Activity Report 2017

Project-Team RITS

Robotics & Intelligent Transportation Systems

RESEARCH CENTER
Paris

THEME
Robotics and Smart environments

Table of contents

Project-Team RITS

Creation of the Team: 2014 February 17, updated into Project-Team: 2015 July 01

Keywords:

Computer Science and Digital Science:

A1.5. - Complex systems
A1.5.1. - Systems of systems
A1.5.2. - Communicating systems
A2.3. - Embedded and cyber-physical systems
A3.4. - Machine learning and statistics
A3.4.1. - Supervised learning
A3.4.5. - Bayesian methods
A3.4.6. - Neural networks
A3.4.8. - Deep learning
A5.3. - Image processing and analysis
A5.3.4. - Registration
A5.4. - Computer vision
A5.4.1. - Object recognition
A5.4.4. - 3D and spatio-temporal reconstruction
A5.4.5. - Object tracking and motion analysis
A5.4.6. - Object localization
A5.5.1. - Geometrical modeling
A5.9. - Signal processing
A5.10. - Robotics
A5.10.2. - Perception
A5.10.3. - Planning
A5.10.4. - Robot control
A5.10.5. - Robot interaction (with the environment, humans, other robots)
A5.10.6. - Swarm robotics
A5.10.7. - Learning
A6. - Modeling, simulation and control
A6.1. - Mathematical Modeling
A6.2.3. - Probabilistic methods
A6.2.6. - Optimization
A6.4.1. - Deterministic control
A6.4.3. - Observability and Controlability
A6.4.4. - Stability and Stabilization
A8.6. - Information theory
A8.9. - Performance evaluation
A9.2. - Machine learning
A9.5. - Robotics
A9.7. - AI algorithmics

Other Research Topics and Application Domains:

B5.6. - Robotic systems
B6.6. - Embedded systems
B7.1.2. - Road traffic
B7.2. - Smart travel
B7.2.1. - Smart vehicles
B7.2.2. - Smart road
B9.4.5. - Data science

1. Personnel

Research Scientists

Fawzi Nashashibi [Team leader, Inria, Senior Researcher, HDR]
Guy Fayolle [Inria, Senior Researcher Emeritus]
Jean-Marc Lasgouttes [Inria, Researcher]
Gérard Le Lann [Inria, Senior Researcher Emeritus]
Anne Verroust-Blondet [Inria, Researcher, HDR]

PhD Students

Zayed Alsayed [VEDECOM]
Pierre de Beaucorps [Inria]
Carlos Flores [Inria]
Fernando Garrido [VEDECOM]
Farouk Ghallabi [CIFRE Renault]
David González Bautista [Inria, until Mar 2017]
Maximilian Jaritz [CIFRE Valeo]
Imane Mahtout [CIFRE Renault, from Dec 2017]
Kaouther Messaoud [Inria, from Apr 2017]
Francisco Navas [Inria]
Dinh-Van Nguyen [Vietnamese grant]
Danut-Ovidiu Pop [Inria]
Luis Roldao Jimenez [CIFRE AKKA, from Oct 2017]

Technical staff

Rafael Colmenares [Inria, until May 2017]
Azary Abboud [Inria, until Jan 2017]
Mohammad Abualhoul [Inria]
Younes Bouchaala [Inria, from Oct 2017]
Raoul de Charette [Inria]
Mohamed Elhadad [Inria, from Oct 2017]
Ahmed Soua [Inria, until Jun 2017]
Thomas Streubel [Inria, until Aug 2017]
Ilias Xydias [Inria, from Aug 2017]
Armand Yvet [Inria]

Interns

Julio Blanco Deniz [Inria, from Aug 2017]
Aitor Gomez [Inria, until Aug 2017]
Ziyang Hong [Inria, from Jul 2017 until Aug 2017]
Sule Kahraman [Inria, from Jun 2017 until Aug 2017]
Arthur Lecert [Inria, from Sep 2017 until Oct 2017]
Nievsabel Molina [Inria, from Aug 2017]

Maradona Rodrigues [University of Warwick, Jun 2017]
Edgar Talavera Munoz [Universidad Politécnica de Madrid, from Sep 2017]
Alfredo Valle [Inria, until Jan 2017]

Administrative Assistant
Chantal Chazelas [Inria]

External Collaborators
Oyunchimeg Shagdar [VEDECOM, until Aug 2017]
Itheri Yahiaoui [Univ de Reims Champagne-Ardennes]

2. Overall Objectives

2.1. Overall Objectives

The focus of the project-team is to develop the technologies linked to Intelligent Transportation Systems (ITS) with the objective to achieve sustainable mobility by the improvement of the safety, the efficiency of road transport according to the recent "Intelligent Vehicle Initiative" launched by the DG Information Society of the European Commission (for "Smarter, Cleaner, and Safer Transport"). More specifically, we want to develop, demonstrate and test some innovative technologies under the framework of LaRA, "La Route Automatisée [1]" which covers all the advanced driver assistance systems (ADAS) and the traffic management systems going all the way to fully automated vehicles.

These developments are all based on the sciences and technologies of information and communications (STIC) and have the objective to bring significant improvements in the road transport sector through incremental or breakthrough innovations. The project-team covers fundamental R&D work on key technologies, applied research to develop techniques that solve specific problems, and demonstrator activities to evaluate and disseminate the results.

The scientific approach is focused on the analysis and optimization of road transport systems through a double approach:

1. the control of individual road vehicles to improve locally their efficiency and safety,
2. the design and control of large transportation systems.

The first theme on vehicle control is broadly based on signal processing and data fusion in order to have a better machine understanding of the situation a vehicle may encounter, and on robotics techniques to control the vehicle in order to help (or replace) the driver to avoid accidents while improving the performance of the vehicle (speed, comfort, mileage, emissions, noise...). The theme also includes software techniques needed to develop applications in a real-time distributed and complex environment with extremely high safety standards. In addition, data must be exchanged between the vehicles; communication protocols have thus to be adapted to and optimized for vehicular networks characteristics (e.g. mobility, road safety requirements, heterogeneity, density), and communication needs (e.g. network latency, quality of service, network security, network access control).

The second theme on modeling and control of large transportation systems is also largely dependent on STIC. The objective, there, is to improve significantly the performance of the transportation system in terms of throughput but also in terms of safety, emissions, energy while minimizing nuisances. The approach is to act on demand management (e.g. through information, access control or road charging) as well as on the vehicles coordination. Communications technologies are essential to implement these controls and are an essential part of the R&D, in particular in the development of technologies for highly dynamic networks.

[1] LaRA is a Joint Research Unit (JRU) associating three French research teams: Inria's project-team RITS, Mines ParisTech's CAOR and LIVIC.

In order to address those issues simultaneously, RITS is organized into three research axes, each of which being driven by a separate sub-team. The first axis addresses the traditional problem of vehicle guidance and autonomous navigation. The second axis focuses on the large scale deployment and the traffic analysis and modeling. The third axis deals with the problem of telecommunications from two points of view:

- *Technical*: design certified architectures enabling safe vehicle-to-vehicle and vehicle-to-vehicle communications obeying to standards and norm;
- *Fundamental*, design and develop appropriate architectures capable of handling thorny problems of routing and geonetworking in highly dynamic vehicular networks and high speed vehicles.

Of course, these three research sub-teams interact to build intelligent cooperative mobility systems.

3. Research Program

3.1. Vehicle guidance and autonomous navigation

Participants: Mohammad Abualhoul, Zayed Alsayed, Pierre de Beaucorps, Younes Bouchaala, Raoul de Charette, Rafael Colmenares, Aitor Gomez, Fernando Garrido, Farouk Ghallabi, Aitor Gomez, David González Bautista, Kaouther Messaoud, Francisco Navas, Fawzi Nashashibi, Carlos Flores, Dinh-Van Nguyen, Danut-Ovidiu Pop, Luis Roldao Jimenez, Oyunchimeg Shagdar, Thomas Streubel, Anne Verroust-Blondet, Itheri Yahiaoui.

There are three basic ways to improve the safety of road vehicles and these ways are all of interest to the project-team. The first way is to assist the driver by giving him better information and warning. The second way is to take over the control of the vehicle in case of mistakes such as inattention or wrong command. The third way is to completely remove the driver from the control loop.

All three approaches rely on information processing. Only the last two involve the control of the vehicle with actions on the actuators, which are the engine power, the brakes and the steering. The research proposed by the project-team is focused on the following elements:

- perception of the environment,
- planning of the actions,
- real-time control.

3.1.1. Perception of the road environment

Participants: Zayed Alsayed, Raoul de Charette, Rafael Colmenares, Farouk Ghallabi, Aitor Gomez, Fawzi Nashashibi, Dinh-Van Nguyen, Danut-Ovidiu Pop, Luis Roldao Jimenez, Anne Verroust-Blondet, Itheri Yahiaoui.

Either for driver assistance or for fully automated guided vehicle purposes, the first step of any robotic system is to perceive the environment in order to assess the situation around itself. Proprioceptive sensors (accelerometer, gyrometer,...) provide information about the vehicle by itself such as its velocity or lateral acceleration. On the other hand, exteroceptive sensors, such as video camera, laser or GPS devices, provide information about the environment surrounding the vehicle or its localization. Obviously, fusion of data with various other sensors is also a focus of the research.

The following topics are already validated or under development in our team:

- relative ego-localization with respect to the infrastructure, i.e. lateral positioning on the road can be obtained by mean of vision (lane markings) and the fusion with other devices (e.g. GPS);
- global ego-localization by considering GPS measurement and proprioceptive information, even in case of GPS outage;
- road detection by using lane marking detection and navigable free space;
- detection and localization of the surrounding obstacles (vehicles, pedestrians, animals, objects on roads, etc.) and determination of their behavior can be obtained by the fusion of vision, laser or radar based data processing;
- simultaneous localization and mapping as well as mobile object tracking using laser-based and stereovision-based (SLAMMOT) algorithms.

Scene understanding is a large perception problem. In this research axis we have decided to use only computer vision as cameras have evolved very quickly and can now provide much more precise sensing of the scene, and even depth information. Two types of hardware setups were used, namely: monocular vision or stereo vision to retrieve depth information which allow extracting geometry information.

We have initiated several works:

- estimation of the ego motion using monocular scene flow. Although in the state of the art most of the algorithms use a stereo setup, researches were conducted to estimate the ego-motion using a novel approach with a strong assumption.
- bad weather conditions evaluations. Most often all computer vision algorithms work under a transparent atmosphere assumption which assumption is incorrect in the case of bad weather (rain, snow, hail, fog, etc.). In these situations the light ray are disrupted by the particles in suspension, producing light attenuation, reflection, refraction that alter the image processing.
- deep learning for object recognition. New works are being initiated in our team to develop deep learning recognition in the context of heterogeneous data.

3.1.2. Cooperative Multi-sensor data fusion

Participants: Fawzi Nashashibi, Oyunchimeg Shagdar.

Since data are noisy, inaccurate and can also be unreliable or unsynchronized, the use of data fusion techniques is required in order to provide the most accurate situation assessment as possible to perform the perception task. RITS team worked a lot on this problem in the past, but is now focusing on collaborative perception approach. Indeed, the use of vehicle-to-vehicle or vehicle-to-infrastructure communications allows an improved on-board reasoning since the decision is made based on an extended perception.

As a direct consequence of the electronics broadly used for vehicular applications, communication technologies are now being adopted as well. In order to limit injuries and to share safety information, research in driving assistance system is now orientating toward the cooperative domain. Advanced Driver Assistance System (ADAS) and Cybercars applications are moving towards vehicle-infrastructure cooperation. In such scenario, information from vehicle based sensors, roadside based sensors and a priori knowledge is generally combined thanks to wireless communications to build a probabilistic spatio-temporal model of the environment. Depending on the accuracy of such model, very useful applications from driver warning to fully autonomous driving can be performed.

The Collaborative Perception Framework (CPF) is a combined hardware/software approach that permits to see remote information as its own information. Using this approach, a communicant entity can see another remote entity software objects as if it was local, and a sensor object, can see sensor data of others entities as its own sensor data. Last year we developed the basic hardware modules that ensure the well functioning of the embedded architecture including perception sensors, communication devices and processing tools.

Finally, since vehicle localization (ground vehicles) is an important task for intelligent vehicle systems, vehicle cooperation may bring benefits for this task. A new cooperative multi-vehicle localization method using split covariance intersection filter was developed during the year 2012, as well as a cooperative GPS data sharing method.

In the first method, each vehicle estimates its own position using a SLAM (Simultaneous Localization And Mapping) approach. In parallel, it estimates a decomposed group state, which is shared with neighboring vehicles; the estimate of the decomposed group state is updated with both the sensor data of the ego-vehicle and the estimates sent from other vehicles; the covariance intersection filter which yields consistent estimates even facing unknown degree of inter-estimate correlation has been used for data fusion.

In the second GPS data sharing method, a new collaborative localization method is proposed. On the assumption that the distance between two communicative vehicles can be calculated with a good precision, cooperative vehicle are considered as additional satellites into the user position calculation by using iterative methods. In order to limit divergence, some filtering process is proposed: Interacting Multiple Model (IMM) is used to guarantee a greater robustness in the user position estimation.

Accidents between vehicles and pedestrians (including cyclists) often result in fatality or at least serious injury for pedestrians, showing the need of technology to protect vulnerable road users. Vehicles are now equipped with many sensors in order to model their environment, to localize themselves, detect and classify obstacles, etc. They are also equipped with communication devices in order to share the information with other road users and the environment. The goal of this work is to develop a cooperative perception and communication system, which merges information coming from the communications device and obstacle detection module to improve the pedestrian detection, tracking, and hazard alarming.

Pedestrian detection is performed by using a perception architecture made of two sensors: a laser scanner and a CCD camera. The laser scanner provides a first hypothesis on the presence of a pedestrian-like obstacle while the camera performs the real classification of the obstacle in order to identify the pedestrian(s). This is a learning-based technique exploiting adaptive boosting (AdaBoost). Several classifiers were tested and learned in order to determine the best compromise between the nature and the number of classifiers and the accuracy of the classification.

