Activity Report 2014

Team RITS

Robotics & Intelligent Transportation Systems

RESEARCH CENTER
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THEME
Robotics and Smart environments

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Team RITS

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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: Zayed Alsayed, Guillaume Bresson, David Gonzalez Bautista, Wei-Lin Ku, Mohamed Marouf, Pierre Merdrignac, Vicente Milanes Montero, Fawzi Nashashibi, Joshué Pérez Rastelli, Plamen Petrov, Evangeline Pollard, Oyunchimeg Shagdar, Guillaume Trehard, Anne Verroust-Blondet.

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, Guillaume Bresson, Wei-Lin Ku, Pierre Merdrignac, Fawzi Nashashibi, Joshué Pérez Rastelli, Evangeline Pollard, Guillaume Trehard, Anne Verroust-Blondet.

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.

This year was the opportunity to focus on two particular topics: SLAMMOT-based techniques for grid-based environment modeling using laser sensors, and belief-based SLAM techniques for vehicle navigation.

3.1.2. 3D environment representation

Participants: Zayed Alsayed, Guillaume Bresson, Fawzi Nashashibi.

In the past few years, we have been focusing on the Disparity map estimation as a mean to obtain dense 3D mapping of the environment. Moreover, many autonomous vehicle navigation systems have adopted stereo vision techniques to construct disparity maps as a basic obstacle detection and avoidance mechanism. Two different approaches where investigated: the Fly algorithm, and the stereo vision for 3D representation.

In the first approach, the Fly algorithm is an evolutionary optimization applied to stereovision and mobile robotics. Its advantage relies on its precision and its acceptable costs (computation time and resources). In the second approach, originality relies on computing the disparity field by directly formulating the problem as a constrained optimization problem in which a convex objective function is minimized under convex constraints. These constraints arise from prior knowledge and the observed data. The minimization process is carried out over the feasibility set and with a suitable regularization constraint: the Total Variation information, which avoids oscillations while preserving field discontinuities around object edges. Although successfully applied to real-time pedestrian detection using a vehicle mounted stereohead (see LOVe project), this technique could not be used for other robotics applications such as scene modeling, visual SLAM, etc. The need is for a dense 3D representation of the environment obtained with an appropriate precision and acceptable costs (computation time and resources).

Stereo vision is a reliable technique for obtaining a 3D scene representation through a pair of left and right images and it is effective for various tasks in road environments. The most important problem in stereo image processing is to find corresponding pixels from both images, leading to the so-called disparity estimation. Many autonomous vehicle navigation systems have adopted stereo vision techniques to construct disparity maps as a basic obstacle detection and avoidance mechanism. We are presently working on an original stereo-vision based SLAM technique, which aimed at reconstructing current surroundings through on-the-fly real-time localization of tens of thousands of interest points. This development should also allow detection and tracking of moving objects [2], and is built on linear algebra (through Inria's Eigen library), using the RANSAC algorithm and multi-target tracking techniques, to quote a few.

This technique complements another laser based SLAMMOT technique developed since few years and extensively validated in large scale demonstrations for indoor and outdoor robotics applications. This technique has proved its efficiency in terms of cost, accuracy and reliability.

3.1.3. Cooperative Multi-sensor data fusion

Participants: Pierre Merdrignac, Fawzi Nashashibi, Evangeline Pollard, 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.

[2] http://www.youtube.com/watch?v=obH9Z2uOMBI

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 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.

3.1.4. Planning and executing vehicle actions

Participants: David Gonzalez Bautista, Mohamed Marouf, Vicente Milanes Montero, Fawzi Nashashibi, Joshué Pérez Rastelli, Plamen Petrov.

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: Thierry Ernst, Oyunchimeg Shagdar, Gérard Le Lann, Younes Bouchaala, Pierre Merdrignac, Ines Ben Jemaa, Mohammad Abu Alhoul, Fawzi Nashashibi, Arnaud de La Fortelle.

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

Participants: Ines Ben Jemaa, Oyunchimeg Shagdar, Thierry Ernst, Arnaud de La Fortelle.

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 themto allow simple and efficient data delivery.

3.2.2. Platooning control using visible light communications

Participants: Mohammad Abu Alhoul, Mohamed Marouf, 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 Abu Alhoul, Pierre Merdrignac, 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.

3.3. Automated driving, intelligent vehicular networks, and safety

Participant: Gérard Le Lann.

Intelligent vehicular networks (IVNs) are one constituent of ITS. IVNs encompass "clusters", platoons and vehicular ad-hoc networks comprising automated and cooperative vehicles. A basic principle that underlies our work is minimal reliance on road-side infrastructures for solving those open problems arising with IVNs. For example, V2V communications only are considered. Trivially, if one can solve a problem P considering V2V communications only, then P is solved with the help of V2I communications, whereas the converse is not true. Moreover, safety in the course of risk-prone maneuvers is our central concern. Since safety-critical (SC) scenarios may develop anytime anywhere, it is impossible to assume that there is always a road-side unit in the vicinity of those vehicles involved in a hazardous situation.

3.3.1. Cohorts and groups – Novel constructs for safe IVNs

The automated driving function rests on two radically different sets of solutions, one set encompassing signal processing and robotics (SPR), the other one encompassing vehicular communications and networking (VCN). In addition to being used for backing a failing SPR solution, VCN solutions have been originally proposed for "augmenting" the capabilities offered by SPR solutions, which are line-of-sight technologies, i.e. limited by obstacles. Since V2V omni-directional radio communications that are being standardized (IEEE 802.11p / WAVE) have ranges in the order of 250 m, it is interesting to prefix risk-prone maneuvers with the exchange of SC-messages. Roles being assigned prior to initiating physical maneuvers, the SPR solutions are invoked under favorable conditions, safer than when vehicles have not agreed on "what to do" ahead of time.

VCN solutions shall belong to two categories: V2V omni-directional (360°) communications and unidirectional communications, implemented out of very-short range antennas of very small beam-width. This has led to the concept of neighbor-to-neighbor (N2N) communications, whereby vehicles following each other on a given lane can exchange periodic beacons and event-driven messages.

Vehicle motions on roads and highways obey two different regimes. First, stationary regimes, where inter-vehicular spacing, acceleration and deceleration rates (among other parameters), match specified bounds. This, combined with N2N communications, has led to the concept of cohorts, where safety is not at stake provided that no violation of bounds occurs. Second, transitory regimes, where some of these bounds are violated (e.g., sudden braking – the "brick wall" paradigm), or where vehicles undertake risk-prone maneuvers such as lane changes, resulting into SC scenarios. Reasoning about SC scenarios has led to the concept of groups. Cohorts and groups have been introduced in [6].

3.3.2. Cohorts, N2N communications, and safety in the presence of telemetry failures

In [6] we show how periodic N2N beaconing serves to withstand failures of directional telemetry devices. Worst-case bounds on safe inter-vehicular spacing are established analytically (simulations cannot be used for establishing worst-case bounds). A result of practical interest is the ability to answer the following question: "vehicles move at high speed in a cohort formation; if in a platoon formation, spacing would be in the order of 3 m; what is the additional safe spacing in a cohort?" With a N2N beaconing period in the range of 100-200 ms, the additional spacing is much less than 1 m. Failure of a N2N communication link translates into a cohort split, one of the vehicles impaired becoming the tail of a cohort, and its (impaired) follower becoming the head of a newly formed cohort. The number of vehicles in a cohort has an upper bound, and the inter-cohort spacing has a lower bound.

3.3.3. Groups, cohorts, and fast reliable V2V Xcasting in the presence of message losses

Demonstrating safety involves establishing strict timeliness ("real-time") properties under worst-case conditions (traffic density, failure rates, radio interference ranges). As regards V2V message passing, this requirement translates into two major problems:

- TBD: time-bounded delivery of V2V messages exchanged among vehicles that undertake SC maneuvers, despite high message loss ratios.
- TBA: time-bounded access to a radio channel in open ad hoc, highly mobile, networks of vehicles, some vehicles undertaking SC maneuvers, despite high contention.

Groups and cohorts have proved to be essential constructs for devising a solution for problem TBD. Vehicles involved in a SC scenario form a group where a 3-way handshake is unfolded so as to reach an agreement regarding roles and adjusted motions. A 3-way handshake consists in 3 rounds of V2V Xcasting of SC messages, round 1 being a Geocast, round 2 being a Convergecast, and round 3 being a Multicast. Worst-case time bound for completing a 3-way handshake successfully is in the order of 200 ms, under worst-case conditions. It is well known that message losses are the dominant cause of failures in mobile wireless networks, which raises the following problem with the Xcasting of SC messages. If acknowledgments are not used, it is impossible to predict probabilities for successful deliveries, which is antagonistic with demonstrating safety. Asking for acknowledgments is a non solution. Firstly, by definition, vehicles that are to be reached by a Geocast are unknown to a sender. How can a sender know which acknowledgments to wait for? Secondly, repeating a SC message that has been lost on a radio channel does not necessarily increases chances of successful delivery. Indeed, radio interferences (causing the first transmission loss) may well last longer than 200 ms (or seconds). To be realistic, one is led to consider a novel and extremely powerful (adversary) failure model (denoted Ω), namely the restricted unbounded omission model, whereby messages meant to circulate on f out of n radio links are "erased" by the adversary (the same f links), ad infinitum. Moreover, we have assumed message loss ratios f/n as high as $2/3$. This is the setting we have considered in [59], where we present a solution for the fast (less than 200 ms) reliable (in the presence of Ω) multipoint communications problem TBD. The solution consists in a suite of Xcast protocols (the Zebra suite) and proxy sets built out of cohorts. Analytical expressions are given for the worst-case time bounds for each of the Zebra protocols.

Surprisingly, while not being originally devised to that end, it turns out that cohorts and groups are essential cornerstones for solving open problem TBA.

3.4. Probabilistic modeling for large transportation systems

Participants: Guy Fayolle, Cyril Furtlehner, Arnaud de La Fortelle, Jean-Marc Lasgouttes.

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 [4], 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.

3.4.1. 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 [60];
- build macroscopic variables that measure the overall state of the underlying graph, in order to improve the local propagation of information [58];
- make the underlying model as sparse as possible, in order to improve BP convergence and quality [40].

3.4.2. 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 [57] 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.

3.4.3. 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 [3]):

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

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 [55], 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

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

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.

3.4.4. Discrete-event simulation for urban mobility

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

- one for collective taxis, a public transportation system with a service quality provided will be comparable with that of conventional taxis (system operating with or without reservations, door-to-door services, well adapted itineraries following the current demand, controlling detours and waits, etc.), and with fares set at rates affordable by almost everyone, simply by utilizing previously wasted vehicle capacity;
- the second for 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.

