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2025 *Activity Report*

RESEARCH CENTRE: **Inria Centre at Université Grenoble Alpes**
IN PARTNERSHIP WITH: **Université de Grenoble Alpes, CNRS**

Project-Team

DANCE

Dynamics and Control of Networks

In collaboration with Grenoble Image Parole Signal Automatique (GIPSA)

Project-Team DANCE

Creation of the Project-Team: 2021 February 01

Each year, Inria research teams publish an Activity Report presenting their work and results over the reporting period. These reports follow a common structure, with some optional sections depending on the specific team. They typically begin by outlining the overall objectives and research programme, including the main research themes, goals, and methodological approaches. They also describe the application domains targeted by the team, highlighting the scientific or societal contexts in which their work is situated. The reports then present the highlights of the year, covering major scientific achievements, software developments, or teaching contributions. When relevant, they include sections on software, platforms, and open data, detailing the tools developed and how they are shared. A substantial part is dedicated to new results, where scientific contributions are described in detail, often with subsections specifying participants and associated keywords. Finally, the Activity Report addresses funding, contracts, partnerships, and collaborations at various levels, from industrial agreements to international cooperations. It also covers dissemination and teaching activities, such as participation in scientific events, outreach, and supervision. The document concludes with a presentation of scientific production, including major publications and those produced during the year.

Keywords

Computer sciences and digital sciences

A1.2.6. – Sensor networks

A1.2.9. – Social Networks

A1.5. – Complex systems

A2.3.5. – Cyber-physical systems

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

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

A6.1.4. – Multiscale modeling

A6.2.6. – Optimization

A6.4. – Automatic control

A8.8. – Network science

A9.16. – Societal impact of AI

Other research topics and application domains

B2.3. – Epidemiology

B6.3.4. – Social Networks

B7. – Transport and logistics

B7.1. – Traffic management

B7.2. – Smart travel

B8.2. – Connected city

B8.3. – Urbanism and urban planning

Contents

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2 Overall objectives

DANCE is a joint research team of *Centre Inria de l'Université 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 [45] 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 Grenoble Traffic Lab [46, 54, 53], the team is currently pursuing the development of software aimed to facilitate the integration of electro-mobility (emob-Twin). 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 limitations, 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 two 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 transportation, 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

- Gustav Nilsson joined the team as a permanent researcher (CRCN) at October 1st 2025.

6.1 Awards

IEEE CSS Italy Chapter Best Thesis Award 2025 for the best master thesis in Automatic Control in Italy by Gaya Cocca, co-advised by Paolo Frasca.

7 Latest software developments, platforms, open data

As a team we are engaged in the open diffusion of various products of our research, including data, code, and publications, for several reasons: (i) complying with obligations towards our financial sponsors and our employers; (ii) making our research reproducible by peers; and (iii) enhancing our impact on the scientific debate and on society.

Regarding publications, all of them are publicly available on the HAL national platform. Regarding data that we collect during our research, data is treated according to each project data plans, when required. In several occasions, we make our data publicly available in full or in part (with due care to GDPR regulations if applicable). This year, there was no new collection or release of data.

The digital twin software eMob-Twin, described below, was presented in the paper [47].

7.1 Latest software developments

7.1.1 eMob-Twin V2

Keywords: Electric vehicle, Road traffic, Digital twin

Functional Description: eMob-Twin is a digital twin that combines electric vehicle (EV) mobility and energy models to predict mobility, energy demand, and EV flexibility. eMob-Twin analyzes multiple infrastructure scenarios to optimize the placement of charging stations. Covering a large part of French cities, it includes tools for developing SDIRVE (strategic charging infrastructure plans) and automatically adjusts the model based on government files. With IRIS-level granularity, it aligns data with SDIRVE, ensuring better consistency and adaptation to local needs.

URL: http://emob-twin.fr

Contact: Carlos Canudas-De-Wit

8 New results

8.1 Research Axis 1: Exact Automatic Control Methods for Networks

Participants: Tarek Bazizi, Giacomo Casadei, Paolo Frasca, Hassen Fourati, Alain Kibangou, Ghadeer Shaaban.

8.1.1 Leader-following consensus

Consensus of multi-agent systems serves as a building block for several complex problems over networks, e.g., graph signal processing, formation control, distributed optimization to mention a few. Leader-following consensus can be regarded as a multi-agent system version of model reference tracking, to control multiple agents (followers) towards a desired reference goal (leader). The problem is particularly interesting when not all followers have direct access to the leader's signals, in which case the tracking should be achieved in a distributed fashion by sharing information with neighbors. Complex networks, neuroscience, and other applications have shown examples of multi-agent adaptive systems that must follow (over possibly short times) reference dynamics that are neither Hurwitz nor neutrally stable. However, such leader-following behavior would be impossible with existing adaptive consensus methods, e.g., based on model reference adaptive control (MRAC), since the stability of the reference dynamics is required. To fill this gap, we propose in [26] a novel model reference adaptive stabilizing control (MRASC) framework for leaderfollowing consensus of multi-agent systems with unknown and heterogeneous dynamics. Differently from several approaches in the leader-following consensus literature, the proposed framework is free of any extra distributed observer layer for the leader's signal, as the reconstruction of such signals is intrinsic in the adaptive laws. Besides, the framework does not require Hurwitz or neutral stability of the leader and generalizes existing acyclic requirements on the communication graph among the followers. Starting from any weakly connected communication digraph, the proposed method allows to derive a lower bound, useful from the network design point of view, for the minimum number of followers that should be pinned by the leader.

