



Activity Report 2013

Project-Team IMARA

Informatics, Mathematics and Automation for
La Route Automatisée

RESEARCH CENTER
Paris - Rocquencourt

THEME
Robotics

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Project-Team IMARA

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Creation of the Project-Team: 2008 July 01, end of the Project-Team: 2013 December 31.

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2. Overall Objectives

2.1. Introduction

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 and the ease of use of road transport according to the recent “Intelligent Vehicle Initiative” launched by the DG Information Society of the European Commission (for “Smarter, Cleaner, and Safer Transport”).

More specifically, we want to develop, demonstrate and test some innovative technologies under the framework of LaRA, “La Route Automatisée”¹ which covers all the advanced driver assistance systems (ADAS) and the traffic management systems going all the way to fully automated vehicles.

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

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

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

The first theme on vehicle control is broadly based on signal processing and data fusion in order to have a better machine understanding of the situation a vehicle may encounter, and on robotics techniques to control the vehicle in order to help (or replace) the driver to avoid accidents while improving the performance of the vehicle (speed, throughput, 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, IMARA 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.

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

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

2.2. Highlights of the Year

- The Grand Prix National de l'Ingénierie 2013 (Grand National Engineering Award 2013 ²) has been awarded to AKKA Technologies and Inria for the Link & Go project: the first dual-mode concept for an electric vehicle.
- Best paper award for the paper entitled "ABV- A Low Speed Automation Project to Study the Technical Feasibility of Fully Automated Driving" [41] at the workshop on Mobility Assistance and Service Robotics (November 9th, 2013, Kumamoto, Japan).
- Carrefour du PREDIT 2013 Prize: Fawzi Nashashibi was the winner of the Carrefour du PREDIT 2013 for the project SPEEDCAM he coordinated (Speed limit determination using camera and maps). The other partners of this 3-years ANR-DEUFRAKO project are: ARMINES, VALEO, DAIMLER, HOSCHULE AALEN.
- As a member of the Robotics Theme in the field "perception, cognition and interaction" at Inria, IMARA passed successfully the evaluation of the theme organized in March 2013. The evaluation committee was composed of international experts from both academia and industrial backgrounds.

3. Research Program

3.1. Vehicle guidance and autonomous navigation

Participants: Zayed Alsayed, Benjamin Lefaudeux, Hao Li, Paulo Lopes Resende, Mohamed Marouf, Pierre Merdrignac, Philippe Morignot, Fawzi Nashashibi, Joshué Pérez Rastelli, Plamen Petrov, Evangeline Pollard, Oyunchimeg Shagdar, Guillaume Tréhard.

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, Benjamin Lefaudeux, Hao Li, Paulo Lopes Resende, Pierre Merdrignac, Fawzi Nashashibi, Joshué Pérez Rastelli, Evangeline Pollard, Guillaume Tréhard.

Either for driver assistance or for fully automated guided vehicles 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.

²<http://www.cgedd.developpement-durable.gouv.fr/le-grand-prix-national-de-l-r159.html>

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 and cooperative perception.

3.1.2. 3D environment representation

Participants: Benjamin Lefaudeux, Hao Li, Fawzi Nashashibi, Paulo Lopes Resende.

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

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

Stereo vision is a reliable technique for obtaining a 3D scene representation through a pair of left and right images and it is effective for various tasks in road environments. The most important problem in stereo image processing is to find corresponding pixels from both images, leading to the so-called disparity estimation. Many autonomous vehicle navigation systems have adopted stereo vision techniques to construct disparity maps as a basic obstacle detection and avoidance mechanism. We also worked in the past on an original approach for computing the disparity field by directly formulating the problem as a constrained optimization problem in which a convex objective function is minimized under convex constraints. These constraints arise from prior knowledge and the observed data. The minimization process is carried out over the feasibility set, which corresponds to the intersection of the constraint sets. The construction of convex property sets is based on the various properties of the field to be estimated. In most stereo vision applications, the disparity map should be smooth in homogeneous areas while keeping sharp edges. This can be achieved with the help of a suitable regularization constraint. We propose to use the Total Variation information as a regularization constraint, which avoids oscillations while preserving field discontinuities around object edges.

The algorithm we developed to solve the estimation disparity problem has a block-iterative structure. This allows a wide range of constraints to be easily incorporated, possibly taking advantage of parallel computing architectures. This efficient algorithm allowed us to combine the Total Variation constraint with additional convex constraints so as to smooth homogeneous regions while preserving discontinuities.

We are presently working on an original stereo-vision based SLAM technique, aimed at reconstructing current surroundings through on-the-fly real-time localization of tens of thousands of interest points. This development should also allow detection and tracking of moving objects³, and is built on linear algebra (through Inria's Eigen library), RANSAC and multi-target tracking techniques, to quote a few.

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

3.1.3. Cooperative Multi-sensor data fusion

Participants: Benjamin Lefaudeux, Pierre Merdrignac, Fawzi Nashashibi, Hao Li, 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. IMARA 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's developments permitted the development of the basic hardware pieces that ensures the well functioning of the embedded architecture including perception sensors, communication devices and processing tools. The final architecture was relying on the *SensorHub* presented in year 2010 report and demonstrated several times in year 2011 (ITS World Congress, workshop "The automation for urban transport" in La Rochelle...)

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.

³<http://www.youtube.com/watch?v=obH9Z2uOMBI>

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

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

3.1.4. Planning and executing vehicle actions

Participants: Plamen Petrov, Joshu   P  rez Rastelli, Fawzi Nashashibi, Philippe Morignot, Paulo Lopes Resende, Mohamed Marouf.

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 manoeuvre selection process using grid-based rating technique or fuzzy technique. For high speed vehicles, Partial Motion Planning techniques we tested, revealed their limitation 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 DLR's JointSystem demonstrator used in the European project HAVEit, as well as in IMARA's electrical vehicle prototype used in the French project ABV. HAVEit was also the opportunity for IMARA 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 IMARA's cybercars. However, for the low speed cybercars that have pre-defined itineraries and basic manoeuvres, 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, IMARA is also investigating the opportunity of fuzzy-based control for specific manoeuvres. First results have been recently obtained for reference trajectory following in roundabouts and normal straight roads.

3.2. V2V and V2I Communications for ITS

Participants: Thierry Ernst, Oyunchimeg Shagdar, G  rard Le Lann, Manabu Tsukada, Younes Bouchaala, Pierre Merdrignac, Satoru Noguchi, Ines Ben Jemaa, Mohammad Abualhouf, 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, IMARA 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. In the context of IPv6, we have been tackling research issues of combinations of MANET and NEMO and Multihoming in Nested Mobile Networks with Route Optimization.

The wireless channel and topology dynamics are the characteristics that require great research challenge in 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. Multihoming in nested mobile networks with route optimization

Participants: Manabu Tsukada, Thierry Ernst.

Network mobility has the particularity of allowing recursive mobility, i.e. where a mobile node is attached to another mobile node (e.g. a PDA is attached to the in-vehicle IP network). This is referred to as nested mobility and brings a number of research issues in terms of routing efficiency. Another issue under such mobility configurations is the availability of multiple paths to the Internet (still in the same example, the PDA has a 3G interface and the in-vehicle network has some dedicated access to the Internet) and its appropriate selection.

3.2.2. Service discovery

Participants: Satoru Noguchi, Thierry Ernst.

Vehicles in a close vicinity need to discover what information can be made available to other vehicles (e.g. road traffic conditions, safety notification for collision avoidance). We are investigating both push and pull approaches and the ability of these mechanisms to scale to a large number of vehicles and services on offer.