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

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, new transportation systems 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 into 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 (i.e. in La Rochelle). 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 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. All our developments and demonstrations on our cybercars (cycabs, Yamaha AGV and new Cybus platforms) are using the RTMaps SDK development platform. 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 HIPERCOM 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. New Software

The following software items have been submitted very recently to the APP; some already have IDDN references. Some of these are under improvement and other have already been transferred to industrial partners.

- **SODA**: This software has been developed in the context of the French ABV [3] project. This package contains the functions that are necessary to automate the vehicle navigation in its secured lane. This software has been purchased by a private partner (Valeo Group) aiming at developing its own automated vehicle.
- **MELOSYM**: this is the latest laser based Hierarchical ML-SLAM algorithm developed by RITS. It contains all the functions needed to perform the vehicle localization and the mapping of the environment. Windows compatible, it was initially developed under the ^{RT}MAPS platform but the version includes a standalone version. This software has been evaluated by a private partner aiming at developing its own automated vehicle for indoor applications. It is currently evaluated by another private partner aiming at implementing our solution on its outdoor automated shuttles.
- **STEREOLOC**: this is the package performing stereovision based localization and mapping. It performs semi-dense mapping of outdoor large environments and provides real-time estimates of the vehicle position. The software was tested and validated using ^{RT}MAPS like databases as well as the KITTI benchmark.

5.1.1. DOLAR

This software performs real-time obstacle detection and tracking using laser data scanned with one or several laser sensors with different geometric configurations. Obstacle detection is based on laser data segmentation while obstacle tracking uses PHD-based filtering techniques. The software is currently evaluated by a private partner aiming at implementing our solution on its outdoor automated unmanned vehicles.

5.1.2. FEMOT

FEMOT (Fuzzy Embedded MOTor) is an experimental motor for implementing fuzzy logic controllers, including all the fuzzy stages (fuzzification, inference, and defuzzification). This library has been compiled in Microsoft Visual (MVS) Studio and RTMaps. The proposed library is modular and adaptable to different situations and scenarios, especially for autonomous driving applications. FEMOT allows the development of the fuzzy rules to be written as sentences in an almost natural language. It allows the user to define variables and their fuzzy rules and to join them with other variables in rules to yield crisp signals for the controllers. The APP deposit was delivered May 2014. The Properties defined in FEMOT shows the number of inputs, outputs and fuzzy rules that the controller needs.
This software is used for the arbitration and control for fully automated functions. The behaviour of a human driver can be emulated with this technique. First simulations are showing promising results, and the library allows an easy adaptation in decision marking situations.

5.1.3. V2Provue

It is a software developed for the Vehicle-to-Pedestrian (V2P) communications, risk calculation, and alarming pedestrians of collision risk [34]. 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.

[3] Automatisation Basse Vitesse

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.

6. New Results

6.1. Highlights of the Year

YoGoKo [4], a startup company of RITS, was founded in 2014 by employees from three research institutes: Mines ParisTech, Telecom Bretagne and Inria. YoGoKo makes use of softwares developed in teams specialized in Internet technologies. RSM (Telecom Bretagne), CAOR (Mines ParisTech) and RITS (Inria) are research teams have been working together since 2006 on innovative communication solutions applied to Intelligent Transportation Systems. They contributed to several collaborative R& D projects related to ITS (CVIS, ITSSv6, GeoNet, DriveC2X, SCORE@F, . . .). In 2012, these laboratories engaged together into the development of a common demonstration platform which comprises connected vehicles (fleet of conventional vehicles from Mines ParisTech and fleet of autonomous vehicles from Inria), roadside equipments and cloud-based services. YoGoKo demonstration platform was finally revealed on Feb. 11 th 2014 during the Mobility2.0 event organized by the French Ministry of Transport. This successful demonstation and the extremely warmfull feedack gained at this occasion triggered the launch of YoGoKo as a company. YoGoKo develops innovative communication solutions for fixed and mobile multi-connected devices. The objective is to maintain secure and continuous connectivity with their communication peers, either in their immediate environment or a remote location (control centers or Internet hosts).

6.2. Development of a Platform for Arbitration and Sharing Control Applications

Participants: David Gonzalez Bautista, Vicente Milanes Montero, Fawzi Nashashibi, Joshué Pérez Rastelli.

RITS have been leading the activities in the framework DESERVE project, related to arbitration and control sharing in automated vehicle. The analysis of existing vehicle control (and arbitration) solutions, considering the driver in the control loop is the main challenge of this work. We consider sharing control techniques and different solutions in the task management. New standard in the taxonomy of autonomous driving, as the SAE J3016, are considered in the arbitration and sharing control design. The aim is to allow the applications to make effective use of the driver model to improve the acceptability of the functions developed, as: Driver Drowsiness and Driver intention.

The arbitration module is defined into the IWI manager of the DESERVE abstraction. This component determines the action to be taken by the driver. The Driver Assistance Systems involve two main decision makers: the driver and the automated systems. This module considers different inputs, as follow: the Trajectory planning, Driver stage, Risk Management. The output determines who should take the control of the vehicle and the level of arbitration (or disposal) of the driver in different situations. This work uses the software tool FEMOT (Fuzzy Embedded MOTor). More detail can be found in [46].

6.3. Optimal Energy Consumption for Urban Electric Vehicles

Participants: David Gonzalez Bautista, Vicente Milanes Montero, Joshué Pérez Rastelli.

[4] http://www.yogoko.fr/

RITS team is specially supporting two kinds of transport systems: electric mass-produced vehicles and Cybernetic Transport Systems (also electrically propelled) for urban environments. One of the key factors for getting a higher market penetration of such vehicles is their autonomy. Having this in mind, the goal of this research line is to create optimal algorithms for improving electric vehicles' battery life. It covers two specific arenas: 1) determining optimal path planning in terms of energy saving (proposed for 2015); and 2) once the route is determined, generating an adequate speed profile for covering that path. The latter objective has been investigated during 2014. Energetic model of vehicle dynamics have been developed in order to determine the lowest consumption for each of the route segments. It has permitted to develop speed references between segments combined with polynomial transition functions for the whole route to be covered. Additionally, a high-level fuzzy controller has been also designed to make the system robust to low-level failures on reference tracking. Up to 20% of battery savings have been obtained in the first tests with the proposed algorithm, showing the proper performance of the system. Additional work for adding more information from the environment as other road agents or potential unexpected diversion on the road will be also investigated during 2015 for adapting the algorithm to more realistic environments. This work has been also developed in cooperation with MSc students from Simon Bolivar University (Venezuela) and AGMUS University System (Puerto Rico, US).

6.4. Perception and control strategies for autonomous docking for electric freight vehicles

Participants: Joshué Pérez Rastelli, Evangeline Pollard, Vicente Milanes Montero, Fawzi Nashashibi.

The freight transportation is defined as the process of carrying goods and persons from one given point to another. Recently, urban freight transportations have been used as an alternative for the delivery problems of goods in urban environments. The present work is developed in the framework of the Furbot project (FP7), which presents a solution for future urban freight transport with new light-duty architecture with full-electrical vehicles. We focused on the onboard intelligent units, dedicated to improve the perception and control systems onboard the vehicle for the parking/docking process, considering loading and unloading phases of the freight transport procedure. Two lasers were placed on the vehicle in order to localize it with respect to the freight box. A polynomial approach is used for the trajectory planning for a smooth docking maneuver. This proposal was first tested in a 3D simulator, and then validated in a real platform. The results presented in [45] shows the good behavior of our approach, which will be implemented in the FURBOT vehicle at the end of the project.

6.5. Description and technical specification of Cybernetic Transportation Systems: an urban transportation concept

Participants: Joshué Pérez Rastelli, Vicente Milanes Montero, David Gonzalez Bautista, Armand Yvet, Fawzi Nashashibi.

The Cybernetic Transportation Systems (CTS) is an urban transportation concept based on two ideas: the car sharing and the automation of dedicated systems with door-to-door capabilities. In the last decade, many European projects have been developed in this context, where some of the most important are: Cybercars, Cybercars II, CyberMove, CyberC3 and CityMobil, where a first fleet of vehicles were developed by different companies and research centers around Europe, Asia and America. Considering these previous works, the FP7 project Citymobil II is in progress since 2012. Its goal is to solve some of the limitations found so far, including the definition of the legal framework for autonomous vehicles on urban environment. Much of the perception and control software has been improved in the Inria's Cybus. New guidance functionalities were developed, mainly with the introduction of stereovision-based SLAM, and Bezier curve in path planning generation. In this work, automated CTSs involved are used in the different showcases in European cities. This work presents the different improvements, adaptation and instrumentation of the vehicle used. Results show tests in our facilities at Inria-Rocquencourt (France) and the first showcase at León (Spain).

6.6. Evidential Simultaneous Localization And Mapping to describe intersection

Participants: Guillaume Trehard, Evangeline Pollard, Fawzi Nashashibi.

Intersections management remains a tough challenge to tackle before reaching autonomous driving in urban environment. The field of view of the vehicle is often limited by several sensors occlusions, the shapes and priority rules can significantly differ from an intersection to another and road users from pedestrian to public transports have to cross each other in sometimes complex manners.
In this context, mapping the surrounding of the vehicle and being able to estimate its position regarding a global database is crucial.
A solution of *Simultaneous Localization And Mapping* (SLAM) have then been proposed based on a 2D LIDAR sensor [49]. In the rich SLAM literature, the originality of this method lays in the use of Transferable Belief Model (TBM) framework instead of a classic probabilistic one. If this proposition was just a change of mathematical context, TBM led to an explicit management of not-known and conflict information so that its application to SLAM algorithm appeared to be really effective and robust in crowded situations. The proposed solution indeed enables to provide a map of the *static* environment crossed by the vehicle and to detect mobile obstacles in the same process and without additional tracking system.
This *Evidential SLAM* have then been tested with success over different sequences and laser set-ups extracted from the KITTI database [50].
Researches are now focused on the fusion between this SLAM solution and a Global Navigation Satellite System (GNSS) receiver to enable a map-matching on a database such as Open Street Map.

6.7. Laser based road obstacle classification

Participants: Pierre Merdrignac, Evangeline Pollard, Oyunchimeg Shagdar, Fawzi Nashashibi.

Vehicle and pedestrian collisions often result in fatality to the vulnerable road users, indicating a strong need of technologies to protect such vulnerable road users. Laser sensors have been extensively used for moving obstacles detection and tracking. Laser impacts are produced by reflection on these obstacles which suggest that more information is available for their classification. This year, we introduced the design of a new system for road obstacles classification that is divided in four parts: definition of geometric features, selection of the best features, multi-class *segment* classification based on Support Vector Machines (SVM) and *track* classification from SVM decision values integration. Our study discloses a sorted list of useful features for road obstacle recognition that were used to construct a multi-class SVM. Finally, we tested our system with 2D and 3D laser sequences and shown that it can successfully estimate the class of some road obstacles around the vehicle.

