IN PARTNERSHIP WITH:
CNRS

Institut polytechnique de Grenoble

Université Joseph Fourier (Grenoble)

Activity Report 2014

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

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Project-Team NECS

Keywords: Distributed Algorithms, Network Modeling, Network Control, Nonlinear Control, Multisensor Fusion

Creation of the Project-Team: 2007 January 01.

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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).

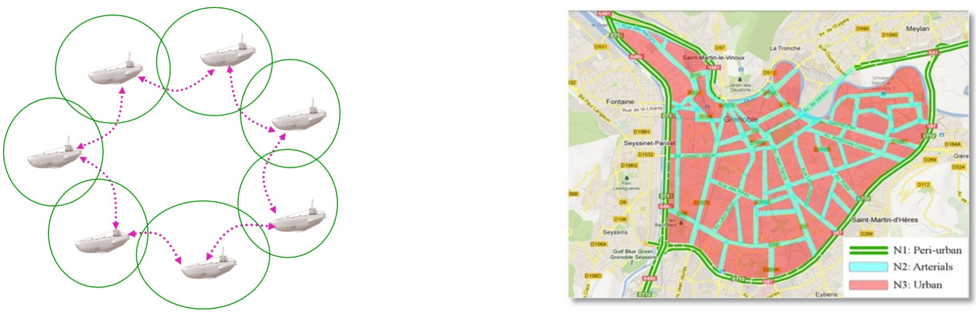

Figure 1. Left: a system of autonomous agents, where the network structure is created by the feedback, used to coordinate agents towards a common goal. Right: a system naturally having a network structure.

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 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. 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.
- 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. 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 starts to explore Pedestrian navigation algorithms in collaboration with Tyrex team from INRIA-Rhône-Alpes Center in Montbonnot. The goal behind is to provide guidance e.g. to first responders after a disaster, or to blind people walking in unfamiliar environments. This tasks is particularly challenging indoor, 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 [11]. 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 adaptive cancellation of oscillations that occur in such operation range.

5. New 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, H. Fourati, F. Morbidi, F. Garin, A. Ladino Lopez, P. Grandinetti, E. Lovisari, R. Singhal, A. Andreev.

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. 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. Highlights of the Year

- C. Canudas de Wit serves as General Chair for the Europeen Control Conference (ECC'14), Strasbourg, France, Jul. 2014 (http://www.ecc14.eu/).
- Launch of the SPEEDD EU FP7 project in Feb. 2014.
- Launch of the COMFORT project, which supports the associate Team between Inria project-team NeCS and the Berkeley University project PATH (http://necs.inrialpes.fr/pages/projects/comfort.php).
- Launch of the LOCATE-ME Persyval project (Apr. 2014 to Aug. 2015) in collaboration with the Tyrex team.
- The team has organized the Hycon2 Show day in May 2014 (http://www.inria.fr/en/centre/grenoble/calendar/hycon2-show-day-traffic-modeling-estimation-and-control).

6.2. Networked systems and graph analysis

6.2.1. Distributed solution to the network reconstruction problem

Participants: A. Kibangou [Contact person], F. Morbidi.

It has been recently shown in [45] that by collecting noise-contaminated time series generated by a coupled-oscillator system at each node of a network, it is possible to robustly reconstruct its topology, i.e. determine the graph Laplacian. Restricting ourselves to linear consensus dynamics over undirected communication networks. In [18], we have introduced a new dynamic average consensus least-squares algorithm to locally estimate these time series at each node, thus making the reconstruction process fully distributed and more easily applicable in the real world. We have also proposed a novel efficient method for separating the off-diagonal entries of the reconstructed Laplacian, and examined several concepts related to the trace of the dynamic correlation matrix of the coupled single integrators, which is a distinctive element of our network reconstruction method.

6.2.2. Distributed estimation of Laplacian eigenvalues and network robustness assessment

Participants: A. Kibangou [Contact person], T.-M. D. Tran, J. Hendrickx [Univ. Louvain-la-neuve].

