IN PARTNERSHIP WITH:
CNRS

Institut polytechnique de Grenoble

Université Joseph Fourier (Grenoble)

Activity Report 2015

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

Creation of the Project-Team: 2007 January 01

Keywords:

Computer Science and Digital Science:

1. - Architectures, systems and networks
1.2. - Networks
1.2.7. - Cyber-physical systems
1.5. - Complex systems
3. - Data and knowledge
3.1. - Data
6. - Modeling, simulation and control
6.1. - Mathematical Modeling
6.2. - Scientific Computing, Numerical Analysis & Optimization
6.4. - Automatic control

Other Research Topics and Application Domains:

4. - Energy
4.2. - Renewable energy production
7. - Transport and logistics
7.1. - Traffic management
7.2. - Smart travel

1. Members

Research Scientists

Carlos Canudas de Wit [Team leader, CNRS, Senior Researcher, HdR]
Federica Garin [Inria, Researcher]
Enrico Lovisari [CNRS, Starting Research position, until Aug 2015]

Faculty Members

Hassen Fourati [Univ. Grenoble I, Associate Professor]
Alain Kibangou [Univ. Grenoble I, Associate Professor]

Engineers

Remi Piotaix [Inria, from Feb 2015]
Rohit Singhal [CNRS]
Anton Andreev [CNRS]

PhD Students

Giovanni de Nunzio [IFPEN, until Sep 2015]
Simon Gerwig [Alstom, granted by CIFRE]
Sebin Gracy [Univ. Grenoble I, from Oct 2015]
Stephane Durand [Univ. Grenoble I, from Oct 2015]
Pietro Grandinetti [CNRS]
Andres Alberto Ladino Lopez [CNRS]
Aida Makni [INP Grenoble]
Thibaud Michel [Univ. Grenoble I]

Thi Minh Dung Tran [Vietnamese Government scholarship, until Mar 2015]
Ruggero Fabbiano [until Mar 2015]

Visiting Scientists

Subhrakanti Dey [Univ. Uppsala, Sweden, from Jun 2015 until Jul 2015]
Paolo Frasca [Univ. Twente, The Netherlands, Nov 2015]

Administrative Assistant

Elodie Toihein [Inria]

Other

Tomas Manuel Pippia [Inria, Master Student (Erasmus), from Mar 2015 until Jul 2015]

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 together with one or more other components of different nature. The NECS team has tackled co-design problems concerning:

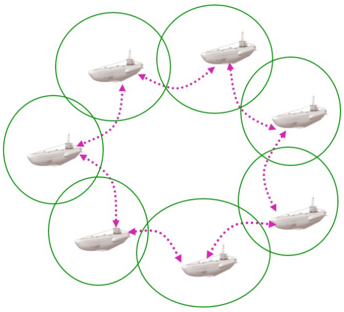
- Control under communications and network constraints;
- Control under resources constraints.

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).

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*



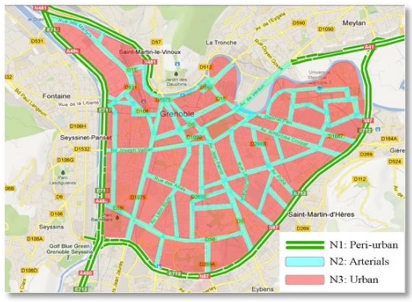


Figure 1. Left: a system of autonomous agents, where the network structure is created by the feedback, used to coordinate agents towards a common goal. Right: a system naturally having a network structure.

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 a new journal, IEEE Transactions on Control of Network Systems, whose first issue appeared 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 started in February 2014 and the LOCATE-ME project, which treats pedestrian navigation.
- 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. Network 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 opinion-forming in social networks or in formation of birds flocks, the potential leader might have a goal different from classical controllability. On the one hand, his goal might be much less ambitious than the classical one of driving the system to any possible state (e.g., he might want to drive everybody near its own opinion, only, and not to any combination of different individual opinions), and on the other hand he might have much weaker tools to construct his control input (e.g., he might not know the whole system's dynamics, but only some local partial information). 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

[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

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.

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.
- 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 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 [36], 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. Inertial navigation

Inertial navigation is a research area related to the determination of 3D attitude and position of a rigid body. Attitude estimation is based on data fusion from accelerometers, magnetometers and gyroscopes. Attitude is used in general to determine the linear acceleration, which needs to be integrated after to calculate the position. More recently, in the Persyval project LOCATE-ME (2014-2015), the team has started exploring Pedestrian navigation algorithms in collaboration with the Tyrex team (INRIA-Rhône-Alpes). The goal is to provide guidance to pedestriants, e.g., to first responders after a disaster, or to blind people walking in unfamiliar environments. This tasks is particularly challenging for indoor navigation, where no GPS is available.

4.4. 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 [1]. On-going research in the team concerns source localization, with a fleet of mobile robots, including wheeled land vehicles.

4.5. Control design of hydroelectric powerplants

We have started a collaboration with ALSTOM HYDRO, on collaborative and reconfigurable resilient control design of hydroelectric power plants. This work is within the framework of the joint laboratory Inria/ALSTOM (see http://www.inria.fr/innovation/actualites/laboratoire-commun-inria-alstom). A first concrete collaboration has been established with the CIFRE thesis of Simon Gerwig, who is currently studying how to improve performance of a hydro-electric power-plant outside its design operation conditions, by cancellation of oscillations that occur in such operation range.

5. Highlights of the Year

5.1. Highlights of the Year

- The publication of the book *Multisensor Data Fusion: From Algorithms and Architectural Design to Applications*, edited by Hassen Fourati
- Carlos Canudas de Wit was in the organizing committee of IPAM Long Program 'New Directions in Mathematical Approaches for Traffic Flow Management'
- Hassen Fourati was elected at CNU 61 and Alain Kibangou was elected at Conseil du pôle MSTIC, UGA

6. New Software and Platforms

6.1. GTL – Grenoble Traffic Lab

Participants: C. Canudas de Wit [contact person], I. Bellicot, P. Bellemain, L. Leon Ojeda, D. Pisarski, A. Kibangou, H. Fourati, F. Morbidi, F. Garin, A. Ladino Lopez, P. Grandinetti, E. Lovisari, R. Singhal, A. Andreev, R. Piotaix.

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 traffic control policies (ramp metering for the south-ring and optimization of urban signals); the micro-simulator is developed using AIMSUN.

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

6.2. Senslogs – Sensors recorder for Android application

Participants: T. Michel [contact person], H. Fourati, P. Geneves, N. Layaida.