6.8. Deformable Parts Model based approach for on-road object detection and classification

Participants: Wei-Lin Ku, Evangeline Pollard, Anne Verroust-Blondet.

An important perception problem for driver assistance is the detection of the road obstacles and the recognition of their type (cars, cycles, pedestrians). This year, we tackled the on-road objects detection problem by testing and improving vision-based methods. We proposed and compared several DPM based strategies for on-road object detection and classification, laying emphasis on the problem of detecting smaller/occluded cars and pedestrians. A hybrid approach combining detection from small/large models trained with different clustering method has been introduced to boost the detection performance in both Average Precision and Maximum Recall in every difficulty level. Finally, a geometry reasoning based filtering has been employed to eliminate false alarms while preserving a great deal amount of true positives. Experimental results showed the improvement both in hybrid and geometry reasoning approaches. Most of this work has been done during the internship of Wei-Lin Ku.

6.9. Saturated Feedback Control for an Automated Parallel Parking Assist System

Participants: Mohamed Marouf, Fawzi Nashashibi, Plamen Petrov.

In 2014, RITS extended its activities in the design and development of specific automated maneuvres. One particular interesting topic is the parallel parking problem of automatic front-wheel steering vehicles. The problem of stabilizing the vehicle at desired position and orientation is seen as an extension of the tracking problem. A saturated control has been proposed which achieves quick steering of the system near the desired position of the parking spot with desired orientation and can be successfully used in solving parking problems. In addition, in order to obtain larger area of the starting positions of the vehicle with respect to the parking spot for the first reverse maneuver of the parallel parking, an approach using saturated control with two different levels of saturation is proposed. The vehicle can be automatically parked by using one or multiple maneuvers, depending on the size of the parking spot. Simulation results were presented first in [44] to confirm the effectiveness of the proposed control schemes. New results extended to all types of parking lots shapes were recently obtained using this approach. The validation has been performed with real vehicles in the Inria test site.

6.10. Vehicle to pedestrian communications

Participants: Pierre Merdrignac, Oyunchimeg Shagdar, Evangeline Pollard, Fawzi Nashashibi.

Vehicle and pedestrian collisions often result in fatality and serious injury to the vulnerable road users. While vehicle to vehicle (V2V) communications have taken much attention in the academic and industrial sectors, very limited effort has been made for vehicle to pedestrian communications. Unlike the V2V cases, where antennas are often installed on the vehicle rooftop, pedestrian's handheld device can be carried in such a way e.g, in a bag or in a pocket, which results in poor and unpredictable communications quality. In this work, we seek to an answer to the question whether the Wi-Fi-based V2P communications meet the requirements of the pedestrian safety. This year, we studied the performances of the V2P communications especially for the receive signal strength, packet inter-arrival time, and message delivery ratio. Moreover, in order to demonstrate the feasibility of pedestrian safety supported by the V2P communications, we developed a software tool, V2ProVu, which has the functionalities of Wi-Fi based V2P communications, collision risk calculations, and hazard alarming. This work has been published in [34].

6.11. Multicast Communications for Cooperative Vehicular Systems

Participants: Ines Ben Jemaa, Oyunchimeg Shagdar, Arnaud de La Fortelle.

Vehicular communications allow emerging new multicast applications such as fleet management and point of interest (POI). Both applications require Internet-to-vehicle multicasting. These approaches could not be applied to vehicular networks (VANET) due to their dynamic and distributed nature. In order to enable such multicasting, our work deals with two aspects. First, reachability of the moving vehicles to the multicast service and second, multicast message dissemination in VANET. We propose a simplified approach that extends Mobile IP and Proxy Mobile IP. This approach aims at optimizing message exchange between vehicles and entities responsible for managing their mobility in Internet. To study the dissemination mechanisms that are suitable for fleet management applications, we propose to revisit traditional multicast routing techniques that rely on a tree structure. For this purpose, we study their application to vehicular networks. In particular, as vehicular networks are known to have changing topology, we study the application of Multicast Adhoc On Demand Vector, MAODV. We propose then Motion-MAODV [35] [16] an improved version of MAODV that aims at enhancing routes built by MAODV in vehicular networks and guarantee longer route lifetime. Finally, to enable geographic dissemination as required by POI applications, we propose the routing protocol Melody that provides a geocast dissemination in urban environments. Through simulations, Melody ensures more reliable and efficient packet delivery to a given geographic area compared to traditional geo-broadcasting schemes in highly dense scenarios.

6.12. Visible Light Communication for ITS applications

Participants: Mohammad Abu Alhoul, Oyunchimeg Shagdar, Fawzi Nashashibi.

Visible Light Communication (VLC) technology is an efficient supportive communication technology for platooning applications over short inter-vehicle distances. After implementing a complete VLC channel model, which enabling precise calculations of the optical link performance for different intervehicle distances presented in our previous work [1], this year we have studied and proposed tracking-alike method aiming at ensuring the continuity of the Line-of-Sight (LOS) and extending the Field of view (FOV) limitations. This method benefits from the exchanged information about the relative directional position of each member of the platoon, together with front and rear facing directions of each vehicle, which can be very useful data for building a reliable smooth geometrical-based compensation method. The simulation results showed that trajectory influences on the optical incidence and irradiance angles can be compensated efficiently and without deploying any tracking method.

6.13. Study on the IEEE 802.11p Channel Congestion Problem

Participant: Oyunchimeg Shagdar.

The IEEE 802.11p is a standardized WiFi technology dedicated to V2X communications for especially road safety and efficiency applications. It is expected that vehicles periodically broadcast messages to announce their existences using the IEEE 802.11p frequency channel. However, because the IEEE 802.11p has a limited wireless bandwidth, in dense traffic conditions the V2V communications performances are poor, failing to satisfy the application requirements. In RITS, we study the issue and develop congestion control algorithms. In 2014, we studied the reactive distributed congestion control algorithm, proposed by the European Telecommunications Standards Institute (ETSI), and showed that the algorithm creates unstable resource utilization, which can cause the reactive Distributed Congestion Control (DCC) to perform worse than non-DCC systems. We proposed an asynchronous algorithm, where DCC control is made in such a way that channel resource is used in an asynchronous manner by the different stations. Our results show that the asynchronous DCC approach outperforms both the non-DCC and reactive DCC mechanisms. The work has been reported at a ETSI meeting in December 18, 2014 [54].

6.14. Study on V2V Communications and Emergent Behavior of Heuristically-Driven Intelligent Vehicles

Participant: Oyunchimeg Shagdar.

The automated cooperative driving applications require efforts on multiple research domains including robotics, artificial intelligence, and communications to build a safe and intelligent collective driving behavior. While some studies show the potentials of the V2V communications for safer and smoother automated driving, it is still not clear if the standardized technologies can meet the strict requirements of the automated driving applications. More importantly, if the decisions for individual vehicles' control are based on the V2V communications, the communications performance must largely affect the ”quality” of the collective behavior. Motivated by this, we study the inter-dependencies between communications and collective automated driving behavior. In our study [43] we combine different V2V communication modes with different dynamic path-finding heuristics, over a population of several hundreds of intelligent vehicles, to observe convergence towards stable traffic. The various traffic stability levels are compared in order to exhibit most efficient combinations of communication modes and path-finding heuristics.

6.15. Distributed Agreement and String Control in Intelligent Vehicular Networks (IVNs)

Participant: Gérard Le Lann.

IVNs are composed of automated (autonomous and communicating) vehicles, ranging from pre-planned platoons to ad hoc vehicular networks (VANETs). Agreement problems in the presence of concurrency and failures are not well investigated yet in IVNs. We have examined a specific class of such problems, those arising in string formations. Regarding string membership (vehicles leaving or joining a string), with few exceptions, safety issues have been addressed so far assuming that (1) no more than 1 insertion operation would be performed at any given time or, (2) every vehicle decides unilaterally, i.e. undertakes a maneuver after having activated some signal, leaving to surrounding vehicles the responsibility of inferring intended maneuvers. Assumption (1) is not realistic. There are numerous risk-prone scenarios where a posteriori reactive approaches (assumption (2)) may fail. Therefore the need for investigating proactive approaches, where vehicles (1) are made aware of intended impending maneuvers, (2) agree on which maneuvers can be safely undertaken, prior to performing physical maneuvers. It follows that a solution to numerous string control problems consists of a pair (A,Φ), where A stands for a distributed agreement algorithm which achieves global coordination in the presence of failures and concurrency, and Φ stands for control laws drawn from control theory and robotics. Algorithm A is run prior to local activations of Φ.

Our work is based on the cohort construct, which serves to formalize the concept of strings. Velocity Agreement is the generic problem selected. At any time, some number of string/cohort members may propose each a new velocity value. In fine, every vehicle computes a unique new velocity V. Proposed values are propagated via neighbor-to-neighbor (N2N) radio communications. We have devised a solution called the VAgree algorithm. In the presence of up to f failures (on-board systems, N2N message losses), the following properties shall hold:

- Validity: Decision value $V = \Psi$(proposed values).
- Agreement: No two members decide differently.
- Time-Bounded Termination: VAgree terminates at most θ time units.
- Synchronicity: Times at which V is posted to on-board systems are comprised within a small time interval ϵ. Distance traveled during ϵ by the member earliest to post V until the latest member does so is an order of magnitude smaller than vehicle sizes.

The VAgree algorithm is presented in a paper which is under submission.

6.16. Standardization and automated vehicles

Participant: Michel Parent.

Michel Parent has been active over the last 4 years in this group to introduce automated vehicles in the scope of service robots and he contributed actively in the activities of several working groups (WGs). In WG7, he participated in the writing of the document ISO13482 on the safety of service robots. This document has reached the Final Draft for an International Standard level (FDIS) and is now published in English and French. It has already been used by companies to certify some robotics products, including Robosoft in France for automated vehicles. In WG8, Michel Parent participated in the elaboration of standard procedures for the testing of service robots and in particular for automated vehicles. The document CD18646 « Robots and robotic devices — Performance criteria and related test methods for service robots — Part 1: Locomotion for wheeled robots » is in progress.

6.17. Legislation and certification of fully automated road vehicles for urban public transport

Participant: Michel Parent.

An important research area of automated road vehicles and one of the focuses of the CityMobil2 Project is to look at the legislation and certification of fully automated road vehicles for urban public transport (the cybercars). This part of the research was done essentially by Michel Parent in 2014 and gave birth to several CityMobil2 deliverables.

One of the tasks was to identify the current legislation in France and the organizations involved in the changes for this legislation. Several meetings were therefore organized at the French level with key persons from the Ministry of Transport, the Ministry of Interior (responsible for the road legislation) and their services (in particular the SRMTG in charge of certifying the guided transport systems). These meetings were essential in obtaining the authorization to operate the cybercars for the demonstration in La Rochelle. At the European level, a meeting was organized in May 2014 with representatives of 12 of the European countries (mostly those involved directly with CityMobil2 or with automated vehicles R&D).