As recently shown, Laplacian eigenvalues can be estimated by solving the factorization of the average consensus Matrix [46]. The problem was viewed as a constrained consensus optimization one. The main assumption was about the knowledge of the final consensus value. Indeed, estimation of the Laplacian eigenvalues can be carried out using measurements of the transient of the consensus protocol and the steady state (consensus value). In [34], we relaxed the assumptions by considering that the consensus value is only approximately known. We formulated a convex optimization, which allowed us to make use of recent well-known techniques and results dealing with convex optimization problem proposed in the literature (the Alternating Direction of Multipliers Method, ADMM), [40], [42]. Recently, we assumed that the consensus value is completely unknown and has to be found simultaneously with Laplacian eigenvalues. In such a case the problem becomes a convex combination problem where the cost function comprises two terms, one that is average consensus problem, and the rest is the consensus problem to estimate the Laplacian eigenvalues. The simulations indicate that the proposed algorithm is efficient enough to provide the nonzero distinct Laplacian eigenvalues with high accuracy. These eigenvalues are then used to assess the robustness of the graph by means of some spectral metrics, the number of spanning trees and the Kirchoff index precisely.

6.2.3. Observability and privacy preserving features in consensus networks

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

In [16], we have studied of observability in consensus networks modeled with strongly regular graphs or distance regular graphs. The first result consists in a Kalman-like simple algebraic criterion for observability in distance regular graphs. This criterion consists in evaluating the rank of a matrix built with the components of the Bose-Mesner algebra associated with the considered graph. Then, we have defined some bipartite graphs that capture the observability properties of the graph to be studied. In particular, we showed that necessary and sufficient observability conditions are given by the nullity of the so-called local bipartite observability graph (resp. local unfolded bipartite observability graph) for strongly regular graphs (resp. distance regular graphs). When the nullity cannot be derived directly from the structure of these bipartite graphs, the rank of the associated bi-adjacency matrix allows evaluating observability. Eventually, as a by-product of the main results we have shown that non-observability can be stated just by comparing the valency of the graph to be studied with a bound computed from the number of vertices of the graph and its diameter. Similarly non-observability can also be stated by evaluating the size of the maximum matching in the above mentioned bipartite graphs. Non-observability is strongly linked to privacy preserving feature of a given network. Indeed, when a node is neighborhood non-observable, it means that the data of the other nodes (excluding those of its neighborhood) cannot be retrieve from such a node. Therefore security efforts in order to preserve privacy of the entire network must be focused on nodes that are neighborhood-observable.

6.2.4. Average and parametric consensus

Participants: A. Kibangou [Contact person], F. Morbidi.

We have studied average consensus in wireless sensor networks with aim of providing a way to reach consensus in a finite number of steps [17]. In particular, we investigate the design of consensus protocols when, for security reasons for instance, the underlying graph is constrained to be strongly regular or distance regular. The proposed design method is based on parameters of the intersection array characterizing the underlying graph. With this protocol, at execution time, average consensus is achieved in a number of steps equal to the diameter of the graph, i.e. the smallest possible number of steps to achieve consensus. We have extended the parametric consensus protocol recently introduced by F. Morbidi, to more realistic agents modeled as double integrators and interacting over an undirected communication network. The stability properties of the new protocol in terms of the real parameter "s" are studied for some relevant graph topologies, and the connection with the notion of bipartite consensus is highlighted. The theory is illustrated with the help of two worked examples, dealing with the coordination of a team of quadrotor UAVs and with cooperative temperature measurement in an indoor environment [32].

