Activity Report 2019

Team CHORALE

Collaborative and HeterOgeneous Robots interActing in Live Environment

Inria teams are typically groups of researchers working on the definition of a common project, and objectives, with the goal to arrive at the creation of a project-team. Such project-teams may include other partners (universities or research institutions).

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Robotics and Smart environments

Table of contents

Team CHORALE

Creation of the Team: 2018 April 01

CHORALE team is the continuation of the LAGADIC team at Sophia Antipolis.

Keywords:

Computer Science and Digital Science:

A3.1.1. - Modeling, representation
A3.1.10. - Heterogeneous data
A3.2.3. - Inference
A3.4.1. - Supervised learning
A3.4.3. - Reinforcement learning
A3.4.8. - Deep learning
A5.4.2. - Activity recognition
A5.4.4. - 3D and spatio-temporal reconstruction
A5.4.7. - Visual servoing
A5.10.2. - Perception
A5.10.3. - Planning
A5.10.4. - Robot control
A5.10.5. - Robot interaction (with the environment, humans, other robots)
A5.10.6. - Swarm robotics
A5.10.7. - Learning
A5.11. - Smart spaces
A5.11.1. - Human activity analysis and recognition
A5.11.2. - Home/building control and interaction
A6.4.2. - Stochastic control
A6.4.3. - Observability and Controlability
A6.4.5. - Control of distributed parameter systems
A6.5.3. - Transport
A8.3. - Geometry, Topology
A9.5. - Robotics
A9.9. - Distributed AI, Multi-agent
A9.10. - Hybrid approaches for AI

Other Research Topics and Application Domains:

B1.2.2. - Cognitive science
B5.2.1. - Road vehicles
B5.6. - Robotic systems
B7.1.1. - Pedestrian traffic and crowds
B7.2. - Smart travel
B7.2.1. - Smart vehicles
B7.2.2. - Smart road
B8.1.2. - Sensor networks for smart buildings

1. Team, Visitors, External Collaborators

Research Scientists

Philippe Martinet [Team leader, Inria, Senior Researcher, HDR]
Patrick Rives [Inria, Senior Researcher, HDR]
Paolo Salaris [Inria, Researcher, until Aug 2019]

Post-Doctoral Fellow

Renato Martins [Inria, Post-Doctoral Fellow, from Apr 2019]

PhD Students

Mohamed Boussaha [IGN, PhD Student]
Luis Federico Contreras Samane [École centrale de Nantes, PhD Student, until Mar 2019]
Franco Fusco [Univ de Nantes, PhD Student]
Dayana Hassan [AXYN, PhD Student, granted by CIFRE]
Ihab Mohamed [Univ Côte d'Azur, PhD Student]
David Perez Morales [École centrale de Nantes, PhD Student, until December 2019]

Technical staff

John Thomas [Inria, Engineer, from Dec 2019]

Interns and Apprentices

Wanting Jin [Inria, from Feb 2019 until Aug 2019]
John Thomas [Inria, from Feb 2019 until Aug 2019]
Haozhou Zhang [CNRS, from Feb 2019 until Aug 2019]

Administrative Assistant

Patricia Riveill [Inria, Administrative Assistant, from April 2018]

Visiting Scientist

Enric Cervera [Jaume I University (Spain), from May 2019 until Aug 2019]

External Collaborators

Guillaume Allibert [Univ de Nice - Sophia Antipolis]
Nesrine Chedly [Univ de Nice - Sophia Antipolis, until Jun 2019]
Ahmed Khalifa [École centrale de Nantes, until Aug 2019]
Beatriz Pascual Escudero [Univ de Nantes, until Mar 2019]

2. Overall Objectives

2.1. Overall Objectives

The main objective is to study autonomous robotic systems, from the perception and the control point of views, interacting and evolving among the human beings in live and dynamic environments. By autonomous robotic systems, we refer to Autonomous Vehicles, Mobile robots, UAV and combination of them. Our research ambition is to explore new paradigms and concepts allowing autonomous robotic systems i) to acquire and share a task-oriented representation of the world (accounting for interactions with humans) ii) to act and interact in human-like environments (accounting for interactions with humans) in a safe and efficient way. Task specification, world and interaction modelling, situation awareness, multi sensor based perception and control, the coupling between perception and action, and hybrid model based/deep learning based architectures will be the main focuses of our researches. Although the underlying concepts could be potentially applied to manipulator arms, we have voluntarily restricted the scope of the project to mobile robotic applications that sound more topical and challenging.

3. Research Program

3.1. Task based world modeling and understanding

Executing a robotic task needs to specify a task space and a set of objective functions to be optimized. One research issue will be to define a framework allowing to represent the tasks in a generic canonic space in order to make their design and their analysis easier thanks to the control theory tools (observability, controllability, robustness…). All along the execution of the task, autonomous robotics systems have to acquire and maintain a model of the world and of the interactions between the different components involved in the task (heterogeneous robots, human beings, changes in the environment…). This model evolves in time and in space. In this research axis, we will investigate novel task-oriented world multi-layers representations (photometry, geometry, semantic) embedded in a short/long term memory framework able to handle static and dynamic events (long term mapping). A particular attention will be also paid to integrate human-robot interactions in shared environment (social skills). Another ambition of the project will be to build a bridge between model-based and machine learning methods. Understanding the world evolution is one of the key of autonomy. In this aim, we will focus on situation awareness.

3.2. Multi-sensory perception and control

Multi-sensory based perception and control is an area that starts from one single robot evolving in the environment with a set of sensors, up to a set of heterogeneous robots collaborating for the execution of a global shared task. We will address problems such as the active selection of the most suitable source of information (e.g. sensors and features) during the execution of the task and the active sensing control in order to maximize the collected information about the world modeling (including calibration and environment parameters, exogenous disturbances), allowing the task-driven sensor-based control framework to be more efficiently and robustly executed. Another issue will be the execution of a task defined by another robot or human, and to be replicated with a robot with different capabilities in perception, control and level of autonomy (i.e. heterogeneous robots). Last issues will come from the collaboration of different autonomous and heterogeneous robots in order to accomplish a shared task (mapping, robust localization, calibration, tracking, transporting, moving, …)

4. Application Domains

4.1. Transportation of people and goods

The researches developed in CHORALE can be applied in different applications fields. We are particularly interested in *transportation of people and goods*. CHORALE contribute to the development of Autonomous Connected Vehicles (e.g. Learning, Mapping, Localization, Navigation) and the associated services (e.g. towing, platooning, taxi).

4.2. Assistance and services robots

We are also interested in *assistance and service robotics*. By adding the social level in the representation of the environment, CHORALE develops social and proactive navigation.

4.3. Survey and monitoring of environments

CHORALE studies multi-robots systems to explore, survey and monitor different kind of environments (e.g. agricultural space, forest space, destroyed space), which are of particular importance in the field of *Exploration and monitoring of poorly structured environments*.

5. New Software and Platforms

5.1. Perception360

Perception360 is an integration software platform for all perception developments in the Inria CHORALE team. All functions have been coded in a modular and scalable ROS environment by including a generic model to take into account the different sensors (monocular perspective vision (RGB), vision stereo perspective (RGB-D), spherical vision (RGB and RGB-D).

The main application concerns representation of the environment (multi-layers topological and spherical representation of the environment), Localization, SLAM and Navigation.

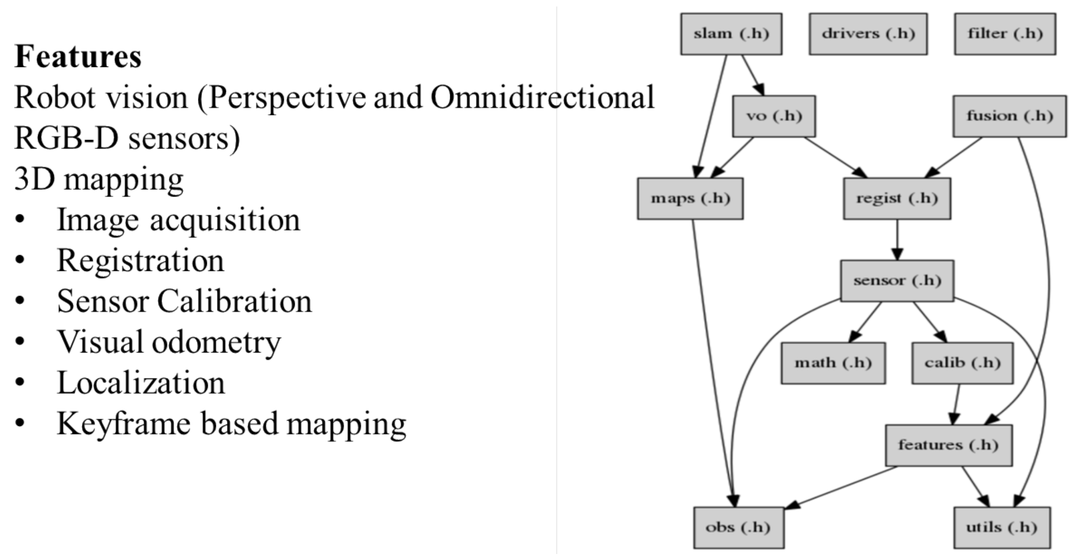

Figure 1. PERCEPTION360

5.2. ICAV

ICAV is an Intelligent and Connected Autonomous Vehicle. It is composed of a Renault ZOE robotized by Ecole Centrale of Nantes (by the team setup by Philippe Martinet in LS2N/ARMEN).

Figure 2. ICAV plateform and its web interface

The robotization allows to have access to the control of:

- Steering angle (or steering torque)
- Braking torque
- Acceleration
- Gear box
- Blinking light

In its original version, it is composed of embedded sensors:

- Car odometry and velocity
- Low cost GPS (Ublox 6)
- Low cost IMU
- Lidar VLP16 from Velodyne
- Two front cameras in the bumper
- One rear camera in the bumper

and one embedded computer, with a web interface connected to a simple tablet. All the equipments are connected to the existing comfort battery. This equipment has been funded by UCA (Digital Reference Centre) and delivered late 2018.
In addition, in the framework of a collaboration between CHORALE and LS2N/ARMEN one global application of Mapping/Localization/Navigation/Parking is installed in the vehicle. This application is using LIDAR VLP16 based mapping algorithm developed in Nantes including the last two years collaboration work between CHORALE and ARMEN. In January 2019, we have done the map of the Inria Sophia Antipolis Center, and other places of Sophia Antipolis. On all places, it is possible to localize the vehicle, register a path and then proceed to autonomous navigation (if we obtain the authorization to make it). Fast prototyping tools environment called ICARS is available for both simulation and development purposes.
In december 2019, we have evaluated the navigation algorithm on the new experimental site made available by CASA.