This Android application records direct and computed measurements from internal sensors (Accelerometer, gyroscope, magnetometer, calibrated gyroscope, calibrated magnetic field, game rotation vector, geomagnetic, rotation vector, gravity, linear acceleration, significant motion, step counter, step detector, ambient temperature, light, pressure, relative humidity, heart rate, proximity, GPS location, cell and wifi location, passive location, NMEA data, wifi signals, Bluetooth signals (not yet), NFC (not yet), and others available...). Data are stored in files using space-separated values. This application has been designed for post-processing projects. It will be used in pedestrian navigation and augmented reality applications. This application is available online: https://play.google.com/store/apps/details?id=fr.inria.tyrex.senslogs&hl=fr_BE

7. New Results

7.1. Network systems and graph analysis

7.1.1. Distributed estimation of graph Laplacian eigenvalues

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

Linear average-consensus is a well-known iterative protocol allowing agents to converge to the average of initial values by taking suitable convex combinations of the messages received from neighbors. From the recent literature, it is known that, after a finite time, some consecutive measurements of a state of the consensus dynamical system can be used to compute the exact average of the initial condition. In [23], we have shown that these measurements can also be used for estimating the Laplacian eigenvalues of the graph representing the network. As recently shown in the literature, by solving the factorization of the averaging matrix, the Laplacian eigenvalues can be inferred. In our paper, the problem is posed as a constrained consensus problem. A first formulation (direct approach) yields a non-convex optimization problem, which we solve in a distributed way using Lagrange multipliers. A second formulation (indirect approach) is obtained after a suitable re-parameterization. The problem is then convex and is solved by using the distributed subgradient algorithm and the alternating direction method of multipliers (ADMM). The proposed algorithms allow estimating the actual Laplacian eigenvalues with high accuracy. However, they face numerical instability when considering very large graphs.

7.1.2. Distributed solution to the network reconstruction problem

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

We address the problem of reconstructing the network topology from data propagated through the network by means of a linear average-consensus protocol. In [34], we propose a new method based on the distributed estimation of graph Laplacian spectral properties. Precisely, the identification of the network topology is implemented by estimating both eigenvalues and eigenvectors of the consensus matrix, which is related to the graph Laplacian matrix. Having already solved in [23] the problem of estimating the eigenvalues (see paragraph above), in this paper we focus on the eigenvectors. We show how the topology can be reconstructed in presence of anonymous nodes, i.e., nodes that do not disclose their ID. Actually, in presence of anonymous nodes, eigenvectors are estimated up to a permutation of rows; the obtained graph is then isomorphic to the original one. Moreoved, under some observability assumption on the consensus dynamical system (if the graph is node-observable or neighborhood-observable from the node of interest) and if all the entries of the initial condition of the network state are distinct, then the node can exactly reconstruct the network topology. If the entries of the initial condition of the network state are independently generated from a continuous probability distribution, then the node can reconstruct the network topology almost surely. The main assumption in this work is: all eigenvalues are distinct, that is the case of most random graphs. Future works encompass the design of the network reconstruction protocol that deals with spectrums in which the multiplicities of the eigenvalues can be higher than 1 and also directed graphs. In addition, numerical issues for large graphs are to be considered for making the proposed method scalable.

7.2. Sensor networks: estimation and data fusion

7.2.1. Multisensor data fusion for attitude estimation

Participants: H. Fourati [Contact person], A. Kibangou, A. Makni, T. Michel, P. Geneves [Tyrex, Inria], N. Layaida [Tyrex, Inria].

Multisensor data fusion has gained in importance over the last decades and found applications in an impressive variety of areas within diverse disciplines: navigation, sensor networks, intelligent transportation systems, security, medical diagnosis, biometrics, environmental monitoring, remote sensing, measurements, robotics, and so forth. Different concepts, techniques, and architectures have been developed to optimize the overall system output in applications for which sensor fusion might be useful and enables development of concrete solutions. These concepts and ideas are treated in the book [35], as a response to the great interest and strong activities in the field of multisensor data fusion during the last few years, both in theoretical and practical aspects.

In the team, we have carried out works related to attitude estimation for pedestrian navigation purpose.

In [32], we investigated a new modeling and filtering approach for rigid body attitude estimation. In contrast to the current state-of-the-art. where the process model is driven by gyroscope measurements, we propose an alternative modeling formulation where the process model is fed by the magnetometer measurements. The resulting dynamic model takes the form of a descriptor system, also known as singular system. Based on this model and using the quaternion formalism we derive a recursive filter whose performance is validated through numerical and experimental tests.

In [20], we focused on two main challenges. The first one concerns the attitude estimation during dynamic cases, in which external acceleration occurs. In order to compensate for such external acceleration, we design a quaternion-based adaptive Kalman filter q-AKF. Precisely, a smart detector is designed to decide whether the body is in static or dynamic case. Then, the covariance matrix of the external acceleration is estimated to tune the filter gain. The second challenge is related to the energy consumption issue of gyroscope. In order to ensure a longer battery life for the Inertial Measurement Units, we study the way to reduce the gyro measurements acquisition by switching on/off the sensor while maintaining an acceptable attitude estimation. The switching policy is based on the designed detector. The efficiency of the proposed scheme is evaluated by means of numerical simulations and experimental tests.

In [33], we investigated the precision of attitude estimation solutions in the context of Pedestrian Dead-Reckoning (PDR) with commodity smartphones and inertial/magnetic sensors by carrying out a concise comparison of various methods. We conducted an experimental study with a precise ground truth obtained with a motion capture system. We precisely quantified the error in attitude estimation obtained with each filter which combines a 3-axis accelerometer, a 3-axis magnetometer and a 3-axis gyroscope measurements.

7.2.2. Sensor placement of unreliable sensors

Participants: F. Garin [Contact person], P. Frasca [U. Twente], B. Gerencsér [U. Catholique de Louvain], J. Hendrickx [U. Catholique de Louvain].

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. In our work, we assume that sensor can fail, independently and with a same failure probability, and we aim to minimize, in expectation, the largest distance between a point in the environment and an active sensor. Our first result states that the problem at hand is equivalent to a linear program, albeit with a number of variables growing exponentially with the number of sensors. This fact allows for a computational solution that is tractable if the number of sensors is not large. Secondly, we show that for large number of sensors n, the cost of the equispaced placement is asymptotically optimal, i.e., the ratio between its cost and the optimal cost tends to 1 when n grows. By contrast, we show in that a random sensor placement has an expected cost which is larger. This work is described in the paper [18].

