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ACTIVITY REPORT

Project-Team

RITS

Robotics & Intelligent Transportation Systems

DOMAIN

Perception, Cognition and Interaction

THEME

Robotics and Smart environments

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Project-Team RITS

Creation of the Project-Team: 2015 July 01

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1 Team members, visitors, external collaborators

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- Jean-Marc Lasgouttes [Inria, Researcher]
- Gérard Le Lann [Inria, Emeritus]
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- Yacine Ben Ameur [Inria, From Oct 2021]
- Anh Quan Cao [Inria]
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- Ivan Lopes [Inria, from Sep 2021]
- Imane Mahtout [Renault, Jan 2021]
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External Collaborators

- Jean Francois Lalonde [Université Laval - Québec Canada, from Mar 2021]
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2 Overall objectives

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

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

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

1. the control of individual road vehicles to improve locally their efficiency and safety,

2. the design and control of large transportation systems.

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

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

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

- *Technical*: design certified architectures enabling safe vehicle-to-vehicle and vehicle-to-vehicle communications obeying to standards and norm;

- *Fundamental*: design and develop appropriate architectures capable of handling thorny problems of routing and geonetworking in highly dynamic vehicular networks and high speed vehicles.

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

3 Research program

3.1 Vehicle guidance and autonomous navigation

Participants: Pranav Agarwal, Yacine Ben Ameur, Anh Quan Cao, Raoul de Charette, Amina Ghoul, Jean François Lalonde, Ivan Lopes, Imane Mahtout, Kathia Melbouci, Kaouther Messaoud, Fawzi Nashashibi, Fabio Pizzati, Renaud Poncelet, Luis Roldao, Anne Verroust-Blondet, Itheri Yahiaoui, Jiahao Zhang.

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.

3.2 Perception of the road environment

Participants: Anh Quan Cao, Raoul de Charette, Jean François Lalonde, Ivan Lopes, Kaouther Messaoud, Fawzi Nashashibi, Fabio Pizzati, Luis Roldao, Anne Verroust-Blondet, Itheri Yahiaoui.

Either for driver assistance or for fully automated guided vehicle purposes, the first step of any robotic system is to perceive the environment in order to assess the situation around itself. Proprioceptive sensors (accelerometer, gyrometer,...) provide information about the vehicle by itself such as its velocity or lateral acceleration. On the other hand, exteroceptive sensors, such as video camera, laser or GPS devices, provide information about the environment surrounding the vehicle or its localization. Obviously, a holistic scene understanding from such sensors is an obvious prerequisite for autonomous driving.

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

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

Scene understanding is a large perception problem. In this research axis we leverage various computer vision sensors, such as conventional cameras, depth sensors (Time-of-flight, LiDAR, etc.), but also neuromorphic cameras.

We have initiated several works:

- image-to-image (i2i) adversarial networks allow to learn the source-target mapping and are great adjunctions to train on unseen domains of data. We have investigated a few i2i setups where domain gaps is variable (e.g. day-to-night), leveraging domain knowledge, or physics. This boost performance of the tested vision algorithms.

- vision in adverse weather. Most often perception algorithms work under the premise of a transparent atmosphere which breaks in bad weathers (rain, snow, hail, fog, etc.). In these situations the light ray are disrupted by the particles in suspension, producing light attenuation, reflection, refraction that alter the image processing.
- semantic scene completion. Being able to extract a complete dense representation of the scene is important for robots that evolve in our world. We addressed this from depth or image data.
- domain adaptation. To relax the need of supervision, domain adaptation was investigated in an unsupervised, self-supervised or cross-modal fashion.
- deep learning for object recognition. New works are being initiated in our team to develop deep learning recognition in the context of heterogeneous data.
- deep learning for vehicle motion prediction.

3.3 Planning and executing vehicle actions

Participants: Yacine Ben Ameur, Imane Mahtout, Fawzi Nashashibi, Renaud Poncelet, Anne Verroust-Blondet.

From the understanding of the environment, thanks to augmented perception, we have either to warn the driver to help him in the control of his vehicle, or to take control in case of a driverless vehicle. In simple situations, the planning might also be quite simple, but in the most complex situations we want to explore, the planning must involve complex algorithms dealing with the trajectories of the vehicle and its surroundings (which might involve other vehicles and/or fixed or moving obstacles). In the case of fully automated vehicles, the perception will involve some map building of the environment and obstacles, and the planning will involve partial planning with periodical recomputation to reach the long term goal. In this case, with vehicle to vehicle communications, what we want to explore is the possibility to establish a negotiation protocol in order to coordinate nearby vehicles (what humans usually do by using driving rules, common sense and/or non verbal communication). Until now, we have been focusing on the generation of geometric trajectories as a result of a maneuver selection process using grid-based rating technique or fuzzy technique. We are now focusing on decision processes based on reinforcement learning combined with attention mechanisms in order to tackle multi-criteria based decision. Such a system needs several heterogeneous inputs, some of them are related to the accurate estimation and prediction of neighboring vehicles and their interaction. This was a major topic we focused on last year especially through the thesis of Kaouther Messaoud [46]. The outcome of the decision system is naturally the planning module that generates the coming trajectory to be followed by the ego-vehicle. For high speed vehicles, we use of quintic polynomials we designed earlier (theses of David Bautista [39] and Fernando Garrido [38]), allowed us to elaborate trajectories with different dynamics adapted to the driver profile. These trajectories have been implemented and validated in in the past on different platforms (the JointSystem demonstrator of the German Aerospace Center (DLR) used in the European project HAVEit, RITS's electrical vehicle prototype used in the French project ABV). HAVEit was also the opportunity for RITS to take in charge the implementation of the Co-Pilot system which processes perception data in order to elaborate the high level command for the actuators. These trajectories were also validated on RITS's cybercars.

However, for the low speed cybercars that have pre-defined itineraries and basic maneuvers, it was necessary to develop a more adapted planning and control system. Therefore, we have developed a nonlinear adaptive control for automated overtaking maneuver using quadratic polynomials and Lyapunov function candidate and taking into account the vehicles kinematics. For the global mobility systems we are developing, the control of the vehicles includes also advanced platooning, automated parking, automated docking, etc. For each functionality a dedicated control algorithm was designed (see publication of previous years).

In the past few years we initiated and conducted focused research on the so-called "Plug & Play Control" as well as on their application to the control of autonomous vehicles. Two PhD thesis (Francisco

Navas Matos and Imane Mahtout) have centered their studies on the design of control architectures that are able to deal with changes in the operating conditions and assure vehicle performance and stability. Youla-Kucera parametrization has been used to design control structures able to recognize the driving situation changes, adapting the controller response to satisfy the required performance level and keeping the motion stability with a natural vehicle behavior. These architectures were validated through real implementations on RITS and Renault autonomous prototype vehicles; more specifically to develop longitudinal and lateral control of the vehicle in the presence of disturbances and context sudden modifications.

3.4 Cyberphysical constructs and mobile communications for fully automated networked vehicles

Participants: Gérard Le Lann.

Safety, privacy, efficiency, and cybersecurity (SPEC) properties are key to the advent of self-forming and self-healing networks of fully automated driverless terrestrial vehicles.