Figure 3. CASA experimental site in Sophia Antipolis

In the near future, in the framework of the project SPHERE we will integrate a novel 360 degree camera system with the Perception360 platform and embed this system in ICAV. A global 360 degree navigation system will be developed.

5.3. DRONIX

In 2019, we have defined and installed a capture motion system composed of 6 cameras coming from the QUALISYS company. This system allows to track and localize a multi robot system.

Figure 4. DRONIX plateform

In our applications, we will consider the use of UAVs and possibly the collaboration between UAVs and AGV. The DRONIX platform will be used for real time navigation, and as a ground truth system. The system has a central computer and each robots will have possible access to the global information by wifi.

6. New Results

6.1. Task based world modeling and understanding

6.1.1. Hidden robot

Participants: John Thomas (Master student), Philippe Martinet, Paolo Salaris, Sébastien Briot (LS2N-ARMEN)

When robots want to execute a task, they require to have an adequate representation of the environment where they will evolve. In model based approach, it is classical to describe environment using Metric Map where the function of perception (localization) and control (Path or trajectory tracking) refer to Cartesian state. In sensor based control, the methodology "teaching by showing" has been developed during the last 30 years. The concept of sensory memory has been then introduced in order to represent the task to be executed in sensor space. This concept is used in order to represent the task directly in the sensor space for a particular set of sensors. In summary, building the representation of the task (or the environment) is building the sensory memory, defining a particular motion (or trajectory) is defining a particular occurrence of sensor features, and executing the task is done when a control is designed to perceive the same as stored in the sensory memory. This approach has shown great ability in terms of robustness. However, it is still difficult to analyze the singularities and to demonstrate the stability property for those approaches (mainly when it is necessary to control 6 degree of freedom). In 2013, Sébastien Briot and Philippe Martinet have studied the visual servoing scheme of a Gough-Stewart Platform [18] and shown that it exists an hidden robot in the controller that can be used to study the behaviour and properties of it. The Hidden robot allows to transform the analysis of the controller by viewing it as a parallel robot. Recently, this concept has been applied to study the singularities of the visual servoing scheme of points and of lines [19]. This work continues in the framwork of the ANR project SESAME.

The idea of the new initial work done in 2019, is to find a methodology to design a task by using the Hidden robot concept. Navigation of a mobile robot has been considered in a first time. The followed methodology considers a topological navigation framework where a successive interaction situation are modelled by using an hidden robot: in some words, navigation is done by using a set of successive hidden parallel robots holding the robot when moving. At least two main question have been identified: What is the structure of the virtual robot which fits to task to be done? and Where to fix (or How to select) the anchors of this virtual robots?

For the first question, the idea is, considering different kind of features, to define a virtual parallel robot based on virtual legs. These virtual legs are directly linked to the considered feature. We have studied two cases, distance and angle, considering that existing sensors allow us to obtain the corresponding extracted features. After the modeling of sensors features, different control laws have been investigated allowing to produce motion of the mobile plateform. The corresponding hidden robots and the properties have been studied.
For the second question, two methods have been investigated using selection matrix of features or weighted features. The main used criteria is the transmibility index which relates the faculty of motion transmission of the virtual parallel mecanism.
This work [52] is preliminary and on going. We already have obtained preliminary results in simulation allowing a mobile plateform to evolve in a dedicated environment. It was the work done by John Thomas under the supervision of Philippe Martinet and Paolo Salaris.

6.1.2. End to end navigation

Participants: Renato Martins (Post-doc), Patrick Rives

This research deals with the problem of end-to-end learning for navigation in dynamic and crowded scenes solely from visual information. We investigate the problem of navigating an unknown space to reach a target of interest, for instance “doors", exploring the possibilities given by data-driven based models in the context of ANR MOBI-Deep project around the guidance of visually impaired people. A successful agent navigation policy requires learning general relationships between the agent actions, safety rules and its surrounding environment. We started studying a simple guidance model (turn left, right or stop), whose guidance task is to remain inside a specific region of the scene (to avoid collusion). This is equivalent to take the action to stay in the center of a corridor (indoor scene) or road (outdoor scenario). We first evaluate a relatively small supervised net composed of sixteen ResNet convolutional layers. This model was trained with real images from the Udacity autonomous driving challenge, but presented limited generalization when tested in either non-structured scenes or in scenes with humans. In order to overcome these limitations, we plan to train an A3C agent (Asynchronous Actor-Critic Agent) to learn the action policies in a reinforcement learning scheme, using data acquired of virtual environments with crowds. We also plan to evaluate the use of inputs from different levels as: scene semantic segmentation; depth inference from monocular images; and human and object detection information in the learning scheme.

6.1.3. Semantization of scene

Participants: Mohammed Boussaha (PhD, IGN), E. Fernandez-Moral, R. Martins, Patrick Rives

The work carried out in the ANR PlaTINUM project concerns the semantic labeling of images [17] acquired by agents (autonomous vehicles or pedestrians) moving in an urban-like environment and their accurate localization and guidance. A semantic labeling based on a machine learning approach (CNN) was developed. A same methodology is used to semantize virtual images built from a textured 3D mesh representation of the environment and images from the camera handled by the agents. Several strategies have been studied to exploit complementary information, such as color and depth for improving the accuracy of semantization. Our results show that exploiting this complementarity requires to perfectly align the different sources of informations. We proposed a new approach to the problem of calibration of heterogeneous multi sensors systems [41], [44]. We also looked for evaluating a new metric to quantify the accuracy of semantization provided by the CNN by taking into account the boundaries of semantized objects during the learning step. As a consequence, we show that weighting the boundary pixels in the images allows to segment more clearly the navigable areas used by different agents such as pedestrians (sidewalks) and cars (road). The results of this research were published in [29], [30]. The CNN used for labeling imagesacquired by different image sensors (perspective and spherical) was pre-trained from public datasets with perspective images of urban-like environments (simulated or real). In the context of the Platinum ANR project, a fine-tuning was done with some spherical images acquired in Rouen by the IGN Stereopolis vehicle and then hand-labelled. A Docker version of the software has been made available on the project server in order to be used by the other partners.

A localization method has also been implemented to exploit information of color, depth and semantics (when this information is available). An estimation of the agent position (6DOV, rotation and translation) is computed thanks to a dense method that minimizes the geometric, photometric and semantic differences between a spherical view provided by a SIG (Système d'Information Géographique) data base hosted in a cloud server and the current view of the agent.

During the last year of the project, the methods developed in PlaTINUM were consolidated and validated on the data acquired in Rouen. As originally planned in the project, Inria enlisted the help of iXblue-division Robopec to integrate the various functions developed during the project. This software, called Perception360, will be from now the software platform for all perception developments in the Inria CHORALE team.

6.1.4. Optical Flow Estimation Using Deep Learning In Spherical Images

Participants: Haozhou Zhang (Master), Cédric Demonceaux (Vibot), Guillaume Allibert

In a complex environment such as in a forest, the autonomous navigation is a challenging problem due to many constraints such as the loss of GPS signals because dense and unstructured environments (branches, foliage, ...) reduce the visibility. Without GPS signals, a vision system with the ability to capture everything going on around you seems more valuable than ever and crucial to navigate in this environment. Spherical images offer great benefits over classical cameras wherever a wide field of view is essential.

The equirectangular projection is a popular representation of images taken by spherical cameras. In this projection, the latitude and longitude of the spherical images are projected to horizontal and vertical coordinates on a 2D plane. However, this equirectangular projection suffers from distortions, especially in polar regions. In this case, the density of features is no longer regular at different latitudes of the images. As a result, traditional image processing methods that have been used for perspectives images do not have good performance when they are applied to equirectangular images.

Optical flow estimation is a basic problem of computer vision [50]. It is generally used as input of algorithm for autonomous navigation. Given two successive images, it estimates the motion vector in 2D (in x and y direction) for each pixel from between the two input images. Optical flow is usually considered as a good approximation of the true physical motion mapped on the image plane. It provides a concise description of the direction and velocity of the motion. In [24] and [36], CNNs which are capable of solving the optical flow estimation problem as a supervised learning task are proposed and became the standard for optical flow estimation. However, the dataset used to train [24], [36] is only based on perspective images. Even if they can be used directly with spherical images as input, the high distortions coming from equirectangular projection drastically reduce the global performance of these networks. One possible way to solve this issue is to train the networks proposed in [24], [36] with spherical images. Unfortunately, these databases do not exist and generating them would be a long and costly process.

In the Master's Hoazhou [55], we have proposed a solution to overcome this issue in proposing an adaptation of FlowNet networks to deal with the distortions in the equirectangular projection of spherical images. The proposed approach lies a distortion aware convolution used as convolution layers in the network to deal with distortions in equirectangular images. The proposed networks allows the models to be trained by perspective images and be applied to spherical images using an adapted convolution which is coherent with the spherical image. This solution avoids training a large number of spherical images which is not available and costly to generate.

