANUDAS-DE-WIT, C. ALBEA-SANCHEZ. *Dispositive de Commande numérique pour un tableau de transistors PMOS en parrallèle*, n° 08/007342, 2009, http://hal.archives-ouvertes.fr/hal-00394986/en/, Patent.

[48] S. DURAND, N. MARCHAND. *Dispositif de commande d'alimentation d'un calculateur*, n° 09/001576, 2009, http://hal.archives-ouvertes.fr/hal-00404397/en/, Patent.

[49] S. DURAND, N. MARCHAND. *Dispositif de commande d'alimentation d'un calculateur*, n° 09/004686, 2009, http://hal.archives-ouvertes.fr/hal-00439352/en/, Patent.

[50] L. MALRAIT, N. MARCHAND, S. BOUCHENAK. *Dispositif de commande d'admission pour un serveur*, n° 09/002551, 2009, http://hal.archives-ouvertes.fr/hal-00404402/en/, Patent.

References in notes

[51] R. BARRETO-JIJON, C. CANUDAS-DE-WIT, S. NICULESCU. *Adaptive Observer Design under Low Data Rate Transmission with Applications to Oil Well Drill-string*, in "Proceeding of the IEEE American Control Conference 2010", 2010, submitted.

[52] J.-J. BORRELLY, E. COSTE MANIÈRE, B. ESPIAU, K. KAPELLOS, R. PISSARD-GIBOLLET, D. SIMON, N. TURRO. *The Orccad Architecture*, in "International Journal on Robotic Research", vol. 17, n° 4, 1998, p. 338–359.

[53] L. BRIÑÓN-ARRANZ, A. SEURET, C. CANUDAS-DE-WIT. *Contraction Control of a Fleet Circular Formation of AUVs under Finite C ommunication Range*, in "American Control Conference ACC'10", 2010, submitted.

[54] R. CECCARELLI, P. MOULIN, C. CANUDAS-DE-WIT. *Turbine Efficiency Estimation for Fault Detection Application*, in "SAE Technical Paper Series", 2010, submitted.

[55] A. CERVIN, J. EKER, B. BERNHARDSSON, K.-E. ÅRZÉN. *Feedback-Feedforward Scheduling of Control Tasks*, in "Real Time Systems", vol. 23, n° 1, 2002, p. 25–54.

[56] E. FRIDMAN, A. SEURET, J.-P. RICHARD. *Robust Sampled-Data Stabilization of Linear Systems: An Input Delay Approach*, in "Automatica", vol. 40, n° 8, 2004, p. 1141-1446.

[57] F. GOMEZ-ESTERN, C. CANUDAS-DE-WIT, F. RUBIO, J. FORNES. *Adaptative delta-modulation coding for networked controlled systems*, in "Proceedings of the 26th American Control Conference, ACC'2007, New York City, USA", IEEE, 2007, http://hal.archives-ouvertes.fr/hal-00130512/en/.

[58] J. JAGLIN, C. CANUDAS-DE-WIT, C. SICLET. *Delta Modulation for Multivariable Centralized Linear Networked Controlled Systems*, in "Proceedings of the 47th IEEE Conference on Decision and Control, CDC 2008, Cancun Mexique", 2008, p. 4910 - 4915, http://hal.archives-ouvertes.fr/hal-00315933/en/.

[59] N. JIA, Y.-Q. SONG, F. SIMONOT-LION. *Graceful degradation of the quality of control through data drop policy*, in "European Control Conference, ECC, Kos, Greece", 2007.

[60] KARL HENRIK. JOHANSSON, M. TÖRNGREN, L. NIELSEN. *Vehicle applications of controller area network*, Handbook of Networked and Embedded Control Systems, Birkhauser, 2005.

[61] A. KIBANGOU, C. SICLET, L. ROS. *Joint Channel and Doppler estimation for multicarrier underwater communications*, in "IEEE Int. Conf. on Acoustics, Speech, and Signal Processing (ICASSP) 2010", 2010, To appear.