6.3. Collaborative and distributed algorithms

6.3.1. Distributed computation methods for large-scale multidimensional data

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

From Internet to large research infrastructures, the volume of data generated by our societies is continuously increasing. A deluge faced by the producers of these data as well as their users. The big data issue is a significant scientific challenge that requires deep investigations in both engineering and fundamental science. Low-rank matrix factorization has received a particular attention in recent years, since it is fundamental to a variety of mining tasks that are increasingly being applied to massive datasets. In large applications, matrix factorizations can involve matrices with billions of entries. At this massive scale, distributed algorithms for matrix factorization are essential to achieve reasonable performance [43]. However, in many disciplines, data inherently has more than two axes of variation and can be arranged as tensors (i.e. multi-way arrays). Computing tensor decompositions of multi-way datasets is particularly useful to extract hidden patterns and structure in data analytics problems. Specifically, CPD (Canonical Polyadic Decomposition) also known as PARAFAC (Parallel factor analysis) is an extension of a low rank matrix decomposition to tensors. In [26], we have introduced a fully distributed method to compute the CPD of a large-scale data tensor across a network of machines with limited computation resources. The proposed approach is based on collaboration between the machines in the network across the three modes of the data tensor. Such a multi-modal collaboration allows an essentially unique reconstruction of the factor matrices in an efficient way. We provide an analysis of the computation and communication cost of the proposed scheme and address the problem of minimizing communication costs while maximizing the use of available computation resources.

6.3.2. 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 [13] 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 [28], 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 [41], the moving agents do not need to know their absolute position, but only relative bearing angle of their neighbours.

6.4. Sensor networks: estimation and data fusion

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

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

The problem of rigid body attitude estimation under external acceleration from a small inertial/magnetic sensor module containing a triaxial gyroscope, accelerometer, and magnetometer is considered [15]. We are focused on two main challenges. The first one concerns the attitude estimation during dynamic conditions, in which external acceleration occurs [30]. 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. A quaternion based adaptive Kalman filter (q-AKF) compensating external acceleration from the residual in the accelerometer is designed. At each step, the covariance matrix associated with the external acceleration is estimated to adaptively tune the filter gain. The second challenge deals with the energy consumption issue of gyroscope for a long-term battery life of Inertial Measurement Units (IMUs). We study the way to reduce the gyro measurement acquisition by switching on/off the sensor while maintaining acceptable attitude estimation. A smart detection approach is proposed to decide whether the body is in dynamic or static motion. The efficiency of the q-AKF is investigated through numerical simulations and experimental tests, under external acceleration and parsimonious use of gyroscope. This work is described in a submitted in IEEE/ASME Transactions on Mechatronics.

6.4.2. Pedestrian dead-reckoning navigation

Participant: H. Fourati [Contact person].

We propose a foot-mounted Zero Velocity Update (ZVU) aided Inertial Measurement Unit (IMU) filtering algorithm for pedestrian tracking in indoor environment. 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. 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 [14].

6.4.3. Sensor placement of unreliable sensors

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

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 has been presented at MTNS conference [35] and is described in a submitted journal paper (see http://arxiv.org/abs/1404.7711).

6.5. Control design and co-design

6.5.1. Energy-aware networked control

Participants: C. Canudas de Wit [Contact person], F. Garin, N. Cardoso de Castro, D. Quevedo [U. 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 [36]) or over a finite receding horizon (joint work with D. Quevedo, Univ. Newcastle, Australia, described in a paper in preparation).

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

Participants: H. Fourati [Contact person], Z. Samigulina [Kazakh National Technical University], O. Shiryayeva [Institute of Informatics and Control Problems].

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 [19]. 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 [20].

6.5.3. Control design for hydro-electric power-plants

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

We have initiated 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 adaptive 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.

6.5.4. Controller for switched linear systems

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

We designed a robust output feedback tracking controller for a class of Switched Linear Systems (SLS) subject to external disturbances [23]. The proposed synthesis approach, based on a descriptor redundancy formulation, allows to avoid of the crossing terms appearance between the switched Proportional-Derivative (PD) controller's and the switched system's matrices. Using the multiple Lyapunov functional methods, a robust output feedback tracking performance has been formulated in terms of set of Linear Matrix Inequality (LMI). The effectiveness of the proposed synthesis procedure has been illustrated by a numerical example [24].

