IN PARTNERSHIP WITH:
CNRS

Institut polytechnique de Grenoble

Université Joseph Fourier (Grenoble)

Activity Report 2013

Project-Team NECS

Networked Controlled Systems

IN COLLABORATION WITH: Grenoble Image Parole Signal Automatique (GIPSA)

RESEARCH CENTER
Grenoble - Rhône-Alpes

THEME
Optimization and control of dynamic systems

Table of contents

Project-Team NECS

Keywords: Distributed Algorithms, Network Modeling, Network Control, Robust Control, Nonlinear Control

Creation of the Project-Team: 2007 January 01.

1. Members

Research Scientists
- Carlos Canudas de Wit [Team leader, CNRS, Senior Researcher, HdR]
- Federica Garin [Inria, Researcher]
- Daniel Simon [Inria, Researcher, until Jan 2013, HdR]

Faculty Members
- Hassen Fourati [Univ. Grenoble I, Associate Professor]
- Alain Kibangou [Univ. Grenoble I, Associate Professor – Chaire CNRS]

Engineers
- Pascal Bellemain [CNRS, from Sep 2013]
- Iker Bellicot [Inria, ADT-GTL]
- Jonathan Dumon [CNRS]

PhD Students
- Abir Ben Khaled [IFPEN]
- Valentina Ciarla [CNRS, until Oct 2013]
- Giovanni de Nunzio [IFPEN]
- Ruggero Fabbiano [Inria]
- Luis Leon [Inria, FP7 HYCON2 project]
- Aida Makni [Grenoble INP]
- Dominik Pisarski [Inria, FP7 HYCON2 project]
- Thi-Minh Dung Tran [Vietnamese Government scholarship]

Post-Doctoral Fellow
- Fabio Morbidi [Inria, Mocopo project]

Administrative Assistant
- Elodie Toihein [Inria]

Others
- Patrick Blanchard [Student, from Jun 2013 until Jul 2013]
- Giulio Bontadini [Master student, from Mar 2013 until Aug 2013]
- Yvan Gaudfrin [Master student, from Jun 2013 until Sep 2013]

2. Overall Objectives

2.1. Context and overall goal of the project

NECS is a joint INRIA/GIPSA-LAB team, bi-located at the INRIA-Rhône-Alpes center in Montbonnot and at GIPSA-LAB (http://www.gipsa-lab.grenoble-inp.fr) in the Saint-Martin-d'Hères campus, both locations being in the Grenoble area. NECS team's research is focused on Networked Controlled Systems.
The research field of Networked Controlled Systems deals with feedback systems controlled over networks, but also concerns systems that naturally exhibit a network structure (e.g., traffic, electrical networks, etc.).

The first system category results from the arrival of new control problems posed by the consideration of several factors, such as: new technological components (e.g., wireless, RF, communications, local networks, etc.), increase of systems complexity (e.g., increase in vehicle components), the distributed location of sensor and actuator, and computation constraints imposed by their embedded nature. In this class of systems, the way that the information is transferred and processed (information constraints), and the manner in which the computation resources are used (resources management), have a substantial impact in the resulting stability and performance properties of the feedback controlled systems. One main challenge here is the co-design of control and one or more other components of different nature are considered. The NECS team has tackled co-design problems concerning:

- Control under communications and network constraints;
- Control under resources constraints.

The second category of systems is motivated by the natural network structure in which the original systems are built. Examples are biologic networks, traffic networks, and electrical networks. The complex nature of such systems makes the classical centralized view of the control design obsolete. New distributed and/or collaborative control and estimation algorithms need to be devised as a response to this complexity. Even if the dynamic behavior of each individual system is still important, the aggregated behavior (at some macroscopic level), and its interconnection graph properties become of dominant importance. To build up this research domain, the team has put a strong focus on traffic (vehicular) networks, and in some associated research topics capturing problems that are specific to these complex network systems (distributed estimation, graph-discovering, etc).

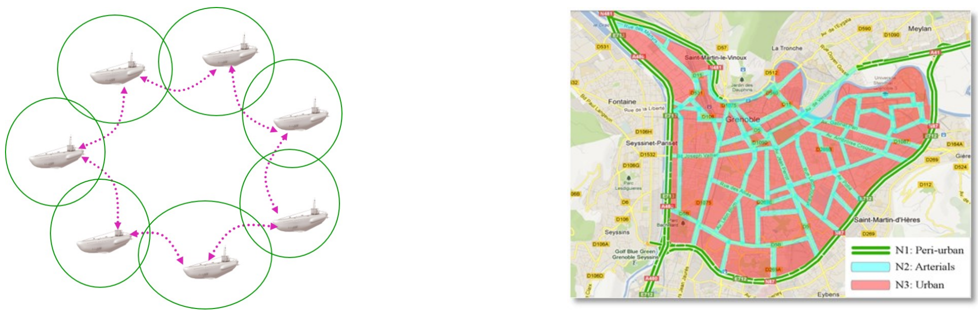

Figure 1. Left: a system of autonomous agents, where the network structure is created by the feedback, used to coordinate agents towards a common goal. Right: a system naturally having a network structure.

2.2. Highlights of the Year

In 2013, Carlos Canudas de Wit, leader of the NECS team, has become:

- President Elect of the European Control Association EUCA (http://www.euca-control.org/);
- IEEE CSS distinguished lecturer;
- Associate Editor of IEEE Transactions on Control System Technology (since January 2013) and of IEEE Transactions on Control of Network Systems (since June 2013).

3. Research Program

3.1. Introduction

NECS team deals with Networked Control Systems. Since its foundation in 2007, the team has been addressing issues of control under imperfections and constraints deriving from the network (limited computation resources of the embedded systems, delays and errors due to communication, limited energy resources), proposing co-design strategies. The team has recently moved its focus towards general problems on *control of network systems*, which involve the analysis and control of dynamical systems with a network structure or whose operation is supported by networks. This is a research domain with substantial growth and is now recognized as a priority sector by the IEEE Control Systems Society: IEEE has started in a new journal, IEEE Transactions on Control of Network Systems, whose first issue will appear in 2014.

More in detail, the research program of NECS team is along lines described in the following sections.

3.2. Distributed estimation and data fusion in network systems

This research topic concerns distributed data combination from multiple sources (sensors) and related information fusion, to achieve more specific inference than could be achieved by using a single source (sensor). It plays an essential role in many networked applications, such as communication, networked control, monitoring, and surveillance. Distributed estimation has already been considered in the team. We wish to capitalize and strengthen these activities by focusing on integration of heterogeneous, multidimensional, and large data sets:

- Heterogeneity and large data sets. This issue constitutes a clearly identified challenge for the future. Indeed, heterogeneity comes from the fact that data are given in many forms, refer to different scales, and carry different information. Therefore, data fusion and integration will be achieved by developing new multi-perception mathematical models that can allow tracking continuous (macroscopic) and discrete (microscopic) dynamics under a unified framework while making different scales interact with each other. More precisely, many scales are considered at the same time, and they evolve following a unique fully-integrated dynamics generated by the interactions of the scales. The new multi-perception models will be integrated to forecast, estimate and broadcast useful system states in a distributed way. Targeted applications include traffic networks and navigation, and concern recent grant proposals that team has elaborated, among which the SPEEDD EU FP7 project, which has been accepted and will start in February 2014.
- Multidimensionality. This issue concerns the analysis and the processing of multidimensional data, organized in multiway array, in a distributed way. Robustness of previously-developed algorithms will be studied. In particular, the issue of missing data will be taken into account. In addition, since the considered multidimensional data are generated by dynamic systems, dynamic analysis of multiway array (or tensors) will be considered. The targeted applications concern distributed detection in complex networks and distributed signal processing for collaborative networks. This topic is developed in strong collaboration with UFC (Brazil).

3.3. Networked systems and graph analysis

This is a research topic at the boundaries between graph theory and dynamical systems theory.

A first main line of research will be to study complex systems whose interactions are modeled with graphs, and to unveil the effect of the graph topology on system-theoretic properties such as observability or controllability. In particular, on-going work concerns observability of graph-based systems: after preliminary results concerning consensus systems over distance-regular graphs, the aim is to extend results to more general networks. A special focus will be on the notion of ‘generic properties’, namely properties which depend only on the underlying graph describing the sparsity pattern, and hold true almost surely with a random choice of the non-zero coefficients. Further work will be to explore situations in which there is the need for new notions different from the classical observability or controllability. For example, in social networks or in birds flocking the potential leader might have a goal different from classical controllability, because on the one hand he might have a goal much less ambitious than being able to drive the system to any possible state (e.g., he might want to drive everybody near its own opinion, only), and on the other hand he might have much weaker tools to construct its input (e.g., he might not know the whole system's dynamics, but only a few things, possibly that the system is linear and one row of the matrix only). Another example is the question of detectability of an unknown input under the assumption that such an input has a sparsity constraint, a question arising from the fact that a cyber-physical attack might be modeled as an input aiming at controlling the system's state, and that limitations in the capabilities of the attacker might be modeled as a sparsity constraint on the input.

