2019

DOSSIER DE CANDIDATURE

APPLICATION

Cochez le concours sur lequel vous candidatez
Check the competition exam for which you are applying

☐ **CRCN - (Chargés de recherche de classe normale / Young graduate scientist position)**

☒ **DR2 - (Directeurs de recherche de deuxième classe / Senior researcher position)**

Nom[1] **:** FRAICHARD
Last name

Prénom : Thierry
First name

Sexe : ☐ **F** ☒ **M**
Sex

Nom utilisé pour vos publications (facultatif) :
Name used for your publications (optional):

[1] Il s'agit du nom usuel figurant sur vos pièces d'identité
It is the name appearing on your identity cards

DEPOT DE VOTRE CANDIDATURE
SUBMITTING YOUR APPLICATION

Le dossier de candidature doit comprendre :

- Formulaire 1 : Parcours professionnel
- Formulaire 2 : Description synthétique de l'activité antérieure
- Formulaire 3 : Contributions majeures
- Formulaire 4 : Programme de recherche
- Formulaire 5 : Liste complète des contributions

CRCN :

- Les rapports de thèse ou de doctorat (si disponibles)
- Une copie des derniers titres et diplômes
- Une photographie récente de la candidate / du candidat (facultative)

DR2 :

- Les rapports d'habilitation à diriger des recherches (si applicables)
- Une copie des derniers titres et diplômes
- Une photographie récente de la candidate / du candidat (facultative)

The application file must include:

- *Form 1: Professional history*
- *Form 2: Summary of your past activity*
- *Form 3: Major contributions*
- *Form 4: Research program*
- *Form 5: Complete list of contributions*

CRCN :

- *PhD dissertation reports (when available)*
- *A copy of most recent titles and diplomas*
- *A recent photography of the applicant (optional)*

DR2 :

- *Habilitation dissertation reports (if applicable)*
- *A copy of most recent titles and diplomas*
- *A recent photography of the applicant (optional)*

SOMMAIRE / *SUMMARY*

Formulaire 1 — PARCOURS PROFESSIONNEL
Form 1 — PROFESSIONAL HISTORY

1) Parcours Professionnel / *Professionnal history*

Recruté par l'INRIA en oct. 93 en tant que Chargé de Recherche.

Date début / Start	Date Fin / End	Établissements / Institutions	Fonction et statut / Positions and status
June 14	May 15	Bar Ilan Univ. Ramat Gan (IL)	Guest Scientist
Sep. 07	Aug. 08	Swiss Federal Inst. of Technology (ETH), Zurich (CH)	Guest Scientist
Sep. 02	Dec. 02	Riken Inst. Tokyo (JP)	JSPS[1] Research Fellow
Nov. 01	Dec. 01	Nanyang Technological Univ. (SG)	Tan Chin Tuan Fellow
Nov. 00	Jan. 01	Nanyang Technological Univ. (SG)	Tan Chin Tuan Fellow
Dec. 93	Nov. 94	Robotics Inst., Carnegie Mellon Univ., Pittsburgh (US)	Post-Doctoral Fellow
Oct. 93	*Present*	*INRIA Grenoble Rhône-Alpes*	*Research Scientist*
Sep. 91	Aug. 93	Univ. Pierre Mendès-France, Grenoble	Junior Lecturer (ATER)
Sep. 88	Aug. 91	Grenoble Inst. of Technology (Grenoble INP)	Doctoral Fellow

2) Interruptions de carrière/*Career breaks*

3) Prix et distinctions / *Prizes and awards*

- Honours:
  Admissible en 6ème position ex-aequo au concours DR2 INRIA 2018.
  INRIA Scientific Excellence Award (PEDR): awarded by INRIA to its top researchers *[March 14]*,
  IEEE Senior Member Status: awarded by IEEE to its top 10% members in recognition of their professional excellence *[Feb. 09]*.
  European Robotics PhD Award: granted to my PhD student, Dizan Vasquez, by the European Robotics Network (EURON) *[Apr. 09]*. This award is yearly given to the best Robotics PhD thesis in Europe.
- Conference paper awards:
  Paper [32] **nominated for the best paper award** at the IEEE Int. Symp. on Robot and Human Interactive Communication (RO-MAN), Edinburgh (UK) *[Aug. 14]*.
- Conference papers selected for publication in journals:
  Paper [30] of 2016 Conf. on Computing Systems and Applications (CSA) selected for publication in EL MIR'AT Sciences [3].
  Paper [51] of 2007 Int. Symp. of Robotics Research (ISRR) selected for publication in IEEE Trans. on Intelligent Transportation Systems [8].
  Paper [76] of 2003 Int. Conf. on Field and Service Robotics (FSR) selected for publication in Int. Journal of Robotics Research [14].
  Paper [75] of 2003 IEEE-RSJ Int. Conf. on Intelligent Robots and Systems (IROS) selected for publication in Advanced Robotics journal [16].
- Merit-Based Grants and Fellowships:
  Japan Society for the Promotion of Science, Visiting Fellowship *[02]*.
  Nanyang Tech. Univ. (Singapore), Tan Chin Tuan Visiting Fellowships *[00]* and *[01]*.
  French Ministry of Research and Education, Doctoral Scholarship *[88-91]*.

4) Encadrement d'activités de recherche / *Supervision of research activities*

I regularly supervise the work of graduate students originating from the French academic system or from foreign universities. I have also supervised the work of a number of Post-Doctoral fellows and contracted engineers. They are listed below, names in bold are for people currently supervised. Unless otherwise indicated, the supervision was complete.

PhD Students

1. **Matteo Ciocca**, Univ. Grenoble Alpes (UGA), *Guaranteed Safe Robot Motion for Biped Robots, Expected Spring 20*. Co-supervision with Dr. Pierre-Brice Wieber.
2. **Jose Grimaldo Da Silva Filho**, UGA, *Human-Robot Motion - An Effort-Based Approach, Expected Fall 19*.

