Activity Report 2015

Project-Team RITS

Robotics & Intelligent Transportation Systems

RESEARCH CENTER
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THEME
Robotics and Smart environments

Table of contents

Project-Team RITS

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Keywords:

Computer Science and Digital Science:

5.1. - Human-Computer Interaction
5.10. - Robotics
5.11. - Smart spaces
5.3. - Image processing and analysis
5.4. - Computer vision
5.9. - Signal processing
6.1. - Mathematical Modeling
6.4. - Automatic control
8.2. - Machine learning
8.5. - Robotics

Other Research Topics and Application Domains:

5.6. - Robotic systems
6.5. - Information systems
6.6. - Embedded systems
7. - Transport and logistics

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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.

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

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.

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, Raoul de Charette, Fernando Garrido Carpio, David Gonzalez Bautista, Mohamed Yassine Maddouri, Pierre Merdrignac, Vicente Milanés Montero, Francisco Navas Matos, Fawzi Nashashibi, Joshué Pérez Rastelli, Plamen Petrov, Carlos Eduardo Flores Pino, Evangeline Pollard, Oyunchimeg Shagdar, Guillaume Trehard, Anne Verroust-Blondet, Itheri Yahiaoui.

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

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

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

3.1.1. Perception of the road environment

Participants: Zayed Alsayed, Raoul de Charette, Mohamed Yassine Maddouri, Pierre Merdrignac, Fawzi Nashashibi, Joshué Pérez Rastelli, Evangeline Pollard, Guillaume Trehard, Anne Verroust-Blondet, Itheri Yahiaoui.

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

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

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. 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.

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.

3.1.3. Planning and executing vehicle actions

Participants: Fernando Garrido Carpio, David Gonzalez Bautista, Vicente Milanés Montero, Fawzi Nashashibi, Francisco Navas Matos, Joshué Pérez Rastelli, Plamen Petrov, Carlos Eduardo Flores Pino.

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, 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.

3.2.4. Fully automated driving, intelligent vehicular networks, and safety

Participant: Gérard Le Lann.

In the future, which of the following approaches may dominate: the progressive approach (human-assisted driving) or the disruptive approach (fully automated/driverless driving)? Prior to opting for one approach, a number of clarifications are in order such as, e.g., defining targeted goals and conditions unambiguously. According to SAE standard J3016, full automation (level 5) means "the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver." From a strictly logical viewpoint, this definition is problematic. An obvious corollary is "Level 5 vehicles will be as safe as human-driven vehicles, but no more". Which appears to be antagonistic with one of the primary motivations behind the autonomous/automated driving revolution: a quasi-elimination of accidents caused by humans, who are major contributors according to acknowledged statistics. Choosing between human-assisted or fully automated driving is pointless unless fully automated driving is shown to be achievable. This question is at the core of the work reported here. We consider ad hoc/open intelligent vehicular networks (IVNs) comprised of fully automated vehicles circulating on highways and main roads, with minimal reliance on road-side infrastructures as regards the handling of safety-critical (SC) scenarios. For example, V2V communications only are considered. (IVNs in urban environments, where infrastructures are "naturally" available, will be studied later.) We proceed as follows:

- Identification of real challenging SC scenarios hardly manageable by humans,
- Identification and specification of cyber-physical problems that arise in such SC scenarios,
- Specification of cyber-physical solutions, along with analytical proofs, with a strong focus on time-bounded reliable communications and distributed algorithms.

3.3. 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.

3.3.1. Traffic reconstruction

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

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

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

- find the best way to inject real-valued data in an Ising model with binary variables [51];
- build macroscopic variables that measure the overall state of the underlying graph, in order to improve the local propagation of information [49];
- make the underlying model as sparse as possible, in order to improve BP convergence and quality [50].

3.3.2. Exclusion processes for road traffic modeling

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

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

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

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

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

We have considered in [48] some classes of models dealing with the dynamics of discrete curves subjected to stochastic deformations. It turns out that the problems of interest can be set in terms of interacting exclusion processes, the ultimate goal being to derive hydrodynamic limits after proper scaling. A seemingly new method is proposed, which relies on the analysis of specific partial differential operators, involving variational calculus and functional integration. Starting from a detailed analysis of the Asymmetric Simple Exclusion Process (ASEP) system on the torus $\mathbb{Z}/n\mathbb{Z}$, the arguments a priori work in higher dimensions (ABC, multi-type exclusion processes, etc), leading to systems of coupled partial differential equations of Burgers' type.

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

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

One essential question concerns the computation of stationary measures (when they exist). As for the answer, it has been given by original methods formerly developed in the team (see books and related bibliography). For instance, in the case of small steps (jumps of size one in the interior of $\mathbb{Z}_+^2$), the invariant measure $\{\pi_{i,j}, i, j \geq 0\}$ does satisfy the fundamental functional equation (see [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 [20], a criterion has been found in terms of a determinant of order 3 or 4, depending on the arity of the group.
- *Nature of the counting generating functions*. Enumeration of planar lattice walks is a classical topic in combinatorics. For a given set of allowed jumps (or steps), it is a matter of counting the number of paths starting from some point and ending at some arbitrary point in a given time, and possibly restricted to some regions of the plane. A first basic and natural question arises: how many such paths exist? A second question concerns the nature of the associated counting generating functions (CGF): are they rational, algebraic, holonomic (or D-finite, i.e. solution of a linear differential equation with polynomial coefficients)?

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

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

  satisfies the functional equation

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

  where z is considered as a time-parameter. Clearly, equations (2) and (1) are of the same nature, and answers to the above questions have been given in [Fayolle-2010].
- *Some exact asymptotics in the counting of walks in $\mathbb{Z}_+^2$*. A new and uniform approach has been proposed about the following problem: *What is the asymptotic behavior, as their length goes to infinity, of the number of walks ending at some given point or domain (for instance one axis)?* The method in [Fayolle-2012] works for *both* finite or infinite groups, and for walks not necessarily restricted to excursions.