3.1.3. Planning and executing vehicle actions

Participants: Fernando Garrido, David González Bautista, Imane Mahtout, Fawzi Nashashibi, Francisco Navas, Carlos Flores.

From the understanding of the environment, thanks to augmented perception, we have either to warn the driver to help him in the control of his vehicle, or to take control in case of a driverless vehicle. In simple situations, the planning might also be quite simple, but in the most complex situations we want to explore, the planning must involve complex algorithms dealing with the trajectories of the vehicle and its surroundings (which might involve other vehicles and/or fixed or moving obstacles). In the case of fully automated vehicles, the perception will involve some map building of the environment and obstacles, and the planning will involve partial planning with periodical recomputation to reach the long term goal. In this case, with vehicle to vehicle communications, what we want to explore is the possibility to establish a negotiation protocol in order to coordinate nearby vehicles (what humans usually do by using driving rules, common sense and/or non verbal communication). Until now, we have been focusing on the generation of geometric trajectories as a result of a maneuver selection process using grid-based rating technique or fuzzy technique. For high speed vehicles, Partial Motion Planning techniques we tested, revealed their limitations because of the computational cost. The use of quintic polynomials we designed, allowed us to elaborate trajectories with different dynamics adapted to the driver profile. These trajectories have been implemented and validated in the JointSystem demonstrator of the German Aerospace Center (DLR) used in the European project HAVEit, as well as in RITS's electrical vehicle prototype used in the French project ABV. HAVEit was also the opportunity for RITS to take in charge the implementation of the Co-Pilot system which processes perception data in order to elaborate the high level command for the actuators. These trajectories were also validated on RITS's cybercars. However, for the low speed cybercars that have pre-defined itineraries and basic maneuvers, it was necessary to develop a more adapted planning and control system. Therefore, we have developed a nonlinear adaptive control for automated overtaking maneuver using quadratic polynomials and Lyapunov function candidate and taking into account the vehicles kinematics. For the global mobility systems we are developing, the control of the vehicles includes also advanced platooning, automated parking, automated docking, etc. For each functionality a dedicated control algorithm was designed (see publication of previous years). Today, RITS is also investigating the opportunity of fuzzy-based control for specific maneuvers. First results have been recently obtained for reference trajectories following in roundabouts and normal straight roads.

3.2. V2V and V2I Communications for ITS

Participants: Oyunchimeg Shagdar, Gérard Le Lann, Mohammad Abualhoul, Younes Bouchaala, Fawzi Nashashibi.

Wireless communications are expected to play an important role for road safety, road efficiency, and comfort of road users. Road safety applications often require highly responsive and reliable information exchange between neighboring vehicles in any road density condition. Because the performance of the existing radio communications technology largely degrades with the increase of the node density, the challenge of designing wireless communications for safety applications is enabling reliable communications in highly dense scenarios. Targeting this issue, RITS has been working on medium access control design and visible light communications, especially for highly dense scenarios. The works have been carried out considering the vehicle behavior such as vehicle merging and vehicle platooning.

Unlike many of the road safety applications, the applications regarding road efficiency and comfort of road users, on the other hand, often require connectivity to the Internet. Based on our expertise in both Internet-based communications in the mobility context and in ITS, we are now investigating the use of IPv6 (Internet Protocol version 6 which is going to replace the current version, IPv4, in a few years from now) for vehicular communications, in a combined architecture allowing both V2V and V2I.

The wireless channel and the topology dynamics need to be studied when understanding the dynamics and designing efficient communications mechanisms. Targeting this issue, we have been working on channel modeling for both radio and visible light communications, and design of communications mechanisms especially for security, service discovery, multicast and geocast message delivery, and access point selection.

Below follows a more detailed description of the related research issues.

3.2.1. Geographic multicast addressing and routing

Participant: Oyunchimeg Shagdar.

Many ITS applications such as fleet management require multicast data delivery. Existing work on this subject tackles mainly the problems of IP multicasting inside the Internet or geocasting in the VANETs. To enable Internet-based multicast services for VANETs, we introduced a framework that:
i) defines a distributed and efficient geographic multicast auto-addressing mechanism to ensure vehicular multicast group reachability through the infrastructure network,
ii) introduces a simplified approach that locally manages the group membership and distributes the packets among them to allow simple and efficient data delivery.

3.2.2. Platooning control using visible light communications

Participants: Mohammad Abualhoul, Oyunchimeg Shagdar, Fawzi Nashashibi.

The main purpose of our research is to propose and test new successful supportive communication technology, which can provide stable and reliable communication between vehicles, especially for the platooning scenario. Although VLC technology has a short history in comparison with other communication technologies, the infrastructure availability and the presence of the congestion in wireless communication channels lead to propose VLC technology as a reliable and supportive technology which can takeoff some loads of the wireless radio communication. The first objective of this work is to develop an analytical model of VLC to understand its characteristics and limitations. The second objective is to design vehicle platooning control using VLC. In platooning control, a cooperation between control and communication is strongly required in order to guarantee the platoon's stability (e.g. string stability problem). For this purpose we work on VLC model platooning scenario, to permit for each vehicle the trajectory tracking of the vehicle ahead, altogether with a prescribed inter-vehicle distance and considering all the VLC channel model limitations. The integrated channel model of the main Simulink platooning model will be responsible for deciding the availability of the Line-of-Sight for different trajectory's curvatures, which means the capability of using light communication between each couple of vehicles in the platooning queue. At the same time the model will compute all the required parameters acquired from each vehicle controller.

3.2.3. V2X radio communications for road safety applications

Participants: Mohammad Abualhoul, Oyunchimeg Shagdar, Fawzi Nashashibi.

While 5.9 GHz radio frequency band is dedicated to ITS applications, the channel and network behaviors in mobile scenarios are not very well known. In this work we theoretically and experimentally study the radio channel characteristics in vehicular networks, especially the radio quality and bandwidth availability. Based on our study, we develop mechanisms for efficient and reliable V2X communications, channel allocation, congestion control, and access point selection, which are especially dedicated to road safety and autonomous driving applications.

3.2.4. *Safety-critical communications in intelligent vehicular networks*

Participant: Gérard Le Lann.

Intelligent vehicular networks (IVNs) are constituents of ITS. IVNs range from platoons with a lead vehicle piloted by a human driver to fully ad-hoc vehicular networks, a.k.a. VANETs, comprising autonomous/automated vehicles. Safety issues in IVNs appear to be the least studied in the ITS domain. The focus of our work is on safety-critical (SC) scenarios, where accidents and fatalities inevitably occur when such scenarios are not handled correctly. In addition to on-board robotics, inter-vehicular radio communications have been considered for achieving safety properties. Since both technologies have known intrinsic limitations (in addition to possibly experiencing temporary or permanent failures), using them redundantly is mandatory for meeting safety regulations. Redundancy is a fundamental design principle in every SC cyber-physical domain, such as, e.g., air transportation. (Optics-based inter-vehicular communications may also be part of such redundant constructs.) The focus of our on-going work is on safety-critical (SC) communications. We consider IVNs on main roads and highways, which are settings where velocities can be very high, thus exacerbating safety problems acceptable delays in the cyber space, and response times in the physical space, shall be very small. Human lives being at stake, such delays and response times must have strict (non-stochastic) upper bounds under worst-case conditions (vehicular density, concurrency and failures). Consequently, we are led to look for deterministic solutions.

Rationale

In the current ITS literature, the term *safety* is used without being given a precise definition. That must be corrected. In our case, a fundamental open question is: what is the exact meaning of *SC communications*? We have devised a definition, referred to as space-time bounds acceptability (STBA) requirements. For any given problem related to SC communications, those STBA requirements serve as yardsticks for distinguishing acceptable solutions from unacceptable ones with respect to safety. In conformance with the above, STBA requirements rest on the following worst-case upper bounds: λ for channel access delays, and Δ for distributed inter-vehicular coordination (message dissemination, distributed agreement).

Via discussions with foreign colleagues, notably those active in the IEEE 802 Committee, we have comforted our early diagnosis regarding existing standards for V2V/V2I/V2X communications, such as IEEE 802.11p and ETSI ITS-G5: they are totally inappropriate regarding SC communications. A major flaw is the choice of CSMA/CA as the MAC-level protocol. Obviously, there cannot be such bounds as λ and Δ with CSMA/CA. Another flaw is the choice of medium-range omnidirectional communications, radio range in the order of 250 m, and interference range in the order of 400 m. Stochastic delays achievable with existing standards are just unacceptable in moderate/worst-case contention conditions. Consider the following setting, not uncommon in many countries: a highway, 3 lanes each direction, dense traffic, i.e. 1 vehicle per 12.5 m. A simple calculation leads to the following result: any vehicle may experience (destructive) interferences from up to 384 vehicles. Even if one assumes some reasonable communications activity ratio, say 25%, one finds that up to 96 vehicles may be contending for channel access. Under such conditions, MAC-level delays and string-wide dissemination/agreement delays achieved by current standards fail to meet the STBA requirements by huge margins.

Reliance on V2I communications via terrestrial infrastructures and nodes, such as road-side units or WiFi hotspots, rather than direct V2V communications, can only lead to poorer results. First, reachability is not guaranteed: hazardous conditions may develop anywhere anytime, far away from a terrestrial node. Second, mixing SC communications and ordinary communications within terrestrial nodes is a violation of the very fundamental segregation principle: SC communications and processing shall be isolated from ordinary communications and processing. Third, security: it is very easy to jam or to spy on a terrestrial node; moreover, terrestrial nodes may be used for launching all sorts of attacks, man-in-the-middle attacks for example. Fourth, delays can only get worse than with direct V2V communications, since transiting via a node inevitably introduces additional latencies. Fifth, the delivery of every SC message must be acknowledged, which exacerbates the latency problems. Sixth, availability: what happens when a terrestrial node fails?

Trying to tweak existing standards for achieving SC communications is vain. That is also unjustified. Clearly, medium-range omnidirectional communications are unjustified for the handling of SC scenarios. By definition, accidents can only involve vehicles that are very close to each other. Therefore, short-range directional communications suffice. The obvious conclusion is that novel protocols and inter-vehicular coordination algorithms based on short-range direct V2V communications are needed. It is mandatory to check whether these novel solutions meet the STBA requirements. Future standards specifically aimed at SC communications in IVNs may emerge from such solutions.

Naming and privacy

Additionally, we are exploring the (re)naming problem as it arises in IVNs. Source and destination names appear in messages exchanged among vehicles. Most often, names are IP addresses or MAC addresses (plate numbers shall not be used for privacy reasons). A vehicle which intends to communicate with some vehicle, denoted V here, must know which name *name(V)* to use in order to reach/designate V. Existing solutions are based on multicasting/broadcasting existential messages, whereby every vehicle publicizes its existence (name and geolocation), either upon request (replying to a Geocast) or spontaneously (periodic beaconing). These solutions have severe drawbacks. First, they contribute to overloading communication channels (leading to unacceptably high worst-case delays). Second, they amount to breaching privacy voluntarily. Why should vehicles reveal their existence and their time dependent geolocations, making tracing and spying much easier? Novel solutions are needed. They shall be such that:

- At any time, a vehicle can assign itself a name that is unique within a geographical zone centered on that vehicle (no third-party involved),
- No linkage may exist between a name and those identifiers (plate numbers, IP/MAC addresses, etc.) proper to a vehicle,
- Different (unique) names can be computed at different times by a vehicle (names can be short-lived or long-lived),
- *name(V)* at UTC time t is revealed only to those vehicles sufficiently close to V at time t, notably those which may collide with V.

We have solved the (re)naming problem in string/cohort formations [48]. Ranks (unique integers in any given string/cohort) are privacy-preserving names, easily computed by every member of a string, in the presence of string membership changes (new vehicles join in, members leave). That problem is open when considering arbitrary clusters of vehicles/strings encompassing multiple lanes.

3.3. Probabilistic modeling for large transportation systems

Participants: Mohamed Elhadad, Guy Fayolle, Jean-Marc Lasgouttes, Ilias Xydias.

This activity concerns the modeling of random systems related to ITS, through the identification and development of solutions based on probabilistic methods and more specifically through the exploration of links between large random systems and statistical physics. Traffic modeling is a very fertile area of application for this approach, both for macroscopic (fleet management [44], traffic prediction) and for microscopic (movement of each vehicle, formation of traffic jams) analysis. When the size or volume of structures grows (leading to the so-called "thermodynamic limit"), we study the quantitative and qualitative (performance, speed, stability, phase transitions, complexity, etc.) features of the system.

In the recent years, several directions have been explored.

3.3.1. Traffic reconstruction

Large random systems are a natural part of macroscopic studies of traffic, where several models from statistical physics can be fruitfully employed. One example is fleet management, where one main issue is to find optimal ways of reallocating unused vehicles: it has been shown that Coulombian potentials might be an efficient tool to drive the flow of vehicles. Another case deals with the prediction of traffic conditions, when the data comes from probe vehicles instead of static sensors.

While the widely-used macroscopic traffic flow models are well adapted to highway traffic, where the distance between junction is long (see for example the work done by the NeCS team in Grenoble), our focus is on a more urban situation, where the graphs are much denser. The approach we are advocating here is model-less, and based on statistical inference rather than fundamental diagrams of road segments. Using the Ising model or even a Gaussian Random Markov Field, together with the very popular Belief Propagation (BP) algorithm, we have been able to show how real-time data can be used for traffic prediction and reconstruction (in the space-time domain).

This new use of BP algorithm raises some theoretical questions about the ways the make the belief propagation algorithm more efficient:

- find the best way to inject real-valued data in an Ising model with binary variables [50];
- build macroscopic variables that measure the overall state of the underlying graph, in order to improve the local propagation of information [45];
- make the underlying model as sparse as possible, in order to improve BP convergence and quality [49].