3.2.3. Geographic multicast addressing and routing

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

Many ITS applications such as fleet management require multicast data delivery. Existing works on this subject tackle 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) to ensure vehicular multicast group reachability through the infrastructure network, defines a distributed and efficient geographic multicast auto-addressing mechanism, and ii) to allow simple and efficient data delivery, introduces a simplified approach that locally manages the group membership and distributes the packets among them.

3.2.4. Platooning control using visible light communications

Participants: Mohammad Abualhoul, Mohamed Marouf, Oyunchimeg Shagdar, Fawzi Nashashibi.

The main purpose of our research is to propose and test new successful supportive communication technology, which can provide stable and reliable communication between vehicles, especially for the platooning scenario. Although that VLC technology has a short history in comparing with other communication technologies, the infrastructure availability and the presence of the congestion in wireless communication channels are proposing VLC technology as reliable and supportive technology which can takeoff some loads of the wireless radio communication. First objective of this work is to develop an analytical model of VLC to understand its characteristics and limitation. 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 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 to the main Simulink platooning model will be responsible for deciding the availability of the Line-of-Sight for different trajectory's curvatures, which mean 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.

3.2.5. V2X radio communications for road safety applications

Participants: Mohammad Abualhoul, Younes Bouchaala, Pierre Merdrignac, Oyunchimeg Shagdar.

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

3.3. Automated driving, intelligent vehicular networks, and safety

Participant: Gérard Le Lann.

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

3.3.1. Cohorts and groups – Novel constructs for safe IVNs

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

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

Vehicle motions on roads and highways obey two different regimes. First, stationary regimes, where inter-vehicular spacing, acceleration and deceleration rates (among other parameters), match specified bounds. This, combined with N2N communications, has led to the concept of cohorts, where safety is not at stake provided that no violation of bounds occurs. Second, transitory regimes, where some of these bounds are violated (e.g., sudden braking – the “brick wall” paradigm), or where vehicles undertake risk-prone maneuvers such as lane changes, resulting into SC scenarios. Reasoning about SC scenarios has led to the concept of groups. Cohorts and groups have been introduced in [7].

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

In [7] we show how periodic N2N beaconing serves to withstand failures of directional telemetry devices. Worst-case bounds on safe inter-vehicular spacing are established analytically (simulations cannot be used for establishing worst-case bounds). A result of practical interest is the ability to answer the following question: “vehicles move at high speed in a cohort formation; if in a platoon formation, spacing would be in the order of 3 m; what is the additional safe spacing in a cohort?” With a N2N beaconing period in the range of 100-200 ms, the additional spacing is much less than 1 m. Failure of a N2N communication link translates into a cohort split, one of the vehicles impaired becoming the tail of a cohort, and its (impaired) follower becoming the head of a newly formed cohort. The number of vehicles in a cohort has an upper bound, and the inter-cohort spacing has a lower bound.

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

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

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

Groups and cohorts have proved to be essential constructs for devising a solution for problem TBD. Vehicles involved in a SC scenario form a group where a 3-way handshake is unfolded so as to reach an agreement regarding roles and adjusted motions. A 3-way handshake consists in 3 rounds of V2V Xcasting of SC messages, round 1 being a Geocast, round 2 being a Convergecast, and round 3 being a Multicast. Worst-case time bound for completing a 3-way handshake successfully is in the order of 200 ms, under worst-case conditions. It is well known that message losses are the dominant cause of failures in mobile wireless networks, which raises the following problem with the Xcasting of SC messages. If acknowledgments are not used, it is impossible to predict probabilities for successful deliveries, which is antagonistic with demonstrating safety. Asking for acknowledgments is a non solution. Firstly, by definition, vehicles that are to be reached by a Geocast are unknown to a sender. How can a sender know which acknowledgments to wait for? Secondly, repeating a SC message that has been lost on a radio channel does not necessarily increase chances of successful delivery. Indeed, radio interferences (causing the first transmission loss) may well last longer than 200 ms (or seconds). To be realistic, one is led to consider a novel and extremely powerful (adversary) failure model (denoted Ω), namely the restricted unbounded omission model, whereby messages meant to circulate on f out of n radio links are “erased” by the adversary (the same f links), ad infinitum. Moreover, we have assumed message loss ratios f/n as high as $2/3$. This is the setting we have considered in [56], where we present a solution for the fast (less than 200 ms) reliable (in the presence of Ω) multipoint communications problem TBD. The solution consists in a suite of Xcast protocols (the Zebra suite) and proxy sets built out of cohorts. Analytical expressions are given for the worst-case time bounds for each of the Zebra protocols.

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

3.4. Managing the system (via probabilistic modeling)

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

The research on the management of the transportation system is a natural continuation of the research of the Preval team, which joined IMARA in 2007. For many years, the members of this team (and of its ancestor Meval) have been working on understanding random systems of various origins, mainly through the definition and solution of mathematical models. The traffic modeling field is very fertile in difficult problems, and it has been part of the activities of the members of Preval since the times of the Praxitèle project.

Following this tradition, the roadmap of the group is to pursue basic research on probabilistic modeling with a clear slant on applications related to LaRA activities. A particular effort is made to publicize our results among the traffic analysis community, and to implement our algorithms whenever it makes sense to use them in traffic management. Of course, as aforementioned, these activities in no way preclude the continuation of the methodological work achieved in the group for many years in various fields: random walks in Z_+^n ([1], [2], [5]), large deviations, birth and death processes on trees, particle systems.

In practice, the group explores the links between large random systems and statistical physics, since this approach proves very powerful, both for macroscopic (fleet management [4]) and microscopic (car-level description of traffic, formation of jams) analysis. The general setting is mathematical modeling of large systems (mostly stochastic), without any a priori restriction: networks [3], random graphs or even objects coming from biology. When the size or the volume of those structures grows (this corresponds to the so-called thermodynamical limit), one aims at establishing a classification based on criteria of a twofold nature: quantitative (performance, throughput, etc) and qualitative (stability, asymptotic behavior, phase transition, complexity).

3.4.1. Exclusion processes

One of the simplest basic (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.

Most of these generalizations lead to models that are obviously difficult to solve and require upstream theoretical studies. Some of these models have already been investigated by members of the group, and they are part of wide ongoing researches.

3.4.2. Message passing algorithms

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. Using the Ising model, together with the Belief Propagation (BP) algorithm very popular in the computer science community, 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 properties of the Bethe approximation of Ising models:

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

3.4.3. Statistical physics and hydrodynamic limits

These last years, having in mind a global project concerning the analysis of complex systems, we did focus on the interplay between discrete and continuous description: in some cases, this recurrent question can be addressed quite rigorously via probabilistic methods (see e.g. [52]).

To describe the systems of interest, which are in touch with many application domains, we started from *paradigmatic* elements, namely discrete curves subject to stochastic deformations. Up to some convenient mappings, it appears that most models can be set in terms of interacting exclusion processes, the ultimate goal being to derive *hydrodynamic limits* after proper scalings.

The key ideas can be found in [53], where the basic ASEP system on the torus is the toy model. In this case, the usual sequence of empirical measures, converges in probability to a deterministic measure, which is the unique weak solution of a Cauchy problem.

The Gordian knot is indeed the analysis of a family of specific partial differential operators in infinite dimension. Indeed, the values of functions at given points play here the role of usual variables, their number becoming infinite. The method presents some new theoretical features, involving path integrals, promeasures (as introduced by Bourbaki), variational calculus, and the construction of *generalized measures*. In [53], we present a detailed analysis of the ASEP system on the torus $\mathbb{Z}/N\mathbb{Z}$. Then, we claim that most of the arguments a priori for multi-type exclusion processes, and should lead to systems of coupled partial differential equations of Burgers' type. At the moment, this claim is being proved for the famous ABC model, reformulated in terms of the dynamics of a random walk on the triangular lattice.