3.3.4. 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, cars available in self-service mode and fully automated vehicles (cybercars).

4.2. Driving assistance

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

4.3. New transportation systems

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

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

These systems are now operating (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 to this time) on a second CAN bus. This external source can be a PC or a dedicated CPU, we call it high level. To work on the high level, in the past years we have been developing a R&D framework called (Taxi) which used to take control of the vehicle (Cycab and Yamaha) and process data such as gyro, GPS, cameras, wireless communications and so on. Today, in order to rely on a professional and maintained solution, we have chosen to migrate to the RTMaps SDK development platform. Today, all our developments and demonstrations are using this efficient prototyping platform. Thanks to RTMaps we have been able to do all the demonstrations on our cybercars: cycabs, Yamaha AGV and new Cybus platforms. These demonstrations include: reliable SLAMMOT algorithm using 2 to 4 laser sensors simultaneously, automatic line/road following techniques, PDA remote control, multi sensors data fusion, collaborative perception via ad-hoc network. The second main topic is inter-vehicle communications using ad-hoc networks. We have worked with the EVA team for setting and tuning OLSR, a dynamic routing protocol for vehicles communications. Our goal is to develop a vehicle dedicated communication software suite, running on a specialized hardware. It can be linked also with the Taxi Framework for getting data such GPS information's to help the routing algorithm.

5. Highlights of the Year

5.1. Highlights of the Year

5.1.1. Awards

Fawzi Nashashibi was awarded by the Higher Council for Innovation & Excellence in Palestine for his innovation research on intelligent transportation. The award was delivered by President Mahmoud ABBAS at the 1st HCIE National Forum for Innovators on innovation, September 12-13 2015, Ramallah, Palestine.

BEST PAPERS AWARDS:

[30]
A. DE LA FORTELLE, X. QIAN. *Autonomous driving at intersections: combining theoretical analysis with practical considerations*, in "ITS World Congress 2015", Bordeaux, France, ERTICO - ITS Europe, October 2015, https://hal-mines-paristech.archives-ouvertes.fr/hal-01217925

[35]
R. LUIS, J. PÉREZ RASTELLI, D. GONZALEZ BAUTISTA, V. MILANÉS. *Description and Technical specifications of Cybernetic Transportation Systems: an urban transportation concept*, in "2015 IEEE International Conference on Vehicular Electronics and Safety", Yokohama, Japan, November 2015, https://hal.inria.fr/hal-01232627

6. New Software and Platforms

6.1. DOLAR

FUNCTIONAL DESCRIPTION

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.

- Contact: Fawzi Nashashibi

6.2. MELOSYM

FUNCTIONAL DESCRIPTION

MELOSYM 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 RTMAPS platform but the version includes a standalone version.

- Participants: Fawzi Nashashibi, Benjamin Lefaudeux, Jianping Xie and Paulo Lopes Resende
- Contact: Benjamin Lefaudeux

6.3. PML-SLAM

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

6.4. STEREOLOC-3D

FUNCTIONAL DESCRIPTION

STEREOLOC 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.

- Participants: Benjamin Lefaudeux and Fawzi Nashashibi
- Contact: Fawzi Nashashibi

6.5. SODA

SOftwares for Driving Automation
KEYWORD: Environment perception
FUNCTIONAL DESCRIPTION

This software has been developed in the context of the French ABV (Automatisation Basse Vitesse) project. This package contains the functions that are necessary to automate the vehicle navigation in its secured lane.

- Participants: Paulo Lopes Resende and Fawzi Nashashibi
- Contact: Fawzi Nashashibi

6.6. AutoPathPlan

Automatic Path Planning Generation
FUNCTIONAL DESCRIPTION
Automatic method for a real time path planning generation path for automated vehicles.

- Participants: David Gonzalez Bautista, Joshué Pérez Rastelli and Vicente Milanés Montero
- Contact: Fawzi Nashashibi

6.7. FEMOT

Fuzzy Embedded MOTor
FUNCTIONAL DESCRIPTION

FEMOT 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.

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.

- Participants: Joshué Pérez Rastelli and Vicente Milanés Montero
- Contact: Fawzi Nashashibi

6.8. Platools

KEYWORD: Telecommunications

- Participant: Marios Makassikis
- Contact: Thierry Ernst

6.9. V2Provue

Vehicle-to-Pedestrian
KEYWORD: vehicle-to-pedestrian communications
FUNCTIONAL DESCRIPTION

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

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

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

- Contact: Fawzi Nashashibi

6.10. Taxi-col

KEYWORD: Mobile Computing, Transportation

- Participant: Eugenie Lioris
- Contact: Fawzi Nashashibi

7. New Results

7.1. 2D Laser Based Road Obstacle Classification for Road Safety Improvement

Participants: Pierre Merdrignac, Evangeline Pollard, Fawzi Nashashibi.

Vehicle and pedestrian collisions often result in fatality to the vulnerable road users (VRU), indicating a strong need to protect such persons. Laser sensors have been extensively used for moving obstacles detection and tracking. Laser impacts are produced by reflection on these obstacles which suggests an information is available to recognize multiple road obstacles classes (pedestrian, cyclists, vehicles,...). We introduce a new system to address this problem that is divided in three parts: definition of geometric features describing road obstacles, multi-class object classification from an adaboost trained classifier and Bayesian estimation of the obstacle class. This approach benefits from consecutive observations of a single obstacle to estimate its class more precisely. We tested our system on some laser sequences and showed that it can estimate the class of some road obstacles around the vehicle with an accuracy of 87.4%. The vehicle class is determined with more than 97% of success. However, the main source of confusion is for static obstacles (posts and trees) for which 15% are classified as pedestrians. More detail can be fund in [36], [16].