3.3.2. Exclusion processes for road traffic modeling

The focus here is on road traffic modeled as a granular flow, in order to analyze the features that can be explained by its random nature. This approach is complementary to macroscopic models of traffic flow (as done for example in the Opale team at Inria), which rely mainly on ODEs and PDEs to describe the traffic as a fluid.

One particular feature of road traffic that is of interest to us is the spontaneous formation of traffic jams. It is known that systems as simple as the Nagel-Schreckenberg model are able to describe traffic jams as an emergent phenomenon due to interaction between vehicles. However, even this simple model cannot be explicitly analyzed and therefore one has to resort to simulation.

One of the simplest solvable (but non trivial) probabilistic models for road traffic is the exclusion process. It lends itself to a number of extensions allowing to tackle some particular features of traffic flows: variable speed of particles, synchronized move of consecutive particles (platooning), use of geometries more complex than plain 1D (cross roads or even fully connected networks), formation and stability of vehicle clusters (vehicles that are close enough to establish an ad-hoc communication system), two-lane roads with overtaking.

The aspect that we have particularly studied is the possibility to let the speed of vehicle evolve with time. To this end, we consider models equivalent to a series of queues where the pair (service rate, number of customers) forms a random walk in the quarter plane $\mathbb{Z}_+^2$.

Having in mind a global project concerning the analysis of complex systems, we also focus on the interplay between discrete and continuous description: in some cases, this recurrent question can be addressed quite rigorously via probabilistic methods.

We have considered in [42] some classes of models dealing with the dynamics of discrete curves subjected to stochastic deformations. It turns out that the problems of interest can be set in terms of interacting exclusion processes, the ultimate goal being to derive hydrodynamic limits after proper scaling. A seemingly new method is proposed, which relies on the analysis of specific partial differential operators, involving variational calculus and functional integration. Starting from a detailed analysis of the Asymmetric Simple Exclusion Process (ASEP) system on the torus $\mathbb{Z}/n\mathbb{Z}$, the arguments a priori work in higher dimensions (ABC, multi-type exclusion processes, etc), leading to systems of coupled partial differential equations of Burgers' type.

3.3.3. Random walks in the quarter plane $\mathbb{Z}_+^2$

This field remains one of the important *violon d'Ingres* in our research activities in stochastic processes, both from theoretical and applied points of view. In particular, it is a building block for models of many communication and transportation systems.

One essential question concerns the computation of stationary measures (when they exist). As for the answer, it has been given by original methods formerly developed in the team (see books and related bibliography). For instance, in the case of small steps (jumps of size one in the interior of $\mathbb{Z}_+^2$), the invariant measure $\{\pi_{i,j}, i, j \geq 0\}$ does satisfy the fundamental functional equation (see [39]):

$$Q(x,y)\pi(x,y) = q(x,y)\pi(x) + \widetilde{q}(x,y)\widetilde{\pi}(y) + \pi_0(x,y). \tag{1}$$

where the unknown generating functions $\pi(x,y), \pi(x), \widetilde{\pi}(y), \pi_0(x,y)$ are sought to be analytic in the region $\{(x,y) \in \mathbb{C}^2 : |x| < 1, |y| < 1\}$, and continuous on their respective boundaries.

The given function $Q(x,y) = \sum_{i,j} p_{i,j} x^i y^j - 1$, where the sum runs over the possible jumps of the walk inside $\mathbb{Z}_+^2$, is often referred to as the *kernel*. Then it has been shown that equation (1) can be solved by reduction to a boundary-value problem of Riemann-Hilbert type. This method has been the source of numerous and fruitful developments. Some recent and ongoing works have been dealing with the following matters.

- *Group of the random walk*. In several studies, it has been noticed that the so-called *group of the walk* governs the behavior of a number of quantities, in particular through its *order*, which is always even. In the case of small jumps, the algebraic curve R defined by $\{Q(x,y) = 0\}$ is either of *genus* 0 (the sphere) or 1 (the torus). In [Fayolle-2011a], when the drift of the random walk is equal to 0 (and then so is the genus), an effective criterion gives the *order* of the group. More generally, it is also proved that whenever the genus is 0, this order is infinite, except precisely for the zero drift case, where finiteness is quite possible. When the *genus* is 1, the situation is more difficult. Recently [43], a criterion has been found in terms of a determinant of order 3 or 4, depending on the arity of the group.
- *Nature of the counting generating functions*. Enumeration of planar lattice walks is a classical topic in combinatorics. For a given set of allowed jumps (or steps), it is a matter of counting the number of paths starting from some point and ending at some arbitrary point in a given time, and possibly restricted to some regions of the plane. A first basic and natural question arises: how many such paths exist? A second question concerns the nature of the associated counting generating functions (CGF): are they rational, algebraic, holonomic (or D-finite, i.e. solution of a linear differential equation with polynomial coefficients)?

  Let $f(i,j,k)$ denote the number of paths in $\mathbb{Z}_+^2$ starting from $(0,0)$ and ending at (i,j) at time k. Then the corresponding CGF

  $$F(x,y,z) = \sum_{i,j,k \geq 0} f(i,j,k) x^i y^j z^k \tag{2}$$

  satisfies the functional equation

  $$K(x,y)F(x,y,z) = c(x)F(x,0,z) + \widetilde{c}(y)F(0,y,z) + c_0(x,y), \tag{3}$$

where z is considered as a time-parameter. Clearly, equations (2) and (1) are of the same nature, and answers to the above questions have been given in [Fayolle-2010].

- *Some exact asymptotics in the counting of walks in* $\mathbb{Z}_+^2$. A new and uniform approach has been proposed about the following problem: *What is the asymptotic behavior, as their length goes to infinity, of the number of walks ending at some given point or domain (for instance one axis)?* The method in [Fayolle-2012] works for *both* finite or infinite groups, and for walks not necessarily restricted to excursions.

3.3.4. Simulation for urban mobility

We have worked on various simulation tools to study and evaluate the performance of different transportation modes covering an entire urban area.

- Discrete event simulation for collective taxis, a public transportation system with a service quality comparable with that of conventional taxis.
- Discrete event simulation a system of self-service cars that can reconfigure themselves into shuttles, therefore creating a multimodal public transportation system; this second simulator is intended to become a generic tool for multimodal transportation.
- Joint microscopic simulation of mobility and communication, necessary for investigation of cooperative platoons performance.

These two programs use a technique allowing to run simulations in batch mode and analyze the dynamics of the system afterward.

4. Application Domains

4.1. Introduction

While the preceding section focused on methodology, in connection with automated guided vehicles, it should be stressed that the evolution of the problems which we deal with remains often guided by the technological developments. We enumerate three fields of application whose relative importance varies with time and which have strong mutual dependencies: driving assistance, cars available in self-service mode and fully automated vehicles (cybercars).

4.2. Driving assistance

Several techniques will soon help drivers. One of the first immediate goal is to improve security by alerting the driver when some potentially dangerous or dangerous situations arise, i.e. collision warning systems or lane tracking could help a bus driver and surrounding vehicle drivers to more efficiently operate their vehicles. Human factors issues could be addressed to control the driver workload based on additional information processing requirements. Another issue is to optimize individual journeys. This means developing software for calculating optimal (for the user or for the community) paths. Nowadays, path planning software is based on a static view of the traffic: efforts have to be done to take the dynamic component in account.

4.3. New transportation systems

The problems related to the abusive use of the individual car in large cities led the populations and the political leaders to support the development of public transport. A demand exists for a transport of people and goods which associates quality of service, environmental protection and access to the greatest number. Thus the tram and the light subways of VAL type recently introduced into several cities in France conquered the populations, in spite of high financial costs. However, these means of mass transportation are only possible on lines on which there is a keen demand. As soon as one moves away from these "lines of desire" or when one deviates from the rush hours, these modes become expensive and offer can thus only be limited in space and time. To give a more flexible offer, it is necessary to plan more individual modes which approach the car as we know it. However, if one wants to enjoy the benefits of the individual car without suffering from their disadvantages, it is necessary to try to match several criteria: availability anywhere and anytime to all, lower air and soils pollution as well as sound levels, reduced ground space occupation, security, low cost. Electric or gas vehicles available in self-service, as in the Praxitèle system, bring a first response to these criteria. To be able to still better meet the needs, it is however necessary to re-examine the design of the vehicles on the following points:

- ease empty car moves to better distribute them;
- better use of information systems inboard and on ground;
- better integrate this system in the global transportation system.

These systems are now operating. The challenge is to bring them to an industrial phase by transferring technologies to these still experimental projects.

4.4. Automated vehicles

The long term effort of the project is to put automatically guided vehicles (cybercars) on the road. It seems too early to mix cybercars and traditional vehicles, but data processing and automation now make it possible to consider in the relatively short term the development of such vehicles and the adapted infrastructures. RITS aims at using these technologies on experimental platforms (vehicles and infrastructures) to accelerate the technology transfer and to innovate in this field. Other application can be precision docking systems that will allow buses to be automatically maneuvered into a loading zone or maintenance area, allowing easier access for passengers, or more efficient maintenance operations. Transit operating costs will also be reduced through decreased maintenance costs and less damage to the braking and steering systems. Regarding technical topics, several aspects of Cybercars have been developed at RITS this year. First, we have stabilized a generic Cycab architecture involving Inria SynDEx tool and CAN communications. The critical part of the vehicle is using a real-time SynDEx application controlling the actuators via two Motorola's MPC555. Today, we have decided to migrate to the new dsPIC architecture for more efficiency and ease of use. This application has a second feature, it can receive commands from an external source (Asynchronously to this time) on a second CAN bus. This external source can be a PC or a dedicated CPU, we call it high level. To work on the high level, in the past years we have been developing a R&D framework called (Taxi) which used to take control of the vehicle (Cycab and Yamaha) and process data such as gyro, GPS, cameras, wireless communications and so on. Today, in order to rely on a professional and maintained solution, we have chosen to migrate to the RTMaps SDK development platform. Today, all our developments and demonstrations are using this efficient prototyping platform. Thanks to RTMaps we have been able to do all the demonstrations on our cybercars: cycabs, Yamaha AGV and new Cybus platforms. These demonstrations include: reliable SLAMMOT algorithm using 2 to 4 laser sensors simultaneously, automatic line/road following techniques, PDA remote control, multi sensors data fusion, collaborative perception via ad-hoc network. The second main topic is inter-vehicle communications using ad-hoc networks. We have worked with the EVA team for setting and tuning OLSR, a dynamic routing protocol for vehicles communications. Our goal is to develop a vehicle dedicated communication software suite, running on a specialized hardware. It can be linked also with the Taxi Framework for getting data such GPS information's to help the routing algorithm.

5. New Software and Platforms

5.1. PML-SLAM

KEYWORD: Localization
SCIENTIFIC DESCRIPTION: Simultaneous Localization and Mapping method based on 2D laser data.

- Participants: Fawzi Nashashibi and Zayed Alsayed
- Contact: Fawzi Nashashibi

5.2. V2Provue

Vehicle-to-Pedestrian

FUNCTIONAL DESCRIPTION: It is a software developed for the Vehicle-to-Pedestrian (V2P) communications, risk calculation, and alarming pedestrians of collision risk. This software is made of an Android application dedicated to pedestrians and RtMaps modules for the vehicles.

On the pedestrian side, the application is relying on GPS data to localize the user and Wi-Fi communications are used to receive messages about close vehicles and send information about the pedestrian positioning. Besides, a service has been developed to evaluate the collision risk with the vehicles near the pedestrian and an HMI based on OpenStreetMap displays all the useful information such as pedestrian and vehicles localization and, collision risk.

On the vehicle side, RtMaps modules allowing V2X communications have been developed. These modules contain features such as TCP/UDP socket transmissions, broadcast, multicast, unicast communications, routing, forwarding algorithms, and application specific modules. In the V2ProVu software, a particular application module has been implemented to create data packets containing information about the vehicle state (position, speed, yaw rate,...) and the V2X communication stack is used to broadcast these packets towards pedestrians. Moreover, the V2proVu application can also receive data from pedestrians and create objects structures that can be shared with the vehicle perception tools.

- Contact: Fawzi Nashashibi

5.3. SimConVA

Connected Autonomous Vehicles Simulator

FUNCTIONAL DESCRIPTION: The software provides an interface between the network simulator ns-3 (https://www.nsnam.org/) and the modular prototyping framework RTMaps (https://intempora.com/).

This code allows to create an RTMaps component which activates and controls the ns-3 simulator. The component handles the sending and reception of data packets between ns-3 and RTMaps for each vehicle. It also handles the mobility of vehicles in ns-3 using their known position in RTMaps.

- Authors: Pierre Merdrignac, Oyunchimeg Shagdar and Jean-Marc Lasgouttes
- Contact: Jean-Marc Lasgouttes

6. New Results

6.1. Scene Understanding with Computer Vision

Participants: Maximilian Jaritz, Raoul de Charette, Rafael Colmenares, Ziyang Hong, Fawzi Nashashibi.

This axis is in the continuation of previous year axis on scene understanding. It is crucial for autonomous driving. While last year we focused more on road estimation and ego velocity estimation (research report [51]), this year we focused on object recognition either from a single RGB camera or from a fusion of sensors (PhD of Maximilian Jaritz). Road estimation was also extended using graph energy minimization techniques and lead to interesting results in the scope of Rafael Colmenares internship. For object recognition a number of popular deep learning techniques were evaluated and the outcome of this evaluation study is that existing approaches suffers either from performance issues or processing time issues. In the scope of Maximilian Jaritz thesis a multi-modal approach is being developed were RGB and LiDAR are used to detect objects in the direct vicinity of the autonomous car. Preliminary results using state-of-the-art network architecture leads to satisfactory performances in terms of precision but a non-optimal localization of their spatial position (especially when rotated).

6.2. Computer Vision in Bad Weather

Participants: Raoul de Charette, Aitor Gomez, Sule Kahraman.