6.2. Multi-sensory perception and control

6.2.1. Autonomous Parking Maneuvers

Participants: David Perez Morales (PhD, LS2N-ARMEN), Olivier Kermorgant (LS2N-ARMEN), Salvador Dominguez Quijada (LS2N-ARMEN), Philippe Martinet

Automated parking is used as new functionality to sell different model of cars right now. Mainly, the different versions of parking abilities are not autonomous and are based on motion planning only. There is no ability to evolve in dynamic environment: it remains automated in static environment, or even an assistant to park under the control of the driver. The purpose of the PhD work of David Perez Morales was to investigate how the problem of autonomous parking by using different sensor based techniques is able to handle any kind of parking situations (parallel, perpendicular, diagonal) for parking an unparking (backward and forward).
Two different frameworks has been developed. The first framework, using a Multi-Sensor-Based Control (MSBC) approach [47], [48], [46], [45] allows to formalize different parking and unparking operations in a single maneuver with either backward or forward motions. Building upon the first one and by using an MPC strategy [49], a Multi-Sensor-Based Predictive Control (MSBPC) framework has been developed, allowing the vehicle to park autonomously (with multiple maneuvers, if required) into perpendicular and diagonal parking spots with both forward and backward motions and into parallel ones with backward motions in addition to unpark from parallel spots with forward motions. These frameworks have been tested extensively using a robotized Renault ZOE with positive outcomes and now they are part of the autonomous driving architecture being developed at LS2N.
In 2019, the main focus was on MSBPC, and on taking into account the dynamic aspect in the environment (mainly pedestrians). Detection and tracking for pedestrian has been included in the perception aspect, in parallel to the detection of empty spots for parking. An additional terms has been added as a contraint in the cost function to be minimized in order to take into account the dynamic aspect, and a mecanism has been put in place in order to switch automatically the maneuver. In presence of pedestrian, an additional maneuver is engaged, which is what human are generally doing if place is enough for performing safely the maneuver. Comparison with state of the art motion planning approach have been done in simulation. The proposed method have demonstrated the efficiency while the others fails in a very long set of maneuvers. Real experiments have been done also in presence of pedestrians.

6.2.2. Platoon control and observer

Participants: Ahmed Khalifa (Post-Doc, LS2N-ARMEN), Olivier Kermorgant (LS2N-ARMEN), Salvador Dominguez Quijada (LS2N-ARMEN), Philippe Martinet

In the framework of the ANR Valet project, we are interested in platooning control of cars for a service of VALET Parking where it is necessary to join a platoon (after unparking), to evolve among the platoon, and leave the platoon (for parking). We are considering the case when the leader is autonomous (following an already defined path) or manually driven by a human (the path must be build on line). The lateral controller to follow a path has been designed earlier [23] and the localization technique largelly evaluated experimentally [33]. The main exteroceptive sensor is the Velodyne VLP16.
The first work [38] [15] concerned the design of a distributed longitudinal controller for car-like vehicles platooning that travel in an urban environment. The presented control strategy combines the platoon maintaining, gap closure, and collision avoidance functionality into a unified control law. A consensus-based controller designed in the path coordinates is the basis of the proposed control strategy and its role is to achieve position and velocity consensus among the platoon members taking into consideration the nature of the motion in an urban environment. For platoon creation, gap closure scenario is highly recommended for achieving a fast convergence of the platoon. For that, an algorithm is proposed to adjust the controller parameters online. A longitudinal collision between followers can occur due to several circumstances. Therefore, the proposed control strategy considers the assurance of collision avoidance by the guarantee of a minimum safe inter-vehicle distance. Convergence of the proposed algorithm is proved in the different modes of operations. Finally, studies are conducted to demonstrate and validate the efficiency of the proposed control strategy under different driving conditions. To better emulate a realistic setup, the controller is tested by an implementation of the car-like vehicles platoon in a vehicular mobility simulator called ICARS, which considers the real vehicle dynamics and other platooning staff in urban environments.

The second work [14] adresses the problem of controlling the longitudinal motion of car-like vehicles platoon navigating in an urban environment that can improve the traffic flow with a minimum number of required communication links. To achieve a higher traffic flow, a constant-spacing policy between successive vehicles is commonly used but this is at a cost of increased communication links as the leader information must broadcast to all the followers. Therefore, we propose a distributed observer-based control law that depends on a hybrid source of neighbours information in which a sensor-based link is used to get the predecessor position while the leader information is acquired through a communication-based link. Then, an observer is designed and integrated into the control law such that the velocity information of the predecessor can be estimated. We start by presenting the platoon model defined in the Curvilinear coordinates with the required transformation between that coordinate and the Cartesian Coordinates so that one can design the control law directly in the Curvilinear coordinates. After that, internal and string stability analysis are conducted. Finally, we provide simulation results, through dynamic vehicular mobility simulator called ICARS, to illustrate the feasibility of the proposed approach and corroborate our theoretical findings.
Both work have been tested in real with a platoon of 3 up to 4 cars.

6.2.3. High speed visual servoing

Participants: Franco Fusco (PhD, LS2N-ARMEN), Olivier Kermorgant (LS2N-ARMEN), Philippe Martinet

Controlling high speed robot with visual feedback may require to develop more complex models including the dynamics of the robots and the environment. Some previous work done in the field of dynamic visual feedback of parallel robots [42] have demonstrated the efficiency regarding the classical Joint computed torque control. Also, it has been shown that it is also possible to develop more complex interaction models [20].

In recent years, many efforts have been dedicated to extend Sampling-based planning algorithms to solve problems involving constraints, such as geometric loop-closure, which lead the valid Configuration Space to collapse to a lower-dimensional manifold. One proposed solution considers an approximation of the constrained Configuration Space that is obtained by relaxing constraints up to a desired tolerance. The resulting set has then non-zero measure, allowing therefore to exploit classical planning algorithms to search for a path that connects two given states. When the constraints involve kinematic loops in the system, relaxation generally bears to undesired contact forces, which needs to be compensated during execution by a proper control action. We propose a new tool that exploits relaxation to plan in presence of constraints [32]. Local motions inside the approximated manifold are found as the result of an iterative scheme that uses Quadratic Optimization to proceed towards a new sample without falling outside the relaxed region. By properly guiding the exploration, paths are found with smaller relaxation factors and the need of a dedicated controller to compensate errors is reduced. We complete the analysis by showing the feasibility of the approach with experiments on a real manipulator platform.

The commonly exploited approach in visual servoing is to use a model that expresses the rate of change of a set of features as a function of sensor twist. These schemes are commonly used to obtain a velocity command, which needs to be tracked by a low-level controller. Another approach that can be exploited consists in going one step further and to consider an acceleration model for the features. This strategy allows also to obtain a natural and direct link with the dynamic model of the controlled system. The work done in [13] aims at comparing the use of velocity and acceleration-based models in feed-back linearization for Visual Servoing. We consider the case of a redundant manipulator and discuss what this implies for both control techniques. By means of simulations, we show that controllers based on features acceleration give better results than those based on velocity in presence of noisy feedback signals.

We are working to propose new prediction models for Visual Predictive Control that can lead to both better motions in the feature space and shorter sensor trajectories in 3D. Contrarily to existing local models based only on the Interaction Matrix, it is proposed to integrate acceleration information provided by second-order models. This helps to better estimate the evolution of the image features, and consequently to evaluate control inputs that can properly steer the system to a desired configuration. By means of simulations, the performances of these new predictors are shown and compared to those of a classical model. Real experiments confirm the validity of the approach and show that the increased complexity.

6.2.4. Proactive and social navigation

Participants: Maria Kabtoul (PhD), Wanting Jin (Master), Anne Spalanzani (CHROMA), Philippe Martinet, Paolo Salaris

In the last decade, many works have been done concerning navigation of robots among humans [34], [27] or human robots interaction [22], [31]. In very few cases, a robot can realize an intention to move.

In this work, we would like that robots can express their needs for sharing spaces with humans in order to perform their task (i.e. navigation in crowdy environments). This requires to be proactive and adapt to the behavior by exploiting the potential collaborative charcateritics of the nearby environment of the robots.

In the framework of the ANR project HIANIC, Maria Kabtoul is doing her PhD on the topic Proactive Social navigation for autonomous vehicles among crowds. We consider shared spaces where humans and cars are able to evolve simultaneously. The first step done in this way is to introduce a pedestrian to vehicle interaction behavioral model. The model estimates the pedestrian's cooperation with the vehicle in an interaction scenario by a quantitative time-varying function. Then, the trajectory of the pedestrian is predicted based on its cooperative behavior. Both parts of the model are tested and validated using real-life recorded scenarios of pedestrian-vehicle interaction. The model is capable of describing and predicting agents' behaviors when interacting with a vehicle in both lateral and frontal crossing scenarios.

In the framework of the ANR project MOBI-DEEP, we have addressed the problem of navigating a robot in a constrained human-like environment. We provide a method to generate a control strategy that enables the robot to proactively move in order to induce desired and socially acceptable cooperative behaviors in neighboring pedestrians. Contrary to other control strategies that simply aim to passively avoid neighboring pedestrians, this approach greatly simplifies the navigation task for both robots and humans, especially in crowded and constrained environments. In order to reach this objective, the co-navigation process between humans and robots is formalized as a multi-objective optimization problem and a control strategy for the robot is obtained by using the Model Predictive Control (MPC) approach. The Social Force Model (SFM) is used to predict the human motion in cooperative situations. Different social behaviors of humans when moving in a group are also taken into account to generate the proper robot motion. Moreover, a switching strategy between purely reactive (if cooperation is not possible) and proactive-cooperative planning depending on the evaluation of the human intentions is also provided. Simulations under different navigation scenarios show how the proactive-cooperative planner enables the robot to generate more socially and understandable behaviors.

This work has been done by Wanting Jin during her Master thesis [37].

6.2.5. Safe navigation

Participants: Luiz Guardini (PhD), Anne Spalanzani (CHROMA), Christian Laugier (CHROMA), Philippe Martinet, Anh-Lam Do (Renault), Thierry Hermitte (Renault)

Today, car manufacturer are selling systems to brake in presence of obstacle. Those systems are based on the fact that the risk of collision is always detected and well evaluated. Their action are limited on brake only, which is in some case not sufficient to limit the risk. A global and safe system must be more efficient in environment perception awareness and also in action to be decided (break, steer, acceleration). In such a case, it is very complicated to find the best solution as long as we have to evaluate the different solutions in a near horizon in terms of risk of colisions and severity injuries. Car manufacturer are interested to find solution (i.e evaluation of trajectories (planification and action) in terms of risks and injuries.

Evaluating a scene to perform a collision avoidance maneuver is a hard task for both humans and (semi-) autonomous vehicles. There are some cases though that collision avoidance is inevitable. Interpreting the scene for a possible collision avoidance is difficult already a difficult task. Choosing how to mitigate the damage seems even harder, specially when humans have only a split of second to decide how to proceed.