6.6. Transportation networks and vehicular systems

6.6.1. Traffic estimation and prediction

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

In the PhD thesis of Leon Ojeda, we have been concerned with the design of a methodology for the real-time multi-step ahead travel time forecasting using flow and speed measurements from an instrumented freeway. Two main methodologies have been considered. The first one, a signal-based, uses only speed measurements collected from the freeway, where a mean speed is assumed between two consecutive collection points. The travel time is forecasted using a noise Adaptive Kalman Filter (AKF) approach. The process noise statistics are computed using an online unbiased estimator, while the observations and their noise statistics are computed using the clustered historical traffic data. Forecasting problems are reformulated as filtering ones through the use of pseudo-observations built from historical data. The second one, a model-based, uses mainly traffic flow measurements. Its main appealing is the use of a mathematical model in order to reconstruct the internal state (density) in small road portions, and consequently exploits the relation between density and speed to forecast the travel time. The methodology uses only boundary conditions as inputs to a switched Luenberger state observer, based on the “Cell Transmission Model" (CTM), to estimate the road initial states. The boundary conditions are then forecasted using the AKF developed above. Consequently, the CTM model is run using the initial conditions and the forecasted boundaries in order to obtain the future evolution of densities, speeds, and finally travel time. The added innovation in this approach is the space discretization achieved: indeed, portions of the road, called “cells", can be chosen as small as desired and thus allow obtaining a finer tracking of speed variations. The developed methodologies were assessed using the city-lab GTL [31]. Features and activities of this platform are described in [39].

6.6.2. Traffic control

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

The work was mainly focused on the final design of a distributed controller and its implementation to the model of the south ring of Grenoble in the context of the project Hycon2. For the sake of the controller design, a distributed optimal control method for balancing of freeway traffic density was studied. The optimization was performed in a distributed manner by utilizing the controllability properties of the freeway network represented by the Cell Transmission Model. By using these properties, the subsystems to be controlled by local ramp meters were identified. The optimization problem was then formulated as a non-cooperative Nash game. The game was solved by decomposing it into a set of two-players hierarchical and competitive games. The process of optimization employed the communication channels matching the switching structure of system interconnectivity. By defining the internal model for the boundary flows, local optimal control problems were efficiently solved by utilizing the method of Linear Quadratic Regulator. The developed control strategy was tested via numerical simulations on the macroscopic model in two scenarios for uniformly congested and transient traffic. The controller was also validated through a microscopic simulations with the use of Aimsun software. The controller was implemented through Matlab under which a relevant program simulating distributed architecture was designed. The controller was then plugged to the Aimsun micro-simulator. The simulated scenario was based on real traffic data collected from the south ring of Grenoble. Were examined both, the balancing metric (optimized) and a set of standard traffic metrics (not optimized). The results showed that the balancing has a positive impact on the traffic flow, in particular, by smoothing the vehicle dynamics, it can potentially increase the average velocity (and thus, reduce the travelling time) and reduce the fuel consumption (and related emissions). The proposed modular architecture enabled to perform the optimization for long freeway sections in the real-time.

6.6.3. Control of urban traffic networks

Participants: C. Canudas de Wit [Contact person], F. Garin, P. Grandinetti.

This work deals with efficient operation of urban traffic networks, by controlling traffic lights. A first contribution has been to devise a model for urban networks, based on the Cell-Transmission-Model adapted to signalized intersections, and then simplified with an average-based approximation. Then, based on this model, a control law has been designed, where the duty cycle of each traffic light is optimized in real time, globally considering the whole network. We have chosen a simple one-step-ahead optimization, which can be formulated as a linear program, thus resulting in simple and fast optimization. This work is part of the PhD thesis of Pietro Grandinetti.

6.6.4. Stability of Monotone Dynamical Flow Networks

Participants: E. Lovisari [Contact person], G. Como [U. Lund], K. Savla [U. of Southern California].

The stability properties of monotone dynamical flow networks are studied [22]. Demand and supply functions relate states and flows of the network, and the dynamics at junctions are subject to fixed turning rates. Our main result consists in the characterization of a stability region such that: If the inflow vector in the network lies strictly inside the stability region and a certain graph theoretical condition is satisfied, then a globally asymptotically stable equilibrium exists. In contrast, if the inflow vector lies strictly outside the region, then every trajectory grows unbounded in time. As a special case, our framework allows for the stability analysis of the Cell Transmission Model on networks with arbitrary topologies. These results extend and unify previous work by Gomes et al. on stability of the Cell Transmission Model on a line topology as well as that by the authors on throughput optimality in monotone dynamical flow networks.