[1] Japan Society for the Promotion of Science.

3. **Muhammad Bouguerra**, Univ. of Annaba (DZ), *Viability and Guaranteed Motion Safety, Expected Fall 19*. Co-supervision with Prof. Mohamed Fezari.
4. Rémi Paulin, UGA, *Human-Robot Motion - An Attention-Based Approach, March 18*. Co-supervision with Prof. Patrick Reignier.
5. Sara Bouraine, Univ. of Blida (DZ), *Contribution to Motion Planning in Dynamic Environments for Car-Like Robots - The Robucar Case, May 16*. Co-Supervision with Prof. Hassen Salhi.
6. Marco Polo Cruz Ramos, Technològico de Monterrey (ITESM), *Design of Interaction Systems for Mobile Robots Collaboration; a Marsupial Robot Team for Search and Rescue Operations Case Study, Dec. 12*. Co-Supervision with Prof. Jose-Luis Gordillo.
7. Alessandro Renzaglia, Univ. of Grenoble, *Adaptive Stochastic Optimization for Cooperative Coverage with a Swarm of Micro Air Vehicles, Apr. 12*. Co-Supervision with Dr. Agostino Martinelli.
8. Qadeer Baig, Univ. of Grenoble, *Multi Sensor Data Fusion for Detection and Tracking of Moving Objects from a Dynamic Autonomous Vehicle, Mar. 12*. Co-Supervision with Prof. Olivier Aycard.
9. Luis Martinez, Inst. Nat. Polytechnique de Grenoble (INPG), *Safe Navigation for Autonomous Vehicles in Dynamic Environments: an Inevitable Collision State (ICS) Perspective, Nov. 10*.
10. Vivien Delsart, Univ. Joseph Fourier (UJF), *Autonomous Navigation in Dynamic Environments: a Trajectory Deformation Approach, Oct. 10*.
11. Stéphane Petti, Ecole Nat. Sup. des Mines de Paris, *Safe Navigation within Dynamic Environments: a Partial Motion Planning Approach, Jul. 07*.
12. Dizan Vasquez, INPG, *Incremental Learning for Motion Prediction of Pedestrians and Vehicles, Feb. 07*.
13. Christophe Coué, INPG, *Bayesian Model for Multi-Modal Analysis of Cluttered Environments : an Automotive Application, Dec. 03*, co-supervision with P. Bessière.
14. Alexis Scheuer, INPG, *Continuous-Curvature Path Planning for Nonholonomic Mobile Robots, Jan. 98*.
15. Raphaël Mermond, INPG, *Motion Planning with Geometric Uncertainty in Sensing and Control, June 97*.
16. Philippe Garnier, INPG, *Reactive Motion Execution Control for Vehicles in Dynamic and Structured Environments, Dec. 95*. Co-Supervision with Dr. C. Laugier.

Master Students

1. **Jing Xiao**, Int. Master of Science in Informatics at Grenoble (MOSIG), Univ. Grenoble Alpes, *Human-Robot Motion: an Attention-Based Approach, Expected Sep. 19*. Co-supervision with Prof. Patrick Reignier and Dr. Jose Ernesto Gomez-Balderas.
2. **Valentin Levesy**, MOSIG, *Human-Robot Motion: a Bio-Inspired Approach, Expected June 19*. Co-supervision with Dr. Jose Ernesto Gomez-Balderas.
3. Angan Mitra, MOSIG, *Situation-Aware Navigation for a Telepresence Robot, June 18*. Co-supervision with Prof. James Crowley.
4. Vilma Muço, MOSIG, *Safe Navigation for Robots, June 17*.
5. Hang Yu, MOSIG, *Safe Navigation of Biped Robots Subject to Passive Friendly Safety and Balance Constraints, June 16*. Co-supervision with Dr. Pierre-Brice Wieber.
6. Andre Van Den Berg, MOSIG, *Analysis of Social Navigation for a Robot, June 13*.
7. Antoine Bautin, MOSIG, *Uncertainty and Inevitable Collision States, June 09*.
8. Juan Lahera, MOSIG, *Cooperative Navigation for Car-Like Vehicles, June 09*.
9. Vivien Delsart, “Image, Vision and Robotics” Master (IVR), Univ. of Grenoble, *Motion Autonomy in Dynamic Environments: an Elastic Approach, June 07*.
10. Ouri Maler, IVR, *Multi-Robot Navigation in Urban Dynamic Environment, June 07*.
11. Rishikesh Parthasarathi, IVR, *Characterization of the Inevitable Collision States for a Car-Like vehicle, June 06*.
12. Alejandro Vargas, IVR, *Coupling On-Board and Off-Board Vision for Localization, Sep. 04*.
13. Julien Burlet, “Intelligence, Interaction and Information” Master, Univ. of Grenoble,*Motion under Uncertainty of a Mobile Robot*. Co-supervision with Prof. Olivier Aycard, *June 04*.
14. Dizan Vasquez, IVR, *Motion Estimation for Mobile Obstacles: A Statistical Approach, Sep. 03*.
15. Stéphane Blondin, IVR, *Motion Planning for an Automated Vehicle in a Partially Known Environment, June 02*.
16. Fabrice Vincent, IVR, *Environment Modelling and Localization for a Vehicle, June 97*.
17. Raphaël Mermond, IVR, *Path Planning for a Nonholonomic Robot under Geometric Uncertainty, June 96*.
18. Alexis Scheuer, IVR, *Nonholonomic Trajectory Planning in a Dynamic Workspace, June 92*.