8.1.2 Synchronization of networks of 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 or when the systems are subject to uncertainties., disturbances or attacks. Several domains of applications such as power networks want to exploit nonlinearities to achieve better performances but face increased difficulties in designing control laws that enforce synchronization between agents.

In global interaction models, like the mean-field model, all oscillators influence each other's time evolution. However, this globally connected interaction structure does not reflect how coupling occurs in practice. For instance, in microgrids operating under droop control, frequency adjustments are obtained through the computation of phase shifts based on local reference frames, for which measurements could be more accurate and practically available. This motivates the use of limited range interaction models, where an oscillator interacts only with a particular subset of oscillators based on some predefined criteria. In our work [25] we analyze coupled oscillators that interact if their geodesic distances are within a prescribed bound. Steady state behaviors of this system depend on the natural frequencies of the oscillators and on the underlying graph structure. A necessary and sufficient condition is provided for the graph to remain complete. If the graph is connected over time, it is proved that phase ordering is preserved among the oscillators according to their natural frequencies. The asymptotic convergence to frequency synchronization is proved if the graph is assumed to stay connected and all natural frequencies are the same. A comprehensive analysis of the three-oscillator case shows that phase ordering is not necessary for frequency synchronization, and that graph connectivity, together with an appropriate bound on the range of natural frequencies, ensures frequency synchronization.

Due to the cyber-physical structure of the applications, the systems can be exploited by various attacks. Motivated by this, our recent work [9] introduces a masking protocol to enhance the security of a consensus protocol for nonlinear multiagent systems. The main idea is that by adding a masking signal to each agent's output and applying a de-masking filter at the receiving agent, eavesdropping attacks can be avoided while sufficent conditions that the proposed security protocol preserves output consensus can be still provided.

Moreover, the models of the agents in a synchronization network can be subject to uncertainties. In our work [35] we revisit the adaptive stabilization of linear uncertain systems concept and extend the analysis to multi-agent network frameworks. Firstly, by adopting a more general stabilizing direction and introducing a sigma modification based control design, a robust adaptation law is demonstrated to effectively handle uncertainties in the model. To enable a more flexible adaptation law design, the cancellation constraint associated with a key matrix therein is relaxed. Additionally, a novel Lyapunov function is constructed to establish sufficient conditions for stability, which are crucial for ensuring robust synchronization in multi-agent systems. Finally, a simulation example is provided to validate the proposed approach, highlighting its novelty and practical effectiveness.

8.1.3 Distributed optimization in networked systems

The need for distributed optimization emerges in many multi-agent systems, such as sensor networks and power systems. In our new work [27], we revisit a classical distributed gradient-descent algorithm, introducing an interesting class of perturbed multi-agent systems. The state of each subsystem represents a local estimate of a solution to the global optimization problem. Thereby, the network is required to minimize local cost functions, while gathering the local estimates around a common value. Such a complex task suggests the interplay of consensus-based dynamics with gradient-descent dynamics. The latter descent dynamics involves the projection operator, which is assumed to provide corrupted projections of a specific form, reminiscent of existing (fast) projection algorithms. Hence, for the resulting class of perturbed networks, we are able to adaptively tune some gains in a fully distributed fashion, to approach the optimal consensus set up to arbitrary-desired precision.

8.1.4 Magneto-inertial navigation in the presence of unknown inputs

Across many navigation and control applications, estimating the position, velocity, and attitude of a rigid body is challenging when sensor measurements are corrupted by unknown inputs, such as external accelerations or unmodeled angular velocities. Traditional MARG-based algorithms (using magnetometers, accelerometers, and gyroscopes) often fail when these unknown inputs violate common assumptions—for example, when accelerometers measure not only gravity but also external accelerations, or when gyroscope readings are unreliable due to bias or power constraints. The works [22, 23] collectively address these challenges by developing state estimation algorithms on the special orthogonal group SO(3) and, in one case, the full position-velocity-attitude space, while explicitly modeling unknown inputs in both the system dynamics and measurement equations. These algorithms explore different unknown-input scenarios: external accelerations with and without direct feedthrough into measurements, as well as treating gyroscope angular velocity as an unknown input. They also provide theoretical guarantees such as local optimality and local stability, and propose practical estimation methods including a robust two-stage Kalman filter. Validation through Monte Carlo simulations and, in some cases, real datasets, consistently demonstrates that these approaches outperform existing attitude estimation techniques (such as TRIAD, IEKF, or accelerometer-magnetometer-only methods), especially in scenarios where disturbances or unknown inputs play a significant role.