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. IMARA 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 IMARA this year. First, we have stabilized a generic Cycab architecture involving Inria Syndex tool and CAN communications. The critical part of the vehicle is using a real-time Syndex application controlling the actuators via two Motorola's MPC555. Today, we have decided to migrate to the new dsPIC architecture for more efficiency and ease of use.

This application has a second feature, it can receive commands from an external source (Asynchronously this time) on a second CAN bus. This external source can be a PC or a dedicated CPU, we call it high level. To work on the high level, in the past years we have been developing a R&D framework called (Taxi) which used to take control of the vehicle (Cycab and Yamaha) and process data such as gyro, GPS, cameras, wireless communications and so on. 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 HIPERCOM team for setting and tuning OLSR, a dynamic routing protocol for vehicles communications (see Section 3.2). 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. Software and Platforms

5.1. MELOSYM

Participants: Fawzi Nashashibi [correspondant], Benjamin Lefaudeux, Paulo Lopes Resende.

MELOSYM is the acronym for “**M**odélisation de l’**E**nvironnement et **L**ocalisation en temps réel pour un **S**ystème **M**obile autonome ou pas, fondé sur des données du capteur laser”. This is a SLAM based algorithm for the environment mapping and vehicle localization in real-time using laser data. The particularity of the algorithm is its hierarchical approach that improves the accuracy of the system and speeds up the computations. Version 3 is under edition. It runs now in standalone mode without the use of RTMaps software libraries.

- Version: V2

5.2. Stereoloc-3D

Participants: Benjamin Lefaudeux, Fawzi Nashashibi [correspondant].

This software is a stereovision based system capable of performing a vehicle or robot ego-localization and 3D environment mapping in real-time. It has also the capability to ensure mobile objects detection and tracking. A new updated version has been released and tested on a mobile platform.

- Version: V1

5.3. Fuzzy logic tool

Participant: Joshué Pérez Rastelli [correspondant].

A fuzzy logic module has been implemented to translate human knowledge to driverless control processes, considering risk/warning situation. Fuzzy logic techniques have been widely implemented in different industrial process in the last decade. For this reason, many libraries, mainly developed in C++, are easily found in the literature. The goal is to achieve the autonomous driving of the vehicle using simple sentences defined in a rule base. Then, it is just necessary to define the input and output membership functions. Two modules based on fuzzy logic libraries were created. One of them was developed in order to compare the classic controller of a previous work with a fuzzy controller to improve the lateral control tracking previously developed. Moreover, another module to warn speed references at intersections with traffic lights was done in the framework of the project CoDrive. The idea is that the vehicle is able to know at which speed it must travel to avoid abrupt braking and save fuel.

5.4. Dynamic path generation

Participant: Joshué Pérez Rastelli [correspondant].

An algorithm for dynamic path generation in urban environments is presented, taking into account structural and sudden changes in straight and bend segments (e.g. roundabouts and intersections). The results present some improvements in path generation (previously hand plotted) considering parametric equations and continuous-curvature algorithms, which guarantees a comfortable lateral acceleration. This work is focused in a smooth and safe path generation using road and obstacle detection information. Finally, some simulation results show a good performance of the algorithm using different ranges of urban curves.

5.5. V2ProVu

Participants: Pierre Merdrignac, Oyunchimeg Shagdar [correspondant].

A Java-based software is developed to enable direct Wi-Fi communications between devices, especially between vehicle on-board communication devices and pedestrian hand-held devices (e.g., tablets). The software includes an algorithm that calculates vehicle-to-pedestrian collision risk and GUI, for hazard alarming.

5.6. Network Selector

Participant: Oyunchimeg Shagdar [correspondant].

An OSGi based software is developed under the scope of SCORE@F project. The software has the functionality of switching between Geo- and IP-networks in vehicular communications allowing e.g., Cooperative Awareness Messages (CAM) as well as Decentralized Event Notification Messages (DENM) being able distributed over one or both of the Geo- and IP-networks.

5.7. FAC-CM

Participant: Manabu Tsukada [correspondant].

An OSGi based software is developed under the scope of SCORE@F project. The software allows information exchange between Facilities and Management entities of ITS stations (e.g., vehicle on-board communication device).

6. New Results

6.1. ABV

Participants: Hao Li, Paulo Lopes Resende, Evangeline Pollard, Joshu   P  rez Rastelli, Fawzi Nashashibi.

The ABV project builds on the HAVEit philosophy (a previous IMARA project for high speed automation) by offering higher levels of automation on highways and organizing the cooperation between human and system along novel automation levels. It differs from HAVEit by focusing on congested traffic at speeds below 50 km/h and adding fully automated driving to the automation spectrum. By automatically following congested traffic, the ABV system relieves the human driver from monotonous tasks. During fully automated driving, the human driver is not required to monitor the system, but has to take over control at the end of the application zone. Real experiments on a prototype vehicle have been conducted. The experiment objective was to realize several use-cases: lane following, changing of lane, overtaking, ACC and emergency braking. All these maneuvers have been successfully conducted several times on the Satory tracks (cf. [46], [41] for more details) during the final event of the project which took place late March 2013.

6.2. Urban Autonomous Driving

Participants: Evangeline Pollard, Guillaume Tr  hard, Fawzi Nashashibi.

Beyond low speed automation, IMARA is tackling a very important issue for autonomous driving on open roads, which is: dealing with intersections. In collaboration with Valeo, Imara wants to provide innovative way to safely cross any kind of intersections for an autonomous vehicle in a urban context and without communication. The goal is to deal with intersection with different shapes, (roundabout, T junctions , X junctions, *etc.*), with different rules, specific (traffic lights, main road...) or not ("priority to the right" in France), with different traffic (busy or empty).

6.3. Vehicle to pedestrian communications

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

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

6.4. Visible light communications for platooning control

Participants: Mohammad Abualhoul, Oyunchimeg Shagdar, Mohamed Marouf, Fawzi Nashashibi.

While V2V communications is requisite for platooning stability, the existing radio communications technologies suffer from poor performance in highly dense road scenarios, which are exactly to be created for platooning. Targeting this issue, we study the applicability of visible light communications (VLC) for information exchange between the platoon members [20], [35]. Because the existing studies on VLC mainly focus on indoor applications or for communications from traffic light to vehicle, the performances of VLC for V2V is not clear. In this work, we develop a complete VLC channel and noise model by taking account of the key parameters including background noise and incidence angle. Our studies show that it is feasible to achieve up to 7 meters line of sight communication range even in the presence of optical noise at significant levels and with up to 60 degree of road curvature.

6.5. ITS-G5 for road safety and efficiency applications

Participants: Oyunchimeg Shagdar, Younes Bouchaala, Mohammad Abualhoul, Manabu Tsukada, Thierry Ernst.

To support V2V and V2I communications for road safety and efficiency applications, ETSI standardized ITS-G5 technology. One of key objectives of the SCORE@F project is to study the performance of ITS-G5 in real-world scenarios and demonstrate its applicability to road safety and efficiency applications. Under the scope of the SCORE@F project, we studied the performances of ITS-G5 for both the V2V and V2I communications based on field tests and theoretical studies with emphasis on the effects of channel in combination with MAC and some parameters of car traffic [32]. An important insight achieved from the study is that in addition to the distance dependent pathloss, the signal fading and road traffic characteristics provide significant impacts on the reliability of ITS-G5.

We also study the performance of the ITS-G5 medium access control protocol for realistic autonomous driving applications especially to seek answers to the questions of whether the IEEE 802.11p can support merging control and how the communications performance is translated into that of CACC (Cooperative Adaptive Cruise Control) [33]. The study discloses several useful insights including packet inter-arrival time and throughput but not packet delivery ratio, gives good indications of the CACC performance; the V2I communications structure is preferred over the V2V structure for CACC.