- Safety (S): Ratios of fatalities and non-lethal accidents should be much smaller than those achieved with non-fully automated systems that rely on human supervision or interventions.
- Privacy (P): No personal data should be inferred or extracted from cyber information, wireless communications, or from physical information such as paths and routes followed by vehicles.
- Efficiency (E): Road capacity and vehicular densities should be much higher than those achieved with non-fully automated systems for identical velocities. For example, inter-vehicular gaps are much smaller, which is antagonistic with the safety property.
- Cybersecurity (C): Safety should not be compromised by internal or external cyberattacks such as spoofing, Sybil attacks, Man-in-the-Middle attacks, message falsification or suppression, injection of bogus data, replay attacks, Denial-of-Service.

CAVs and NGVs rest on robotics capabilities (radars, lidars, cameras, motion control laws, learning engines, GNSS devices, actuators, etc.). CAVs use (1) V2X (vehicle-to-everything) functionalities based on medium range WiFi DSRC communications, cellular C-V2X communications, local dynamic maps built out of periodic beaconing of messages that carry their GNSS coordinates, and (2) V2I (vehicle-to-infrastructure) communications, as per ETSI standards. Owing to shortcomings proper to the V2X framework, it is reasonably straightforward to demonstrate that spontaneous networks of CAVs cannot be endowed with SPEC properties (safety, privacy, efficiency, cybersecurity). A particularly interesting case is that of periodic beaconing. In addition to enabling tracking and illegitimate cyberespionage, local dynamic maps cannot be of any help regarding safety, since they cannot be mutually consistent[1].

SPEC properties must hold in heterogeneous and spontaneous vehicular networks. Moreover, interoperability issues raised by the coexistence of vehicles of different generations must also be addressed in such networks. Some framework other than V2X is needed. CMX is such a framework. The CMX framework matches mobile edge computing models, whereby everything that is needed for achieving the SPEC properties is available from onboard systems of vehicles, referred to as NGVs[2].

NGVs are equipped with very short-range directional C-V2V communications (cellular radio and optics), medium range WiFi communications, and explicit agreement algorithms aimed at handling safety-critical maneuvers. NGVs do not rely on V2I communications relayed via terrestrial infrastructures and nodes. Periodic beaconing is banished. Every NGV is assigned a SAE driving level ranging from 0 (human driving) to 5 (no human driving or supervision, any time, everywhere), as well as a cyberphysical

[1] see the famous FLP85 impossibility result by M.J. Fischer, N.A. Lynch, and M.S. Paterson, "Impossibility of distributed consensus with one faulty process", Journal of the ACM, vol. 32(2), April 1985, 374–382.

[2] See INRIA Research Report 9297, Oct. 2019)

level, denoted cpl. A cpl is a pair cl, pl, where cl stands for a cyber level and pl stands for a physical level, each ranging from 0 to 5. Low-cost vehicles have cp levels closest to 0, 0, while premium vehicles have cp levels closest 5, 5. NGVs are equipped with proactive security modules (PSMs are extensions of hardware security module), enabling self-checking and self-awareness. Numerous abnormal behaviors can be detected by a PSM, in which case the faulty vehicle is halted by its onboard system.

3.5 Probabilistic modeling for large transportation systems

Participants: Guy Fayolle, Jean-Marc Lasgouttes.

This activity concerns the modeling of random systems related to ITS, through the identification and development of solutions based on probabilistic methods and more specifically through the exploration of links between large random systems and statistical physics. Traffic modeling is a very fertile area of application for this approach, both for macroscopic (fleet management [35], traffic prediction) and for microscopic (movement of each vehicle, formation of traffic jams) analysis. When the size or volume of structures grows (leading to the so-called "thermodynamic limit"), we study the quantitative and qualitative (performance, speed, stability, phase transitions, complexity, etc.) features of the system.

In the recent years, several directions have been explored.

3.5.1 Traffic reconstruction

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

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

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

- find the best way to inject real-valued data in an Ising model with binary variables [44];
- build macroscopic variables that measure the overall state of the underlying graph, in order to improve the local propagation of information [37];
- make the underlying model as sparse as possible, in order to improve BP convergence and quality [43].

Finally, in collaboration with PTV SISTeMA (Italy), we have shown that this method has a very good ability to predict flow variables. This has been demonstrated on two large scale datasets covering the cities of Turin and Vienna [12].

3.5.2 Exclusion processes for road traffic modeling

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

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

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

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

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

We have considered in [32] some classes of models dealing with the dynamics of discrete curves subjected to stochastic deformations. It turns out that the problems of interest can be set in terms of interacting exclusion processes, the ultimate goal being to derive hydrodynamic limits after proper scaling. A seemingly new method is proposed, which relies on the analysis of specific partial differential operators, involving variational calculus and functional integration. Starting from a detailed analysis of the Asymmetric Simple Exclusion Process (ASEP) system on the torus $\mathbb{Z}/n\mathbb{Z}$, the arguments a priori work in higher dimensions (ABC, multi-type exclusion processes, etc), leading to systems of coupled partial differential equations of Burgers' type.

3.5.3 Random walks in the quarter plane

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

One essential question concerns the computation of stationary measures (when they exist). As for the answer, it has been given by original methods formerly developed in the team (see books and related bibliography). For instance, in the case of small steps (jumps of size one in the interior of $\mathbb{Z}_+^2$), the invariant measure $\{\pi_{i,j}, i, j \geq 0\}$ does satisfy the fundamental functional equation (see [1]):

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

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

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

- *Group of the random walk.* In several studies, it has been noticed that the so-called *group of the walk* governs the behavior of a number of quantities, in particular through its *order*, which is always even. In the case of small jumps, the algebraic curve R defined by $\{Q(x,y) = 0\}$ is either of *genus* 0 (the sphere) or 1 (the torus). In [Fayolle-2011a], when the drift of the random walk is equal to 0 (and then so is the genus), an effective criterion gives the *order* of the group. More generally, it is also proved that whenever the genus is 0, this order is infinite, except precisely for the zero drift case, where finiteness is quite possible. When the *genus* is 1, the situation is more difficult. Recently [34], a criterion has been found in terms of a determinant of order 3 or 4, depending on the arity of the group.

- *Nature of the counting generating functions.* Enumeration of planar lattice walks is a classical topic in combinatorics. For a given set of allowed jumps (or steps), it is a matter of counting the number of paths starting from some point and ending at some arbitrary point in a given time, and possibly restricted to some regions of the plane. A first basic and natural question arises: how many such paths exist? A second question concerns the nature of the associated counting generating functions (CGF): are they rational, algebraic, holonomic (or D-finite, i.e. solution of a linear differential equation with polynomial coefficients)?

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

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

satisfies the functional equation

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

where z is considered as a time-parameter. Clearly, equations 2 and 1 are of the same nature, and

answers to the above questions have been given in [Fayolle-2010].

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

3.5.4 Simulation for urban mobility

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

- Discrete event simulation for collective taxis, a public transportation system with a service quality comparable with that of conventional taxis.

- Discrete event simulation a system of self-service cars that can reconfigure themselves into shuttles, therefore creating a multimodal public transportation system; this second simulator is intended to become a generic tool for multimodal transportation.

- Joint microscopic simulation of mobility and communication, necessary for investigation of cooperative platoons performance.