7.2. On line Mapping and Global Positioning technique based on evidential SLAM

Participants: Guillaume Trehard, Evangeline Pollard, Fawzi Nashashibi.

Locate a vehicle in an urban environment remains a challenge for the autonomous driving community. By fusing information from a LIDAR, a Global Navigation by Satellite System (GNSS) and the vehicle odometry, we introduced and developed an original solution based on evidential grids and a particle filter to map the static environment and simultaneously estimate the position in a global reference at a high rate and without any prior knowledge (see [39]).

7.3. PML-SLAM

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

Our goal is to improve localization systems performances in order to be able to navigate in large-scale urban environments. In this context, we first optimized CPU and memory consumption of a SLAM laser-based technique [52] by introducing a map manager system. This strategy allows a smooth navigation while saving and loading probabilities-grid submaps into/from a hard-disc in a transparent way (cf. [27]). This work was validated and extended in the context of ITS Bordeaux demonstrations (VEDECOM demonstrator), where GPS information was integrated into SLAM environment Maps.

7.4. Motion planning techniques

Participants: David Gonzalez Bautista, Fernando Garrido Carpio, Joshué Pérez Rastelli, Vicente Milanés Montero, Fawzi Nashashibi.

Intelligent vehicles have increased their capabilities for highly, and even fully, automated driving under controlled environments. Scene information is received using on-board sensors and communication network systems–i.e. infrastructure and other vehicles. Considering the available information, different motion planning techniques have been implemented to autonomously driving on complex environments. The main goal is focused on executing strategies to improve safety, comfort and energy optimization. However, research challenges such as navigation in urban dynamic environments with obstacle avoidance capabilities–i.e. Vulnerable Road Users (VRU) and vehicles–and cooperative maneuvers among automated and semi-automated vehicles still need further efforts for a real environment implementation. We have recently carried out a deep state-of-the-art review to find the gaps in this hot topic into the autonomous vehicle field, paying special attention to overtaking and obstacle avoidance maneuvers.

Based on this review, we have mainly identified two main gaps: trajectory and speed planning with dynamics obstacle avoidance capabilities and real-time performance of the algorithms in the sense of significantly reducing the computational time, moving the system closer to what a vehicle should be able to provide in the real world.

According to this review, a speed planner has been designed with specific considerations on computing time efficiency, with an optimal comfort and avoiding to exceed speed and acceleration limits [31]. The comfort is evaluated as the minimization and smoothness of acceleration and jerk profiles, while maintaining a coherent speed profile with respect to traffic rules, the geometry of the path and the lateral accelerations associated to it. Specifically, this speed planner uses fifth order polynomial curves. These curves are C2 continuous and smooth, meaning that the jerk profile is also continuous and smooth. The method proposed computes the velocity in terms of the length of the path, instead of time, greatly reducing the errors. Specific targets for the speed planner are:

- Compute a smooth and continuous speed profile accounting for acceleration limits (longitudinal and lateral) according to ISO 2631-1 standard.
- Minimize distance error problems by associating the speed profile in the path speed planner instead of the time.

This speed planner was tested against other techniques providing better results in terms of computational time and smoothness (cf. [32]).

Additionally, a novel trajectory planning with a significant reduction on the computational time with respect to prior implementations from the team has been implemented. Our approach is mainly affected by vehicle's kinematics and physical road constraints. Based on these assumptions, computational time for path planning can be significantly reduced by creating a database containing already optimized versions of all the potential trajectories in each curve the vehicle can carry out. Therefore, this algorithm generates a database of smooth and continuous curves considering a big set of different intersection scenarios, taking into account the constraints of the infrastructure and the physical limitations of the vehicle. According to the real scenario, the local planner selects from the database the appropriate curves, searching for the ones that fit with the intersections defined on it. The path planning algorithm has been tested in simulation against the previous control architecture. The results obtained show path generation improvements in terms of smoothness and to continuity. Next steps on this algorithm is to test its performance in real platform and add the dynamics obstacle avoidance capabilities, establishing the link with the perception algorithms research line currently open in the team.

7.5. Control techniques

Participants: Francisco Navas Matos, Carlos Eduardo Flores Pino, David Gonzalez Bautista, Joshué Pérez Rastelli, Vicente Milanés Montero.

The final stage for automating a vehicle relies on the control algorithms. They are in charge of providing the proper behavior and performance to the vehicle, leading to provide the fully automated capabilities. Having this in mind, there are two research lines currently open in the time: the first one is mainly related to what we call "naturalistic driving" in the sense of adding the human reasoning to the vehicle. We are mainly focusing our effort on artificial intelligent algorithms as neuro-fuzzy techniques. The main reason is the growing interest of the car makers in adding sharing control capabilities (between the vehicle and the driver) to the automated car. Our initial results show a big potential of using this approach and we already achieved some simulations results that were well-accepted by the scientific community and will be shown in mid-December at the final event of the EU project DESERVE.

On the other hand, we are also further investigating robust control algorithms for providing stability not only to an automated vehicle but also to a chain of automated vehicles that should be able to cooperate intelligently. This work is mainly divided in two main research lines:

1) Controllability and stability of dynamic complex systems are the key aspects when it comes to design intelligent control algorithms for vehicles. Current advances in the field are mainly oriented to advanced multi-sensor fusion toward multi-target decision-making systems. These artificial intelligence-based algorithms are able to provide reasonable responses under controlled environments (i.e. highly-detailed maps). However, new trends are proposing intelligent algorithms able to handle any unexpected circumstances as unpredicted uncertainties or even fully outages from sensors. The goal of this new research line at RITS is to further investigate control algorithms able to provide stability responses for autonomous vehicles under uncontrolled circumstances, including modifications on the input/output sensors. Dynamic plant models where different inputs/outputs can be added or subtracted in real-time during its operation is one of the hot topics in the control research arena. This system has to provide stable enough response when these operations occur. This is especially true on high-risk environments as autonomous driving; and
2) Data-driven control techniques based on model-free algorithms. Vehicles exhibit a highly non-linear behavior, especially at low speeds (as occur in urban environments). The research on novel data-driven techniques that are independent of the plant model provides huge benefits when applying them to automated vehicles. This novel research line in the team tries to further investigate on stable algorithm that doesn't need an accurate model of the vehicle dynamic, leading to compensate the effects of nonlinear dynamics, disturbances, or uncertainties in the parameters. [35]

7.6. Study on Perception and Communication Sytems for Safety

Participants: Pierre Merdrignac, Oyunchimeg Shagdar, Ines Ben Jemaa, Fawzi Nashashibi.