A second line of research will concern graph discovery, namely algorithms aiming at reconstructing some properties of the graph (such as the number of vertices, the diameter, the degree distribution, or spectral properties such as the eigenvalues of the graph Laplacian), using some measurements of quantities related to a dynamical system associated with the graph. It will be particularly challenging to consider directed graphs, and to impose that the algorithm is anonymous, i.e., that it does not makes use of labels identifying the different agents associated with vertices.

3.4. Collaborative and distributed network control

This research line deals with the problem of designing controllers with a limited use of the network information (i.e. with restricted feedback), and with the aim to reach a pre-specified global behavior. This is in contrast to centralized controllers that use the whole system information and compute the control law at some central node. Collaborative control has already been explored in the team in connection with the underwater robot fleet, and to some extent with the source seeking problem. It remains however a certain number of challenging problems that the team wishes to address:

- Design of control with limited information, able to lead to desired global behaviors. Here the graph structure is imposed by the problem, and we aim to design the "best" possible control under such a graph constraint [1]. The team would like to explore further this research line, targeting a better understanding of possible metrics to be used as a target for optimal control design. In particular, and in connection with the traffic application, the long-standing open problem of ramp metering control under minimum information will be addressed.
- Clustering control for large networks. For large and complex systems composed of several sub-networks, feedback design is usually treated at the sub-network level, and most of the times without taking into account natural interconnections between sub-networks. The team wishes to explore new control strategies, exploiting the emergent behaviors resulting from new interconnections between the network components. This requires first to build network models operating in aggregated clusters, and then to re-formulate problems where the control can be designed using the cluster boundaries rather than individual control loops inside of each network. Examples can be found in the transportation application domain, where a significant challenge will be to obtain dynamic partitioning and clustering of heterogeneous networks in homogeneous sub-networks, and then to control the perimeter flows of the clusters to optimize the network operation.

3.5. Transportation networks

This is currently the main application domain of the NeCS team. Several interesting problems in this area capture many of the generic networks problems described above. For example, distributed collaborative algorithms can be devised for ramp-metering control and traffic-density balancing can be achieved using consensus concepts. The team is already strongly involved in this field, both this theoretical works on traffic prediction and control, and with the Grenoble Traffic Lab platform. These activities will be continued and strengthened.

[1] Such a problem has been previously addressed in some specific applications, particularly robot fleets, and only few recent theoretical works have initiated a more systematic system-theoretic study of sparsity-constrained system realization theory and of sparsity-constrained feedback control

4. Application Domains

4.1. A large variety of application domains

Sensor and actuator networks are ubiquitous in modern world, thanks to the advent of cheap small devices endowed with communication and computation capabilities. Potential application domains for research in networked control and in distributed estimation are extremely various, and include the following examples.

- 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.
- Smart grids: the operation of electrical networks is changing from a centralized optimization framework towards more distributed and adaptive protocols, due to the high number of small local energy producers (e.g., solar panels on house roofs) that now interact with the classic large power-plants.
- Disaster relief operations, where data collected by sensor networks can be used to guide the actions of human operators and/or to operate automated rescue equipment.
- Pedestrian navigation, providing guidance e.g. to first responders after a disaster, or to blind people walking in unfamiliar environments. This tasks is particularly challenging in-door, where no GPS is available.
- Surveillance using swarms of Unmanned Aerial Vehicles (UAVs), where sensor information (from sensors on the ground and/or on-board) can be used to guide the UAVs to accomplish their mission.
- Environmental monitoring and exploration using self-organized fleets of Autonomous Underwater Vehicles (AUVs), collaborating in order to reach a goal such as finding a pollutant source or tracing a seabed map.
- 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 threats.

In particular, NECS team is currently focusing in the areas described in detail below.

4.2. Vehicular transportation systems

4.2.1. 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. The research activity is on two main challenges: forecasting, so as to provide accurate information to users, e.g., travel times; and control, via ramp-metering and/or variable speed limits. The Grenoble Traffic Lab (see Sect. 5.1 and http://necs.inrialpes.fr/pages/grenoble-traffic-lab.php) is an experimental platform, collecting traffic infrastructure information in real time from Grenoble South Ring, together with innovative software e.g. for travel-time prediciton, and a show-case where to graphically illustrate results to the end-user. This activity is done in close collaboration with local traffic authorities (DIR-CE, CG38, La Metro), and with the start-up company Karrus (http://www.karrus-its.com/)

4.2.2. Advanced and interactive vehicle control

Car industry has been already identified as a potential homeland application for Networked Control [44], 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.), loss 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).

More recently, in the ANR project VOLHAND (2009-2013), the team has been developing a new generation of electrical power-assisted steering specifically designed for disabled and aged persons.

Currently, on-going work under a grant with IFPEN studies how to save energy and reduce pollution, by controlling a vehicle's speed in a smart urban environment, where infrastructure-to-vehicle and vehicle-to-vehicle communications happen and can be taken into account in the control.

4.3. Multi-robot collaborative coordination

Due to the cost or the risks of using human operators, many tasks of exploration, or of after-disaster intervention are performed by un-manned drones. When communication becomes difficult, e.g., under water, or in spatial exploration, such robots must be autonomous. Complex tasks, such as exploration, or patrolling, or rescue, cannot be achieved by a single robot, and require a self-coordinated fleet of autonomous devices. NECS team has studied the marine research application, where a fleet of Autonomous Underwater Vehicles (AUVs) self-organize in a formation, adapting to the environment, and reaching a source, e.g., of a pollutant. This has been done in collaboration with IFREMER, within the national project ANR CONNECT and the European FP7 project FeedNetBack. On-going research in the team concerns source localization, with a fleet of mobile robots, including wheeled land vehicles.

5. Software and Platforms

5.1. GTL – Grenoble Traffic Lab

Participants: C. Canudas de Wit [contact person], I. Bellicot, P. Bellemain, L. Leon Ojeda, D. Pisarski, A. Kibangou, F. Morbidi.

The Grenoble Traffic Lab (GTL) initiative, led by the NECS team, is a real-time traffic data center (platform) that collects traffic road infrastructure information in real-time with minimum latency and fast sampling periods. The main elements of the GTL are: a real-time data-base, a show room, and a calibrated micro-simulator of the Grenoble South Ring. Sensed information comes from a dense wireless sensor network deployed on Grenoble South Ring, providing macroscopic traffic signals such as flows, velocities, densities, and magnetic signatures. This sensor network was set in place in collaboration with Inria spin-off Karrus-ITS, local traffic authorities (DIR-CE, CG38, La Metro), and specialized traffic research centers. In addition to real data, the project also uses simulated data, in order to validate models and to test the ramp-metering; the micro-simulator is a commercial software (developed by TSS AIMSUN ©).

More details at http://necs.inrialpes.fr/pages/grenoble-traffic-lab.php

5.2. NeCSCar

Participants: C. Canudas de Wit [contact person], J. Dumon, V. Ciarla.

NeCSCar is an electrical vehicle (scale 1:3) used as an experimental platform to study new control architectures. The vehicle is designed to be remotely tele-operated from our active steering-wheel platform, ant it will be equipped of a 3D vision system to provide the operator with stereo vision capabilities. Bilateral teleoperation can be performed using wheel contact torque measurements, fed back for force deflexion; wireless connection allows us to test coding algorithms, resource sharing, and robustness against transmission delays.

NeCSCar has been recently used for simulation tests in the framework of the VolHand project, a multi-disciplinary project with the goal to develop a new generation of electronic power assistance steering (EPAS) systems for disabled people.

5.3. Source-seeking robot

Participants: R. Fabbiano [contact person], J. Dumon, Y. Gaudfrin.

The source-seeking algorithms developed in the thesis of Ruggero Fabbiano have been implemented in hardware, with a wheeled robot performing 2-dimensional search. The considered scenario is a source of pollutant in the ocean, where the pollutant can be detected thanks to the fact that it is warmer than water, so that data from an infra-red camera can be used by one or multiple helicopters to move along the ocean surface towards the source. In our experimental equipment, the 2-dimensional movement has been performed with a wheeled vehicle, and the camera was a regular camera, taking pictures of a color-coded image from an actual infra-red image of a pollutant leak. Videos of the experiments are available online: http://necs.inrialpes.fr/pages/platforms.php

6. New Results

6.1. Networked systems and graph analysis

6.1.1. Distributed graph-discovery

Participants: A. Kibangou [Contact person], T.-M. D. Tran, F. Garin, A. de Almeida [UFC Brazil].

