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ACTIVITY REPORT

Project-Team DANCE

Dynamics and Control of Networks

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

DOMAIN

Applied Mathematics, Computation and Simulation

THEME

Optimization and control of dynamic systems

Contents

Project-Team DANCE

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Keywords

Computer sciences and digital sciences

A1.2.6. – Sensor networks

A1.2.7. – Cyber-physical systems

A1.2.9. – Social Networks

A1.5. – Complex systems

A6.1.1. – Continuous Modeling (PDE, ODE)

A6.1.3. – Discrete Modeling (multi-agent, people centered)

A6.4. – Automatic control

A8.8. – Network science

Other research topics and application domains

B2.3. – Epidemiology

B6.3.4. – Social Networks

B7. – Transport and logistics

B8.2. – Connected city

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2 Overall objectives

DANCE is a joint research team of *Centre Inria de l'Université de Grenoble Alpes* and GIPSA-lab, established in February 2021 as the evolution of former team NeCS. The team is bilocated at the Inria center in Montbonnot and at Gipsa-Lab on Saint-Martin-d'Hères campus, both locations being in the Grenoble area.

The team's mission is to advance the field of Automatic Control to meet the challenges of today's hyper-connected society. We perform both fundamental research about control systems theory and network science and applied research in relevant domains such as mobility, transportation, social networks, and epidemics.

Both researchers and general public have become aware that our society and our lives depend on **complex dynamical systems** that can be understood as **networks**. Examples are plentiful and we shall only remind a few: transportation networks allow ourselves to travel, commute, and transport goods; power networks provide our homes and factories with energy; supply chains are the backbone of manufacturing; social networks support our professional and personal relationships; networks of neurons constitute our brains; and ecological networks such as foodwebs sustain our survival.

In stark contrast with this reality and its popular recognition, the mathematical and conceptual tools available to scientists and engineers to understand and manage these systems are lagging behind. We believe that these *complex network systems are first and foremost dynamical systems* and therefore amenable to an Automatic Control approach, since Automatic Control, as a field, is devoted to study dynamics and the ways to monitor and to regulate them. However, the century-old theory of Automatic Control has been developed to study other kinds of mechanical or electrical systems that lack a network structure: inspecting a 1999 landmark book like [38] shows that control theorists did not yet consider networks to be a topic of study as late as 20 years ago. Despite substantial efforts by the research community during the last 15 years, the theory of systems and control has not yet been able to integrate itself with the big advances that have been made in network science. The ambition of this team is to contribute to closing this gap.

The research of the DANCE team encompasses both methodological work and applications in close interdependence since methodological questions are motivated by selected application areas. The dominant one is the broad area of **mobility**. By this term we encompass questions about vehicular and multi-modal transportation, navigation methods for pedestrians in urban and cluttered/noisy environments, and Connected Autonomous Vehicles, namely their cooperative behavior and their effect on the overall transportation system. The team maintains and develops experimental platforms on mobility: after the experiences of the GTL-Rocade (Grenoble Traffic Lab) [39] and GTL-Ville [50], the team is currently pursuing the development of the platform GTL-Healthmob [49], as well as its evolution towards the study of electro-mobility. The second application area concerns **social systems**, mainly in relation with the dynamics that take place in online social media: on this topic we collaborate at the national and international levels with researchers from engineering, computer science and social sciences.

From our application scenarios, it appears that the networks that we are interested in share several important features:

- they are inherently dynamical and their evolution can be influenced from the outside;
- their structure (that is, the topology of their interconnections) shapes their global behavior;
- their structure and their composition evolve together with the evolution of their components;
- they are large and therefore require tools that scale well with size;

- their dynamics, structure, and state are known with possibly large uncertainties (even though they may generate big data streams).

Our approach is a **control systems approach**, that begins by identifying suitable state variables, input variables and output variables. To cope with the specific features of complex network systems, we develop new system-theoretic tools for modeling, estimation, and control. Depending on the application and on the modeling methodology, the mathematical models will be differential (or difference) equations on graphs or continuous models such as partial differential equations. In the applications, estimation and control take advantage of the structure of the systems and of their specific, physical, features.

3 Research program

In presenting our research, we shall distinguish four research *Axes*. The first two axes present our theoretical work that develops a broad set of tools for modeling, identification and control of network dynamics. Focusing on the nexus between networks and control systems implies that our methods will blend ideas from network science and control science. The first axis regards methods that define network dynamics by the graph that naturally describes their physical or informational structure; the second axis goes beyond this graph-theoretic representation by using approximations or aggregations to deliver methods that are suitable to large networks. The remaining Axes present methods that are tailored to our main applications in transportation and in social networks.

Research Axis 1: Exact Automatic Control methods for networks

Most methods from Automatic Control do not apply well to networks, simply because they were designed for systems that do not have a network structure. Once the presence of network structure is recognized, it has to be accounted for in analysis and design. Firstly, a network structure implies *obstructions to the flow of information* between different parts of the system. A key instrument to take them into account is the deployment of graph-theoretical methods, as we will exemplify below. Secondly but not less importantly, a network structure implies the opportunity (or sometimes the need) to *scale* the network up in size, growing larger and larger networks by the addition of nodes and edges. Sometimes, classical control methods scale poorly in terms of complexity or performance, and therefore need overhaul. This research axis therefore pertains to the development of system-theoretic methods that are based on graph theoretical representations of the system and whose complexity and performance scale well with the size of the network, so that networks with tens or hundreds of nodes can be studied.

Research Axis 2: Approximate methods for large-scale networks

Axis 1 was devoted to the control-theoretic analysis of networks by Graph Theory tools. These methods are suitable for systems with a relatively small number of nodes (tens or hundreds), like formations of moving robots or sensor networks, but become ineffective for larger networks. Complete knowledge of the network is typically not available, because of the presence of noise, errors in data, links changing in time. Additionally, even if in some cases it is possible to obtain a good approximation of the network structure, the applicability of estimation and control methods is reduced by the limitation of computational resources. In order to address these limitation, this research axis (Axis 2) develops system-theoretic methods that abstract from the detailed network state, by performing operations of aggregation or approximation. These tools are meant to be applied to networks with thousands of nodes.

The remaining three axes develop methods that are directly motivated by the applications: we therefore describe them in the next section.

4 Application domains

Research Axis 3: Smart Transportation Systems

Smart transportation is the main domain of application for the team. The research topics include cooperative control of Connected and Autonomous Vehicles, pedestrian navigation, vehicular traffic in urban road networks, and multi-modal transportation. The experimental platforms Grenoble Traffic Lab (GTL) and GTL-Ville continuously collect real-time data about traffic in Grenoble. Other data collection campaigns, such as TMD-CAPTIMOVE, have produced datasets about multi-modal transportation.