6.6.5. Control of communicating vehicles in urban environment

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

The stability properties analysis of the Variable Length Model (proposed by Prof. Canudas de Wit in 2011), adapted to the urban environment was studied. It has been found that the canonical definition of Lyapunov stability for the equilibrium points does not hold for the system under analysis. A different approach for the analysis of the stability properties of the system has been introduced. Furthermore, an energy map of the equilibrium points has been obtained. Namely, a cost was associated with each feasible equilibrium point of the system, thus obtaining an assessment of the efficiency of any operation point of the system. A Variable-Speed-Limits tracking controller of the desired operation point (i.e. equilibrium) has been also devised, in order to simulate the response of the driver to the energy-efficient speed advisory. This work was submitted and accepted at the IEEE Conference on Decision and Control 2014, with the title “Urban Traffic Eco-Driving: Speed Advisory Tracking”. A previous work on the steady-state analysis of the Variable Length Model in urban environment was carried out in [27]. The effort has been put also on the validation of the macroscopic model (i.e. the Variable Length Model), used for traffic evolution prediction and control synthesis. The validation procedure was run with a microscopic traffic simulator, and aims at proving that the evolution of the state of the mathematical model replicates accurately the true evolution of the traffic conditions. In particular, an important variable modeled by the system is the length of the congested area of the road section under analysis, which may be thought of as the queue length. It has been shown that the macroscopic model is able to depict the evolution in time of the queue length, with only a small error with respect to the real congestion simulated by the highly-detailed microscopic simulator. Furthermore, the validation process aims, not only at confirming the reliability of the dynamical model, but also the accuracy of the energy consumption model and the other macroscopic traffic performance metrics that have been defined in order to formulate the optimization problem. Within the COMFORT project exchange program, the work on bandwidth maximization on signalized arterials by introducing VSL as an additional degree of freedom, and by considering the energetic aspects of the problem was expanded. The canonical bandwidth maximization problem is defined as the maximization of the time interval that the vehicles can use to drive though a sequence of signalized intersections without stopping; this is achieved solely by offset control. The extension of this framework aims at showing that the additional degree of freedom (i.e. variable speed limits) improves in every case the bandwidth. A further simulation campaign in a microscopic simulator shows the benefits of the theoretical bandwidth maximization on the standard traffic performance metrics. In particular, fluidity of traffic and lower number of stops result to be highly beneficial in terms of energy consumption, without losing much in terms of traveling time.

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.

7.1.2. 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 adaptive cancellation of oscillations that occur in such operation range.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. 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).

8.1.2. 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 will construct 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 will bring some responses on how to advance the current pedestrian navigation solutions for the critical domains, using robust software. The specific contribution of LOCATE-ME will be 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).

8.1.3. Other collaborations

Inertial and magnetic data integration for human movements analysis

The goal of this consortium, which is in its second year, is to work on how to deal with inertial data in different or complementary fields. Orange Grenoble lab works on the analysis of inertial data and 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, Ecole des mines de Douai, ISFTTAR, UTT et Orange Labs.

8.2. European Initiatives

8.2.1. 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

8.2.2. 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

8.3. International Initiatives

8.3.1. Inria Associate Teams

8.3.1.1. COMFORT

Title: COntrol and FOrecasting in Transportation networks

International Partner (Institution - Laboratory - Researcher):

University of California Berkeley (ÉTATS-UNIS)

Duration: 2014 - 2016

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

COMFORT is an Associate Team between Inria project-team NeCS and the Berkeley University project PATH. The joint team is in its 1st year of activity. 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 will address issues related to model validation before developing new traffic forecasting and distributed control algorithms. In particular the crucial issue of robustness will be considered through a complementary approach based on both stochastic and deterministic methods. 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. Three main objectives will be addressed in this collaboration: a) Model validation and robust modeling for traffic estimation, control and forecasting; b) New methods for traffic forecasting; c) New methods for distributed traffic control and estimation.

8.3.2. Inria International Partners

H. Fourati has a collaboration with the Kazakhstan National Technical University (KazNTU). He co-advised (with Pr. Olga Shiryayeva in KazNTU) Zarina Samigulina, a PhD student in KazNTU, which defended her PhD Thesis in May 2014.

