Activity Report 2012

Project-Team IMARA

Informatics, Mathematics and Automation for La Route Automatisée

RESEARCH CENTER
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THEME
Robotics

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Project-Team IMARA

Keywords: Intelligent Transportation Systems, Robotics, Perception, Stochastic Modeling, Robot Motion, Safety, Signal Processing

Creation of the Project-Team: July 01, 2008 .

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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 "La Route Automatisée" 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 innovation. 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 system 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 two 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 trafic analysis and modeling. The third axes deals with the problem of telecommunications from two points of view:

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

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

2.2. Highlights of the Year

Gérard Le Lann has been awarded the Willis Lamb Prize by the French Académie des Sciences in November 2012, for his work on distributed, resilient, and real-time systems and networks.
BEST PAPER AWARD :
[36] **Multi-vehicle cooperative localization using indirect vehicle-to-vehicle relative pose estimation in ICVES 2012 - IEEE International Conference on Vehicular Electronics and Safety**. H. LI, F. NASHASHIBI.

3. Scientific Foundations

3.1. Vehicle guidance and autonomous navigation

Participants: Fawzi Nashashibi, Evangeline Pollard, Benjamin Lefaudeux, Hao Li, Paulo Lopes Resende, Guillaume Tréhard, Pierre Merdrignac, Zayed Alsayed.

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

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. 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 mapping

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

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

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 other approach, originality relies in 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.

Presently, we are currently 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 objects [1], 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: Fawzi Nashashibi, Hao Li, Evangeline Pollard, Benjamin Lefaudeux, Pierre Merdrignac.

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

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.

Both methods should be experimentally tested on IMARA veicles in 2013.

3.1.4. Planning and executing vehicle actions

Participants: Plamen Petrov, Joshué Pérez 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've 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've 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, controlling the vehicles include also advanced platooning, automated parking, automated docking, etc. Foreach 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, Gérard Le Lann, Manabu Tsukada, Thouraya Toukabri, Satoru Noguchi, Ines Ben Jemaa, Mohammad Abu Alhoul, Fawzi Nashashibi, Arnaud de la Fortelle.

Wireless communications is 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 vehicles' behavior such as vehicles' merging and 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 Abu Alhoul, Mohamed Marouf, Oyunchimeg Shagdar, Fawzi Nashashibi.

The main purpose of our research is to propose and test new successful supportive communication technology, which can provide stable and reliable communication between vehicles, especially for the platooning scenario. Although 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 develop analytical model of VLC to understand its characteristics and limitation. The second objective of this work is to design vehicle platooning control using VLC. In platooning control, a corporation 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 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 two vehicles in the platooning queue, at the same time the model will calculate all the required parameters acquired from each vehicle controller.

3.2.5. Access point selection

Participant: Oyunchimeg Shagdar.

While 5.9 GHz radio frequency band is dedicated to ITS applications, there is not much known how the channel and network behave in mobile scenarios. 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 access point selection method to achieve high speed V2I communications.

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 omnidirectional 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 omnidirectional (360°) communications and unidirectional communications, implemented out of very-short range antennas of very small beamwidth. 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] and [31].

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

In [7] and [31], 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 [49], 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, Yufei Han, 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. The reader is therefore encouraged to read the recent activity reports for the Preval team for more details.

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 them models have already been investigated by members of the group, and they are part of wide ongoing research.

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 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:

- determine the effect of the various variants of BP (in terms of normalization or changes to the Bethe free energy) on the fixed points and their stability;
- 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.

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 who 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) path. 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. Cybercars

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 breaking 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 RT-MAPS we've 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

5.1. MELOSYM

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

MELOSYM is the acronym for "**M**odélisation de l'**E**nvironnement et **LO**calisation en temps réel pour un **SY**stème **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: 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.

- Version: V1

6. New Results

6.1. Low speed automation

Participants: Paulo Lopes Resende, Fawzi Nashashibi, Hao Li, Evangeline Pollard.

The ABV project builds on the HAVEit philosophy (a previous IMARA project for high speed automation) of 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.

6.2. Urban autonomous driving: dealing with intersections

Participants: Guillaume Tréhard, Evangeline Pollard, Fawzi Nashashibi.

The goal of this project, made in collaboration with Valeo is to develop a complete solution for autonomous driving on open roads. More specifically, IMARA's objectives are to provide the way to safely cross any kind of intersections for an autonomous vehicle in a urban context. Among the different relevant scenarios, we can notice:

- Intersection with different shapes: Roundabout, T junctions , X junctions;
- Intersection with different rules: With specific rules (traffic lights, main road...) or unspecified rules ("priority to the right");
- Different traffic: Busy or empty intersections;
- Deal with abnormal situations: road works, policemen, firemen,...

Possible steps for this work can be listed as follows:

- Model the intersection: define relevant information, find a generic model for every intersection;
- Detect the intersection (shape, drivable area, traffic flows);
- Understand the priorities that rules it;
- Locate the car in the intersection by crossing it;
- Plan a path to get out of the intersection.