The availability of information on the communication topology of a wireless sensor network is essential for the design of the estimation algorithms. In the context of distributed self-organized sensor networks, there is no central unit with the knowledge of the network, and the agents must run some distributed network discovery algorithm.

We have studied the problem of estimating the eigenvalues of the Laplacian matrix associated with a graph modeling the interconnections between the nodes of a given network. Our approach is based on properties resulting from the factorization of the average consensus matrix. Indeed, as recently shown [45], the average consensus matrix can be written as a product of Laplacian based consensus matrices whose stepsizes are given by the inverse of the nonzero Laplacian eigenvalues. By distributively solving the factorization of the average consensus matrix, we have shown that the Laplacian eigenvalues can be computed as the inverse of the stepsizes in each estimated factor, where these factors are constrained to be structured as Laplacian based consensus matrices. A constrained optimization problem was formulated and distributed gradient descent methods have been formulated. As formulated, the problem can be viewed as a consensus problem with equality constraints. In contrast to the state-of-the-art, the proposed algorithm does not require great resources in both computation and storage. This algorithm can also be viewed as a way for decentralizing the design of finite-time average consensus protocol recently proposed in the literature.

Laplacian eigenvalues have several interesting properties that can help to study networks, however they cannot uniquely characterize the topology of the network. Therefore, we have directly studied the problem of topology identification in [20]. The considered set-up concerns a collaborative wireless sensor network where nodes locally exchange coded informative data before transmitting the combined data towards a remote fusion center equipped with an antenna array. For this communication scenario, a new blind estimation algorithm was developed for jointly recovering network transmitted data and connection topology at the fusion center. The proposed algorithm is based on a two-stage approach. The first stage is concerned with the estimation of the channel gains linking the nodes to the fusion center antennas. The second stage performs a joint estimation of network data and connection topology matrices by exploiting a constrained (PARALIND) tensor model for the collected data at the fusion center.

Distributed network-discovery algorithms become even more challenging in the case where the algorithm must be anonymous, namely in the case when the agents do not have or do not want to disclose their identifiers (id.s), either for technological reasons (in time-varying self-organized networks, assigning unique identifiers to agents is a challenge) or for privacy concerns. In anonymous networks, even simple tasks such as counting the number of agents are challenging problems. In [24] we have proposed an algorithm for node-counting in anoymous networks. It is based on a graph-constrained LTI system similar to linear consensus, and on system identification: the idea is that the order of the system is the number of agents, and based on local observations each agent tries to identify the order of the system, testing the rank of the Hankel matrix from the output data.

6.1.2. Observability in consensus networks

Participants: A. Kibangou [Contact person], C. Commault [Grenoble INP].

Studying the observability problem of a system consists in answering the question: is it possible, for a given node, to reconstruct the entire network state just from its own measurements and those of its neighbors? Studying observability for arbitrary graphs is particularly a tough task, therefore, studies are generally restricted to some families of graphs; for instance, recently, observability has been studied for paths and circular graphs and also grids where the study was carried out based on rules on number theory. We have considered families of graphs admitting an association scheme such that strongly regular graphs and distance regular graphs. The regularity properties of these kinds of graphs can particularly be useful for robustifying the network as for cryptographic systems. Based on the so-called Bose-Mesner algebra, we have stated observability conditions on consensus networks modeled with graphs modeled with strongly regular graphs and distance regular graphs; for this purpose, we have introduced the notion of local observability bipartite graph that allows characterizing the observability in consensus networks. We have shown that the observability condition is given by the nullity of the so-called "local bipartite observability graph"; when the nullity of the graph cannot be derived directly from the structure of the local bipartite observability graph, the rank of the associated bi-adjacency matrix allows evaluating the observability. The bi-adjacency matrix of the local bipartite observability graph must be full column rank for guaranteeing observability. From this general necessary and sufficient condition, we have deduced sufficient conditions for strongly regular graphs and distance regular graphs [25].

6.2. Collaborative and distributed algorithms

6.2.1. Finite-time average consensus

Participants: A. Kibangou [Contact person], T.-M. D. Tran.

Nowadays, several distributed estimation algorithms are based on the average consensus concept. Average consensus can be reached using a linear iterations scheme where each node repeatedly updates its value as a weighted linear combination of its own value and those of its neighbors; the main benefit of using a linear iterations scheme is that, at each time-step, each node only has to transmit a single value to each of its neighbors. Based on such a scheme, several algorithms have been proposed in the literature; however, in the most proposed algorithms the weights are chosen so that all the nodes asymptotically converge to the same value. Sometimes, consensus can be embedded as a step of more sophisticated distributed; obviously, asymptotic convergence is not suitable for these kinds of distributed methods, and therefore it is interesting to address the question of exact consensus in finite-time. For time-invariant network topologies and in the perfect information exchange case, i.e., without channel noise nor quantization, we have shown that the finite-time average consensus problem can be solved as a matrix factorization problem with joint diagonalizable matrices depending on the graph Laplacian eigenvalues; moreover, the number of iterations is equal to the number of distinct nonzero eigenvalues of the graph Laplacian matrix. The design of such a protocol requires the knowledge of the Laplacian spectrum, which can be carried out in a distributed way (see Section 6.1.1. The matrix factorization problem is solved in a distributed way, in particular a learning method was proposed and the optimization problem was solved by means of distributed gradient backpropagation algorithms. The factor matrices are not necessarily symmetric and the number of these factor matrices is exactly equal to the diameter of the graph [30].

6.2.2. Linear consensus in large-scale geometric graphs

Participants: F. Garin [Contact person], E. Lovisari [Lund], S. Zampieri [Padova].

Traditional analysis of linear average-consensus algorithms studies, for a given communication graph, the convergence rate, given by the essential spectral radius of the transition matrix (i.e., the second largest eigenvalues' modulus). For many graph families, such analysis predicts a performance which degrades when the number of agents grows, basically because spreading information across a larger graph requires a longer time; however, when considering other well-known quadratic performance indices (involving all the eigenvalues of the transition matrix), the scaling law with respect to the number of agents can be different. This is consistent with the fact that, in many applications, for example in estimation problems, it is natural to expect that a larger number of cooperating agents has a positive, not a negative effect on performance. It is natural to use a different performance measure when the algorithm is used for different purposes, e.g., within a distributed estimation or control algorithm. We are interested in evaluating the effect of the topology of the communication graph on performance, in particular for large-scale graphs. We have focused on graph families which can describe sensor networks, and hence have geometric constraints, namely nodes can be connected only with nearby nodes in the sense of Euclidean distance [16].

6.2.3. Distributed computation methods for multidimensional data

Participants: A. Kibangou [Contact person], A. de Almeida [UFC Brazil].

In [19], we consider the issue of distributed computation of tensor decompositions. A central unit observing a global data tensor assigns different data sub-tensors to several computing nodes grouped into clusters. The goal is to distribute the computation of a tensor decomposition across the different computing nodes of the network, which is particularly useful when dealing with large-scale data tensors. However, this is only possible when the data sub-tensors assigned to each computing node in a cluster satisfies minimum conditions for uniqueness. By allowing collaboration between computing nodes in a cluster, we show that average consensus based estimation is useful to yield unique estimates of the factor matrices of each data sub-tensor. Moreover, an essentially unique reconstruction of the global factor matrices at the central unit is possible by allowing the subtensors assigned to different clusters to overlap in one or several modes. The proposed approach is useful to a number of distributed tensor-based estimation problems in signal and data processing.

6.2.4. Collaborative source seeking

Participants: C. Canudas de Wit [Contact person], R. Fabbiano, F. Garin, Y. Gaudfrin, J. Dumon.

The problem of source localization consists in finding, with one or several agents possibly cooperating with each other, the point or the spatial region from which a quantity of interest is being emitted. Source-seeking agents can be fixed sensors, that collect and exchange some information about the signal field and try to identify the position of the source (or the smallest region in which it is included), or moving devices equipped with one or more sensors, that physically reach the source in an individual or cooperative way. This research area is attracting a rapidly increasing interest, in particular in applications where the agents have limited or no position information and GPS navigation is not available, as in underwater navigation or in cave exploration: for instance, source localization is relevant to many applications of vapor emitting sources such as explosive detection, drug detection, sensing leakage or hazardous chemicals, pollution sensing and environmental studies. Other fields of interest are sound source localization, heat source localization and vent sources in underwater field. Techniques present in literature either are based on a specific knowledge of the solution of the diffusion process, or make use of an extremum-seeking approach, exciting the system with a periodic signal so as to explore the field and collect enough information to reconstruct the gradient of the quantity of interest. Our approach lies in the computation of derivatives (potentially of any order) from Poisson integrals that, for isotropic diffusive source in steady-state, whose solution satisfies the Laplace equation, allows for a gradient search with a small computation load (derivatives are computed by integrals) and without requiring any knowledge of the closed-form solution, avoiding in the same time extremum-seeking oscillations; this has the additional advantage of an intrinsic high-frequency filtering, that makes the method low sensitive to measurement noise. This work is the topic of the Ph.D. of Ruggero Fabbiano, and is described in papers under review.