Another task was to propose a certification methodology for automated road transport systems. For this task, a careful analysis of the test site in La Rochelle was conducted and led to a number of use cases. Key elements were defined to perform the risk analysis. Many hazards were identified but the most important ones are the behavior of pedestrian and cyclists. For the analysis, two key variables were defined: the minimum mobile object detection distance (MMODD) and the maximum mobile object speed (MMOS). For each use case, a combination of these 2 variable lead to a maximum vehicle speed in order to reach an acceptable risk evaluated as a combination of severity and probability.

In order to verify the proper behavior of the vehicle itself (lane tracking, obstacle avoidance, comfort,...), a number of standard tests have also been defined and are now proposed at the International level (ISO standards).

6.18. Belief propagation inference for traffic prediction

Participants: Cyril Furtlehner, Jean-Marc Lasgouttes.

This work [60] 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.

These studies have been done in particular in the framework of the projects Travesti and Pumas.

This year, the work about the theoretical aspects of encoding real valued variables into a binary Ising model has been under review for a Journal and has been largely revised in the process.

6.19. Sparse covariance inverse estimate for Gaussian Markov Random Field

Participants: Cyril Furtlehner, Jean-Marc Lasgouttes.

We investigate the problem of Gaussian Markov random field selection under a non-analytic constraint: the estimated models must be compatible with a fast inference algorithm, namely the Gaussian belief propagation algorithm. To address this question, we introduce the ☆-IPS framework, based on iterative proportional scaling, which incrementally selects candidate links in a greedy manner. Besides its intrinsic sparsity-inducing ability, this algorithm is flexible enough to incorporate various spectral constraints, like e.g. walk summability, and topological constraints, like short loops avoidance. Experimental tests on various datasets, including traffic data from San Francisco Bay Area, indicate that this approach can deliver, with reasonable computational cost, a broad range of efficient inference models, which are not accessible through penalization with traditional sparsity-inducing norms.

This work has been presented at ECML/PKDD 2014 [40]. The code for ☆-IPS has been made available at https://who.rocq.inria.fr/Jean-Marc.Lasgouttes/star-ips/.

6.20. Herding behavior in a social game

Participants: Guy Fayolle, Jean-Marc Lasgouttes.

The system *Ma Micro Planète* belongs to the so-called *Massively Multi-Player online Role Playing game* (MMORPG), its main goal being to incite users to have a sustainable mobility. Two objectives have been pursued.

- Construct an experimental platform to collect data in order to prompt actors of the mobility to share information (open data system).
- See how various mechanisms of a game having an additive effect could modify the transportation requests.

At the heart of the game are community-driven *points of interest* (POIs), or *sites*, which have a score that depends on the players activity. The aim of this work is to understand the dynamics of the underlying stochastic process. We analyze in detail its stationary regime in the thermodynamic limit, when the number of players tends to infinity. In particular, for some classes of input sequences and selection policies, we provide necessary and sufficient conditions for the existence of a complete meanfield-like measure, showing off an interesting *condensation* phenomenon.

The work has been published this year in *Queueing Systems* [20].

6.21. Properties of random walks in orthants

Participant: Guy Fayolle.

We pursued works initiated these last years in several directions.

6.21.1. Explicit criterion for the finiteness of the group in the quarter plane

In the book [3], original methods were proposed to determine the invariant measure of random walks in the quarter plane with small jumps, 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 in [3] for the solution to be rational or algebraic. When the underlying algebraic curve is of genus 1, we propose, in collaboration with R. Iasnogorodski (St-Petersbourg, Russia), a concrete criterion ensuring the finiteness of the group. It turns out that this criterion is always tantamount to the cancellation of a single constant, which can be expressed as the determinant of a matrix of order 3 or 4, and depends in a polynomial way on the coefficients of the walk [55].

6.21.2. About a possible analytic approach for walks with arbitrary big jumps in $\mathbb{Z}_+^2$

The article [21], achieved in collaboration with K. Raschel (CNRS and University F. Rabelais, Tours) considers random walks with arbitrary big jumps. For that class of models, we announce a possible extension of the analytic approach proposed in [3], initially valid for walks with small steps in the quarter plane. New technical challenges arise, most of them being tackled in the framework of generalized boundary value problems on compact Riemann surfaces.

6.21.3. Correction of papers

Guy Fayolle found important errors in several articles dealing with models involving random walks in $\mathbb{Z}_+^2$. This is the object of the letter to the editors [19]. The concerned authors have provided new correct versions of their studies.

6.21.4. Communication networks with harvesting energy supply

In collaboration with S. Foss (Heriot-Watt University, Edinburgh), we started to analyze stability and performance of a number of models of parallel queues with multiple access and individual energy supplies. Energy limitation in general decreases the stability region, but also may increase it for specific parameter regions. The most difficult and intriguing cases arise when the input rates of requests and of energy items are close. Preliminary models of physical interest involve random walks in $\mathbb{Z}_+^4$.

6.22. Global optimization for online resource allocation

Participant: Jean-Marc Lasgouttes.

As part of the Mobility 2.0 FP7 project, we have considered the possibility to allocate charging stations to Full Electric Vehicle (FEV) users in a way that, instead of merely minimizing their travel time, tries to improve the travel time for the whole community.

The aim of the global optimization algorithm is to pursue the minimization of the mean squared travel time encountered by each user. Our setting can be seen as a resource allocation problem, known as the "Transportation Problem" in Operational Research literature. It is solvable using several algorithms, among which the simplex algorithm. Unfortunately, these algorithms are not usable here for two reasons:

- The allocation of slots to the users is done online, when the user does a request. It is not possible to wait until all the users are known before doing the allocation;
- The complexity of these algorithms is very high, especially since, due to the effect of range limitations, each request has different characteristics.

We therefore present here a simplified approach, which should be fast enough to scale for large systems. The principle of the algorithm is to penalize the cost for the user with an approximation of the extra cost incurred to future users who compete for the same resource (a charging or parking slot). Since the implications can be intricate, we only consider a first order effect.

Our work in the Mobility 2.0 project has been briefly described in [37].

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. Valeo financed the PhD thesis of G. Trehard under the framework of Valeo internal project *"V50"* and is currently a major financing partner of the "GAT" international Chaire / JointLab. Technology transfer is also a major collaboration topic between RITS and Valeo.
- GAT JointLab: Inria is a main partner of this Joint Lab which is composed of Valeo, SAFRAN, Peugeot-Citroën, Inria, Armines and IFSTTAR. GAT will focus on the development of Automated driving architectures for implementation on real prototypes equipped with near-to-market sensors provided by the industrial partners.
- AKKA Technologies: a strong partnership was born as a result of Link & Go project funded by the Yvelines Department CG78. The Link & Go has become a common platform for development between Inria and AKKA. These two institutions are now partners in several research projects and established a roadmap for joint developments around the automatic full-by-wire driving.
- ROBOSOFT – EasyMile: Robosoft is a spin-off of Inria created in 1985. Partners in several national and European research programs, RITS and Robosoft share the same vision on the automated urban transportation needs and modalities. They coped on the design and development of the Cycab and are currently collaborating – together with EZ Mile – on the development of on-demand automated transportation based on automated shuttles; this includes technology transfer especially in laser-based navigation systems.
- *YAMAHA Motor Company (YMC)*: a MoU was signed in 2012 between YMC and RITS giving the two parties the framework to work on the *New generation of AGV*. The previous similar cooperation (2000-2010) led to a 750 000 Euros financing program that allowed the development of several AGV platforms. The new agreement settles the basis of more advanced collaboration more focused on machine intelligence and on the design of innovative electric AGV dedicated to mass transportation in urban areas. The EU-CityMobil-2 project is an ideal opportunity to maintain technical exchanges within the cooperation.

- AXTER Automation: RITS has signed a MoU with AXTER Technologies for the cooperation on the autonomous navigation in indoor environments for automated industrial vehicles.
- YoGoKo: This is the newly created spin-off of RITS team. It has been created by Thierry Ernst, previous researcher of RITS and the initiator of the telecommunications activities in the team. YoGoKo is specialized in the design and development of V2X telecommunication architectures and software based on recent IETF internet protocols (e.g., IPv6) and cooperative ITS norms of ISO/CEN/ETSI. RITS is equipping its mobile prototypes with YoGoKo's products and they are solid partners in French research programs.

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.

8.1.2. 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.

8.1.3. 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 Pierre Merdrignac, Younes Bouchaala, Fernando Garrido Carpio and Zayed Alsayed.

8.2. European Initiatives

8.2.1. FP7 & H2020 Projects

8.2.1.1. CATS

Type: FP7

Instrument: Specific Targeted Research Project

Duration: January 2010 - December 2014

Coordinator: Lohr Industrie (France)

Partner: Inria (France), CTL (Italy), EPFL (Switzerland), TECHNION (Israel), GEA (Switzerland), ERT (France), and the cities of Formello (Italy), Strasbourg (France) and Ploiesti (Romania).

Inria contact: Michel Parent

Abstract: CATS' aim is the full development and experimentation of a new urban transport service based on a new generation of vehicle. Its major innovation is the utilization of a single type of vehicle for two different uses: individual use or semi collective transport. This new transport service is aimed at filling the gap between public mass transport and private individual vehicles.

See also: http://www.cats-project.org

8.2.1.2. FURBOT

Type: FP7

Instrument: Specific Targeted Research Project

Duration: November 2011 - February 2015

Coordinator: Genova University (Italy

Partner: Bremach (Italy), ZTS (Slovakia), Universite di Pisa (Italy), Persico (Italy), Mazel (Spain), TCB (Portugal), Inria (France).

Inria contact: Fawzi Nashashibi

Abstract: The project proposes novel concept architectures of light-duty, full-electrical vehicles for efficient sustainable urban freight transport and will develop FURBOT, a vehicle prototype, to factually demonstrate the performance expected.

8.2.1.3. CityMobil2

Type: COOPERATION (TRANSPORTS)

Instrument: Large-scale integrating project

Duration: September 2012 - August 2016

Coordinator: University of Rome La Sapienza, CTL (Italy)

Partner: Inria (France), DLR (germany), GEA Chanard (Switzerland), POLIS (Belgium), ERT (Belgium), EPFL (Switzerland),...(45 partners!)

Inria contact: Fawzi Nashashibi

Abstract: The CityMobil2 goal is to address and to remove three barriers to the deployment of automated road vehicles: the implementation framework, the legal framework and the unknown wider economic effect. CityMobil2 features 12 cities which will revise their mobility plans and adopt wherever they will prove effective automated transport systems. Then CityMobil2 will select the best 5 cases (among the 12 cities) to organize demonstrators. The project will procure two sets of automated vehicles and deliver them to the five most motivated cities for a 6 to 8 months demonstration in each city. CityMobil2 will establish a workgroup that will deliver a proposal for a European Directive to set a common legal framework to certify automated transport systems.