Foreign Graduate Students

PhD Level:

1. Frank Moosmann, Univ. of Karlsruhe (DE), *Detecting Moving Objects Using a 3D Range Sensor [Nov. 08–Apr. 09]*.
2. Kristijan Macek, Swiss Federal Inst. of Technology (ETH), Zurich (CH) *Safe Vehicle Navigation in Dynamic Urban Environments [Sep. 07–Aug. 08]*.

3. Hannah Kurniawati, Nat. Univ. of Singapore, *Motion Autonomy in Dynamic Environments: An Elastic Strip Approach [Mar.–Aug. 06]*.

Master Level:

1. Carlos Di Pietro, Universidad de Buenos Aires (AR), *Design of Robot Companion [June-Nov. 13]*.
2. Thomas Fisher, Univ. of Buenos Aires (AR), *Attention-Based Navigation for a Service Robot [May-Oct. 12]*.
3. Nicolas Alvarez-Picco, Univ. of Rosario (AR), *Safe Navigation with Uncomplete Information [Apr.-Sep. 10]*.
4. Leonardo Scandolo, Univ. of Rosario (AR), *Anthropomorphic Navigation in Dynamic Environments [Sep. 10-Feb. 11]*.
5. Luis Martinez, Instituto Tecnológico Autónomo de México (ITAM), México (MX), *Inevitable Collision States, [Aug.-Oct. 06]*.
6. Hugo Ortega, Technològico de Monterrey (ITESM), Campus Monterrey (MX), *Detecting and tracking moving objects with a pan-tilt camera [Apr.–Jul. 04]*.
7. Alejandro Vargas, Technològico de Monterrey (ITESM), Campus Cuernavaca (MX), *Iterative motion planning in dynamic environments [Sep. 01–Feb. 02]*.

Post-doctoral Fellows

1. Gang Chen, Inst. Nat. des Sciences Appliquées de Lyon (FR), *Autonomous Navigation in Dynamic Environments [Feb. 06–Jan. 07]*.
2. Fernando De La Rosa, Inst. Nat. Polytechnique de Grenoble (FR), *ParkView: an Experimental platform for the interpretation of Complex Dynamic Scenes [Sep. 03–Aug. 04]*.
3. Guo Dong, Nanyang Tech. Univ. (SG), *Multi-Sensor Data Fusion to Sense The Environment of a Car [Nov. 99–Oct. 00]*.
4. Alain Lambert, Université de Technologie de Compiègne (FR), *Planning Safe Motion Strategies for Nonholonomic Vehicle [Apr.–Oct. 99]*.

Contracted Engineers

1. Gang Chen, *Autonomous Navigation in Dynamic Environments [Jan.–June 10]*.
2. Stéphane Laforêt, *Design of a Control Architecture for Autonomous Navigation [Jan.–Dec. 07]*.
3. Eric Boniface, *Design of a Map Server for Dynamic Environments [Nov. 04–Oct. 05]*.
4. Frédéric Hélin, *Design of a Map Server for Dynamic Environments [Jan.–Jul. 03]*.
5. Gilles Liévin Gilles, *Reactive Motion Planning for Car-Like Vehicles [Sep. 89–Aug. 90]*.

Engineer Interns

1. Adrian Bourgaud, Ecole Nat. Supérieure d'Informatique et de Mathématiques Appliquées de Grenoble (ENSIMAG), *Déplacement d'un robot dans une foule [Feb.-May 13]*.
2. Antoine Durand-Gasselin, Ecole Nat. Supérieure de Cachan, *Inevitable Collision States: A Tool for Safety [June–Aug. 07]*.
3. Frédéric Favier, Magistère Univ. Joseph Fourier de Grenoble (UJF), *Collision Detection in an Automotive Context [Jan.–Sep. 04]*.
4. Joël Schaerer, Inst. Nat. des Sciences Appliquées de Lyon (INSA), *Computing Inevitable Collision States [Aug–Dec. 03]*.
5. Pierre Billiau, ENSIMAG, *Steering Methods for Car-Like Vehicles [Jul.–Sep. 01]*.
6. Sébastien Fave, Ecole Universitaire d'Informatique de Grenoble, *Iterative motion planning [Jul.–Sep. 01]*.
7. Kok Hin Chan, Nanyang Tech. Univ. (NTU), *Planning and controlling the motion of the Cycab vehicle [Jan.–June 00]*.
8. Richard Desvigne, Ecole des Hautes Etudes Industrielles de Lille, *Continuous-Curvature Path Planning for Nonholonomic Mobile Robots [June–Nov. 99]*.

5) Responsabilités collectives / *Responsibilities*

Conference Organization

I have contributed to the organization of a number of international events including two high-profile Robotics conferences: IEEE-RSJ Int. Conf. on Intelligent Robots and Systems (IROS) in 97, and Robotics Science and Systems Int. Conf. (RSS) in 08. I have also set up the first two international workshops on guaranteed motion safety [10 & 11]. I was ***Program Co-Chair for the 2018 IEEE Int. Conf. on Simulation, Modeling, and Programming for Autoomous Robots (SIMPAR)****.*

- IEEE Int. Conf. on Simulation, Modeling, and Programming for Autonomous Robots (SIMPAR), Brisbane (AT), *May 2018* (**Program Co-Chair**).
- Guaranteeing Motion Safety for Robots, workshop of the Robotics Science and Systems Int. Conf. (RSS), Los Angeles (US), *June 11* (**Organization**) http://safety2011.inrialpes.fr.
- Guaranteeing Safe Navigation in Dynamic Environments, workshop of the IEEE Int. Conf. on Robotics and Automation (ICRA), Anchorage (US), *May 10* (**Organization**) http://safety2010.inrialpes.fr.