7.3. Control design and networked control

7.3.1. Control design for hydro-electric power-plants

Participants: C. Canudas de Wit [Contact person], S. Gerwig, F. Garin, B. Sari [Alstom].

We have a collaboration with Alstom on collaborative and resilient control of hydro-electric power-plants, with the CIFRE PhD thesis of Simon Gerwig. The first goal of this research is to improve performance of a hydro-electric power-plant outside its design operation conditions, by cancellation of oscillations that occur in such an operation range. Indeed, current operation of power-plants often requires to operate on a variety of conditions, often different from the ones initially considered when designing the plant. At off-design operation pressure, the hydraulic turbine exhibits a vortex rope below the runner. This vortex generates pressure fluctuations after the turbine and can excite the hydraulic pipes. Indeed the water is compressible and the pipe walls elastic, so the system can oscillate. The goal is to damp these pressure oscillations as they create vibrations in the system and can lead to damages. Our first contribution has been to model the effect of the vortex rope on the hydraulic system as an external perturbation source acting on pipes. The pipes themselves are described with equations taking into account water compressibility and pipe-wall elasticity. The resulting model is nonlinear with hyperbolic functions in the equations (analogous to high-frequency transmission lines), from which we obtain a suitably linearized model.

7.3.2. Collaborative source seeking

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

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 is particularly difficult when 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 robust to measurement noise. We also propose a distributed version of this algorithm, where agents communicate in order to reconstruct gradient information from local pointwise measurements, and a control law combines the two objectives of formation control (to have a circular formation, so that measurements are taken around circle) and gradient ascent (so as to move towards the source); differently from previous literature, the moving agents do not need to know their absolute position, but only relative bearing angle of their neighbours. This work is the topic of the Ph.D. thesis of Ruggero Fabbiano [12].

7.3.3. Synchronization of heterogenous networks

Participants: E. Lovisari [Contact person], C.-Y. Kao [National Sun Yat-Sen University, Taiwan].

Syncronization of agents in large-scale networks is studied in [19]. Each agent is modeled as a Single Input Single Output operator composed of the series of a common Linear Time-Invariant system and a possibly nonlinear perturbation. Interconnection is represented via a graph whose edges model communication channels between agents, in turn modeled as a nominal component and a possibly nonlinear perturbation. Two agents are synchronized if their outputs are the same, possibly time-varying signal. The main result provides synchronization certificates based on the Robust Control Technique of Integral Quadratic Constraints. Exploitation of graph structures allows then to reduce the computational burden of the certificate in a way that scales with the dimension of the network. This provides framework which unifies and extendes several results already presented in the literature.

7.3.4. Observer-based FDI scheme for switched systems with sensor faults

Participants: H. Fourati [Contact person], D. E. C. Belkhiat [U. Setif], D. Jabri [U. Setif].

The Fault Detection and Isolation (FDI) problem for a class of Switched Linear Systems (SLS) subject to sensor faults and unknown bounded Disturbances is proposed in [24]. The main work is based on the design of a generalized switched observer scheme. The FDI problems have been solved by using a robust control techniques. A suitable trade-off between the robustness to disturbances and the sensitivity to sensor faults was obtained. The main results are reformulated by using Linear Matrix Inequality (LMI) formulation. An example is included to illustrate the efficiency of the proposed approach.

7.4. Transportation networks and vehicular systems

7.4.1. Traffic estimation: sensors placement and data fusion

Participants: C. Canudas de Wit [Contact person], E. Lovisari, A. Kibangou.

Ability to reconstruct the state of a transportation network is of paramount importance. Indeed, such an information is used to forecast traffic evolution, to inform drivers in real-time through navigation systems, to provide statistical information to public authorities to detect in a timely fashion accidents and predict hazardous scenarios, and finally to compute controls and to actuate the network through traffic lights, ramp metering, or adaptive speed limits.

A primary source of information on the state of the network are fixed traffic detectors, namely, devices able to measure density, flow and average speed of vehicles crossing the section of the road where they are placed. We have addressed the Optimal Sensor Placement problem [31], namely, the problem of finding the best physical location for sensors. This is based on a trade-off of two contrasting objectives: the first, to maximize the performance of state reconstruction; the second, to minimize the total economic cost of the network. To simplify the setting, we consider the related problem of reconstruction in a static setting, by considering as performance metric the error covariance of an estimator of the cumulative flows in the network over a long period of time. Since the resulting trade-off problem remains a combinatorial problem, we relax it using a method that we call Virtual Variance algorithm, based on the idea to associate to each sensor a virtual variance, which is large when the sensor is not needed for good reconstruction of the flow vector. The only input that the algorithm needs is an estimate of the matrix of splitting ratios and the nominal variance of each sensor. Since in real application a pre-existing sensor network is often unavailable, possible alternatives are field surveys with operators visually counting vehicles, as commonly done for calibration of traffic software, or temporary non-invasive equipment such as radar traffic detectors.

In addition to fixed traffic detectors, the spread of wireless devices allows new sensing and communication capabilities. In particular, for the traffic application, any vehicle equipped with a GPS device can act as a probe in the traffic and provide Floating Car Data (FCD). If a non negligible fraction of vehicles acts as probe, the collected data provides an estimate of the evolution of speed in the network. Due to privacy reasons, single vehicles traces are usually not directly used, but rather aggregated as average speed of vehicles in segments of road. Advanced methodologies, such as the one used by INRIX, ensure a very fine spatial partition of the network, with segments as short as 250 meters (see the INRIX official website http://www.inrix.com/xd-traffic). Compared to fixed sensors, this technology is less precise, but since it exploits existing communication systems it is relatively less expensive and already covers all major traffic networks. In our work [30], [29], we propose an algorithm that aims at reconstructing the traffic density by fusing fixed sensors measurements and Floating Car Data. We employ a macroscopic model, partitioning the network in cells and assigning to each cell a density of vehicles. The latter evolves dynamically according to a first order mass-conservation law. Our approach inherits from the CTM the cell-based topology, but we do not directly employ the resulting dynamical model. Instead, inflows and outflows are estimated on the basis of the available flow measurements only, and speed measurements are employed to compute a pseudo-measurement of the density. These quantities are the inputs for the density observer. In addition, we propose a gradient descent method to calibrate the Fundamental Diagram, and we implement the proposed solution using real fixed sensor measurements from the Grenoble Traffic Lab [14] and speed FCD measurements provided by INRIX, one of the most well known traffic solutions companies.