See also: http://www.citymobil2.eu/en/

8.2.1.4. Mobility2.0

Title: Co-operative ITS systems for enhanced electric vehicle mobility

Type: COOPERATION (TRANSPORTS)

Duration: September 2012 - February 2015

Coordinator: Broadbit (Slovakia)

Partner: ETRA (Spain), Barcelona Digital (Spain), ICCS (Greece), MRE (Italy), Armines (France), University of Twente (Netherlands), Privé (Italy), NEC (United Kingdom)

Inria contact: Jean-Marc Lasgouttes

Abstract: Mobility2.0 will develop and test an in-vehicle commuting assistant for FEV mobility, resulting in more reliable and energy-efficient electro-mobility. In order to achieve a maximum impact, Mobility2.0 takes an integrated approach of addressing the main bottlenecks of urban FEV mobility: "range anxiety" related to the limited FEV range, scarcity of parking spaces with public recharging spots, and the congestion of urban roads. Our integrated approach means the application developed by Mobility2.0 will utilize co-operative systems to simultaneously consider these bottlenecks, so that such an optimization can be achieved which still guarantees reliable transportation for each FEV owner. Mobility2.0 will focus on assisting the daily urban commute, which represents the bulk of urban mobility.

See also: http://mobility2.eu/

8.2.1.5. DESERVE

Title: DEvelopment platform for Safe and Efficient dRiVE

Duration: September 2012 - August 2015

Coordinator: VTT (Finland)

Partner: CRF (Italy), Armines (France), CONTINENTAL AUTOMOTIVE FRANCE SAS (France), FICOSA (Italy), Inria (France), TRW (Great Britain), AVL (Austria), BOSCH (Germany), DAIMLER (Germany), VOLVO (Sweden),...(26 partners)

Inria contact: Fawzi Nashashibi

Abstract: To manage the expected increase of function complexity together with the required reduction of costs (fixed and variable) DESERVE will design and build an ARTEMIS Tool Platform based on the standardization of the interfaces, software (SW) reuse, development of common non-competitive SW modules, and easy and safety-compliant integration of standardized hardware (HW) or SW from different suppliers. With innovative design space exploration (DSE) methods system design costs can be reduced by more than 15%. Hence, DESERVE will build an innovation ecosystem for European leadership in ADAS embedded systems, based on the automotive R&D actors, with possible applications in other industrial domains.

See also: http://www.artemis-ju.eu/project/index/view?project=38

8.2.1.6. AutoNet2030

Title: Co-operative Systems in Support of Networked Automated Driving by 2030

Duration: November 2013 – October 2016

Coordinator: Andras KOVACS – BROADBIT (Hungary)

Partner: BROADBIT (Hungary), BASELABS (Germany), CRF (Italy), Armines (France), VOLVO (Sueden), HITACHI EUROPE (France), EPFL (Switzerland), ICCS (Greece), TECHNISCHE UNIVERSITAET DRESDEN (Germany) (9 partners)

Inria contact: Fawzi Nashashibi

Abstract: AutoNet2030 shall develop and test a co-operative automated driving technology, based on a decentralized decision-making strategy which is enabled by mutual information sharing among nearby vehicles. The project is aiming for a 2020-2030 deployment time horizon, taking into account the expected preceding introduction of co-operative communication systems and sensor based lane-keeping/cruise-control technologies. By taking this approach, a strategy can be worked out for the gradual introduction of fully automated driving systems, which makes the best use of the widespread existence of co-operative systems in the near-term and makes the deployment of fully automated driving systems beneficial for all drivers already from its initial stages.

See also: http://www.autonet2030.eu/

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.
- RITS is a full partner of **VRA**: VRA – Vehicle and Road Automation is 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.
- RITS is member of the Working Group on Automation: **iMobility**. This group has been created and is animated by ERTICO ITS Europe. The Automation Working Group was formed under the iMobility Forum, with the initial high level aims of exploring and promoting the potential of highly automated vehicles and applications and working towards the development of a roadmap for the deployment of automated systems.

8.3. International Initiatives

8.3.1. Informal International Partners

In the following we are highlighting only some selected collaborations, partners with whom there are: signed MoU's, researchers exchanges, softwares and hardwares exchanges, scientific close collaboration, etc.

- *NAIST – Japan* The RITS team has a close cooperation with NAIST (Nara institute of Science and Technology), Japan since 2009. Based on this collaboration NAIST and Inria established the MoU agreement to accelerate and strengthen future research collaborations and the exchange of researchers and students (4 Japanese researchers were hosted by IMARA/RITS since 2012).
- *University of Zaragoza – Spain* The team has strong collaborations with University of Zaragoza, Spain, especially the Intelligent Networks and Information Technologies group (INIT) directed by Prof. Francisco J. Martinez Domingues. Professor Martinez and Professor Piedad had a 3 months stay at Inria in summer 2014 during which closer collaborations and joint publications and a workshop co-organization was agreed on.
- CNIT (Consorzio Nazionale Inter-unviversitario per le Telecomunicazioni), Italy, directed by Professor Paolo Pagano, and University of Western Ontario, especially the department of the Electrical & Computer Engineering.
- *SwRI – USA*: Since 2007, a collaboration agreement exists with the Southwest Research Institute (San Antonio, Texas, USA) for the joint development of autonomous vehicle technologies, focusing on the areas of perception, intelligence, command and control, communications, platforms and safety. SwRI is one of the oldest and largest nonprofit applied research and development organizations in the U.S. The partnership conducted joint researches and exchanged intellectual properties to foster rapid technology and system advancements in vehicle autonomy. A joint vehicle demonstration took place in 2009 during the ITS World Congress in London.

- *Shanghai Jiao Tong University (SJTU) – China*: Professor Ming Yang is now leading Department of Automation in SJTU. Previously he has been a Post-doc fellow at Inria (IMARA/RITS team) from 2003 to 2005. Thus he shares RITS research areas and his main research activities are around the development of intelligent Cybercars. Several researchers and graduate students from SJTU were hired by RITS in the past. Both teams are partners of several joint French-Asian collaborative projects (e.g., CityHome, PAMM,...). Prof. Ming Yang Lab, RITS and e-Motion are currently discussing seriously the creation of an Inria International Research Lab., a common lab focusing on the topic of mobile robotics (including Intelligent Vehicles and Assistive Robotics). M. Hao Li, recently awarded PhD from Mines ParisTech under the supervision of Fawzi Nashashibi (RITS), is also a former student of Prof. Yang. He will be helping in the coordination of this new partnership project.
- *MICA LAB – Vietnam*: a growing partnership is under construction with MICA Lab under the co-direction of M. Eric Castelli. Partners in joint French-Asian projects, RITS and MICA lab have submitted an application to the Vietnamese Program 911 to support the financing of a joint PhD thesis.
- Institut du transport avancé du Québec (ITAQ) – Canada ITAQ wishes to conduct a project on the guidance of electric and hybrid semi-autonomous and autonomous applications for off-road vehicles. They want to develop this project in close collaboration with several Quebec companies and universities / colleges in Quebec (University of Sherbrooke-CRVI), France (Inria) and the United States (MIT). ITAQ holds expertise in electric vehicles but wants to develop its capacity for research in robotics, artificial intelligence, autonomous vehicles, etc. For this reason, a partnership is under construction (MoU) with Inria and especially with RITS to identify all the ways in which we could work together closely in order to transfer knowledge and expertise.
- *International Chaire "GAT"*: Inria-RITS, Mines ParisTech, EPFL, Univ. of Berkeley (PATH Program) and Shanghai Jiao Tong Univ. (SJTU) are the academic partners of the international Chaire GAT, funded and supported by: Valeo Group, SAFRAN Group and MPSA Group (Peugeot-Citroën). A recent NDA has been signed recently. This Chaire will promote and fund academic activities related to Ground Automated Transportation and autonomous driving.
- *Technical University of Sophia – Bulgaria*: RITS is conducting a close partnership with the Technical University of Sophia (Department of Mechanical Engineering). Since 2009, Professor Plamen Petrov has been a visiting professor at Inria. He contributed in conducting common advanced researches with RITS researchers in the field of dynamic modeling and adaptive motion control for vehicles and robots. Joint works have been also driven to develop and validate platooning concepts for normal speed driving of automated vehicles. This collaboration will continue with further scientific challenges to tackle especially in the field of vehicle control and motion planning.

8.3.2. Participation In other International Programs

- *STIC-Asia – French-Asian cooperation*: in the context of the Asian-French projects CityHome and PAMM, very close collaboration were driven between Inria's IMARA/RITS and E-Motion project-teams and Asian laboratories such as: NTU (Singapore), Dept. of Computer Science and Electrical Engineering Graduate School of Science and Technology Kumamoto University (Japan), Department of Automation of the Shanghai Jiao Tong University (SJTU University, China) and the Information and Communication Engineering and the Intelligent Systems Research Center at the SungKyunKwan University (SKKU), (Korea). Two cooperation projects were conducted together: CityHome (ended in 2011) and PAMM (ended in 2014). A new collaborative project has been recently accepted under the coordination of F. Nashashibi, head of RITS (SIM-Cities project [5]).
- *ECOS NORD – Simon Bolivar University (Venezuela)*: RITS and University of Simon Bolivar have started an official privileged cooperation under the framework of the ECOS Nord international Program. This program started effectively in 2014 with the expected visit of two researchers and a

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PhD student from each institute to the other institute. Collaborations between our institutions started already in 2012. Since this date, one researcher and 7 engineers (trainees) from SBU made several months stay each at RITS. They all worked in the field of intelligent control.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

- **Prof. Plamen PETROV**: professor at the Technical University of Sofia (Bulgaria). He has been an invited professor at Inria from June to September 2014. Prof. Petrov's visit is the sixth of its kind since 2009. This close collaboration in the area of automatic control has very fruitful results and outcomes. This year's joint research topic dealt with the design and implementation of saturated control for automated parking maneuvers (cf. section 6.9). In validation to 2013 activities, two articles were published in 2014: [28] and [44].
- **Dr. Maria Piedad Garrido Picazo and Dr. Francisco Jose Martinez Dominguez**: assistant professors of the University of Zaragoza, invited from June until September 2014. During their visit, they worked on routing and multicast issues in VANET.