Transportation research is currently at a crucial stage: we are facing the emergence of new technologies and systems such as vehicle connectivity, automation, shared-mobility, multimodal navigation and advanced sensing which are rapidly changing mobility and accessibility. This in turn will fundamentally transform how transportation planning and operations should be conducted to enable smart and connected communities. On one hand, this process presents us with a great opportunity to build safer, more efficient, reliable, accessible, and sustainable transportation systems. On the other hand, the uncertainties regarding how such disruptive technologies will evolve pose a number of fundamental challenges. These challenges include: (a) understanding the impacts of connected and automated vehicles on the traffic flow; (b) shifts in travel demand induced by new paradigms in mobility, such as shared mobility; (c) the computational challenges of real-time control strategies for large-scale networks, enabled by emergent technologies; (d) transitioning to predictive and proactive traffic management and control, thus substantially expanding the horizons of transportation network management; (e) the need for identifying different modes of transport used by a certain population. The need to effectively address these challenges provides the opportunity for fundamental advances in transportation and navigation and will be the object of this research axis.

Research Axis 4: Cyber-Social Systems

Online social networks, such as online blogging platforms and social media, are chief examples of complex systems where social and technological components interact. We can refer to such systems as *Cyber-social networks*: social components are human individuals whose collective behavior produces the overall behavior of the system, whereas technological (or cyber) components are devices or platforms endowed with sensing, computation, and communication capabilities. In these contexts, the interactions between the individuals are mediated and determined by the ubiquitous presence of digital technology. Online social services routinely record behaviors and interactions and exploit this information to constantly optimize themselves for the users, by the ubiquitous presence of recommendation systems. These large data streams can also enhance our understanding of social dynamics. Beyond the analysis power, these tools offer new opportunities to influence the behaviors of the individuals. This influence can be obtained in various ways, including advertising, diffusing sensitive information, or altering the way individuals interact. These evidences open the way to identify ways to "actuate" (in engineering jargon) social systems. Understanding these dynamics in a control systems perspective is thus not only a scientific challenge, but also an urgent need for the society.

5 Social and environmental responsibility

Several of our research activities have a direct societal impact. Our research on mobility has the objective of facilitating the ecological transition, through the electrification of transportation and the wise choice of the means of transportantion, including soft mobility such as biking. Our research on social media has potential implications for understanding the formation of public opinion and managing online social media platforms, including the prevention of fake news diffusion and manipulation.

6 Highlights of the year

- G. Casadei joined the team on October 1st as UGA Associate Professor.
- Team members under the leadership of C. Canudas de Wit have developed eMob-Twin, a digital twin platform to study the electrification of urban mobility. More information on emob-twin.inrialpes.fr
- P. Frasca defended his HDR Habilitation on July 13 in front of an international committee of peers from France, Sweden, Italy, and the Netherlands: his dissertation is available at [30].
- P. Frasca has jointly edited the Springer book [28] on Hybrid and Networked Dynamical Systems.

7 New software, platforms, open data

The digital twin software eMob-Twin, described below, was presented in the paper [18].

7.1 New software

7.1.1 eMob-Twin

Keywords: Road traffic, Digital twin, Electric vehicle

Functional Description: On a city scale, road traffic includes many electric vehicles whose batteries must be adequately charged. The eMob-Twin project, supported by an ERC Proof of Concept grant, and coordinated by Carlos Canudas-de-Wit from the Grenoble Image, Parole, Signal, Automatique laboratory (GIPSA-lab - CNRS/Université Grenoble Alpes), aims to adapt a mathematical model of traffic in the Grenoble metropolitan area to the needs of the electric cars that circulate there. It also involves optimizing electricity networks and better integrating intermittent renewable energies.

URL: `http://emob-twin.inrialpes.fr/`

Contact: Carlos Canudas-De-Wit

8 New results

8.1 Research Axis 1: Exact Automatic Control Methods for Networks

Participants: P. Frasca, G. Casadei.

8.1.1 Open Multi-Agent Systems

Open Multi-Agent Systems, also known as Open Networks or Dynamic Networks, are networks whose nodes can exit or enter the network at any time, as opposed to closed networks whose node set is fixed. In practice, this is a relevant question because large networks and populations often evolve with time. Mathematically, the evolution of the node set makes the utilization of control-theoretic notions, such as stability, delicate. A broad overview of the topic is presented in our very recent survey [29]. Our approach has developed in three phases. First, we have studied the stability of consensus in an open system under the assumption of having a finite "universe" set of possible nodes, from which the actual nodes of the network are chosen [55]. Second, we have have studied the stability of contractive dynamics in the presence of joining/leaving nodes, essentially by understanding the process of node arrival/departure as a disturbance [42]. Similar ideas underpin the analysis of epidemics in open networks that we have published this year in [27]. Third, we have concentrated on the important special case in which agents can be replaced by newcomers, but the total number of agents remains constant. Under this assumptions, we have studied optimization and resource allocation problems: convergence results about random coordinate descent in presence of replacements have appeared this year [14].

8.1.2 Synchronization of networks of nonlinear systems

The problem of synchronization and consensus is still a rich and interesting topic, especially when dynamics of the agents in the networks are nonlinear. Several domains of applications such as power networks (review paper on the issues if needed) want to exploit nonlinearities to achieve better performances but face increased difficulties in designing control laws that enforce synchronization between agents. To this end, contraction theory seems a promising path that allows for a systematic design procedure for nonlinear control laws to achieve incremental stability, a property that in general shows the convergence of trajectories of different systems to each other.

By leveraging this property, we considered in [43] the problem of exponential synchronization of a network of identical input-affine nonlinear time-varying systems connected through an undirected graph, in the presence of a leader. We propose sufficient metric-based conditions to design a distributed diffusive coupling feedback law in two frameworks. For the sake of simplicity, we consider a state feedback design, where synchronization is obtained for every initial condition by means of a nonlinear control law whose designed is based on the solution of contraction-based inequalities. Furthermore, we show that synchronization can still be achieved regionally under milder assumptions which relax some of the contraction-based conditions and allows computing the proposed controller by means of an algorithm based on deep neural networks (DNNs) for practical implementation. A similar approach as been used to tackle the problem of synchronization for nonlinear discrete time systems over networks [35]. As a matter of fact, the problem of synchronization for discrete time systems is much more involved and requires more complex inequalities, which depend not only on the algebraic connectivity of the graph but also on the biggest Laplacian eigenvalue. By generalizing results on synchronization of linear discrete time agents, we build strong links between the solution to the synchronization problem in the linear and nonlinear framework. We focus on the class of almost differentiable (possibly time-varying) dynamics that are linear in the input and we designed contraction-based nonlinear control law which enforce synchronization in the network.

8.2 Research Axis 2: Approximate methods for large-scale networks

Participants: C. Canudas de Wit, P. Frasca, F. Garin, R. Prisant, S. Fueyo.

The task of controlling large-scale networks is very difficult in the first place because of its large dimensionality, making the computation of traditional control algorithms too expensive. In systems of large dimensions, the number of sensors is often much lower than the number of states, which makes it hard to identify the mathematical model of the system and to estimate its state. Similar issues arise regarding the number of actuators. Another difficulty is that the energy needed to control all nodes of the network can grow exponentially with the number of nodes, at least for some network structures [48]. Therefore, in some cases, it can be preferable to *control and estimate some aggregated measure* of the entire network rather than all individual states, since the energy required to control aggregated quantities instead of all network states is much less. Examples of aggregate quantities would be, for instance, the average state of the whole network and its variance, or the average values in different regions of the network.