Common assumption of any perception system is to consider the atmosphere transparent so that the light rays travel directly from a point in the scene to the camera. While this assumption is true in clear weather, in fog/rain/hail or snow conditions this assumption isn't valid and all perception system will struggle. This can have a dramatic impact in autonomous driving. Following some of his previous works in former labs, Raoul de Charette lead several works to investigate and quantify the influence of rain and fog on computer vision for autonomous driving. Two internships were conducted in that axis (Aitor Gomez, Sule Kahraman) and there are on going results and research to be output. More detail can be found in [41].

6.3. Perception for Cooperative Driving

Participants: Raoul de Charette, Carlos Flores, Francisco Navas, Fawzi Nashashibi.

In cooperation with the control/planning group the computer vision group has worked on practical and applied research for 2D processing of LiDAR sensors in the context of cooperative driving. Practical failures cases were addressed such as the case of occluded vulnerables. In a dense urban environment were buildings may occlude pedestrian we proposed for example a perception system fusing both LiDAR and communication data retrieved from pedestrian communication streaming there GPS position. This allows us to detect and predict possible collisions of car and pedestrians. Experiments were conducted in the site of Rocquencourt and the results lead to a submit journal publication in cooperation with Vicente Milanés from Renault. Another practical case of failures in cooperative driving occurs are the cut-in or cut-out cars in platoon scenarios. When cars travel in a platoon, a car leaving or entering may disrupt the whole platoon. In collaboration with the control group, the detection and prediction of such behavior was addressed using 2D LiDAR data and tested on Cycabs. A journal was submitted in cooperation with Vicente Milanés from Renault.

6.4. Recognizing Pedestrians using Cross-Modal Convolutional Networks

Participants: Danut-Ovidiu Pop, Fawzi Nashashibi.

Pedestrian detection and recognition is of great importance for autonomous vehicles. A pedestrian detection system depends on: 1) the sensors utilized to capture the visual data, 2) the features extracted from the acquired images and 3) the classification process. Considering existing data-sets of images (Daimler, Caltech and KITTI) we have focused only on the last two points. Our question is whether one modality can be used exclusively (standpoint one) for training the classification model used to recognize pedestrians in another modality or only partially (standpoint two) for improving the training of the classification model in another modality. If it is trained on multi-modal data, can the system still work when the data from one of the domains is missing? How much information is redundant across the domains (can we regenerate data in one domain on the basis of the observation from the other domain)? How could a multi-modal system be trained, when data in one of the modalities is scarce (e.g. many more images in the visual spectrum than depth). To our knowledge, these questions have not yet been answered for the pedestrian recognition task. Our work proposes to solve this brain-teaser through various experiments based on the Daimler stereo vision data set. This year, we perform the following experimental studies (More detail can be found in [32], [33], [34]):

1. Three different image modalities (Intensity, Depth, Optical Flow) for improving the classification component are considered. The Classical Training and the Cross Training methods are analyzed. On the Cross Training method, the CNN is trained and validated on different images modalities, in contrast to classical training method in which the training and validation of each CNN is on same images modality.
2. In [33], [34] we study how learning representations from one modality would enable prediction for other modalities, which one terms as cross modality. Several approaches are proposed:

   a) A correlated model where a unique CNN is trained with Intensity, Depth and Flow images for each frame,

   b) An incremental model where a CNN is trained with the first modality images frames, then a second CNN, initialized by transfer learning on the first one is trained on the second modality images frames, and finally a third CNN initialized on the second one, is trained on the last modality images frames.

c) A particular cross-modality model, where each CNN is trained on one modality, but tested on a different one.

3. In [32] two different fusion schemes are studied:

   a) The early fusion model is built by concatenating three image modalities (intensity, depth and optical flow) to feed a unique CNN.

   b) The late fusion model consists in fusing the outputs scores (the class probability estimate) of three independent CNNs, trained on intensity, depth and optical flow images, by a classifier system.

6.5. A Fusion method of WiFi and Laser-SLAM for Vehicle Localization

Participants: Dinh-Van Nguyen, Fawzi Nashashibi.

Precise positioning plays a key role in successful navigation of autonomous vehicles. A fusion architecture of Global Positioning System (GPS) and Laser-SLAM (Simultaneous Localization and Mapping) is widely adopted. While Laser-SLAM is known for its highly accurate localization, GPS is still required to overcome accumulated error and give SLAM a required reference coordinate. However, there are multiple cases where GPS signal quality is too low or not available such as in multi-story parking, tunnel or urban area due to multipath propagation issue etc. [30] proposes an alternative approach for these areas with WiFi Fingerprinting technique to replace GPS. Result obtained from WiFi Fingerprinting are then fused with LaserSLAM to maintain the general architecture, allow seamless adaptation of vehicle to the environment (cf. [29]).

6.6. SLAM failure scenario detection for laser-based SLAM methods

Participants: Zayed Alsayed, Anne Verroust-Blondet, Fawzi Nashashibi.

Computing a reliable and accurate pose for a vehicle in any situation is one of the challenges for Simultaneous Localization And Mapping methods (SLAM) methods [18]. This year, we worked on the detection of SLAM failure and non-failure scenarios and a technique detecting *a priori* potential failure scenarios for 2D laser-based SLAM methods has been introduced. Our approach is independent of the underlying SLAM implementation as it uses raw sensor data to extract a relevant scene descriptor, which is used in a decision-making process to detect failure scenarios. Experimental evaluations on three realistic experiments show the relevance of our approach. See [22] for more detail.

6.7. Motion planning techniques

Participants: Fernando Garrido, David González Bautista, Fawzi Nashashibi.

Overtaking and lane change maneuvers represent some of the major causes of fatalities in road transport. The role of the path planning in these maneuvers is essential, not only for designing collision-free trajectories, but also to provide comfort to the occupants of the vehicle.

Having this in mind, a novel two-phase dynamic local planning algorithm to deal with these dynamic scenarios has been proposed, based on previous work. In the first phase (pre-planning) [47], a multi-objective trajectory optimization considering static information (i.e. digital maps) is carried out, using quartic Bézier curves as the path generation, which let us consider the constraints of both vehicle and road, generating continuous paths in the next phase. In the second phase (real-time planning) [46], time-horizon based trajectory generation is provided on a real-time using the pre-planned information. A human-like driving style is provided evaluating the sharpness of the road bends and the available space among them, smoothing the path. There, the paths are generated by joining the already optimized quartic Bézier curves ensuring continuity in the transitions among bends and straights.

Based on this architecture, a dynamic path planning approach has been introduced to safely avoid the possible obstacles in the path. A grid based solution has been developed to discretize the space and process the obstacles. It computes a virtual lane that re-plans the local path to be tracked by modifying the global itinerary using a geometric approach considering dynamics of both overtaking and overtaken vehicles to find smooth lane changes. That way, the dynamic problem can be addressed with the described real-time static local planner. Then, the overtaking path is built by joining two curves for each lane change, minimizing the slopes, according to the virtual lane configuration, loading these curves from the pre-planning stage.

The proposed architecture has been validated both on simulation (with Pro-Sivic and RTMaps) and on the Inria Rocquencourt terrain (with Cybercars and a Citroen C1) for the static scenario, and on simulation for the dynamic scenario. The results showed a smoother tracking of the curves, reduction on the execution times and reduced global accelerations increasing comfort. Future works will improve the capacity to deal with unexpected circumstances while making the overtaking maneuvers, testing with different car types as obstacles.

6.8. Decision-making for automated vehicles adapting human-like behavior

Participants: Pierre de Beaucorps, Thomas Streubel, Anne Verroust-Blondet, Fawzi Nashashibi.

Learning from human driver's strategies for solving complex and potentially dangerous situations including interaction with other road users has the potential to improve decision-making methods for automated vehicles. In [37], we focus on simple unsignalized intersections and roundabouts in presence of another vehicle. We propose a human-like decision-making algorithm for these scenarios built up from human drivers recordings. The algorithm includes a risk assessment to avoid collisions in the intersection area. Three road topologies with different interaction scenarios were presented to human participants on a previously developed simulation tool. The same scenarios have been used to validate our decision-making process. We obtained promising results with no collisions in all setups and the ability to successfully determine to go before or after another vehicle. A further study was conducted in [36] to assess the acceptability of the approach by human drivers.

6.9. Deep Reinforcement Learning for end-to-end driving

Participants: Maximilian Jaritz, Raoul de Charette, Fawzi Nashashibi.

We conducted works on a very new research field that is end-to-end driving, where an artificial intelligence learns to drive directly from RGB images, without the use of any mediated perception (object recognition, scene understanding). Using a recent rally game with realistic physics and graphics we have trained a car in a simulator to drive. Several approaches were attempted. The most successful one uses an Asynchronous Actor Critic (A3C) trained in an end-to-end fashion and propose new strategies that improve training and generalization. The network was trained simultaneously on tracks with various road structures (sharp turns, etc.), graphics (snow, mountain, and coast) and physics (road adherence). As for other problems, we have shown that learning in a simulated environment (here a racing car game) can be transposed to other tracks and even real driving. Despite complex and varying dynamics of the car and road the trained agent learns to drive in challenging scenarios using only RGB image and vehicle speed. To prove its generalization the algorithm is also tested in unseen tracks, under legal speed limit and with real images. Initial work was published in [31] and recent works were submitted. The work was conducted in cooperation with Etienne Perot and Marin Toromanoff from Valeo.

6.10. A Time Gap-Based Spacing Policy for Full-Range Car-Following

Participants: Carlos Flores, Fawzi Nashashibi.

Car-Following techniques are a promising solution to reduce traffic jams, while increasing driver comfort and safety. The first version of such systems, Adaptive Cruise Control (ACC), proposes the employment of throttle/brake automation with ranging sensors to regulate the spacing gap with respect to the vehicle in front. Afterwards, the addition of Vehicle to Vehicle (V2V) communication links permits tighter string formations allowing Cooperative-ACC (CACC). The reaction time towards speed changes from forward vehicles can be significantly reduced, given that the ego-vehicle reacts before an spacing error is detected in feedback, employing preceding or leader vehicles' information.

To take further advantage of car-following benefits, a spacing policy is introduced in the control structure in function of the application requirements. In the state-of-the-art approaches, several works have proposed different policies to address performance metrics as: safety, traffic flow increase, stability, string stability, among others. A more complete spacing policy is studied to target all of these criteria for the full speed range and adaptable for both ACC and CACC techniques.

Towards achieving these goals, it is proposed to divide the speed range in low/high speeds and employ a variable time gap setting. A time gap transition from the minimum value for which string stability is ensured to the targeted value in high speeds is suggested. The minimal distance required in case of an unexpected braking on the preceding vehicle is also evaluated to determine the distance to keep at standstill. Both the time gaps and standstill distance are in function of the employed technique–i.e. ACC or CACC–. Among the research lines to be followed, one can mention:

- Development of a robust controller based on fractional-order calculus to achieve a more performing car-following, fulfilling more requirements.
- Further investigation on the effects of communication delays and latency in the V2V links, as well as study different control structures that react not with the preceding vehicle's behavior but also other string members.
- Consider strings which vehicles may account with different dynamics, which introduces perturbations to the car-following control structure.

More detail can be found in [23].

6.11. Plug&Play control for highly non-linear systems: Stability analysis of autonomous vehicles

Participants: Francisco Navas, Fawzi Nashashibi.

The final stage for automating a vehicle relies on the control algorithms. They are in charge of providing the proper behavior and performance to the vehicle, leading to provide fully automated capabilities. Controllability and stability of dynamic complex systems are the key aspects when it comes to design intelligent control algorithms for vehicles.

Nowadays, the problem is that control systems are "monolithic". That means that a minor change in the system could require the entire redesign of the control system. It addresses a major challenge, a system able to adapt the control structure automatically when a change occurred.

An autonomous vehicle is built by combining a set-of-sensors and actuators together with sophisticated algorithms. Since sensors and actuators are prone to intermittent faults, the use of different sensors is better and more cost effective than duplicating the same sensor type. The problem is to deal with the different availability of each sensor/actuator and how the vehicle should react to these changes. Another possible modification is the change in vehicle dynamics over time; or difference in dynamics from one vehicle to another.

A methodology that improves the security of autonomous driving systems by providing a framework managing different dynamics and sensor/actuator setups should be carried out. New trends are proposing intelligent algorithms able to handle any unexpected circumstances as unpredicted uncertainties or even fully outages from sensors. This is the case of Plug & Play control, which is able to provide stability responses for autonomous vehicles under uncontrolled circumstances.

Here, the basis of Plug & Play control, Youla-Kucera parameterization, has been used to develop different applications within the autonomous driving field.

- Stable controller reconfiguration when some change occurs. Last year, the already commercially available Adaptive Cruise Controller (ACC) system, and its evolution by adding vehicle-to-vehicle communication (CACC) were examined. The Youla-Kucera parameterization was used for providing stable transitions between both controllers when the vehicle-to-vehicle communication link is changing from available to disable or vice-versa. More details can be found in [52]. This year, this work has been extended in what is called Youla-Kucera-based Advanced Cooperative Adaptive Cruise Control (ACACC). In the literature, CACC degrades to ACC when communication when the preceding vehicle is no longer available. This degradation occurs even if information from another V2V-equipped vehicle ahead (different from the preceding vehicle) is still available. ACACC benefits from the existing communication with this vehicle ahead in the string, reducing the inter-vehicle distance whereas keeping string stability. The proposed structure uses YK parameterization to obtain a hybrid behavior between two CACC controllers with different time gaps. Stable transition between both controllers is also ensured. This work has been submitted to IEEE Transactions on Vehicular Technology. Finally, Youla-Kucera has been also employed to assure stable transitions when other CACC-equipped vehicles are joining/leaving a CACC string of vehicles.
- Online closed loop identification. Youla-Kucera has a dual formulation that allows recasting closed-loop identification into open-loop-like identification. [28] deals with the identification of longitudinal dynamics of a cycab for subsequent control performance's improvement. Here, the dual Youla-Kucera formulation is used to transform a closed-loop identification problem in an open-loop-like. The algorithm is tested in a string of two cycabs equipped with a proportional-derivative-based CACC, showing how the resulting model is improved in comparison with a classical open-loop identification algorithm. Closed-loop identification results have been also obtained for a production vehicle when connected to a lane following control system. Thanks to that, lateral dynamics are known for velocities between 8 and $20m/s$.
- A final step that integrates both stable controller reconfiguration and closed-loop identification: Automatic control reconfiguration to achieve optimal performance based on the identification of the new situation. This idea has been used to obtain an adaptive approach able to ensure string stability when different dynamics are involved in the same string of vehicles (a heterogeneous string of vehicles). A supervisor is able to provide the closest model in a predefined set, activating the controller that ensures string stability. The closest model in the set can be known without using identification algorithms, thanks to Youla-Kucera properties, with the consequent computational saving.