Intending to decrease the reaction time and to increase safety on dangerous driving situations, one can rely on intelligent systems. Nevertheless, autonomous vehicles simulation and testing usually focus on risk assessment and path planing on regular driving conditions [40]. For instance, Waymo from Google, still do not have the full capability of avoiding collision initiated by other vehicles [28].

Developing Advanced Driver Assistance Systems (ADAS) technologies is one alternative for these emergency scenarios. It includes systems such as Active Braking System (ABS), Forward Collision Warning (FCW) and Collision Avoidance (CA). The latter is one of the most complex systems developed in order to assure safety. It perceives technologies such as Advanced Emergency Braking (AEB) and Autonomous Emergency Steering (AES) System. Those systems attempt to avoid the crash or at least reduce its severity. Developing a CA system starts by assessing the available information in the scene. This is made by establishing safe zones that the vehicle can access. The notion of safety of severity is usually addressed by the concept of risk. Risk can be intuitively understood as the likelihood and severity of the damage that an object of interest may suffer or cause in the future. Threat Assessment (also referred as Risk Assessment or Hazard Assessment) makes use of such concept.

The excellence of the data evidenced in the scene plays a major role in risk assessment and mitigation. Up to date, objects in the scene are not contextualized. For instance, pedestrians are treated as forbidden zones whereas cars are allowed to be collided when mitigation is necessary. This might be a correct assessment in some cases, but not always. The injury risk changes independently to each object according to aspects on the scene, such as the impact velocity and angle of collision.

This work focus on the development of a probabilistic cost map that expresses the Probability of Collision with Injury Risk (PCIR). On top of the information gathered by sensors, it includes the severity of injury in the event of a collision between ego and the objects in the scene. This cost map provides enhanced information to perform vehicle motion planning in emergency trajectories where collision is impending.

We represent the environment though probabilistic occupancy grids. It endures agile and robust sensor interpretation mechanisms and incremental discovery procedures. It also handles uncertainty thanks to probabilistic reasoning [25].

We use the Conditional Monte Carlo Dense Occupancy Tracker (CMCDOT developed in CHROMA). It is a generic spatial occupancy tracker that infers dynamics of the scene through a hybrid representation of the environment. The latter consists of static and dynamic occupancy, empty spaces and unknown areas. This differentiation enables the use of state-specific models as well as relevant confidence estimation and management of dataless areas [51].

Although CMCDOT occupancy grid leads to a very reliable global occupancy of the environment, it works on a sub-object level, meaning that the grid by itself does not carry the information on object classification. To overcome this, Erkent et al [26] proposes a method, which estimates an occupancy grid containing detailed semantic information. The semantic characteristics include classes like road, car, pedestrian, sidewalk, building, vegetation, etc.

The proposed Probabilistic risk map has been built and validation has been done in simulation using Gazebo using different scenarios (identified by the car manufacturer).

6.2.6. 3D Autonomous navigation using Model Predictive Path Integral approach

Participants: Ihab Mohamed (PhD), Guillaume Allibert, Philippe Martinet

Having a safe and reliable system for autonomous navigation of autonomous systems such as Unmanned Aerial Vehicles (UAVs) is a highly challenging and partially solved problem for robotics communities, especially for cluttered and GPS-denied environments such as dense forests, crowded offices, corridors, and warehouses. Such a problem is very important for solving many complex applications, such as surveillance, search-and-rescue, and environmental mapping. To do so, UAVs should be able to navigate with complete autonomy while avoiding all kinds of obstacles in real-time. To this end, they must be able to (i) perceive their environment, (ii) understand the situation they are in, and (iii) react appropriately.

To solve this problem, the applications of the path-integral control theory have recently become more prevalent. One of the most noteworthy works is Williams's iterative path integral method, namely, Model Predictive Path Integral (MPPI) control framework Williams et al. [53]. In this method, the control sequence is iteratively updated to obtain the optimal solution based on importance sampling of trajectories. In Williams et al [54], authors derived a different iterative method in which the control- and noise-affine dynamics constraints, on the original MPPI framework, are eliminated. This framework is mainly based on the information-theoretic interpretation of optimal control using KL-divergence and free energy, while it was previously based on the linearization of Hamilton-Jacob Bellman (HJB) equation and application of Feynman-Kac lemma.

The attractive features of MPPI controller, over alternative methods, can be summarized as: (i) a derivative-free optimization method, i.e., no need for derivative information to find the optimal solution; (ii) no need for approximating the system dynamics and cost functions with linear and quadratic forms, i.e., non-linear and non-convex functions can be naturally employed, even that dynamics and cost models can be easily represented using neural networks; (iii) planning and execution steps are combined into a single step, providing an elegant control framework for autonomous vehicles.

In the context of autonomous navigation, it is observed that the MPPI controller has been mainly applied to the tasks of aggressive driving and UAVs navigation in cluttered environments. For instance, to navigate in cluttered environments, the obstacle map is assumed to be known (either available a priori or built off-line), and only static 2D floor-maps are used. Conversely, in practice, the real environments are often partially observable, with dynamic obstacles. Moreover, only 2D navigation tasks are performed, which limits the applicability of the control framework.

For this reason, our work focuses on MPPI for 2D and 3D navigation tasks in cluttered environments, which are inherently uncertain and partially observable. To the best of our knowledge, this point has not been reported in the literature, presenting a generic MPPI framework that opens up new directions for research.

We propose a generic Model Predictive Path Integral (MPPI) control framework that can be used for 2D or 3D autonomous navigation tasks in either fully or partially observable environments, which are the most prevalent in robotics applications. This framework exploits directly the 3D-voxel grid, e.g., OctoMap [35], acquired from an on-board sensing system for performing collision-free navigation.We test the framework, in realistic RotorS-based simulation, on goal-oriented quadrotor navigation tasks in a 2D/3D cluttered environment, for both fully and partially observable scenarios. Preliminary results demonstrate that the proposed framework works perfectly, under partial observability, in 2D and 3D cluttered environments.

We demonstrate our proposed framework on a set of simulated quadrotor navigation tasks in a 2D and 3D cluttered environment, assuming that: (i) there is a priori knowledge about the environment (namely, fully observable case); (ii) there is not any a priori information (namely, partially observable case); here, the robot is building and updating the map, which represents the environment, online as it goes along.

6.2.7. Perception-aware trajectory generation for robotic systems

Participant: Paolo Salaris, Marco Cognetti (PostDoc, RAINBOW), Valerio Paduano (Master, RAINBOW), Paolo Robuffo Giordano (RAINBOW)

We now focus on our planned research activities on task-oriented perception and control of a robotic system engaged in executing a task. The main objective is to improve the execution of a given task by fruitfully *coupling action and perception*. We aim at finding the correct balance between efficient task execution and quality of the information content since the amount of the latter has an impact on the possibility of correctly executing the task. Indeed, a robot needs to solve an estimation problem in order to safely move in unstructured environments and accomplishing a task. For instance, it has to self-calibrate and self-localize w.r.t. the environment while, at the same time, a map of the surroundings may be built. These possibilities are highly influenced by the quality and amount of sensor information (i.e., available measurements), especially in case of limited sensing capabilities and/or low cost (noisy) sensors.

For nonlinear systems (i.e., the most of the robotics systems of our interest) the amount and quality of the collected information depends on the robot trajectories. It is hence important to find, among all possible trajectories able to accomplish a task, the most informative ones. One crucial point in this context, also known as *active sensing control*, is the choice of an appropriate *measure of information* to be optimized. The Observability Gramian (OG) measures the level of observability of the *initial state* and hence, its maximization (e.g. by maximizing its smallest eigenvalue) actually increase the amount of information about the initial state and hence improves the performances in estimating (observing) the initial state of the robot. However, when the objective is to estimate the current/future state of the robot (which is implicitly the goal of most of the previous literature in this subject, and of our research too), the OG is *not* the right metric even if is often used in the literature for this goal. Recently, in [12], we showed that, the right metric is instead the *Constructibility Gramian* (CG) that indeed quantifies the amount of information about the current/future state, which is obviously the state of interest for the sake of motion control/task execution. We then propose an *online* optimal sensing control problem whose objective is to determine at *runtime*, i.e. anytime a new estimate is provided by the employed observer (an EKF in our case), the future trajectory that maximizes the smallest eigenvalue of the CG. We applied our machinery to two robotics platforms: a unicycle vehicle and a quadrotor UAV moving on a vertical plane, both measuring two distances w.r.t. two markers located in the environment. Results show the effectiveness of our solution not only for pure robot's state estimation, but also with instances of active self-calibration and map building.

The proposed solution is not able to cope with the process/actuation noise as CG is not able to measure its degrading effects on the current amount of the collected information and by consequence its negative effects in the estimation process. For all the cases where an EKF is used as an observer, we overcame this issue in [21] where we minimized the largest eigenvalue of the covariance matrix of the EKF that is the solution of the Riccati differential equation.

We also extended the methodology to the problem of shared control by proposing a shared control active perception method aimed at fusing the high-level skills of a human operator in accomplishing complex tasks with the capabilities of a mobile robot in maximizing the acquired information from the onboard sensors for improving its state estimation (localization). In particular, a persistent autonomous behaviour, expressed in terms of a cyclic motion represented by a closed B-Spline, is executed by the robot. The human operator is in charge of modifying online some geometric properties of this path for executing a given task (e.g., exploration). The path is then autonomously processed by the robot, resulting in an actual path that tries to follow the human's commands while, at the same time, maximizing online the acquired information from the sensors. This work has been done by Valerio Paduano during his Master thesis [43] and submitted to ICRA 2020.