- Robotics Science and Systems Int. Conf., Zürich (CH), *June 08* (**Local arrangements**).
- France-Korea Workshop on Advanced Driver Assistance Systems, Paris, *Dec. 05* (**Organization**).
- France-Korea Symposia on Dependable Robotic Navigation, Seoul (KR) *Oct. 04 and Oct. 05* (**Organization**).
- IEEE-RSJ Int. Conf. on Intelligent Robots and Systems (IROS). Grenoble, *Sep. 97* (**Secretary**).
- European Workshop on Intelligent Co-pilot. Grenoble, *Dec. 91* (**Organization**).

Program Committee Membership

I regularly serve on Program Committees (see list below). In particular, I served as an Associate Editor[2] for the two main conferences in Robotics, namely the IEEE Int. Conf. on Robotics and Automation (ICRA), and the IEEE-RSJ Int. Conf. on Intelligent Robots and Systems (IROS). I also served as an Associate Editor for the 2010 edition of the IEEE Intelligent Vehicles Symp. (IV), the premier annual forum on Intelligent Transport.

- IEEE Int. Conf. on Robotics and Automation (ICRA): *PC member since 05*, **Associate Editor *[09-14]***.
- IEEE-RSJ Int. Conf. on Intelligent Robots and Systems (IROS): *PC member since 97*, **Associate Editor *[10-16]***.
- Eur. Conf. on Mobile Robots (ECMR): *PC Member since 09*.

- Int. Workshop on Robot Learning and Planning (RLP) in association with RSS, Ann Harbor (US), *June 16*.
- IEEE Int. Symp. on Robot and Human Interactive Communication (RO-MAN), Kobe (JP), *Sep. 15*.
- Robotics Science and Systems Int. Conf. (RSS), Rome (IT), *July 15*.
- IFAC Symp. on Robot Control (SYROCO), Dubrovnik (HR) *Sep. 12*, **Associate Editor**.
- Robotics Science and Systems Int. Conf. (RSS), Los Angeles (US), *June 11*.
- IEEE Intelligent Vehicle Symp. (IV), San Diego (US), *June 10*, **Associate Editor**.
- Int. Symp. on Distributed Autonomous Robotic Systems (DARS), Tsukuba (JP), *Nov. 08*.
- Int. Workshop on Planning, Perception and Navigation for Intelligent Vehicles, Roma (IT), *Apr. 07*.
- IEEE Int. Conf. Robotics and Biomimetics (ROBIO), Kunming (CN), *Dec. 06*; Bangkok (TH), *Feb. 09*.
- Workshop on Robotics of the Mexican Encounters in Computer Science, San Luis Potosi (MX), *Sep. 06*.
- Robotics Science and Systems Int. Conf. (RSS), Philadelphia (US), *Aug. 06*.
- Iberoamerican Conf. on Artificial Intelligence, Puebla (MX), *Nov. 04*.
- Int. Symp. on Automotive Technology and Automation. Florence (IT), *June 92*.
- European Workshop on Intelligent Co-pilot. Grenoble, *Dec. 91*.

Reviewing Activities

*I review papers for the main international journals and conferences in my field on a regular basis. I am also an expert evaluator for different research agencies worldwide. In May 2015, I have become an **Associate Editor for the IEEE Robotics and Automation Letters (RA-L)**, the new journal of the IEEE Robotics and Automation Society.*

Expertise

- Expert evaluator for the European Commission (6^{th}, 7^{th} and H2020 Framework Programs) *since 03*.
- Expert evaluator for the CNRS and the French Research Agency (ANR) *since 02*.
- Expert evaluator for the Italian Research Agency, *May 08, Oct. 18*.
- Expert evaluator for the Cyprus Research Foundation, *Oct. 17*.
- Expert evaluator for the Czeck Science Foundation, *Sep. 14*.
- Expert evaluator for the Israel Science Foundation, *May 06*.

Journals

- IEEE Robotics and Automation Letters (RA-L).
- IEEE Trans. on Robotics (TRO).
- IEEE Trans. on Robotics and Automation (TRA).
- IEEE Trans. on Control Systems Technology (TCST).
- IEEE Trans. on Systems, Man and Cybernetics (TSMC).
- IEEE Systems Journal (ISJ).
- IEEE Trans. on Intelligent Vehicles (TIV).
- IEEE Trans. on Industrial Electronics (TIE).
- Int. Journal of Robotics Research (IJRR).
- Advanced Robotics (AR)
- Autonomous Robots (AURO).
- Journal of Field Robotics (JFR).
- Robotics and Autonomous Systems (RAS).
- IFAC Int. Journal on Mechatronics (IJM).
- Int. Journal on Robotics and Autonomous Systems (IJRA).
- Int. Journal of AI Research (JAIR).

[2] An Associate Editor has to handle the review process of a set of papers, *i.e.* assign reviewers, assess each paper and write its review report.

- Int. Journal of Aerospace Engineering (IJAE).
- Revue d'Intelligence Artificielle (RIA).

Conferences

- Int. Workshop on the Algorithmic Foundations of Robotics (WAFR).
- Robotics Science and Systems Int. Conf. (RSS).
- IEEE Int. Conf. on Robotics and Automation (ICRA).
- IEEE-RSJ Int. Conf. on Intelligent Robots and Systems (IROS).
- Int. Joint Conf. on Artificial Intelligence (IJCAI).
- IEEE Intelligent Vehicle Symp. (IV).
- IEEE Conf. on Decision and Control (CDC).
- EuroGraphics (EG).
- Eur. Conf. on Mobile Robots (ECMR).
- IFAC Symp. on Robot Control (SYROCO)
- IEEE Int. Conf. on Robotics and Biomimetics (ROBIO).
- IEEE Int. Conf. on Advanced Intelligent Mechatronics (AIM).
- Int. Symp. on Distributed Autonomous Robotic Systems (DARS).
- Int. Conf. on Control, Automation, Robotics and Vision (ICARCV).
- IEEE Int. Symp. on Assembly and Task Planning (ISATP).
- IEEE Int. Conf. on Advanced Robotics (ICAR).
- IEEE/IEEJ/JSAI Int. Conf. on Intelligent Transportation Systems (ITSC).
- Int. Conf. on Intelligent Autonomous Systems (IAS).
- Iberoamerican Conf. on Artificial Intelligence (IBERAMIA).