Finally, we demonstrate the low latency video streaming over ITS-G5 to support platoon and reverse parking maneuvers [21].

6.6. Cooperative driving

Participants: Joshué Pérez Rastelli, Fawzi Nashashibi.

In the scope of the French project “*Co-Drive*” one task assigned to Inria was the development of a smart controller capable of driving the vehicle, allowing it to perform optimal traversal of traffic lights in order to reduce vehicle accelerations and thus the gas emissions. This controller needs remote information regarding the traffic lights’ status, the distance to it and the time needed to reach it.

Three input variables, which are the traffic light times, red light, green light and the distance to interception (DTI), were defined in fuzzy logic tool [37].

Two variables are used for the traffic light (Red and Green), where each of them has defined two completely symmetrical membership functions covering all the possible inputs. In this application the time cycle of the lights are 30 seconds for green and 20 seconds for red. The values of input membership functions were defined considering these times.

The DTI membership function (see Figure 1) gives more weight to the distance when the vehicle is closer at the intersection. In this situation, the vehicle can be inside the *short* or the *middle* label, because in these cases the response has to be faster than in the case where the vehicle is in the *long* label. The cross rule base, based on driver knowledge when the vehicle is arriving to an intersection, are defined using natural language.

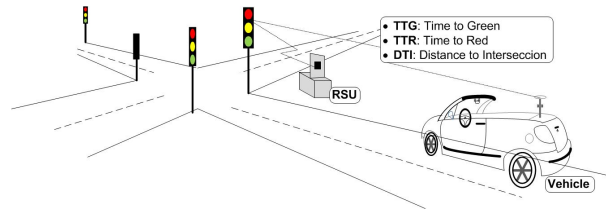


Figure 1. Codrive: input variables for the speed reference fuzzy controller

Some Simulations were performed to validate the controller. However, the final implementation will be presented in 2014 during the final event of Co-Drive Project.

6.7. Intelligent Planning algorithm using Bezier curves

Participants: Joshué Pérez Rastelli, Fawzi Nashashibi.

The Bezier curve is the heart of the Local Planning, which allows a fast trajectory computation in order to send the trajectory in real-time to the controller stage. This method has been recently used in robot mobile solutions due to its versatility and simplicity for intersections.

We have proposed a novel method for the generation of control points for two distinct road configurations: roundabouts and a standard intersections. If an intersection is being dealt with, the control points will be generated based on the reference path given by the Global Planner.

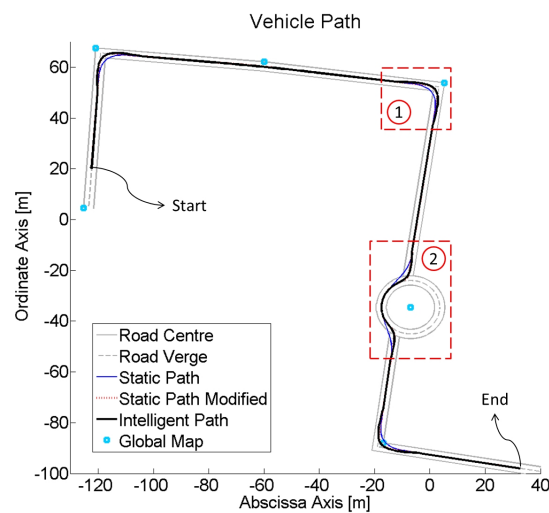


Figure 2. Generated path using different methods

The experiments we made presented several urban intersections. Figure 2 shows the whole generated path with four intersections and a roundabout, using the global map. A comparison with different methods is drawn. The first one (thin line) is based on the static method used in [22], which sets the control points by hand. In this case

we can see how sometimes the path passes over the sidewalk. The second experiment (dotted line) is using the same previous method, but modifying the distance used to position the control points, in order to obtain a path into the road. The third method (thick line) is the Intelligent Planning algorithm. As we can see in the figure, the automatic algorithm sets the control points of Bezier (based on the convex hull property) achieving a smooth path, without going over sidewalks or obstacles.

6.8. Ontologies

Participants: Evangeline Pollard, Philippe Morignot, Fawzi Nashashibi.

Full autonomy of ground vehicles is a major goal of the ITS (Intelligent Transportation Systems) community. However, reaching such highest autonomy level in all situations (weather, traffic, . . .) is seen as impossible in practice, despite recent results regarding driverless cars (e.g., Google Cars). In addition, an automated vehicle should also self-assess its own perception abilities, and not only perceive its environment. In this new research axis, we propose an intermediate approach towards full automation, by defining a spectrum of automation levels, from fully manual (the car is driven by a driver) to fully automated (the car is driven by a computer), based on an ontological model for representing knowledge. We also propose a second ontology for situation assessment (what does the automated car perceive?), including the sensors/actuators state, environmental conditions and driver's state. Finally, we also define inference rules to link the situation assessment ontology to the automation level one [24].

6.9. Communications and Management Control for Cooperative Vehicular Systems

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

One of the attractive applications of electric autonomous vehicles is electric automated Car Sharing service, where on-demand passenger transportation is provided by a set of automated vehicles and a control center, which is installed in the Internet. Data transmission from the control center to the set of vehicles requires an efficient multicast data delivery, i.e. multi-cast routing. The conventional multicast routing in the Internet is based on protocols such as Protocol Independent Multicast (PIM), which relies on a tree structure to deliver packets from the source to the destinations. Thanks to the fixed topology of the Internet, it is possible to build a large and stable multicast trees. However, due to the highly mobile nature of vehicular networks, it is not clear how stable and large can be such trees in vehicular environments. This year, we studied the stability of multicast trees for data flows from the Internet to a set of vehicles [38], [36]. Our study shows that the stability of multicast tree largely depends on the relative velocity (inter-vehicle) and the road density but not directly on the road shape or moving direction. Based on our study we are developing a mobility aware multicast routing protocol, which constructs its tree based on the vehicles' mobility dynamics and the road condition.

6.10. New urban transportation platforms: Inria's Cybus

Participants: François Charlot, Joshué Pérez Rastelli, Fawzi Nashashibi, Paulo Lopes Resende, Michel Parent, Armand Yvet.

Cybus is the best known prototyping and demonstration platform designed at Inria. Apart from the chassis and engines, the whole hardware and software systems were developed thanks to IMARA's researchers and engineers talents. These electric vehicles are based on a Yamaha chassis but the embedded intelligence is the result of two years of development.

Much of the perception and control software has been improved. New guidance functionalities were developed this year, mainly with the introduction of stereovision-based SLAM, and Bezier curve in path planning generation. The platforms developed here (*Cybus*) will be demonstrated in the context of the EU CityMobil-2 project. This time real operational mobility services demonstrations will be extended to 6-12 months in selected European cities! Other showcases are expected to take place in Asian cities in 2014.



Figure 3. The Cybus operated at La Rochelle City during 3 months as a free transport service.

6.11. Real-time visual perception: detection and localization of static and moving objects from a moving stereo rig

Participants: Benjamin Lefaudeux, Fawzi Nashashibi.

Perception of the surrounding environment is one of the many tasks an automated vehicle has to achieve in complex and ever-changing surroundings. This, typically includes several distinct sub-tasks, such as map-building, localization, static obstacles and moving objects detection and identification. Some of these tasks are nowadays very well known, such as the map-building process which has been extensively investigated in the last decade ; whereas the perception, localization and classification of moving objects from an equally moving vehicle are in many aspects a work in progress. The objective of the PhD thesis of Benjamin Lefaudeux was to propose a vision-based approach built on the extensive tracking of numerous visual features over time, from a stereo-vision pair.