7.4.2. Traffic forecasting

Participants: A. Kibangou [Contact person], C. Canudas de Wit, H. Fourati, A. Ladino Lopez.

Traffic forecasting is one of the most desired tools for traffic management, requested by operators and commuters. In the era of data deluge in which we are, measurements collected by sensors are important sources of information that require analysis, classification and processing in order to detect patterns and behaviours that can be exploited for traffic prediction ([30], [37]). The collected information can be classified by clustering algorithms such as K-means; each cluster collects traffic patterns, which in some cases characterize typical regimes such as congestion. Based on clustered data, we have first developed forecasting schemes based on adaptive Kalman filtering [14]. These schemes were designed for specific origin-destination (OD) pairs, assuming availability of meaurements whatever the time instants. Recently, within the PhD thesis in progress of Andres Ladino Lopez, we considered a network-oriented forecasting scheme, where travel time measurements are assumed to be available only for a few sets of OD pairs and sporadically (missing data), but forecasting is to be achieved for all the OD pairs of the network. To reduce the dimensionality of the problem, we actually predicted the travel time for the internal state of the network. In addition, since travel time measurements for all the OD pairs cannot be available all the time, we faced a missing data problem. To overcome this issue, we resorted to a data imputation based on a dictionary learning approach. From the imputed data, a clusterization was achieved, defining different clusters characterized by a centroid containing the mean of the data and a given dispersion around it. The evolution of the centroid can be used as future observation, herein called pseudo-observation, that can feed a Kalman filter. Therefore the prediction problem was solved as a filtering one. However, the main question was, how to associate the current day data to a specific cluster, since we didn't know its future? To solve this issue, we run Kalman filters for each cluster and then made the fusion of the obtained forecasts.

7.4.3. Traffic control

Participants: C. Canudas de Wit [Contact person], F. Garin, D. Pisarski, P. Grandinetti, E. Lovisari, G. Como [U. Lund], K. Savla [U. of Southern California].

The activities of the team on traffic control can be organized in three parts: freeway traffic control, urban control, and analysis and control of monotone flows.

First,we have studied optimal balancing of vehicle density in the freeway traffic. The optimization is performed in a distributed manner by utilizing the controllability properties of the freeway network represented by the Cell Transmission Model. By using these properties, we identify the subsystems to be controlled by local ramp meters. The optimization problem is then formulated as a non-cooperative Nash game that is solved by decomposing it into a set of two-players hierarchical and competitive games. The process of optimization employs the communication channels matching the switching structure of system interconnectivity. By defining the internal model for the boundary flows, local optimal control problems are efficiently solved by utilizing the method of Linear Quadratic Regulator. The developed control strategy is tested via numerical simulations in two scenarios for uniformly congested and transient traffic. This work is described in the paper [21].

Second, we have considered optimal or near-optimal operation of traffic lights in an urban area. The goal is on-line optimization of traffic light schedule in real time, so as to take into account variable traffic demands, with the objective of obtaining a better use of the road infrastructure. More precisely, we aim at maximizing total travel distance within the network, while also ensuring good servicing of demands of incoming cars in the network from other areas. One way to address the complexity of the resulting optimization problem is to use a simplified averaged model for the traffic variables, and to optimize only the duty-cyles of traffic lights, i.e., the fractions of green time. This, together with a one-step optimization horizon, allows us to turn the problem into a simple linear program [27]. Another approach is to include as optimization variables both duty-cycles and phases of the traffic lights. We show how to turn the resulting problem into a mixed-integer linear program (MILP). Then, to overcome its complexity, we propose a sub-optimal distributed solution, while the global MILP can be used off-line for performance comparison [28].

Third, stability and throughput properties of monotone dynamical flow networks are studied in [15]. Vehicular density on the cells of the networks evolves according to laws that deterministically split the traffic flow at each intersection as a function of the density of other cells around the intersection. By exploiting the theory of monotone operators it is proven that under certain condition the system achieves an equilibrium that maximizes the throughput of the network, namely, if the inflow is smaller than the network capacity, then asymptotically the total outflow matches the total inflow, otherwise the total outflow matches the network capacity. In [25] a different traffic model is employed which uses demand and supply functions to relate density and flows of the network. The Social Optimum Dynamic Traffic Assignment, which is an optimal control problem with cost corresponding to the total travel time of vehicles in the network, is solved making use of ramp metering and speed limits. The optimization is shown to be a convex optimization problem, making its numerical solution feasible by employing well known tools.

7.4.4. Energy-aware control of communicating vehicles

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

The research in this domain focuses mainly on efficient traffic energy consumption and has been carried out at two levels. Strategies for both the vehicles-side and the infrastructure-side eco-management have been proposed or extended. As for the vehicle-side control of communicating vehicles, assuming I2V communication, and therefore full knowledge of the traffic lights timings, the goal is to analyze the driving horizon and compute an energy-efficient speed advisory for the driver. As in previous works, stops at a red traffic light are to be avoided. The novelty of our approach is summarized as follows. Given a set of green traffic light phases, there exist different driving profiles to reach a given destination at a given final time in compliance with traffic lights constraints (i.e. always catching the green light) and city speed limits. The presented strategy is capable of an a priori identification of the most energy-efficient velocity trajectory, by approximating the available paths and their energy cost with an oriented weighted graph. The computational complexity of the graph creation has been reduced in this work from exponential [26] to polynomial, thanks to the introduction of the line graph. The computation time has been consequently significantly reduced. Only after this preliminary stage of path selection, a formal optimization problem is solved in order to calculate the optimal arrival times at each intersection, by explicitly minimizing the energy consumption of the vehicle. This approach qualifies as a pre-trip eco-driving ADAS, since the speed advisory is provided to the driver at the beginning of the driver horizon. However, given the very little computation time required by the algorithm, it may be employed online thus enabling in-trip assistance features. This allows to respond dynamically to traffic perturbations and/or deviations from the speed advisory, and to increase the robustness and the applicability of the strategy in a realistic environment. Simulations in a microscopic traffic simulator demonstrate that the proposed strategy is able to deal online with perturbations coming from traffic and to reduce the overall energy consumption without affecting travel time [16].

At a lower level, the eco-driving from the vehicle perspective has been also addressed in a comprehensive analysis of the optimal driving strategy for different types of powertrains [22].