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

4 Application domains

4.1 Introduction

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

4.2 Driving assistance

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

4.3 New transportation systems

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

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

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

4.4 Automated vehicles

The long term effort of the project is to put automatically guided vehicles (cybercars) on the road. It seems too early to mix cybercars and traditional vehicles, but data processing and automation now make it possible to consider in the relatively short term the development of such vehicles and the adapted infrastructures. RITS aims at using these technologies on experimental platforms (vehicles and infrastructures) to accelerate the technology transfer and to innovate in this field. Other application can be precision docking systems that will allow buses to be automatically maneuvered into a loading zone or maintenance area, allowing easier access for passengers, or more efficient maintenance operations. Transit operating costs will also be reduced through decreased maintenance costs and less damage to the braking and steering systems.

5 Social and environmental responsibility

5.1 Footprint of research activities

May the more noticeable outcome of RITS research activities would be the creation of several spinoffs by the team members ansdespecially your PhD holders. Pierre de Beaucorps and Pierre Bourré created AVACAR dedicated to the remote control of automated vehicles and fleets. Danut Ovidiu-Pop created IPYA, a multi-task pedestrian protection system based on mulmodal signal processing using deep AI architectures.

5.2 Impact of research results

The pioneering work of the RITS team in the field of autonomous shuttles, particularly within the framework of European projects (CityMobil, Citymobil-2...), has encouraged many French and international players to embark on the field of intelligent mobility based on autonomous shuttles. Nowadays, the two reference companies in this field worldwide are EasyMile and NAVYA; both have also recruited alumni from the RITS team to strengthen their research and development teams.

6 Highlights of the year

With the help of its strategic partners Valeo and SAFRAN and the support of other partners, the RITS team is the winner of the AMI call for projects *Plan de relance Auto R&D* dedicated to Auto Recovery Plan: the **SAMBA** project. An important and accelerated research and development effort will be deployed by RITS in order to address scientific and technical challenges related to autonomous driving and driving assistance in order to reach advanced levels of TRL (Technology Readiness Level). Non less than 5 researchers were hired for this purpose.

7 New software and platforms

star-ips a family of incremental GMRF estimation algorithms.

Web site: https://gitlab.inria.fr/bptraffic/star-ips.

Software Family: `research`

Audience: `partners`

Evolution and maintenance: `basic`

Duration of the Development: > 4 years

`star-ips` is an open-source program that implements the family of algorithms $\star$-ips based on the Iterative Proportional Scaling (IPS) procedure. Using IPS, it incrementally selects links and partial correlations of a GMRF imposing spectral and/or topological constraints.

xMUDA / xMoSSDA Cross-Modal Learning for 3D Semantic Segmentation [42] [25]

Web site: https://github.com/valeoai/xmuda

Contribution: `leader`

Software Family: `research`

Audience: `community`

Evolution and maintenance: `basic`

Duration of the Development: ≥ 2 years

CoMoGAN Continuous model-guided image-to-image translation

Web site: https://github.com/cv-rits/CoMoGAN

Contribution: `leader`

Software Family: `research`

Audience: community

Evolution and maintenance: basic

Duration of the Development: ≥ 1 year

PBR-Rain Physics-Based Rendering for Improving Robustness to Rain [40, 51]

Website: https://github.com/cv-rits/rain-rendering

Contribution: `leader`

Software Family: `research`

Audience: `community`

Evolution and maintenance: `basic`

Duration of the Development: ≥ 2 years

Description: Opensource code for rendering physically-calibrated rain in clear weather images. We also released a multi-weather dataset with that code, which encompasses 390k images and was downloaded by ≈200 unique users since Dec. 2019.

LMSCNet Lightweight Multiscale 3D Semantic Completion [50]

Web site: https://github.com/cv-rits/LMSCNet

Contribution: `leader`

Software Family: `research`

Audience: `community`

Evolution and maintenance: `basic`

Duration of the Development: ≥ 1 year

MonoScene Monocular 3D Semantic Scene Completion [21]

Web site: https://github.com/cv-rits/MonoScene

Contribution: `leader`

Software Family: `research`

Audience: `community`

Evolution and maintenance: `basic`

Duration of the Development: ≥ 1 year

ManiFest Manifold Deformation for Few-shot Image Translation [28]

Web site: https://github.com/cv-rits/ManiFest (upon release)

Contribution: `leader`

Software Family: `research`

Audience: `community`

Evolution and maintenance: `basic`

Duration of the Development: ≥ 1 year

MVPNet Multi-view PointNet for 3D Scene Understanding [41]

Web site: https://github.com/maxjaritz/mvpnet

Contribution: `leader`

Software Family: `research`

Audience: `community`

Evolution and maintenance: `basic`

Duration of the Development: ≥ 1 year

6-DOF RGB-D-E Event Camera Calibration for Fast 6-DOF Object Tracking [31]

Web site: https://github.com/lvsn/rgbde_tracking

Contribution: `devel` (leader: *Université Laval*)

Software Family: `research`

Audience: `community`

Evolution and maintenance: `basic`

Duration of the Development: ≥ 1 year

Description: Opensource code for 6-DOF tracking. We also released a unique RGB-D-E datasets with ad-hoc labels..

WPSimulator Weather Particle Simulator [30]

Web site: https://github.com/cv-rits/weather-particle-simulator

Contribution: `devel`

Software Family: `research`

Audience: `community`

Evolution and maintenance: `basic`

Duration of the Development: ≥ 3 years

Description: Binaries for physical simulation of particulate weather. The project was initiated at Carnegie Mellon University, and revived recently in RITS for public release.

8 New results

8.1 Image-to-image translation

Participants: Fabio Pizzati, Raoul de Charette
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Following the work [20] presented in CVPR 2021, the main research carried on this year has been done in collaboration with Jean-François Lalonde (Université Laval) and submitted to conference in November 2021. Most image-to-image translation methods require a large number of training images, which restricts their applicability. We instead propose ManiFest: a framework for few-shot image translation that learns a context-aware representation of a target domain from a few images only [28]. To enforce feature consistency, our framework learns a style manifold between source and proxy anchor domains (assumed to be composed of large numbers of images). The learned manifold is interpolated and deformed towards the few-shot target domain via patch-based adversarial and feature statistics alignment losses. All of these components are trained simultaneously during a single end-to-end loop. In addition to the general few-shot translation task, our approach can alternatively be conditioned on a single exemplar image to reproduce its specific style. Extensive experiments demonstrate the efficacy of ManiFest on multiple tasks, outperforming the state-of-the-art on all metrics and in both the general- and exemplar-based scenarios.

Additionally, an extension of the paper published in ECCV 2020 [47] has been submitted to the International Journal of Computer Vision (IJCV). Image-to-image translation (i2i) networks suffer from entanglement effects in presence of physics-related phenomena in target domain (such as occlusions, fog, etc), thus lowering the translation quality and variability. In our paper [27], we present a comprehensive method for disentangling physics-based traits in the translation, guiding the learning process with neural or physical models. For the latter, we integrate adversarial estimation and genetic algorithms to correctly achieve disentanglement. The results show our approach dramatically increase performances in many challenging scenarios for image translation.