8.1.5 Cyber-physical security in navigation and active defense strategies

Recent developments in cyber-physical system (CPS) security for navigation and control applications highlight the necessity of integrating robust state estimation, resilient control design, and active defense mechanisms to maintain system integrity under cyber threats. In attitude estimation using MARG sensors, a secure estimation framework formulated on the special orthogonal group SO(3) has been proposed to mitigate the impact of false data injection (FDI) attacks on sensor measurements. This approach leverages an invariant extended Kalman filter (IEKF) with an optimized Kalman gain matrix designed to minimize the upper bound of the state estimation error covariance, ensuring accurate attitude reconstruction even in adversarial environments. Within vehicular control systems, analyzes of zero-dynamics attacks have demonstrated that malicious inputs exploiting the system's internal model and unobservable subspaces can manipulate yaw rate and lateral acceleration without altering measurable outputs [24]. Such stealthy perturbations emphasize the importance of observer-based detection schemes, redundant sensing architectures, and secure feedback design to preserve dynamic stability. Beyond passive protection, active defense strategies such as the Misleading Unauthorized Observer (MUO) technique introduce deceptive input-output signal modulation to disrupt unauthorized state estimation [21]. By solving an optimization problem with undetectability constraints, the defender injects auxiliary control signals that increase the estimation error of eavesdropping observers while maintaining nominal system performance. Collectively, these advancements merge robust filtering, secure control theory, and adaptive deception techniques into a cohesive framework that enhances the resilience of modern navigation and vehicular CPS against sophisticated cyber-physical attacks.

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

Participants: Giacomo Casadei, Carlos Canudas-de-Wit, Paolo Frasca, Sebastien Fueyo, Federica Garin, Raoul Prisant.

When considering very large networks, it can be useful to consider 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.

In this research, we have developed two distinct approaches, the "continuation method" and methods based on the notion of graphon.

8.2.1 The continuation method

With this novel method, introducted in the thesis work of D. Nikitin and a series of papers, we have developed a sound and complete theoretical framework for the PDE approximation of large networked ODE systems, and we have applied this framework to multiple applications including swarms of autonomous robots, traffic networks, and spin-torque oscillators.

Recent work has focused on the development of continuation-based, control-oriented PDE models for traffic flows on circular roads. Recent contributions include the rigorous derivation of macroscopic models from second-order microscopic dynamics using the continuation method [14], following the framework of [52]. This approach enables classical driver models (OV-FTL, IDM) to be linked to PDE representations for control design. A macroscopic control strategy has also been developed and projected onto implementable acceleration laws for autonomous vehicles, and the method has been extended to non-stationary target profiles of density and velocity [28, 40], allowing traffic to be steered toward spatio-temporal configurations under heterogeneous communication structures. Current research aims to analyze the influence of a single autonomous vehicle on the collective traffic dynamics and its potential stabilizing effect [41].

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 [51]. 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.

In our work [42] we study the connectedness of graphons. We show that connectedness is related to some spectral property of the graphon-Laplacian operator, which is important for convergence of consensus and other diffusion-based dynamics on large-scale networks. Some equivalent characterizations of connectedness are provided, and some subtleties in their definition are discussed through examples.

Apart from analyzing general properties of graphons, we have also exploited how graphons can be utilized in opionion dynamics modeling. In our work [20], we make use of graphon theory to study opinion dynamics on large undirected networks. The opinion dynamics models that we take into consideration allow for negative interactions between the individuals, whose opinions can thus grow apart. We consider both the repelling and the opposing models of negative interactions, which have been studied in the literature. We define the repelling and the opposing dynamics on signed graphons and we show that their initial value problem solutions exist and are unique. We then show that, in a suitable sense, the graphon dynamics is a good approximation of the dynamics on large graphs that converge to a graphon. This result applies to large random graphs that are sampled according to a graphon (W-random graphs), for which we provide a new convergence result under very general assumptions; in particular, the graphs' average degrees only need to grow faster than log n.

In our recent work [34], we then extend the analysis to the asymptotic behavior of the dynamics, through the study of the properties of the opposing Laplacian operator. Our results are consistent with known facts about the classical Altafini model on signed graphs: on a connected signed graphon with degree essentially bounded away from zero, the dynamics converges to a bipartite consensus if the signed graphon is structurally balanced, and converges to zero if it is not.

8.3 Research Axis 3: Mobility systems and transportation networks

Participants: Carlos Canudas-de-Wit, Alain Kibangou, Paolo Frasca, Manuel Campero Jurado, Federica Garin, Guillaume Gasnier, Gustav Nilsson, Eduardo Steve Rodriguez Canales, Hassen Fourati, Omar Meebed
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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 [48].

In our recent work [29], we undertake a game theoretic approch to develop optimal pricing method for multiple charging stations. By casting the problem into a congestion game framework, we compute the equilibrium flows for each pricing strategy and select the prices that maximize the operator's revenue. The demand at each station is influenced by travel times and incentives to charge. Vehicle types and behaviors (thermal vs. electric, must/may/not charge) are considered. This results in a bi-level optimization problem, which is solved using a Branch-and-Bound approach enhanced with pruning techniques for improved efficiency. Our experiment integrates three levels of optimization: maximizing revenue by optimizing the placement of stations when maximizing their pricing strategies, while minimizing the demand derived from the congestion game model. We examine the total travel time and maximizing revenue does not increase congestion.

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 our work [15], we outline the development of an Android application, designed for two complementary purposes: 1) to collect data from smartphone sensors (accelerometer, gyroscope, magnetometer, and Global Positioning System (GPS)) and 2) to predict four green transportation modes (walk, bike, public transport and kick scooter) based on accelerometer and gyroscope data only. GPS data are omitted in this work, to address privacy concerns and energy consumption. Unlike existing works that focused solely on modeling and classification in TMD, the main contribution of the work goes beyond and provides moreover a detailed overview of the implementation of the mobile application, as well as the challenges encountered during data acquisition and practical solutions we applied and the entire automatic cycle from data acquisition to classification, prediction and display of results on the application. Developing this application and its automated pipeline with a reliable client-server communication presented many technical challenges, requiring reliable data transfer and robust design to ensure good performances. The results obtained show good predictions, providing the user with an efficient tool to evaluate their sustainable mobility habits. Encouraging such modes contributes to ease traffic congestion, and more sustainable urban lifestyles.