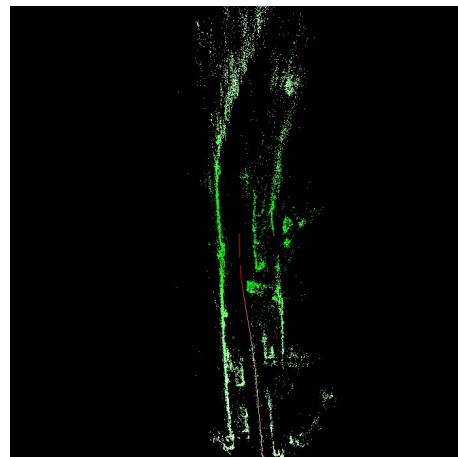


Figure 4. Left: A single camera view from the KITTI sequence. Right: A bird view of the scene as modeled by the system: point cloud and estimated trajectory.

Through on-the-fly environment 3D reconstruction, based on visual clues, we proposed an integrated method to detect and localize static and moving obstacles, whose position, orientation and speed vector is estimated. Our implementation runs in real-time depending on the number of processed points, and should in the future be enclosed in a more complete, probabilistic pipeline. The complete achievements are described in the thesis of Benjamin Lefaudeux ([8] defended on September 30th) with very interesting and competitive results obtained with international benchmarks (cf. Figure 4) and on the real vehicles of IMARA.

6.12. Belief propagation inference for traffic prediction

Participants: Cyril Furtlehner, Jean-Marc Lasgouttes, Victorin Martin.

This work [55] 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's highlights are

- Victorin Martin has defended his PhD thesis entitled “Modélisation probabiliste et inférence par l’algorithme Belief Propagation” [9] at Mines-ParisTech on May 23.
- The work about the theoretical aspects of encoding real valued variables into a binary Ising model has been published as a research report [44] and submitted for publication.

6.13. Sparse covariance inverse estimate for Gaussian Markov Random Field

Participants: Cyril Furtlehner, Jean-Marc Lasgouttes, Victorin Martin.

We investigate the problem of Gaussian Markov random field (GMRF) selection under the constraint that the model is suitable for Gaussian belief propagation (GaBP) inference. We develop a method based on iterative proportional scaling (IPS) to incrementally select optimal GMRF factors, while maintaining GaBP compatibility. Besides the intrinsic sparsity-inducing capability, the proposed method is indeed sufficiently flexible to incorporate various spectral constraints like e.g. walk summability (WS) to insure the compatibility of the solutions with Gaussian Belief Propagation inference. Experimental tests on various datasets with refined L_0 or L_1 regularized sparse inverse estimate indicate that this approach is competitive and provides us with useful alternatives to traditional sparsity-inducing penalizations norms, giving more freedom in the graph structure selection process with no additional computational cost.

6.14. Evaluation of dual mode transport system by event-driven simulation

Participants: Arnaud de La Fortelle, Jean-Marc Lasgouttes, Thomas Liennard.

The European project CATS — City Alternative Transport System — is developing and evaluating a new vehicle system using a single type of vehicle for two different usages: individual use or collective transport. Real experiments will necessarily take place with a limited number of vehicles and stations. Hence, there is a need for evaluation using simulations.

We are developing a discrete events simulator for that purpose, which model relies on an adapted events/decision graph. The new feature of this model is the way we deal with two modes that can be extended to many other modes. This work therefore shows on a concrete example a method to efficiently merge multiple modes into one model.

This year has seen a partial rewrite of the simulator in order to make it more generic and handle the new setting of the CATS project with automated vehicles.

6.15. Herding behavior in a social game

Participants: Guy Fayolle, Jean-Marc Lasgouttes.

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

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

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

The work has been published this year in *Queueing Systems* [11].

6.16. Analytic properties of random walks in the quarter plane

Participant: Guy Fayolle.

In collaboration with K. Raschel (CNRS, Université F. Rabelais à Tours), we pursued the works initiated these last three years in two main directions.

6.16.1. The group and zero drift case

In several recent studies on random walks with small jumps in the quarter plane, 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*. When the *drift* of the random walk is equal to 0, we have provided an effective criterion (see RA 2012) giving the order of this group. More generally, we showed that in all cases where the *genus* of the algebraic curve defined by the so-called *kernel* is 0, the group is infinite, except precisely for the zero drift case, where finiteness is quite possible.

This year, we investigated new proofs of this results, which could lead to an explicit tractable criterion for the finiteness of the group, which a priori, as shown in [2] involves a ratio of elliptic integrals.

6.16.2. Counting and asymptotics

The enumeration of planar lattice walks is a classical topic in combinatorics. For a given set \mathcal{S} of allowed unit 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.

Like in the probabilistic context, a common way of attacking these problems relies on the following analytic approach. 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 . In the case of small jumps (size at most one), the corresponding CGF

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

satisfies the functional equation

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

where x, y, z are complex variables, $K(x, y, z)$ is a polynomial of degree 2 (both in x and y), and linear in the time variable z which plays somehow the role of a parameter. The question of the type of the associated counting generating functions, rational, algebraic, or holonomic (i.e. solution of a linear differential equation with polynomial coefficients), was solved whenever the group is *finite* (see RA 2010). When the group is infinite, the problem is still largely open.

The nature of the singularities of the function F plays a key role for this classification. Starting from our study [54], we proved in various cases that the first singularities of $F(1,0,z)$ are either polar or correspond to a value z_g for which the genus of the algebraic curve $K(x, y, z) = 0$ passes from 1 to 0 (i.e. a torus becomes a sphere).

6.16.3. Harmonic functions and more general jumps

The determination of Martin boundaries in the case of random walks is a longstanding problem, solved only in special situations. For homogeneous random walks in the quarter plane, stopped on the boundary (the axes), with upward jumps of size 1, and arbitrary downward jumps of size d , it turns out that the computation of harmonic functions is here plainly equivalent to find a positive function H satisfying a functional equation of the form

$$L(x, y)H(x, y) = L(x, 0)H(x, 0) + L(0, y)H(0, y) - L(0, 0)H(0, 0).$$

Here the chief difficulty to make the reduction to a boundary value problem is to analyze the algebraic curve $L(x, y) = 0$, which might be of arbitrary genus. Some examples lead us to conjecture the existence of a *single real cut* inside the unit disk, which should allow to get integral form solution.

6.16.4. Correction of papers

Guy Fayolle found important errors in several articles dealing with models involving random walks in the quarter plane. This is the object of the letter to the editors [10]. The Concerned authors are currently preparing corrected versions.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

- Valeo – "Driver Monitoring". Objective: achieve the state of the art of existing devices, algorithms and systems performing driver monitoring in real-time with embedded sensors.
- ADM Concept – "TRANS'YVES: Valet de Parking Automatisé". Two objectives: realize the control boards of the steering and the acceleration pedal of an automated vehicle, realize the automated valet using a single camera for vehicle guidance in a parking.
- AXTER Automation – "Laser-based navigation in industrial plants". Confidential.
- Valeo – "V50 project". Objective: dealing with intersection by an automated vehicle using on-board perception. This is the framework of the PhD thesis of Guillaume Tréhard.

8. Partnerships and Cooperations

8.1. Regional Initiatives

The Yvelines General Council has designated the winners of its second call for projects "Intelligent Car - City of the Future". Following a selection made by a jury, the winners were four consortia. IMARA was involved in two of the four winning projects: TRANS'YVES, coordinated by ADM Concept, and Link & Go coordinated by AKKA Technologies (with Controlsys, Inria and DBT) project. The Yvelines department wanted to promote the emergence of projects on sustainable development and automated driving with electric vehicles. On four projects selected, two of them are just referring to a concept of automatic parking, the vehicle comes to park all alone with no one on board. The call for proposals with a budget of 3 million Euros has been used to finance demonstrators that were exhibited at the Geneva Motor Show in 2013 as part of the Green Pavilion.