6.3. Conception of a new communicative system for the protection of vulnerable people

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

A new research has been recently launched at IMARA team. The goal is to elaborate a new communicative system between vulnerable people (pedestrian, person with reduced mobility, bicyclist, etc.) and intelligent vehicles in order to improve safety and to limit collision risk. The main idea of this project is as follows. Intelligent vehicles are equipped with an obstacle detection/classification /tracking module in order to prevent injuries. On the other hand, to help the driver in this challenging task, vulnerable people use an application on their mobile phone to inform/share their status on location, type, and dynamics. The status information is transmitted to the driver utilizing wireless communications technology (e.g., 3G and Wi-Fi). In the vehicle, information coming from the communications device and obstacle detection module will be merged to improve the detection and classification tasks. In case of emergency, the vehicle can broadcast safety information to vulnerable people.

6.4. Visible Light V2V Communications for Platooning Control

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

Fully automated vehicles have the potential to greatly improve the comfort of humans' life. For driving from one place to another, an automated vehicle must avoid collisions and be able to select non-congested roads for safe and efficient driving. In order to do that the vehicle needs to control its mobility in both macroscopic and microscopic levels by utilizing information exchange with other vehicles and roadside infrastructures based on wireless communications technology. While radio frequency channel is a convincing choose for vehicular communications due to its high data rate over relatively long coverage range (minimum several 100's meters), it is expected to experience channel congestion and low communication reliability especially for the scenario where there is high-density vehicles. In such scenarios vehicles still require to control the mobility on both the macroscopic and microscopic levels, we need to look for supportive and at the same time practical communication media with the ability to support sufficient connection between vehicles. According to the latest standard from IEEE, 802.15.7 for 2011, the communication coverage of Visible Light Communication (VLC) can reach up to 10's of meters, which match the information exchange requirements for mobility control in microscopic level. Motivated by this we started our research activity on modeling of visible light communications channel and design of microscopic mobility control, specifically platooning control, using VLC.

6.5. Augmented reality for the protection of vulnerable people

Participants: Hao Li, Fawzi Nashashibi.

A brand new idea of cooperative augmented reality is under development in IMARA team. It utilizes the results of cooperative local mapping to realize certain augmented reality effect. More specifically, the idea is to obtain an augmented effect of "seeing" through front vehicle, based on the intelligent vehicle sensor configurations.

Given a scenario of two vehicles: a front (first) vehicle and a following (second) vehicle. This front-following vehicles scenario is typical in traffic environment and is potentially dangerous, especially in some occasions such as during an overtaking, where the front vehicle occludes a part of the scene to the following vehicle. The idea of cooperative augmented reality is thus to project the visual perception of the front vehicle onto that of the following vehicle, abiding by perspective geometry. In other words, we patch the occluded part of the view of the following vehicle with corresponding part of the view of the front vehicle. This is not simply a process of partial view copying and pasting between the two vehicles; we have to transform the partial view of the front vehicle according to perspective geometry, in order to make a vivid and natural reproduction of this partial view for the following vehicle, just like if the following vehicle can directly see into the occluded area.

A prerequisite for performing the perspective transformation between the visual perceptions of the two vehicles is the knowledge of the visual perception depth. This knowledge can be estimated by stereo-vision, if correct correspondence is established (yet a challenging process) between the images pair in stereo-vision. However, approximate estimate of the visual perception depth was obtained with the help of 2D range perception in an innovative way and indirect vehicle-to-vehicle relative pose estimation method introduced in [36].

6.6. Step detection for Personal Mobility Vehicles

Participants: Evangeline Pollard, Joshué Pérez Rastelli, Fawzi Nashashibi.

Personal Mobility Vehicles (PMV) is an important part of the Intelligent Transportation System (ITS) domain. These new transport systems have been designed for urban traffic areas, pedestrian streets, green zones and private parks. In these areas, steps and curbs make the movement of disable or mobility reduced people with PMV, and with standard chair wheels difficult. In this work, a step and curb detection system based on laser sensors has been developed. This system is dedicated to vehicles able to cross over steps, for transportation systems, as well as for mobile robots. The system is composed of three laser range finders. Hokuyo UTM 30 LX devices were chosen for their large detection angle (270°) and their high angular resolution (0.25°) and range (30m).

Two laser sensors dedicated to the step detection have a vertical orientation in order to scan the altitude profile of the environment over two lines of sight and the third one, with a vertical orientation is dedicated to obstacle detection.

The step detection process is thus based on the study of the first derivative of the altitude and highlights the use of a new algebraic derivative method (Alien) adapted to laser sensor data. The system has been tested on several real scenarios. It provides the distance, altitude and orientation of the steps in front of the vehicle and offers a high level of precision, even with small steps.

6.7. PROSIVIC-CTS simulator

Participant: Joshué Pérez Rastelli.