Moreover, a hardware implementation of the source-seeking algorithm has been done during the internship of Yvan Gaudfrin, at GIPSA-LAB with the support of Jonathan Dumon. A description of the setup and videos of the source-seeking robot are available online: http://necs.inrialpes.fr/pages/platforms.php

6.3. Sensor networks: estimation and data fusion

6.3.1. Data fusion approaches for motion capture by inertial and magnetic sensors

Participants: H. Fourati [Contact person], A. Makni, A. Kibangou.

We are interested to motion capture (or attitude) by fusing Inertial and Magnetic Sensors. In [15], we present a viable quaternion-based Complementary Observer (CO) which is designed for rigid body attitude estimation. The CO processes data from a small inertial/magnetic sensor module containing tri-axial angular rate sensors, accelerometers, and magnetometers, without resorting to GPS data. The proposed algorithm incorporates a motion kinematic model and adopts a two-layer filter architecture. In the latter, the Levenberg Marquardt Algorithm (LMA) pre-processes acceleration and local magnetic field measurements, to produce what will be called the system's output. The system's output together with the angular rate measurements will become measurement signals for the CO. In this way, the overall CO design is greatly simplified. The efficiency of the CO is experimentally investigated through an industrial robot and a commercial IMU during human segment motion exercises. In a recent work [35], a viable quaternion-based Adaptive Kalman Filter (q-AKF) that is designed for rigid body attitude estimation. This approach is an alternative to overcome the limitations of the classical Kalman filter. The q-AKF processes data from a small inertial/magnetic sensor module containing triaxial gyroscopes, accelerometers, and magnetometers. The proposed approach addresses two challenges. The first one concerns attitude estimation during various dynamic conditions, in which external acceleration occurs. Although external acceleration is one of the main source of loss of performance in attitude estimation methods, this problem has not been sufficiently addressed in the literature. An adaptive algorithm compensating external acceleration from the residual in the accelerometer is proposed. At each step, the covariance matrix associated with the external acceleration is estimated to adaptively tune the filter gain. The second challenge is focused on the energy consumption issue of gyroscopes for long-term battery life of Inertial Measurement Units. We study the way to reduce the gyro measurement acquisition while maintaining acceptable attitude estimation. Through numerical simulations, under external acceleration and parsimonious gyroscope's use, the efficiency of the proposed q-AKF is illustrated.

6.3.2. Pedestrian dead-reckoning navigation

Participant: H. Fourati [Contact person].

We proposes a foot-mounted Zero Velocity Update (ZVU) aided Inertial Measurement Unit (IMU) filtering algorithm for pedestrian tracking in indoor environment [22]. The algorithm outputs are the foot kinematic parameters, which include foot orientation, position, velocity, acceleration, and gait phase. The foot motion filtering algorithm incorporates methods for orientation estimation, gait detection, and position estimation. A novel Complementary Filter (CF) is introduced to better pre-process the sensor data from a foot-mounted

IMU containing tri-axial angular rate sensors, accelerometers, and magnetometers and to estimate the foot orientation without resorting to GPS data. A gait detection is accomplished using a simple states detector that transitions between states based on acceleration measurements [32]. Once foot orientation is computed, position estimates are obtained by using integrating acceleration and velocity data, which has been corrected at step stance phase for drift using an implemented ZVU algorithm, leading to a position accuracy improvement. We illustrate our findings experimentally by using of a commercial IMU during regular human walking trial in a typical public building. Experiment results show that the positioning approach achieves approximately a position accuracy less than 1 m and improves the performance regarding a previous work of literature [33].

6.3.3. Sensor placement of unreliable sensors

Participants: F. Garin [Contact person], P. Frasca [Twente].

In this work (see [23]), we consider problems in which sensors have to be deployed in a given environment in such a way to provide good coverage of it. It is clear that sensor failures may deteriorate the performance of the resulting sensor network. Then, it is also natural to ask if taking into account such uncertainties changes the coverage optimization problem and leads to a different optimal solution. For simplicity, we start considering a one-dimensional problem, where sensors are to be placed on a line in such a way to optimize the disk-coverage cost The optimal solution for reliable sensors is simply an equally-spaced configuration of the sensors. If we allow that the sensors may fail to take or communicate their measurements, this solution may instead not be optimal. However, as the number of sensors grows to infinity, the ratio between the cost of equally-spaced configurations and the optimal failure-free cost only grows as the logarithm of the number of sensors. We interpret this result as a confirmation of the intrinsic robustness of sensor networks.

6.4. Control design and co-design

6.4.1. Energy-aware networked control

Participants: C. Canudas de Wit [Contact person], F. Garin, N. Cardoso de Castro, D. Quevedo [Newcastle].

We have considered an event-based approach to energy-efficient management of the radio chip in the sensor node of a wireless networked control system. Indeed the radio is the main energy consumer, and intermittent data transmission allows one to reduce the use of the radio. While the existing literature in the control community on event-based control only addresses policies using two radio modes (transmitting/sleep), our work follows some considerations on the radio chip modes well-known in the communication networks literature, and introduces various radio-modes: different ‘idle’ non-transmitting modes, where only part of the radio chip is switched off (thus consuming more energy than ‘sleep’, but allowing for faster transition to transmission), and various transmitting modes, with different power levels. We propose an event-based radio-mode switching policy, which allows to perform a trade-off between energy saving and performance of the control application; to this end, a switched model describes the system, taking into account control and communication. The optimal switching policy is computed using dynamic programming, considering a cost either over an infinite time-horizon (see [31]) or over a finite receding horizon (joint work with D. Quevedo, Univ. Newcastle, Australia, described in a paper in preparation).

6.4.2. Adaptive control strategy based reference model for spacecraft motion trajectory

Participants: H. Fourati [Contact person], Z. Samigulina.

In aerospace field, the economic realization of a spacecraft is one of the main objectives which should be accomplished by conceiving the optimal propulsion system and the best control algorithms. Our work focuses on the development of a viable Adaptive Control Approach (ACA) for Spacecraft Motion Trajectory (SMT), see [39].The proposed strategy involves the nonlinear mathematical model of SMT expressed in the central field, which is linearized by the Taylor expansion, and the second Lyapunov method to offer a high rate and unfailing performance in the functioning. The adaptive control system is composed of the cascade of adaptation loop and feedback control loop. When the spacecraft deviates from its reference trajectory model, the ACA acts on the control system to correct this deviation and follow the optimal reference trajectory.

Therefore, when the states of the adjustable model are different from its reference values, then the error signal is provided as an input to the adaptation law, which contains the adaptation algorithm. The output will be the state variable feedback control matrix which will be used to calculate the new control law vector. The efficiencies of the linearization procedure and the control approach are theoretically investigated through some realistic simulations and tests under MATLAB. The steady state errors of control between the reference model and the adjustable model of SMT converge to zero. This work is described in [38].

6.5. Transportation networks and vehicular systems

6.5.1. Traffic estimation and prediction

Participants: C. Canudas de Wit [Contact person], A. Kibangou, L. Leon Ojeda, F. Morbidi.

Reconstructing densities in portions of the road links not equipped with sensors constitutes an important task in traffic estimation, forecasting, and control problems. Among many other approaches, model-based observers is one popular technique to build this information. They can also be understood as *virtual sensors* deployed inside of the cells not equipped with *true sensors*. They are used to better track, in real-time, density variations with a fine degree of granularity in the space, as the *virtual cells* can be selected as small as desired.

In [43], a graph constrained-CTM observer was introduced. It allows reconstructing rather accurately the internal states (densities) of a road portion not equipped with sensors. This strategy for real-time density estimation was applied on Grenoble South Ring. In [27], this observer has been associated with an adaptive Kalman filtering approach for traffic prediction in terms of travel time. The adaptive Kalman filtering approach was also been used for predicting input flows in [26].

6.5.2. Traffic control

Participants: C. Canudas de Wit [Contact person], D. Pisarski.

This work has been conducted in two parallel directions, combining steady state analysis and design of an optimal ramp metering controller.