8.3.3 Multimodal mobility: Safety 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. In South Africa, this mode of transport is more regularly involved in road traffic accidents compared to other modes. However, very few studies have focused on analyzing driving in this transportation mode from the perception of the commuter. In our new work [11], the analysis is carried out using qualitative (questionnaires) and quantitative (speed and acceleration) data with the aim of finding factors that characterize public transportation drivers, specifically understanding how minibus taxi drivers differ from other drivers and how the regulatory environment influences their on-road behavior. The personality and skills of the drivers are shown to be the two main factors to analyze. It is shown that minibus taxi drivers perform lower than ride-hailing drivers. In addition, their driving is more aggressive in a controlled environment, while it is more reckless in an uncontrolled environment. Cultural, training, and technology-oriented actions are suggested to improve the on-road driving of the minibus taxi in the chosen study area.

8.3.4 Multimodal mobility: Modeling of user satisfaction in public transport

The issue of mobility from disadvantaged areas to places of interest for work, health care, education, or entertainment poses specific challenges that cannot be approached under the same prism as that of well-resourced areas. In such areas, commuters are often captive of available transportation modes. However, very few studies have focused on identifying the key factors that influence the satisfaction of these commuters. In our work [10], we introduce an agent based modeling and simulation approach, to identify and classify these factors. We show, for the case study of a township in South Africa, that speed and quality of the infrastructure are crucial factors, while waiting time and accessibility are to be improved; safety and travel time being to be watched. Then recommendations are provided to improve the service according to these factors.

8.3.5 Space allocation strategies for bike lanes

In recent research, we developed a graph-based framework aimed at improving cycling networks, with a focus on optimizing safety and comfort. As an initial approch, in [43], we assign weights to a six-category system for bike lanes based on their segregation from motorized vehicles using the well-developed CycleRAP tool. Each bike lane is weighted based on its category and topological features. Graph theory metrics are then applied to analyze the core topological characteristics of cycling networks across various French municipalities. These metrics form the basis for estimating and predicting cyclists' perceived safety and comfort levels, as reported in local surveys. Building on this relationship, we formulate a topology optimization problem aimed at maximizing predicted safety and comfort within budgetary constraints. To tackle this complex problem, we introduce a topological optimization algorithm and compare its performance with existing algorithms to ensure reliability. This approach integrates graph theory with real-world indicators, providing a comprehensive quantitative framework to support decision-making in urban planning and resource allocation. The framework was then extended to incorporate actual cycling flows in [32].

However, infrastructure upgrades on the bike lanes usually cause more limited road space for vehicles. Motivated by this, in our subsequent work [31] we study the effect increased space for bike lanes have on vehicular traffic. While, this work only considers the impact with respect to travel time, our later work [30] incorperates fairness aspects.

8.3.6 Cycling adaptation

To address the consequences of climate change, policies promoting green transportation, particularly cycling and public transit, are gaining importance. To address this need, we have in [36] developed a novel compartmental model to analyze the dynamics of bicycle adoption. For the proposed model, we prove the existence and global asymptotic stability of a single equilibrium point using order-preserving monotonic systems theory. Furthermore, we establish the system's identifiability, ensuring unique parameter estimation from observed trajectories. To illustrate the applicability of the results, a case study of Stockholm, Sweden, showcases the model's ability to accurately characterize cycling adoption dynamics, highlighting its potential for informing sustainable transportation strategies.

8.3.7 Incentivizing public transit for large events

Large crowds at events disrupt city transportation networks, and incentivizing public transit to mitigate these impacts remains challenging. To address this problem, the team developed in [33] a method to design and assess public transit incentives for large events. This was done by first developing a traveller mobility model that describes how information from routing apps data, public transit fare and frequency guides the choice of travellers between two modes and updates the traffic state based on their mode choice. Traveller's wait time, departure time, public transit capacity, road capacity, road congestion, and parking capacity of private vehicles at destination are all considered when updating the number of users who completed their trip. The influence of public transit fare and frequency on the population's overall travel time, modal split and parking overcapacity was studied, along with the influence of the ratio of travellers informed with routing apps. Finally, incentives are selected by including operational cost and user satisfaction in an optimization approach.

8.3.8 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 the paper [19], 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.

8.3.9 Multicommodity freeway network control

Freeway Network Control (FNC), i.e., controlling the traffic flow on freeways by variable speed limits and ramp-metering has been shown to be a successful approch to reduce congestion. Straightforward formulations of both single- and multi-commodity FNC problems based on the Cell Transmission Model are known to be non-convex, mainly due to the congestion effects at diverge junctions. However, recent studies have shown that it is possible to formulate a tight convex relaxation of the single-commodity FNC problem. In [44], we extend these results to the multi-commodity FNC problem by considering concave commodity-specific demand functions and concave aggregate supply functions, so that different variable speed limits can be applied to different commodities. Hence, it is possible to efficiently compute the optimal control action to reduce congestion phenomena in the network. We also present a case study of a segment of the freeway network in California, using data from the PeMS database, to demonstrate the effectiveness of the proposed solution. Finally, we draw a comparison with a setting where the multi-commodity flows are modeled and controlled as a single-commodity flow, to emphasize the relevance of acting separately on different classes of vehicles.