The Architecture validation and experiments presented in this document have been implemented in a simulated environment, called ProSiVIC, which allows implementing a virtual Cybercars, among other vehicles. The algorithms are the same as in our Cybus platform, using the position from the SLAM and DGPS sensors. The ProSivic simulator offers a multi-sensorial environment, and takes into account several parameters of a real car such as the inertia, steering wheel response, lateral acceleration with yaw angles, damping suspension, simple weather conditions, friction parameters and more.

Moreover, synchronized time, acceleration (in wheel torque), steering, odometer information, lidar information and camera viewports are some of the components supporting the connection between the control architecture in RTMaps and the simulation.

The simulations show the behavior of the control architecture implemented for CTSs. Two urban scenarios were tested: roundabouts and intersections.

6.8. Autonomous docking based on infrared system for electric vehicle charging in urban areas

Participants: Benjamin Lefaudeux, Joshué Pérez Rastelli, Fawzi Nashashibi.

One of the recent aims of the Intelligent Transportation Systems (ITS) is the reduction of air pollution, reducing the fuel consumption in urban areas and improving road security. To this purpose, electric vehicles are a good and high demanded alternative. Nowadays, some big cities are launching the first electric car-sharing projects to clear its traffic jam, as an alternative to the classic public transportation systems. However, there are still some problems related to energy storage, charging and autonomy to be solved. To tackle this problem in the context of the French project AMARE, IMARA has developed an autonomous docking system, based on an infrared camera embarked in a vehicle equipped with dedicated ADAS, and some infrared diodes installed in the infrastructure, for recharging the vehicle batteries in a street parking area. The results obtained show a good behavior of the implemented system, which is working in a real scenario in the city of Paris.

Different experiments, departing from different points, show a good behavior of the proposed systems. Both lateral and longitudinal errors are lower that the limits of the charging station. The controller used is easy and intuitive for tuning, and the gains can be adapted according of the different vehicles characteristics. This technology permits to assist to human drivers in the charging process of electric vehicles in cities.

6.9. Reasoning for relaxing traffic regulations

Participants: Philippe Morignot, Fawzi Nashashibi.

This work [39] deals with relaxation of traffic rules in unusual but practical situations. For example, if a truck is unloading on a roadway, the automated vehicle should overtake it despite a continuous yellow line: traffic rules are indeed broken, which is illegal, but this might be tolerated due to the unusual aspect of the situation at hand.

An ontology has been developed in order to represent the road network (a directed graph, vertices being intersections and edges being lanes), the infrastructure (road signs, marks), the other road users and the intelligent vehicle. Reasoning on this representation is performed by inference rules (IF/THEN symbolic structures), encoding the deliberation on the encoded situation. Main rules conclude on the next discrete motion of the vehicle, e.g., “pass onto the adjacent lane” which involves crossing a continuous yellow line.

In practice, this ontology has been created using the PROTEGE ontology editor from Stanford University. IF/THEN rules are represented in SWRL (Semantic Web Rule Language), using the reasoner PELLET from the company Clark & Parsia (a plug-in of the tool PROTEGE).

Work over the next year involves porting this reasoning module on the vehicles: porting the generated JAVA source code as one component inside the RTMAPS architecture of CyberCars, and linking the ABoxes (assertional boxes) of the ontology to symbols extracted from signals by perception.

6.10. Communications and Management Control for Cooperative Vehicular Systems

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

One of the attractive applications of electric autonomous vehicles is electric automated Car Sharing service. In this application, a user requests a vehicle at a given geographical location triggering the car sharing system to allocate an autonomous vehicle for the user transport from the station to the user’s desired destination. The application requires efficient cooperation among the autonomous vehicles and a service management centre for reliable and responsive car sharing service. Such cooperation is not possible unless vehicles exchange their information on e.g., position, motion, and coordination messages among themselves and with central management entities. While the existing wireless communications technologies can be applied for vehicle to vehicle and vehicle to the infrastructure communications, important research challenges remain including network partitioning problem caused by vehicles’ mobility and inability of the convergence of geographically scoped V2V and Internet-based V2I communications. Targeting these issues, we study a topology control solution to tackle the network portioning problem and design of unicast/multicast/Geonetworking schemes for convergence of V2V and V2I communications systems for car-sharing applications [28].

6.11. New urban transportation platforms: Inria’s Cybus

Participants: Laurent Bouraoui, François Charlot, Fawzi Nashashibi, Paulo Lopes Resende, Michel Parent, Armand Yvet.

Cybus is the newest 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.

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

6.12. Belief propagation inference for traffic prediction

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

This work [57] 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 are done in particular in the framework of the projects Travesti and Pumas.

This year's highlights are

- A paper describing a new sufficient condition for local stability of the Belief Propagation algorithm has been published and presented in an international conference [38].
- The work about the theoretical aspects of encoding real valued variables into a binary Ising model has been summarized in a publication currently under reviewing process.
- Ideas about adding macroscopic variables within the Ising model are currently being tested using the software BPstruction developed last year.
- Victorin Martin has given a talk at the "Colloque Jeunes Probabilistes et Statisticiens" at CIRM, where he presented his work one the design of a latent Ising model for real valued inference.
- Cyril Furtlehner, Yufei Han and Victorin Martin presented the work done in the Travesti project at the workshop on inference organized by Inria and Mines ParisTech (see 9.1).