8.2.1 The continuation method

When considering limit models for large networks, we naturally fall into continuous limits. These limits can take different forms. One way to define continuous limits is to regard, instead of the agent states, their *distribution*. The evolution of the distribution would then be naturally described by a partial differential (PDE) or integro-differential equation. A good approximation implies that control actions can be designed on the continuous system and have guaranteed performance on the original (graph-based) one. By the thesis work of D. Nikitin and a series of papers, we have reached a twofold objective: (1) we have developed a sound and complete theoretical framework for the PDE approximation of large networked ODE systems [47]; and (2) we have applied this framework to multiple applications including swarms of autonomous robots [47], traffic networks [52], and spin-torque oscillators [46]. Ongoing work focuses on developing control-oriented PDE models for traffic flows on ring roads, in which one controlled vehicles aims to smooth the flow of many human-driven ones [33].

8.2.2 Graphons

Another promising way to define continuous limits is by the concept of graph function, or *graphon*, which is the limit object of a sequence of dense networks [44]. Conversely, finite graphs can be generated by sampling from the continuous graphon: in this case, the properties of the finite networks can be inferred from the properties of the graphon. Inspired by results on centrality measures [37], we have recently been able to use graphons to define performance metrics that quantify system-theoretic properties of the SIS epidemics model, such as stability, controllability, or sensitivity to noise [54]. These metrics can be computed from the graphon at low computational cost and approximate well the system-theoretic properties of the corresponding dynamics on graphs of large-but-finite size. We have also studied the eigenvalues of the Laplacian matrix of graphs sampled from graphons, because of the importance of such eigenvalues to evaluate performance of consensus dynamics and of Markov chains, see [56] and the more recent refinements in [34].

The graphon-based approach is currently developed in the COCOON projet and the ongoing thesis of Raoul Prisant, who has already obtained results on two specific models of opinion evolution with negative interactions [24]. In the meanwhile, we have also deepened our analysis of the graphon-counterpart of the SIS model by proving a limit result as the number of agents goes to infinity [7].

8.3 Research Axis 3: Mobility systems and transportation networks

Participants: C. Canudas de Wit, N. Cele, M. Čičić, H. Fourati, P. Frasca, R. Kalaoane, A. Kibangou, G. Gasnier, F. Garin, R. Mourgues, G. Shaaban, T. Toso, I. Gharbi, O. Meebed.

8.3.1 Electromobility

With the growing number of electric vehicles (EVs) in our car fleet in the coming years, combined with an increase in electricity production from renewable energy sources, stabilizing the frequency on the electrical grid will become increasingly challenging. EV charging will represent a significant source of electricity consumption. Therefore, having a transportation model for electric vehicles is crucial to understanding the evolution of their state of charge across the road network. This, in turn, enables accurate predictions of demand at charging stations [40].

One of the tools available to grid operators to address this issue is the use of various regulation systems. One such system involves incentivizing consumers to either increase or decrease their electricity consumption in exchange for compensation. There are several European markets for frequency regulation trading. The most suitable market for EV charging stations has been identified as the Frequency Containment Reserve (FCR) market, the primary European reserve market, which responds most quickly to grid operator demands [21].

To participate in this market, a charging station operator must decide, one day in advance, what capacity they can provide to support the grid. When there are many vehicles at a station, it is easier to modulate energy consumption on a larger scale compared to when there are fewer vehicles. Therefore, it is crucial for operators to predict how many vehicles will be present at their stations throughout the day. We have developed a macroscopic mobility model to predict mobility and state of charge in space and time coupled with one or more charging station operators participating in the FCR market [21] [20]. This model also includes decision-making processes on the part of EVs, which decide whether to charge based on their remaining battery level and the price at charging stations and in which station. We aim to determine the optimal pricing strategy for charging stations to maximize their revenue [21]. In a competitive environment, where multiple charging station operators compete directly to attract vehicles, our results indicate significant benefits for EV users and the electrical grid. Prices decrease, and the capacity available to grid operators increases [20].

8.3.2 Multimodal mobility: Transportation mode classification

Due to increasing traffic congestion, travel modeling has gained importance in the development of transportion mode detection (TMD) strategies over the past decade. Nowadays, recent smartphones, equipped with integrated inertial measurement units (IMUs) and embedded algorithms, can play a crucial role in such development. In particular, obtaining much more information on the transportation modes used by users through smartphones is very challenging due to the variety of the data (accelerometers, magnetometers, gyroscopes, proximity sensors, etc.), the standardization issue of datasets and the pertinence of learning methods for that purpose. Reviewing the latest progress on TMD systems is important to inform readers about recent datasets used in detection, best practices for classification issues and the remaining challenges that still impact the detection performances. Existing TMD review papers until now offer overviews of applications and algorithms without tackling the specific issues faced with real-world data collection and classification. Compared to these works, the proposed review [9] provides some novelties such as an in-depth analysis of the current state-of-the-art techniques in TMD systems, relying on recent references and focusing particularly on the major existing problems, and an evaluation of existing methodologies for detecting travel modes using smartphone IMUs (including dataset structures, sensor data types, feature extraction, etc.). This review paper can help researchers to focus their efforts on the main problems and challenges identified.

8.3.3 Multimodal mobility: Analysis of informal minibus driving

Traffic accidents pose a significant public health challenge, especially in developing countries where many people rely on informal transport, such as minibus taxis. The paper [19] aims to enhance our understanding of the driving behavior of minibus taxi drivers by employing machine learning techniques to compare driving behaviors in controlled versus uncontrolled environments in Durban (eThekwini Municipality, South Africa). Informal minibus taxis play a crucial role in urban transportation, particularly in developing countries, yet their driving patterns and safety implications remain under-explored. We utilize exploratory factor analysis to analyze data collected from smartphone GPS carried by a passenger of a minibus taxi, identifying key driving behaviors and patterns. Our study highlights significant differences in driving styles between controlled and uncontrolled environments, offering insights into safety and efficiency. The findings provide valuable information for policymakers, transportation planners, and technology developers aiming to enhance urban mobility and safety in the informal transport sector. The primary finding is that a controlled environment fosters aggressive driving, while a less controlled setting encourages speeding. These findings support the eThekwini Municipality's stance in its road safety plan, which identifies driver aggressiveness as a major factor in road traffic accidents in Durban.

8.3.4 Multimodal mobility: Public transportation quality of service analysis

Public transport is a fundamental aspect of urban life and its quality of service can significantly impact the daily life of passengers. Research on quality of service in public transport is vital to creating efficient and inclusive public transport systems. The study in [11], which is both timely and imperative, provides a systematic literature review and bibliometric analysis of quality of service in public transport with special focus on gender and machine learning. The study employed a systematic search in Web of Science using relevant keywords. Based on 270 published articles on the Web of Science, we evaluate the state of knowledge through keyword analysis, cooccurrences, and co-citations. It appears that key themes in quality of service in public transportation have shifted from efficiency to user satisfaction and perceptions. However, there is limited literature on public transport service quality in the global south, particularly in Africa, compared to the global north. In particular, the study revealed that the total publications focusing on gender in Africa is two. Moreover, much of the literature on the African continent emanates from authors and countries outside the continent. It often does not reflect the lived realities of the state of public transport in Africa. Similarly, emerging issues pertaining to machine learning and gender in public transport also require consideration. This paper paves the way for policy, practice, and further research. The review will be useful reference for evolutions of quality of service in public transport research.