As for the infrastructure-side eco-management, this year's research focused on extending the results published in [26]. The two-way arterial bandwidth maximization problem is addressed with a particular focus on the benefits induced by the speed advisory, and on reducing energy consumption. The problem with internal offsets constraints presents difficulties that make necessary the formulation of the problem as an MILP. The first contribution of our work lies in the addition of terms representing traffic energy consumption and network travel time to the objective function of the two-way arterial bandwidth maximization. The segment speeds, as additional control action, allow to reach higher theoretical bandwidths but might induce driving discomfort and higher energy consumption if the variability of the recommended speeds is too high. Furthermore, optimal solutions with low speeds and high travel time are to be avoided, in trade-off with the energy consumption. The second contribution is given by the extensive evaluation of the benefits of bandwidth maximization via a microscopic traffic simulator. Bandwidth is a theoretical quantity and a correlation with known traffic performance metrics needs to be established in order to justify its use. The combined control of offsets and speed advisory is shown to have a large impact on energy consumption without affecting the travel time. Lastly, an analysis of the traffic performance at different levels of traffic demands has been conducted, testing both under-saturated traffic conditions with the existence of a green wave, and saturated conditions. The goal of this analysis is to identify the best operation conditions of the presented approach, assess the performance degradation with traffic load, and, most importantly, propose a demand-dependent optimization. Several strategies were compared to the presented one in order to assess its performance. This work has been submitted for review to the IEEE Transactions on Control Systems Technology.

Finally, a detailed description of the proposed strategies and the achieved results in the domain of the energy-aware traffic management in urban networks can be found in the dissertation [11].

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

8.1.1. ALSTOM

Contract with ALSTOM in the framework of Inria/ALSTOM joint laboratory, and CIFRE PhD grant of Simon Gerwig. This thesis explores collaborative and reconfigurable resilient control design of hydroelectric power plants; current work is on improving performance of a hydro-electric power-plant outside its design operation conditions, by cancellation of oscillations that occur in such operation range.

8.1.2. INRIX

A collaboration with INRIX has concerned floating car data, namely data about cars velocity collected from mobile devices, that are useful to complement density and velocity measurements from road sensors.

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. 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).

9.1.2. Projet exploratoire Persyval LOCATE-ME

LOCATE-ME (LOcalization teChniques for pedestriAn navigaTion based on inErtial MEasurements in indoor environments) is a Persyval project funded from April 2014 to August 2015. It aims at proposing a new and fresh look on innovative technologies for localization. It constructs the scientific foundations for development of a prototype of a pedestrian indoor localization system, which has the ability to monitor and track the positions of pedestrians in an indoor environment, where GPS is not available. LOCATE-ME brings some answers on how to advance the current pedestrian navigation solutions for the critical domains, using robust software. The specific contribution of LOCATE-ME is the development of a novel fusion algorithm merging two different methods of localization (INS and SHS) to obtain a concrete improvement on tracking position. This project involves also Tyrex team (LIG, Inria Grenoble). The collaboration has also included a visit to Grenoble of Valérie Renaudin (IFSTTAR, Nantes), in March 2015.

9.2. European Initiatives

9.2.1. FP7 & H2020 Projects

9.2.1.1. 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 is developing 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 leads the intelligent traffic-management use and show case.

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

9.3. International Initiatives

9.3.1. Inria International Labs

Inria@SiliconValley
Associate Team involved in the International Lab:

9.3.1.1. COMFORT

Title: COntrol and FOrecasting in Transportation networks

International Partner (Institution - Laboratory - Researcher):

University of California Berkeley (United States) - Mechanical Engineering - Roberto Horowitz

Start year: 2014

See also: http://necs.inrialpes.fr/v2/pages/comfort/EA_homepage_COMFORT.html

COMFORT addresses open issues for Intelligent Transportation Systems (ITS). The goal of these systems is to use information technologies (sensing, signal processing, machine learning, communications, and control) to improve traffic flow, as well as enhance the safety and comfort of drivers. It has been established over the past several decades, through field studies and many scholarly publications, that the tools of ITS can significantly improve the flow of traffic on congested freeways and streets. Traffic operators can manage the system in a top-down fashion, for example, by changing the speed limit on a freeway, or by controlling the flow on the onramps (ramp metering). Individual drivers can also affect traffic conditions from the bottom up, by making decisions based on reliable predictions. These predictions must be provided by a centralized system that can evaluate the decisions based on global information and sophisticate modeling techniques. It is now crucial to develop efficient algorithms for control and prediction that are well adapted to current and emerging sensing and communication technologies. The areas of traffic modeling and calibration, state estimation, and traffic control remain central to this effort. Specifically, COMFORT addresses issues related to model validation and development of new traffic forecasting and distributed control algorithms. The efficiency of the derived methods will be assessed using large networks simulators and real data obtained from the Californian and the Grenoble's testbed.

9.3.2. Participation In other International Programs

9.3.2.1. TICO-MED

TicoMed (Traitement du signal Traitement numérique multidimensionnel de l'Information avec applications aux Télécommunications et au génie Biomédical) is a French-Brazilian project funded by CAPES-COFECUB. It started in February 2015 with University of Nice Sophia Antipolis (I3S Laboratory), CNAM, SUPELEC, University of Grenoble Alpes (Gipsa-Lab), Universidade Federal do Ceara, Universidade Federal do Rio de Janeiro, and Universidade Federal do Santa Catarina as partners.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

- Prof. Subrhakanty Dey (University of Uppsala, Sweden) visited the team from June 6th to July 7th, for reserach discussions, in particular with F. Garin and A. Kibangou on privacy issues in cyber-physical systems.
- Prof. Gerhard Hancke (Dept of Electrical, Electronic and Computer Engineering, University of Pretoria, South Africa) visited the team and the Doctoral college of UGA in order to set up student exchange program in July 2015.
- Prof. Paolo Frasca (University of Twente, Enschede, The Netherlands) visited the team for two weeks in October, for research discussions with team members, and in particular with C. Canudas de Wit on open problems in social dynamics related to traffic drivers.
- Prof. Joao Cesar Moura Mota (Universidade Federal do Ceara, Brazil) visited the team in December 2015 within the framework of the French-Brazilian CAPES-COFECUB project TICO-MED.

9.4.1.1. Internships

- Tomas Manuel Pippia from University of Pavia, Italy, made his reserach internship for his master thesis in the team, from March to July.

9.4.2. Visits to International Teams

9.4.2.1. Research stays abroad

- A. Kibangou visited UC Berkeley during the BIS workshop (Berkeley-Inria-Stanford, May 12-15). During this stay, A. Kibangou participated as a member for the panel dedicated to Urban mobility. He had discussions with G. GOMES (UC Berkeley) on different topics about traffic including flow prediction and interfacing traffic micro-simulator such as AIMSUM with Matlab.