6.13. Non-negative Tensor factorization for spatio-temporal data analysis

Participant: Yufei Han.

This is a joint work with Fabien Moutarde from Mines ParisTech.

We investigate the use of non-negative tensor factorization for spatio-temporal data clustering and prediction. In general case, a spatio-temporal signal is represented as a set of multiple-variant temporal sequences. In the domain of intelligent traffic, the temporal records of traffic flow states (free-flowing/congestion) over a specific time duration with respect to hundreds of links in a transportation network can be considered as a simple but direct example of spatio-temporal signal. Both temporal causality between neighboring time sampling steps and spatial layout of the multiple-variant observation captured at each time sampling step are the focus of the spatio-temporal data analysis. Non-negative tensor factorization enables us to project the high dimensional spatio-temporal data into low-dimensional subspace and clustering/prediction can be then achieved on the derived subspace projection easily.

This year's highlights are

- A conference paper describing application of non-negative tensor factorization in traffic flow state prediction and clustering has been published and presented at ITS World Congress [30];
- The application of non-negative matrix factorization in clustering network-level traffic flow state in large-scale transportation network has been accepted for publication in a journal [11].

6.14. Sparse covariance inverse estimate for Gaussian Markov Random Field

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

We investigate in [53] different ways of generating approximate solutions to the inverse problem of pairwise Markov random field (MRF) model learning. We focus mainly on the inverse Ising problem, but discuss also the somewhat related inverse Gaussian problem. In both cases, the belief propagation algorithm can be used in closed form to perform inference tasks. We propose a novel and efficient iterative proportional scaling (IPS) based graph edit method to identify sparse graph linkage of GMRF model to fit underlined data distribution. We remark indeed that both the natural gradient and the best link to be added to a maximum spanning tree solution can be computed analytically. These observations open the way to many possible algorithms, able to find approximate sparse solutions compatible with belief propagation inference procedures and sufficiently flexible to incorporate various spectral constraints like e.g. walk summability. Experimental tests on various data sets with refined L_0 or L_1 regularization procedures indicate that this approach may be a competitive and useful alternative to existing ones.

The part of this work dedicated to Gaussian Markov Random Field has been submitted to the AISTATS 2013 conference.

6.15. 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 have been developing a discrete events simulator for that purpose, based on a previous work done for collective taxis [58].

Our model relies on an adapted events/decision graph that extends previous graphs. 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 the overhaul of the simulator implementation, as well as the development of a result visualizer that can replay the simulations on a map and show various statistics.

6.16. Multi-speed exclusion processes

Participants: Cyril Furtlehner, Jean-Marc Lasgouttes.

The slow-to-start mechanism is known to play an important role in the particular shape of the fundamental diagram of traffic and to be associated to hysteresis effects of traffic flow. We study this question in the context of stochastic processes, namely exclusion and queueing processes, by including explicitly an asymmetry between deceleration and acceleration in their formulation. Spatial condensation phenomena and metastability are observed, depending on the level of the aforementioned asymmetry. The relationship between these 2 families of models is analyzed on the ring geometry, to yield a large deviation formulation of the fundamental diagram (FD)

This work has been published in the Journal of Statistical Physics [10].

6.17. 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 the stationary regime of the system 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 completed during this year [51] and has been submitted to a journal for publication.

6.18. Exact asymptotics 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 in 2011.

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. Then 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

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

where x, y, z are complex variables, although the time variable z plays somehow the role of a parameter. The question of the type of the associated counting generating functions, that is rational, algebraic, holonomic (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.

It turns out that the nature of singularities play a deep important role in this classification. Making use of the general and powerful approach proposed in the book [2], the paper [9] has been presented at the 23rd International Conference *AofA 2012* on *Combinatorial and Asymptotic Methods for the Analysis of Algorithms*, Montreal, June 17-22.

6.19. Statistical physics and hydrodynamic limits

Participant: Guy Fayolle.

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 previous activity reports).

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 [56], 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 [56], 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.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

In 2012, a new bilateral collaboration between Valeo and IMARA started involving the development of advanced driving assistance systems. The first topic was in the development of an advanced docking system using vision based perception and automatic control of the vehicle. The second topic has just started around driver monitoring using vision. Two bilateral contracts where signed as well as an associated NDA between both institutions.