Community Service

Whenever possible, I get involved in the life of my host institutions (primarily by sitting on different institutional committees). I am currently a member of the Technological Development Committee, the IT Service Committee and the Center Committee of the INRIA Grenoble Rhône-Alpes Research Center. I have contributed to the writing of the "Interactive systems that assist and adapt to humans" challenge of the 2018-2022 INRIA Strategic Plan. I have also been co-responsible of the "Graphics, Vision and Robotics" track of the Int. Master of Science in Informatics at Grenoble (MOSIG).

- INRIA Grenoble Rhône-Alpes Research Center Committee[3] ***[June 16, present]***, *[Nov. 10-May 13], & [Feb. 01-Jan. 08]*.
- INRIA Grenoble Rhône-Alpes IT Service Committee[4], ***[Jan. 12-Present]***.
- INRIA Grenoble Rhône-Alpes Technological Development Committee[5] ***[May 10-Present]***.

- "Graphics, Vision and Robotics" track of the MOSIG Master *[Aug. 12-June 14]*.
- CNRS-GRAVIR Laboratory Committee *[Jan. 03–Dec. 06]*.
- INRIA Grenoble Rhône-Alpes Health and Safety Committee[6] *[Sep. 00–Aug. 07]*.
- INRIA Joint Administrative Committee[7] *[Jan. 97–Dec. 99]*.

Since my HDR, I have been a member of the following PhD/HDR defence committees:

- Florent Altché (PhD), Ecole Nat. Sup. des Mines de Paris, *Sep. 18* (expert evaluator).
- Alexandre Boeuf (PhD), Univ. of Toulouse (FR), *July 17* (expert evaluator).
- Suhyeon Gim (PhD), Univ. of Clermont-Ferrand (FR), *June 17* (expert evaluator).
- Sawssen Jalel (PhD), Univ. of Toulouse (FR), *Dec. 16* (expert evaluator).
- Vicent Girbés Juan (PhD), Universitat Politécnica de València (ES), *Apr. 16* (expert evaluator).
- Jose Miguel Vilca Ventura (PhD), Univ. of Clermont-Ferrand (FR), *Oct. 15* (expert evaluator).
- Hélène Vorobieva (PhD), Univ. d'Evry (FR), *Nov. 14*.
- Jean Grégoire (PhD), Ecole Nat. Sup. des Mines de Paris, *Sep. 14* (expert evaluator).
- Asma Azim (PhD), Univ. of Grenoble, *Dec. 13* (president).
- Adam Houénou (PhD), Technological Univ. of Compiègne, *Dec. 13* (expert evaluator).
- Jim Mainprice (PhD), Univ. of Toulouse (FR), *Dec. 12* (expert evaluator).
- Sébastien Rubrecht (PhD), Univ. Pierre et Marie Curie, Paris, *Sep. 11* (president).
- Ahmed Benzerrouk (PhD), Univ. of Clermont-Ferrand (FR), *Apr. 11* (president).
- Olivier Aycard (HDR), Univ. of Grenoble (FR), *Dec. 10*.
- Pierre Avanzini (PhD), Univ. of Clermont-Ferrand (FR), *Dec. 10* (expert evaluator).

[3] Comité de centre (CC).
[4] Comité des utilisateurs des moyens informatiques (CUMI)
[5] Commission du développement technologique (CDT).
[6] Comité local hygiène et sécurité (CLHS).
[7] Commission Administrative Paritaire (CAP).

- Kristijan Macek (PhD), Swiss Federal Inst. of Technology (ETH), Zurich (CH), *Jul. 10* (expert evaluator).
- Sofiane Ahmed Ali (PhD), Univ. du Havre (FR), *Apr. 08* (expert evaluator).

I also served as an expert evaluator in the selection committee for an Associate Professor position at Univ. Polytech, Clermont-Ferrand (FR) (May 11), and in the Robotics PhD 1st Year Validation Jury of the Ecole Nat. Sup. des Mines de Paris (May 12).

6) Management / *Management*

I have so far been involved in 28 National, European and Bilateral research projects. I was the coordinator of four of these. I also took the leadership of two European project workpackages.

6.1 Current Projects

Research Project Coordination

1. French EMERGENCE-LIG project "Human-Robot Motion: a Bio-Inspired Approach" ***[Jan.-Dec 19]***.
   It involves two partners from the Grenoble academic scene: GIPSA and LIG. In collaboration with Jose Ernesto Gomez Balderas, we will explore whether human visual cues can be combined with a sociological behavior theory in order to address Human-Robot Motion, *i.e.* how robots should move among humans.

Partnership in Research Project

1. French project FUI **STAR**, "Système de Transport Autonome Rapide" ***[Jan. 18-Dec. 20]***.
   STAR involves partners from the research and transport sector: EasyMile, IFFSTAR, INRIA, ISAE, IVECO BUS, Michelin, Sector and Transpolis. Its goal is to develop a 12m long self-driving shuttle that can reach 40km/h. In collaboration with Pierre-Brice Wieber, we will contribute to the safety and passenger comfort aspects.
2. European project H2020-ICT-645097 **COMANOID**, "Multi-Contact Collaborative Humanoids in Aircraft Manufacturing" ***[Jan. 15-Dec. 19]***.
   COMANOID involves CNRS, DLR, INRIA, Sapienza and Airbus. It aims at deploying humanoid robots to work in aircraft assembly operations. Because the robots evolve among human workers, safety issues are a concern. In collaboration with Pierre-Brice Wieber via our joint PhD student, Matteo Ciocca, we contribute to the safety aspects.
3. French action ANR-11-LABX-0025-01 **RHUM**, "Robots in Human Environments" ***[Sep. 15-Dec. 19]***.
   The RHUM project brings together ten teams from different labs from the Grenoble academic scene: GIPSA, INRIA, LIG, LJK and TIMC. Its goal is to tackle scientific problems related to active perception, navigation in human environments, learning and adaptation of robots behaviors for social interaction. In collaboration with Patrick Reignier via our joint PhD student, Rémi Paulin, we contribute to the navigation in human environments aspects.