8.3.3. Participation In other International Programs

F. Garin, A. Kibangou, P. Grandinetti, and C. Canudas de Wit participated in the workshop Berkeley-Inria-Stanford (BIS'2014, Paris) wich is the joint research program inria@Silicon Valley.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

8.4.1.1. Internships

- Massinissa Boudraham, Master student, University of Bordeaux, from March to September 2014, co-advised by H. Fourati and P. Geneves, master thesis: *Systèmes de navigation pédestre : Analyse et étude comparative*.

8.4.2. Visits to International Teams

8.4.2.1. Sabbatical programme

- C. Canudas de Wit spent one week at the UC Berkeley. He has several meetings with Prof. Horowitz and Dr. Gomes to set up the ground for the collaboration with the student Giovanni De Nunzio on the problem of bandwidth optimization of green waves under eco-driving constraints. He has also two working meetings with Prof. Varaiya on issues of back-pressure control for light intersections, and discussion on modeling limitations of the CTM. He participated also in two seminars organized by the Transportation Institute at UC Berkeley. He also met with Prof. Murat Arcak and his student Sam Coogan and have some discussions on issues of monotonicity in traffic models.
- A. Kibangou spent one week in the Advanced Sensor Networks Group of the department of Electrical and Electronical Engineering of the University of Pretoria (South Africa), one of the top university in Africa.

8.4.2.2. Explorer programme

Giovanni De Nunzio

Date: 24/09/2014 – 14/12/2014

Institution: University of California Berkeley (USA) Visit of Giovanni De Nunzio (Ph.D. student at NeCS team) at PATH, UC Berkeley. Collaboration with Dr. Gabriel Gomes and Prof. Roberto Horowitz. Participation to weekly meeting both for Freeway Traffic research group (held by Prof. Howitz) and Arterial Traffic research group (held by Prof. Varaiya). Two presentations were given at the Arterial meeting: one about the preliminary results with Dr. Gomes, one about the research activities carried out at NeCS team. Participation to the bi-weekly Intelligent Transportation Systems seminars at UC Berkeley.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. International activities

C. Canudas de Wit, leader of the team, is member of the Board of Governors (BoG) of the IEEE Control System Society (CSS), and president of the European Control Association EUCA. He is IEEE CSS distinguished lecturer (2013-2015).

9.1.2. Scientific events organisation

9.1.2.1. general chair, scientific chair

C. Canudas de Wit serves as General Chair for the Europeen Control Conference (ECC'14), Strasbourg, France, July 2014 (http://www.ecc14.eu/).

9.1.2.2. member of the organizing committee

F. Garin was a student activities chair at the Europeen Control Conference (ECC'14). A. Kibangou is the co-animator of the research action PCS (Pervasive Computing Systems) of the Labex Persyval-Lab (https://persyval-lab.org/research/action/pcs) and the organizer of seminars for the Control Department of Gipsa-Lab.

9.1.3. Scientific events selection

9.1.3.1. member of the conference program committee

H. Fourati serves as international advisory member for the international conference on Sciences and Techniques of Automatic control and computer engineering STA'14 (http://www.sta-tn.com/STA.htm) and the international Conference on Systems and Control ICSC'15 (http://lias.labo.univ-poitiers.fr/icsc/icsc2015/index.php).

9.1.3.2. reviewer

All the members of the permanent staff serve as peer-reviewers for the main conferences in 2014 and 2015 (CDC, ECC, ACC, ICRA, IROS, STA, IFAC World Congress, EUSIPCO, ICASSP, MTNS).

9.1.4. Journal

9.1.4.1. member of the editorial board

C. Canudas de Wit serves as Associate Editor of IEEE Transactions on Control System Technology (since January 2013) and of IEEE Transactions on Control of Network Systems (since June 2013), and Editor of the Asian Journal of Control (since 2010).