Link & Go was coordinated has been awarded the prestigious 2013 Grand National Engineering Award.

8.2. National Initiatives

8.2.1. ANR

8.2.1.1. ABV

Title: Automatisation basse vitesse

Instrument: ANR

Duration: January 2009 - April 2013

Coordinator: IFFSTAR

Others partners: Continental, IBISC, IEF, Induct, Inria, LAMIH, Vismetris, UHA-MIPS, Veolia Environnement

See also: <http://www.projet-abv.fr/>

Abstract: This ambitious project aims at demonstrating automated driving at low speed in urban areas and on peri-urban roads. The aim is to demonstrate the technical feasibility of automating driving at low speeds, typically in situations of congestion or heavy traffic.

8.2.1.2. SCORE@F

Title: Système COopératif Routier Expérimental Français

Instrument: FUI

Duration: 2010-2013

Coordinator: Renault-REGIENOV

Others partners: UTAC, LAB, EURECOM, IFSTTAR, Inria, Télécom Ecole de Management

See also: <http://www.scoref.fr/>

Abstract: SCORE@F (French Experimental Road Cooperative System) is a collaborative research project, experimental road cooperative systems as part of a European framework for experimentation. The SCORE@F is intended to prepare the deployment of "road cooperative systems" on motorways and other road environments through the implementation of operational tests in an open environment. Road cooperative systems are based on wireless local communication between vehicles and road infrastructure (V2I - I2V) and between vehicles (V2V). The deployment of cooperative systems will be strongly influenced by road Framework Directive of the European Commission ITS.

8.2.1.3. COCOVEA

Title: Coopération Conducteur-Véhicule Automatisé

Instrument: ANR

Duration: 01/11/2013 – 30/04/2017

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

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

Inria contact: Fawzi Nashashibi

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

8.2.2. Competitivity Clusters

IMARA team is a very active partner in the competitiveness clusters, especially MOV'EO and System@tic. We are involved in several technical committees like the DAS SUR of MOV'EO for example. IMARA is also the main Inria contributor in the VeDeCoM institute (IEED). VeDeCoM is financing a PhD thesis of Pierre Merdrignac; his scientific research topic is on the fusion of perception and communication for pedestrian assistance, monitoring and tracking.

8.3. European Initiatives

8.3.1. FP7 Projects

8.3.1.1. DRIVE C2X

Type: COOPERATION

Defi: Driving implementation of car 2 x communication technology

Instrument: Integrated Project

Objectif: ICT for Mobility of the Future

Duration: January 2011 - December 2013

Coordinator: DAIMLER AG (Germany)

Partner: 31 partners from automotive industry, electronic and supplier industry, software development, traffic engineering, research institutes and road operators.

Inria contact: Thierry Ernst

Abstract: With 31 partners, 15 support partners and 18.8 million Euro budget, DRIVE C2X will lay the foundation for rolling out cooperative systems in Europe. Hence, lead to a safer, more economical and more ecological driving.

8.3.1.2. ITSSV6

Type: COOPERATION

Defi: IPV6 ITS Station Stack for Cooperative Systems FOTs

Instrument: Specific Targeted Research Project

Objectif: ICT for Mobility of the Future

Duration: February 2011 - January 2014

Coordinator: Inria (France)

Partner: Universidad de Murcia (Spain), Institut Télécom (France), Mines ParisTech (France), Inria (France), Lesswire (Germany), SZTAKI (Hungary), IPTE (Austria), BlueTechnix (Austria).

Inria contact: Thierry Ernst

Abstract: ITSSv6 builds on the base of existing standards from ETSI, ISO and IETF and IPv6 software available from CVIS and GeoNet projects. Its main objective is to deliver an optimized IPv6.

See also: <http://itssv6.inria.fr/>

8.3.1.3. SANDRA

Type: COOPERATION

Instrument: Integrated Project

Objectif: NC

Duration: October 2009 - September 2013

Coordinator: SELEX ES SPA (Italy)

Partner: Acreo (Sweden), Airtel ATN (Ireland), Alenia Aermacchi (Italy), Altys (France), Bradford University (United Kingdom), Cyner (Netherlands), Dassault Aviation (France), Deutsche Flugsicherung GmbH (Germany), Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany), EADS Innovation Works (France), Gatehouse (Denmark), IMST GmbH (Germany), Inria (France), Intecs (Italy), LionixBV (Netherlands), Monitorsoft (Russian Federation), Nationaal Lucht- en Ruimtevaartlaboratorium - NLR (Netherlands), Paris Lodron Universität (Salzburg), RadioLabs (Italy), SITA (Switzerland), Slot Consulting (Hungary), Thales Aerospace (United Kingdom), Thales Alenia Space (France), Thales Avionics (France), Thales TRT-UK (United Kingdom), TriaG-noSys GmbH (Germany), University of Pisa (Italy), University of Twente (Netherlands).

Inria contact: Thierry Ernst

Abstract: The SANDRA concept consists of the integration of complex and disparate communication media into a lean and coherent architecture for aeronautical networking.

See also: <http://sandra.aero/2013/>

8.3.1.4. CATS

Title: City Alternative Transport System

Type: COOPERATION (TRANSPORTS)

Instrument: Specific Targeted Research Project (STREP)

Objectif: NC

Duration: January 2010 - December 2013

Coordinator: Lohr Industrie (France)

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

Inria contact: Michel Parent

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

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

8.3.1.5. FURBOT

Title: Architectures of Light Duty Vehicles for urban freight transport

Type: COOPERATION (TRANSPORTS)

Instrument: Specific Targeted Research Project (STREP)

Objectif: NC

Duration: November 2011 - October 2014

Coordinator: Genova University (Italy)

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

Inria contact: Fawzi Nashashibi

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

8.3.1.6. CityMobil2

Type: COOPERATION (TRANSPORTS)

Instrument: Large-scale integrating project

Objectif: NC

Duration: September 2012 - August 2016

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

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

Inria contact: Fawzi Nashashibi

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

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

8.3.1.7. DESERVE

Title: DEvelopment platform for Safe and Efficient dRiVE

Objectif: NC

Duration: September 2012 - August 2015

Coordinator: VTT (Finland)

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

Inria contact: Fawzi Nashashibi

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

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

8.3.1.8. Mobility2.0

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

Type: COOPERATION (TRANSPORTS)

Objectif: NC

Duration: September 2012 - February 2015

Coordinator: Broadbit (Slovakia)

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

Inria contact: Jean-Marc Lasgouttes

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

See also: <http://mobility2.eu/>

8.3.2. Collaborations with Major European Organizations

- **IMARA is a full partner of VRA:**
VRA – Vehicle and Road Automation is a support action funded by the European Union to create a collaboration network of experts and stakeholders working on deployment of automated vehicles and its related infrastructure. VRA project is considered as the cooperation interface between EC funded projects, international relations and national activities on the topic of vehicle and road automation. It is financed by the European Commission DG CONNECT and coordinated by ERTICO – ITS Europe.
- **IMARA is member of the Working Group on Automation.** This group has been created and is animated by ERTICO ITS Europe. The Automation Working Group was formed under the iMobility Forum, with the initial high level aims of exploring and promoting the potential of highly automated vehicles and applications and working towards the development of a roadmap for the deployment of automated systems.

8.4. International Initiatives

8.4.1. Inria International Partners

8.4.1.1. Declared Inria International Partners

IMARA has developed a wide collaboration network with international partners from both academia and industry.