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. LINK&GO

Title: LINK&GO

Duration: 12 months

Coordinator: AKKA Group

Others partners: AKKA Technologies, Inria, ControlSys Engineering, DBT

See also: http://automobile.yvelines.fr/fr/lappel-a-projets-2011/laureats-du-2nd-appel-a-projets/linkandgo-le-vehicule-autonome-dakka-technologies/

Abstract: LINK&GO in a regional project financed by the CG78 (Yvelines Region). Link & Go is presented as the solution for next-generation mobility. It is the first dual-mode electric vehicle: the driver can choose between manual and automatic modes. The vehicle will move independently from the specific infrastructure such as car parks or roads. Safe and secure, Link & Go vehicle is intelligent establishing contact with the users through their personal devices and with the infrastructure via touch screen controls, voice and gestures. In addition, the system Sarveca allow the vehicle to automatically connect to the charging station can intelligently optimize the grid and facilitate the identification, payment, maintenance, etc..

8.1.2. TRANSY'VES

Title: TRANSY'VES

Duration: 12 months

Coordinator: ADM Concept

Others partners: Inria

See also: http://automobile.yvelines.fr/fr/lappel-a-projets-2011/laureats-du-2nd-appel-a-projets/transyves-la-borne-automatique-dadm-concept/

Abstract: The proposed project, called Transy'Ves, is based on two technological components. The first brick aims to optimize routes with electric vehicles, developing an indispensable tool for the appropriation of its use: the EVCO (Electric Vehicle Cruise Optimizer). This is a system for real-time assistance and course management for users of electric vehicles. The second brick aims to facilitate intermodal transport by developing a fully automatic guidance system in order to democratize the parking valet system in new generation parking lots.

8.2. National Initiatives

8.2.1. ANR

8.2.1.1. ABV

Title: Automatisation basse vitesse

Instrument: ANR

Duration: 2009-2012

Coordinator: IFFSTAR

Others partners: Continental, IBISC, IEF, Induct, 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. PUMAS

Title: Plate-forme Urbaine de Mobilité Avancée et Soutenable

Instrument: FUI

Duration: February 2010 - October 2012

Coordinator: Egis Mobilité

Others partners: Induct, Intempora, Armines, Insa-Rouen, Esigelec

See also: http://www.projet-pumas.fr/

Abstract: The purpose of the project PUMAS is to create a platform for travel time information for cities and towns.

8.2.1.3. SCORE@F

Title: Système COopératif Routier Expérimental Français

Instrument: FUI

Duration: 2010-2013

Coordinator: Renault-REGIENOV

Others partners: UTAC, LAB, EURECOM, IFSTTAR, Inria, Telecom 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.

8.2.1.4. Travesti

Title: Traffic Volume Estimation via Space-Time Inference

Instrument: ANR SYSCOMM

Duration: January 2009 - June 2012

Coordinator: Inria (TAO)

Others partners: Armines

See also: http://travesti.gforge.inria.fr

Abstract: This project addresses the problem of modelling large scale complex systems to provide predictions of their macroscopic behaviour. For application purpose, we focus here on the particular problem of the real-time prediction of traffic conditions on a road network.

8.2.2. Competitivity Clusters

IMARA team is a very active partner in the competitivity clusters, especially MOV'EO and System@tic. We are involved in several technical committees like the DAS SUR of MOV'EO for example. IMARA is also the main Inria contributor in the VeDeCoM institute (IEED). Vedecom is financing a new PhD thesis student supervised by IMARA research; 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

Title: DRIVE C2X – Accelerate cooperative mobility

Type: COOPERATION (ICT)

Defi: Driving implementation of car 2 x communication technology

Instrument: Integrated Project (IP)

Duration: January 2011 - December 2013

Coordinator: DAIMLER AG (Germany)

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

See also: http://www.drive-c2x.eu/project

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

Title: IPv6 ITS Station Stack for Cooperative ITS FOTs

Type: COOPERATION (ICT)

Defi: IPV6 ITS Station Stack for Cooperative Systems FOTs

Instrument: Specific Targeted Research Project (STREP)

Duration: February 2011 - January 2014

Coordinator: Inria (France)

Others partners: Universidad de Murcia, Institut Telecom, lesswire, SZTAKI, IPTE and BlueTechnix.

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

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 objectif is to deliver an optimized IPv6.

8.3.1.3. SANDRA

Title: Seamless Aeronautical Networking through integration of Data links, Radios and Antennas.

Type: COOPERATION (TRANSPORTS)

Instrument: Integrated Project (IP)

Duration: October 2009 - September 2013

Coordinator: Selex Communications (Italy)

Others partners: 30 partners.

See also: http://www.sandra-project.eu/2012/

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

8.3.1.4. PICAV

Title: Personal Intelligent City Accessible Vehicle System (PICAV)

Type: COOPERATION (TRANSPORTS)

Instrument: Specific Targeted Research Project (STREP)

Duration: August 2009 - July 2012

Coordinator: Univ. Gènes (Italy)

Others partners:University College London (UK), Universite di Pisa (Italy), TCB (Portugal), ZTS (Slovakia), Mazel (Spain)

See also: http://www.dimec.unige.it/pmar/picav/

Abstract: The proposal presents a new mobility concept for passengers ensuring accessibility for all in urban pedestrian environments. The concept addresses a new Personal Intelligent City Accessible Vehicle (PICAV) and a new transport system that integrates a fleet of PICAV units.