6.2 Past Projects

Research Project Coordination

1. French-Korean project Star **SafeMove**, "Dependable Robotic Navigation" *[Jan. 04–Dec. 05]*.
   This project involved three partners: (1) Sungkyunkwan University, Seoul (KR), (2) CNRS-LASMEA Clermont-Ferrand, and (3) INRIA Grenoble (E-MOTION team). Eleven permanent researchers (including myself) and six PhD students were primarily involved. The key purpose of the project goal was to strengthen the cooperation between France and Asia in the domain of Automated Tranportation. To that end, three bilateral workshops were organized. In the wake of Safemove, two larger French-Asian projects with partners from China, Japan and Singapore were launched: (1) **FACT**, "French-Asian Cyber Transportation", *[Nov. 05–Dec. 07]*, and (2) **Cityhome**, "From Cyber Transportation to Mobile Service Robots", *[Nov. 08–Dec. 11]*.
2. French project Robea **ParkNav**, "Interpretation of Complex Dynamic Scenes and Reactive Motion Planning" *[Oct. 02–Sep. 05]*.
   This project involved six official partners: (1) LAAS-CNRS Toulouse, (2-5) INRIA Grenoble (E-MOTION, MOVI and PRIMA teams + SED support group), and (6) INRIA Rennes (LAGADIC team). Blue Eye Video, a spin-off company of PRIMA, was also involved in the project. Seven permanent researchers (including myself), three engineers, one post-doc and five PhD students were primarily involved. The purpose of the project was to study real-world modeling using vision and autonomous navigation in dynamic environments.
3. French-Mexican project Lafmi **NavDyn**, "Navigation of an Autonomous Vehicle in a Dynamic Environment" *[Oct. 02–Sep. 04]*.
   This project involved two partners: (1) Instituto Technologico y de Estudios Superiores de Monterrey (ITESM) and (2) INRIA Grenoble (SHARP team). Five permanent researchers (including myself) and three PhD students were primarily involved. The purpose of the project was to study moving object detection using vision and autonomous navigation in dynamic environments.

Research Workpackage Coordination

1. European project FP6-IST-12224 **Carsense**, "Sensing of Car Environment at Low Speed Driving", "Sensor Data Fusion" workpackage *[Jan. 00–Dec. 02]*.
   CarSense was a large European project with 13 partners including major car manufacturers (BMW, Fiat, Renault) and part suppliers (Autocruise, Jena, IBEO, Thales, TRW). The "Sensor Data Fusion" workpackage involved two academic partners: (1) INRETS-LCPC, and (2) INRIA Grenoble (SHARP team). Three permanent researchers (including myself) and two PhD students were primarily involved. The purpose of this workpackage was to build a map of the surroundings of the CarSense vehicle.
2. European project Inco-Copernicus "Multi-Agent Robot Systems for Industrial Applications in the Transport Domain", "Navigation of Mobile Robots" workpackage *[Feb. 97–Jan. 99]*.
   Copernicus was a European project with nine partners from Germany, France and Eastern Europe including Mercedes-Benz. The "Navigation of Mobile Robots" workpackage involved four partners: (1) St Petersburg University, (2) Minsk University, (3) Ufa University, and (4) INRIA Grenoble (SHARP team). Five permanent researchers (including myself), one post-doc and five PhD students were primarily involved. The purpose of this workpackage was to develop novel navigation strategies for transport vehicles.

Partnership in Research Project

1. French project FUI **PRAMAD 2**. "Domestic Assistance Robot", *[Sep. 11-Aug. 14]*.
2. INRIA Large Scale Initiative Action **PAL**, "Personally Assisted Living", *[Jan. 11-Dec. 14]*.
3. European project FP7-ICT-246587 **INTERACTIVE**, "Accident Avoidance by Active Intervention for Intelligent Vehicles", *[Jan. 10-June 13]*.
4. French-Asian ICT project **CITYHOME**, "From Cyber Transportation to Mobile Service Robots", *[Nov. 08–Dec. 11]*.
5. European project FP7-IST-212154 **HAVEIT**, "Highly Automated Vehicles for Intelligent Transport", *[Feb. 08–Aug. 11]*.
6. European project FP6-IST-27140 **BACS**, "Bayesian Approach to Cognitive Systems", *[Jan. 06–Feb. 10]*.
7. European project FP6-IST-212154 **CYBERCARS 2**, "Close Communications for Cooperation between Cybercars" *[Jan. 06–Dec. 08]*.
8. French-Asian ICT project **FACT**, "French-Asian Cyber Transportation", *[Nov. 05–Dec. 07]*.
9. **PROFUSION I**, "Robust and Optimized Perception by Sensor Data Fusion", horizontal activity within the European Integrated Project FP6-507075 Prevent, "Preventive and Active Safety Applications" *[Feb. 04–Jan. 08]*.
10. French project PREDIT3 **MOBIVIP**, "Véhicules Individuels Publics pour la Mobilité en Centre Ville" *[Jan. 04–Dec. 06]*.
11. French projet PREDIT3 **PUVAME**, "Protection des usagers Vulnérables par Alarmes ou Manœuvres d'Evitement" *[Oct. 03–Apr. 06]*.
12. European project FP6-IST-28487 **CYBERCARS**, "Cybernetic Cars for a New Transportation System in the Cities" *[Aug. 01–Jul. 04]*.
13. French CNRS programme "Man-Machine Cooperation For Driving Assistance" *[Sep. 99–Aug. 03]*
14. French project **La Route Automatisée** *[Jan. 98–Dec. 01]*
15. French-Russian Liapunov Inst. project, "Optimal Control For Nonholonomic Vehicles" *[Jan. 97–Dec. 98]*.
16. French project **PRAXITÈLE** *[May 93–June 97]*.
17. French CNRS "Intelligent Machines" programme on driving assistance *[Jan. 94–Dec. 97]*.
18. European project Eurêka **Prometheus Pro-Art**, "Programme for a European Traffic with Highest Efficiency and Unprecedented Safety" [Jan. 87–Dec. 94].
19. European project Cost "Modeling an Autonomous Agent in a Multi-Agent World" *[Jan. 88–Dec. 89]*.