Finally, a collaboration with University of Parma and VisLab (Italy) resulted in an additional publication in VISAPP 2022. Image-to-image (i2i) networks struggle to capture local changes because they do not affect the global scene structure. For example, translating from highway scenes to offroad, i2i networks easily focus on global color features but ignore obvious traits for humans like the absence of lane markings. In our paper [22], we leverage human knowledge about spatial domain characteristics which we refer to as “local domains” and demonstrate its benefit for image-to-image translation. Relying on a simple geometrical guidance, we train a patch-based GAN on few source data and hallucinate a new unseen domain which subsequently eases transfer learning to target. We experiment on three tasks ranging from unstructured environments to adverse weather. Our comprehensive evaluation setting shows we are able to generate realistic translations, with minimal priors, and training only on a few images. Furthermore, when trained on our translations images we show that all tested proxy tasks are significantly improved, without ever seeing target domain at training. In [48] – an earlier work –, we also leverage high level domain knowledge and propose automatic identification of domain bridge that ease the i2i task, leading to more stable and qualitative outputs.

8.2 Multi-task learning domain adaptation for dense predictions

Participants: Ivan Lopes, Raoul de Charette.

We aim to unify two problems that are commonly addressed separately: multi-task learning and domain adaptation. Our primary goal is to encourage the information flow between tasks to improve the overall performance of each task. Departing from the recent findings in computer vision, we introduce a novel distillation block to leverage cross interactions between task modalities. With the proposed multi-task design, we tackle semantic segmentation, depth estimation (as well as self-supervised depth), and surface normals estimation. Our current line of work extends on this approach to provide a method for multi-task learning in the synthetic-to-real domain adaptation setup. This work is conducted with Tuan-Hung Vu from Valeo.ai.

8.3 Point Cloud Registration

Participants: Anh-Quan Cao.

In [18] a deep learning technique solving the point cloud registration problem is proposed. This problem is usually tackled by first finding the correspondences between the point clouds, then selecting the good ones to compute the transformation. The key element of our method is the supervision of the element-wise product of the cross-attention matrices that mix the low-level geometric and high-level contextual information to find point correspondences. These matrices also enable the exchange of context information between the point clouds at multiple layers of the deep net, resulting in richer learned features. We demonstrate the state-of-the-art results on several real-world point cloud registration benchmarks. This work has been done in part during an intership at Valeo.ai.

8.4 Semantic Scene Completion from Single Image

Participants: Anh-Quan Cao, Raoul de Charette.

We introduce a deep learning technique named MonoScene that infers the dense geometry and semantics of a scene from a single monocular RGB image. At the core of our method is the features line of sight projection module bridging the 2D and 3D network. To further enhance the spatio-semantic information, we propose the 3D relation context prior layer that encodes the voxel semantic relations. Furthermore, we introduce novel global scene and local frustums losses. Our method outperforms the literature on all metrics and datasets while properly hallucinating the scenery outside the field of view (cf. [21]).

8.5 3D Semantic Scene Completion

Participants: Luis Roldão, Raoul de Charette, Anne Verroust-Blondet.

Semantic Scene Completion (SSC) aims to jointly estimate the complete geometry and semantics of a scene, assuming partial sparse input.

In the last years following the multiplication of large-scale 3D datasets, SSC has gained significant momentum in the research community because it holds unresolved challenges. In [17],[49] we propose a survey on SSC, which aims to identify, compare and analyze the techniques providing a critical analysis of the SSC literature on both methods and datasets. We also evaluate and analyze SSC performance of the SoA on the most popular datasets. This research is partially funded by AKKA Technology.

8.6 Implicit neural representation for LiDAR based navigation

Participants: Kathia Melbouci, Fawzi Nashashibi.

In our previous work [45] we showed that occupancy surface representation obtained by projecting the 3D point cloud enables accurate localization on challenging benchmarks. This representation is easy to store and contains additional information like reflectance but it is less adapted if we want to extract the 3D model.

Recent works choose a neural network as a surface representation function, as for example representation of neural radiation fields (NeRF) that achieved significant results by capturing volume density and color implicitly with a neural network.

This year, we investigate whether neural network representation trained online could be used as the only world representation for LIDAR based navigation, without prior learning over the ground truth dataset. The aim is to achieve real-time LIDAR based SLAM via continual learning of the neural network. To that end, an extended tracking process is performed by warping the live range image - generated from spherical projection of the 3D point cloud -, against the predicted one -rendered from the neural network world map-. In parallel, a mapping process selects a bunch of range images to fed and maintain the neural network world representation, to avoid catastrophic forgetting property of this latest.

8.7 Vehicle trajectory prediction

Participants: Kaouther Messaoud, Fawzi Nashashibi, Anne Verroust-Blondet, Itheri Yahiaoui, Amina Ghoul.

This year, we pursued our work on vehicle trajectory prediction, using the attention mechanism to exploit information about the surrounding agents [14] in a Highway context and using both the vehicles interactions and the scene context with MHA-JAM approach [19] on a urban environment (More details and additional architectures are presented in the PhD manuscript of Kaouther Messaoud [46]).

An extension of this work and evaluations on the Waymo dataset have started with the arrival of Amina Ghoul, PhD student funded by SAMBA project.

8.8 Vehicle motion planning in a dynamic urban environment

Participants: Renaud Poncelet, Anne Verroust-Blondet, Fawzi Nashashibi.

Extending the work on RIS[29] introduced for robots, we worked on developing a navigation method combining speed and path planning adapted to an autonomous vehicle which moves in a dynamic urban environment and respects driving rules. Preliminary evaluations have been made using CARLA simulator.

8.9 Explainable driving decision for autonomous driving

Participants: Yacine Ben Ameur, Kaouther Messaoud, Anne Verroust-Blondet, Fawzi Nashashibi.

Within the PhD thesis of Yacine Ben Ameur we begun to work on decision systems for autonomous driving.

Although reinforcement learning has shown impressive results in the past few years, its application to autonomous driving has been altered by the fact that the reinforcement learning agent outputs black-box decisions and is not suited for such a safety-critical system. To alleviate this issue, we trained a deep reinforcement learning agent (Deep Q Network) using a network equipped with an attention mechanism to drive a vehicle in a simulated highway environment. Visualizing the attention weights in real-time allow us to quantify the importance given to each actor in the scene when taking the decision.

8.10 Cyberphysical constructs and SPEC properties in the presence of attacks

Participants: Gérard Le Lann.

Work on cyberphysical constructs (cohorts and flocks) and SPEC properties has been continued. The motivation was to verify a major objective Γ set for the CMX framework: in the presence of attacks **S** (safety) is always preserved (0 fatalities), possibly at the expense of reduced **E** (efficiency)—larger inter-vehicular gaps for example. Objective Γ is reached for all cases examined in 2021.
Solutions coined in 2020 for safe and efficient crossing of unsignalized intersections of arbitrary topologies (any number of arteries) by spontaneous vehicular flocks rest on radio communications. Work in 2021 has focused on how to cope with jamming attacks against radio channels. Solutions are based on immediate detection and reliance on optical communications (native in the CMX framework).

Work with a North-American company has been continued, focused on spontaneous cohorts. More than a dozen cyberattacks (via messaging) aimed at creating chaos when NGVs undertake safety-critical maneuvers (e.g., conflicting lane changes, lane merging, overtaking) have been examined. LgJoin and LtJoin protocols (longitudinal and lateral maneuvers for joining a cohort, respectively) have been shown to be immune to such attacks. Cyberattacks against a PSM are unfeasible. Physical attacks on a PSM (by a human, e.g., an owner, an evil mechanic) have been explored in detail. We show how to thwart such attacks, which lead to a total blocking of the NGV under attack.