9.1.4.2. reviewer

All the members of the permanent staff serve as peer-reviewers for the main international journals of the community (IEEE Trans. on Automatic Control, Automatica, System and Control Letters, IEEE Trans. on Control Systems and Technology, IEEE Trans. on Signal Processing, Signal Processing (Elsevier), IET Signal Processing, IET Communications, Int. J. of Adaptive control and Signal Processing, Journal of the Franklin Institute, Control Engineering Practice, IEEE Trans. on on Industrial Electronics, IEEE Trans. in Industrial Informatics, Discrete Event Dynamic Systems, European Journal of Control, IEEE Sensors Journal, IEEE Trans. on Instrumentation and Measurement, IEEE/ASME Trans. on Mechatronics, Micromachines, Sensors).

9.1.5. Book

H. Fourati started the process of editing a book on "Multisensor data fusion: from algorithm and architecture design to applications" in collaboration with Kris Iniewski (Redlen Technologies, Canada). The book will be published by CRC Press, Taylor & Francis by Jun. 2015.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence: H. Fourati, Informatique Industrielle, 105h, L1, IUT 1 (GEII2), University Joseph Fourier, France;

Licence: H. Fourati, Réseaux locaux industriels, 62h, L1 et L2, IUT1 (GEII2), University Joseph Fourier, France.

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

Master: F. Garin, Distributed Algorithms and Network Systems, 19.5h, M2, 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.

E-learning

Pedagogical resources (Victory, Pedagotice) : H. Fourati, Systèmes d'Informations Numériques, video, L1, http://chamilo1.grenet.fr/ujf/courses/IUT1GEIIM1102/?id_session=0.

9.2.2. Supervision

PhD: Abir Ben Khaled, Distributed real time simulation of numerical models: application to powertrain, Grenoble INP, May. 27th, 2014, co-advised by D. Simon and M. Ben Gaid (IFPEN).

PhD: Luis R. Leon Ojeda, Short-term multi-step ahead traffic forecasting, Grenoble University, Jul. 3th, 2014, Co-advised by C. Canudas de Wit and A. Kibangou.

PhD: Dominik Pisarski, Collaborative Ramp Metering Control: Application to Grenoble South Ring, Grenoble University, Sep. 16, 2014, Advised by C. Canudas de Wit.

PhD: Zarina Samigulina, Development of an intelligent complex objects management system, KazNTU University, May. 30, 2014, Advised by O. Shiryayeva and H. Fourati.

PhD in progress: Ruggero Fabbiano, Distributed source seeking control, Grenoble University, Dec. 2011 - in progress, 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, Jan. 2012 - Mar. 2015, co-advised by A. Kibangou and C. Canudas de Wit.

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

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.

PhD in progress: Pietro Grandinetti, Control of large-scale traffic networks, CNRS, Apr. 2014 - Mar. 2017, 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, CNRS, Oct. 2014 - Sep. 2017, co-advised by C. Canudas de Wit, A. Kibangou and H. Fourati.

PhD in progress: Simon Gerwig, Collaborative, reconfigurable and resilient control for hydro-electric power-plants, Alstom, Oct. 2014 - Sep. 2017, co-advised by C. Canudas de Wit, F. Garin and B. Sari (Alstom).

PhD in progress: Thibaud Michel, Mobile Augmented Reality Applications for Smart Cities, Persyval, Nov. 2014 - Oct. 2017, co-advised by N. Layaïda, H. Fourati and P. Geneves.

9.2.3. Juries

H. Fourati participated in the jury of recruitment of students within the department of Electrical Engineering, IUT Grenoble, France.

9.3. Popularization

- The team published a flyer entitled "City Labs for Intelligent Road Transportation Systems" in the report "Impact of Control Technology", http://ieeecss.org/sites/ieeecss.org/files/CSSIoCT2Update/IoCT2-RC-CanudasdeWit-1.pdf.
- The team has organized the Hycon2 Show day in May 2014 with technical presentations and posters on traffic modeling, estimation and control. We got more than 40 registered peoples from different universities and compagnies, http://www.inria.fr/en/centre/grenoble/calendar/hycon2-show-day-traffic-modeling-estimation-and-control.
- The team has organized the 1st technical SPEEDD meeting in May 2014 with a specific visit organized to the traffic center (DIR-CE, Grenoble).

10. Bibliography

Major publications by the team in recent years

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