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

Participants: Paolo Frasca, Alain Kibangou, Raul Prisant.

8.4.1 Effect of state discretization in opinion dynamics

One of the most basic principles in opinion dynamics is that opinions of individuals who communicate approach each other [49]. In our work [12], we assume that communication of one's opinion is not precise. The reason for such imprecision may be poor language, or the fact that opinion is not expressed verbally, but through a behavior or a choice among a finite number of options or actions, namely the quantized states. The starting point of this work is a well-known class of linear systems on a graph that asymptotically converge to a consensus state. We consider a variation of this dynamics, by modifying some of the states through the nearest integer function: this change sets the dynamics apart from the consensus dynamics. We focus our study on the case in which the underlying graph is a line, which is particularly significant as it exhibits asymptotic behaviors that are far from consensus. In this case, we compute the equilibria of the system and prove convergence of solutions.

8.4.2 Popularity dynamics in social media

Social media play a prominent role in contemporary societies. Therefore, it is important to understand how the popularity of contents, topics, and influencers evolves therein. Popularity dynamics in social media depend on a complex interplay of social influence between users and popularity-based recommendations that are provided by the platforms. In our work [13], we introduce a discrete-time dynamical system to model the evolution of popularity on social media. Our model generalizes the well-known Friedkin-Johnsen model to a set of influencers vying for popularity. We study the asymptotic behavior of this model and illustrate it with numerical examples. Our results highlight the interplay of social influence, past popularity, and content quality in determining the popularity of influencers.

8.4.3 Dissatisfaction dynamics in user communities

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 can lead to user dissatisfaction and complex social dynamics. Building on a recent dynamic model [50], similar to the SIS-dynamics for epidemics, we in [17] extend the analysis of captive user dissatisfaction to networks of interconnected communities, using a directed bipartite leader-follower structure. We investigate the steady-state properties of the model and analyze how leader communities can mitigate or amplify dissatisfaction among their followers. A key insight is that consensus in dissatisfaction levels does not stem from network topology but from the alignment of a Dissatisfaction Index, a new metric introduced in this work that reflects each community's perception of service quality

9 Bilateral contracts and grants with industry

Participants: Carlos Canudas-de-Wit, Hassen Fourati, Alain Kibangou, Yann Cauchepin.

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

Participants: Carlos Canudas-de-Wit

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 has 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 from real mobility data. Learning techniques are therefore used to extract useful information from the various sources of mobility data, among which an important role is played by the mobility data available at IFPEN, in particular Geco air and Geovelo data.

IMAnAI Improved Bearings-only Target Motion Analysis Using AI Tools

Participants: Alain Kibangou, Hassen Fourati

Partner Institutions: Naval Group and IIT Delhi

Date/Duration: 2023–2027

Description: The objective of the project is to revisit several BOTMA (Bearing Only Target Motion Analysis) scenarios, starting from conventional settings where both agents are performing rectilinear motion, which limits observability, and extending to cases where one or both agents maneuver (with or without constant speed in the case of the observer). The project aims to provide various estimation algorithms by combining modern methods from control and estimation theory with artificial intelligence tools. Naval Group generated a database of several thousand cases representing different conditions for BOTMA with realistic measurement noise, which will be used for machine learning applications. The project is organized into four work packages: WP1 focuses on an interval or probabilistic bounding framework; WP2 addresses the application of nonlinear and AI-based estimation tools; WP3 concerns the quickest detection of changes in the trajectory; and WP4 deals with the strategic maneuvering of both the own ship and the target.

From Inria, several teams are participating:

- Auctus (Bordeaux) works in robotics and interval methods (WP1)
- DANCE (Grenoble) develops control and estimation methods using AI tools (WP2)
- Larsen (Nancy) specializes in the intersection of robotics and AI (WP1)
- Modal (Lille) focuses on statistical learning with complex multivariate or heterogeneous data (WP2, to be confirmed)
- Valse (Lille) designs control and estimation algorithms with accelerated convergence for cyber-physical systems applications (WP1, WP3)

This project is supporting the PhD thesis of Yann Cauchepin funded by a CIFRE contract from Naval Group.

10 Partnerships and cooperations

Participants: Carlos Canudas de Wit, Giacomo Casadei, Hassen Fourati, Paolo Frasca, Federica Garin, Alain Kibangou.

10.1 International research visitors

10.1.1 Invited professorships

Alain Kibangou was appointed Visiting Associate Professor at the Faculty of Science of the University of Johannesburg (UJ, South Africa) for the period from September 1, 2022 to August 31, 2025 (renewal in progress).

This appointment reflects his sustained involvement in establishing a long-term collaborative partnership between Univ. Grenoble Alpes (UGA) and UJ. His efforts contributed to the signing of Memoranda of Understanding (MoUs) between the two institutions in 2018 and 2023, providing a formal framework for all collaborative activities between the universities. As an invited professor, he actively contributes to the supervision and training of doctoral and master's students. In 2022, he designed and delivered a 10-hour Machine Learning training course, intended for end-users rather than developers of machine-learning tools. The course, taught in English, benefited 20 master's and doctoral students at the University of Johannesburg.