Recently we are also working on extending the methodology to Multiple Robot Systems (in particular a group of quadrotor UAVs). In this context, the goal is to propose an optimal and *online* trajectory planning framework for addressing the localization problem of a group of multiple robots without requiring the rigidity condition. In particular, by leveraging our recent work on optimal online active estimation, we will propose the use of CG for quantifying the localization accuracy, and develop an *online* decentralized optimal trajectory planning able to optimize the CG during the robot motion. We particularly focus on the *online* component, since the planned trajectory are *continuously refined* during the robot motion by exploiting the (continuously converging) decentralized estimation of the robot relative poses. In order to illustrate the approach, we will consider the localization problem for a group of quadrotor UAVs measuring relative distances with maximum range sensing constraints and a decentralized Extended Kalman Filter [39] that estimates the relative configuration of each robot in the group w.r.t. a special one (randomly chosen in the group).

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

7.1.1. AXYN (2017 - 2021)

Participants: Patrick Rives and Paolo Salaris

This contract (30k€) is linked to the PhD Thesis of Dyanna Hassan (Cifre Thesis). The objective is to develop assistive navigation techniques.

7.1.2. Renault (2018 - 2021)

Participant: Philippe Martinet (in collaboration with A. Spalanzani and C. Laugier from CHROMA)

This contract (CHROMA 45k€, CHORALE (15k€ for supervision)) is linked to the PhD Thesis of Luiz Guardini (Cifre Thesis). The objective is to develop contextualized emergency trajectory planning with minimum criticality by employing dynamic probabilistic occupancy grid.

7.2. Bilateral Grants with Industry

7.2.1. AXYN (2017 - 2021)

Phd Student: Dayanna Hassan
Dayanna Hassan is employed by AXYN (Cifre Thesis).
Title of the PhD: Plate-forme robotisée d'assistance aux personnes à mobilité réduite

7.2.2. Renault (2018 - 2021)

Phd Student: : Luiz Guardini
Luiz Guardini is employed by Renault (Cifre Thesis).
Title of the PhD: Autonomous car driving: use of dynamic probabilistic occupancy grids for contextualized planning of emergency trajectory with minimal criticity

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. SPHERE ADT Inria project, 2019-20

Participants: Philippe Martinet, Patrick Rives, Renato Martins. The project SPHERE is an Inria ADT coordinated by Philippe Martinet. The aim is to put in place the PERCEPTION360 framework embedded inside the vehicle ICAV in order to map, localize and navigate autonomously in urban areas. It funds an Inria expert engineer position in CHORALE (John Thomas, 12/19-05/20) focusing on instrumentation, control and software development around the autonomous vehicle ICAV.

8.1.2. E-WHEELED ATT Inria project, 2019-21

Participants: Philippe Martinet. The project E-WHEELED is an Inria ATT coordinated by Philippe Martinet. The aim is to provide mobility to things by implementing connectivity techniques. It makes available an Inria expert engineer (Nicolas Chleq) in CHORALE in order to demonstrate the Proof of Concept using a small size demonstrator.

8.1.3. Local initiatives

CHORALE is in touch with local government CASA (Communauté d'Agglomération de Sophia Antipolis) in order to have access to the experimental site dedicated to Autonomous Vehicle demonstration. The first demonstration of autonomous driving has been done mid December. This site will be inaugurated during spring 2020.
Contacts with local companies involved in connected and autonomous driving have been made (including Renault Software Lab and Hitachi). CHORALE has participated to the GetTogether meetings organized by the local initiative SmartVehicles06.

8.2. National Initiatives

8.2.1. ANR Platinum (14-19)

The ANR Platinum (ended in november 2019), led locally by P. Rives, aims to develop methods and algorithms to map an urban environment, enrich it and automatically update it using visual sensors that communicate and are embedded by system users. The consortium is made of 4 academic partners: LITIS, Le2I (VIBOT), Inria-LAGADIC (CHORALE) et IGN-MATIS. One Phd (Mohammed Boussaha) is working on semantization of urban scenes.

8.2.2. ANR Mobi-Deep (17-22)

The ANR MOBI-Deep project, led locally by P. Rives (then P. Martinet since December 2019) aims to develop technologies that enable (or help) autonomous navigation in open and unknown environments using low-cost sensors such as digital cameras. The consortium is made of 2 academic partners: GREYC, Inria-LAGADIC (CHORALE), one association INJA and 3 industrial partners SAFRAN, SAFRAN Electronic & Defence and NAVOCAP. Philippe Martinet took the coordination of the project in December 2019. One master student (Wanting Jin) has worked (6 months) on proactive navigation, and one post-doc (Renato Martins) has been recruted in April 2019 for two years to work on End to End deep learning navigation.

8.2.3. ANR CLARA (19-22)

The ANR CLARA project, led and coordinated by G. Allibert, is focused in autonomous navigation of an aerial drone, equipped with 360-degree cameras, evolving in a forest to provide 3D mapping using deep learning techniques. The consortium is made of 3 academic partners: I3S/Inria CHORALE, LITIS, ViBot. One PhD student (Ihab Mohamed) is working on autonomous navigation using MPPI technics and one master (Haozhou Zhang) has investigated Optical Flow Estimation in Spherical Images.

8.2.4. Collaboration with LS2N-ARMEN

Philippe Martinet as a strong collaboration with the ARMEN team at LS2N. This mainly concerns autonomous parking maneuvers (with Olivier Kermorgant and Salvador Dominguez; we had a phd student), platoon control and observers (with Olivier Kermorgant and Salvador Dominguez; we had 1 post-doc), high speed visual servoing (with Olivier Kermorgant; we have one phd student), collaborative SLAM (with Olivier Kermorgant; we had one phd student), and Control based design (Sébastien Briot; we had one phd student and have one postdoc). These collaborations are mainly funded by ANR projects (initialized and/or prepared when I was in Nantes).

8.2.4.1. ANR Valet (15-19)

The ANR VALET (coordinated by F. Nashashibi from Inria RITS) proposes the development of an automatic redistribution system for sharing vehicles in urban environments. The principle is based on the creation of automated vehicle platoons guided by manually driven vehicles. The collected vehicles are transported to a charging centre or to a car park; here, each vehicle is assigned a parking space to which it must go and then in which it must park fully autonomously. Throughout the movement of platoons and vehicles, they must interact with other road users, including vehicle-type obstacles and pedestrians. The consortium is made of 2 academic partners: Inria (RITS, Chroma, Prima) and Ircyyn (LS2N) Ecole Centrale de Nantes and the AKKA company. One phD student (David Perez Morales) has worked on autonomous parking. One post doc (Ahmed Khalifa) has worked on observer and control design for platoon applications. CHORALE is working inside Hianic via the collaboration with ARMEN.

8.2.4.2. ANR Hianic (18-21)

The HIANIC project (coordinated by A. Spalanzani from Inria CHROMA) proposes to endow autonomous vehicles with smart behaviors (cooperation, negotiation, socially acceptable movements) that better suit complex shared space situations. It integrates models of human behaviors (pedestrian, crowds and passengers), social rules, as well as smart navigation strategies that will manage interdependent behaviors of road users and of cybercars. The consortium is made of 3 academic partners: Inria (RITS, Chroma, Pervasive Interaction teams), Lig Laboratory (Magma team) and LS2N laboratory (ARMEN and PACCE teams). CHORALE is working inside Hianic via the collaboration with CHROMA and ARMEN. One phd student (Maria Kabtoul) is working on proactive navigation of a vehicle among the crowd.

8.2.4.3. ANR SESAME (19-22)

The ANR SESAME (coordinated by S. Briot from LS2N ARMEN) aims to study singularities and stability of sensor-based controllers The consortium is made of 3 academic partners: LS2N (ARMEN and OGRE), Inria (RAINBOW), LIP6 (POLSYS). One master student (John Thomas) has worked on the design of controller based on the concept of hidden robot. One post doc (Abhilash Nayak) is working of the determination of singularities. CHORALE is working inside SESAME via the collaboration with ARMEN.

8.2.5. Collaboration with VIBOT

Guillaume Allibert has a strong collaboration with Pr Cédric Demonceaux from the ERL VIBOT. This mainly concerns activities around perception for robotics. Specifically, we are interested in how to integrate model-based knowledge into deep learning approaches. Two Master students have been involved in 2019: Haozhou Zhang (Optical Flow Estimation In Spherical Images) and Yanis Marchand (New Convolution for Spherical Images Using Depth Information).

8.2.6. Collaboration with RAINBOW Inria Team

Paolo Salaris has a strong collaboration with the RAINBOW Inria team about the research field on active sensing control for robotic platforms where the objective is to determine the robot trajectories that maximise the amount of information coming from sensors. In this activity was involved 1 PostDoc (2017-2019) and recently 1 Master student. This collaboration gave raise to 1 journal and 3 conference papers (one of them under review in the procedeeing of ICRA 2020).

8.3. FP7 & H2020 Projects

Program: H2020

Project acronym: CROWDBOT

Project title: Safe Navigation of Robots in Dense Human Crowds

Duration: Jan 2018 - Jun 2021

Coordinator: Julien Pettré

Other partners: ETHZ (Switzerland), EPFL (Switzerland), UCL (UK), RWTH (Germany), Softbank (France), Locomotec (Germany)

Abstract: CrowdBot will enable mobile robots to navigate autonomously and assist humans in crowded areas. Today's robots are programmed to stop when a human, or any obstacle is too close, to avoid coming into contact while moving. This prevents robots from entering densely frequented areas and performing effectively in these high dynamic environments. CrowdBot aims to fill in the gap in knowledge on close interactions between robots and humans during navigation tasks.

8.4. International Initiatives

8.4.1. Collaboration with Universidade Federal de Minas Gerais, San Paolo

Patrick Rives and Renato Martins have strong collaborations with two research groups at Universidade Federal de Minas Gerais (UFMG), Brazil. The research topics of CHORALE have a large coverage and share common interests with ongoing projects at these groups.

In this context, Patrick Rives spent two months (Nov-Dec 2018) on a Chair Position at UFMG conjointly funded by Le Ministère des Affaires étrangères (France) and UFMG (Brazil). During his stay, he worked with Prof. Alessandro Correa Victorino in the domain of advanced perception for autonomous vehicles.

One objective of his visit was to initiate a long-term scientific collaboration between UFMG and Inria, based on scientific internships of researchers and PhD students (co-tutelle). Originally, this collaboration should be funded by the CAPES-COFECUB International Program. Unfortunately, due to the political changes in Brazil, this project of collaboration is still pending.