As for **P** (privacy), work on UPFs (Unambiguous Physical Functions), simple variations of PUFs (Physically Unclonable Functions), has been continued, with a focus on the cohort construct and risk-prone maneuvers (joining a cohort longitudinally, laterally, and leaving a cohort). We show how a NGV may designate a specific NGV within line-of-sight, and how to engage reciprocal privacy-preserving messaging out of zero-knowledge protocols (no ID, no MAC, no IP addresses).

8.11 3D transportation systems

Participants: Gérard Le Lann.

This work addresses issues that arise with spontaneous networks of autonomous aerial vehicles, such as air taxis, drones, airliners, constellations of satellites, space probes, and space exploration vehicles. In organized skies, vehicles of different capabilities are bound to move within well-defined corridors, physically separated from each other. Nevertheless, some may share the same corridor (e.g., air taxis and small drones, fleets of micro-satellites orbiting at low altitude), and corridors are crossed all the time by vehicles during ascending and descending phases. It follows that distributed agreement algorithms must be used in order to achieve safe and efficient coordination of aerial vehicles. A significant difficulty is due to the need to thwart all kinds of cyberattacks, in addition to achieving conventional fault-tolerance.

A first step toward distributed agreement algorithms in 3D space consists in showing how to achieve reliable communications among aerial vehicles. Building on 40 years of experience with Internet, we show that distributed agreement algorithms are a generalization of the well-known TCP/IP protocol. This work has drawn attention from the InterPlanetary Networking Special Interest Group (see https:ipnsig.org), leading to a first publication [26].

8.12 Belief propagation inference for traffic prediction

Participant: Jean-Marc Lasgouttes.

This line of work, in collaboration with Cyril Furtlehner (TAU, Inria), deals with real-time prediction of traffic conditions in a urban setting with incomplete data. The main focus is on finding a good way to encode available information (flow, speed, counts,. . .) in a Markov Random Field, and to decode it in the form of real-time traffic reconstruction and prediction. Our approach relies in particular on the Gaussian belief propagation algorithm.

Through our collaboration with PTV Sistema, we obtained extensive results on large-scale datasets containing 250 to 2000 detectors. The results show very good ability to predict flow variables and a reasonably good performance on speed or occupancy variables. Some element of understanding of the observed performance are given by a careful analysis of the model, allowing to some extent to disentangle modeling bias from intrinsic noise of the traffic phenomena and its measurement process.

This work has been published in *IEEE Transactions on Intelligent Transportation Systems* [12].

8.13 Stabilization of traffic through cooperative autonomous vehicles

Participant: Guy Fayolle, Jean-Marc Lasgouttes.

We investigate in [36] the transfer function emanating from the linearization of a car-following model for human drivers, when taking into account their reaction time, which is known to be a cause of the stop-and-go traffic phenomenon. This leads to a non rational transfer function, implying nontrivial stability conditions which are explicitly given. They are in particular satisfied whenever string stability holds. We also show how this reaction time can introduce a *partial string stability*, where the transfer function modulus remains smaller than 1 up to some critical frequency. We explore conditions in the parameter space discriminating between 3 different regimes (stability, string stability, partial string stability).

This is intended as a foundation of a larger work on traffic stabilization by means of a fleet of co-operative automated vehicles. However, contrary to some earlier work, our approach is based on a car-following model with reaction-time delay, rather than on a first order fluid model. While the focus of the present work is on human-driven vehicles, the next steps will be to tackle shockwave analysis and adapted traffic-stabilizing control strategies.

This is a joint work with Carlos Flores from UC Berkeley, which has been submitted to *SIAM Journal on Applied Mathematics*.

8.14 Automated vehicle collection using an hedonic game

Participants: Jean-Marc Lasgouttes.

This is a joint work with Mohamed Hadded (Vedecom) and Pascale Minet (EVA, Inria).

We consider in [13] a shared transportation system in an environment where human drivers collect vehicles that are no longer being used. Each driver, also called a platoon leader, is in charge of driving collected vehicles as a platoon to bring them back to some given location (e.g. an airport, a railway station). Platoon allocation and route planning for picking up and returning automated vehicles is one of the major issues of shared transportation systems that need to be addressed. We propose a coalition game approach to compute 1) the allocation of unused vehicles to a minimal number of platoons, 2) the optimized tour of each platoon and 3) the minimum energy consumed to collect all these vehicles.

In this coalition game, the players are the parked vehicles, and the coalitions are the platoons that are formed. This game, where each player joins the coalition that maximizes its payoff, converges to a stable solution. The quality of the solution obtained is evaluated with regard to three optimization criteria and its complexity is measured by the computation time required. Simulation experiments are carried out in various configurations. They show that this approach is very efficient to solve the multi-objective optimization problem considered, since it provides the optimal number of platoons in less than a second for 300 vehicles to be collected, and considerably outperforms other well-known optimization approaches like MOPSO (Multi-Objective Particle Swarm Optimization) and NSGA-II (Non dominated Sorting Genetic Algorithm).

This work has been published in *Concurrency and Computation: Practice and Experience*.

8.15 Genus and classification of Random walks in the quarter plane

Participants: Guy Fayolle.

In collaboration with R. Iasnogorodski (SPCPA, Saint-Petersburg), we analyze in [11] the *kernel* $K(x,y,t)$ of the basic functional equation associated with the tri-variate counting generating function (CGF) of walks in the quarter plane. In this paper, taking $t\in]0,1[$, we provide the conditions on the step set $\{p_{i,j}\}$ to decide whether the walks are *singular* or *regular*, as defined in [33, Section 2.3]. These conditions are independent of $t\in]0,1[$ and given in terms of *step set configurations*. We also find the configurations for the kernel to be of genus 0, knowing that the genus is always ≤ 1. All these conditions are very similar to the case $t=1$ considered in [33]. Our results extend previous work by Dreyfus *et al*, which considers only very special situations, namely when $t\in]0,1[$ is a transcendental number over the field $Q(p_{i,j})$.

8.16 Reflected brownian motion in a non convex cone

Participants: Guy Fayolle.

In collaboration with S. Franceschi (LMO, Paris-Saclay University) and K Raschel (CNRS, Tours University), we study the stationary reflected Brownian motion in a non-convex wedge, which, compared to its convex analogue model, has been much rarely analyzed in the probabilistic literature. We prove that its stationary distribution can be found by solving a two dimensional vector boundary value problem (BVP) on a single curve (an hyperbola) for the associated Laplace transforms. The reduction to this kind of vector BVP seems to be quite new in the literature. As a matter of comparison, one single boundary condition is sufficient in the convex case. When the parameters of the model (drift, reflection angles and covariance matrix) are symmetric with respect to the bisector line of the cone, the model is reducible to a standard reflected Brownian motion in a convex cone. Finally, we construct a one-parameter family of distributions, which surprisingly provides, for any wedge (convex or not), one particular example of stationary distribution of a reflected Brownian motion. The version [24] has been submitted for publication in the journal *Stochastic Processes and their Applications*.