The first direction was to extend the preliminary results presented in the papers [10] and [46]. The goal was to implement the idea of optimal steady state balancing. A relevant software was built up and tested on the model representing the south ring of Grenoble. The results were published in [28]. A comprehensive study of steady state balancing was submitted as a journal paper, under review.

The second direction was to develop a distributed optimal ramp metering controller. This study is motivated by two following facts. The first one is to decentralize and parallelize computation for optimal freeway traffic control problem, and thus to reduce computational complexity. The second one is to reduce the lengths of the communication channels, in order to eliminate the probability of information delay or packet loss. The proposed new control objective provides a uniformly distributed (or balanced) vehicle density such that the usage of freeway (measured by the Total Travel Distance and Total Input Volume) is maximized. This optimal balancing objective is reached by taking a proper state feedback control structure and optimizing the set of gains. Here we imposed distributed condition for both, the feedback structure and the optimization process. We have focused the efforts to design the controller network architecture that is based on the common elements (ramp meter controllers), executing the same computational procedures and applying the control signals based on the same state-feedback structure. This meets a spirit of ‘plug and play’ (PnP), and is beneficial for both, architecture assembling and component replacement (in case of failure). In order to define the functionality for each of this PnP controller, the analysis on both system controllability and conditions for optimality were carried on. The preliminary work let us to determine the what type of information and upon which communication topology it is required to be sent in order to solve the posed optimization problem. Firstly, the feedback controls for each of the controllers require state information of the section that is controllable for it. In general, each of the controllers demands the state for its closest surrounding sections (downstream and upstream). Secondly, each of the controllers communicates with its closest active neighbors to exchange the information of optimal solution, namely optimal boundary flow or optimal control. We also observed that in any system mode there might be only one inactive controller (the controller that does not have any controllable section) surrounded by two active ones, and thus the maximum required information comes from the two closest neighbors for each of the directions. We noticed also that inactive controllers may serve to convey the information for the active ones, so the communication can be based on a path (or linear) graph. Part of this research was realized in UC Berkeley during the visit of Dominik Pisarski in PATH laboratory.

Traffic control is based on models of traffic, usually the so-called CTM – Cell transmission Model. Some work in the team aims at developing different models, more suitable for control. One such model is based on cells of variable length, as an alternative way to describe the congestion position. This model, proposed in [42], has been refined in the master thesis of Giulio Bontadini, taking into account mass conservation laws.

6.5.3. Vehicle control for disabled people

Participants: C. Canudas de Wit [Contact person], V. Ciarla, J. Dumon, F. Quaine [UJF], V. Cahouet [UJF].

Disabled people face the effort to turn the steering wheel while driving their vehicle. This study, funded by the VolHand project, focuses on the aspect of the assistance during driving maneuver at low speeds (for instance, parking). On common vehicles for healthy people, the system that improves the driver's steering feel in these situations is the power-steering stage, which is mounted at the basis of the steering column and is based on hydraulic technology; the new generation uses an electric motor instead of the hydraulic pump, with more advantages in terms of fuel consumption, better road-feel feedback to the driver and better return-to-center performances of the steering wheel. This work has developed a general methodology to adapt the current technology for disabled people, by introducing additional blocks that can be implemented via software without altering the hardware of the vehicle. In this way, it can be easily exported without additional costs in terms of design and technology for the industrial partner. The methodology has been studied theoretically, joining control aspects with bio-mechanical ones. Moreover, the theoretical study has been tested in laboratory on the hardware-in-the loop setup, using the experimental platform NeCSCar (see Section 5.2). First, a real steering wheel has been linked to a real-time PC-unit and to an electrical motor. A graphical user interface has been implemented to facilitate the access to the software. Then, the last part of the study has been the experimental validation with a tele-operated real vehicle. The vehicle provided the measure of the friction torque to the PC-unit, simulating a real driving situation.

This work is described in [41] and in the Ph.D. thesis [11].

6.5.4. Control of communicating vehicles in urban environment

Participants: C. Canudas de Wit [Contact person], G. de Nunzio.

For a given vehicle there are different ways to travel on a given distance in a given time, associated to different levels of energy consumption; therefore, it is always possible to find an energy-optimal trajectory. Advising the driver via a suitable interface can reduce the energy consumed during the travel, and thus improve the energy efficiency: this is the principle of eco-driving. In urban areas, the optimal trajectory of the vehicle depends on interactions with other vehicles, also on passive signs (panels, priorities, etc.) and active signs (traffic lights); in each case, constraints are imposed on the command (vehicle speed). From the infrastructure perspective, traffic control in urban areas consists in determining the state of traffic signals in order to solve an optimization problem, for example minimizing average travel time of vehicles in the road network. If all vehicles could communicate with one another and with the active infrastructure (traffic lights), we could imagine benefits for each of the two problems which can be considered as a whole: on the one hand, from the vehicles' point of view, more information is available that can be integrated into the online optimization problem; on the other hand, there are new measures and new commands available to control traffic. Indeed, the estimation of the traffic is no longer necessary, as the position and speed of approaching vehicles is known and shared. More importantly, the traffic manager can send instructions to the vehicles. The aim of the research is to evaluate the potential in terms of energy saving and traffic improvement made possible by communicating vehicles. This work is the topic of the Ph.D. thesis of Giovanni De Nunzio, a CIFRE thesis with IFPEN. The paper [21] considers the scenario where vehicle and infrastructure (traffic lights) can communicate, and describes a suitable optimization algorithm that can be run on-board the vehicle so to optimize its energy consumption by avoiding stops and abrupt changes of speed at traffic lights, thanks to the information on upcoming traffic lights on the same road.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

7.1.1. IFPEN

Accompanying PhD contract with IFPEN (IFP Energies Nouvelles), in the framework of the PhD grant of A. Ben Khaled. The thesis explores new architectures and flexible scheduling methods to enhance the trade-off between the integration accuracy and the simulation speed of distributed real-time (hardware-in-the-loop) simulators, in particular in the framework of automotive power-trains.

Accompanying PhD contract with IFPEN (IFP Energies Nouvelles), in the framework of the PhD grant of Giovanni de Nunzio. The thesis explores eco-driving for comunicating vehicles in urban environment.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR VOLHAND

VOLHAND (**VOL**ant pour personne âgée et/ou **HAND**icapée) is a project funded by the ANR (National Research agency). This project, started in October 2009, is a result of collaboration between C. Canudas de Wit and Franck Quaine/Violaine Cahouët (from the biomechanical team of GIPSA-LAB). The project has concerned the development of a new generation of Electrical power-assisted steering specifically designed for disabled and aged people. Our contribution has been to design new assisted laws, taking into account the specific mechanical characteristics of this particular population of drivers. The consortium was composed by: LAMIH, CHRU, Fondation Hopale, GIPSA-LAB, INRETS and JTEKT. More information can be found on-line: http://www.univ-valenciennes.fr/volhand/.

8.1.2. PREDIT MoCoPo

The MOCoPo project (Measuring and mOdelling traffic COngestion and POllution) is funded by the French Ministry in charge of Transport (MEDDTL), through the PREDIT (Research and Innovation in Land Transport Program). The project began in January 2011 and will end up in December 2013. Various research institutes and universities, some teams of the MEDDTL and pollution measurements associations are involved in the project: LICIT (Transport and Traffic Engineering Laboratory, joint unit of IFSTTAR and ENTPE), LTE (Transports and Environment Laboratory, IFSTTAR), LEPSIS (Laboratory for Road Operations, Perception, Simulators and Simulations, IFSTTAR), IM (Infrastructures and Mobility Department, IFSTTAR), MACS (Monitoring, Assessment, Computational Sciences, IFSTTAR), Inria-NECS, Atmo Rhône Alpes, DIR-CE (Center-East Direction of Roads), LRPC Angers (Regional Laboratory of Angers), CERTU (Center for Cities and Urban Transportation), and CEREA (Center of Teaching and Research in Atmospheric Environment, laboratory Ecole des Ponts ParisTech / EDF Research and Development). NECS is particularly involved in tasks devoted to travel-time estimation and prediction. For this purpose one post-doc (Fabio Morbidi) has been hired. More information can be found on-line: http://mocopo.ifsttar.fr/.

8.1.3. PEPS META-TRAM

META-TRAM is a PEPS-CNRS project funded for two years (2013-2015). It aims at studying tensor methods for analyzing traffic data. Indeed, for a better management of mobility in modern cities (avoid or better control episodes of congestion, accurately predict traffic trends, finely analyze urban and suburban trips via multimodal networks), it is necessary to develop appropriate analytic tools that integrate multimodality and heterogeneity of networks from inherently multidimensional measures. Three areas are studied: tensor modeling for estimating origin-destination matrices, dynamic clustering flow and synthesis of distributed algorithms adapted to large volume of data, diversity of sensors, and their spatial dispersion. This project involves also I3S Lab (Sophia Antipolis) and CRAN (Nancy).