Renato Martins, for his part, is a former postdoctoral researcher in the Computer Vision and Robotics Laboratory - VeRLab (UFMG), where he is currently an external collaborator. He actively collaborates on computer vision, perception and robotic vision with Prof. Erikson R. Nascimento, whose research interests and expertise spans from Computer Vision to Computer Graphics.

8.4.2. Inria International Partners

8.4.2.1. Informal International Partners

Universidade Federal de Minas Gerais (UFMG), Brazil

Jaume I University (UJI), Spain
National University of Singapore, Singapore (Marcelo H. Ang)
Universidade de Sao Paulo, Brazil

8.5. Visits of International Scientists

Enric Cervera Associated Professor at the Jaume I University (SPAIN). He is working in visual servoing application. During his stay (May-July 2019) as invited professor, he has worked on 360 degree view visual perception for autonomous navigation.

8.5.1. Visits to International Teams

8.5.1.1. Research Stays Abroad

Patrick Rives spent two months (Nov-Dec 2018) on a Chair Position at UFMG conjointly funded by Le Ministère des Affaires étrangères (France) and UFMG (Brazil).

9. Dissemination

9.1. Scientific Events: Organisation

9.1.1. General Chair, Scientific Chair

Philippe Martinet the corresponding chair for the PPNIV19 IRO19 workshop (https://project.inria.fr/ppniv19). He has managed the reviewing process, the website update and the general publicity. More than 300 attendees for this 11th edition.

9.1.2. Member of the Organizing Committees

Philippe Martinet has co-organized the IROS19-PPNIV19 (https://project.inria.fr/ppniv19) workshop with Christian Laugier, Marcelo H. Ang, Christoph Stiller and Miguel Sotelo (over 300 attendees).
Philippe Martinet has co-organized the Cutting edge Forum on Autonomous Driving (https://project.inria.fr/ad19/) with Christian Laugier, Marcelo H. Ang, Christoph Stiller and Miguel Sotelo (more than 150 attendees).

9.1.3. Scientific Events: Selection

9.1.3.1. Chair of Conference Program Committees

Philippe Martinet was Regional Chair for CISRAM 2019.

9.1.3.2. Member of the Conference Program Committees

Philippe Martinet was member for the IPC for ICINCO 2019.
Patrick Rives was Program Committee member of the Conférence Française de Photogrammétrie et de Télédétection 2019 (CFPT)

9.1.3.3. Reviewer

Philippe Martinet was Associated Editor for ITSC 2019, and reviewer for ICINCO19, PPNIV19.
Guillaume Allibert has reviewed papers for ICRA, IROS, IFAC WC, CDC, ACC.
Paolo Salaris has reviewed papers for ICRA, CDC, RSS.
Patrick Rives has reviewed papers for ICRA, IROS, IV, ICAR.
Renato Martins has reviewed papers for WACV, ICRA, IROS, ITSC, ICAR, PPNIV19.

9.1.4. Journal

9.1.4.1. Member of the Editorial Boards

Philippe Martinet is member of the Editorial Board of the Springer ISCA Book Series since 2014.

Philippe Martinet is co-Editor of the Springer book collection “Parallel Robots : Theory and Applications” setup in january 2015.

9.1.4.2. Reviewer - Reviewing Activities

Philippe Martinet is Associate Editor of the journal IEEE-Transactions on Intelligent Vehicles.
Guillaume Allibert has reviewed papers for RA-L and IEEE Trans. on Mechatronics.
Paolo Salaris has reviewed: RA-L, TRO, AURO
Renato Martins has reviewed papers for RA-L and Elsevier JVCI.

9.1.5. Invited Talks

Patrick Rives gave a Plenary Talk at the Universidade Federal de Minas Gerais (UFMG), Brazil
Title: Towards new sensors and representations for autonomous navigation in large scale human-like environments

9.1.6. Scientific Expertise

- International:
  - Philippe Martinet is corresponding chair and co-chair with C. Laugier and Christoph Stiller, of the IEEE RAS Technical Committee on “Autonomous Ground Vehicles and Intelligent Transportation Systems (AGVITS)”.
  - Philippe Martinet is Deputy director of the GdR Robotique.
  - Philippe Martinet was member of CNU 61 from 2011 until September 2019.
  - H2020: Philippe Martinet has participated of the ICT-2019-2 call (4 projects were evaluated)
  - STIC Amsud: Philippe has evaluated one proposal in 2019
  - Skywin (Aerospace Cluster of Wallonia): Patrick Rives has evaluated one proposal
  - Program BRIDGE Discovery (Swiss National Science Foundation): Patrick Rives has evaluated one proposal
- National:
  - Philippe Martinet is deputy director of the GdR robotics.
  - ANR: Guillaume Allibert was part of the CES33 in 2019. He has participated to the evaluation of the pre-projects and to the final projects evaluation.
  - ANR: Patrick Rives has evaluated one proposal in 2019
  - HCERES: Philippe has participated of the evaluation of LAAS (November 2019), IFFSTAR AME department (March 2019) and ONERA DTIS Department (December 2019).
  - ISITE-NEXT in Nantes: Philippe Martinet has evaluated one Talent application in 2019
  - ANRT: Philippe Martinet has evaluated one application for CIFRE grant in 2019
  - Philippe Martinet is coordinator of the ANR MOBI-Deep project
  - Guillaume Allibert is coordinator of the ANR CLARA project
- Local:
  - Paolo Salaris was member of CSD (Comité de Suivi Doctoral) in Inria Sophia Antipolis until end of August 2019.

9.1.7. Research Administration

Guillaume Allibert is the SIS team deputy head at I3S since 2017. This team is composed of 57 people (18 teacher-researchers, 11 researchers, 6 ATER & post doc, 3 emeritus and 19 PhD students).

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Guillaume Allibert is assistant professor at the Cote-d'Azur-University. He teaches at the GEII department of the IUT of Nice Côte d'Azur. He is in charge of two complete teaching modules: control and computer science. He also participates in the mathematics course.

Philippe Martinet managed four main actions in 2019 in relation with the education system:

- EIT Digital AUS: Participation in the definition of the educational program. This master program will be done at Polytech Sophia.
- New engineering track on autonomous system: Participation in the discussion to put in place a new engineering track between Polytech Sophia and Ecole des Mines. This Engineering track will start in 2021.
- EMJMD MIR (Erasmus Mundus Joint Master Degree on Marine and Maritime Intelligent Robotics): Jean-Pierre Merlet and Philippe Martinet have discussed with the coordinator of the master Vincent Hugel in order that Inria become an associated partner for this new educational program in robotic.
- Philippe Martinet, Jean-Pierre Merlet and Guillaume Allibert have co-organized the first GdR Robotics Winter school on Robotics Principia (https://project.inria.fr/roboticsprincipia/). An HAL collection has been setup (https://hal.inria.fr/ROBOTICA-PRINCIPIA).

9.2.2. Supervision

PhD : David Perez Morales, Multisensor based control in intelligent parking applications, Ecole Centrale de Nantes, December 6th 2019, P. Martinet, O. Kermorgant, S. Dominguez

PhD : Luis Contreras, SLAM collaboratif dans des environnements extérieurs, Ecole Centrale de Nantes, April 10th 2019, P. Martinet, O. Kermorgant

PhD in progress : Mohammed Boussaha, Hybrid urban scene analysis from mobile mapping images and laser scan, Université Paris Est -MSTIC, 15/10/2016, Bruno Vallet (IGN-Matis), Patrick Rives

PhD in progress : Dyanna Hassan, Plate-forme robotisée d'assistance aux personnes à mobilité réduite, Univ Côte d'Azur, 1/01/2017, P. Rives, P. Salaris

PhD in progress : Ihab Mohammed, Coupling Deep Learning and Advanced Control in UAV Navigation, Univ Côte d'Azur, 1/12/2018, P. Martinet, G. Allibert, P. Salaris

PhD in progress: Franco Fusco, High-speed visual servoing, Ecole Centrale de Nantes, 1/9/2017, P. Martinet, O. Kermorgant

PhD in progress : Maria Kabtoul, Proactive Social navigation for autonomous vehicles among crowds, Univ Grenoble Alpes, 1/09/2018, A. Spalanzani, P. Martinet

PhD in progress : Luiz Alberto Serafim Guardini, Autonomous car driving: use of dynamic probabilistic occupancy grids for contextualized planning of emergency trajectory with minimal criticity, Univ Grenoble Alpes, 1/10/2018, A. Spalanzani, P. Martinet, C. Laugier

PhD in progress : Zongwei Wu, New convolution for spherical images using depth, Université de Bourgogne Franche Comté, 1/10/19, C. Demonceaux, G. Allibert,

9.2.3. Juries

HdR : Guillaume Caron, Vision robotique directe, Univ Picardie Jules Verne, December 10th 2019 (P. Martinet, reviewer)

PhD : David Sierra Gonzales, Towards Human like prediction and decision making for automated vehicles on highway scenarios, Univ Grenoble Alpes, April 1st 2019, (P. Martinet, reviewer)

PhD : Soler Ulun, Multi-robot relative localization using computer vision, NTU Singapore, 2019, (P. Martinet, reviewer)

PhD : Jiang Xiaoyue, Visual and Lidar based SLAM by variational Bayesian method, NTU Singapore, 2019, (P. Martinet, reviewer)

PhD : Michel Moukari, Estimation de profondeur à partir d'images monoculaires par apprentissage profond, Univ de Caen, July 1st 2019, (P. Martinet, reviewer)

PhD : Pavan Vasishta, Building and Leveraging prior knowledge for predicting pedestrain behavior around autonomous vehicles, Univ Grenoble Alpes, September 30th 2019, (P. Martinet, examinator)

PhD : David Perez Morales, Multisensor based control in intelligent parking applications, Ecole Centrale de Nantes, December 6th 2019 (G. Allibert, examinator)

PhD : Thibaut Tezenas du Montcel, Evitement d'obstacles pour quadrirotors en utilisant un capteur de profondeur, Univ Grenoble Alpes, December 16th 2019 (G. Allibert, examinator)

PhD : Jose Juan Tellez, Teleoperation of an UAV for navigation in unstructured environments using a portable haptic interface, Univ Grenoble Alpes, June 26th 2019 (G. Allibert, examinator)

PhD : Kevin Giraud Esclasse, Towards reactive motion generation on exteroceptive feedback for generalized locomotion of humanoid robots, Univ Toulouse Midi-Pyrénées, December 18th 2019 (G. Allibert, examinator)

PhD : Thiago L. Gomes. Transferring human motion and appearance in monocular videos, PhD Qualifying Exam on Computer Science, Universidade Federal de Minas Gerais, Brazil, July 12th 2019 (R. Martins, examinator)

9.3. Popularization

9.3.1. Articles and contents

Philippe Martinet and Renato Martins have been interviewed in December 2019 by France 3 Côte d'Azur in order to popularize the work of CHORALE in the field of Connected Autonomous Vehicles. Real demonstrations of autonomous driving have been done at Inria Sophia Antipolis, and another one at CASA experimental site. An FR3 magazine will be launched in february 2020.