8.3.1.5. CATS

Title: City Alternative Transport System

Type: COOPERATION (TRANSPORTS)

Instrument: Specific Targeted Research Project (STREP)

Duration: January 2010 - December 2013

Coordinator: Lohr Industrie (France)

Others partners: CTL (I), EPFL (CH), TECHNION (IL), GEA (CH), ERT (F), and the cities of Formello (I), Strasbourg (F), Ploiesti (R)

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

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 utilisation 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.

8.3.1.6. FURBOT

Title:Architectures of Light Duty Vehicles for urban freight transport

Type: COOPERATION (TRANSPORTS)

Instrument: Specific Targeted Research Project (STREP)

Duration: November 2011 - October 2014

Coordinator: Univ. Gênes (Italy)

Others partners: Bremach (Italy), ZTS (Slovakia), Universite di Pisa (Italy), Persico (Italy), Mazel (Spain), TCB (Portugal)

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

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.

8.3.1.7. DESERVE

Title: DEvelopment platform for Safe and Efficient dRiVE

Duration: September 2012 - August 2015

Coordinator: VTT (Finland)

Others partners: CRF (I), CONTINENTAL (F), FICOSA (I), Inria (F), TRW (GB), AVL (A), BOSCH (D), DAIMLER (D), VOLVO (S),...(26 partners)

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

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.

8.3.1.8. CITYMOBIL-2

Title: CityMobil-2

Duration: September 2012 - August 2016

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

Others partners: Inria (F), DLR (D), GEA Chanard (CH), POLIS (B), ERT (B), EPFL (CH),...(45 partners!)

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.

8.4. International Initiatives

8.4.1. Inria International Partners

- NAIST (Nara Institute of Sciences and Technologies – Nara – Japan): IMARA and NAIST are extending their cooperation on research activities regarding ITS communications. In 2012, IMARA received 2 visiting researchers, 1 PhD student, and 1 internship student, deepening cooperative research activities on service discovery, geo-networking, and medium access control for vehicular communications.
- IMARA and YAMAHA Motors Company (YMC) have signed a NDA for the exchange of information in view of the participation of both parties in the New generation AGV project.
- IMARA and the South-West Research Institute (SwRI) renewed their collaboration agreement on the collaboration in the design and development of innovative Advanced Driver Assistance System.

8.4.2. Participation In International Programs

IMARA is a partner of ict-PAMM, which is an ICT-ASIA project accepted in 2011 for 2 years. It is funded by the French Ministry of Foreign Affairs and Inria. The coordinator of the project is Anne Spalanzani from UPMF University and Inria Co-coordinator is Philippe Martinet from Blaise Pascal Institute. This project aims at conducting common research activities in the areas of robotic mobile service and robotic assistance of human in different contexts of human life. From France the partners are: Inria/e-Motion, Inria/IMARA, Institut Blaise Pascal. From Asia, the partners are: ISRC-SKKU - Suwon, (Korea), ITS Lab - Kumamoto (Japan), IRA-Lab (Taiwan), Mica Institute - Hanoi (Vietnam).

http://emotion.inrialpes.fr/people/spalanzani/HomePAMM.html

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- Professor Masatoshi Kakiuchi (Nara Institute of Sciences and Technologies) visited IMARA from November 2011 to October 2012;
- Professor Satoshi Matsuura (Nara Institute of Sciences and Technologies) visited IMARA from April 2012 to March 2013;
- Professor Plamen Petrov (Technical University of Sofia) visited IMARA from July 2012 to September 2012.

9. Dissemination

9.1. Scientific Animation

- An interdisciplinary workshop on inference, “Information processing in complex systems with applications to traffic forecasting” was organized on June 12, 2012 at Inria Paris-Rocquencourt. The intent was to bring together researchers from statistics, statistical mechanics and machine learning interested in the development of methods and algorithms to process data emerging from complex systems. Organizers were Cyril Furtlehner (TAO), Fabien Moutarde (CAOR, Mines-ParisTech) and Jean-Marc Lasgouttes.
- Guy Fayolle is
  - Scientific advisor at the *Robotics Laboratory of Mines ParisTech*.
  - 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 in 2012. The chairman-organizer is E. Gelenbe (Imperial College, UK).

He was invited at the *Séminaire de Probabilités* of Institut Fourier (Grenoble, 11 dec. 2012) to speak on *Asymptotics of Random Walks in the Quarter Plane*. He participated in the redaction of the proposal MACCA *(Marches aléatoires confinées dans des cônes: aspects probabilistes, combinatoires et algébriques)*, to be submitted January 2013. This project will be managed from the *Laboratoire de Mathématiques et Physique Théorique* à Tours (LMPT).