8.3.5 Heterogeneity and autonomy in traffic

After 70 years of research, traffic flows of homogeneous vehicles are fairly well understood. More elusive is the understanding of heterogeneous traffic flows. As of today, a novel and peculiar sort of heterogeneity is appearing in traffic: the presence of automated (possibly autonomous) and connected vehicles (CAVs). Their appearance has motivated us to assess their impact on traffic and explore their potential as means for estimation and for control. This year, we have obtained results about the coordination of heterogeneous autonomous vehicles and the ability of heterogenous platoons to withstand limitations in communication and actuation (braking, acceleration) [13].

8.3.6 Cycling

In recent research, we developed a graph-based framework aimed at improving cycling networks, with a focus on optimizing safety and comfort. In our first study [36], we proposed a methodology to analyze and enhance safety in cycling networks through incremental infrastructure upgrades. By employing graph theory metrics, we modeled and optimized safety levels, addressing the challenge of resource allocation via a gradual improvement strategy. This methodology was applied to the cycling network of Grenoble, demonstrating its effectiveness in enhancing overall safety by optimizing both connectivity and infrastructure upgrades. Building on this, our subsequent work [17] expanded the framework by introducing a topology optimization problem to predict and improve perceived safety and comfort. We create a model using graph theory metrics validated with real-world data on perceived safety and comfort from cyclist surveys, we designed a novel algorithm to tackle the challenge of budget allocation for maximizing these metrics. This approach achieved significant improvements in multiple real-world networks across French cities, offering actionable insights for urban planners to implement resource-efficient upgrades while maintaining a balance between accuracy and computational efficiency.

8.3.7 Route recommendations in road traffic

This line of research, which has lead to the thesis defence of Tommaso Toso [31], investigates the impact of autonomy and user connectivity on mobility. The tools we adopt are centered on studying network flows, congestion games, and associated control systems. The main focus has been real-time route recommendations by navigation apps and their effects on road congestion. The analytical approach of [51] involves a state-dependent switching system modeling a supply-demand mechanism, utilizing established macroscopic traffic flow models. The stability analysis of the system, with a particular emphasis on key parameters like road capacities, critical densities, and traffic demand, reveals that real-time recommendations have the potential to induce congestion in the network and result in unmet user demand. Other important question is the role of cooperative, connected, fleets of users. We have obtained analaytical results showing that the deployment of cooperative fleets can bring benefits to the transportation system, but for these effects to materialize the penetration rate may need to be higher than a threshold [26].

8.3.8 Data fusion for navigation

Our activities on data fusion for navigation have been multifold, spanning filtering methods, applications of deep learning, noise compensation and applications that range from mobility to aerospace.

Key to our approach to navigation is the problem of *velocity estimation*. Velocity estimation of a rigid body using measurements from low-cost inertial and magnetic sensors plays an important role in various applications. The extended Kalman filter (EKF) is widely used for this purpose. However, EKF's estimation performance relies on the knowledge of process and measurement noise covariance matrices, and this information is generally unavailable. In [25], we introduce a solution that combines two techniques: the generation of velocity pseudo-measurements using a Bidirectional Long Short-Term Memory (BiLSTM) network, and the Q-learning method for online adaptation of noise covariance matrices. The performance of the proposed solution is validated using real experimental datasets, demonstrating that Q-learning can select appropriate noise covariance matrices to enhance velocity estimation.

A key application for our team is pedestrial navigation.

A magnetic-field-aided inertial navigation system (MAINS) for indoor navigation is proposed in [10]. MAINS leverages an array of magnetometers to measure spatial variations in the magnetic field, which are then used to estimate the displacement and orientation changes of the system, thereby aiding the inertial navigation system (INS). Experiments show that MAINS significantly outperforms the stand-alone INS, demonstrating the remarkable two orders of magnitude reduction in position error. Furthermore, when compared with the state-of-the-art magnetic-field-aided navigation approach, the proposed method exhibits slightly improved horizontal position accuracy. On the other hand, it has noticeably larger vertical error on datasets with large magnetic-field variations. However, one of the main advantages of MAINS compared with the state of the art is that it enables flexible sensor configurations. The experimental results show that the position error after 2 min of navigation in most cases is less than 3 m when using an array of 30 magnetometers. Thus, the proposed navigation solution has the potential to solve one of the key challenges faced with current magnetic-field simultaneous localization and mapping (SLAM) solutions—the very limited allowable length of the exploration phase during which unvisited areas are mapped.

Another application is in aerospace. There is a growing incorporation of unmanned aerial vehicles (UAVs) within remote and urban environments due to their versatility and ability to access hard-to-reach and/or congested places. UAVs offer low-cost solutions for many applications, including healthcare (e.g., medical supplies delivery) and surveillance during public events, protests, or emergencies (e.g., a nuclear accident). However, drone utilization in urban areas often relies on strict regulations to ensure safe and responsible operation. UAVs are subject to radiation-induced soft errors, and identifying the most vulnerable software and hardware components to radiation exposure is an advisable task, which is difficult to undertake. An essential task to UAVs correct operation is attitude estimation (AE). We assessed in [8] the soft error reliability of three AE algorithms running on two resource-constrained microprocessors under neutron radiation.

8.3.9 Urban mobility and epidemics

Reducing human mobility is a very effective non-pharmaceutical intervention to reduce epidemics spread, and lockdowns have been effectively used in various countries in 2020. However, it is clear that mobility reductions have heavy economic and social effects.

In our team, we have focused on understanding the interplay of human mobility and epidemics spread at the urban level. In this context, we had proposed a human mobility model ([45]) that captures daily mobility pattern between residences and different destinations in a city and also incorporates epidemic spread at each location. Interestingly, the model has a modular structure, so that the mobility model can be used without the epidemics model for other purposes, and indeed it has been used in the team as the basis for further modelling efforts in the electro-mobility context.

In the paper [15], we consider this city-wide mobility-epidemics model, and we provide techniques to compute optimal mobility control policies, which tune the operating capacities of different destinations depending on their type. To obtain this kind of policies, we solve an optimization problem that takes into account the current epidemic status, and maximizes the socio-economic activity while keeping the total infections below a desired threshold. The proposed solution techniques use an outer approximation method, thanks to the monotonic nature the problem, and a receding horizon approach. We apply these techniques to the mobility network of Grenoble metropolitan area, as it is showcased in the web interface GTL-Healthmob.

8.4 Research Axis 4: Social dynamics and Cyber-social networks

Participants: P. Frasca, G. Cocca, R. Prisant, A. Kibangou, R. Kalaoane.

8.4.1 Opinion dynamics and social influence

Models of social influence are much studied in network science to understand the dynamics of opinions and beliefs in societies. The team activity in this field has been focused on the following issue. Social influence, through phenomena of imitation and peer pressure, tends to favour the agreement of opinions and beliefs: nevertheless, disagreement persists in social groups. How can we explain the persistence of disagreement? Our research has rigorously studied multiple mathematical models that aim to understand the persistence of disagreement. The most recent results [23] regard the effects of limited precision in the exchange of information during social interactions: for instance, individuals may not communicate directly, but only display their preferences by choosing among a small number of options. This kind of dynamics can explain the formation of groups that hold distinct opinions. The rigorous study of this dynamics requires delicate mathematical tools for nonsmooth and hybrid dynamical systems.