6.12. Large scale simulation interfacing

Participants: Ahmed Soua, Jean-Marc Lasgouttes, Oyunchimeg Shagdar.

The SINETIC FUI project aims to build a complete simulation environment handling both mobility and communication. We are interested here in a so-called system-level view, focusing on simulating all the components of the system (vehicle, infrastructure, management center, etc.) and its realities (roads, traffic conditions, risk of accidents, etc.). The objective is to validate the reference scenarios that take place on a geographic area where a large number of vehicles exchange messages using 802.11p protocol. This simulation tool is done by coupling the SUMO microscopic simulator and the ns-3 network simulator thanks to the simulation platform iTETRIS.

We have focused in this part of the project on how to reduce the execution time of large scale simulations. To this end, we designed a new simulation technique called Restricted Simulation Zone which consists on defining a set of vehicles responsible of sending the message and an area of interest around them in which the vehicles receive the packets.

6.13. Belief propagation inference for traffic prediction

Participant: Jean-Marc Lasgouttes.

This work [50], [49], in collaboration with Cyril Furtlehner (TAU, Inria), deals with real-time prediction of traffic conditions in a setting where the only available information is floating car data (FCD) sent by probe vehicles. The main focus is on finding a good way to encode some coarse information (typically whether traffic on a segment is fluid or congested), and to decode it in the form of real-time traffic reconstruction and prediction. Our approach relies in particular on the belief propagation algorithm.

This year, following an agreement signed with the company SISTeMA ITS (Italy), we obtained access to large amounts of data from the cities of Vienna and Turin. We are now working on assessing the performance of our techniques in real-world city networks, and to compare it to the sate of the art techniques.

6.14. Platoons Formation for autonomous vehicles redistribution

Participants: Mohamed Elhadad, Jean-Marc Lasgouttes, Ilias Xydias.

As part of the VALET ANR project, we aim to optimize platoon formation for vehicle retrieval, where parked vehicles are collected and guided by a fleet manager in a given area. Each platoon follows an optimized route to collect and guide the parked vehicles to their final destinations. The Multi-Platoons Parked Vehicles Collection consists in minimizing the total travel duration, total travel distance, the number of platoons, under constraints of battery level. After a linear formal definition of the problem, we show how to use a multi-objective version of genetic algorithms, more precisely the NSGA-II algorithm, to solve this multi-criteria optimization problem.

This is a work in progress.

6.15. Random Walks in Orthants

Participant: Guy Fayolle.

The Second Edition of the Book [39] *Random walks in the Quarter Plane*, prepared in collaboration with R. Iasnogorodski (St-Petersburg, Russia) and V. Malyshev (MGU, Moscow), has been published by Springer in the collection *Probability Theory and Stochastic Processes*.

Part II of this second edition borrows specific case-studies from queueing theory and enumerative combinatorics. Five chapters have been added, including examples and applications of the general theory to enumerative combinatorics. Among them:

- Explicit criteria for the finiteness of the group, both in the genus 0 and genus 1 cases.
- Chapter *Coupled-Queues* shows the first example of a queueing system analyzed by reduction to a BVP in the complex plane.
- Chapter *Joining the shorter-queue* analyzes a famous model, where maximal homogeneity conditions do not hold, hence leading to a system of functional equations.
- Chapter *Counting Lattice Walks* concerns the so-called *enumerative combinatorics*. When counting random walks with small steps, the nature (rational, algebraic or holonomic) of the generating functions can be found and a precise classification is given for the basic (up to symmetries) 79 possible walks.

6.16. Lattice path combinatorics

Participant: Guy Fayolle.

In the second edition of the book [39], original methods were proposed to determine the invariant measure of random walks in the quarter plane with small jumps (size 1), the general solution being obtained via reduction to boundary value problems. Among other things, an important quantity, the so-called *group of the walk*, allows to deduce theoretical features about the nature of the solutions. In particular, when the *order* of the group is finite, necessary and sufficient conditions have been given for the solution to be rational, algebraic or D-finite (i.e. solution of a linear differential equation) in which case the underlying algebraic curve is of genus 0 or 1. In this framework, number of difficult open problems related to lattice path combinatorics are currently being explored, in collaboration with A. Bostan and F. Chyzak (project-team SPECFUN, Inria-Saclay), both from theoretical and computer algebra points of view: concrete computation of the criteria, utilization of Galois theory for genus greater than 1 (i.e. when some jumps are ≥ 2), etc.

6.17. Facing ADAS validation complexity with usage oriented testing

Participant: Guy Fayolle.

Validating Advanced Driver Assistance Systems (ADAS) is a strategic issue, since such systems are becoming increasingly widespread in the automotive field.

But, ADAS validation is a complex issue, particularly for camera based systems, because these functions maybe facing a very high number of situations that can be considered as infinite. Building at a low cost level a sufficiently detailed campaign is thus very difficult.

The COVADEC project (type FUI/FEDER 15), which was aiming to provide methods and techniques to deal with these problems, was actually successfully completed in May 2017. The test cases automatic generation relies on a *Model Based Testing (MBT)* approach. The tool used for MBT is the software MaTeLo (Markov Test Logic), developed by the company All4Tec. MaTeLo is an MBT tool, which makes it possible to build a model of the expected behavior of the system under test and then to generate, from this model, a set of test cases suitable for particular needs. MaTeLo is based on Markov chains, and, for non-deterministic generation of test cases, uses the Monte Carlo methods. To cope with the inherent combinatorial explosion, we couple the graph generated by MaTeLo to an ad hoc *random scan Gibbs sampler (RSGS)*, which converges at geometric speed to the target distribution. Thanks to these test acceleration techniques, MaTeLo also makes it possible to obtain a maximal coverage of system validation by using a minimum number of test cases. As a consequence, the number of driving kilometers needed to validate an ADAS is substantially reduced, see [53] and [54]. These methods do interest the French manufacturer *Groupe PSA*, who wishes to establish a contractual collaboration involving Armines-MINES ParisTech.

6.18. Safety, Privacy, Trust, and Immunity to Cyberthreats

Participant: Gérard Le Lann.

Safety (significant reductions of severe accident figures) and traffic efficiency (smaller safe inter-vehicular gaps, higher occupancy of asphalt resources) are dual and antagonistic goals targeted with autonomous vehicles. On-board robotics and inter-vehicular communications (IVCs) are essential for achieving proactive and reactive safety (ability to influence behaviors and moves of nearby vehicles).

Existing US standards (WAVE) and European standards (ETSI ITS-G5) for IVCs based on omnidirectional radio technologies have been shown to be inadequate in this respect. Numerous publications demonstrate that they induce channel access delays which are unacceptably high in average and worst-case load or contention conditions. Periodic beaconing (the broadcasting of messages carrying identifiers, UTC time and GNSS positions) at frequencies ranging from 1 Hz to 10 Hz is mistakenly believed to provide every vehicle with a correct local dynamic map (LDM) giving the accurate geo-localizations of surrounding vehicles. Radio broadcasts are unreliable. Therefore, the LDMs of any two vehicles arbitrarily close to each other may differ. Safe coordination implies exact agreements (a.k.a. consensus), i.e. strictly identical LDMs. This has been shown to be impossible in asynchronous systems (WAVE/G5 networks) and in synchronous systems (deterministic MAC protocols) in the presence of message losses.

Periodic beaconing may lead to radio channel saturation. Furthermore, since GNSS coordinates are unencrypted, periodic beaconing atop WAVE/G5 favors eavesdropping and tracking, as well as cyberattacks from unknown distant entities (malicious vehicles or terrestrial nodes). Pseudonymous authentication based on asymmetric key pairs and certificates delivered by Public Key Infrastructures shall thwart such threats. Unfortunately, numerous problems are yet unsolved. Tracking and cyberattacks are feasible with the set of aforementioned solutions (referred to as WAVE 1.0).

In 2017, we have contributed to the work conducted by scientists and engineers in various countries, aimed at demonstrating that it is possible to achieve safety, privacy, trust, and immunity to cyberthreats altogether (no mitigation), following approaches that differ from WAVE 1.0. We are also working with experts who have expressed concerns regarding the risks of cyber-surveillance induced by WAVE 1.0 solutions when better solutions are available. Two essential observations are in order.

Firstly, networks of connected autonomous vehicles are instances of life-critical systems. Inevitably, future on-board (OB) systems will have to be designed in accordance with the segregation principle (a fundamental design rule in the domain of safety/life-critical systems). A critical sub-system must be isolated from a non-critical sub-system. In a vehicle, a critical sub-system hosts critical robotics and critical IVCs (novel IVC protocols and distributed algorithms for time-bounded decision-making and IV coordination). WAVE 1.0 solutions are implemented in the non-critical sub-system.

Secondly, only vehicles very close to each other may be involved in an accident. It follows that short-range and directional IVCs are necessary and sufficient for safety. In [25] and [27], we present IVC protocols and agreement algorithms that achieve small worst-case time bounds for longitudinal and lateral message dissemination within and across cohorts (spontaneous linear vehicular networks). These bounds are such that no vehicle moves by more than 1 asphalt slot while messages are being disseminated and agreements are reached, in the presence of message losses. A brief summary can be found in [38]. Similar IVC protocols and agreement algorithms can be devised for upcoming technologies, namely 5G radio communications (MIMO antennas) and optical communications ignored in WAVE 1.0 solutions.

These solutions (referred to as WAVE 2.0) have additional merits regarding cyberthreats. Remote cyberattacks cannot jeopardize safety (contrary to WAVE 1.0), given that OB critical sub-systems are isolated from *the outside world*. This is discussed in [24] and in [26]. In [26], we introduce an OB system architecture consistent with the segregation principle, which includes a tamper-proof device (for non-repudiation and accountability), and novel protocols for IVCs. In addition to pseudonymous authentication, sources and destinations of safety messages are fully anonymous, and certified pseudonyms can be used ad infinitum, thus circumventing the deficiencies of WAVE 1.0 solutions. With WAVE 2.0 solutions, proximate eavesdropping and tracking are unfeasible and vain. Also, we show that proximate cyberattacks (e.g., masquerading, injection of bogus data, falsification, Sybil attack) are immediately detected, and how to stop a malicious or misbehaving vehicle safely.

Our on-going research targets crossings of un-signaled intersections, roundabouts, and spontaneous formations of heterogeneous vehicular networks (SAE automation levels from 0 to 5), where properties of safety, efficiency, privacy and immunity to cyberattacks shall hold.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

VALEO Group: a very strong partnership is under reinforcement between VALEO and Inria. Several bilateral contracts were signed to conduct joint works on Driving Assistance, some of which VALEO is funding. This joint research includes:

- The PhD thesis of Pierre de Beaucorps and the post-doc of Thomas Streubel under the framework of VALEO project “Daring”

- *SMART* project: on the *Design and development of multisensor fusion system for road vehicles detection and tracking*. This project funds the internship of Alfredo Valle.
- A CIFRE like PhD thesis is ongoing between VALEO and Inria (Maximilian JARITZ), dealing with multisensor processing and learning techniques for free navigable road detection.
- VALEO is currently a major financing partner of the “GAT” international Chaire/JointLab in which Inria is a partner. The other partners are: UC Berkeley, Shanghai Jiao-Tong University, EPFL, IFSTTAR, MPSA (Peugeot-Citroën) and SAFRAN.
- Technology transfer is also a major collaboration topic between RITS and VALEO as well as the development of a road automated prototype.
- Finally, Inria and VALEO are partners of the PIA French project CAMPUS (Connected Automated Mobility Platform for Urban Sustainability) including SAFRAN, Invia and Gemalto. The aim of the project is the development of autonomous vehicles and the realization of two canonical uses-cases on highways and urban like environments.

Renault Group: Collaboration between Renault and RITS re-started in 2016. Different research teams in Renault are now working separately with RITS on different topics.

- A CIFRE like PhD thesis is ongoing between Renault and Inria (Farouk GHALLABI) The thesis deals with the accurate localization of an autonomous vehicle on a highway using mainly on-board low-cost perception sensors.
- Another CIFRE PhD thesis begun on November 2017 (Imane MATHOUT).

AKKA Technologies: Collaboration with AKKA since 2012 (for the Link & Go prototype).

- Inria and AKKA Technologies are partners in the COCOVEA and the VALET projects (ANR projects).
- A new CIFRE PhD thesis (Luis ROLDAO JIMENEZ) dealing with 3D-environment modeling for autonomous vehicles begun in October 2017.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR

8.1.1.1. COCOVEA

Title: Coopération Conducteur-Véhicule Automatisé

Instrument: ANR

Duration: November 2013 - April 2017

Coordinator: Jean-Christophe Popieul (LAMIH - University of Valenciennes)

Partners: LAMIH, IFSTTAR, Inria, University of Caen, COMETE, PSA, CONTINENTAL, VALEO, AKKA Technologies, SPIROPS

Inria contact: Fawzi Nashashibi

Abstract: CoCoVeA project aims at demonstrating the need to integrate from the design of the system, the problem of interaction with the driver in resolving the problems of sharing the driving process and the degree of freedom, authority, level of automation, prioritizing information and managing the operation of the various systems. This approach requires the ability to know at any moment the state of the driver, the driving situation in which he finds himself, the operating limits of the various assistance systems and from these data, a decision regarding activation or not the arbitration system and the level of response.