10.1.2 Visits of international scientists

Other international visits to the team

Alexia Ambrogio

Status: PhD

Institution of origin: Politecnico di Torino, Turin

Country: Italy

Dates: February-July 2025

Context of the visit: Collaboration on information design in congestion games

Mobility program/type of mobility: Research stay

10.1.3 Visits to international teams

Research stays abroad

Guillaume Gasnier

Visited institution: University of California, Berkeley.

Country: USA.

Dates: 20/01/2025 – 20/03/2025.

Context of the visit: Working with Prof. Murat Arcak and Kameshwar Poolla.

Mobility program / Type of mobility: Research stay, funded by NSF grant CNS-2135791 and the UGA 2025 outgoing international mobility support grant for PhD students.

Carlos Canudas-de-Wit

Visited institution: University of California, Berkeley.

Country: USA.

Dates: 2 weeks in March 2025.

Mobility program / Type of mobility: Collaboration with Marta Gonzalez and with Maria Laura delle Monache.

10.2 European initiatives

10.2.1 eMob-Twin

Grant: ERC Proof of Concept (PoC)

Duration: 2023–2025

PI: Carlos Canudas-de-Wit

Abstract: We have developed eMob-TwinV1, built upon the findings of the ERC-AdG Scale-FreeBack and ERC-PoC eMob-Twin, 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.

10.3 National initiatives

10.3.1 COCOON - Continuous Methods for the Control of Large Networks

Funding: ANR (the French national science foundation)

Duration: 2023-2027

PI: Paolo Frasca

Abstarct: 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.

10.3.2 FORBAC

Funding: PEPR MOBIDEC government initiative

Duration: 2023 - 2027

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.

10.4 Regional initiatives

10.4.1 BOOT - Robots for real world interaction

Funding: CDP project IDEX University Grenoble Alpes

Duration: 2022-2025

Member: Hassen Fourati

Abstract: Robotics is rapidly transforming industry, services, and healthcare, and large-scale investments such as the "France 2030" plan (800 M€) signal its growing societal importance. Yet no existing robot fully meets the challenge of operating safely and effectively in complex, evolving human environments. The CDP BOOT addresses this gap by uniting Grenoble's strong and diverse expertise in engineering (automation, mechatronics, signal and image processing, computer science) and the human and social sciences (cognition, psychology, neurobiology, language processing, ergonomics). Structured around four axes –robot construction, perception, decision and control, and human-robot synergy– it leverages UGA's numerous robotic platforms to conduct ambitious experimental, methodological, technological, and theoretical work. By developing new interaction models, design guidelines, and integrated robotic systems, the project aims to advance both robotics and our understanding of human behavior in real-world ecosystems, and to establish Grenoble as a leading national and international center for robotics interacting with the real world.

As part of the project budget, we supported a master's student and a postdoctoral fellow (I. Gharbi).

10.4.2 INSPECT - Enhancing surgery with deep learning-controlled continuum robots

Funding: Multidisciplinary Institute in Artificial Intelligence Grenoble Alpes (chaire MIAI CLUSTER)

Duration: 2025-2029

Member: Hassen Fourati

Abstract: Developing reliable and explainable Artificial Intelligence (AI) approaches is of paramount importance especially in clinical applications. The wide adoption of robots for surgery is established, with a market of some billion in 2024. This domain was marked by the introduction of continuum robots in the last decades, a break-through in the robotics paradigm, allowing for inherently safe, miniaturized, and deformable systems, able to access and navigate through complex anatomy and closely reach confined therapeutical targets. Their wide spread is yet limited by the ability to localize and control such small devices in medical images. INSPECT will provide AI (deep/reinforcement learning) methods, combined with recent sophisticated robot mathematical models, in order to precisely estimate the entire shape of continuum robots and assist surgeons to accurately control their motion. INSPECT will aim for advances in AI-based surgical robots: less invasive, safe, reliable, and accurate.

As part of the project budget, we can support a postdoctoral fellow.

11 Dissemination

11.1 Promoting scientific activities

11.1.1 Scientific events: selection

Member of the conference program committees

- Giacomo Casadei is Associate Editor, IEEE-CSS Conference Editorial Board (CEB), since 2023.
- Gustav Nilsson is Associate Editor, IEEE-CSS Conference Editorial Board (CEB), since 2023.

Reviewer

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

11.1.2 Journal

Member of the editorial boards

- Carlos Canudas-de-Wit was Senior Editor, IEEE Transactions on Control of Network Systems (IEEE-TCNS), 2021-2025.
- Carlos Canudas-de-Wit is Editor at Large, Asian Journal of Control, since 2012.
- Carlos Canudas-de-Wit is part of the Editorial Advisory Board, Transportation Research Part C since 2021.
- Hassen Fourati is Associate Editor, IEEE Transactions on Control Systems Technology, since 2024.
- Hassen Fourati was Associate Editor, IEEE Transactions on Automation Science and Engineering (TASE), 2022-2025.
- Federica Garin is Associate Editor, IEEE Control Systems Letters, since 2021.
- Alain Kibangou is Associate Editor, IEEE Transactions on Control of Network Systems, since 2022.

Reviewer - reviewing activities

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

11.1.3 Invited talks

Paolo Frasca has given two invited talks, including a plenary talk at the French national congress of Automatic Control and Production Engineering.