[62] A. KIBANGOU, C. SICLET, L. ROS. *ZF OFDM Receiver for Underwater Communications*, in "Int. Symp. on Communications, Control and Signal Processing (ISCCSP) 2010", 2010, submitted.

[63] B.-C. KIM, I.-T. LU. *Parameter study of OFDM underwater communications system*, in "Proc. of OCEANS 2000 MTS/IEEE Conference and Exhibition", vol. 2, September 11-14 2000, p. 1251–1255.

[64] B. LI, S. ZHOU, M. STOJANOVIC, L. FREITAG, P. WILLETT. *Multicarrier communication over underwater acoustic channels with nonuniform Doppler shifts*, in "IEEE Journal of Oceanic Engineering", vol. 33, n° 2, 2008, p. 198–209.

[65] I. LOPEZ, C. T. ABDALLAH, C. CANUDAS-DE-WIT. *Gain-Scheduling Multi-Bit Delta-Modulator for Networked Controlled System*, in "Proceedings of the European Control Conference, ECC'07, Kos Grèce", 07 2007, http://hal.archives-ouvertes.fr/hal-00201789/en/.

[66] P. NAGHSHTABRIZI, J. HESPANHA, A. TEEL. *Exponential stability of impulsive systems with application to uncertain sampled-data systems*, in "Systems and Control Letters", vol. 57, n° 5, 2008, p. 378-385.

[67] R. OLFATI-SABER, A. FAX, R. MURRAY. *Consensus and cooperation in networked multi-agent systems*, in "Proceedings of the IEEE", vol. 95, n° 1, 2007, p. 215-233.

[68] C.A. SEGALL, G.J. SULLIVAN. *Spatial Scalability Within the H.264/AVC Scalable Video Coding Extension*, in "IEEE Transactions on Circuits and Systems for Video Technology", vol. 17, n° 9, 2007, p. 1121–1135.

[69] A. SEURET, J.-P. RICHARD. *Convergence rate of a networked control systems with time-varying delays and packet dropout*, in "provisionnaly accepted in IEEE Tans. on Automatic Control", 2008.

[70] A. SEURET. *Networked control under synchronization errors*, in "ACC'08, Seattle, USA", June 2008.

[71] D. SIMON, R. PISSARD-GIBOLLET, S. ARIAS. *Orccad, a framework for safe robot control design and implementation*, in "1st National Workshop on Control Architectures of Robots: software approaches and issues CAR'06, Montpellier", april 6-7 2006.

[72] D. SIMON, D. ROBERT, O. SENAME. *Robust control/scheduling co-design: application to robot control*, in "RTAS'05 IEEE Real-Time and Embedded Technology and Applications Symposium, San Francisco", march 2005.

[73] D. SIMON, O. SENAME, D. ROBERT. *Conception conjointe commande/ordonnancement et ordonnancement régulé*, in "Systèmes Temps Réel Tome II : Ordonnancement, Réseaux, Qualité de Service", vol. 2, Hermes, 2006.

[74] S. TATIKONDA, S. K. MITTER. *Control under communications constaints*, in "IEEE Transaction on Automatic Control", vol. 49, n° 7, July 2004, p. 1056–1068.

[75] M. TÖRNGREN, D. HENRIKSSON, O. REDELL, C. KIRSCH, J. EL-KHOURY, D. SIMON, Y. SOREL, H. ZDENEK, K.-E. ÅRZÉN. *Co-design of Control Systems and their real-time implementation - A Tool Survey*, n° TRITA - MMK 2006:11, Royal Institute of Technology, KTH, Stockolm, 2006, Technical report.

[76] E. WITRANT, D. GEORGES, C. CANUDAS-DE-WIT, O. SENAME. *Stabilisation des systèmes commandés par réseau: une approche prédictive*, in "Systèmes commandés en réseaux", JEAN-PIERRE. RICHARD, T. DIVOUX (editors), Traité IC2, Lavoisier - Hermès, 2007, p. 83-124, http://hal.archives-ouvertes.fr/hal-00176046/en/.

[77] K.-E. ÅRZÉN. *A Simple Event-Based PID Controller*, in "Preprints 14th World Congress of IFAC, Beijing, P.R. China", January 1999.