8.1.4. Other collaborations

Inertial and magnetic data integration for human movements analysis

The goal of this consortium is to work together on how to deal with inertial data in different or complementary fields. Orange Grenoble lab works on the analysis of inertial data. Orange sells some smart-phones equipped with inertial unit. The goal of Orange is to develop from these data some analysis bricks. The bricks are identified by: a) Monitoring of activity by identifying postures and deduce the activity by a correlation table, b) Prevention of falls by an analysis of walking monitoring, c) Monitoring of indoor and outdoor trajectory, d) Position of the sensor, and e) Identification of the dynamic parts of the signal. Orange offers to provide laboratories participating in the consortium: a) The database created through a 2012 IGS experiment where 7 peoples wore smart-phones for 3 months and the report of the experiment, b) The ability to store the data recorded by the consortium on a server in the capacity limit of the predefined server, c) The loan of smart-phones, and d) A schedule of specifications of a service activity monitoring of remote person. A consortium agreement has been signed by eight laboratories: INSA-INL, UJF-AGIM, UJF-GIPSA, CNRS-LAAS, CNRS-IRIT, Amines- école des mines de Douai, ISFTTAR, UTT et Orange Labs.

8.2. European Initiatives

8.2.1. FP7 Projects

8.2.1.1. Hycon2

Type: COOPERATION

Objective: Engineering of Networked Monitoring and Control Systems

Instrument: Network of Excellence

Objective: Engineering of Networked Monitoring and Control systems

Duration: September 2010 - August 2014

Coordinator: CNRS (France)

Partners: Inria (France), ETH Zurich (Switzerland), TU Berlin (Germany), TU Delft (Netherlands) and many others

Inria contact: C. Canudas de Wit

Abstract: Hycon 2 aims at stimulating and establishing a long-term integration in the strategic field of control of complex, large-scale, and networked dynamical systems. It focuses in particular on the domains of ground and aerospace transportation, electrical power networks, process industries, and biological and medical systems.

See also: http://www.hycon2.eu

8.2.1.2. SPEEDD (Scalable ProactivE Event-Driven Decision making)

Type: STREP

Objective: ICT-2013.4.2a – Scalable data analytics – Scalable Algorithms, software frameworks and viualisation

Duration: Feb. 2014 to Jan. 2017.

Coordinator: National Centre of Scientific Research ‘Demokritos’ (Greece)

Partners: IBM Israel, ETH Zurich (CH), Technion (Israel), Univ. of Birmingham (UK), NECS CNRS (France), FeedZai (Portugal)

Inria contact: C. Canudas de Wit

Abstract: SPEEDD will develop a prototype for robust forecasting and proactive event-driven decision-making, with on-the-fly processing of Big Data, and resilient to the inherent data uncertainties. NECS will lead the intelligent traffic-management use and show case.

See also: http://speedd-project.eu

8.2.1.3. CPSoS

Carlos Canudas de Wit participates to the working group WG1 “Systems of Systems in transportation and logistics” of the support action CPSoS “Towards a European Roadmap on Research and Innovation in Engineering and Management of Cyber-physical Systems of Systems”, led by TU Dortmund (Germany).

8.3. International Initiatives

8.3.1. Inria Associate Teams

NECS has submitted a proposal for the construction of a new associate team: COMFORT, with partner UC Berkeley/PATH. The proposal has been accepted, and the associate team will be funded for the period 2014-2016.

8.3.2. Inria International Partners

H. Fourati has a collaboration with the Kazakhstan National Technical University (KazNTU). He currently co-advises (with Pr. Olga Shiryayeva in KazNTU) Zarina Samigulina, a PhD student in KazNTU.

8.3.3. Participation In other International Programs

8.3.3.1. TeMP

TeMP (Tensor-based information Modelling and Processing) is a project funded in the framework of the French-Brazilian bilateral collaboration program (FUNCAP-Inria). It started from August 2011 and ended in December 2013. It was coordinated for the French part by A. Kibangou and aimed to study, analyze, propose and evaluate new models and techniques for digital communication systems using tensors and multilinear algebra tools, through in-depth theoretical analysis of mathematical models, optimization algorithms, and computational simulations. Distributed and collaborative algorithms have been devised for processing tensors involved in cooperative communications. In addition, new methods for processing very large tensors (big data issue) have been obtained. A special session has been organized in CAMSAP 2013 by A. de Almeida, the coordinator of the Brazilian side of the project.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

- Zarina Samigulina, PhD student, Kazakhstan National Technical University (KazNTU), one-month visit (mid-May to mid-July).
- The following professors from UFC Brazil visited NECS within the framework of the TeMP project: André L. F. de Almeida (Associate Professor) in February and November for one week each stay; Carlos Alexandre Rolim Fernandes (Associate Professor) in May for one week; Carlos Estevao Rolim Fernandes (Associate Professor) in May for three days.
- prof. Antonella Ferrara, from Università di Pavia (Italy), has been visiting NECS regularly, with multiple visit of a few days, for an active collaboration on the traffic application, within Hycon2 project.

8.4.1.1. Internships

- Giulio Bontadini, Master student, Università di Pavia (Italy), from March to August, co-advised by C. Canudas de Wit and A. Ferrara, master thesis: *Modeling and control of traffic systems*
- Yvan Gaudfrin, Master student, University of Bristol (UK), from June to September, co-advised by F. Garin, R. Fabbiano and J. Dumon, master thesis: *Source seeking via Poisson integrals – Practical implementation of a source-localization set-up.*

8.4.2. Visits to International Teams

- D. Pisarski has been a visiting scholar at UC Berkeley, Mechanical Engineering Dept., for three months (Oct.-Dec.). His stay was supported by Inria ‘Programme Explorateur’ and CMIRA ‘Explora Doc’.
- A. Kibangou spent two weeks in UFC, Brazil, in October, within the framework of the TeMP project.

9. Dissemination

9.1. Scientific Animation

- C. Canudas de Wit is President Elect of the European Control Association (EUCA) 2013-2015, and member of the Board of Governors of IEEE Control Systems Society. He is General Chair of the forthcoming European Control Conference, Strasbourg, July 2014 (http://www.ecc14.eu/). He is Associate Editor of IEEE Transactions on Control System Technology (since January 2013), Associate Editor of IEEE Transactions on Control of Network Systems (since June 2013), and Editor of the Asian Journal on Control.
- H. Fourati has been a peer-reviewer for international journals (IEEE Sensors Journal, IEEE/ASME Transactions on Mechatronics, Journal of Mechanics Engineering and Automation).
- F. Garin has been a peer-reviewer for international journals (IEEE Trans. Automatic Control, Automatica) and conferences (CDC 2013, ACC 2014, ECC 2014, ICCPS 2014) and for a chapter in a book in Springer LNCS. She is chair for student activities of the forthcoming European Control Conference ECC 2014.
- A. Kibangou has been a peer-reviewer for international journals (Automatica, IEEE Trans. on Control Systems and Technology, IEEE Trans. on Control of Network Systems, Elsevier Signal Processing, IEEE Trans. on Signal Processing, IET Communications, Int. J. of Adaptive Control and Signal Processing, and System & Control Letters) and conferences (CDC 2013, ACC 2014, ECC 2014). Locally, he is the organizer of seminars for the Control Department of GIPSA-LAB.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence: H. Fourati, Informatique Industrielle, 100h, L1, IUT 1 (GEII2), University Joseph Fourier, France;

Licence: H. Fourati, Automatique, 24h, L2, IUT 1 (GEII2), University Joseph Fourier, France;

Licence: H. Fourati, Automatismes industriels et réseaux, 90h, L1 et L2, IUT1 (GEII2), University Joseph Fourier, France.

Licence: H. Fourati, Automatique, 45h, L3, UFR physique, University Joseph Fourier, France

Licence: F. Garin, Automatique, 26h, L2, IUT1 (GEII1), University Joseph Fourier, France.

Licence: A. Kibangou, Automatique,62h, L2, IUT1(GEII1), University Joseph Fourier, France.

Licence: A.Kibangou, Mathématiques, 14h, L2, IUT1 (GEII1) , University Joseph Fourier, France.

9.2.2. Supervision

PhD: Valentina Ciarla, Commande d'un système de puissance électrique pour personne âgée et/ou handicapée, Grenoble University, Oct. 10th, 2013, co-advised by C. Canudas de Wit, F. Quaine, and V. Cahouet.

PhD in progress: Abir Ben Khaled, Distributed real time simulation of numerical models: application to powertrain, Grenoble INP, Jan. 2011 - Apr. 2014, co-advised by D. Simon and M. Ben Gaid (IFPEN).