- "Opinion dynamics on signed graphons and W-random graphs". Workshop on Control and Games on Large Networks, IFAC NECSYS 2025, Hong Kong, June 2, 2025
- "Graphons: A tool to study dynamics on large networks", 3rd SAGIP Congress, Mulhouse, France, May 21, 2025 (**plenary**)

11.1.4 Leadership within the scientific community

IEEE and IFAC Carlos Canudas-de-Wit is Fellow of the IEEE and of the IFAC (International Federation of Automatic Control), both since 2016. Paolo 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 "Network Systems" (Paolo Frasca, Federica Garin, and Gustav Nilsson); IFAC Technical Committee 1.5 on Networked Systems (Carlos Canudas-de-Wit and Paolo Frasca); IFAC Technical Committee 2.5 on Robust Control (Paolo Frasca); IFAC Technical Committee 7.1 Automotive Control (Carlos Canudas-de-Wit); IFAC Technical Committee 7.4 Transportation systems (Carlos Canudas-de-Wit); IFAC TC 9.2. Systems and Control for Societal Impact (Paolo Frasca).

EUCA Federica Garin has been Secretary of the European Control Association since June 2024.

IAGSUA Hassen Fourati is a Board Member, since 2023.

11.1.5 Scientific expertise

- Carlos Canudas-de-Wit was a member of Panel 7 ERC-Consolidator Grant.
- Paolo Frasca was a member of Panel CE48 of ANR (French research agency).

11.1.6 Research administration

Inria Grenoble Carlos Canudas-de-Wit is a COST-Inria-RA member since 2017; Federica Garin is the President of Comité des Emplois Scientifiques since July 2019; Hassen Fourati is a member of Commission de Développement Technologique since 2022.

GIPSA-lab Federica Garin was the chair of the Automatic Control and Diagnostics division, 2020-2025; Alain Kibangou has been an Elected member, Conseil de laboratoire, since Jan 2020.

UGA Alain Kibangou is a Deputy Director of pôle MSTIC at Univ. Grenoble Alpes since December 2023. He is also a nominated member of CED (College des écoles Doctorales) council. Paolo Frasca is an elected member of the same council.

UGA, ED EEATS Paolo Frasca is Coordinator of the program in Automatic Control and Production Engineering, EAATS Doctoral School, since October 2025

Persyval-lab Hassen Fourati is the co-leader of the research axis on Large-Scale Hybrid Systems (LSHS).

Recruiting committees Federica Garin was member of the recruiting committee for an Associate Professor position at Centrale Supélec.

11.2 Teaching - Supervision - Juries - Educational and pedagogical outreach

11.2.1 Teaching

Giacomo Casadei is a lecturer in the department of Physical Measures, IUT1, Grenoble. Courses include Control Theory, Signal Processing and Electrical Engineering.

Hassen 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.

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

Alain 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.

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

Gustav Nilsson supervised one project in the course "Projet intégrateur", M2, Grenoble INP.

11.2.2 Supervision

Completed PhDs

Ghadeer Shaaban "Contributions to Navigation Under Unknown Input and Cyber-Physical Security" [38], September 2025, co-advised by Alain Kibangou, Hassen Fourati and Christophe Prieur (GIPSA-lab). Supported by a scholarship from the EEATS doctoral school.

PhDs in progress

Alex Ardelean *Synchronization of discrete-time network dynamics*, since October 2025. Co-advised by Giacomo Casadei and Paolo Frasca.

Tarek Bazizi *Multi-agent systems*, since October 2024. Co-advised by Paolo Frasca and Mohamed Maghenem (GIPSA-lab). 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. Advised by Carlos Canudas-de-Wit. Supported by the OpNet grant.

Yann Cauchepin *Underwater navigation*, since December 2024. Co-advised by Alain Kibangou, Hassen Fourati, and Adrien Nègre (Naval Group).

Guillaume Gasnier *Modeling and optimal control of electro-mobility networks*, since January 2023. Advised by Carlos Canudas-de-Wit.

Omar Meebed *Modeling multimodal transportation networks*, since July 2024. Co-advised by Alain Kibangou and Hassen Fourati.

Raoul Prisant *Continuous models for the control of large networks: graphon limits*, since November 2023. Co-advised by Federica Garin, Paolo Frasca and Giacomo Casadei.

Eduardo Steve Rodriguez Canales *Adoption dynamics in social networks for green mobility*, since November 2024. Co-advised by Alain Kibangou and Paolo Frasca.

Master students, interns, long-term student visitors

Alexia Ambrogio (PhD student, Politecnico di Torino, Turin, Italy) *Information design in congestion games*, February-July 2025. Hosted by Paolo Frasca.

Julia Clement-Echeverria *Synchronization of network dynamics*, May-September 2025. Advised by Giacomo Casadei.

Hamidou Diallo (ENSIMAG Grenoble) *Analysis of systemic risk in financial networks: from static simulation to stochastic dynamics*, Spring 2025. Co-advised by Paolo Frasca, Federica Garin and Nicolas Gast (GHOST team).

11.2.3 Juries

- Paolo Frasca was member of the PhD defense committee of Quang Hung Pham, Université Grenoble Alpes November 26, 2025
- Paolo Frasca was *rapporteur* and member of the PhD defense committee of Min Li, Ecole Centrale Lille, October 30, 2025.
- Federica Garin was member of the PhD defense committee of Antoine Legat, Univ. Catholique de Louvain, Belgium.
- Alain Kibangou was member of the PhD thesis committee of Alireza Akhavi Zadegan at university of Tartu, Estonia (June 2025). He was one of the two opponents.
- Alain Kibangou was member of PhD thesis committee of Isaac Olawanreju at University of Lorraine, Metz, France (November 2025).