8.17 Random walks in orthants and lattice path combinatorics

Participants: Guy Fayolle.

In the second edition of the book [33], original methods were proposed to determine the invariant measure of random walks in the quarter plane with small jumps (size 1), the general solution being obtained via reduction to boundary value problems. Among other things, an important quantity, the so-called *group of the walk*, allows to deduce theoretical features about the nature of the solutions. In particular, when the *order* of the group is finite and the underlying algebraic curve is of genus 0 or 1, necessary and sufficient conditions have been given for the solution to be rational, algebraic or D-finite (i.e. satisfying a linear differential equation). In this framework, number of difficult open problems related to lattice path combinatorics are currently being explored, in collaboration with A. Bostan and F. Chyzak (project-team SPECFUN, Inria-Saclay), both from theoretical and computer algebra points of view: concrete computation of the criteria, utilization of differential Galois theory, genus greater than 1 (i.e. when some jumps are of size ≥ 2), etc. A recent topic (mentioned in 2019) deals with the connections between simple product-form stochastic networks (so-called *Jackson networks*) and explicit solutions of functional equations for counting lattice walks, Some partial extensions of [23] are under development.

9 Bilateral contracts and grants with industry

9.1 Bilateral contracts with industry

Participants: Fawzi Nashashibi, Anne Verroust-Blondet.

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

- Valeo is currently a major financing partner of the "GAT" international Chaire/JointLab in which Inria is a partner. The other partners are: UC Berkeley, Shanghai Jiao-Tong University, EPFL, IFSTTAR, MPSA (Peugeot-Citroën) and SAFRAN.
- Technology transfer is also a major collaboration topic between RITS and Valeo as well as the development of a road automated prototype.
- Finally, Inria and Valeo are partners of the French project SAMBA (Sécurité Active et MoBilités Autonomes) including SAFRAN Group, Inria Paris, TwinwHeel, Soben, Stanley Robotics and EXPLEO.

Participants: Raoul de Charette, Anne Verroust-Blondet.

AKKA Technologies: Collaboration with AKKA since 2012 (for the Link & Go prototype). A CIFRE PhD thesis (Luis ROLDAO) dealing with 3D-environment modeling for autonomous vehicles begun in October 2017.

10 Partnerships and cooperations

Participants: Yacine Ben Ameur, Ahn-Quan Cao, Raoul de Charette, Amina Ghoul, Yvan Lopes, Kathia Melbouci, Kaouther Messaoud, Fawzi Nashashibi, Anne Verroust-Blondet.

10.1 International initiatives

10.1.1 Participation in other International Programs

Samuel de Champlain Québec-France collaboration program: "Vision par ordinateur en conditions difficiles", 2018–2022, cooperation between Raoul de Charette and Jean-François Lalonde from Laval University.

10.2 National initiatives

10.2.1 ANR

SIGHT

- Title: viSIon throuGH weaTher
- Instrument: ANR JCJC
- Duration: January 2021- December 2024
- Coordinator: Raoul de Charette
- Partners: Inria Paris, Université Laval, Mines ParisTech
- Inria contact: Raoul de Charette
- Abstract: SIGHT investigates invariant algorithms for complex weather conditions (rain, snow, hail). The project leverages un-/self-supervised algorithms with physic-guidance to model physically realistic weather, and learn weather-invariant features to improve vision algorithms.

10.2.2 ADEME – Bpifrance

SAMBA

- Title: Sécurité Active et MoBilités Autonomes (SAMBA2022)
- Instrument: Plan de soutien R&D automobile France
- Duration: September 2020 – January 2023

Grant: 902 302 €

- Partners: Valeo Group, SAFRAN Group, Inria Paris, TwinwHeel, Soben, Stanley Robotics, EXPLEO.
- Inria contact: Fawzi Nashashibi
- Abstract: The project aims to design active safety and autonomous mobility solutions that are affordable and can be deployed quickly, particularly on private vehicles. Technological solutions for new mobility services are proposed.

10.2.3 AMI – EquipEx+

TIRREX

- Inria is a major partner and beneficiary of the new EquipEx+ national initiative **TIRREX (Infrastructure technologique pour la recherche d'excellence en robotique)**. RITS team is an active participant of the "Autonomous Land Robotics" axis.
- Project start: Dec. 18, 2021
- Kick-off: Jan. 14, 2022

10.2.4 Competitivity Clusters

- RITS team is a very active partner in the competitivity clusters, especially **NextMove** (prev. MOV'EO). We are particularly involved in several technical committees like the DAS SMI (Systèmes de Mobilité Intelligents) for example.

- RITS is also the main Inria contributor in the VEDECOM institute (IEED). RITS is an active participant to the CD2 domain dedicated to autonomated driving.
- RITS is a close partner of **SystemX Institute** with a joint supervised PhD thesis (Jiahao Zhang).

11 Dissemination

Participants: Raoul de Charette, Guy Fayolle, Jean-Marc Lasgouttes, Gérard Le Lann, Fawzi Nashashibi, Fabio Pizzati, Anne Verroust-Blondet.

11.1 Promoting scientific activities

11.1.1 Scientific events: selection

Member of the conference program committees

- Raoul de Charette: Committee member of Conference on Artificial Intelligence (AAAI 2020), CVPR-Workshop on Deep Learning for Robotic Vision (CVPR-DRLV 2018), Conference on Photogrammetry and Remote Sensing (CFPT 2018).
- Fawzi Nashashibi: Member of the steering committee of the IEEE International Conference on Intelligent Computer Communication and Processing (ICCP), Cluj-Napoca, Romania.

Reviewer

- Raoul de Charette: Regular reviewer of CVPR, ECCV, ICCV, WACV, ICRA, IROS, and of AAAI, BMVC, CVIU, IV, ACCV.
- Fawzi Nashashibi: Regular reviewer of IEEE ICRA, IEEE/ISJ IROS, IEEE IV, IEEE ITSC, IEEE ICARCV, IEEE ICVES, ROBOVIS.
- Fabio Pizzati: WACV 2021, CVPR 2022.
- Anne Verroust-Blondet: IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2021), IEEE International Conference on Robotics and Automation (ICRA 2022), IEEE Intelligent Vehicles Symposium (IV 2021), IEEE Intelligent Transportation Systems Conference (ITSC 2021), Computer Graphics International (CGI 2021).

11.1.2 Journal

Member of the editorial boards

- Guy Fayolle: associate editor of the journal MPRF*Markov Processes and Related Fields*.
- Fawzi Nashashibi: Associate editor of the journals IEEE Transactions on Intelligent Vehicles (T-IV), IEEE Transactions on Intelligent Transportation Systems (T-ITS); guest Editor of the IEEE Sensors journal. Special Issue on "The Application of Sensors in Autonomous Vehicles".
- Anne Verroust-Blondet: associate editor of the journal *The Visual Computer*.

Reviewer – reviewing activities

- Raoul de Charette: PAMI, IJCV, RA-L, T-ITS, CVIU.
- Guy Fayolle: AAP, MPRF, PTRF, QUESTA, European Journal of Combinatorics, JSP, Physica A, Springer Science.
- Jean-Marc Lasgouttes: IEEE Transactions on Intelligent Transportation Systems.
- Fawzi Nashashibi: Regular reviewer of IEEE Transactions on Intelligent Vehicles, IEEE Transactions on Intelligent Transportation Systems, Transportation Research Part C, Journal of Traffic and Transportation Engineering, Transactions on Robotics, Journal on Transportation Engineering.
- Fabio Pizzati: Computer Vision and Image Understanding (CVIU), Information Fusion, and Transactions on Image Processing (T-IP).
- Anne Verroust-Blondet: IEEE Transactions on Intelligent Vehicles.