8.4.1.1. Internships

- **Wei Lin Ku**: master student at National Chiao Tung University (Hsinchu, Taiwan). He has been an Inria intership student from April until October 2014. During this period, he studied and developed several DPM based strategies to detect and classify road obstacles (cars, pedestrians,...).
- **Mickaël Bergem, Hugues Thomas, Roxane Delpeyrat, Laurent Laflèche**: 2nd year at ENPC. They had a group project on reactive path planning using potential fields from April to June 2014.
- **Carlos Eduardo Flores Pino, Giampaolo Otero Ridolfi, Luis Guillermo Roldao Jimenez, Jean Carlos Rivera Pabon**: they worked on different methods for improving energy consumption of urban vehicles.
- **Leopoldo Gonzalez Clarembaux**: He was in master 2 at Telecom Paris-Sud (Evry). He developed perception and control strategies for autonomous docking for the electric freight vehicle Furbot. His work was implemented in simulation and on our Cybus platform.

8.4.2. Visits to International Teams

8.4.2.1. Research stays abroad

Guy Fayolle has been invited two weeks (5-19 oct. 2014) at Heriot-Watt University, Edinburgh (Prof. S. Foss, math. dept.).

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific events organisation

9.1.1.1. General chair, scientific chair

Fawzi Nashashibi: co-organiser of the session "Advanced Perception, Localization and Control for Ground Robots" of the International Conference on Control, Automation, Robotics and Vision (ICARCV 2014);

Joshué Pérez Rastelli: co-Chair of the Poster Session IIIB1, Vehicle Environment Perception III of the IEEE Intelligent Vehicles Symposium 2014.

Oyunchimeg Shagdar: co-chair of the International Workshop on vehicular networking and intelligent transportation systems, 2015.

9.1.1.2. Member of the organizing committee

Vicente Milanés: publicity co-chair of the International Conference on Internet of Vehicles 2014.

Michel Parent : organization of a session on "International Connected Vehicle & ITS" at IoT China 2014 Conference (Oct. 28-30, 2014, Shanghai, China)

9.1.1.3. Invited speaker

Guy Fayolle: invited speaker at Heriot-Watt University (Edinburgh), where he presented various aspects of the article [20].

Fawzi Nashashibi: invited speaker at ETSI ITS meeting in at Berlin (February),Franco-British Workshop; keynote speaker at the IROS'14 PPNIV workshop (Chicago, September) and participant of the roundtable “Towards driverless vehicles ?”; participant of the euRobotics-aisbl meeting (Frankfurt); invited speaker at the AHB030 committee of the TRB'14 conference (Washington, January), at Princeton University on "Automated Urban Vehicles" (January 10, 2014, Princeton, USA)

Michel Parent: invited speaker at VDI - Automated Driving 2014 (http://www.vdi-wissensforum.de/en/events/822/event/01KO905/), and at iMobility Challenge Conference (http://www.imobilitychallenge.eu/roadshow/view/id/15)

Oyunchimeg Shagdar: invited speaker at 6th ETSI ITS Workshop 2014, Berlin, March 2014; Seminar “Industrial connected objects, M2M, and Networking” Paris June 2014.

9.1.2. Scientific events selection

9.1.2.1. Member of the conference program committee

Guy Fayolle: program committee member of the regular Int. Symposium on Computer and Information Sciences (Krakow, Poland, oct. 27-28 2014).

Vicente Milanés: member of the IPC in the International Conference on Internet of Vehicles 2014.

Fawzi Nashashibi: technical program committee member of the IEEE Intelligent Vehicles Symposium 2014, of the 13th International Conference on Control, Automation, Robotics and Vision (ICARCV 2014), 2014 IEEE International Conference on Robotics and Automation (ICRA'14), 2014 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS'14).

Joshué Pérez Rastelli: technical program committee member of the IEEE Intelligent Vehicles Symposium 2014.

Oyunchimeg Shagdar: technical program committee member of the IARIA international conference on Emerging network Intelligence (EMERGING), 2014, and of the IEEE Vehicular Technology Conference (VTC 2014).

Anne Verroust-Blondet: technical program committee member of MMEDIA 2014.

9.1.2.2. Reviewer

Guillaume Bresson: 13th International Conference on Control, Automation, Robotics and Vision (ICARCV 2014).

Fawzi Nashashibi: 2014 IEEE Intelligent Transportation Systems Conference, 2014 IEEE Intelligent Vehicles Symposium, International conference on embedded computer Systems: Architecture, MOdeling and Simulatons (SAMOS) XIV, 2014 IEEE International Conference on Robotics and Automation, 2014 IEEE/RSJ International Conference on Intelligent Robots and Systems, 2014 Transportation Research Board, 2014 Intelligent Transportation Systems World Congress.

Michel Parent: IEEE Control Systems Society Conference, IEEE Intelligent Transportation Systems Conference, IFAC World Congress, ITS World Congress, IEEE International Conference on Robotics and Automation (ICRA).

Evangeline Pollard: 13th International Conference on Control, Automation, Robotics and Vision (ICARCV 2014), IEEE Intelligent Vehicles Symposium 2014, IEEE Vehicular Technology Conference (VTC 2014), International IEEE Conference on Intelligent Transportation Systems 2014, IEEE International Conference on Intelligent Robots and Systems 2014.

Joshué Pérez Rastelli: International IEEE Conference on Intelligent Transportation Systems 2014, 2014 IEEE Intelligent Vehicles Symposium, International conference on embedded computer Systems: Architecture, MOdeling and Simulations (SAMOS) XIV.

Oyunchimeg Shagdar:IEEE Vehicular Technology conference (VTC) 2014, International IEEE Conference on Intelligent Transportations Systems (ITSC) 2014, IEEE International conference on connected vehicles and expo (ICCVE) 2014, IEEE Intelligent Vehicles Symposium (IV) 2014, IARIA conference on Emerging network Intelligence (Emerging) 2014.

9.1.3. Journal

9.1.3.1. Member of the editorial board

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

Vicente Milanés: editor-in-chief of *Journal of Computer and Communications*, guest editor Special Issue of *Electronics journal on: Intelligent and Cooperative Vehicles*, associate editor of *Journal of Intelligent Systems*, associate editor of *Journal of Intelligent Transportation and Urban Planning*.

Fawzi Nashashibi: associate editor of the journal *Traitement du signal*.

Joshué Pérez Rastelli: guest-Editor of *IEEE Intelligent Transportation Systems Magazine*, special issue of ELECTRO-MOBILITY, July 2014.

Oyunchimeg Shagdar: associate editor of *Wiley International Journal of Communication Systems*.

9.1.3.2. Reviewer

Guy Fayolle: *PTRF, MPRF, QUESTA, IEEE-IT, JSP, AMS Mathematical Reviews*.

Vicente Milanés: *IEEE Trans. on Intelligent Transportation Systems*.

Fawzi Nashashibi: *Transportation Research Part C, IJRR, IJVAS, IEEE Transactions on Instrumentation and Measurement, IEEE Robotics and Automation Magazine, IEEE Transactions on ITS, IEEE TVT, IEEE Sensors*.

Michel Parent: *Journal of Intelligent Transportation Systems, Transportation Research Board Journal*.

Joshué Pérez Rastelli: *IEEE Robotics and Automation Magazine, Ad Hoc Networks, Mathematics and Computers in Simulation, Information Sciences, Dyna, Revista Bimestral de Ingeniería Multidisciplinar, Robotics, Electronics, IEEE Intelligent Transportation Systems Magazine*.

Evangeline Pollard: *IEEE Transactions on Vehicular Technology (TVT), IEEE Transactions on Aerospace and Electronics Systems (AES)*.

Oyunchimeg Shagdar: *IEEE Transactions on Dependable and Secure computing, IEEE Transactions of Vehicular Technology,IEEE Transactions of Wireless Communications* and *Wiley International Journal of Communications Systems*.

Anne Verroust-Blondet: *Computer & Graphics, International Journal of Information and Communication Technology (IJICT), Journal of Theoretical Biology, Information Sciences*.

9.1.4. Other

Guy Fayolle: member of the working group IFIP WG 7.3 and scientific advisor at the Robotics Laboratory of Mines ParisTech. In this respect, he participates in the contract COVADEC, which is an industrial project (FUI / FEDER 15) involving 8 partners, among which Peugeot, Valeo, Armines and All4tec. The acronym stands for *Conception et Validation des Systèmes Embarqués d'Aide à la Conduite*. Armines will propose a Markov chain analysis aiming at optimizing test generation, taking into account non independent parameters.

Fawzi Nashashibi: scientific advisor at the *Robotics Laboratory of Mines ParisTech*, member of the European working group on Automation of the iMobility Forum, member of the International Committee on Vehicle Highway Automation (AHB30), Topic Leader at the euRobotics (aisbl) robotics network.

Michel Parent: project evaluator for the European Commission and for the Belgium Ministry of Research ("Service Public de la Wallonie DGO6"), French representative for ISO TC184 SC2 (Service Robots), participate as French representative to the ISO TC204 WG14 on the standards for driving assistance and full automatic driving.

Anne Verroust-Blondet: expert for the call "H2020 REFLECTIVE-7-2014" at European Commission, member of the CES 31 committee ("Cultures, patrimoines") for the “Blanc” and “Young researcher” 2014 programmes of the French National Research Agency (ANR), scientific correspondent of the Inria European Partnerships Department for the Inria Paris-Rocquencourt research centre.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

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

Licence: Guillaume Trehard,“C programming language”, L1, 50h, DUT Génie Electrique et Informatique Industrielle, IUT Chartres, France

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

Master: Fawzi Nashashibi, “Programmation C++/OpenGL”, 16h, 2nd year (MAREVA), Mines ParisTech, France.

Master: Fawzi Nashashibi, “Synthèse d’images”, 12h, M2, INT Télécom SudParis, France.

Master: Fawzi Nashashibi, “Détection d’obstacles et fusion multicapteurs”, 4h, M2, INSA de Rouen.

Master: Joshué Pérez Rastelli, “Robotique et contrôle temps réel”, M1, 15 hours, Leonard Da Vinci University -l’ESILV- (La Defense, France), Apr-May 2014.

Master: Joshué Pérez Rastelli, “Standards for Automobiles”, M2, 30 hours, François Rabelais University (Tours, France), François Rabelais University (Tours, France), Feb-March 2014.

Master: Joshué Pérez Rastelli, “Digital environment and road – ITS applications”, M2, 32.5 hours, Feb-March 2014.

Master: Guillaume Trehard, “C++ programming language”, M1, 30h, Paris 8 University, France.

Engineering school: Evangeline Pollard, “Le véhicule autonome”, 1.5 h, Ecole des Ponts ParisTech, Champs-sur-Marne, France, Sept. 2014.