7) Collaborations, mobilité / *Collaborations, visits*

7.1. Visiting Positions

Besides my post-doctoral stay at the Robotics Inst. in Carnegie Mellon Univ., Pittsburgh PA (I was there from Dec. 93 to Nov. 94 to work with Prof. Matthew Mason on non-prehensile manipulation), I have made a number of long-term stays in different research groups worldwide.

- *June 14–May 15*: Guest Scientist @ Robotics & Artificial Intelligence Lab., Bar Ilan Univ., Ramat Gan (IL).
  Host: Prof. Gal Kaminka; Topic: Human-Robot Motion.
  The primary purpose of my stay there was to explore how Gal Kaminka's computer-based cognitive models that can understand human actions and intent can be adapted to address Human-Robot Motion. One such model will be evaluated this year in the scope of the EMERGENCE-LIG project "Human-Robot Motion: a Bio-Inspired Approach".

- *Sep. 07–Aug. 08*: Guest Scientist @ Autonomous Systems Lab., Swiss Federal Inst. of Technology (ETH), Zürich (CH).
  Host: Prof. Roland Siegwart; Topic: Safe Automated Driving.
  The Autonomous Systems Lab. is a high-profile research lab. with a reputation for designing robotic systems "that works" (*cf.* Robox, a guide robot that operated for six months during a public exhibit). My stay there was the op-

portunity to transfer some of my research results on an actual automated car, the SmartTer, and to learn from that experience the constraints imposed by a real robotic system (control, perception) and real urban environments.

- *Sep.–Dec. 02*: Japan Society for the Promotion of Science Fellow @ Distributed Adaptive Robotics Research Unit, Riken Inst., Saitama (JP).
  Host: Prof. Hajime Asama; Topic: Inevitable Collision States.
  This visit triggered my reflection on motion safety. I developed there the foundations of the Inevitable Collision State concept.

- *Nov. 00–Jan. 01* and *Nov. 01*: Tan Chin Tuan Fellow @ Intelligent Systems Lab., Nanyang Tech. Univ. (NTU), Singapore.
  Host: Prof. Michel Pasquier; Topic: Partial Motion Planning
  This visit was the opportunity to confront motion planning to the the decision time constraint imposed by the real world. It yielded the Partial Motion Planning principle.

7.2. Collaborations

Besides the collaborations that took place during my long-term visiting positions, I have/had collaborations with the researchers listed below.

Current Collaborations

- Anne-Hélène Olivier, INRIA MimeTIC & Julien Pettré, INRIA Rainbow *[17-present]*
  This collaboration is in the scope of the PhD of Jose Grimaldo Da Silva Filho on the topic of shared collision avoidance effort. We investigate how collision avoidance effort should be shared between a robot and a person when they interact (*cf.* Research Program, §5.2).

- Pierre-Brice Wieber, INRIA Grenoble-Rhône-Alpes *[17-present]*
  This collaboration was initiated via the joint supervision of the PhD of Matteo Ciocca on the topic of motion safety for legged robots moving among humans. We investigate how to design walking strategies that guarantee both collision and fall avoidance (*cf.* Research Program, §5.1).

- Jose Ernesto Gomez Balderas, GIPSA Laboratory, Grenoble *[19-present]*
  This collaboration is in the scope of the exploratory EMERGENCE-LIG project “Human-Robot Motion: a Bio-Inspired Approach” that has just started, we investigate whether human visual cues can be combined with a sociological behavior theory in order to address navigation in a crowd (*cf.* Research Program, §5.2).

Past Collaborations

- James Kuffner, Robotics Inst., Carnegie Mellon Univ., Pittsburgh (US). *[09-12]*
  This collaboration on the topic of Inevitable Collision States prompted us to organize the first workshop on *Guaranteeing Safe Navigation in Dynamic Environments* in association with the 2010 IEEE Int. Conf. on Robotics and Automation (http://safety2010.inrialpes.fr). It culminated in the edition of a special issue on motion safety for the Autonomous Robot journal [121].

- Zvi Shiller, Univ. of California, Los Angeles (US) and Univ. of Judea and Samaria, Ariel (IL). *[08-12]*
  This collaboration on the topic on Motion Safety has lasted several years now. Besides a joint publication [127], the primary outcome of this collaboration has been the development of several key concepts pertaining to safe motion in dynamic environments.

- Jose-Luis Gordillo, Centro de Sistemas Intelligentes, Tecnológico de Monterrey (MX). *[02-04, 11-12]*
  This collaboration on the topic of autonomous navigation in dynamic environments started informally in the early 00's. It was formalized in the framework of the French-Mexican project LAFMI NavDyn, *Navigation of an Autonomous Vehicle in a Dynamic Environment [Oct. 02–Sep. 04]*. It was later revived via the PhD of Marco Polo Cruz Ramos.