8.4.2 Attention dynamics in social media

According to some popular narrative, social media are plagued by issues like the viral diffusion of *fake news* and the formation of *filter bubbles*, that is situations in which an Internet user encounters only information and opinions that conform to and reinforce his/her own beliefs. Our research makes the hypothesis that these phenomena are a natural byproduct of the very nature of online social networks, which make interactions highly dynamical and introduce unprecedented effects of *feedback* and scale through the action of algorithms that measure, personalize, and monetize an individual's online experience [53]. In the last several years we have developed a line of research that aims at identifying the concentration and scattering of media attention through a parsimonious mathematical model that captures the time evolution of collective behaviors. This has lead to several works on attention dynamics [41], including an important empirical work about the popularity of videos in YouTube channels. In this direction, this year we have published results showing that *fake views*, that is, views that are illicitly made by bots, play a prominent role in determining the popoularity of videos [6].

8.4.3 Modeling satisfaction in a captive users context to prevent social bomb

This research investigates the critical issue of user dissatisfaction within essential service sectors, such as water, energy, and transportation. Recognizing that many consumers are "captive" within these markets due to limited service options, a key concern is the potential for widespread dissatisfaction to escalate into significant social disruption, a phenomenon the research metaphorically terms a "social bomb." Acknowledging this risk, the study employs a novel modeling approach inspired by infectious disease models. By analyzing how dissatisfaction spreads and evolves within a population of captive users, much like the spread of a contagious disease, this research aims to inform proactive interventions in order to develop strategies for proactively addressing user concerns, improving service quality, and mitigating potential social unrest before it reaches a critical point. In [22], similar to SIS, we have introduced the SDS (Satisfied-Dissatisfied-Satisfied) model as a compartmental model for analysing the spreading of dissatisfaction among captive users of a given service. The model was analyzed, the equilibria explicitly computed and their stability analyzed. In addition, the trajectory of the system can be precisely derived. We use this property to solve an optimal time and magnitude of intervention problem to prevent dissatisfaction going beyond a given threshold. To overcome uncertainties in the model parameters, randomized strategies as in scenario optimization approach.

9 Bilateral contracts and grants with industry

Participants: C. Canudas de Wit.

OpNet IFPEN-INRIA, "Optimal urban mobility network design for sustainable space sharing between vehicles and soft transport modes" (2022-2025)

Abstract: This project aims to find the optimal topological structure of a road network that can be modeled in several layers, each representing a mode of transport. The primary objective of this network is to optimize the mobility of people in urban areas in terms of environmental impacts and exposure to pollutant concentrations. In practice, the optimization variables considered are the location and size (or capacity) of new roads, the change in traffic direction, new public transport lines, the location of new cycle paths, the sizing low emission zones (or arcs of the road graph with restricted access), etc. To achieve this objective of topological optimization of the mobility network, an important part of the thesis will have to be devoted to the analysis of mobility data. Indeed, the different graph structures that can be explored in this thesis and which are often transformations of the original road graph according to mathematical laws, require a calibration of the parameters which will be made from real mobility data. Learning techniques will therefore be used to extract useful information from the various sources of mobility data, among which an important role will be played by the mobility data available at IFPEN, in particular Geco air and Geovelo data.

10 Partnerships and cooperations

10.1 International initiatives

10.1.1 Associate Teams in the framework of an Inria International Lab or in the framework of an Inria International Program

IMAnAI :

Participants: Alain Kibangou, Hassen Fourati.

Title: Improved Bearings-only Target Motion Analysis Using AI Tools

Partner Institutions: Naval Group and IIT Delhi

Date/Duration: 2023-2027

Description The objective of the present project is to revisit several BOTMA (Bearing Only Target Motion Analysis) scenarios, starting from the conventional setting, where both agents are doing rectilinear motion, damaging the observability of one another, and shifting to the cases when one or both agents are doing maneuvers (with or without a constant speed in the case of the observer), and to provide different estimation algorithms by combining up today methods from the theory of control and estimation or the artificial intelligence. To this end, Naval Group generated a database of several thousands cases representing different conditions for BOTMA with realistic measurement noises. This database will be used for application of machine learning tools. The project is organized into 3 workpackages: WP1-Interval or probabilistic bounding framework; WP2-Application of nonlinear and AI-based estimation tools; WP3-Quickest detection of a change in the trajectory; WP4-Strategic maneuvering by the own ship and the target.

From Inria side, several project-teams are participating having different competences in the control theory, robotics and AI domains:

- Auctus (Bordeaux) works in robotics and interval methods (WP1).
- Dance (Grenoble) develops control and estimation methods, with use of AI tools (WP2).
- Larsen (Nancy) specializes in the intersection of robotics and AI (WP1).
- Modal (Lille) concentrates on statistical learning dealing with complex multivariate and/or heterogeneous data (WP2 – to be confirmed).
- Valse (Lille) designs control and estimation algorithms with accelerated convergence for applications in cyberphysical systems (WP1, WP3).

10.2 International research visitors

10.2.1 Visits of international scientists

Other international visits to the team

Trisha SRIVASTAVA

Status: PhD student

Institution of origin: University of Benevento

Country: Italy

Dates: 9/09/24 – 20/12/24

Context of the visit: Collaboration on synchronization of networked oscillators

Type of mobility: Research stay

Gaya COCCA

Status: Master student (intern)

Institution of origin: Politecnico di Torino, Turin

Country: Italy

Dates: 30/09/24 – 13/12/24

Context of the visit: Collaboration with IEIIT-CNR Turin on the study of popularity dynamics on YouTube

Type of mobility: Internship

10.2.2 Visits to international teams

Research stays abroad

Manuel CAMPERO JURADO

Visited institution: Eindhoven University of Technology

Country: Netherlands

Dates: from 08/10/2024 to 08/12/2024

Context of the visit: working with prof. Mauro SALAZAR

Type of mobility: research stay

Ghadeer Shaaban

Visited institution: University of Ottawa

Country: Canada

Dates: from 15/07/2024 to 15/10/2024

Context of the visit: working with prof. Mohammad Pirani on security of cyberphysical systems

Type of mobility: research stay funded by MITACS

10.3 European initiatives

eMob-Twin ERC Proof of Concept (PoC), 2023–2025. PI: C. Canudas de Wit. *Abstract.* We have developed eMob-TwinV1, built upon the findings of the ERC-AdG Scale-FreeBack (emob-twin.inrialpes.fr), and ERC-PoC resulting in an e-mobility simulation tool driven by digital twin technology. eMob-TwinV1 serves a wide range of purposes including forecasting, analysis, and unlocking EV flexibility, catering to the needs of companies, stakeholders, and electricity markets. Initially designed for the Grenoble metropolitan area, a new version currently under development, eMob-TwinV2, will have the capability to encompass any other metropolitan city in France, incorporating auto-calibration functionalities. Primarily focused on electric vehicle (EV) mobility and their state of charge, it also integrates multi-power charging stations.