11.1.3 Invited talks

- Raoul de Charette: talk on *3D vision with less data*, Automotive connection, Montiny, France, 2021
- Fawzi Nashashibi: Keynote on *Connected Autonomous Vehicles: objectives and challenges*, the 21st edition of SUPCOM Annual Forum, Tunisia (hybrid), Jan. 6, 2021.
- Fawzi Nashashibi: Keynote on *Autonomous vehicles navigation: where AI addresses next challenges*, at Seminar@SystemX (webinar), March 18, 2021.
- Fabio Pizzati: talk on CoMoGAN at Valeo.ai (28/04/2021); talk on Physics-based image translation at EPFL (31/06/2021).

11.1.4 Scientific expertise

- Guy Fayolle: scientific advisor and associate researcher at the *Robotics Laboratory of Mines Paris-Tech*. He is also collaborating member of the research-team SPECFUN at Inria-Saclay.
- Jean-Marc Lasgouttes: member of the *Commission d'Évaluation* of Inria.
- Jean-Marc Lasgouttes: member of the CRCN recruiting commissions of Inria research centers of Bordeaux and Lyon.
- Fawzi Nashashibi: member of the international Automated Highway Board Committee of the TRB conference (AHB30).
- Fawzi Nashashibi: member of the Global Partnership on AI's (GPAI) working group on Innovation and Commercialization.
- Fawzi Nashashibi: member of the SMI (Intelligent Mobility Systems) Working Group (NextMove).
- Fawzi Nashashibi: reviewer at the European Commission for Horizon-2020 projects.
- Anne Verroust-Blondet is a reviewer for a FET-Open project (H2020 programme for research and innovation).

11.1.5 Research administration

- Guy Fayolle: a member of the working group IFIP WG 7.3.
- Jean-Marc Lasgouttes: member of the *Comité Technique Inria* and of the *Comité Local Hygiène Sécurité et Conditions de Travail* of Inria Paris.
- Fawzi Nashashibi is member of the Board of Governors of the VEDECOM Institute representing Inria and of the Board of Governors of NextMove Competitiveness cluster representing Inria.
- Anne Verroust-Blondet is the scientific correspondent of the International Partnerships for Inria Paris.

11.2 Teaching – Supervision – Juries

11.2.1 Teaching

- Engineering, 2nd year: Fawzi Nashashibi, "Image synthesis and 3D Infographics", 12h, M2, INT Télécom SudParis, IMA4503 "Virtual and augmented reality for autonomy".
- Master: Fawzi Nashashibi, "Obstacle detection and Multisensor Fusion", 4h, M2, INSA de Rouen.
- Master: Fawzi Nashashibi, "Perception and Image processing for Mobile Autonomous Systems", 12h, M2, University of Evry.
- Mastère: Raoul de Charette, "Scene Understanding with Computer Vision", 20h, post master, Mines ParisTech, France.
- Mastère: Jean-Marc Lasgouttes, "Introduction au Boosting", 10.5h, Mastère Spécialisé "Expert en sciences des données", INSA-Rouen, France.

11.2.2 Supervision

- PhD: Kaouther Messaoud, "Deep learning based trajectory prediction for autonomous vehicles", UPMC Sorbonne University, June 2021, supervisor: Anne Verroust-Blondet, co-supervisors: Fawzi Nashashibi, Itheri Yahiaoui.
- PhD: Luis Roldao, UPMC Sorbonne University, "3D Scene Reconstruction and Completion for Autonomous Driving", July 2021, supervisor: Anne Verroust-Blondet, co-supervisor: Raoul de Charette.
- PhD in progress: Yacine Ben Ameur, UPMC Sorbonne University, "Planification de trajectoires et systèmes de décision pour un véhicule autonome évoluant dans un environnement complexe", October 2021, supervisor Fawzi Nashashibi, co-supervisor: Anne Verroust-Blondet.
- PhD in progress: Ahn Quan Cao, PSL Research University, "Compréhension de la scène 3D non supervisée à partir d'images", March 2021, co-supervisors: Fawzi Nashashibi and Raoul de Charette.
- PhD in progress: Amina Ghoul, UPMC Sorbonne University, "Prédiction des mouvements d'usagers évoluant dans un environnement urbain ou péri-urbain", May 2021, supervisor Fawzi Nashashibi, co-supervisors: Anne Verroust-Blondet, Itheri Yahiaoui.
- PhD in progress: Ivan Lopes, PSL Research University, "Apprentissage guidé par modèle physique pour la vision en conditions météorologiques défavorables", November 2021, co-supervisors: Fawzi Nashashibi and Raoul de Charette.
- PhD in progress: Fabio Pizzati, "Style transfer and domain adaptation for semantic segmentation", PSL Research University and University of Bologna, November 2019, co-supervisors: Andrea Prati, Stefano Selleri, Fawzi Nashashibi and Raoul de Charette.

- PhD in progress: Renaud Poncelet, "Navigation autonome en présence d'obstacles fortement dynamiques au mouvement incertain", UPMC Sorbonne University, September 2018, supervisor: Anne Verroust-Blondet, co-supervisor: Fawzi Nashashibi.
- PhD in progress: Jiahao Zhang, "Misbehavior detection for collective perception in Intelligent Transportation System", October 2021, UPMC Sorbonne University, supervisor Fawzi Nashashibi, co-supervisor: Ines Ben Jemaa.

11.2.3 Juries

- Anne Verroust-Blondet was a jury member of the PhD thesis of Rémi Defraiteur, *Évaluation de systèmes d'aide à la conduite. Génération automatique de vérité terrain augmentée à partir d'un capteur haute résolution et d'une cartographie sémantique et 3D ; évaluation de fonctions de perception tierces*, Université Paris Saclay, June 15th, 2021.
- Anne Verroust-Blondet was a reviewer of the mid-term PhD thesis of Haoming Zhao, *Mitigating Catastrophic Interference in Deep Continual Learning for Visual Recognition*, Sorbonne Université, May 21st, 2021.
- Fawzi Nashashibi was president of the jury of the PhD of Rodolphe Dubois, *Méthodes de partage d'informations visuelles et inertielles pour la localisation et la cartographie simultanées décentralisées multi-robots*, Ecole Centrale de Nantes, Jan. 12, 2021.
- Fawzi Nashashibi was a reviewer and member of the PhD thesis of Nelson de Moura Martins Gomes, *Governing automated vehicle behavior*, Sorbonne Université, June 21st, 2021.
- Fawzi Nashashibi was president of the jury of the PhD thesis of Tiago Rocha Goncalves, *Robust control of platooning systems over imperfect wireless channels*, Université Paris-Saclay, Nov. 23, 2021.
- Fawzi Nashashibi was reviewer and jury member of the PhD thesis of Ali Alharake, *Localisation d'un véhicule basée sur l'utilisation et l'enrichissement d'informations cartographiques*, Normandie Université, Nov. 26, 2021.
- Fawzi Nashashibi was reviewer and jury member of the PhD thesis of Ameni Chtourou, *Communications contextuelles pour systèmes de transport intelligents dans des environnements hybrides*, Université Paris-Saclay, Dec. 13, 2021.
- Fawzi Nashashibi participated to the mid-term doctoral disertation of: Tristan Klempka (Université de Toulouse-3), Antoine Lima (Université de Technologie de Compiègne), Haodi Zhang (Université de Caen Normandie) and Minh-Quan DAO (Université Bretagne Loire).
- Raoul de Charette was a jury member of the PhD thesis of Wei Zhou, *Analysing the Robustness of Semantic Segmentation for Autonomous Vehicles*, The University of Sidney, June 26th, 2020.