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] V. Giammarino, S. Baldi, P. Frasca and M. L. Delle Monache. 'Traffic Flow on a Ring With a Single Autonomous Vehicle: An Interconnected Stability Perspective'. In: *IEEE Transactions on Intelligent Transportation Systems* 22.8 (Aug. 2021), pp. 4998–5008. DOI: 10.1109/TITS.2020.2985680. URL: https://hal.inria.fr/hal-03011895.

[3] M. U. B. Niazi, C. Canudas de Wit and A. Kibangou. 'Average State Estimation in Large-scale Clustered Network Systems'. In: *IEEE Transactions on Control of Network Systems* 7.4 (Dec. 2020), pp. 1736–1745. DOI: 10.1109/TCNS.2020.2999304. URL: https://hal.archives-ouvertes.fr/hal-02524982.

[4] 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.

[5] 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.

[6] 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.

[7] 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.

[8] M. Zmitri, H. Fourati and C. Prieur. 'BiLSTM Network-Based Extended Kalman Filter for Magnetic Field Gradient Aided Indoor Navigation'. In: *IEEE Sensors Journal* 22.6 (2022), pp. 4781–4789. DOI: 10.1109/JSEN.2021.3091862. URL: https://hal.science/hal-03425006.

12.2 Publications of the year

International journals

[9] P. Baldomà-Mitjans, A. Cecilia, G. Casadei, D. Astolfi and V. Puig. 'A Masking Protocol for Nonlinear and Incrementally Passive Average Consensus Algorithms'. In: *IEEE Control Systems Letters* 9 (2025), pp. 1928–1933. DOI: 10.1109/LCSYS.2025.3585996. URL: https://hal.science/hal-05390792 (cit. on p. 10).

[10] N. Cele, A. Kibangou and W. Musakwa. 'Agent based modeling and simulation approach to identify and classify the key influential factors for satisfaction of public transport users'. In: *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations* (21st Mar. 2025), pp. 1–15. DOI: 10.1080/15472450.2025.2477051. URL: https://hal.science/hal-05238265 (cit. on p. 13).

[11] N. Cele, A. Kibangou and W. Musakwa. 'Qualitative and Quantitative Assessment of Public Minibus Taxi Driving'. In: *International Journal of Intelligent Transportation Systems Research* 23 (3rd Feb. 2025), pp. 513–524. DOI: 10.1007/s13177-025-00465-0. URL: https://hal.science/hal-04945988 (cit. on p. 13).

[12] F. Ceragioli, P. Frasca and R. Prisant. 'The disruptive effect of state discretization in an opinion dynamics system'. In: *Journal of Optimization Theory and Applications* 206.2 (1st June 2025), p. 47. DOI: 10.1007/s10957-025-02729-x. URL: https://hal.science/hal-05099667 (cit. on p. 15).

[13] G. Cocca, P. Frasca and C. Ravazzi. 'A Coupled Friedkin–Johnsen Model of Popularity Dynamics in Social Media'. In: *IEEE Control Systems Letters* 9 (16th June 2025), pp. 1159–1164. DOI: 10.1109/LCSYS.2025.3579762. URL: https://hal.science/hal-05367751 (cit. on p. 15).

[14] S. Fueyo and C. Canudas de Wit. 'From Microscopic Driver Models to Macroscopic PDEs in Ring Road Traffic Dynamics'. In: *European Journal of Control* (31st July 2025). URL: https://hal.science/hal-04806729 (cit. on p. 11).

[15] I. Gharbi, D. Faure-Vincent, H. Fourati and N. Vuillerme. 'Android Application-based Automated Prediction for Green Transportation Mode Detection: Architecture, Challenges and Results'. In: *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations* (28th Oct. 2025). DOI: 10.1080/15472450.2025.2576935. URL: https://hal.science/hal-05355698 (cit. on p. 13).

[16] P. Gogendeau, S. Bonhommeau, H. Fourati, M. Julien, M. Contini, T. Chevrier, A. E. Nieblas and S. Bernard. 'An autonomous surface vehicle for acoustic tracking, bathymetric and photogrammetric surveys'. In: *Ocean Engineering* 331 (July 2025), 121201 (15p.) DOI: 10.1016/j.oceaneng.2025.121201. URL: https://hal.science/hal-05105648.

[17] A. Kibangou and R. Kalaoane. 'Dissatisfaction Dynamics in Directed Bipartite Networks of Captive User Communities'. In: *IEEE Control Systems Letters* 9 (30th June 2025), pp. 1766–1771. DOI: 10.1109/LCSYS.2025.3584301. URL: https://hal.science/hal-05238225 (cit. on p. 15).

[18] T. Lefebvre, H. Brogniez, I. Gharbi, L. Hermozo, D. Bouniol, F. Dralet and R. Roca. 'Bridging time-delayed microwave radiometric observations and deep convection characteristics: a machine learning approach for the C^2OMODO mission'. In: *IEEE Transactions on Geoscience and Remote Sensing* 63 (2025), p. 5303117. DOI: 10.1109/TGRS.2025.3583571. URL: https://hal.science/hal-05136936.

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