- Jean-Marc Lasgouttes has been reviewer for Euro Working Group on Transportation (EWGT 2012) and European Journal on Operation Research (EJOR).
- Gérard Le Lann was invited keynote speaker at Vehicular Communications and Applications (VCA 2012) Workshop (MED-HOC-NET 2012), Cyprus, June 2012.
- Philippe Morignot has been re-elected 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 is reviewer of the International Journal of Advanced Robotics Systems.
- Fawzi Nashashibi is:
  - Scientific advisor at the *Robotics Laboratory of Mines ParisTech.*
  - Supervisor of 2 PhD thesis at Mines ParisTech in 2012: Mr. Raoul de Charette de la Contrie and Miss Anne-Sophie Puthon and supervisor of 4 PhD thesis at Inria: B. Lefaudeux, H. Li, G. Tréhard, P. Merdrignac.
  - Supervisor of 2 PhD thesis at the École Polytechnique d'Alger: Mr. Samir Meniche et Mr. Madjid Hank.
  - 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, 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 12th International Conference on Control, Automation, Robotics and Vision (ICARCV 2012) in Guangzhou (China). He was organizer and chairman of the invited session entitled "*Coordinated Guidance of Multiple Autonomous Robots/vehicles*".

  Fawzi Nashashibi was an invited keynote speaker at the "*Workshop on Navigation, Perception, Accurate Positioning and Mapping for Intelligent Vehicles*", at IEEE International Intelligent Vehicles Symposium (June 3-7), Alcalá de Henares (Spain). He was a keynote speaker at the seminar entitled "*Electric vehicles and urban integration*", June 8th, Mines ParisTech. He was an invited speaker at the plenary meeting of MOV'EO on November 29th with a round table dedicated to the "*Connected Vehicle*".
- Evangeline Pollard was a member of the Technical Program Committee of the International Conference on Information Fusion. She was the chairman of the session entitled "Localization, Navigation and Mapping" for the 12th International Conference on Control, Automation, Robotics and Vision (ICARCV 2012) in Guangzhou (China). She is reviewer for several international journals and conferences: IEEE International Conference on Robotics and Automation (ICRA'12), IEEE International Conference on Vehicular Electronics and Safety (ICVES'12), Journal of Selected Topics in Signal Processing, IEEE Transactions on Vehicular Technology, Journal of Zhejiang University Science C (Computers & Electronics).

- Oyunchimeg Shagdar is an associate editor of Wiley International Journal of Communication Systems. She was a member of Technical Program Committee of the IARIA International Conference on Emerging Network Intelligence (Emerging 2012). She is a reviewer of a number of international journals and conferences, including IEEE Communications Magazine, IEEE Communications Letter, IEICE Transactions on Communications, IEEE Vehicular Technology Conference (VTC), and IEEE International Conference on Communications (ICC).

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Fawzi Nashashibi

Licence: "Programmation avancée", 84h, niveau (L1), Université Paris-8 Saint-Denis, France

Master: "Vision pour la robotique", 16h, 2nd year (MAREVA), Mines ParisTech, France
"Programmation C++/OpenGL", 16h, 2nd year (MAREVA), Mines ParisTech, France
"Programmation avancée et infographie 3D", 25h, niveau (M1), Ecole d'ingénieurs ESILV, France
"Synthèse d'images", 12h, niveau (M2), INT Sud Telecom, France.

Jean-Marc Lasgouttes

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

Gérard Le Lann

Master: "Communications et coordination temps réel dans les réseaux véhiculaires ad hoc", Module du cours de 5ème année "Réseaux temps réel", INSA Lyon, January 2011
"Vehicular Ad Hoc Networks", Module de Master, TELECOM Bretagne, Rennes, June 2011

Victorin Martin

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

Philippe Morignot

Licence: "Constraint programming", 15h, L3, Epita (Le Kremlin-Bicêtre)
Licence: "Linear programming", 15h, L3, Epita (Le Kremlin-Bicêtre)
Licence: "Rule-based systems", 15h, L3, Epita (Le Kremlin-Bicêtre)

9.2.2. Supervision

PhD: Manabu, "Communications Management in Cooperative Intelligent Transportation Systems", Mines Paris Tech, defended on December 20, 2012, supervisor: Arnaud de La Fortelle, co-supervisor Thierry Ernst

PhD: Hao Li, "Cooperative perception: application in the context of intelligent vehicles systems", Mines ParisTech, defended on the 21st September 2012, supervisor: Fawzi Nashashibi

PhD in progress: Victorin Martin, "Modélisation probabiliste et inférence par propagation de croyances: application au trafic routier", from 01/12/2009, supervisor Arnaud de La Fortelle, co-supervisors Cyril Furtlehner and Jean-Marc Lasgouttes

PhD in progress: Benjamin Lefaudeux, "Multi-sensors fusion for dynamic road mapping: application to autonomous vehicles", from 01/10/2012, supervisor: Fawzi Nashashibi

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 in progress: Guillaume Tréhard, "Autonomous urban driving: dealing with intersections", from 01/10/2012, supervisor: Fawzi Nashahibi, co-supervisor: Evangeline Pollard

PhD in progress: Pierre Merdrignac, “Development of cooperative perception and communication system for vulnerables’ safety enhancement”, started at the 1st October 2012, supervisor: Fawzi Nashashibi, co-supervisor: Oyunchimeg Shagdar, Evangeline Pollard

9.2.3. Juries

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

- Mr. Alain Lambert, “Contribution à la navigation en robotique mobile”, University of Orsay Paris-Sud, Orsay, 10/12/2012.
- Mr. Raphaël Labayrade, “Perceptions artificielle et humaine pour l’amélioration de la sécurité et du confort dans les espaces construits”, University Pierre et Marie Curie (Paris 6), Paris, 06/04/2012.