10.4 National initiatives

COCOON COCOON is a 4-year research project (2023-2027) funded by ANR (the French national science foundation). The acronym COCOON stands for **Continuous Methods for the Control of Large Networks**. PI: Paolo Frasca

Abstract: The theory of Automatic Control needs substantial advancements to manage dynamics on large-scale networks, because achieving control and estimation objectives using standard methods is made intractable by the network size. Instead, large networks and the dynamics therein require adapted tools for modeling, learning, monitoring, and control. For this reason, the COCOON project advocates a scalable approach to large networks that is based on continuous network models instead of the usual (discrete) graphs. Towards this broad objective, this proposal aims at concurrently developing and cross-fertilising two promising methods to define continuous dynamics that approximate large-network dynamics: (1) Using graph limit objects such as graphons; (2) Defining analog approximations through a continuation process that replaces a large systems of ordinary differential equations with a single partial differential equation. These methods can be beneficial in a multitude of potential applications: the project will address three distinct applications with potentially high societal impact: epidemic models, electro-mobility networks and, with a bigger thrust, multimodal mobility networks.

FORBAC FORBAC is a project funded within PEPR MOBIDEC government initiative. PI: Carlos Canudas-de-Wit

Abstract: The FORBAC project aims to develop a methodology to predict the impact of changes in the mobility system on environmental and socio-economic objectives and to create decision-support tools for designing optimal mobility systems based on multiple criteria. On one hand, the project will develop a system model to analyze the causal chains resulting from new policies, technologies, or lifestyle changes in mobility systems. This model will identify all the input, output, and state variables of the subsystems and represent the interconnections between them. It will include a map of these interconnections, equations, and a spatiotemporal database to quantify the positive or negative effects of decisions at different levels and over various time scales. On the other hand, the project will develop a retrospective approach to identify the best combinations of mobility policies, services, and technologies to achieve the objectives specified beforehand. The project requires a multidisciplinary research approach and the involvement of a wide range of users and citizens, experts, operators, and decision-makers.

10.5 Regional initiatives

MOBIDOU Détection fiable des modes de déplacement pour la navigation hybride en mobilité urbaine douce, Multidisciplinary Institute in Artificial Intelligence (MIAI) Grenoble Alpes. *Abstract:* The surge in urban mobility poses a significant challenge for cities in terms of organizing public space, promoting health, and preserving the environment. The key challenge cities face is harmonizing the increasing variety of travel modes with automobile traffic. This requires strategic actions and decisions to revamp infrastructure. To enhance the reorganization of public space and optimize it, surveys and community panels are conducted to decipher users' multimodal strategies. The goal is to analyze and enhance the quality of urban mobility services. However, municipal investigations often lack precision in identifying different travel modes. On an individual level, users need a reliable tool to track their usage rates and distances traveled for each mode over a chosen period (day, week, etc.). In response to this need, the MOBIDOU project aims to develop a user-friendly solution for urban mobility assessment. The project's objectives are to provide users with precise usage rates and distances traveled for each urban travel mode based on their preferred time frame. Additionally, a smartphone application will record and organize data from various phone sensors, offering users clear insights and practical recommendations. To achieve these goals, we'll leverage smartphone sensors, including the inertial unit, GPS module, sound and light sensors, and pressure sensors. These innovative tools promise extended functionality over prolonged periods. Research methods will involve classification techniques, data and machine analysis, deep learning, and GPS navigation. A smartphone application consolidating this information in an organized manner will prove highly beneficial: it will empower users to gauge their walking habits, optimize public transport subscriptions, and assess their biking activities, providing valuable insights for a healthier and more efficient urban lifestyle.

ON ROUTE Initiative de Recherche Grenoble Alpes (IRGA). PI: A. Kibangou (2021-2024). Co-PI: P. Frasca

Abstract: Nowadays, millions of users regularly seek routing advice from Online Routing Applications (ORAs) like Waze, Google Maps and TomTom. Their adoption is so pervasive that ORAs have the potential to influence the patterns of congestion in traffic networks and the modal split in multimodal transportation networks. Online routing can be seen as an example of "social feedback" from the users, where information is collectively gathered from and used to influence back a complex dynamical system, whose evolution depends on the users' choices. Online routing is in general formulated as a multicriteria optimization problem which is solved by the ORA to satisfy the user utilities, while the transportation network manager aims at optimizing some overall measure of the efficiency of the network. To fulfill its purpose, the network manager (at the level of a city, for instance, or at larger scale) has the possibility to intervene through multiple control actions (such as variable speed limits, ramp metering, access control, traffic lights) and by setting regulatory policies for the ORAs activities. It is therefore crucial for the network manager to understand the dynamics induced by ORAs in order to take adequate control actions and set effective regulatory policies. Unlike most existing projects and works, which mainly study the problem from the service providers' points of view in order to generate smart routing or parking recommendations, we adopt the point of view of the transportation network manager that seeks to optimize the overall system. This project therefore aims at (i) analyzing the effect of online routing on transportation network congestion; and (ii) introducing mitigation strategies against the adverse effects of ORAs through control actions (variable speed limits, ramp metering, access control, traffic lights) and regulatory policies (frequency of routing recommendations).

11 Dissemination

All permanent members, C. Canudas de Wit, G. Casadei, H. Fourati, P. Frasca, A. Kibangou and F. Garin contributed to the dissemination activities over the year.

11.1 Promoting scientific activities

11.1.1 Scientific events: organisation

P. Frasca has co-organized

- Yearly GDR MACS Seminar 2024, on the topic "Multi-agent Systems", ENSAM Paris, September 30–October 1st, 2024.
- Invited session on "Open Multi-Agent Systems: Theory and Applications", IEEE Conference on Decision and Control, Milan, Italy, December 2024 (with M. Franceschelli, G. Oliva, J. Hendrickx)

11.1.2 Scientific events: selection

Member of the conference program committees

- G. Casadei has been Associate Editor in the IEEE-CSS Conference Editorial Board since 2021
- F. Garin has been Associate Editor in the European Control Association (EUCA) Conference Editorial Board (ECC) since 2017

Reviewer

All permanent members are active in reviewing for the main conferences in Automatic Control.

11.1.3 Journal

Member of the editorial boards

- C. Canudas de Wit is Senior Editor of IEEE Transactions on Control of Networks Systems IEEE-TCNS (2021-2025)
- C. Canudas de Wit is Editor at Large. Asian Journal of Control (2010-today)
- C. Canudas de Wit memeber of the Editorial Advisory Board du Transportation Research part C. (2021-today)
- H. Fourati is Associate Editor of IEEE Transactions on Control Systems Technology, since January 2024.
- P. Frasca has been Associate Editor of Automatica (the flagship journal of the International Federation of Automatic Control), 2021–2024
- F. Garin is Associate Editor of IEEE Control Systems Letters, since Dec. 2021
- A. Kibangou is Associate Editor of IEEE Transactions on Control of Networks Systems IEEE-TCNS, since Jan. 2022

Reviewer - reviewing activities

All permanent members are active in reviewing activities for a variety of journals in Automatic Control, Engineering and Applied Mathematics.

11.1.4 Invited talks

- C. Canudas de Wit has given the Plenary Lecture "EVs and Renewable Energy: Paving the Way for Greener Electromobility Networks" at the MFTS 2024: The 5th Symposium On Management Of Future Motorway And Urban Traffic Systems, Heraklion, Crete, Greece.
- P. Frasca has given the invited lecture "Graphons and dynamics on large graphs, from a control systems perspective", Symposium on Collective Models for Networked Particle Systems, University of Pavia, April 16, 2024.