12 Scientific production

12.1 Major publications

[1] G. Fayolle, R. Iasnogorodski and V. A. Malyshev. *Random Walks in the Quarter Plane: Algebraic Methods, Boundary Value Problems, Applications to Queueing Systems and Analytic Combinatorics*. Ed. by S. Asmussen, P. W. Glynn and Y. L. Jan. Vol. 40. Probability Theory and Stochastic Modelling. The first edition was published in 1999. Springer International Publishing, Feb. 2017, p. 255. DOI: 10.1007/978-3-319-50930-3. URL: https://hal.inria.fr/hal-01651919.

[2] C. Furtlehner, J.-M. Lasgouttes, A. Attanasi, M. Pezzulla and G. Gentile. 'Short-term Forecasting of Urban Traffic using Spatio-Temporal Markov Field'. In: *IEEE Transactions on Intelligent Transportation Systems* (2021), p. 10. URL: https://hal.inria.fr/hal-03285664.

[3] D. Gonzalez Bautista, J. Pérez, V. Milanés and F. Nashashibi. 'A Review of Motion Planning Techniques for Automated Vehicles'. In: *IEEE Transactions on Intelligent Transportation Systems* (Apr. 2016). DOI: 10.1109/TITS.2015.2498841. URL: https://hal.inria.fr/hal-01397924.

[4] M. Jaritz, T.-H. Vu, R. De Charette, E. Wirbel and P. Pérez. 'xMUDA: Cross-Modal Unsupervised Domain Adaptation for 3D Semantic Segmentation'. In: *Conference on Computer Vision and Pattern Recognition (CVPR)*. For a demo video, see http://tiny.cc/xmuda. Virtual, United States, June 2020. URL: https://hal.inria.fr/hal-02388974.

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[8] F. Pizzati, P. Cerri and R. De Charette. 'CoMoGAN: continuous model-guided image-to-image translation'. In: CVPR 2021 - IEEE Conference on Computer Vision and Pattern Recognition. IEEE Conference on Computer Vision and Pattern Recognition. Online, France, 19th June 2021. URL: https://hal.archives-ouvertes.fr/hal-03359098.

[9] L. Roldão, R. De Charette and A. Verroust-Blondet. 'LMSCNet: Lightweight Multiscale 3D Semantic Completion'. In: *3DV 2020 - International Virtual Conference on 3D Vision*. Accepted at 3DV 2020 (Oral). For a demo video, see http://tiny.cc/lmscnet. Code is available at https://github.com/cv-rits/LMSCNet. Fukuoka / Virtual, Japan, Nov. 2020. URL: https://hal.inria.fr/hal-02979521.

[10] M. Tremblay, S. S. Halder, R. De Charette and J.-F. Lalonde. 'Rain Rendering for Evaluating and Improving Robustness to Bad Weather'. In: *International Journal of Computer Vision* (Sept. 2020). 19 pages, 19 figures, IJCV 2020. DOI: 10.1007/s11263-020-01366-3. URL: https://hal.inria.fr/hal-03133284.

12.2 Publications of the year

International journals

[11] G. Fayolle and R. Iasnogorodski. 'Conditions for some non stationary random walks in the quarter plane to be singular or of genus 0'. In: *Markov Processes And Related Fields* 27.1 (Mar. 2021), p. 12. URL: https://hal.inria.fr/hal-03008556.

[12] C. Furtlehner, J.-M. Lasgouttes, A. Attanasi, M. Pezzulla and G. Gentile. 'Short-term Forecasting of Urban Traffic using Spatio-Temporal Markov Field'. In: *IEEE Transactions on Intelligent Transportation Systems* (2021), p. 10. URL: https://hal.inria.fr/hal-03285664.

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[14] K. Messaoud, I. Yahiaoui, A. Verroust-Blondet and F. Nashashibi. 'Attention Based Vehicle Trajectory Prediction'. In: *IEEE Transactions on Intelligent Vehicles* 6.1 (2021), pp. 175–185. DOI: 10.1109/TIV.2020.2991952. URL: https://hal.inria.fr/hal-02543967.

[15] J. E. Naranjo, F. Jiménez, R. Castiñeira, M. Gil, C. Premebida, P. Serra, A. Valejo, F. Nashashibi and C. Magalhães. 'Cross-Border interoperability for Cooperative, Connected and Autonomous Driving'. In: *IEEE Intelligent Transportation Systems Magazine* (10th Feb. 2021). URL: https://hal.inria.fr/hal-03521114.

[16] F. Navas, V. Milanés, C. Flores and F. Nashashibi. 'Multi Model Adaptive Control for CACC applications'. In: *IEEE Transactions on Intelligent Transportation Systems*. {IEEE} Trans. Intell. Transp. Syst. 22.2 (11th Feb. 2021), p. 11. DOI: 10.1109/TITS.2020.2964320. URL: https://hal.inria.fr/hal-02470639.

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International peer-reviewed conferences

[18] A.-Q. Cao, G. Puy, A. Boulch and R. Marlet. 'PCAM: Product of Cross-Attention Matrices for Rigid Registration of Point Clouds'. In: ICCV 2021 - International Conference on Computer Vision. International Conference on Computer Vision. Montreal / Virtual, Canada, 11th Oct. 2021. URL: https://hal.archives-ouvertes.fr/hal-03364975.

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[20] F. Pizzati, P. Cerri and R. De Charette. 'CoMoGAN: continuous model-guided image-to-image translation'. In: CVPR 2021 - IEEE Conference on Computer Vision and Pattern Recognition. IEEE Conference on Computer Vision and Pattern Recognition. Online, France, 19th June 2021. URL: https://hal.archives-ouvertes.fr/hal-03359098.

Reports & preprints

[21] A.-Q. Cao and R. De Charette. *MonoScene: Monocular 3D Semantic Scene Completion*. 21st Dec. 2021. URL: https://hal.archives-ouvertes.fr/hal-03498508.

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[23] G. Fayolle. *A note on the connection between product-form Jackson networks and counting lattice walks in the quarter plane*. 2021. URL: https://hal.inria.fr/hal-02415746.

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[27] F. Pizzati, P. Cerri and R. De Charette. *Guided Disentanglement in Generative Networks*. 20th Dec. 2021. URL: https://hal.inria.fr/hal-03498130.

[28] F. Pizzati, J.-F. Lalonde and R. De Charette. *ManiFest: Manifold Deformation for Few-shot Image Translation*. 20th Dec. 2021. URL: https://hal.inria.fr/hal-03498131.

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