The existing R&D efforts for protecting vulnerable road users (VRU) are mainly based on perception techniques, which aim to detect VRUs utilizing vehicle embedded sensors. The efficiency of such a technique is largely affected by the sensor's visibility condition. Vehicle-to-Pedestrian (V2P) communication can also contribute to the VRU safety by allowing vehicles and pedestrians to exchange information. This solution is, however, largely affected by the reliability of the exchanged information, which most generally is the GPS data. Since perception and communication have complementary features, we can expect that a combination of such approaches can be a solution to the VRU safety. This is the motivation of this work. We develop theoretical models to present the characteristics of perception and communications systems. Experimental studies are conducted to compare the performances of these techniques in real-world environments. Our results show that the perception system reliably detects pedestrians and other objects within 50 m of range in the line-of-sight (LOS) condition. In contrast, the V2P communication coverage is approximately 340 and 200 meters in LOS and non-LOS (NLOS) conditions, respectively. However, the communication-based system fails to correctly position the VRU w.r.t the vehicle, preventing the system from meeting the safety requirement. Finally, we propose a cooperative system that combines the outputs of the communication and perception systems. More detail can be fund in [37], [16].

7.7. Asynchronous Reactive Distributed Congestion Control Algorithms for the ITS G5 Vehicular Communications

Participant: Oyunchimeg Shagdar.

The IEEE 802.11p is the technology dedicated to vehicular communications to support road safety, efficiency, and comfort applications. A large number of research activities have been carried out to study the characteristics of the IEEE 802.11p. The key weakness of the IEEE 802.11p is the channel congestion issue, where the wireless channel gets saturated when the road density increases. The European Telecommunications Standardization Institute (ETSI) is in the progress of studying the channel congestion problem and proposed so-called Reactive Distributed Congestion Control (DCC) algorithm as a solution to the congestion issue. In this work we investigate the impacts of the Reactive DCC mechanism in comparison to the conventional IEEE 802.11p with no congestion control. Our study shows that the Reactive DCC scheme creates oscillation on channel load that consequently degrades communication performance. The results reveal that the channel load oscillation is due to the fact that in the Reactive DCC, the individual CAM (Cooperative Awareness Message) controllers react to the channel congestion in a synchronized manner. To reduce the oscillation, we propose a simple extension to Reactive DCC, Asynchronous Reactive DCC, in which the individual CAM controllers adopt randomized rate setting, which can significantly reduce the oscillation and improve the network performance. See [45] for more detail.

7.8. Vehicle to vehicle visible light communication

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

Visible Light Communication (VLC) technology utilizes the light spectral range between 380 nm and 750 nm, which enables the dual functionality of lightning and information delivery. A use of VLC for the ITS domain has many benefits including that it can be a complementary technology to the IEEE 802.11p, which is the radio communications technology dedicated to the V2X communication but suffers from its channel congestion problem.

This year, we conducted theoretical and experimental studies on the optical channel characteristics. Based on our studies and the previous contributions, we developed a transmitter and receiver VLC prototype to be integrated to the vehicle lightning systems dedicated to platooning applications. Using the low-cost Arduino micro-controller, a transmitter broadcasts the vehicle status information including the vehicle identity, velocity, orientation, acceleration through the vehicle rear Light Emitting Diodes (LED). The receiver is based on a simple Photo Diode (PD) with an accurate 635 nm optical filtering stage to overcome the saturation and the unwanted ambient noise issues. Experimental studies show that the system can provide 8.5 Kbps of information delivery between vehicles with up to 30 meters of bumper to bumper distance.

7.9. Analysis of broadcast strategies in IEEE 802.11p VANETs

Participants: Younes Bouchaala, Oyunchimeg Shagdar, Paul Muhlethaler.

We analyze different broadcast strategies in IEEE 802.11p Vehicular Ad-hoc NETworks (VANETs). The first strategy is the default IEEE 802.11p strategy. Using a model derived from the Bianchi model, we provide the network performance in terms of throughput and success rate. The second strategy consists in using an acknowledgment technique similar to the acknowledgment with point-to-point traffic. A node will send its broadcast packet as in the default case, but it requires an acknowledgment from a neighbor node. This node may be a random neighbor or may be selected according to precise rules. We analyze this second strategy in terms of throughput and success rate. Somewhat surprisingly, we show that this second strategy improves the delivery ratio of the transmitted packets but reduces the overall throughput. This means that if the CAM messages (Cooperative Awareness Messages) are broadcasted, the total number of packets actually delivered will be greater with the default strategy than with the improved strategy. We propose a third strategy which consists in using the default strategy for normal packets, but we add random redundant transmissions to ensure greater reliability for very important packets. We show that with this simple technique, not only do we obtain suitable reliability, but we also achieve larger global throughput than with the acknowledgment-oriented technique. This is described in [26]. Another contribution of this paper is to compute network performance in terms of throughput and success rate with respect to the network parameters and to analyze their impact on performances.