11.1.5 Leadership within the scientific community

GdR MACS P. Frasca is member of the steering committee of the GdR MACS, a CNRS body that coordinates national activities in Automatic Control in France, 2019-2023.

IEEE and IFAC C. Canudas de Wit is Fellow of the IEEE and of the IFAC (International Federation of Automatic Control), both since 2016. P. Frasca is Senior member of the IEEE since 2018. Team members participate to the following technical committees of IEEE Control Systems Society and of the IFAC: IEEE-CSS Technical Committee "Networks and Communications Systems" (P. Frasca and F. Garin); IFAC Technical Committee 1.5 on Networked Systems (P. Frasca and C. Canudas de Wit); IFAC Technical Committee 2.5 on Robust Control (P. Frasca); IFAC Technical Committee 7.1 Automotive Control (C. Canudas de Wit); IFAC Technical Committee 7.4 Transportation systems (C. Canudas de Wit); IFAC TC 9.2. Systems and Control for Societal Impact (P. Frasca).

EUCA F. Garin is Secretary of the European Control Association (EUCA), since June 2024.

IAGSUA H. Fouratiis board member of the 'International Association of Grey Systems and Uncertainty Analysis (IAGSUA)' (link), 2023-.

11.1.6 Scientific expertise

- Carlos Canudas de Wit has been Chairman of the IFAC High Impact Paper Award Selection Committee 2021-2023.
- Carlos Canudas de Wit has been Chairman of 7th Kimura Best Paper Award Selection Committee.
- Carlos Canudas de Wit has been Member of the ECC 2024 Best Paper Award committee.
- P. Frasca has been a member of the CE48 committee of the National Research Agency (ANR) for the general call (AAPG) 2024.
- P. Frasca has been member of the selection committee of the National French Best PhD Thesis "GdR MACS" 2024.
- F. Garin has participated to the award selection committee for the 2024 Outstanding Student Paper Prize by the Networks and Communication Systems Technical Committed of the IEEE Control Systems Society.

11.1.7 Research administration

Inria Grenoble Several team members have been involved in committees at Inria Grenoble Rhône-Alpes. C. Canudas de Wit is a member of the COST-Inria-RA (Conseil d'Orientation Scientifique et Technologique, Inria Rhône-Alpes), since 2017. F. Garin has been president (since July 2019) of 'Comité des Emplois Scientifiques' (post-docs and 'délégations'). H. Fourati has been a member of 'Commission de développement technologique' (research engineers), since 2022.

GIPSA-lab F. Garin is 'responsable du pôle automatique et diagnostic' (chair of the Automatic Control and Diagnostics division) at GIPSA-lab, since Jan 2020. A. Kibangou is an elected member of 'Conseil de laboratoire' of GIPSA-lab, since Jan 2020.

UGA A. Kibangou is in his second term as an elected member of "Conseil du pôle MSTIC" at Univ. Grenoble Alpes. Since December 2023 he has been appointed Deputy Director of pôle MSTIC. H. Fourati has been in the selection committee of the yearly funding call ''Initiatives de Recherche à Grenoble Alpes (IRGA)'' - pôle ''Mathématiques, Sciences et Technologies de l'Information et de la Communication (MSTIC)'', Université Grenoble Alpes, 2023-. H. Fourati has been co-leader of the reasearch Axis Cyber-Physical Systems (CPS) for LabEx Persyval-lab 2, 2023-2024.

11.2 Teaching - Supervision - Juries

11.2.1 Teaching

H. Fourati gives each year around 250h of lectures and labs on average for first and second year students at the electrical engineering department (GEII) of IUT1, and third year students of bachelor's degree at Univ. Grenoble Alpes. The courses include Mathematics, logics, networks and automatic control. He also teaches for the MARS master of the University of Grenoble. He has several responsibilities related to his teaching:

- Unité d'Enseignement (UE) at UFR Physique, Ingénierie, Terre, Environnement, Mécanique (PhITEM), Université Grenoble Alpes : ''Single input single output (SISO) automatic control", 15h CM, 9h TD, 15h TP, master 1 Electronique, Energie électrique, Automatique (EEA). Since 2023
- 2nd and 3rd tear internships, département GEII, IUT 1 Grenoble. Since 2023.

P. Frasca has lectured about Intelligent Transportation Systems & Coordination of Autonomous Vehicles in the Master Autonomous and Robotics Systems (MARS) of the University of Grenoble.

A. Kibangou gives each year 250h of lectures and labs on average for first and second year students at the electrical engineering department (GEII) of IUT1 at Univ. Grenoble Alpes. The courses include Control theory and Mathematics. He is director of studies for the second year of the BUT program (Bachelor Universitaire de Technologie) and responsible of Control theory teaching.

F. Garin gives each year a class 'Distributed Algorithms and Network Systems', M2, Univ. Grenoble Alpes.

11.2.2 Supervision

Completed PhDs

Tommaso Toso. Dynamics and games for information-aware routing in traffic networks, October 2024, co-advised by A. Kibangou and P. Frasca.

Nomfundo Cele. Perception of Quality of Service on public transportation in developing countries, August 2024, co-advised by A. Kibangou and W. Musakwa (Univ. of Johannesburg).

Retsepile Kalaoane. Quality of service in public transportation: case analysis of Braamfontein, Johannesburg, April 2024, co-advised by A. Kibangou, T. Gumbo, W. Musakwa and I. Musonda (Univ. of Johannesburg).

PhDs in progress

Tarek Bazizi. EEATS doctoral school, Grenoble, co-advised by P. Frasca and Mohamed Maghenem (GIPSA-lab), since November 2024. Supported by a scholarship from the EEATS doctoral school.

Eduardo Steve Rodriguez Canales. EEATS doctoral school, Grenoble. Co-advised by P. Frasca and A. Kibangou, since October 2024. Supported by PEPR grant MOBIDEC-FORBAC.

Ghadeer Shaaban. Magneto-visual-inertial navigation with invariance and learning: Improving estimation in benign cases and under attacks, from October 2022, co-advised by A. Kibangou, H. Fourati and C. Prieur. Supported by a scholarship from the EEATS doctoral school.

Manuel Campero-Jurado. Optimal design of the urban mobility network for sustainable sharing between vehicles and soft modes of transport, since February 2023. Advisor: C. Canudas de Wit. Supported by the OpNet grant.

Guillaume Gasnier. Modeling and optimal control of electro-mobility networks, since January 2023. Advisor: C. Canudas de Wit

Raoul Prisant. Continuous models for the control of large networks: graphon limits, since November 2023. Advisors: F. Garin and P. Frasca

Omar Meebed. Modeling multimodal transportation networks, since July 2024. Advisors: A. KIbangou and H. Fourati

Yann Cauchepin. AI-based methods for bearing only target motion analysis, From December 2024. Advisors: A. Kibangou, H. Fourati, and A. Nègre (Naval Group)

Eduardo Canales. Mobility mode adoption models, since October 2023. Advisors: P. Frasca and A. Kibangou

Aborted PhDs:

Arold Gaborit. Perception and human-robot interfaces: application to continuous robots for assistance with medical-surgical procedures, October 2023-2024. Advisors: A. Hably, S. Caroly, H. Fourati, T. Chikhaoui

Rémi Mourgues. Variable price-optimal policies for urban electro-mobility networks, since January 2023-June 2024. Advisor: C. Canudas de Wit

Interns:

Théo Onillon. Data-based electromobility calibration models using learning tools, Summer 2024. Advisor: C. Canudas de Wit, in collaboration with Marta Gonzalez (UC Berkeley, USA).