- C. Canudas de Wit visited UC Berkeley for a week in October. He had research meetings with faculty and students at ITS an PATH, and in particular with prof. Horowitz and dr. Gomes. On Oct 23rd he gave an invited lecture at Institute of Tranpsortation Studies (ITS) and the Transportation Program of the Civil and Enviromental Engineering Department at the University of California, Berkeley, in the ITS tranpsortation seminar program.
- Various team members attended the IPAM Long Program New Directions in Mathematical Approaches for Traffic Flow Management (http://www.ipam.ucla.edu/programs/long-programs/new-directions-in-mathematical-approaches-for-traffic-flow-management), at UCLA, Los Angeles. IPAM long programs are a collection of one-week workshops, intertwined with study periods, where participants are encouraged to pursue their own research while interacting with other participants.
  - A. Ladino, 26 Sept. to 24 Oct. (Workshops I Mathematical Foundations of Traffic and II Traffic Estimation, and a study period)
  - P. Grandinetti, 25 Oct. to 20 Nov. (Workshops III Traffic Control and IV Decision Support for Traffic, and a study period)
  - C. Canudas de Wit, Oct. 10-16 and 25-31 (Workshops II Traffic Estimation and III Traffic Control)
  - F. Garin, Oct. 25-30 (Workshop III Traffic Control)

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific events organisation

10.1.1.1. Member of the organizing committees

Alain Kibangou was member of the organizing committe of ‘Premières Journées de l’Automatique du GDR MACS’, 5-6 October 2015, Grenoble.

10.1.2. Scientific events selection

10.1.2.1. Member of the conference program committees

Alain Kibangou was a member of the program committee for the International Workshop on Big Data and Smart Sustainable Society (BigData-2015), http://www2.docm.mmu.ac.uk/STAFF/L.Han/BigData-2015/index.htm, held in conjunction with the 14th IEEE International Conference on Ubiquitous Computing and Communications (IUCC-2015), http://cse.stfx.ca/~iucc2015.
Hassen Fourati was a member of the International and Scientific Program Committees of:

- 4th International Conference on Systems and Control (ICSC’15), Hammamet, Tunisia, April 28-30, 2015 (http://lias.labo.univ-poitiers.fr/icsc/icsc2015/index.php);
- International Electrical and Computer Engineering Conference IECEC’15, Setif, Algeria, May 23-25, 2015 (http://www.univ-setif.dz/IECEC2015);
- 16th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering STA’2015, Monastir, Tunisia, December 21-23, 2015.

10.1.2.2. Reviewer

Team members have been reviewers for many conferences (including the most prestigious ones in their research area): IEEE Conference on Decision and Control CDC, European Control Conference ECC, American Control Conference ACC, European Signal Processing Conference, IEEE International Conference on Robotics and Automation ICRA, IEEE/RSJ International Conference on Intelligent Robots and Systems IROS, IFAC Workshop on Distributed Estimation and Control in Networked Systems (NecSys).

10.1.3. Journal

10.1.3.1. Member of the editorial boards

Carlos Canudas de Wit is Associate Editor of IEEE Transactions on Control of Networks Systems IEEE-TCNS (since June 2013), Associate Editor of IEEE Transactions on Control System Technology IEEE-TCST (since January 2013), and Editor of the Asian Journal of Control AJC (since 2010).

10.1.3.2. Reviewer

Team members have been reviwers for many journals (including the most prestigious ones in their reserach area): IEEE Trans. on Automatic Control, IEEE Trans. on Control of Network Systems, IEEE Trans. on Signal Processing, Automatica, IEEE Signal Processing Letters, Systems and Control Letters, IEEE Transactions on Information Theory, Journal of the Franklin Institute, Journal of Process Control, Elsevier Signal Processing, Int. Journal of Robust and Nonlinear Control, IET Communications, IET Wireless Sensor Networks. IEEE/ASME Trans. on Mechatronics, IEEE Trans. on Instrumentations and Measurements, IEEE Sensors journal, Sensors, IEEE Trans. on Robotics, Micromachines.

10.1.4. Invited talks

- C. Canudas de Wit, *Nash Game Based Distributed Control Design for Balancing of Traffic Density over Freeway Networks*, Transportation seminar series of the Institute of Transportation Studies (ITS) and the Transportation Program of the Civil and Environmental Engineering Department at the University of California, Berkeley, Oct. 2015.
- C. Canudas de Wit, *Distributed Optimal Traffic Control*, IPAM Workshop 'New Directions in Mathematical Approaches for Traffic Flow Management – Workshop III-Traffic Control', Oct. 2015.
- F. Garin, *Towards on-line optimization of urban traffic lights*, IPAM Workshop 'New Directions in Mathematical Approaches for Traffic Flow Management – Workshop III-Traffic Control', Oct. 2015.

10.1.5. Leadership within the scientific community

C. Canudas de Wit has been president of the European Control Association (EUCA) until June 2015, and is now Past-president and member of the EUCA Council.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Master: F. Garin, Distributed Algorithms and Network Systems, 13.5h, M2, University Joseph Fourier, France.

Licence: H. Fourati, Informatique Industrielle, 105h, L1, IUT 1 (GEII), University Joseph Fourier, France;

Licence: H. Fourati, Réseaux locaux industriels, 50h, L1 et L2, IUT1 (GEII), University Joseph Fourier, France.

Licence: H. Fourati, Automatique, 61,5h, L3, UFR physique, University Joseph Fourier, France.

Licence: H. Fourati, Automatique échantillonnée, 15h, L2, IUT 1 (GEII), University Joseph Fourier, France.

Licence: A. Kibangou, Automatique, 52h, L2, IUT1(GEII1), University Joseph Fourier, France.

Licence: A. Kibangou, Mathématiques, 33h, L2, IUT1 (GEII1), University Joseph Fourier, France.

Licence: A. Kibangou, Mathématiques, 44h, L1, IUT1 (GEII1), University Joseph Fourier, France.

Licence: A. Kibangou, Automatique, 16h, L3, IUT1 (GEII1), University Joseph Fourier, France

10.2.2. Supervision

PhD: Thi-Minh Dung Tran, Methods for finite-time average concensus protocols design, network robustness assessment and network topology reconstruction, Grenoble University, March 26th, 2015

PhD: Ruggero Fabbiano, Collaborative source seeking-seeking control, Grenoble University, May 25th, 2015.

PhD: Giovanni de Nunzio, Traffic eco-management in urban traffic networks, Grenoble University, Oct. 2nd, 2015.