- **NAIST :** IMARA has signed a MoU with the Nara Institute of Science and Technology (NAIST). The research themes of cooperation are in the area of *advanced intelligent transportation systems (ITS)*.
- **YAMAHA :** IMARA has signed a MoU with YAMAHA to conduct joint research on the *New Generation of AGV projects (Autonomous Ground Vehicles)*.
- **AXTER Technologies :** IMARA has signed a MoU with AXTER Technologies for the cooperation on the *autonomous navigation in indoor environments for automated industrial vehicles*.
- **Simon Bolívar University :** IMARA and University Simon Bolivar (Venezuela) have started a privileged cooperation thanks to the ECOS Nord Program. The collaboration will start effectively in 2014. Researchers and PhD from both institutes will visit each other and conduct common research on the benefits of ITS solutions for an enhanced mobility in congested cities. IMARA has already hosted in the past 3 engineers as trainees working in the field of intelligent control.

8.4.1.2. Informal International Partners

CITRIS : IMARA has been part of Inria's teams involved in the cooperation with the CITRIS (Center for Information Technology Research in the Interest of Society, California), as a key actor of the joint research between Inria and the University of Berkeley around the smart city.

8.4.2. Participation In other International Programs

ECOS Nord : Since December 4th (2013), Inria and the University of Simon Bolivar (Venezuela) are partners of a project financed by the ECOS Nord Program (ECOS Nord No. V14M01). This project is co-financed by the Ministries of Foreign Affairs of Venezuela and France.

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- **Prof. Plamen PETROV** : professor at the Technical University of Sofia (Bulgaria). He has been an invited professor at Inria from June to September 2013. During this period he made joint research on intelligent adaptive control applied to vehicle manoeuvring (automated parking and assisted overtaking).
- **Satoshi MATSUURA** : He has been a Visiting Professor from NAIST (Nara Institute of Science and Technology, Japan). Until March 2013, he has been working in the area of telecommunications applied to ITS. He was also the initiator of the signed MoU between NAIST and IMARA.

8.5.1.1. Internships

- M. Kenta Mori : he was an intern from NAIST, working in the field of telecommunications applied to ITS applications, under the supervision of Mrs. Oyunchimeg Shagdar.
- M. José Javier Anaya Catala : he was an intern from the Technical University of Madrid (UPM, Spain). He developed a vehicle-to-pedestrian communication protocol using WiFi devices.
- Miss Oriana Rojas-Michelena : she was an intern from Simón Bolívar University and she developed an on-board vehicle controller dedicated to the management of the approach of traffic lights.
- M. Ray Lattarulo Arias : he was an intern from Simón Bolívar University (Venezuela). He developed a fuzzy controller to follow Bezier-like trajectories executed by a cybercar.
- Ernest Creiser : he was an intern from ENSAE ParisTech / Univ. Paris Dauphine. He worked on the development of man-machine interfaces dedicated to the EU-FURBOT project.
- Mohamed Maddouri : he was intern from Télécom SudParis and he developed a tool dedicated to the calibration of a laser-camera set used in a moving vehicle.

9. Dissemination

9.1. Scientific Animation

- Guy Fayolle is
 - Scientific advisor at the *Robotics Laboratory of Mines ParisTech*. In this respect, he participates in the contract COVADEC, which is an industrial project (FUI / FEDER 15) involving 8 partners, among which Peugeot, Valeo, Armines and All4tec. The acronym stands for *Conception et Validation des Systèmes Embarqués d'Aide à la Conduite*. Armines will propose a Markov chain analysis aiming at optimizing test generation, taking into account non independent parameters.
 - Associate editor of the journal *Markov Processes and Related Fields*,
 - Regular reviewer for some journals of high repute (PTRF, MPRF, QUESTA, IEEE-IT, JSP), and also for the *AMS Mathematical Reviews*.
 - Member of the working group IFIP WG 7.3.
 - Program committee member of the regular *Int. Symposium on Computer and Information Sciences*, held in Paris at IHP (28-29 oct. 2013). The chairman-organizer is E. Gelenbe (Imperial College, UK).

He gave two invited talks :

- *Séminaire de Probabilités* of the LAGA Laboratory (Univ. Paris 13, 23 may 2013) to speak on *Random walks in the quarter Plane: analytic and probabilistic aspects*.
- *Séminaire du Groupe de travail en Probabilités du MAP5, Univ. Paris 5*, where he presented the paper [11].

He was invited to attend the follow-up meeting of the Workshop Programme *Modern probabilistic techniques for design and analysis of stochastic systems and networks*, held at the *Isaac Newton Institute* (Cambridge Univ. UK), 12-16 aug. 2013. He also chaired a session at the *Rencontres de Probabilités*, 9-10 sept. 2013, Rouen University.

- Jean-Marc Lasgouttes has been reviewer for the European Journal on Operation Research (EJOR) and the IEEE Transactions on Intelligent Transportation Systems.

- Philippe Morignot

has been member of the steering committee of the French association for Artificial Intelligence (AFIA). He is Editor-in-Chief of the newsletter of this association. He has been session chair of the session entitled "Human and Hydrologic applications" at the IASTED AIA'13 conference.

- Fawzi Nashashibi is:
 - Scientific advisor at the *Robotics Laboratory of Mines ParisTech*.
 - Supervisor of 1 PhD thesis at Mines ParisTech in 2013: Miss Anne-Sophie Puthon
 - supervisor of 4 PhD thesis at Inria: B. Lefaudeux, H. Li, G. Tréhard, P. Merdrignac.
 - Associate editor of the journal *Traitement du signal*,
 - Associate editor and reviewer of major conferences in ITS and Robotics (IEEE IV, IEEE, ITSC, IEEE ICRA, IEEE ICARCV, IEEE ICVES,...)
 - Regular reviewer for some journals of high repute (Transportation Research Part C, IJRR, IJVAS, IEEE Transactions on Instrumentation and Measurement, IEEE Robotics and Automation Magazine, IEEE Transactions on ITS, IEEE TVT,...).
 - Member of the European working group on Automation of the iMobility Forum.
 - Member of the International Committee on Vehicle Highway Automation (AHB30)
 - Member of the Technical Program Committee of the WUSPE Workshop on in Kumamoto (Japan).

Fawzi Nashashibi was co-organizer of the ict-PAMM Workshop on "*Mobility Assistance and Service Robotics*" held in Kumamoto (Japan) on November 9th, 2013.

Fawzi Nashashibi was an invited keynote speaker at the following events:

- ITSWC'2013 (Tokyo, Japan): Executive session "*ES01: Autonomous Vehicles - the Path to Implementations*", at the International 20th ITS World Congress, Tokyo (Japan).
- ITS Dublin: presentation at the session "*Towards Automation of Vehicles and Roads in Europe*" entitled "*Design of fully automated vehicle transport system in urban settings and related Requirements for fully automated urban vehicles*".
- WUSPE'2013 (Hanoi, Vietnam), Sept. 2013. International workshop on Wireless Communications and User centered Services in Pervasive Environments 2013. Presentation on "*Cooperative wireless communications for road users*" at the International Research Institute MICA of the HANOI UNIVERSITY of SCIENCE and TECHNOLOGY.
- AHB030 TRB Committee: a presentation at the Vehicle-Highway Automation session entitled "*Current advancements in urban mobility: the CityMobil use-case.*".
- eu-Robotics Workshop: presentation about the results of the EU project PICAV.
- Intech seminar: presentation at Inria Rhône-Alpes about the "Technical lessons learned from the urban mobility demonstration in La Rochelle" (joint presentation with M. Matthieu Graindorge from the City of La Rochelle), Oct. 24th, Grenoble.

Fawzi Nashashibi participated to the following round tables:

- ITS Dublin: participation in the International round table on "*ITS Standardization towards deployment*".