Dawn Gora. Detailed simulation of informed traffic, Summer 2024. Advisors: T. Toso, P. Frasca, A. Kibangou

Mattéo Gautier. Graphons and graph properties for systems and control, June-July 2024. (1st-year Ensimag - Grenoble INP) Advisors: F. Garin and P. Frasca.

Titouan Vial. Temporal analysis of YouTube dynamics, May-June 2024. (Prépa Grenoble INP) Advisor: P. Frasca

Gaya Cocca. Popularity dynamics: mathematical models and validation on YouTube data, since September 2024. (MS student, Politecnico di Torino, Italy). Advisors: P. Frasca and C. Ravazzi (IEIIT-CNR, Italy)

11.2.3 Juries

P. Frasca has been member of the PhD graduation committees of

- Robin Vaudry. *Modeling, analysis and simulation of structured complex systems in epidemiology.* Université Grenoble Alpes, PhD advisor: Clementine Prieur and Didier Georges. October 24, 2024
- Alain Toupance. *Controllability of complex systems: an information theoretic approach.* Université Grenoble Alpes (Valence campus), PhD advisors: Laurent Lefèvre and Bastien Chopard. August 26, 2024

F. Garin has been a member of the PhD graduation committees of

- Lucas Magnana, INSA Lyon, Feb. 2024, thesis: *Algorithmes d'apprentissage pour le cyclisme urbain : modèles implicites et infrastructure dynamique*, PhD advisors: Hervé Rivano and Nicolas Chiabaut
- Pablo Andrés De Villeros Arias, Université Polytechnique Hauts de France and CINVESTAV del IPN Unidad Guadalajara (Mexico), Nov. 2024, thesis: *Contributions to Multi-agent System Control through Fixed-Time Distributed Optimization*, PhD advisors: Michaël Defoort, Alexander Loukianov, and Mohamed Djemai
- Elis Stefansson, KTH, Stockholm, Dec. 2024, thesis: *Complexity in Decision-making with Applications to Large-scale and Human-in-the-loop Systems*, PhD advisors: Karl Henrik Johansson and Henrik Sandberg

A. Kibangou has been a member of the PhD graduation committee of

- Hugo Jaquard, Univ. Grenoble Alpes, Nov. 2024, thesis: *Parallel Transport for Monte-Carlo Estimation on Graph Bundles*, PhD advisors: P.O. Amblard, S. Barthelmé, N. Tremblay.

F. Garin has been member of the recruiting committees:

- for CRCN/ISFP (researcher) positions at Centre Inria de Lyon, and
- for a MCf (assistant professor) position, sect. 61, at Université de Lorraine.

11.3 Popularization

11.3.1 Productions (articles, videos, podcasts, serious games, ...)

Press coverage

- Carlos Canudas de Wit has been interviewed by Célia Amphoux for "Le Dauphiné libéré", resulting in the article "Tirer parti des voitures électriques, ces batteries sur roues" (16/04/2024)
- Paolo Frasca has been interviewed by Denis Delbecq, resulting in the article "La lutte opaque de YouTube contre les fake views" on the Swiss newspaper "Le Temps" (19/07/2024).

11.3.2 Participation in Live events

Participation in trade shows for the presentation of our eMob-Twin technologies:

Tech&Fest February 2024, Alpexpo, Grenoble: A major national event aimed at bringing together innovative companies from the Auvergne-Rhône-Alpes region and highlighting key players in the technology and entrepreneurial ecosystem.

Drive-to-Zero June 2024, Hippodrome de Longchamp, Paris: A European event bringing together public and private decision-makers committed to zero-carbon mobility.

12 Scientific production

12.1 Major publications

[1] M. Castaldo, P. Frasca, T. Venturini and F. Gargiulo. 'Fake views removal and popularity on YouTube'. In: *Scientific Reports* 14.1 (4th July 2024), p. 15443. DOI: 10.1038/s41598-024-63649-w. URL: https://hal.science/hal-04637232.

[2] D. Nikitin, C. Canudas de Wit and P. Frasca. 'A Continuation Method for Large-Scale Modeling and Control: from ODEs to PDE, a Round Trip'. In: *IEEE Transactions on Automatic Control* 67.10 (Oct. 2022), pp. 5118–5133. DOI: 10.1109/TAC.2021.3122387. URL: https://hal.science/hal-03140368.

[3] D. Nikitin, C. Canudas de Wit and P. Frasca. 'Control of Average and Deviation in Large-Scale Linear Networks'. In: *IEEE Transactions on Automatic Control* 67.4 (2022), pp. 1639–1654. DOI: 10.1109/TAC.2021.3065191. URL: https://hal.science/hal-03170606.

[4] F. Taia Alaoui, H. Fourati, A. Kibangou, B. Robu and N. Vuillerme. 'Kick-scooters identification in the context of transportation mode detection using inertial sensors: Methods and accuracy'. In: *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations* (11th Nov. 2022). DOI: 10.1080/15472450.2022.2141118. URL: https://hal.science/hal-03850222.

[5] R. Vizuete, F. Garin and P. Frasca. 'The Laplacian Spectrum of Large Graphs Sampled from Graphons'. In: *IEEE Transactions on Network Science and Engineering* 8.2 (2021), pp. 1711–1721. DOI: 10.1109/TNSE.2021.3069675. URL: https://hal-centralesupelec.archives-ouvertes.fr/hal-03197046.

12.2 Publications of the year

International journals

[6] M. Castaldo, P. Frasca, T. Venturini and F. Gargiulo. 'Fake views removal and popularity on YouTube'. In: *Scientific Reports* 14.1 (4th July 2024), p. 15443. DOI: 10.1038/s41598-024-63649-w. URL: https://hal.science/hal-04637232 (cit. on p. 12).

[7] J.-F. Delmas, P. Frasca, F. Garin, V. Chi Tran, A. Velleret and P.-A. Zitt. 'Individual based SIS models on (not so) dense large random networks'. In: *ALEA : Latin American Journal of Probability and Mathematical Statistics* 21 (2024), pp. 1375–1405. DOI: 10.30757/ALEA.v21-52. URL: https://hal.science/hal-04240258 (cit. on p. 8).

[8] J. Gava, T. Kraemer Sarzi Sartori, A. Hanneman, R. Garibotti, F. G. Moraes, N. Calazans, H. Fourati, R. Possamai Bastos, R. Reis and L. Ost. 'Soft Error Assessment of Attitude Estimation Algorithms Running on Resource-constrained Devices under Neutron Radiation'. In: *IEEE Transactions on Nuclear Science* 71.8 (Aug. 2024), pp. 1511–1519. DOI: 10.1109/TNS.2024.3378689. URL: https://hal.science/hal-04501984 (cit. on p. 11).

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