8.1.1.2. VALET

Title: Redistribution automatique d'une flotte de véhicules en partage et valet de parking

Instrument: ANR

Duration: January 2016 - December 2018

Coordinator: Fawzi Nashashibi

Partners: Inria, Ecole Centrale de Nantes (IRCCyN), AKKA Technologies

Inria contact: Fawzi Nashashibi

Abstract: The VALET project proposes a novel approach for solving car-sharing vehicles redistribution problem using vehicle platoons guided by professional drivers. An optimal routing algorithm is in charge of defining platoons drivers' routes to the parking areas where the followers are parked in a complete automated mode. The main idea of VALET is to retrieve vehicles parked randomly on the urban parking network by users. These parking spaces may be in electric charging stations, parking for car sharing vehicles or in regular parking places. Once the vehicles are collected and guided in a platooning mode, the objective is then to guide them to their allocated parking area or to their respective parking lots. Then each vehicle is assigned a parking place into which it has to park in an automated mode.

8.1.2. FUI

8.1.2.1. Sinetic

Title: Système Intégré Numérique pour les Transports Intelligents Coopératifs

Instrument: FUI

Duration: December 2014 - May 2017

Coordinator: Thomas Nguyen (Oktal)

Partners: Oktal, ALL4TEC, CIVITEC, Dynalogic, Inria, EURECOM, Renault, Armines, IFSTTAR, VEDECOM

Inria contact: Jean-Marc Lasgouttes

Abstract: The purpose of the project SINETIC is to create a complete simulation environment for designing cooperative intelligent transport systems with two levels of granularity: the system level, integrating all the components of the system (vehicles, infrastructure management centers, etc.) and its realities (terrain, traffic, etc.) and the component-level, modeling the characteristics and behavior of the individual components (vehicles, sensors, communications and positioning systems, etc.) on limited geographical areas, but described in detail.

8.1.2.2. PAC V2X

Title: Perception augmentée par coopération véhicule avec l'infrastructure routière

Instrument: FUI

Duration: September 2016 - August 2019

Coordinator: SIGNATURE Group (SVMS)

Partners: DigiMobee, LOGIROAD, MABEN PRODUCTS, SANEF, SVMS, VICI, Inria, VEDECOM

Inria contact: Raoul de Charette

Abstract: The objective of the project is to integrate two technologies currently being deployed in order to significantly increase the time for an automated vehicle to evolve autonomously on European road networks. It is the integration of technologies for the detection of fixed and mobile objects such as radars, lidars, cameras ... etc. And local telecommunication technologies for the development of ad hoc local networks as used in cooperative systems.

8.1.3. Competitivity Clusters

RITS team is a very active partner in the competitivity clusters, especially MOV'EO and System@tic. We are involved in several technical committees like the DAS SUR of MOV'EO for example.

RITS is also the main Inria contributor in the VEDECOM institute (IEED). VEDECOM is financing the PhD theses of Mr. Fernando Garrido and Mr. Zayed Alsayed.

8.2. European Initiatives

8.2.1. FP7 & H2020 Projects

8.2.1.1. AUTOCITS

Title: AUTOCITS Regulation Study for Interoperability in the Adoption of Autonomous Driving in European Urban Nodes

Program: CEF- TRANSPORT Atlantic corridor

Duration: November 2016 - December 2018

Coordinator: Indra Sistemas S.A. (Spain)

Partners: Indra Sistemas S.A. (Spain); Universidad Politécnica de Madrid (UPM), Spain; Dirección General de Tráfico (DGT), Spain; Inria (France); Instituto Pedro Nunes (IPN), Portugal; Autoridade Nacional de Segurança Rodoviária (ANSR), Portugal; Universidade de Coimbra (UC), Portugal.

Inria contact: Fawzi Nashashibi, Mohammad Abualhoul

Abstract: The aim of the Study is to contribute to the deployment of C-ITS in Europe by enhancing interoperability for autonomous vehicles as well as to boost the role of C-ITS as catalyst for the implementation of autonomous driving. Pilots will be implemented in 3 major Core Urban nodes (Paris, Madrid, Lisbon) located along the Core network Atlantic Corridor in 3 different Member States. The Action consists of Analysis and design, Pilots deployment and assessment, Dissemination and communication as well as Project Management and Coordination.

8.2.2. Collaborations with Major European Organizations

RITS is member of the **euRobotics AISBL** and the Leader of “People transport” Topic. This makes from Inria one of the rare French robotics representatives at the European level. See also: http://www.eu-robotics.net/

RITS is a full partner of **VRA – Vehicle and Road Automation**, a support action funded by the European Union to create a collaboration network of experts and stakeholders working on deployment of automated vehicles and its related infrastructure. VRA project is considered as the cooperation interface between EC funded projects, international relations and national activities on the topic of vehicle and road automation. It is financed by the European Commission DG CONNECT and coordinated by ERTICO – ITS Europe. See also: http://vra-net.eu/

8.3. International Initiatives

8.3.1. Participation in Other International Programs

8.3.1.1. ICT-Asia

SIM-Cities

Title: "Sustainable and Intelligent Mobility for Smart Cities"

International Partner (Institution - Laboratory - Researcher):

- Nanyang Technical University (NTU), School of Electrical and Electronic Engineering – Singapore. Prof. Dan Wei Wang

- National University of Singapore (NUS), Department of Mechanical Engineering – Singapore. Dr. Marcelo Ang

- Kumamotoo University - Japan. Intelligent Transportation Systems Lab, Graduate School of Science and Technology, Prof. James Hu / Prof. Ogata

- Shanghai Jiao-Tong University (SJTU), Department of Automation – China. Prof. Ming Yang

- Hanoi University of Science and Technology, International Center MICA Institute – Vietnam. Prof. Eric Castelli

- Inria, RITS Project-Team – France. Dr. Fawzi Nashashibi

- Inria, e-Motion/CHROMA Project-Team – France. Dr. Christian Laugier

- Ecole Centrale de Nantes, IRCCyN – France. Prof. Philippe Martinet

Duration: Jan. 2015 - May 2017

Start year: 2015

This project aims at conducting common research and development activities in the field of sustainable transportation and advanced mobility of people and goods in order to move in the direction of smart, clean and sustainable cities.

RITS and MICA lab have obtained from the Vietnamese Program 911 the financing of the joint PhD thesis of Dinh-Van Nguyen (co-directed by Eric Castelli from MICA lab and Fawzi Nashashibi).

8.3.1.2. ECOS Nord – Venezuela

ECOS Nord

Title: "Les Techniques de l'Information et de la Communication pour la Conception de Systèmes Avancés de Mobilité durable en Milieu Urbain."

International Partner (Institution - Laboratory - Researcher):

- Simon Bolivar University, Department of Mecatronics – Venezuela. Dr. Gerardo Fernandez

- Inria, RITS Project-Team – France. Dr. Fawzi Nashashibi

Duration: Jan. 2014 - Dec. 2017

Start year: 2014

The main objective of this project is to contribute scientifically and technically to the design of advanced sustainable mobility systems in urban areas, particularly in dense cities where mobility, comfort and safety needs are more important than in other types of cities. In this project, we will focus on the contribution of advanced systems of perception, communication and control for the realization of intelligent transport systems capable of gradually integrating into the urban landscape. These systems require the development of advanced dedicated urban infrastructures as well as the development and integration of on-board intelligence in individual vehicles or mass transport.
This year, a session of courses has been organized at University Simon Bolivar, Caracas (Venezuela). Following several PhDs and interns recruitments from this university, prof G. Fernandez and J. Capeletto invited Raoul de Charette to organize a 32Hr Computer Vision Master Class in December 2017. PhDs Carlos Flores and Luis Roldao were also part of the master class and teached control (10Hr) and point cloud processing (7Hr), respectively.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

8.4.1.1. Internships

Julio Blanco Deniz, Nievsabel Molina from Simon Bolivar University, Venezuela.
They both worked on a cascade control architecture based on PID controllers for a Citroen C1: the longitudinal control was developed by Julio Blanco Deniz , under the supervision of Carlos Flores and the lateral control (for the action on the steering wheel) was done by Nievsabel Molina, under the supervision of Francisco Navas. Using this architecture, a reference trajectory can be smoothly followed by the vehicle at different speeds.

Aitor Gomez, Alfredo Valle, Edgar Talavera Munoz from Universidad Politécnica de Madrid, Spain.

Ziyang Hong from Université de Bourgogne, Dijon, France.

Maradona Rodrigues from University of Warwick, United Kingdom.

Sule Kahraman from MIT, USA.

Arthur Lecert from ESIEE Paris, France. He was supervised by Pierre de Beaucorps.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events Organisation

9.1.1.1. Member of the Organizing Committees

Mohammad Abualhoul and Fawzi Nashashibi organized a workshop within the framework of the European project AUTOCITS "Regulation Study for Interoperability in the Adoption of Autonomous Driving in European Urban Nodes". Date: 05/04/2017 - Inria Paris. https://project.inria.fr/autocits/autoc-its-workshop-paris/

9.1.2. Scientific Events Selection

9.1.2.1. Member of the Conference Program Committees

Fawzi Nashashibi: IEEE Intelligent Vehicles Symposium - IV 2017, IEEE 20th International Conference on Intelligent Transportation Systems - ITSC 2017.

9.1.2.2. Reviewer

Carlos Flores: IEEE 20th International Conference on Intelligent Transportation Systems - ITSC 2017.

Francisco Navas: IEEE Intelligent Vehicles Symposium - IV 2017, IEEE 20th International Conference on Intelligent Transportation Systems - ITSC 2017.

Anne Verroust-Blondet: IEEE Intelligent Vehicles Symposium - IV 2017, IEEE 20th International Conference on Intelligent Transportation Systems - ITSC 2017.

9.1.3. Journal

9.1.3.1. Member of the Editorial Boards

Guy Fayolle: associate editor of the journal *Markov Processes and Related Fields*

Fawzi Nashashibi: associate editor of the journal *IEEE Transactions on Intelligent Vehicles* and of *IEEE Transactions on Intelligent Transportation Systems*.

Fawzi Nashashibi: guest editor with Erwin Schoitsch (AIT) of *ERCIM News* N°109 on "Autonomous Vehicles".

9.1.3.2. Reviewer - Reviewing Activities

Guy Fayolle: *AAP, MPRF, PTRF, QUESTA, European Journal of Combinatorics, JSP, Physica A, Springer Science*.

Jean-Marc Lasgouttes: *IEEE Transactions on Knowledge and Data Engineering*, *IEEE Transactions on Intelligent Transportation Systems*.

Anne Verroust-Blondet: *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *The Visual Computer*.

9.1.4. Invited Talks

Raoul de Charette: Talk on "Computer Vision" at Adomik (artificial intelligence software company), Paris, November 29th.

Guy Fayolle was a keynote speaker at the conference at the ACMPT-2017 Conference http://acmpt.moscow/, *(Analytical and Computational Methods in Probability Theory and its Applications)*, held in Moscow State University and in RUDN University, Moscow, 23-27th October 2017. His talk presented the substance of the article [21].

Fawzi Nashashibi was a keynote speaker at IEEE International Conference on Intelligent Vehicles Symposium - IV 2017, *Latest Advancements in Intelligent Vehicles Research in Europe*, held in June 2017.

Fawzi Nashashibi was a keynote speaker at IEEE International Conference on Vehicular Electronics and Safety (ICVES), *(Automated vehicles in urban environments: challenges and technical solutions)*, June 2017.

Fawzi Nashashibi was a keynote speaker at Convergence Technology Symposium 2017 (ConTech 2017) *(Autonomous Driving, Future Mobility, Future Smart City with Autonomous Driving)*, held in June 2017, at the AICT in Suwon, Korea.

Fawzi Nashashibi was a keynote speaker at IEEE International Conference on Intelligent Computer Communication and Processing (ICCP), *(A functional architecture for the navigation of an autonomous vehicle)*, held in September 2017.

9.1.5. Scientific Expertise

Guy Fayolle is scientific advisor and associate researcher at the *Robotics Laboratory of Mines ParisTech*.

Jean-Marc Lasgouttes is member of the *Conseil Académique* of Université Paris-Saclay.

Anne Verroust-Blondet is member of the COST-GTRI committee at Inria and of the "emploi scientifique" committee of Inria Paris.

9.1.6. Research Administration

Jean-Marc Lasgouttes is a member of the *Comité Technique Inria*.

Guy Fayolle is a member of the working group IFIP WG 7.3.

Fawzi Nashashibi is a member of the international Automated Highway Board Committee of the TRB (AHB30). He is a member of the Board of Governors of the VEDECOM Institute representing Inria and of the Board of Governors of MOV'EO Competitiveness cluster representing Inria.

Anne Verroust-Blondet is the scientific correspondent of the European affairs and of the International relations of Inria Paris.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence: Fawzi Nashashibi, “Programmation avancée”, 84h, L1, Université Paris-8 Saint-Denis, France.

Master: Raoul de Charette, "Computer Vision for Autonomous Driving", 32Hr, Master 2, University of Simon Bolivar, Venezuela, December 2017.

Master: Carlos Flores, "Control for Autonomous Driving", 10Hr, Master 2, University of Simon Bolivar, Venezuela, December 2017.

Master: Jean-Marc Lasgouttes, “Analyse de données”, 54h, second year of Magistère de Finance (M1), University Paris 1 Panthéon Sorbonne, France.

Master: Luis Roldao Jimenez, "Point Cloud Processing for Autonomous Driving", 7Hr, Master 2, University of Simon Bolivar, Venezuela, December 2017.

Master: Carlos Flores and Anne Verroust-Blondet, "Le véhicule autonome. Présentation des recherches de l'équipe-projet RITS",1.5 h, 2nd year, Ecole des Ponts ParisTech, France, September 2017.

Master: Fawzi Nashashibi, "Image synthesis and 3D Infographics", 12h, M2, INT Télécom Sud-Paris.

Master: Fawzi Nashashibi, "Obstacle detection and Multisensor Fusion", 4h, M2, INSA de Rouen.