7.10. Multicast communications for cooperative vehicular systems

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

With the advancement of wireless communications technologies, users can now have multicast services while they are driving. Majority of the multicast services require Internet-to-vehicle multicast message dissemination. Conventional group management approaches in Internet is relatively simple because it is performed on the local networks of the multicast members which are usually a priori configured to receive the service. In addition to this, multicast packets flows follow a fixed routing structure that is built between the source and the destinations. 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 the VANET. Regarding the first issue, we find that neither current multicast addressing nor existing mobility management mechanisms are suitable for VANET. We introduce first a self-configuring multicast addressing scheme that allows the vehicles to auto-configure a dynamic multicast address without a need to exchange signalling messages with the Internet. Second, we propose a simplified approach that extends Mobile IP and Proxy Mobile IP. About message dissemination, we first propose to revisit traditional multicast routing techniques that rely on a tree structure. In particular, as vehicular networks are known to have changing topology, we present a theoretical study of the link lifetime between vehicles in urban environments. Then, we propose then Motion-MAODV, an improved version of a tree-based routing mechanism (MAODV) that aims at guaranteeing longer route lifetime. Finally, we also propose a geographic routing protocol Melody that provides a geocast dissemination in urban environments. Through simulations, we show that Melody ensures more reliable and efficient packet delivery to a given geographic area compared to traditional geo-brodcasting schemes in highly dense scenarios. More detail can be found in [28], [41], [47].

7.11. Context Awareness and Priority Control for ITS based on Automatic Speech Recognition

Participants: Oyunchimeg Shagdar, Sakriani Watiasri Sakti.

Bringing rapid assistance to motorists involved in a traffic accident is an important service to be provided by Intelligent Transportation System (ITS). Existing proposals to automatic accident detection are based on the vehicle's perception point of view. In [38] we introduce situational awareness based on the "understanding" of conversational speech of drivers/passengers using an automatic speech recognition (ASR) system. Context-aware priority control and congestion control schemes are presented to ensure coexistence of ASR-triggered applications and cooperative awareness messages (CAM) in the IEEE 802.11p system. Finally, application risk analysis and performance evaluations of ASR and V2X communications are carried out.

7.12. Emergent Behaviors and Traffic Density among Heuristically-Driven Intelligent Vehicles using V2V Communication

Participants: Oyunchimeg Shagdar, Fawzi Nashashibi.

We study the global traffic density and emergent traffic behavior of several hundreds of intelligent vehicles, as a function of V2V communication (for the ego vehicle to perceive traffic) and path-finding heuristics (for the ego vehicle to reach its destination), in urban environments. Ideal/realistic/no V2V communication modes are crossed with straight-line/towards-most-crowded/towards-least-crowded pathfinding heuristics to measure the average trip speed of each vehicle. The behaviors of intelligent vehicles are modeled by a finite state automaton. The V2V communication model is also built based on signal propagation models in an intersection scenario and a Markov-chain based MAC model. Our experiments in simulation over up to 400 vehicles exhibit attractive insights: 1) communication's impact is positive for the performance of the emergent vehicles' behavior, however, 2) the path-finding heuristics may not obtain their expected collective behavior due to the communications errors in realistic road environment (cf. [43]).

7.13. Time-bounded message dissemination in strings

Participant: Gérard Le Lann.

In 2015, besides reviewing prominent open issues regarding safety in IVNs (see [42]), we have investigated coordination problems that arise in string formations. Since the inception of the platoon concept (1977), a number of solutions have been proposed for achieving string control (platoons are a particular case of ad hoc/open string). String control must be exercised in order to avoid rear-end collisions, string instability, and for coping with emergency situations. The cyber components essential for string control have not been fully identified yet. For example, considering the cooperative adaptive cruise control paradigm, data collected in recent platooning experiments show that it is inappropriate to rely on V2V broadcast from a lead vehicle, thus the quest for other approaches. In strings, one can take advantage of short-range directional antennas which enable fast messaging among consecutive string neighbors, leading to the concept of neighbor-to-neighbor (N2N) communications and the cohort construct (a cohort is a string with a specification). String control problems translate into communication protocol issues and distributed algorithmic problems, notably:

- Time-bounded string-wide acknowledged message delivery and dissemination (TBMD),
- Bounded channel access delay (BCAD), a MAC-level problem,
- Time-bounded message acknowledgment (TBMA).

Acceptable solutions shall achieve small non-stochastic worst-case channel access time bounds (BCAD) and bounded delays for successful message delivery (TBMA and TBMD), under worst-case conditions regarding channel contention and message/acknowledgment losses. Non-stochastic worst-case bounds can only be established analytically (obviously, simulations cannot be considered). The importance of the TBMD problem can be exposed simply as follows: would TBMD be solved, then the string instability problem vanishes. Rather than resting solely on stepwise detection-and-reaction strategies based on radars/lasers, every string member adjusts its acceleration/deceleration rate according to observed motions of its predecessor, TBMD delivers a N2N message carrying the newly string-wide targeted velocity, in less than 100 milliseconds in strings comprising in the order of 20 members, in the presence of message/acknowledgment losses. The TBMD problem has been solved (see [34]). The solution rests on assuming that TBMA and TBMD have solutions. Both problems have been solved (solutions are under review). Contrary to strings, groups are ad hoc/open multilane formations. It turns out that solutions aimed at the 3 problems referenced above are instrumental in solving problems arising with multilane SC scenarios. For example, the 3-way handshakes at the core of safe lane changes published previously now achieve significantly better performance figures. Work in progress also includes:

- conflicting concurrent lane changes at high velocities,

- fully automated zipper merging at high velocities, in non-line-of-sight conditions (radio communications), in line-of-sight conditions (optical communications).

7.14. Broadcast Transmission Networks with Buffering

Participants: Guy Fayolle, Paul Muhlethaler.