9.2.2. Supervision

PhD : Ines Ben Jemaa, “Dissemination of Geo-localized information in cooperative ITS”, Mines ParisTech, December 17th 2014, Mines ParisTech, supervisor: Arnaud De La Fortelle, co-supervisor Paul Muhlethaler and Oyunchimeg Shagdar

PhD : Esma Elghoul, “Segmentation de maillages 3D par l’exemple”, Télécom ParisTech, September 29th 2014, supervisor: Anne Verroust-Blondet

PhD in progress : Mohammad Abu Alhoul, “Communications par lumière visible et communications radio pour La Conduite Automatique”, Mines ParisTech, supervisor: Fawzi Nashashibi, co-supervisor: Oyunchimeg Shagdar

PhD in progress : Zayed Al-Sayed, “Système de localisation redondant en environnement extérieur ouvert pour véhicule urbain automatique”, Télécom ParisTech, supervisor: Anne Verroust-Blondet, co-supervisor: Guillaume Bresson

PhD in progress : David Gonzalez Bautista, “Contrôle coordonné et planification dynamique des trajectoires pour un système de transport cybernétique en milieu urbain instrumenté”, Mines ParisTech, supervisor: Fawzi Nashashibi, co-supervisor: Joshué Pérez-Rastelli

PhD in progress : Younes Bouchaala, “Utilisation de la communication véhicule-à-véhicule pour l’amélioration de la sécurité sur la route”, Université de Versailles, supervisor: Paul Muhlethaler, co-supervisor: Oyunchimeg Shagdar

PhD in progress : Fernando Garrido,“Optimal trajectory generation for autonomous vehicles in smart cities” , Mines ParisTech, supervisor: Fawzi Nashashibi, co-supervisor: Joshué Pérez-Rastelli

PhD in progress : Pierre Merdrignac, “Développement d’un système coopératif Perception-Communication pour l’amélioration de la sécurité des personnes vulnérables”, supervisor: Fawzi Nashashibi, co-supervisor: Oyunchimeg Shagdar and Evangeline Pollard

PhD in progress : Sofiene Mouine, “Identification d’espèces végétales par une approche de description géométrique locale d’images de feuilles", Télécom ParisTech, supervisor: Anne Verroust-Blondet, co-supervisor: Itheri Yahiaoui

PhD in progress : Guillaume Trehard, “Gestion des intersections pour la conduite urbaine autonome”, Mines ParisTech, supervisor: Fawzi Nashashibi, co-supervisor: Evangeline Pollard

PhD in progress : Zahraa Yasseen, “Garment design and shape description for Sketch-based applications”, Télécom ParisTech, supervisor: Anne Verroust-Blondet, co-supervisor: Ahmad Nasri

9.2.3. Juries

Fawzi Nashashibi was member of the HDR jury of:

- Dominique GRUYER: “Fusion de données: de la perception de l’environnement aux systèmes coopératifs”, Université d’Évry Val d’Essonne, February 28th, 2014.

Fawzi Nashashibi was the President of the jury of:

- Nicole AL-ZOGHBY: “Distributed Data Fusion in VANETs”, Université de Technologie de Compiègne, February 2014.

Fawzi Nashashibi was a jury member of the following PhD students:

- Guillaume BRESSON: “Localisation d’une flotte de véhicules communicants par approche de type SLAM visuel décentralisé”, Université Blaise Pascal – Clermont II, February 2014.
- Maxime BOUCHER: “Quelques contributions en localisation et cartographie simultanées multi-capteurs : application à la réalité augmentée”, Université d’Évry Val d’Essonne, September 2014.
- Laetitia LAMARD: “Approche modulaire pour le suivi temps réel de cibles multi-capteurs pour les applications routières”, Université Blaise Pascal – Clermont II, July 10th, 2014.

9.3. Popularization

Several members of the team have participated in:

- The exhibition Futur-en-Seine (June 12-22 2014).
- The final Demonstration of Link & Go Project: Automated driving functionalities and SLAM, September 2014 at Magny les Hameaux, France.
- Showcase of CityMobil2: Autonomous maneuver in urban scenarios. September 2014, at Leon, Spain.
- Showcase of CATS project: Autonomous functionalities. October 2014, at Ploiesti, Rumania.
- Large-scale demonstration of automated transport of CityMobil2, December 2014, at La Rochelle.

10. Bibliography

Major publications by the team in recent years

[1] M. ABUALHOUL, M. MAROUF, O. SHAGDAR, F. NASHASHIBI. *Platooning Control Using Visible Light Communications: A Feasibility Study*, in "IEEE ITSC 2013", Hague, Netherlands, March 2013, http://hal.inria.fr/hal-00835804

[2] J. J. ANAYA, P. MERDRIGNAC, O. SHAGDAR, F. NASHASHIBI, J. E. NARANJO. *Vehicle to Pedestrian Communications for Protection of Vulnerable road Users*, in "2014 IEEE Intelligent Vehicles Symposium, Dearborn, Michigan, United States", June 2014, pp. 1-6, https://hal.archives-ouvertes.fr/hal-00992759

[3] G. FAYOLLE, R. IASNOGORODSKI, V. A. MALYSHEV. *Random walks in the Quarter Plane*, Applications of Mathematics, Springer-Verlag, 1999, n^{o} 40

[4] 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

[5] M. KAIS, N. HAFEZ, M. PARENT. *An Intelligent Vehicle Architecture for Automated Transportation in Cities*, in "Proceedings of European Control Conference (ECC'01)", Porto, September 2001

[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, B. LEFAUDEUX, E. POLLARD. *Track-to-Track Fusion Using Split Covariance Intersection Filter-Information Matrix Filter (SCIF-IMF) for Vehicle Surrounding Environment Perception*, in "16th International IEEE Conference on Intelligent Transportation Systems", La Hague, Netherlands, October 2013, https://hal.inria.fr/hal-00848058

[8] H. LI, M. TSUKADA, F. NASHASHIBI, M. PARENT. *Multi-Vehicle Cooperative Local Mapping: A Methodology Based on Occupancy Grid Map Merging*, in "IEEE Transactions on Intelligent Transportation Systems", March 2014, vol. 15, n^{o} 5, pp. 2089-2100

[9] V. MILANÉS, S. E. SHLADOVER. *Modeling cooperative and autonomous adaptive cruise control dynamic responses using experimental data*, in "Transportation Research Part C: Emerging Technologies", September 2014, pp. 285–300

[10] V. MILANÉS, S. E. SHLADOVER, J. SPRING, C. NOWAKOWSKI, H. KAWAZOE, M. NAKAMURA. *Cooperative Adaptive Cruise Control in Real Traffic Situations*, in "IEEE Transactions on Intelligent Transportation Systems", 2014, vol. 15, pp. 296-305

[11] 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

[12] J. PÉREZ RASTELLI, F. NASHASHIBI, B. LEFAUDEUX, P. RESENDE, E. POLLARD. *Autonomous docking based on infrared system for electric vehicle charging in urban areas*, in "Sensors", February 2013, https://hal.inria.fr/hal-00913122

[13] P. RESENDE, E. POLLARD, H. LI, F. NASHASHIBI. *Low Speed Automation: technical feasibility of the driving sharing in urban areas*, in "16th International IEEE Conference on Intelligent Transportation Systems", La Hague, Netherlands, October 2013, https://hal.inria.fr/hal-00848093

[14] O. SHAGDAR, A. DANIEL, S. PRIMAK. *Beacon delivery over practical V2X channels*, in "International Conference on ITS Telecommunications", Tampare, Finland, November 2013, http://hal.inria.fr/hal-00868063

[15] G. TREHARD, Z. ALSAYED, E. POLLARD, B. BRADAI, F. NASHASHIBI. *Credibilist simultaneous Localization And Mapping with a LIDAR*, in "IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2014)", Sept 2014, pp. 2699-2706

Publications of the year

Doctoral Dissertations and Habilitation Theses

[16] I. BEN JEMAA. *Multicast Communications for Cooperative Vehicular Systems*, Mines ParisTech, December 2014, https://hal.inria.fr/tel-01101679

[17] E. ELGHOUL. *A Segmentation transfer method for 3D models*, Télécom ParisTech, September 2014, https://hal.inria.fr/tel-01093509

Articles in International Peer-Reviewed Journals

[18] E. ELGHOUL, A. VERROUST-BLONDET, M. CHAOUCH. *A Segmentation Transfer Approach for Rigid Models*, in "Journal of Information Science and Engineering", 2014, pp. 1-15, https://hal.inria.fr/hal-01081374

[19] G. FAYOLLE, R. IASNOGORODSKI. *Letter to editors*, in "Queueing Systems", January 2014, vol. 76, n^{o} 1, pp. 105-107 [*DOI :* 10.1007/S11134-013-9387-1], https://hal.inria.fr/hal-00922096

[20] G. FAYOLLE, J.-M. LASGOUTTES. *Modeling a Case of Herding Behavior in a Multi-Player Game*, in "Queueing Systems", March 2014, vol. 76, n^{o} 3, pp. 243-265 [*DOI :* 10.1007/S11134-013-9365-7], https://hal.inria.fr/hal-00768324

[21] G. FAYOLLE, K. RASCHEL. *About a possible analytic approach for walks in the quarter plane with arbitrary big jumps*, in "Comptes Rendus de l'Academie des Sciences. Serie 1, Mathematique", December 2014, n^{o} CRASS1:5432, 6 p. , 6 pages, 3 figures, extended abstract [*DOI :* 10.1016/J.CRMA.2014.11.015], https://hal.inria.fr/hal-01021327

[22] Y. HAN, F. MOUTARDE. *Analysis of Large-Scale Traffic Dynamics in an Urban Transportation Network Using Non-Negative Tensor Factorization*, in "International Journal of Intelligent Transportation Systems Research", 2014, pp. 1-14 [*DOI :* 10.1007/S13177-014-0099-7], https://hal-mines-paristech.archives-ouvertes.fr/hal-01085971

[23] H. HOSSEINNIA, I. TEJADO, V. MILANÉS, J. VILLAGRÁ, B. VINAGRE. *Experimental Application of Hybrid Fractional-Order Adaptive Cruise Control at Low Speed*, in "IEEE Transactions on Control Systems Technology", 2014, pp. 2329-2336 [*DOI :* 10.1109/TCST.2014.2308837], https://hal.archives-ouvertes.fr/hal-01091158

[24] H. LI, M. TSUKADA, F. NASHASHIBI, M. PARENT. *Multi-Vehicle Cooperative Local Mapping: A Methodology Based on Occupancy Grid Map Merging*, in "IEEE Transactions on Intelligent Transportation Systems", March 2014, vol. 15, n^{o} 5, 12 p. [*DOI :* 10.1109/TITS.2014.2309639], https://hal.inria.fr/hal-01107534

[25] V. MILANÉS, S. E. SHLADOVER. *Modeling cooperative and autonomous adaptive cruise control dynamic responses using experimental data*, in "Transportation Research Part C: Emerging Technologies", September 2014, pp. 285–300 [*DOI :* 10.1016/J.TRC.2014.09.001], https://hal.archives-ouvertes.fr/hal-01091160