PhD in progress: Luis R. Leon Ojeda, Modélisation macroscopique, estimation de la demande et prédiction du flux pour les systèmes de transport intelligents, Grenoble University, April 2011-March 2014, Co-advised by C. Canudas de Wit and A. Kibangou.

PhD in progress: Dominik Pisarski, Contrôle d'accès collaboratif : application à la Rocade Sud de Grenoble, Grenoble University, June 2011 - May 2014, Advised by C. Canudas de Wit.

PhD in progress: Ruggero Fabbiano, Distributed source seeking control, Grenoble University, Dec. 2011 - Nov. 2014, co-advised by C. Canudas de Wit and F. Garin.

PhD in progress: Thi-Minh Dung Tran, Consensus en temps fini et ses applications en estimation distribuée pour les systèmes de transport intelligents, Grenoble University, co-advised by A. Kibangou and C. Canudas de Wit, Jan. 2012 - Apr. 2015.

PhD in progress: Giovanni de Nunzio, Control of communicating vehicles in urban environnement, Grenoble University, co-advised by C. Canudas de Wit and P. Moulin (IFPEN), Sep. 2012 - Aug. 2015

PhD in progress: Aida Makni, Estimation multi-capteurs et commande temps-réel tolérante aux fautes d'un drone aérien, Grenoble INP, Oct. 2012 - Sep. 2015, co-advised by H. Fourati, A. Kibangou and C. Canudas de Wit.

9.2.3. Juries

- C. Canudas de Wit was member of the AERES Evaluation committee for the RTRA STAE, May 2013.
- F. Garin was a member of the Ph.D. defense committee of Weiguo Xia, Univ. of Groningen (The Netherlands), June 28th, 2013. Thesis: Distributed algorithms for interacting autonomous agents.

9.3. Popularization

Carlos Canudas has given a plenary talk on 'Forecasting and control of traffic systems: a network perspective' at the International Workshop on Smart City, organized by IEEE Control Systems Society in Hangzhou, China, in August 2013, http://smartcity.hdu.edu.cn

10. Bibliography

Major publications by the team in recent years

[1] C. AUBRUN, D. SIMON, Y.-Q. SONG. , *Co-design Approaches for Dependable Networked Control Systems*, ISTE Wiley, 2010, 314 p. , http://hal.inria.fr/inria-00443847/en/

[2] L. BRINON ARRANZ, A. SEURET, C. CANUDAS DE WIT. *Cooperative Control Design for Time-Varying Formations of Multi-Agent Systems*, in "IEEE Transactions on Automatic Control", 2014, to appear, http://hal.archives-ouvertes.fr/hal-00932841

[3] P. DOLCINI, C. CANUDAS DE WIT, H. BECHART. , *Dry Clutch Control for Automotive Applications*, Advances in Industrial Control, Springer, Oct 2010, 114 p. , http://hal.inria.fr/hal-00536612/en

[4] G. FAVIER, A. Y. KIBANGOU, T. BOUILLOC. *Nonlinear system modeling and identification using Volterra-PARAFAC models*, in "International Journal of Adaptive Control and Signal Processing", 2011, vol. 26, n^o 1, pp. 30-53 [*DOI :* 10.1002/ACS.1272], http://hal.inria.fr/hal-00642363

[5] H. FOURATI, N. MANAMANNI, L. AFILAL, Y. HANDRICH. *Rigid body motions capturing by means of wearable inertial and magnetic MEMS sensors assembly : from the reconstitution of the posture toward the dead reckoning: an application in Bio-logging*, in "Novel Advances in Microsystems Technologies and Their Applications (Devices, Circuits, and Systems)", L. A. FRANCIS, K. INIEWSKI (editors), Taylor & Francis Books, July 2013, pp. 393-409, http://hal.inria.fr/hal-00690146

[6] H. FOURATI, N. MANAMANNI, L. AFILAL, Y. HANDRICH. *Complementary Observer for Body Segments Motion Capturing by Inertial and Magnetic Sensors*, in "IEEE/ASME Transactions on Mechatronics", 2014, pp. 1-9, to appear [*DOI :* 10.1109/TMECH.2012.2225151], http://hal.inria.fr/hal-00690145

[7] F. GARIN, S. ZAMPIERI. *Mean square performance of consensus-based distributed estimation over regular geometric graphs*, in "SIAM Journal on Control and Optimization", 2012, vol. 50, n° 1, pp. 306-333 [*DOI :* 10.1137/10079402X], http://hal.inria.fr/hal-00641107

[8] F. GARIN, L. SCHENATO. *A Survey on Distributed Estimation and Control Applications Using Linear Consensus Algorithms*, in "Networked Control Systems", A. BEMPORAD, M. HEEMELS, M. JOHANSSON (editors), Lecture Notes in Control and Information Sciences, Springer, 2011, vol. 406, pp. 75-107 [*DOI :* 10.1007/978-0-85729-033-5_3], http://hal.inria.fr/inria-00541057/en/

[9] A. Y. 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", 2010, vol. Special issue on Model Order Selection in Signal Processing Systems, vol. 4, n° 3, pp. 514-525, http://hal.inria.fr/hal-00417815/en

[10] D. PISARSKI, C. CANUDAS DE WIT. *Optimal Balancing of Road Traffic Density Distributions for the Cell Transmission Model*, in "51th IEEE Conference on Decision and Control (CDC 2012)", Maui, Hawaii, United States, December 2012, pp. 6969-6974, http://hal.inria.fr/hal-00727783

Publications of the year

Doctoral Dissertations and Habilitation Theses

[11] V. CIARLA. , *Control of an Electronic Power Steering System for people with reduced mobility*, Université de Grenoble, spécialité Automatique Productique, October 2013

Articles in International Peer-Reviewed Journals

[12] C. BRIAT, A. SEURET. *Affine characterizations of minimum and mode-dependent dwell-times for uncertain linear switched systems*, in "IEEE Transactions on Automatic Control", May 2013, vol. 58, n° 5, pp. 1304-1310, To appear, http://hal.inria.fr/hal-00760279

[13] C. CANUDAS DE WIT, J. ARACIL, F. GORDILLO ÁLVAREZ, F. SALAS. *The oscillations killer: a mechanism to eliminate undesired limit cycles in a class of nonlinear systems*, in "International Journal of Robust and Nonlinear Control", January 2014, vol. 24, n° 1, pp. 39-53 [*DOI :* 10.1002/RNC.2873], http://hal.inria.fr/hal-00934086

[14] S. DURAND, A.-M. ALT, D. SIMON, N. MARCHAND. *Energy-aware Feedback Control for a H.264 Video Decoder*, in "International Journal of Systems Science", August 2013, 16 p. [*DOI :* 10.1080/00207721.2013.822607], http://hal.inria.fr/lirmm-00834888

[15] H. FOURATI, N. MANAMANNI, L. AFILAL, Y. HANDRICH. *Complementary Observer for Body Segments Motion Capturing by Inertial and Magnetic Sensors*, in "IEEE/ASME Transactions on Mechatronics", 2014, pp. 1-9, (to appear) [*DOI :* 10.1109/TMECH.2012.2225151], http://hal.inria.fr/hal-00690145

[16] E. LOVISARI, F. GARIN, S. ZAMPIERI. *Resistance-based performance analysis of the consensus algorithm over geometric graphs*, in "SIAM Journal on Control and Optimization", 2013, vol. 51, n^o 5, pp. 3918-3945 [*DOI :* 10.1137/110857428], http://hal.inria.fr/hal-00877382

[17] A. SEURET, M. M. PEET. *Stability analysis of sampled-data systems using Sum of Squares*, in "IEEE Transactions on Automatic Control", January 2013, vol. 58, n^o 6, pp. 1620-1625 [*DOI :* 10.1109/TAC.2012.2232378], http://hal.inria.fr/hal-00753538

International Conferences with Proceedings

[18] A. BEN KHALED, M. E. M. BEN GAÏD, D. SIMON. *Parallelization Approaches for the Time-Efficient Simulation of Hybrid Dynamical Systems: Application to Combustion Modeling*, in "EOOLT'2013: 5th International Workshop on Equation-Based Object-Oriented Modeling Languages and Tools", Nottingham, United Kingdom, April 2013, 10 p. , http://www.ep.liu.se/ecp_home/index.en.aspx?issue=084, http://hal.inria.fr/lirmm-00809529

[19] A. DE ALMEIDA, A. Y. KIBANGOU. *Distributed Computation of Tensor Decompositions in Collaborative Networks*, in "5th IEEE workshop on Computational Advances in Multi-Sensor Adaptive Processing (CAMSAP 2013)", Saint-Martin, France, December 2013, http://hal.inria.fr/hal-00912384