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

- Mr. Sébastien Demmel, “Building an augmented map for road risk assessment”, Queensland University of Technology (Australia) and University of Versailles Saint-Quentin-en-Yvelines, Vélizy, 14/12/2012.
- Mr. Antoine Zanuttini, “Du photoréalisme au rendu expressif en image 3D temps réel dans le jeu vidéo : programmation graphique pour la profondeur de champ, la matière, la réflexion, les fluides et les contours. ”, University of Saint-Denis (Paris-8), St-Denis, 16/11/2012.
- Miss Edwige Lelièvre, “Des jeux de rôle en ligne tridimensionnels aux jeux á réalité alternée : expérience esthétique, création et expérimentation”, University of Saint-Denis (Paris-8), St-Denis, 09/11/2012.
- Mr. David Marquez-Gamez, “Towards visual navigation in dynamic and unknown environment: trajectory learning and following, with detection and tracking of moving objects”, INSA (University of Toulouse), Toulouse, 26/10/2012.
- Mr. Naveed Mohammad, “Contribution to the use of 3D lidars for autonomous navigation: calibration and qualitative localization”, University of Toulouse, Toulouse, 01/02/2012.

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

- Mr. Benoît Chrétien, “Simulation of a new automotive concept based on a centralized approach for driver assistance system activation decision”, University Evry-Val-d’Essonne, Evry, 06/01/2012.
- Mr. Raoul de Charette de la Contrie, “Vision Algorithms for Rain and Traffic Lights in Driver Assistance Systems”, Mines ParisTech, Paris, 17/09/2012.
- Mr. Hao Li, “Cooperative Perception: Application in the Context of Outdoor Intelligent Vehicle Systems”, Mines ParisTech, Paris, 21/12/2012.

9.3. Popularization

- Several members of the project-team participated to demonstrations at the national “Fête de la Science”, October 10-13.
- Philippe Morignot presented the domain of Artificial Intelligence to three college students (TPE, Travaux Pratiques Encadrés) from the Lycée Jules Ferry, Versailles.

10. Bibliography

Major publications by the team in recent years

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

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[5] G. FAYOLLE, V. A. MALYSHEV, M. V. MENSHIKOV. *Topics in the constructive theory of countable Markov chains*, Cambridge University Press, 1995.

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

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

Publications of the year

Doctoral Dissertations and Habilitation Theses

[8] J. PÉREZ RASTELLI. *Agentes de control de vehículos autónomos en entornos urbanos y autovías*, Universidad Complutense de Madrid, March 2012, http://hal.inria.fr/tel-00732953.

Articles in International Peer-Reviewed Journals

[9] G. FAYOLLE, K. RASCHEL. *Some exact asymptotics in the counting of walks in the quarter-plane*, in "Discrete Mathematics and Theoretical Computer Science", September 2012, p. 109-124, http://hal.inria.fr/hal-00765851.

[10] C. FURTLEHNER, J.-M. LASGOUTTES, M. SAMSONOV. *One-dimensional Particle Processes with Acceleration/Braking Asymmetry*, in "Journal of Statistical Physics", June 2012, vol. 147, n^o 6, p. 1113-1144 [*DOI :* 10.1007/S10955-012-0521-Y], http://hal.inria.fr/hal-00743369.

[11] Y. HAN, F. MOUTARDE. *Statistical Traffic State Analysis in Large-scale Transportation Networks Using Locality-Preserving Non-negative Matrix Factorization*, in "IET Intelligent Transport Systems", 2013, http://hal.inria.fr/hal-00766716.

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[35] H. LI, F. NASHASHIBI. *Cooperative multi-vehicle localization using split covariance intersection filter*, in "IV 2012 - IEEE Intelligent Vehicles Symposium", Alcala de Henares, Spain, June 2012, p. 211 - 216 [*DOI :* 10.1109/IVS.2012.6232155], http://hal.inria.fr/hal-00763811.

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

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[38] V. MARTIN, J.-M. LASGOUTTES, C. FURTLEHNER. *Local stability of Belief Propagation algorithm with multiple fixed points*, in "STAIRS'12 - Sixth "Starting Artificial Intelligence Research" Symposium", Montpellier, France, K. KERSTING, M. TOUSSAINT (editors), IOS Press, 2012, p. 180-191, http://hal.inria.fr/hal-00719204.

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