Master: Fawzi Nashashibi, "Perception and Image processing for Mobile Autonomous Systems", 12h, M2, University of Evry.

Doctorat: Raoul de Charette, "Introduction, Data Visualization and Signal Processing in Python", 21Hr, class organized with Paris Science et Lettres, France, January 2017.

Doctorat: Jean-Marc Lasgouttes, "Analyse de données fonctionnelles", 31.5h, Mastère Spécialisé "Expert en sciences des données", INSA-Rouen, France

9.2.2. Supervision

PhD: David González Bautista, "Architecture fonctionnelle pour la planification des trajectoires des véhicules automatisés dans des environnements complexes", Mines ParisTech, April 2017, supervisor: Fawzi Nashashibi.

PhD in progress: Zayed Alsayed, "Système de localisation redondant en environnement extérieur ouvert pour véhicule urbain automatique", Télécom ParisTech, October 2014, supervisor: Anne Verroust-Blondet, co-supervisor: Guillaume Bresson.

PhD in progress: Pierre de Beaucorps, "Autonomous vehicle: behavior prediction and Interaction with road users", UPMC Paris, January 2016, supervisor: Anne Verroust-Blondet, co-supervisor: Fawzi Nashashibi.

PhD in progress: Carlos Flores, "Analysis and design of cooperative systems for trains of green cars", Mines ParisTech, December 2015, supervisor: Fawzi Nashashibi, co-supervisor: Vicente Milanés.

PhD in progress: Fernando Garrido, "Optimal trajectory generation for autonomous vehicles in urban environments" , Mines ParisTech, November 2014, supervisor: Fawzi Nashashibi, co-supervisors: Vicente Milanés, Joshué Pérez.

PhD in progress: Farouk Ghallabi, "Environment modeling and simultaneous localization of a mobile vehicle on motorways: a multi-sensor approach", Mines ParisTech, October 2016, supervisor: Fawzi Nashashibi.

PhD in progress: Maximilian Jaritz, "Perception multi-capteur pour la conduite autonome grâce à l'apprentissage profond", Mines ParisTech, January 2017, supervisor: Fawzi Nashashibi, co-supervisor: Raoul de Charette.

PhD in progress: Francisco Navas, "Plug&Play control for highly non-linear systems: Stability analysis of autonomous vehicles", Mines ParisTech, October 2015, supervisor: Fawzi Nashashibi, co-supervisor: Vicente Milanés.

PhD in progress: Dinh-Van Nguyen, "Wireless sensor networks for indoor mapping and accurate localization for low speed navigation in smart cities", Mines ParisTech, December 2015, supervisor: Fawzi Nashashibi, co-supervisor: Eric Castelli.

PhD in progress: Danut-Ovidiu Pop, "Deep learning techniques for intelligent vehicles", INSA Rouen, May 2016, supervisor: Abdelaziz Bensrhair, co-supervisor: Fawzi Nashashibi.

Starting PhD: Imane Matout, "Estimation de l'intention des véhicules pour la prise de décision et le contrôle sans faille en navigation autonome", Mines ParisTech, October 2017, supervisor: Fawzi Nashashibi, co-supervisor: Vicente Milanés.

Starting PhD: Kaouther Messaoud, "Détermination des manoeuvres et des intentions des véhicules avoisinant un véhicule autonome", UPMC Paris, October 2017, supervisor: Anne Verroust-Blondet, co-supervisor: Fawzi Nashashibi, Itheri Yahiaoui.

Starting PhD: Luis Roldao Jimenez, “Modélisation 3D de l’environnement et de la manoeuvrabilité d’un véhicule”, UPMC Paris, October 2017, supervisor: Anne Verroust-Blondet, co-supervisor: Raoul de Charette.

9.2.3. Juries

Guy Fayolle was a jury member of PhD thesis of Younes Bouchaala - *Handling Safety Messages in Vehicular Ad-Hoc Networks (VANETs)*, University of Versailles Saint-Quentin-en-Yvelines, 21 October 2017.

Fawzi Nashashibi was a reviewer of the PhD thesis of Ange Nizard - *Planification et commande pour véhicules à deux trains directeurs en milieu encombré* Université Blaise Pascal, Clermont-Ferrand. 31 March 2017.

Fawzi Nashashibi was an examiner of the PhD thesis of Bastien Béchadergue - *Mesure de distance et transmission de données intervéhicules par phares à LED*. University of Paris-Saclay, prepared at the University of Versailles Saint-Quentin, 10 November 2017.

Fawzi Nashashibi was the Jury President for the thesis of Viet-Cuong Ta - *Smartphone-based indoor positioning using WIFI, inertial sensor and Bluetooth*, under the co-supervision of Université Grenoble Alpes and Hanoi University of Science & Technology, 15 December 2017.

Anne Verroust-Blondet was a reviewer of the PhD thesis of Mathias Paget - *Optimisation discrète et indices de stabilité appliqués à la stéréoscopie en contexte routier*, Université Paris-Est, 13 December 2017.

9.3. Popularization

RITS team: press article on the research axes of Inria RITS team entitled "RITS Team at Inria", with participation of Fawzi Nashashibi, Anne Verroust-Blondet, Jean-Marc Lasgouttes and Raoul de Charette. IEEE Intelligent Transportation Systems Magazine, Vol 9, Issue 2. April 19th. (http://ieeexplore.ieee.org/document/7904770/).

Raoul de Charette: participation to the Hackathon round-table in collaboration with approximately 10 journalists and a handful of Inria researchers. Exchange on the implementation of future autonomous transportation in cities. It lead to several press article. June 7th, Paris.

Raoul de Charette: public conference "Voiture Autonomes: Où en est-on ?" at Futur en Seine, Paris, June 8th.

Raoul de Charette: exchange on upcoming challenges for autonomous driving for the web article "Véhicules Autonomes : Où En Est-On en France ?", journalist Mathilde Ragot. T.O.M. June 14th. (http://www.tom.travel/2017/06/14/vehicules-autonomes-ou-en-est-on-en-france/).

Raoul de Charette: exchange on upcoming challenges for autonomous driving for the web article "Véhicules autonomes : où en est-on réellement ?", journalist Benoit Fleuret. Microsoft RSLN. June 22th. (https://rslnmag.fr/cite/vehicules-autonomes-ou-en-est-on-reellement/).

Raoul de Charette: interview on current progress of autonomous driving and real upcoming challenges for the web article "Pourquoi la voiture 100 % autonome n’est pas près de rouler", journalist Reynald Fléchaux. Silicon. June 26th. (https://www.silicon.fr/voiture-autonome-pas-prete-rouler-178787.html?inf_by=5a0c4d80681db858068b471e).

Raoul de Charette: interview on the progress of computer vision and danger of artificial intelligence for the press article "Robots tueurs soudés pour déssouder", journalist Erwan Cario. Libération. August 24th. (http://www.liberation.fr/futurs/2017/08/24/robots-tueurs-soudes-pour-dessouder_1591778).

Gérard Le Lann: Interview published in *Journal of Internet Histories*, vol. 1, issue 1-2, pp. 188-196, (http://tandfonline.com/doi/full/10.1080/24701475.2017.1301132).

Gérard Le Lann: interview for Inria's 50 years "Networks, distributed algorithms and critical cyber-physical systems", (https://50ans.inria.fr/en/gerard-le-lann-networks-distributed-algorithms-and-critical-cyber-physical-systems/]).

Fawzi Nashashibi: participation to the round-table on "L'Intelligence Artificielle pour le transport autonome" during the workshop "Journée de l'IA / Evenement Public ♯FranceIA" organized by SystemX at Nano-INNOV (Palaiseau), March 3rd.

Fawzi Nashashibi: participation to the round-table on "Transports et mobilité" during the workshop "Les Mystères du XXIème siècle" (http://www.mysteres21.org/edition-2017/), November 25th.

Fawzi Nashashibi: participation to the round-table on "les questions éthiques et juridiques en robotique" during the workshop on "Ethique de la recherche en numérique", organized by the CERNA, Paris (Institut Mines-Télécom), June 15th.

Fawzi Nashashibi: interview for "L'Esprit Sorcier" number 29 on "La voiture autonome", journalist: Melvin Martineau (https://www.lespritsorcier.org/dossier-semaine/la-voiture-autonome/).

Fawzi Nashashibi: interviewed by Tiffany Blandin for the book *Un Monde sans travail ?*, Paris: Seuil, 24 August 2017, (Chapter 7: la recherche sur les voitures autonomes).

Fawzi Nashashibi: interviewed by Coralie Baumard for the article "L'Intelligence Artificielle, Nouveau Moteur De l'Industrie Automobile", FORBES France, February 11th. (https://www.forbes.fr/business/lintelligence-artificielle-nouveau-moteur-de-lindustrie-automobile/).

Fawzi Nashashibi: interviewed by Jérôme Bonaldi (Science & Vie TV) for "Le Mag de la Science" on September 2017 (to be broadcasted in 2018).

10. Bibliography

Major publications by the team in recent years

[1] M. ABUALHOUL, O. SHAGDAR, F. NASHASHIBI. *Visible Light Inter-Vehicle Communication for Platooning of Autonomous Vehicles*, in "2016 IEEE Intelligent Vehicles Symposium IV2016", Gothenburg, Sweden, June 2016, https://hal.inria.fr/hal-01308430

[2] G. FAYOLLE, R. IASNOGORODSKI, V. A. MALYSHEV. *Random walks in the Quarter Plane*, Applications of Mathematics, Springer-Verlag, 1999, n° 40

[3] C. FLORES, V. MILANÉS, F. NASHASHIBI. *Using Fractional Calculus for Cooperative Car-Following Control*, in "Intelligent Transportation Systems Conference 2016", Rio de Janeiro, Brazil, IEEE, November 2016, https://hal.inria.fr/hal-01382821

[4] D. GONZALEZ BAUTISTA, J. PÉREZ, V. MILANÉS, F. NASHASHIBI. *A Review of Motion Planning Techniques for Automated Vehicles*, in "IEEE Transactions on Intelligent Transportation Systems", April 2016 [*DOI :* 10.1109/TITS.2015.2498841], https://hal.inria.fr/hal-01397924

[5] D. GONZÁLEZ BAUTISTA, J. PÉREZ RASTELLI, R. LATTARULO, V. MILANÉS, F. NASHASHIBI. *Continuous curvature planning with obstacle avoidance capabilities in urban scenarios*, in "2014 IEEE 17th International Conference on Intelligent Transportation Systems (ITSC)", Qingdao, China, October 2014, https://hal.inria.fr/hal-01086888

[6] G. LE LANN. *Cohorts and groups for safe and efficient autonomous driving on highways*, in "Vehicular Networking Conference (VNC)", IEEE, 2011, pp. 1-8

[7] H. LI, F. NASHASHIBI. *Multi-vehicle cooperative localization using indirect vehicle-to-vehicle relative pose estimation*, in "ICVES 2012 - IEEE International Conference on Vehicular Electronics and Safety", Istanbul, Turkey, IEEE, July 2012, pp. 267 - 272 [*DOI :* 10.1109/ICVES.2012.6294256], https://hal.inria.fr/hal-00763825

[8] H. LI, F. NASHASHIBI. *Cooperative Multi-Vehicle Localization Using Split Covariance Intersection Filter*, in "IEEE Intelligent Transportation Systems Magazine", April 2013, vol. 5, n^o 2, pp. 33-44, https://hal.inria.fr/hal-00833707

[9] M. MAROUF, E. POLLARD, F. NASHASHIBI. *Automatic parking and platooning for electric vehicles redistribution in a car-sharing application*, in "IOSR Journal of Electrical and Electronics Engineering", 2015, vol. 10, n^o 1, 9 p. , https://hal.inria.fr/hal-01254336

[10] V. MARTIN, C. FURTLEHNER, Y. HAN, J.-M. LASGOUTTES. *GMRF Estimation under Topological and Spectral Constraints*, in "7th European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases", Nancy, France, T. CALDERS, F. ESPOSITO, E. HÜLLERMEIER, R. MEO (editors), Lecture Notes in Computer Science, Springer Berlin Heidelberg, September 2014, vol. 8725, pp. 370-385 [*DOI :* 10.1007/978-3-662-44851-9_24], https://hal.archives-ouvertes.fr/hal-01065607

[11] V. MARTIN, J.-M. LASGOUTTES, C. FURTLEHNER. *Latent binary MRF for online reconstruction of large scale systems*, in "Annals of Mathematics and Artificial Intelligence", 2016, vol. 77, n^o 1, pp. 123-154 [*DOI :* 10.1007/s10472-015-9470-x], https://hal.inria.fr/hal-01186220

[12] P. MERDRIGNAC, O. SHAGDAR, F. NASHASHIBI. *Fusion of Perception and V2P Communication Systems for Safety of Vulnerable Road Users*, in "IEEE Transactions on Intelligent Transportation Systems", 2016, https://hal.inria.fr/hal-01399150

[13] P. MORIGNOT, J. PÉREZ RASTELLI, F. NASHASHBI. *Arbitration for balancing control between the driver and ADAS systems in an automated vehicle: Survey and approach*, in "2014 IEEE Intelligent Vehicles Symposium (IV)", Dearborn, United States, June 2014, pp. 575 - 580 [*DOI :* 10.1109/IVS.2014.6856577], https://hal.inria.fr/hal-01081302

[14] F. NAVAS, V. MILANÉS, F. NASHASHIBI. *Using Plug&Play Control for stable ACC-CACC system transitions*, in "Intelligent Vehicles Symposium 2016", Gothemburg, Sweden, June 2016 [*DOI :* 10.1109/IVS.2016.7535464], https://hal.inria.fr/hal-01304542

[15] P. PETROV, F. NASHASHIBI. *Modeling and Nonlinear Adaptive Control for Autonomous Vehicle Overtaking*, in "IEEE Transactions Intelligent Transportation Systems", August 2014, vol. 15, n^o 4, pp. 1643–1656