PhD in progress: Aida Makni, Fusion de données inertielles et magnétiques pour l'estimation de l'attitude sous contrainte énergétique d'un corps rigide accéléré, from Oct. 2012, co-advised by H. Fourati, A. Kibangou and C. Canudas de Wit.

PhD in progress: Simon Gerwig, Collaborative, reconfigurable and resilient control for hydro-electric power-plants, from Feb. 2014, co-advised by C. Canudas de Wit, F. Garin and B. Sari (Alstom).

PhD in progress: Pietro Grandinetti, Control of large-scale traffic networks, from Apr. 2014, co-advised by C. Canudas de Wit and F. Garin.

PhD in progress: Andrés Alberto Ladino Lopez, Robust estimation and prediction in large scale traffic networks, from Oct. 2014, co-advised by C. Canudas de Wit, A. Kibangou and H. Fourati.

PhD in progress: Thibaud Michel, Mobile Augmented Reality Applications for Smart Cities, from Nov. 2014, co-advised by N. Layaïda, H. Fourati and P. Geneves.

PhD in progress: Sebing Gracy, Cyber-physical systems: a control-theoretic approach to privacy and security, from Oct. 2015, co-advised by A. Kibangou and F. Garin.

PhD in progress: Stéphane Durand, Coupling distributed control and game theory: application to self-optimizing systems, from Oct. 2015, co-advised by B. Gaujal and F. Garin.

10.2.3. Juries

- C. Canudas was president of the Ph.D. defense committee of Pascal Combes, École Nationale Supérieure des Mines de Paris, Spécialité Mathématique et Automatique, Dec. 3rd, 2015
- A. Kibangou was external reviewer and committee member of two master thesis defenses for University of Pretoria: Roy Fisher (July 2015) and Daniel Ramotsoela (November 2015).
- F. Garin was committee member of the master thesis defense of Hourai Bettahar, MiSCIT Master, Grenoble, July 2015.

10.3. Popularization

The team's work on traffic prediction and control, with Grenoble Traffic Lab, has been popularized as follows:

- an interview reported in an article in CNRS 'Le Journal', and a related video (in French, see https://lejournal.cnrs.fr/articles/quelle-voiture-pour-demain)
- a video prepared by Inria for RII–Rencontres Inria-Industrie (in English, see https://www.youtube.com/watch?v=Uia4Y-9c6k0&index=5&list=PLV1fJrIaqWlMe5savY102Oz-M_hVmXg30).
- H. Fourati gave a talk 'Prédiction et contrôle du trafic routier sur Grenoble : une solution automatisée avec MATLAB' at the 'journée Nouveautés MATLAB 2015a, Data Analytics & Calcul Parallèle', Grenoble, March 26th.

11. Bibliography

Major publications by the team in recent years

[1] 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, vol. 59, n° 8, http://hal.archives-ouvertes.fr/hal-00932841

[2] C. CANUDAS DE WIT, F. MORBIDI, L. LEON OJEDA, A. Y. KIBANGOU, I. BELLICOT, P. BELLEMAIN. *Grenoble Traffic Lab: An experimental platform for advanced traffic monitoring and forecasting*, in "IEEE Control Systems", June 2015, vol. 35, n° 3, pp. 23-39, https://hal.archives-ouvertes.fr/hal-01059126

[3] H. FOURATI. *Multisensor Data Fusion: From Algorithms and Architectural Design to Applications (Book)*, Series: Devices, Circuits, and Systems, CRC Press, Taylor & Francis Group LLC, August 2015, 663 p. , https://hal.inria.fr/hal-01169514

[4] 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

[5] 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", February 2014, vol. 19, n° 1, pp. 149-157 [*DOI :* 10.1109/TMECH.2012.2225151], https://hal.archives-ouvertes.fr/hal-00690145

[6] 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

[7] 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/

[8] A. Y. KIBANGOU, C. COMMAULT. *Observability in Connected Strongly Regular Graphs and Distance Regular Graphs*, in "IEEE Transactions on Control of Network Systems", December 2014, vol. 1, n° 4, pp. 360-369 [*DOI :* 10.1109/TCNS.2014.2357532], https://hal.archives-ouvertes.fr/hal-01092954

[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. *Nash Game Based Distributed Control Design for Balancing of Traffic Density over Freeway Networks*, in "IEEE Transactions on Control of Network Systems", 2015, vol. PP, n° 99 [*DOI :* 10.1109/TCNS.2015.2428332], https://hal.archives-ouvertes.fr/hal-01251805

Publications of the year

Doctoral Dissertations and Habilitation Theses

[11] G. DE NUNZIO. *Traffic eco-management in urban traffic networks*, Université Grenoble Alpes, October 2015, https://tel.archives-ouvertes.fr/tel-01225232

[12] R. FABBIANO. *Collaborative source-seeking control*, Université Grenoble Alpes, May 2015, https://tel.archives-ouvertes.fr/tel-01217117

[13] T.-M. D. TRAN. *Methods for finite-time average concensus protocols design, network robustness assessment and network topology reconstruction*, Université Grenoble Alpes, March 2015

Articles in International Peer-Reviewed Journals

[14] C. CANUDAS DE WIT, F. MORBIDI, L. LEON OJEDA, A. Y. KIBANGOU, I. BELLICOT, P. BELLEMAIN. *Grenoble Traffic Lab: An experimental platform for advanced traffic monitoring and forecasting*, in "IEEE Control Systems", June 2015, vol. 35, n^{o} 3, pp. 23-39, https://hal.archives-ouvertes.fr/hal-01059126

[15] G. COMO, E. LOVISARI, K. SAVLA. *Throughput Optimality and Overload Behavior of Dynamical Flow Networks Under Monotone Distributed Routing*, in "IEEE Transactions on Control of Network Systems", March 2015, 11 p. , https://hal.archives-ouvertes.fr/hal-01185515

[16] G. DE NUNZIO, C. CANUDAS DE WIT, P. MOULIN, D. DI DOMENICO. *Eco-Driving in Urban Traffic Networks Using Traffic Signals Information*, in "International Journal of Robust and Nonlinear Control", October 2015 [*DOI :* 10.1002/RNC.3469], https://hal-ifp.archives-ouvertes.fr/hal-01252228

[17] H. FOURATI. *Heterogeneous Data Fusion Algorithm for Pedestrian Navigation via Foot-Mounted Inertial Measurement Unit and Complementary Filter Design*, in "IEEE Transactions on Instrumentation and Measurement", January 2015, vol. 64, n^{o} 1, pp. 221-229, https://hal.inria.fr/hal-00999073