We analyzed the so-called back-off technique of the IEEE 802.11 protocol in broadcast mode with waiting queues. In contrast to existing models, packets arriving when a station (or node) is in back-off state are not discarded, but are stored in a buffer of infinite capacity. As in previous studies, the key point of our analysis hinges on the assumption that the time on the channel is viewed as a random succession of transmission slots (whose duration corresponds to the length of a packet) and mini-slots during which the back-off of the station is decremented. These events occur independently, with given probabilities. The state of a node is represented by a two-dimensional Markov chain in discrete-time, formed by the back-off counter and the number of packets at the station. Two models are proposed both of which are shown to cope reasonably well with the physical principles of the protocol. Stability (ergodicity) conditions are obtained and interpreted in terms of maximum throughput. Several approximations related to these models are also discussed in [44].

7.15. Belief propagation inference for traffic prediction

Participants: Cyril Furtlehner, Jean-Marc Lasgouttes.

This work [51] 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 accepted for publication in Annals of Mathematics and Artificial Intelligence [23]. Moreover, an informal collaboration has been started with the company SISTeMA ITS, in order to assess the performance of our techniques in real-world city networks.

7.16. Random Walks in Orthants

Participant: Guy Fayolle.

7.16.1. 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-Petersburg, 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 [20].

7.16.2. Second Edition of the Book Random walks in the Quarter Plane

In collaboration with R. Iasnogorodski (St-Petersburg, Russia) and V. Malyshev, we prepared the second edition of the book [3], which will be published by Springer, in the collection *Probability Theory and Stochastic Processes*. Part II of this second edition borrows specific case-studies from queueing theory, and enumerative combinatorics. Five chapters will be added, including examples and applications of the general theory to enumerative combinatorics. Among them:

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

7.17. 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.

Our setting can be seen as a resource allocation problem, known as the Transportation Problem in Operations Research literature. It is solvable using several algorithms, among which the simplex algorithm or the Hungarian algorithm. Unfortunately, these algorithms are not well-adapted here for two reasons:

- The allocation of slots to users is done on-line, 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, which is equivalent to increasing the types of customers.

We therefore present a simple heuristic approach, which is fast enough for systems with thousands of stations. Its principle 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).

This work has been presented at the ITSC'2015 conference [33].

8. Bilateral Contracts and Grants with Industry

8.1. 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.

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR

9.1.1.1. 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.

9.1.1.2. VALET

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

Instrument: ANR

Duration: January 2016 - December 2018

Coordinator: Fawzi Nashashibi

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

Inria contact: Fawzi Nashashibi

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

9.1.2. FUI

9.1.2.1. 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.

9.1.3. 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.

9.2. European Initiatives

9.2.1. FP7 & H2020 Projects

9.2.1.1. CityMobil2

Type: COOPERATION (TRANSPORTS)

Instrument: Large-scale integrating project

Duration: September 2012 - August 2016

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

Partners: 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/

9.2.1.2. Mobility2.0

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

Type: COOPERATION (TRANSPORTS)

Duration: September 2012 - February 2015

Coordinator: Broadbit (Slovakia)

Partners: 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/

9.2.1.3. DESERVE

Title: DEvelopment platform for Safe and Efficient dRiVE

Duration: September 2012 - August 2015

Coordinator: VTT (Finland)

Partners: 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: https://artemis-ia.eu/project/38-deserve.html

9.2.1.4. AutoNet2030

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

Duration: November 2013 - October 2016

Coordinator: Andras KOVACS – BROADBIT (Hungary)

Partners: 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

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

9.2.1.5. FURBOT

Title: Freight Urban RoBOTic vehicle

Type: FP7

Instrument: Specific Targeted Research Project

Duration: November 2011 - December 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.

9.2.2. Collaborations with Major European Organizations

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

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

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. See also: http://www.imobilitysupport.eu/imobility-forum/working-groups/automation

9.3. International Initiatives

9.3.1. Inria International Partners

9.3.1.1. International Academics Partners

- NAIST – Japan: RITS 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. This year RITS hosted Sakriani Watiasri Sakti, assistant professor at NAIST.
- International Chaire “Drive4U”: 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.

9.3.2. Participation In other International Programs

- ASIA-ITC (STIC-ASIE) programme: project SIM-CITIES (2015-2016), "Sustainable and Intelligent Mobility for Smart Cities", coordinated by F. Nashashibi.
  Partners: RITS, IRCCyN/CNRS, 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 MICA Lab (Vietnam). RITS and MICA lab have obtained from the Vietnamese Program 911 the financing of the joint PhD thesis of Dinh-Van Nguyen (co-directed by Eric Castelli from MICA lab and Fawzi Nashashibi).
- ECOS Nord international program: cooperation between Simon Bolivar University – Venezuela and RITS. This program started effectively in 2014 with the visit of two researchers and a PhD student from each institute to the other institute. This year, Adriana Zurita Villamizar engineer (trainee) from SBU made several months stay at RITS. She worked in the field of intelligent control.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

- **Plamen Petrov**, professor at Sofia University, Bulgaria, from July 2015 until September 2015.
- **Sakriani Watiasri Sakti**, assistant professor at NAIST, from February 2015. A part of the work done during her stay has been published in [38].

9.4.1.1. Internships

- **Aidos Ibrayev**, from Al-Farabi Kazakh National University, Kazakhstan.
- **Jose Emilio Traver Becerra and Myriam Vaca Recalde** from Universidad de Extremadura, Spain.
- **Jaycee Holmes** from Spelman College, U.S.A.
- **Adriana Zurita Villamiza** from Simon Bolivar University, Venezuela.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific events organisation

10.1.1.1. General chair, scientific chair

Vicente Milanés Montero: advisory Committee Chair at the 2015 2nd International Conference on Computer Engineering (ICOCE 2015), Dubai, UAE October 17-18 2015.

Fawzi Nashashibi: Member of the steering committee at the 1st International Workshop on Vehicular Networking and Intelligent Transportation Systems (VENITS) at the 12th IEEE CNCC'2015 conference, January 9 - 12 2015, Las Vegas, Nevada USA.