9.3.2. Interventions

- Patrick Rives has presented the topic of Autonomous vehicle during the day "Formation IA pour les professeurs des lycées", Sophia Antipolis, 14/11/2019

10. Bibliography

Major publications by the team in recent years

[1] M. BOUSSAHA, B. VALLET, P. RIVES. *Large scale textured mesh reconstruction from mobile mapping images and lidar scans*, in "ISPRS 2018 - International Society for Photogrammetry and Remote Sensing", Istanbul, Turkey, March 2018, pp. 49-56 [*DOI :* 10.5194/ISPRS-ANNALS-IV-2-49-2018], https://hal.archives-ouvertes.fr/hal-01764547

[2] M. COGNETTI, P. SALARIS, P. ROBUFFO GIORDANO. *Optimal Active Sensing with Process and Measurement Noise*, in "ICRA 2018 - IEEE International Conference on Robotics and Automation", Brisbane, Australia, IEEE, May 2018, pp. 2118-2125 [*DOI :* 10.1109/ICRA.2018.8460476], https://hal.inria.fr/hal-01717180

[3] F. FUSCO, O. KERMORGANT, P. MARTINET. *Constrained Path Planning using Quadratic Programming*, in "IROS 2018 - IEEE/RSJ International Conference on Intelligent Robots and Systems", Madrid, Spain, October 2018, https://hal.archives-ouvertes.fr/hal-01867331

[4] F. FUSCO, O. KERMORGANT, P. MARTINET. *A Comparison of Visual Servoing from Features Velocity and Acceleration Interaction Models*, in "IROS 2019 - IEEE/RSJ International Conference on Intelligent Robots and Systems", Macau, China, October 2019, https://hal.archives-ouvertes.fr/hal-02183760

[5] A. KHALIFA, O. KERMORGANT, S. DOMINGUEZ-QUIJADA, P. MARTINET. *An Observer-based Longitudinal Control of Car-like Vehicles Platoon Navigating in an Urban Environment*, in "CDC 2019 - 58th IEEE Conference on Decision and Control", Nice, France, December 2019, pp. 5742-5747, https://hal.archives-ouvertes.fr/hal-02273504

[6] A. KHALIFA, O. KERMORGANT, S. DOMINGUEZ-QUIJADA, P. MARTINET. *Vehicles Platooning in Urban Environments: Integrated Consensus-based Longitudinal Control with Gap Closure Maneuvering and Collision Avoidance Capabilities*, in "ECC19 - European Control Conference", Naples, Italy, June 2019, pp. 1695-1701, https://hal.archives-ouvertes.fr/hal-02057396

[7] E. R. NASCIMENTO, G. POTJE, R. MARTINS, F. CADAR, M. F. M. CAMPOS, R. BAJCSY. *GEOBIT: A Geodesic-Based Binary Descriptor Invariant to Non-Rigid Deformations for RGB-D Images*, in "ICCV 2019 - International Conference on Computer Vision", Seoul, South Korea, October 2019, https://hal.inria.fr/hal-02370753

[8] A. PEREZ-YUS, E. FERNANDEZ-MORAL, G. LOPEZ-NICOLAS, J. J. GUERRERO, P. RIVES. *Extrinsic Calibration of Multiple RGB-D Cameras From Line Observations*, in "IEEE Robotics and Automation Letters", 2018, vol. 3, n^o 1, pp. 273-280 [*DOI :* 10.1109/LRA.2017.2739104], https://hal.inria.fr/hal-01581523

[9] D. PÉREZ-MORALES, O. KERMORGANT, S. DOMINGUEZ-QUIJADA, P. MARTINET. *Automatic Perpendicular and Diagonal Unparking Using a Multi-Sensor-Based Control Approach*, in "ICARCV 2018 - The 15 th International Conference on Control, Automation, Robotics and Vision", Singapore, Singapore, November 2018, https://hal.archives-ouvertes.fr/hal-01874140

[10] P. SALARIS, M. COGNETTI, R. SPICA, P. ROBUFFO GIORDANO. *Online Optimal Perception-Aware Trajectory Generation*, in "IEEE Transactions on Robotics", 2019, pp. 1-16 [*DOI :* 10.1109/TRO.2019.2931137], https://hal.inria.fr/hal-02278900

Publications of the year

Articles in International Peer-Reviewed Journals

[11] R. MARTINS, D. BERSAN, M. F. M. CAMPOS, E. R. NASCIMENTO. *Extending Maps with Semantic and Contextual Object Information for Robot Navigation: a Learning-Based Framework using Visual and Depth Cues*, in "Journal of Intelligent and Robotic Systems", December 2019, https://hal.inria.fr/hal-02418347

[12] P. SALARIS, M. COGNETTI, R. SPICA, P. ROBUFFO GIORDANO. *Online Optimal Perception-Aware Trajectory Generation*, in "IEEE Transactions on Robotics", 2019, pp. 1-16 [*DOI :* 10.1109/TRO.2019.2931137], https://hal.inria.fr/hal-02278900

International Conferences with Proceedings

[13] F. FUSCO, O. KERMORGANT, P. MARTINET. *A Comparison of Visual Servoing from Features Velocity and Acceleration Interaction Models*, in "IROS 2019 - IEEE/RSJ International Conference on Intelligent Robots

and Systems", Macau, China, Proceedings of IROS 2019, October 2019, https://hal.archives-ouvertes.fr/hal-02183760

[14] A. KHALIFA, O. KERMORGANT, S. DOMINGUEZ-QUIJADA, P. MARTINET. *An Observer-based Longitudinal Control of Car-like Vehicles Platoon Navigating in an Urban Environment*, in "CDC 2019 - 58th IEEE Conference on Decision and Control", Nice, France, December 2019, https://hal.archives-ouvertes.fr/hal-02273504

[15] A. KHALIFA, O. KERMORGANT, S. DOMINGUEZ-QUIJADA, P. MARTINET. *Vehicles Platooning in Urban Environments: Integrated Consensus-based Longitudinal Control with Gap Closure Maneuvering and Collision Avoidance Capabilities*, in "ECC19 - European Control Conference", Naples, Italy, June 2019, https://hal.archives-ouvertes.fr/hal-02057396

[16] E. R. NASCIMENTO, G. POTJE, R. MARTINS, F. CADAR, M. F. M. CAMPOS, R. BAJCSY. *GEOBIT: A Geodesic-Based Binary Descriptor Invariant to Non-Rigid Deformations for RGB-D Images*, in "ICCV 2019 - International Conference on Computer Vision", Seoul, South Korea, October 2019, https://hal.inria.fr/hal-02370753

References in notes

[17] M. BOUSSAHA, E. FERNANDEZ-MORAL, B. VALLET, P. RIVES. *On the production of semantic and textured 3d meshes of large scale urban environments from mobile mapping images and lidar scans*, in "Reconnaissance des Formes, Image, Apprentissage et Perception (RFIAP)", 2018

[18] S. BRIOT, P. MARTINET. *Minimal Representation for the Control of Gough-Stewart Platforms via Leg Observation Considering a Hidden Robot Model*, in "the 2013 IEEE International Conference on Robotics and Automation (ICRA 2013)", Karlsruhe, Germany, May 2013, pp. 4653-4658, https://hal.archives-ouvertes.fr/hal-00770761

[19] S. BRIOT, P. MARTINET, F. CHAUMETTE. *Determining the Singularities for the Observation of Three Image Lines*, in "IEEE Robotics and Automation Letters", April 2017, vol. 2, n^{o} 2, pp. 412-419, https://hal.archives-ouvertes.fr/hal-01398925

[20] A. CHRIETTE, S. VANDERNOTTE, P. MARTINET, A. S. ROOS. *Dynamic sensor-based control*, in "2016 14th International Conference on Control, Automation, Robotics and Vision (ICARCV)", Phuket, France, IEEE, November 2016, https://hal.archives-ouvertes.fr/hal-01774848

[21] M. COGNETTI, P. SALARIS, P. ROBUFFO GIORDANO. *Optimal Active Sensing with Process and Measurement Noise*, in "ICRA 2018 - IEEE International Conference on Robotics and Automation", Brisbane, Australia, IEEE, May 2018, pp. 2118-2125 [*DOI :* 10.1109/ICRA.2018.8460476], https://hal.inria.fr/hal-01717180

[22] K. DAUTENHAHN, M. WALTERS, S. WOODS, K. L. KOAY, C. L. NEHANIV, E. A. SISBOT, R. ALAMI, T. SIMEON. *How May I Serve You? A Robot Companion Approaching a Seated Person in a Helping Context*, in "1st ACM SIGCHI/SIGART Conference on Human-Robot Interaction (HRI'06)", Salt Lake City, UT, United States, HRI 2006 Proceedings of the 1st ACM SIGCHI/SIGART conference on Human-robot interaction, ACM, March 2006, pp. 172-179, https://hal.laas.fr/hal-01979221

[23] S. DOMINGUEZ-QUIJADA, A. ALI, G. GARCIA, P. MARTINET. *Comparison of lateral controllers for autonomous vehicle : experimental results*, in "2016 IEEE 19th International Conference on Intelligent Transportation Systems (ITSC 2016)", Rio de Janeiro, Brazil, November 2016, https://hal.archives-ouvertes.fr/hal-02440161