[18] P. FRASCA, F. GARIN, B. GERENCSÉR, J. M. HENDRICKX. *Optimal one-dimensional coverage by unreliable sensors*, in "SIAM Journal on Control and Optimization", 2015, vol. 53, n^{o} 5, pp. 3120-3140 [*DOI :* 10.1137/140968094], https://hal.inria.fr/hal-01234344

[19] E. LOVISARI, C.-Y. KAO. *Synchronization of Networks of Heterogeneous Agents With Common Nominal Behavior*, in "IEEE Transactions on Automatic Control", May 2015, vol. 60, n^{o} 1, 13 p. , https://hal.archives-ouvertes.fr/hal-01185519

[20] A. MAKNI, H. FOURATI, A. Y. KIBANGOU. *Energy-aware Adaptive Attitude Estimation Under External Acceleration for Pedestrian Navigation*, in "IEEE/ASME Transactions on Mechatronics", January 2016 [*DOI :* 10.1109/TMECH.2015.2509783], https://hal.inria.fr/hal-01241403

[21] D. PISARSKI, C. CANUDAS DE WIT. *Nash Game Based Distributed Control Design for Balancing of Traffic Density over Freeway Networks*, in "IEEE Transactions on Control of Network Systems", May 2015, vol. V-PP, n^{o} issue 99, 1 p. [*DOI :* 10.1109/TCNS.2015.2428332], https://hal.archives-ouvertes.fr/hal-01251805

[22] A. SCIARRETTA, G. DE NUNZIO, L. LEON OJEDA. *Optimal Ecodriving Control: Energy-Efficient Driving of Road Vehicles as an Optimal Control Problem*, in "IEEE Control Systems Magazine", October 2015, vol. 35, n^{o} 5, pp. 71-90 [*DOI :* 10.1109/MCS.2015.2449688], https://hal-ifp.archives-ouvertes.fr/hal-01252197

[23] T.-M. D. TRAN, A. Y. KIBANGOU. *Distributed estimation of Laplacian eigenvalues via constrained consensus optimization problems*, in "Systems and Control Letters", May 2015, vol. 80, pp. 56-62 [*DOI :* 10.1016/J.SYSCONLE.2015.04.001], https://hal.archives-ouvertes.fr/hal-01153212

International Conferences with Proceedings

[24] D. E. C. BELKHIAT, S. CHOUABA, H. FOURATI, D. JABRI. *Design of a Robust Observer-Based FDI Scheme For a Class of Switched Systems Subject to Sensor Faults*, in "International Conference on Control,

Engineering & Information Technology (CEIT)", Telemcen, Algeria, IEEE, May 2015, https://hal.inria.fr/hal-01170484

[25] G. COMO, E. LOVISARI, K. SAVLA. *Convex Formulations, Implementations, and Sensitivity Analysis for Dynamic Network Traffic Assignment*, in "53rd Annual Allerton Conference on Communication, Control, and Computing", Monticello, United States, September 2015, https://hal.archives-ouvertes.fr/hal-01185530

[26] G. DE NUNZIO, G. GOMES, C. CANUDAS DE WIT, R. HOROWITZ, P. MOULIN. *Arterial Bandwidth Maximization via Signal Offsets and Variable Speed Limits Control*, in "54th IEEE Conference on Decision and Control", Osaka, Japan, December 2015, https://hal.inria.fr/hal-01197443

[27] P. GRANDINETTI, C. CANUDAS DE WIT, F. GARIN. *An efficient one-step-ahead optimal control for urban signalized traffic networks based on an averaged Cell-Transmission model*, in "14th IEEE European Control Conference", Linz, Austria, July 2015, https://hal.archives-ouvertes.fr/hal-01188535

[28] P. GRANDINETTI, F. GARIN, C. CANUDAS DE WIT. *Towards scalable optimal traffic control*, in "54th IEEE Conference on Decision and Control", Osaka, Japan, December 2015, https://hal.archives-ouvertes.fr/hal-01188811

[29] E. LOVISARI, C. CANUDAS DE WIT, A. Y. KIBANGOU. *A Fusion Algorithm for Traffic Density Estimation using Sensors and Floating Car Data*, in "22nd ITS World Congress", Bordeaux, France, October 2015, https://hal.archives-ouvertes.fr/hal-01185522

[30] E. LOVISARI, C. CANUDAS DE WIT, A. Y. KIBANGOU. *Data fusion algorithms for Density Reconstruction in Road Transportation Networks*, in "54th IEEE Conference on Decision and Control", Osaka, Japan, December 2015, https://hal.archives-ouvertes.fr/hal-01185523

[31] E. LOVISARI, C. CANUDAS DE WIT, A. Y. KIBANGOU. *Optimal Sensor Placement in Road Transportation Networks using Virtual Variances*, in "54th IEEE Conference on Decision and Control", Osaka, Japan, December 2015, https://hal.archives-ouvertes.fr/hal-01185525

[32] A. MAKNI, A. Y. KIBANGOU, H. FOURATI. *Descriptor Approach for Attitude Estimation*, in "IEEE Multi-Conference on Systems and Control (MSC)", Sydney, Australia, September 2015, https://hal.inria.fr/hal-01188631

[33] T. MICHEL, H. FOURATI, P. GENEVÈS, N. LAYAÏDA. *A Comparative Analysis of Attitude Estimation for Pedestrian Navigation with Smartphones*, in "Indoor Positioning and Indoor Navigation", Banff, Canada, October 2015, vol. 2015 International Conference on Indoor Positioning and Indoor Navigation, 10 p. , https://hal.inria.fr/hal-01194811

[34] T.-M. D. TRAN, A. Y. KIBANGOU. *Distributed network topology reconstruction in presence of anonymous nodes*, in "European Signal Processing Conference (EUSIPCO 2015)", Nice, France, August 2015, https://hal.archives-ouvertes.fr/hal-01167337

Scientific Books (or Scientific Book chapters)

[35] H. FOURATI. *Multisensor Data Fusion: From Algorithms and Architectural Design to Applications (Book)*, Series: Devices, Circuits, and Systems, CRC Press, Taylor & Francis Group LLC, August 2015, 663 p. , https://hal.inria.fr/hal-01169514

References in notes

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

[37] E. VLAHOGIANNI, M. KARLAFTIS, J.C. GOLIAS. *Short-term traffic forecasting: Where we are and where were going*, in "Transportation Research Part C: Emerging Technologies", June 2014, vol. 43, pp. 3–19