[16] G. TREHARD, E. POLLARD, B. BRADAI, F. NASHASHIBI. *On line Mapping and Global Positioning for autonomous driving in urban environment based on Evidential SLAM*, in "Intelligent Vehicles Symposium - IV 2015", Seoul, South Korea, June 2015, https://hal.inria.fr/hal-01149504

Publications of the year

Doctoral Dissertations and Habilitation Theses

[17] D. GONZA´LEZ BAUTISTA. *Functional architecture for automated vehicles trajectory planning in complex environments*, PSL Research University, April 2017, https://pastel.archives-ouvertes.fr/tel-01568505

Articles in International Peer-Reviewed Journals

[18] G. BRESSON, Z. ALSAYED, L. YU, S. GLASER. *Simultaneous Localization And Mapping: A Survey of Current Trends in Autonomous Driving*, in "IEEE Transactions on Intelligent Vehicles", 2017, vol. XX, 1 p. [*DOI :* 10.1109/TIV.2017.2749181], https://hal.archives-ouvertes.fr/hal-01615897

[19] D. GONZALEZ, J. PÉREZ, V. MILANÉS. *Parametric-based path generation for automated vehicles at roundabouts*, in "Expert Systems with Applications", April 2017, vol. 71, pp. 332 - 341 [*DOI :* 10.1016/J.ESWA.2016.11.023], https://hal.inria.fr/hal-01674532

[20] Z. YASSEEN, A. VERROUST-BLONDET, A. NASRI. *View selection for sketch-based 3D model retrieval using visual part shape description*, in "Visual Computer", May 2017, vol. 33, n^{o} 5, pp. 565-583 [*DOI :* 10.1007/S00371-016-1328-7], https://hal.inria.fr/hal-01396333

Invited Conferences

[21] G. FAYOLLE. *Functional equations as an important analytic method in stochastic modelling and in combinatorics*, in "ACMPT 2017 - Analytical and Computational Methods in Probability Theory and its Applications", Moscou, Russia, Analytic and Computational Methods in Probability Theory and its Applications, October 2017, pp. 1-25, https://arxiv.org/abs/1712.02271 - To appear in MPRF (Markov Processes and Related Fields), https://hal.inria.fr/hal-01657154

International Conferences with Proceedings

[22] Z. ALSAYED, G. BRESSON, A. VERROUST-BLONDET, F. NASHASHIBI. *Failure Detection for Laser-based SLAM in Urban and Peri-Urban Environments*, in "ITSC 2017 - IEEE 20th International Conference on Intelligent Transportation Systems", Yokohama, Japan, October 2017, pp. 1-7, https://hal.inria.fr/hal-01623394

[23] C. FLORES, V. MILANÉS, F. NASHASHIBI. *A Time Gap-Based Spacing Policy for Full-Range Car-Following*, in "Intelligent Transportation Systems Conference 2017", Yokohama, Japan, October 2017, https://hal.inria.fr/hal-01634494

[24] G. LE LANN. *Anonymat, non-traçabilité et sécurité-innocuité dans les réseaux de véhicules autonomes connectés*, in "8ème Atelier sur la Protection de la Vie Privée (APVP'17)", Autrans, France, Equipe Privatics du laboratoire CITI d'Inria / INSA-Lyon, June 2017, https://hal.archives-ouvertes.fr/hal-01556192

[25] G. LE LANN. *Fast Distributed Agreements and Safety-Critical Scenarios in VANETs*, in "2017 IEEE International Conference on Computing, Networking and Communications", Santa Clara, CA, United States, 2017 IEEE International Conference on Computing, Networking and Communications, IEEE ComSoc, January 2017, 7 p. , https://hal.inria.fr/hal-01402159

[26] G. LE LANN. *Protection de la vie privée, innocuité et immunité envers les cybermenaces dans les futurs réseaux de véhicules autonomes connectés*, in "C&ESAR 2017 - Protection des données face à la menace cyber", Rennes, France, November 2017, pp. 1-22, https://hal.archives-ouvertes.fr/hal-01621500

[27] G. LE LANN. *Safe Automated Driving on Highways – Beyond Today's Connected Autonomous Vehicles*, in "8th Complex Systems Design & Management Conference “Towards smarter and more autonomous systems”", Paris, France, December 2017, https://hal.archives-ouvertes.fr/hal-01610957

[28] F. NAVAS, V. MILANÉS, F. NASHASHIBI. *Youla-Kucera Based Online Closed-Loop Identification For Longitudinal Vehicle Dynamics*, in "21st International Conference on System Theory, Control and Computing", Sinaia, Romania, October 2017, https://hal.inria.fr/hal-01591705

[29] D. V. N. NGUYEN, F. NASHASHIBI, T.-K. DAO, E. CASTELLI. *Improving Poor GPS Area Localization for Intelligent Vehicles*, in "MFI 2017 - IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems", Daegu, South Korea, November 2017, pp. 1-5, https://hal.inria.fr/hal-01613132

[30] D.-V. NGUYEN, F. NASHASHIBI, T.-H. NGUYEN, E. CASTELLI. *Indoor Intelligent Vehicle localization using WiFi Received Signal Strength Indicator*, in "3rd IEEE MTT-S International Conference on Microwaves for Intelligent Mobility 2017", Nagoya, Japan, March 2017, https://hal.inria.fr/hal-01433785

[31] E. PEROT, M. JARITZ, M. TOROMANOFF, R. DE CHARETTE. *End-to-End Driving in a Realistic Racing Game with Deep Reinforcement Learning*, in "International conference on Computer Vision and Pattern Recognition - Workshop", Honolulu, United States, July 2017, https://hal.inria.fr/hal-01620595

[32] D. O. POP, A. ROGOZAN, F. NASHASHIBI, A. BENSRHAIR. *Fusion of Stereo Vision for Pedestrian Recognition using Convolutional Neural Networks*, in "ESANN 2017 - 25th European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning", Bruges, Belgium, April 2017, https://hal.inria.fr/hal-01501735

[33] D. O. POP, A. ROGOZAN, F. NASHASHIBI, A. BENSRHAIR. *Incremental Cross-Modality Deep Learning for Pedestrian Recognition*, in "IV'17 - IEEE Intelligent Vehicles Symposium", Redondo Beach, CA, United States, June 2017, https://hal.inria.fr/hal-01501711

[34] D. O. POP, A. ROGOZAN, F. NASHASHIBI, A. BENSRHAIR. *Pedestrian Recognition through Different Cross-Modality Deep Learning Methods*, in "IEEE International Conference on Vehicular Electronics and Safety", Vienna, Austria, June 2017, https://hal.inria.fr/hal-01588441

[35] O. SHAGDAR, F. NASHASHIBI, S. TOHMÉ. *Performance study of CAM over IEEE 802.11p for cooperative adaptive cruise control*, in "Wireless Days, 2017", Porto, Portugal, March 2017 [*DOI :* 10.1109/WD.2017.7918118], https://hal.inria.fr/hal-01675460

[36] T. STREUBEL, P. DE BEAUCORPS, F. NASHASHIBI. *Evaluation of automated vehicle behavior in intersection scenarios*, in "RSS2017 - Road Safety & Simulation International Conference", The Hague, Netherlands, October 2017, https://hal.inria.fr/hal-01632434

[37] P. DE BEAUCORPS, T. STREUBEL, A. VERROUST-BLONDET, F. NASHASHIBI, B. BRADAI, P. RESENDE. *Decision-making for automated vehicles at intersections adapting human-like behavior*, in "IV'17 - IEEE Intelligent Vehicles Symposium", Redondo Beach, United States, IEEE, June 2017, https://hal.inria.fr/hal-01531516

Conferences without Proceedings

[38] G. LE LANN. *On safety in ad hoc networks of autonomous and communicating vehicles: A rationale for time-bounded deterministic solutions*, in "CoRes 2017- 2ème Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication", Quiberon, France, May 2017, https://hal.archives-ouvertes.fr/hal-01517823

Scientific Books (or Scientific Book chapters)

[39] G. FAYOLLE, R. IASNOGORODSKI, V. A. MALYSHEV. , S. ASMUSSEN, P. W. GLYNN, Y. L. JAN (editors) *Random Walks in the Quarter Plane: Algebraic Methods, Boundary Value Problems, Applications to Queueing Systems and Analytic Combinatorics*, Probability Theory and Stochastic Modelling, Springer International Publishing, February 2017, vol. 40, 255 p. , The first edition was published in 1999 [*DOI :* 10.1007/978-3-319-50930-3], https://hal.inria.fr/hal-01651919

[40] D. GONZÁLEZ, J. PÉREZ, V. MILANÉS, F. NASHASHIBI, M. SAEZ TORT, A. CUEVAS. *Arbitration and Sharing Control Strategies in the Driving Process*, in "Towards a Common Software/Hardware Methodology for Future Advanced Driver Assistance Systems The DESERVE Approach", River Publishers Series in Transport Technology , April 2017, 24 p. , https://hal.inria.fr/hal-01676355

Research Reports

[41] S. KAHRAMAN, R. DE CHARETTE. *Influence of Fog on Computer Vision Algorithms*, Inria Paris, September 2017, pp. 1-3, https://hal.inria.fr/hal-01620602

References in notes

[42] G. FAYOLLE, C. FURTLEHNER. *About Hydrodynamic Limit of Some Exclusion Processes via Functional Integration*, in "Int. Math. Conf. “50 Years of IPPI”", Moscow, Institute for Information Transmission Problems (Russian Academy of Sciences), July 2011, Proceedings on CD. ISBN 978-5-901158-15-9, http://hal.inria.fr/hal-00662674

[43] G. FAYOLLE, R. IASNOGORODSKI. *Random Walks in the Quarter-Plane: Advances in Explicit Criterions for the Finiteness of the Associated Group in the Genus 1 Case*, in "Markov Processes and Related Fields", December 2015, vol. 21, n^{o} 4, Accepted for publication in the journal MPRF (Markov Processes and Related Fields), https://hal.inria.fr/hal-01086684

[44] G. FAYOLLE, J.-M. LASGOUTTES. *Asymptotics and Scalings for Large Product-Form Networks via the Central Limit Theorem*, in "Markov Processes and Related Fields", 1996, vol. 2, n^{o} 2, pp. 317-348

[45] C. FURTLEHNER, Y. HAN, J.-M. LASGOUTTES, V. MARTIN, F. MARCHAL, F. MOUTARDE. *Spatial and Temporal Analysis of Traffic States on Large Scale Networks*, in "13th International IEEE Conference on Intelligent Transportation Systems ITSC'2010", Madère, Portugal, September 2010, https://hal-mines-paristech.archives-ouvertes.fr/hal-00527481

[46] F. GARRIDO, D. GONZALEZ BAUTISTA, V. MILANÉS, J. PÉREZ, F. NASHASHIBI. *Optimized trajectory planning for Cybernetic Transportation Systems*, in "9th IFAC Symposium on Intelligent Autonomous Vehicles IAV 2016", Leipzig, Germany, June 2016, vol. 49, n^{o} 15, pp. 1-6, https://hal.inria.fr/hal-01356691

[47] F. GARRIDO, D. GONZALEZ BAUTISTA, V. MILANÉS, J. PÉREZ, F. NASHASHIBI. *Real-time planning for adjacent consecutive intersections*, in "19th International IEEE Conference on Intelligent Transportation Systems - ITSC 2016", Rio de Janeiro, Brazil, November 2016, https://hal.inria.fr/hal-01356706

[48] G. LE LANN. *Safety in Vehicular Networks-On the Inevitability of Short-Range Directional Communications*, in "14th International Conference ADHOC-NOW, 2015", Athens, Greece, S. PAPAVASSILIOU, S. RUEHRUP (editors), Ad Hoc, Mobile, and Wireless Networks, Springer, June 2015, vol. Lecture Notes in Computer

Science (LNCS), n° 9143, 14 p. , Mobile Ad Hoc Networks [*DOI :* 10.1007/978-3-319-19662-6_24], https://hal.inria.fr/hal-01172595

[49] V. MARTIN, C. FURTLEHNER, Y. HAN, J.-M. LASGOUTTES. *GMRF Estimation under Topological and Spectral Constraints*, in "7th European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases", Nancy, France, T. CALDERS, F. ESPOSITO, E. HÜLLERMEIER, R. MEO (editors), Lecture Notes in Computer Science, Springer Berlin Heidelberg, September 2014, vol. 8725, pp. 370-385 [*DOI :* 10.1007/978-3-662-44851-9_24], https://hal.archives-ouvertes.fr/hal-01065607

[50] V. MARTIN, J.-M. LASGOUTTES, C. FURTLEHNER. *Latent binary MRF for online reconstruction of large scale systems*, in "Annals of Mathematics and Artificial Intelligence", 2016, vol. 77, n° 1, pp. 123-154

[51] A. MEYER, R. DE CHARETTE. *Computing Ego Velocity from Scene Flow estimation*, Inria Paris, December 2016, https://hal.inria.fr/hal-01620608

[52] F. NAVAS, V. MILANÉS, F. NASHASHIBI. *Using Plug&Play Control for stable ACC-CACC system transitions*, in "Intelligent Vehicles Symposium 2016", Gothemburg, Sweden, June 2016, https://hal.inria.fr/hal-01304542

[53] L. RAFFAELLI, G. FAYOLLE, F. VALLÉE. *ADAS Reliability and Safety*, in "20ème Congrès de maîtrise des risques et de sûreté de fonctionnement ", Saint-Malo, France, E. LARDEUX, A. BRACQUEMOND (editors), Congrès Lambda MU 20, Institut pour la Maîtrise des Risques (IMdR), October 2016, 10 p. , https://hal.inria.fr/hal-01398428

[54] L. RAFFAELLI, F. VALLÉE, G. FAYOLLE, P. DE SOUZA, X. ROUAH, M. PFEIFFER, S. GÉRONIMI, F. PÉTROT, S. AHIAD. *Facing ADAS validation complexity with usage oriented testing*, in "ERTS 2016", Toulouse, France, January 2016, 13 p. , https://hal.inria.fr/hal-01277494