[26] V. MILANÉS, S. E. SHLADOVER, J. SPRING, C. NOWAKOWSKI, H. KAWAZOE, M. NAKAMURA. *Cooperative Adaptive Cruise Control in Real Traffic Situations*, in "IEEE Transactions on Intelligent Transportation Systems", 2014, vol. 15, pp. 296 - 305 [*DOI :* 10.1109/TITS.2013.2278494], https://hal.archives-ouvertes.fr/hal-01091154

[27] R. MOLFINO, M. ZOPPI, G. G. MUSCOLO, E. CEPOLINA, A. FARINA, F. NASHASHIBI, E. POLLARD, J. A. DOMINGUEZ. *An Electro-Mobility System for Freight Service in Urban Areas*, in "International Journal of Electric and Hybrid Vehicles", December 2014, 21 p. , https://hal.inria.fr/hal-01090996

[28] 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, 14 p. [*DOI :* 10.1109/TITS.2014.2303995], https://hal.inria.fr/hal-01107533

[29] M. TSUKADA, J. SANTA, S. MATSUURA, T. ERNST, K. FUJIKAWA. *On the Experimental Evaluation of Vehicular Networks: Issues, Requirements and Methodology Applied to a Real Use Case*, in "EAI Endorsed Transactions on Industrial Networks and Intelligent Systems", December 2014, pp. 1-14 [*DOI :* 10.4108/INIS.1.1.E4], https://hal.inria.fr/hal-01095282

[30] E. WIRBEL, S. BONNABEL, A. DE LA FORTELLE, F. MOUTARDE. *Humanoid robot navigation: getting localization information from vision*, in "Journal of Intelligent Systems", June 2014, vol. 23, n^{o} 2, pp. 113-132, https://hal-mines-paristech.archives-ouvertes.fr/hal-00949738

Invited Conferences

[31] M. MAROUF, E. POLLARD, F. NASHASHIBI. *Automatic parallel parking and platooning to redistribute electric vehicles in a car-sharing application*, in "IV'14 - IEEE Intelligent Vehicles Symposium", Dearborn, Michigan, United States, June 2014, https://hal.inria.fr/hal-01018707

International Conferences with Proceedings

[32] M. ABUALHOUL, M. MAROUF, O. SHAGDAR, F. NASHASHIBI. *Enhancing the Field of View Limitation of Visible Light Communication-based Platoon*, in "6th International Symposium on Wireless Vehicular Communications: WIVEC2014", Vancouver, Canada, September 2014, https://hal.inria.fr/hal-01007692

[33] Z. ALSAYED, G. BRESSON, P. MERDRIGNAC, P. MORIGNOT, F. NASHASHIBI, E. POLLARD, G. TREHARD. *Intelligent vehicles: integration and issues*, in "RFIA 2014 - Dix-neuvième congrès national sur la Reconnaissance de Formes et l'Intelligence Artificielle", Rouen, France, June 2014, https://hal.inria.fr/hal-01067615

[34] J. J. ANAYA, P. MERDRIGNAC, O. SHAGDAR, F. NASHASHIBI, J. E. NARANJO. *Vehicle to Pedestrian Communications for Protection of Vulnerable road Users*, in "2014 IEEE Intelligent Vehicles Symposium", Dearborn, Michigan, United States, June 2014, pp. 1-6, 6 pages, https://hal.archives-ouvertes.fr/hal-00992759

[35] I. Ben Jemaa, O. Shagdar, P. Garrido, F. Martinez J, F. Nashashibi. *Extended Mobility Management and Routing Protocols for Internet-to-VANET Multicasting*, in "International Workshop on Vehicular Networking and Intelligent Transportation Systems", Las-Vegas, Nevada, United States, IEEE, January 2015, https://hal.inria.fr/hal-01090204

[36] A. De La Fortelle, X. Qian, S. Diemer, J. Grégoire, F. Moutarde, S. Bonnabel, A. Marjovi, A. Martinoli, I. Llatser, A. Festag, K. Sjöberg. *Network of automated vehicles: the AutoNet 2030 vision*, in "ITS World Congress", Detroit, United States, September 2014, electronic proceedings, https://hal-mines-paristech.archives-ouvertes.fr/hal-01063484

[37] M. Fernández, A. Bolovinou, G. Karagianinis, J.-M. Lasgouttes, I. Varea, R. Kurpatov, Z. Kovács, F. Mastrandea. *Co-operative commuting assistant for enhanced personal electromobility*, in "10th ITS European Congress", Helsinki, Finland, ERTICO, June 2014, https://hal.inria.fr/hal-01108397

[38] D. Gonzalez Bautista, J. Pérez, 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

[39] M. Kutila, P. Pyykönen, P. Van, N. Pallaro, J. Pérez-Rastelli. *The DESERVE project: Towards future ADAS functions*, in "IEEE SAMOS conference", SAMOS, Greece, July 2014, pp. 308 - 313 [*DOI :* 10.1109/SAMOS.2014.6893226], https://hal.inria.fr/hal-01086885

[40] 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

[41] V. Milanés, M. Marouf, J. Pérez, G. B. David, F. Nashashibi. *Low-Speed Cooperative Car-Following Fuzzy Controller for Cybernetic Transport Systems*, in "2014 IEEE 17th International Conference on Intelligent Transportation Systems (ITSC)", Qingdao, China, October 2014 [*DOI :* 10.1109/ITSC.2014.6958009], https://hal.inria.fr/hal-01086877

[42] P. Morignot, J. Pérez Rastelli, F. Nashashibi. *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

[43] P. Morignot, O. Shagdar, F. Nashashibi. *Emergent Behaviors and Traffic Density among Heuristically-Driven Intelligent Vehicles using V2V Communication*, in "2014 International Conference on Connected Vehicles & Expo", Vienna, Austria, November 2014, https://hal.inria.fr/hal-01069062

[44] P. Petrov, F. Nashashibi. *Saturated Feedback Control for an Automated Parallel Parking Assist System*, in "ICARCV - 13th International Conference on Control, Automation, Robotics and Vision", Singapore, December 2014, https://hal.inria.fr/hal-01107530

[45] E. POLLARD, J. PÉREZ RASTELLI, F. NASHASHIBI. *On-board Intelligence for the Furbot: a new Concept for Urban Freight Transport*, in "Transport Research Arena", Paris, France, April 2014, https://hal.inria.fr/hal-01090220

[46] J. PÉREZ RASTELLI, D. GONZALEZ BAUTISTA, F. NASHASHIBI, F. TANGO, N. PALLARO, G. DUNAND, A. ROLFSMEIER. *Development and Design of a Platform for Arbitration and Sharing Control Applications–a DESERVE approach-*, in "IEEE SAMOS Conference", Samos, Greece, July 2014, https://hal.inria.fr/hal-01081317

[47] J. PÉREZ RASTELLI, L. RAY, F. NASHASHIBI. *Dynamic Trajectory Generation Using Continuous-Curvature Algorithms for Door to Door Assistance Vehicles*, in "2014 IEEE Intelligent Vehicles Symposium (IV)", Dearborn, United States, June 2014 [*DOI :* 10.1109/IVS.2014.6856526], https://hal.inria.fr/hal-01081298

[48] X. QIAN, J. GREGOIRE, F. MOUTARDE, A. DE LA FORTELLE. *Priority-based coordination of autonomous and legacy vehicles at intersection*, in "17th International IEEE Conference on Intelligent Transportation Systems", Qingdao, China, October 2014, https://hal-mines-paristech.archives-ouvertes.fr/hal-01059090

[49] G. TREHARD, Z. ALSAYED, E. POLLARD, B. BRADAI, F. NASHASHIBI. *Credibilist Simultaneous Localization and Mapping with a LIDAR*, in "IROS - International Conference on Intelligent Robots and Systems", Chicago, United States, September 2014, https://hal.inria.fr/hal-01067931

[50] G. TREHARD, E. POLLARD, B. BRADAI, F. NASHASHIBI. *Credibilist SLAM Performances with Different Laser Set-ups*, in "ICARCV - 13th International Conference on Control, Automation, Robotics and Vision", Singapore, December 2014, https://hal.inria.fr/hal-01091944

[51] G. TREHARD, E. POLLARD, B. BRADAI, F. NASHASHIBI. *Tracking both pose and status of a traffic light via an Interacting Multiple Model filter*, in "Fusion 2014 - 17th International Conference on Information Fusion", Salamanca, Spain, July 2014, https://hal.inria.fr/hal-01024096

[52] M. TSUKADA, J. SANTA, S. MATSUURA, T. ERNST, K. FUJIKAWA. *AnaVANET: an experiment and visualization tool for vehicular networks*, in "9th International Conference on Testbeds and Research Infrastructures for the Development of Networks & Communities (TRIDENTCOM 2014)", Guangzhou, China, May 2014, https://hal.inria.fr/hal-00983479

Scientific Books (or Scientific Book chapters)

[53] H. GOËAU, A. JOLY, I. YAHIAOUI, V. BAKIC, A. VERROUST-BLONDET, P. BONNET, D. BARTHÉLÉMY, N. BOUJEMAA, J.-F. MOLINO. *PlantNet Participation at LifeCLEF2014 Plant Identification Task*, in "CLEF2014 Working Notes. Working Notes for CLEF 2014 Conference, Sheffield, UK, September 15-18, 2014", L. CAPPELLATO, N. FERRO, M. HALVEY, W. KRAAIJ (editors), CEUR Workshop Proceedings, CEUR-WS, 2014, pp. 724-737, https://hal.archives-ouvertes.fr/halsde-01064569

Research Reports

[54] O. SHAGDAR. *Evaluation of Distributed Congestion Control -Reactive DCC*, Inria, December 2014, https://hal.inria.fr/hal-01107740

Other Publications

[55] 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*, November 2014, Accepted for publication in the journal MPRF (Markov Processes and Related Fields), https://hal.inria.fr/hal-01086684

[56] J. GREGOIRE, S. BONNABEL, A. DE LA FORTELLE. *Priority-based coordination of robots*, April 2014, 20 pages, https://hal.archives-ouvertes.fr/hal-00828976

References in notes

[57] 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

[58] 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

[59] G. LE LANN. *On the Power of Cohorts - Multipoint Protocols for Fast and Reliable Safety-Critical Communications in Intelligent Vehicular Networks*, in "ICCVE - International Conference on Connected Vehicles and Expo - 2012", Beijing, Chine, FEI-YUE, C. WANG (editors), IEEE, TRB, ACM, IFAC, November 2012, http://hal.inria.fr/hal-00769133

[60] V. MARTIN. *Modélisation probabiliste et inférence par l'algorithme Belief Propagation*, Ecole Nationale Supérieure des Mines de Paris, May 2013, http://hal.inria.fr/tel-00867693