[20] A. DE ALMEIDA, A. Y. KIBANGOU, S. MIRON, D. ARAÙJO. *Joint data and connection topology recovery in collaborative wireless sensor networks*, in "38th International Conference on Acoustics, Speech, and Signal Processing, ICASSP 2013", Vancouver, Canada, May 2013, CDROM p. , Poster Session, http://hal.inria.fr/hal-00816687

[21] G. DE NUNZIO, C. CANUDAS DE WIT, P. MOULIN, D. DI DOMENICO. *Eco-Driving in Urban Traffic Networks using Traffic Signal Information*, in "CDC 2013 - 52nd IEEE Conference on Decision and Control", Florence, Italy, December 2013, http://hal.inria.fr/hal-00909223

[22] H. FOURATI, N. MANAMANNI. *Position Estimation Approach by Complementary Filter-aided IMU for Indoor Environment*, in "12th biannual European Control Conference (ECC 2013)", Zurich, Switzerland, July 2013, pp. 4028-4213, http://hal.inria.fr/hal-00797042

[23] P. FRASCA, F. GARIN. *On optimal coverage with unreliable sensors*, in "4th IFAC Workshop on Distributed Estimation and Control in Networked Systems (NecSys)", Koblenz, Germany, 2013, pp. 38-42 [*DOI :* 10.3182/20130925-2-DE-4044.00015], http://hal.inria.fr/hal-00877394

[24] F. GARIN, Y. YUAN. *Distributed privacy-preserving network size computation: A system-identification based method*, in "52nd IEEE Conference on Decision and Control (CDC 2013)", Florence, Italy, 2013, http://hal.inria.fr/hal-00860025

[25] A. Y. KIBANGOU, C. COMMAULT. *Algebraic Characterization of Observability in Distance-Regular Consensus Networks*, in "52nd IEEE Conference on Decision and Control (CDC 2013)", Florence, Italy, December 2013, http://hal.inria.fr/hal-00913926

[26] L. R. LEON OJEDA, A. Y. KIBANGOU, C. CANUDAS DE WIT. *Adaptive Kalman Filtering for Multi-Step ahead Traffic Flow Prediction*, in "2013 American Control Conference (ACC 2013)", Washington, United States, July 2013, http://hal.inria.fr/hal-00842684

[27] L. R. LEON OJEDA, A. Y. KIBANGOU, C. CANUDAS DE WIT. *Online Dynamic Travel Time Prediction using Speed and Flow Measurements*, in "12th biannual European Control Conference (ECC 2013)", Zurich, Switzerland, March 2013, http://hal.inria.fr/hal-00796604

[28] D. PISARSKI, C. CANUDAS DE WIT. *Optimal Balancing of Freeway Traffic Density: Application to the Grenoble South Ring*, in "12th biannual European Control Conference (ECC 2013)", Zurich, Switzerland, July 2013, http://hal.inria.fr/hal-00909159

[29] T.-M. D. TRAN, A. Y. KIBANGOU. *Consensus-based Distributed Estimation of Laplacian Eigenvalues of Undirected Graphs*, in "12th biannual European Control Conference (ECC 2013)", Zurich, Switzerland, July 2013, http://hal.inria.fr/hal-00842568

[30] T.-M. D. TRAN, A. Y. KIBANGOU. *Distributed Design of Finite-time Average Consensus Protocols*, in "4th IFAC Workshop on Distributed Estimation and Control in Networked Systems (NecSys)", Koblenz, Germany, September 2013, http://hal.inria.fr/hal-00863676

Scientific Books (or Scientific Book chapters)

[31] N. CARDOSO DE CASTRO, F. GARIN, C. CANUDAS DE WIT. *Optimal radio-mode switching for Wireless Networked Control*, in "Information and Control in Networks", G. COMO, B. BERNHARDSSON, A. RANTZER (editors), Lecture Notes in Control and Information Sciences, Springer, 2014, vol. 450, pp. 87-119, http://hal.inria.fr/hal-00877365

[32] H. FOURATI, N. MANAMANNI, L. AFILAL, Y. HANDRICH. *Rigid body motions capturing by means of wearable inertial and magnetic MEMS sensors assembly : from the reconstitution of the posture toward the dead reckoning: an application in Bio-logging*, in "Novel Advances in Microsystems Technologies and Their Applications (Devices, Circuits, and Systems)", L. A. FRANCIS, K. INIEWSKI (editors), Taylor & Francis Books, July 2013, pp. 393-409, http://hal.inria.fr/hal-00690146

[33] H. FOURATI, N. MANAMANNI, L. AFILAL, Y. HANDRICH. *Rigid body motions capturing by means of wearable inertial and magnetic MEMS sensors assembly: From the reconstitution of the posture toward the dead reckoning: an application in Bio-logging*, in "MEMS: Fundamental Technology and Applications (Devices, Circuits, and Systems)", Devices, Circuits, and Systems (Book 15), CRC Press, June 2013, pp. 313-329, http://hal.inria.fr/hal-00909138

[34] E. ROCHE, O. SENAME, D. SIMON. *LPV Approaches for Varying Sampling ControlDesign: Application to Autonomous Underwater Vehicles*, in "Robust Control and Linear Parameter Varying Approaches", O. SENAME, P. GASPAR, J. BOKOR (editors), Lecture Notes in Control and Information Sciences ; vol. 437, Springer-Verlag Berlin Heidelberg, January 2013, pp. 375-395 [*DOI :* 10.1007/978-3-642-36110-4_15], http://hal.inria.fr/hal-00802813

Research Reports

[35] M. AIDA, H. FOURATI, A. Y. KIBANGOU. , *Adaptive Kalman Filter for MEMS-IMU based Attitude Estimation under External Acceleration and Parsimonious use of Gyroscopes (submitted to ECC'2014)*, November 2013, http://hal.inria.fr/hal-00931187

[36] L. BRIÑON ARRANZ, A. SEURET, C. CANUDAS DE WIT. , *Cooperative Control Design for Time-Varying Formations of Multi-Agent Systems*, January 2014, http://hal.inria.fr/hal-00932841

[37] H. FOURATI. , *Heterogeneous Data Fusion Algorithm for Indoor Pedestrian Navigation via Foot-Mounted Inertial Measurement Unit (submitted to IEEE Transactions on Instrumentation and Measurement)*, December 2013, http://hal.inria.fr/hal-00931207

[38] H. FOURATI, Z. SAMIGULINA. , *Robust control system for Spacecraft Motion Trajectory (submitted to European Journal of Pure and Applied Mathematics)*, November 2013, http://hal.inria.fr/hal-00931222

[39] H. FOURATI, Z. SAMIGULINA. , *Adaptive Control strategy based reference model for Spacecraft Motion Trajectory (submitted to International Journal of Adaptive Control and Signal Processing)*, January 2014, http://hal.inria.fr/hal-00931219

Other Publications

[40] L. BRINON ARRANZ, A. SEURET. , *Cooperative Translation Control based on Consensus with Reference Velocity: a Source-seeking Application*, June 2013, http://hal.inria.fr/hal-00822715

[41] V. CIARLA, C. CANUDAS DE WIT, J. DUMON, F. QUAINE, V. CAHOUET. , *Definition of a methodology to adapt a model of steering assistance and its experimental validation*, 2013, http://hal.inria.fr/hal-00797633

References in notes

[42] C. CANUDAS DE WIT. *Best-effort Highway Traffic Congestion Control via Variable Speed Limits*, in "Proceedings od the IEEE CDC-ECC 2011", Orlando, Florida, US, December 2011, pp. 5959-5964, http://hal.archives-ouvertes.fr/hal-00642038

[43] C. CANUDAS DE WIT, L. R. LEON OJEDA, A. Y. KIBANGOU. *Graph constrained-CTM observer design for the Grenoble south ring*, in "13-th IFAC Symposium on Control in Transportation Systems", Sofia, Bulgarie, September 2012, http://hal.inria.fr/hal-00728555

[44] K.-H. JOHANSSON, M. TÖRNGREN, L. NIELSEN. , *Vehicle applications of controller area network*, Handbook of Networked and Embedded Control Systems, Birkhauser, 2005

[45] A. Y. KIBANGOU. *Graph Laplacian based Matrix Design for Finite-Time Distributed Average Consensus*, in "2012 American Control Conference (ACC 2012)", Montréal, Canada, June 2012, http://hal.inria.fr/hal-00680344

[46] D. PISARSKI, C. CANUDAS DE WIT. *Analysis and Design of Equilibrium Points for the Cell-Transmission Traffic Model*, in "2012 American Control Conference (ACC 2012)", Montreal, Canada, April 2012, http://hal.inria.fr/hal-00691522