10.1.1.2. Member of the organizing committees

Fawzi Nashashibi was member of the organizing committee of the IEEE ARSO'15 (International Workshop on Advanced Robotics and its SOcial impacts).

10.1.2. Scientific events selection

10.1.2.1. Chair of conference program committees

Fawzi Nashashibi was the Chair of the Special Sessions Committee at the IEEE ARSO 2015 (International Workshop on Advanced Robotics and its SOcial impacts) workshop, 1-3 June 2015, Lyon, France.

10.1.2.2. Member of the conference program committees

Vicente Milanés Montero: member of the International technical committee and of "Los 20 Valientes" committee of IEEE-ITSC 2015; member of the International Program Committee (IPC) in the IEEE International Conference on Vehicular Electronics and Safety 2015 and in the IEEE/TRB ICCVE 2015 (the International Conference on Connected Vehicles & Expo).

Fawzi Nashashibi: member of the Awards Committee of the IEEE International Conference on Intelligent Transportation Systems (ITSC'15), September 15-18 2015, Las Palmas, Spain.
IPC member of the IEEE ARSO 2015.
Member of the scientific committee of the JNRR (French conference on Robotics Research), October 21-23 2015, Cap Hornu, France.

Oyunchimeg Shagdar: technical program committee member of the International Workshop on Vehicular Networking and Intelligent Transportation Systems (VENITS 2015), program committee member of the IEEE International Conference on Advanced Information Networking and Applications (AINA 2016).

Anne Verroust-Blondet: technical program committee member of MMEDIA 2015.

10.1.2.3. Reviewer

Jean-Marc Lasgouttes: Intelligent Vehicles Symposium (IV2015).

Pierre Merdrignac: IEEE International Conference on Intelligent Transportation Systems (ITSC 2015), IEEE International Conference on Vehicular Electronics and Safety (ICVES 2015).

10.1.3. Journal

10.1.3.1. Member of the editorial boards

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

Vicente Milanés Montero: editor-in-chief of Journal of Computer and Communications, associate Editor of Journal of Intelligent Transportation and Urban Planning and guest Editor SI of Electronics journal on Intelligent and Cooperative Vehicles, April 2015.

Fawzi Nashashibi: associate editor of IEEE Transactions on Intelligent vehicles.

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

10.1.3.2. Reviewer - Reviewing activities

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

Jean-Marc Lasgouttes: Journal of Applied Probability.

Gérard Le Lann: IEEE Communications Letters.

Vicente Milanés Montero: Journal of Dynamic Systems, Measurement and Control, Sensors, IEEE Intelligent Transportation Systems Magazine, etc.

Fawzi Nashashibi: Journal Transportation Research Part C, IJRR, IEEE Transactions on Instrumentation and Measurement, IEEE Robotics and Automation Magazine, IEEE Transactions on ITS, IEEE Transaction on Intelligent Vehicles, IEEE Robotics and Autonomous Systems, IEEE Transactions on Robotics; IEEE International Conference on Robotics and Automation (ICRA), IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), IEEE Multisensor Fusion Integration (MFI), IEEE Intelligent Transportation Systems Conference (ITSC), IEEE Int. Symposium on Intelligent Vehicles (IV).

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.

Oyunchimeg Shagdar: the IEEE Wireless Communications magazine.

Anne Verroust-Blondet: Pattern Recognition, Science Magazine.

10.1.4. Invited talks

Guy Fayolle was invited speaker and session Chairman at the Symposium Honouring Professor Erol Gelenbe, Imperial College, London 21st − 24th September 2015. He presented the paper [44].

Gérard Le Lann: "Safe Fully Automated Driving on Roads and Highways: Pie in the Sky or Future Reality?", SystemX Seminar, Palaiseau, October 20, 2015.

Fawzi Nashashibi was an invited at the ITS Wolrd Congress, Topic 6: Automated Roads, Automated Management, Automated Driving, Session II08 - "What's the science inside the autonomous vehicle", October 8, 2015, Bordeaux, France.

10.1.5. Scientific expertise

Guy Fayolle is scientific advisor at the Robotics Laboratory of Mines ParisTech. He has been working in particular on the COVADEC project (type FUI/FEDER 15), which deals with the implementation of ADAS (Advanced Driver Assistance Systems).

Vicente Milanés Montero: reviewer for UAE national projects.

Fawzi Nashashibi: expert/reviewer of Dutch and Portugese National projects.

Anne Verroust-Blondet: expert/reviewer for the French National Research Agency ("Blanc" programme of ANR) and for the Italian Ministry of Cultural Heritage and Activities (JPI Cultural Heritage program).

10.1.6. Research administration

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

Fawzi Nashashibi is a member of the international Automated Highway Board Committee of the TRB (AHB30).

Michel Parent is a member of ISO TC184 SC2 (Service Robots) and of ISO TC204 WG14 on the standards for driving assistance and full automatic driving.

Anne Verroust-Blondet is the scientific correspondent of the European affairs and of the International relations of Inria Paris-Rocquencourt. She is member of the COST-GTRI committee at Inria.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

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

Licence: Guillaume Tréhard,“C++ programming language“, 20h, L1, DUT Génie Electrique et Informatique Industrielle, IUT Chartres, France

Master: Jean-Marc Lasgouttes, “Analyse de données”, 59.5h, 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

Master: Fawzi Nashashibi, “Détection d'obstacle et fusion multicapteurs”, 4h, M2, INSA de Rouen

Master: Joshué Pérez Rastelli, "Robotique et contrôle temps réel", 15h, M1, Leonard Da Vinci University -l'ESILV- (La Defense, France), Apr-May 2015.

Master: Joshué Pérez Rastelli, "Standards for Automobiles", 30 h, M2, François Rabelais University (Tours, France), François Rabelais University (Tours, France), Feb-March 2015.