- National Assembly / Sénat OPECST: participation to the national roundtable organized by the OFFICE PARLEMENTAIRE D'ÉVALUATION DES CHOIX SCIENTIFIQUES ET TECHNOLOGIQUES on the “New serene and sustainable mobility: designing ecological vehicles”.
- Intech: roundtable about legal issues and deployment strategies for vehicle automation. Oct. 24th, Grenoble.
- Joshué Pérez Rastelli
 - Guest-Editor of IEEE Intelligent Transportation Systems Magazine (special issue of ELECTRO-MOBILITY).
 - Associate editor of IEEE Intelligent Vehicles Symposium 2013, Gold Coast, Australia.
 - Session Chairs of Autonomous Marine Vehicles, 2013 IFAC Intelligent Autonomous Vehicles Symposium.
 - Reviewer in a number of international journals: ROBOTICA, IEEE Transactions on Vehicular Technology, Journal of the Franklin Institute, IEEE Transaction on Intelligent Transportation Systems, Journal of Control, IEEE Robotics and Automation Magazine and International Journal of Electrical Power and Energy Systems (Elsevier).
 - Reviewer in a number of international conferences including IEEE Intelligent Vehicles 2013, IEEE International Conference on Vehicular Electronics and Safety 2013, IEEE Intelligent Transportation Systems 2013, ICRA 2013, among others.
 - Responsible of the PAL Inria (Personally Assisted Living) at IMARA team.
 - Séminaire des doctorants (April 2013, Inria Rocquencourt) *Control Architecture for autonomous vehicles in urban environments*.
- Evangeline Pollard

is a reviewer for several international journals and conferences: 15th IEEE Intelligent Transportation Systems Conference, International Conference on Intelligent Robots and Systems, IEEE Intelligent Vehicles Symposium, IEEE Transactions on Vehicular Technology (TVT), IEEE Transactions on Aerospace and Electronics Systems (AES), Journal of Zhejiang University Science C (Computers & Electronics).
- Oyunchimeg Shagdar

is an associate editor of Wiley International Journal of Communication Systems and a technical program committee of the IEEE Vehicular Technology Conference (VTC 2014) and the IARIA International Conference on Emerging Network Intelligence (Emerging 2013). She is a reviewer of a number of international journals and conferences, including IEEE Communications Magazine, IEEE Communications Letter, IEEE Transactions on Communications, IEEE Vehicular Technology Conference (VTC), IEEE International Conference on Communications (ICC), and Intelligent Vehicle Symposium. She was a keynote speaker at the workshops “Journée National Communications dans le Transport 2013”, in June 2013, in Nevers, France and “Wireless Communications and User Centric Services in Pervasive Environments 2013”, in September 2013, in Hanoi, Vietnam

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Jean-Marc Lasgouttes

Master: “Analyse de données”, 59.5h, second year of Magistère de Finance (M1), University Paris 1 Panthéon Sorbonne, France

Victorin Martin

Licence: “Statistiques”, 9h, first year of Ecole Centrale Paris (L3) Châtenay-Malabry, France

Philippe Morignot

Master: “Constraint programming”, 15h, M2, Epita (Le Kremlin-Bicêtre), France
 Master: “Linear programming”, 15h, M2, Epita (Le Kremlin-Bicêtre), France
 Master: “Rule-based systems”, 15h, M2, Epita (Le Kremlin-Bicêtre), France
 Master: “Task planning”, 15h, M2, Epita (Le Kremlin-Bicêtre), France

Fawzi Nashashibi

Licence: “Programmation avancée”, 84h, L1, Université Paris-8 Saint-Denis, France
 Master: “Programmation C++/OpenGL”, 16h, 2nd year (MAREVA), Mines ParisTech, France
 Master: “Synthèse d’images”, 12h, M2, INT Télécom SudParis.

Joshué Pérez Rastelli

Master: “Digital environment and road -ITS applications- (Voie Numérique)”, 20h, M2, François Rabelais University, Tours, France
 Master: “Systèmes embarqués (embedded systems)”, 22,5h, M2, Leonard Da Vinci University - l’ESILV-, La Défense, France

Guillaume Tréhard

Master: “C++ programming language”, M1, 20h, Paris 8 University, France
 DUT Génie Electrique et Informatique Industrielle: “C++ programming language”, L1, 20h, IUT Chartres, France

9.2.2. Supervision

PhD in progress: Mohammad Abualhoul, “Visible Light and Radio Communications for automated driving”, from September 01, 2013, supervisor: Fawzi Nashashibi, co-supervisor: Oyunchimeg Shagdar

PhD in progress: Ines Ben Jemaa, “Communications and Management Control for Cooperative Vehicular Systems”, from January 01, 2011, supervisor: Arnaud De La Fortelle, co-supervisor Paul Muhlethaler, Oyunchimeg Shagdar

PhD: Benjamin Lefaudeux, “Détection, localisation et suivi d’objets mobiles à partir d’une plateforme de stéréovision”, Mines ParisTech, defended on September 30 2013, supervisor: Fawzi Nashashibi

PhD: Victorin Martin, “Modélisation probabiliste et inférence par propagation de croyances: application au trafic routier”, Mines Paristech, May 23, 2013, supervisor Arnaud De La Fortelle, co-supervisors Cyril Furtlehner and Jean-Marc Lasgouttes

PhD in progress: Pierre Merdrignac, “Development of cooperative perception and communication system for vulnerables’ safety enhancement”, from October 01, 2012, supervisor: Fawzi Nashashibi, co-supervisor: Oyunchimeg Shagdar, Evangeline Pollard

PhD in progress: Guillaume Tréhard, “Autonomous urban driving: dealing with intersections”, from October 01, 2012, supervisor: Fawzi Nashashibi, co-supervisor: Evangeline Pollard

9.2.3. Juries

Fawzi Nashashibi was the Jury President of the following PhD thesis defense:

- Yadu PRABAKHAR. “Detection and counting of Powered Two Wheelers in traffic using a single-plane Laser Scanner”. University of Normandy – INSA Rouen. Defended on: 10/10/2013.

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

- Benoit FORTIN. “Méthodes conjointes de détection et suivi basé-modèle de cibles distribuées par filtrage non-linéaire dans les données lidar à balayage”. University of Littoral Côte d’Opale. Defended on: 22/11/2013.
- Maxime CAUSERET. “Peindre avec des matières dynamiques : les systèmes procéduraux pour la création et l’expérimentation artistique.”. University of Paris-8 Saint-Denis. Defended on: 09/07/2013.
- Amnir HADACHI. “Travel Time Estimation using Sparsely Sampled Probe GPS data in Urban Road Networks Context”. University of Normandy – INSA Rouen. Defended on: 31/01/2013.

Fawzi Nashashibi was an examiner of the following PhD thesis defense:

- Jorge GODOY. “Arquitectura de control para la conducción autónoma de vehículos en entornos urbanos y autovías”. Universidad Polytechnica de Madrid – Escuela Tecnica Superior de Ingenieros Industriales. Defended on: 21/10/2013.
- Adam HOUENOU. “Calcul de trajectoires pour la préconisation de manoeuvres automobiles sur la base d’une perception multi-capteurs – Application à l’évitement de collision”. Université de Technologie de Compiègne. Defended on: 09/12/2013.

9.3. Popularization

Several members of the team have participated in the exhibition Futur-en-Seine (104, Paris, June 13-16 2013) by presenting the CITRIS association and explaining videos to industry (June 13-14) and public (June 15-16).

Guillaume Tréhard supervised three students from the Lycée Henri Bergson, Angers for their TIPE (TIPE, travaux d’initiative personnelle encadrés) “Assistance au freinage d’urgence par contrôle moteur d’un véhicule électrique”.

Jean-Marc Lasgouttes has presented “some solvable models for road traffic” at the *demi-heure de science* of the Paris–Rocquencourt Inria research center.

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Major publications by the team in recent years

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

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