[24] A. DOSOVITSKIY, P. FISCHER, E. ILG, P. HASSER, C. G. V. HAZRBAS. *Flownet: Learning optical flow with convolutional networks*, in "International Conference on Computer Vision (ICCV)", 2015

[25] A. ELFES. *Using occupancy grids for mobile robot perception and navigation*, in "Computer", June 1989, vol. 22, n^{o} 6, pp. 46-57

[26] Ö. ERKENT, C. WOLF, C. LAUGIER, D. SIERRA GONZÁLEZ, V. R. CANO. *Semantic Grid Estimation with a Hybrid Bayesian and Deep Neural Network Approach*, in "IROS 2018 - IEEE/RSJ International Conference on Intelligent Robots and Systems", Madrid, Spain, IEEE, October 2018, pp. 1-8, https://hal.inria.fr/hal-01881377

[27] F. FARINA, D. FONTANELLI, A. GARULLI, A. GIANNITRAPANI, D. PRATTICHIZZO. *Walking Ahead: The Headed Social Force Model*, in "Plos One", Jan 2017, vol. 12, https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0169734&type=printable

[28] F. FAVARÒ, S. EURICH, N. NADER. *Autonomous vehicles' disengagements: Trends, triggers, and regulatory limitations*, in "Accident Analysis & Prevention", 2018, vol. 110, pp. 136-148, http://www.sciencedirect.com/science/article/pii/S0001457517303822

[29] E. FERNANDEZ-MORAL, R. MARTINS, D. WOLF, P. RIVES. *A new metric for evaluating semantic segmentation: leveraging global and contour accuracy*, in "Workshop on Planning, Perception and Navigation for Intelligent Vehicles, PPNIV17", Vancouver, Canada, September 2017, https://hal.inria.fr/hal-01581525

[30] E. FERNANDEZ-MORAL, R. MARTINS, D. WOLF, P. RIVES. *A new metric for evaluating semantic segmentation: leveraging global and contour accuracy*, in "2018 IEEE Intelligent Vehicles Symposium (IV)", 2018

[31] G. FERRER, A. ZULUETA, F. HERRERO COTARELO, A. SANFELIU. *Robot social-aware navigation framework to accompany people walking side-by-side*, in "Autonomous Robots", Apr 2017, vol. 41, pp. 775-793, http://dx.doi.org/10.1007/s10514-016-9584-y

[32] F. FUSCO, O. KERMORGANT, P. MARTINET. *Constrained Path Planning using Quadratic Programming*, in "IROS 2018 - IEEE/RSJ International Conference on Intelligent Robots and Systems", Madrid, Spain, October 2018, https://hal.archives-ouvertes.fr/hal-01867331

[33] G. GARCIA, S. DOMINGUEZ-QUIJADA, J. BLOSSEVILLE, A. HAMON, X. KOREKI, P. MARTINET. *Experimental study of the precision of a multi-map AMCL-based localization system*, in "9th Workshop on Planning, Perception and Navigation for Intelligent Vehicle", Vancouver, Canada, September 2017, https://hal.inria.fr/hal-02440155

[34] D. HELBING, P. MOLNÁR. *Social force model for pedestrian dynamics*, in "Phys. Rev. E", May 1995, vol. 51, pp. 4282–4286, https://link.aps.org/doi/10.1103/PhysRevE.51.4282

[35] A. Hornung, K. Wurm, M. Bennewitz, C. Stachniss, W. Burgard. *OctoMap: an efficient probabilistic 3D mapping framework based on octrees*, in "Autonomous Robots", Apr 2013, vol. 34, n^{o} 3, pp. 1189-1206, https://doi.org/10.1007/s10514-012-9321-0

[36] E. Ilg, N. Mayer, T. Saikia, M. Keuper, A. Dosovitskiy, T. Brox. *Flownet 2.0: Evolution of optical flow estimation with deep networks*, in "IEEE Conference on Computer Vision and Pattern Recognition (CVPR)", 2017

[37] W. Jin. *Proactive-Cooperative navigation in crowded environments for autonomous robots, Master thesis*, Ecole Centrale de Nantes, August 2019

[38] A. Khalifa, O. Kermorgant, S. Dominguez-Quijada, P. Martinet. *Vehicles Platooning in Urban Environment: Consensus-based Longitudinal Control with Limited Communications Capabilities*, in "International Conference on Control, Automation, Robotics and Vision", Singapore, Singapore, November 2018, https://hal.archives-ouvertes.fr/hal-01866884

[39] S. S. Kia, S. Rounds, S. Martinez. *Cooperative Localization for Mobile Agents: A Recursive Decentralized Algorithm Based on Kalman-Filter Decoupling*, in "IEEE Control Systems Magazine", April 2016, vol. 36, n^{o} 2, pp. 86-101, https://doi.org/10.1109/MCS.2015.2512033

[40] K. Lee, D. Kum. *Collision Avoidance/Mitigation System: Motion Planning of Autonomous Vehicle via Predictive Occupancy Map*, in "IEEE Access", 2019, vol. 7, pp. 52846-52857, http://dx.doi.org/10.1109/ACCESS.2019.2912067

[41] R. Martins, E. Fernandez-Moral, P. Rives. *An Efficient Rotation and Translation Decoupled Initialization from Large Field of View Depth Images*, in "IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS'17", Vancouver, Canada, September 2017, pp. 5750-5755, https://hal.inria.fr/hal-01581524

[42] F. Paccot, P. Lemoine, N. Andreff, D. Chablat, P. Martinet. *A Vision-based Computed Torque Control for Parallel Kinematic Machines*, in "IEEE International Conference on Robotics and Automation, ICRA 2008", Pasadena, United States, May 2008, pp. 1556-1561, https://hal.archives-ouvertes.fr/hal-00330762

[43] V. Paduano. *Perception-Aware Human-Assisted Navigation of Mobile Robots on Persistent Trajectories, Master thesis*, Sapienza Univerdita di Roma, August 2019

[44] A. Perez-Yus, E. Fernandez-Moral, G. Lopez-Nicolas, J. J. Guerrero, P. Rives. *Extrinsic Calibration of Multiple RGB-D Cameras From Line Observations*, in "IEEE Robotics and Automation Letters", 2018, vol. 3, n^{o} 1, pp. 273-280, https://hal.inria.fr/hal-01581523

[45] D. Pérez-Morales, S. Dominguez-Quijada, O. Kermorgant, P. Martinet. *Autonomous parking using a sensor based approach*, in "8th Workshop on Planning, Perception and Navigation for Intelligent Vehicles at IEEE Int. Conf. on Intelligent Transportation Systems", Rio de Janeiro, Brazil, IEEE, November 2016, https://hal.inria.fr/hal-01396998

[46] D. Pérez-Morales, O. Kermorgant, S. Dominguez-Quijada, P. Martinet. *Autonomous Perpendicular And Parallel Parking Using Multi-Sensor Based Control*, in "9th Workshop on Planning, Perception and Navigation for Intelligent Vehicles at IEEE/RSJ Int. Conf. on Intelligent Robots and Systems", Vancouver, Canada, September 2017, https://hal.inria.fr/hal-01689850

[47] D. PÉREZ-MORALES, O. KERMORGANT, S. DOMINGUEZ-QUIJADA, P. MARTINET. *Automatic Perpendicular and Diagonal Unparking Using a Multi-Sensor-Based Control Approach*, in "ICARCV 2018 - The 15 th International Conference on Control, Automation, Robotics and Vision", Singapore, Singapore, November 2018, https://hal.archives-ouvertes.fr/hal-01874140

[48] D. PÉREZ-MORALES, O. KERMORGANT, S. DOMINGUEZ-QUIJADA, P. MARTINET. *Laser-Based Control Law For Autonomous Parallel And Perpendicular Parking*, in "International Conference on Robotic Computing", Laguna Hills, United States, January 2018, https://hal.inria.fr/hal-01689875

[49] D. PÉREZ-MORALES, O. KERMORGANT, S. DOMINGUEZ-QUIJADA, P. MARTINET. *Multi-Sensor-Based Predictive Control for Autonomous Backward Perpendicular and Diagonal Parking*, in "10th workshop on Planning, Perception and Navigation for Intelligent Vehicles at Int. Conf. on Intelligent Robots and Systems", Madrid, Spain, October 2018, https://hal.archives-ouvertes.fr/hal-01867303

[50] A. RADGUI, C. DEMONCEAUX, E. M. MOUADDIB, M. RZIZA, D. ABOUTAJDINE. *Optical flow estimation from multichannel spherical image decomposition*, in "Computer Vision and Image Understanding", September 2011, vol. 115, n^{o} 9, pp. 1263-1272, https://hal.archives-ouvertes.fr/hal-00637423

[51] L. RUMMELHARD, J. LUSSEREAU, J.-A. DAVID, C. LAUGIER, S. DOMINGUEZ-QUIJADA, G. GARCIA, P. MARTINET. *Perception and Automation for Intelligent Mobility in Dynamic Environments*, in "ICRA 2017 Workshop on Robotics and Vehicular Technologies for Self-driving cars", Singapore, Singapore, June 2017, https://hal.inria.fr/hal-01592566

[52] J. THOMAS. *Autonomous Navigation based on Hidden Robot Concept, Master thesis*, Ecole Centrale de Nantes, August 2019

[53] G. WILLIAMS, A. ALDRICH, E. A. THEODOROU. *Model Predictive Path Integral Control: From Theory to Parallel Computation*, in "Journal of Guidance, Control, and Dynamics", 2017, vol. 40, n^{o} 2, pp. 344-357, https://doi.org/10.2514/1.G001921

[54] G. WILLIAMS, P. DREWS, B. GOLDFAIN, J. M. REHG, E. A. THEODOROU. *Information-Theoretic Model Predictive Control: Theory and Applications to Autonomous Driving*, in "IEEE Transactions on Robotics", Dec 2018, vol. 34, n^{o} 6, pp. 1603-1622, https://doi.org/10.1109/TRO.2018.2865891

[55] H. ZHANG. *Optical Flow Estimation In Spherical Images, Master thesis*, UTC, Compiègne, August 2019