Master: Joshué Pérez Rastelli, "Digital environment and road –ITS applications-", 32.5 h, M2, Feb-March 2015.

Master: Oyunchimeg Shagdar, “Nouvelles technologies de communication”, 32h, M2, University Versailles Saint-Quentin, France.

Master: Guillaume Tréhard, “C++ programming language“, M1, 20h, Paris 8 University, France

Master: Vicente Milanés Montero and Anne Verroust-Blondet, "Le véhicule autonome. Présentation des recherches de l'équipe-projet RITS",1.5 h, 2nd year, Ecole des Ponts ParisTech, France, Sept. 2015.

10.2.2. Supervision

PhD : Pierre Merdrignac, "Système coopératif de perception et de communication pour la protection des usagers vulnérables", Mines ParisTech, October 2015, supervisor: Fawzi Nashashibi, co-supervisor: Oyunchimeg Shagdar.

PhD : Sofiene Mouine, "Identification d'espèces végétales par une description géométrique locale d'images de feuilles", Télécom ParisTech, April 2015, supervisor: Anne Verroust-Blondet, co-supervisor:Itheri Yahiaoui.

PhD : Zahraa Yasseen, "Garment Design and Shape description for Sketch-Based Applications", Télécom ParisTech, June 2015, supervisor: Anne Verroust-Blondet, co-supervisor: Ahmad Nasri.

PhD in progress : Mohammad Abu Alhoul, “Communications par lumière visible et communications radio pour La Conduite Automatique”, Mines ParisTech, September 2013, 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, October 2014, supervisor: Anne Verroust-Blondet, co-supervisor: Guillaume Bresson.

PhD in progress : Younes Bouchaala, “Utilisation de la communication véhicule-à-véhicule pour l'amélioration de la sécurité sur la route”, Université de Versailles, October 2014, supervisor: Paul Muhlethaler, co-supervisor: Oyunchimeg Shagdar.

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, January 2014, supervisor: Fawzi Nashashibi, co-supervisor: Joshué Pérez-Rastelli.

PhD in progress : Fernando Garrido, “Optimal trajectory generation for autonomous vehicles in smart cities” , Mines ParisTech, November 2014, supervisor: Fawzi Nashashibi, co-supervisor: Joshué Pérez-Rastelli.

PhD in progress : Mohamed Yassine Maddouri, "Intégration multi-sensorielle multi-capteurs pour la protection des personnes vulnérables", January 2015, supervisor: Abelaziz Bensrhair, co-supervisor: Fawzi Nashashibi.

PhD in progress : Francisco Navas Matos, “Synthesis of stable control algorithms for dynamic multi-input plants”, Mines ParisTech, October 2015, supervisor: Fawzi Nashashibi, co-supervisor: Vicente Milanés Montero.

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

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

PhD in progress : Guillaume Trehard, “Gestion des intersections pour la conduite urbaine autonome”, Mines ParisTech, October 2012, supervisor: Fawzi Nashashibi, co-supervisor: Evangeline Pollard.

10.2.3. Juries

Fawzi Nashashibi was a reviewer of the following HDR defense:

Jean-Philippe LAUFFENBURGER, "Vers l’autonomie des véhicules routiers : de la commande des systèmes à la perception de l’environnement", Université de Haute-Alsace, Mulhouse, defended on December 7th, 2015.

Fawzi Nashashibi was a reviewer of the following PdD thesis defense:

Alan ALI, "Modélisation et commande d’un convoi de véhicules urbains", Ecole Centrale de Nantes, September 21, 2015.

José Miguel VILCA-VENTURA, "Safe and Flexible Hybrid Control Architecture for the Navigation in Formation of a Group of Vehicles"’, Université Blaise Pascal-Clermont II, October 26, 2015.

Nawal ALIOUA, "Extraction et analyse des caractéristiques faciales: Application à l’hypovigilance chez le conducteur", Université de Normandie (INSA de Rouen) & Université Mohamed V du Maroc, March 23, 2015.

Wenjie LU, "Contribution à la Localisation de Véhicules Intelligents à partir de Marquages Routiers", Université de Paris Sud Orsay, February 9, 2015.

Fawzi Nashashibi was a reviewer and member of the GdR Robotique PhD thesis Award Committee. He reviewed 2 PhD thesis.

Anne Verroust-Blondet was a reviewer of the following PhD thesis defense:

Nicolas Chérin, "Modélisation géométrique à partir de croquis", Université de Haute-Alsace, Mulhouse, defended on September 23, 2015.

10.3. Popularization

As part of the week of mathematics organized by the Ministry of Education, which theme this year was “les mathématiques nous transportent”, Jean-Marc Lasgouttes presented the transportation-related research at Inria, as well of some simple traffic jam models.

Fawzi Nashashibi participated to the "Rencontres Inria Industrie" organized by Inria@SiliconValley on the topic of "Smart City and Mobility". He gave a speech on "On-demand transportation system for sustainable mobility in smart cities", May 11, San Francisco, USA.

Fawzi Nashashibi participated to a round table organized by La Recherche and Le Monde on "The vehicle of the future: which car in 10 years ?" at Arts-et-Métiers, May 28, Paris, France.

Fawzi Nashashibi participated to the round table on "Ethical and legal questions in robotics" at the 1st National day on "Ethics of digital research" organized by the CERNA at the Mines Telecom Institute, June 15, 2015, Paris, France.

Fawzi Nashashibi organized with Christian Laugier the round table on "Intelligent Mobility" at the joint Innorobo/IEEE ARSO'15 workshop day, July 2, Lyon, France.

Fawzi Nashashibi gave a presentation on "How does the climate change affect mobility and transportation ?" at Solution COP21 exhibition, Paris, December 2015. (Video Link: http://www.dailymotion.com/video/x3h8vpm)

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