8) Enseignement / *Teaching*

Table 1.1 summarizes my teaching activities. I teach on a regular basis. Besides courses directly related to my research activities, i.e. *Robotics and motion planning, I am teaching in related areas as well,* e.g. *programming. I have been giving a yearly Motion Planning course at the graduate level (Master 2 of Univ. of Grenoble) and in the French-Mexican Summer School on Image and Robotics (SSIR). In 2011, this course has been completed by two introductory Robotics courses given at the graduate (Master 1) and undergraduate (Licence 3) levels. I was also co-responsible of the “Graphics, Vision and Robotics” track of the Int. Master of Science in Informatics at Grenoble (MOSIG). Since Fall 15, I am in charge of the Autonomous Robotics course of the Master 2 MOSIG.*

[8] **C**: lecture; **TD**: tutoring; **TP**: lab. work.
[9] Annual volume in hours (heqtd).
[10] **P**: participant; **R**: responsible.

Subject	Level	University	Type[8]	Volume[9]	Years	Role[10]
Algorithms & Programming	IUT Info	Grenoble II	TD-TP	41.5	88-91	P
Robot Programming	Eng. 3	ENSIMAG	TD-TP	33.5	88-91	P
Algorithms & Programming	IUT Info	Grenoble II	TD-TP	192	91-93	P
Robot Programming	M2 IVR	ENSIMAG	TD-TP	14	94-07	R
Robot Task Planning	Eng. 3	Damascus (SY)	C	30	00	R
Motion Planning	Summer School IR		C	6	00-09	R
Robotics	Eng. 3	CNAM	C-TD-TP	4.5	01-02	R
Robot Programming	Summer School ACPS	ENSIEG	C-TP	17	01-05	R
Motion Algorithms	M2 IVR	ENSIMAG	C	18	01-08	P
Advanced Motion Planning	PhD	Grenoble I	C	18	04-06	R
Knowledge Representation	Eng. 3	Grenoble I	C-TD-TP	19	05-07	P
Artificial Intelligence	M1 Info	Grenoble I	C-TD	19	05-07	P
Motion Planning	Grad School	Zaragoza (ES)	C	30	06	R
Autonomous Robotics	M2 MOSIG	ENSIMAG	C	18	08-10	P
Introduction to Robotics	L3 Info	Grenoble I	C-TD-TP	15	10-14	R
Introduction to Perception & Robotics	M1 MOSIG	ENSIMAG	C-TD-TP	22.5	10-14	R
Programming, Virtual Reality	High School	INPG	TP	6	11-12	P
Java Project Audit	L3 MIAGE	Grenoble I	TD	20	11-12	P
Introduction to Perception & Robotics	M1 MOSIG	Grenoble	C-TD-TP	22.5	11-16	R
Introduction to Programming	Eng. 1	ENSIMAG	TP	18	12-14	P
Motion planning	Grad School	Algiers (DZ)	C	9	13	R
Java Programming	Eng 2	ENSEEE	TP	8	15	P
Autonomous Robotics	M2 MOSIG	Grenoble	C	18	15-present	R

Table 1.1 – Teaching activities in chronological order.

8.1. Graduate Level

- *Autonomous Robotics*, Master 2 Int. Master of Science in Informatics at Grenoble (MOSIG), half-semester, course given in English *[From Fall 15]*.
- *Autonomous Robotics and Motion Planning*, Master 2 MOSIG, half-semester, course given in English *[08-10]*.
- *Introduction to Perception and Robotics*, Master 1 MOSIG, half-semester, course given in English *[11-16]*.
- *Advanced Motion Planning*, Doctoral course, Univ. of Grenoble, one week *[Spring 05 and 06]*.
- *Motion Planning*, Master 2 “Image, Vision and Robotics” (IVR), Univ. of Grenoble, one semester *[01-07]*.
- *Robot Programming*, Master IVR, one semester *[94-07]*.

8.2. Undergraduate Level

- *Introduction to Robotics*, Univ. of Grenoble *[Spring 11–14]*.
- *Knowledge representation*, Univ. of Grenoble *[Spring 06 and 07]* and Polytech Grenoble, one semester *[Fall 05 and 06]*.
- *Robotics*, Conservatoire Nat. des Arts et Métiers (CNAM), Grenoble, half-day, *May 02*.
- *Robot Programming*, Ecole Nat. Sup. d’Informatique et de Mathématiques Appliquées de Grenoble (ENSIMAG), one semester *[88–96]*.
- *Computer Technology*, Inst. Univ. de Technologie (IUT), Grenoble, one semester *[88–93]*.

8.3. Summer Schools

- *Motion Planning*, Summer School on Image and Robotics, various locations in France and Mexico, half-day *[00-07]*.
- *Robotics and Motion Planning*, Summer School on Automatic Control for Production Systems, Grenoble, one day *[01–05]*.

8.4. Invited Courses

- *Motion in Dynamic Environments*, Bar Ilan Univ., Ramat Gan (IL), half-day, *Dec. 14*.
- *Motion Planning*, Centre for Development of Advanced Technologies, Algiers (DZ), two days, *Jan. 13*.
- *Motion Planning*, Univ. of Zaragoza (ES), one week, *June 06*.
- *Robotics*, Univ. Stendhal, Grenoble, one day, *Aug. 01*.
- *Task and Motion Planning*, Inst. Supérieur des Sciences Appliquées et de Technologies (ISSAT), Damascus (SY), one week, *Feb. 00*.

9) Diffusion de l’information scientifique / *Dissemination of scientific knowledge*

I have been invited to write the entry “Navigation of Mobile Robots” in the upcoming Springer Encyclopedia of Robotics.

9.1. Publications in Non Scientific Journals:

- Th. Fraichard. Will the driver Seat Ever be Empty? *ERCIM News*, 109, Apr. 17.

- Th. Fraichard. Cybercar: l'alternative à la voiture particulière. *Navigation (Paris)*, 53(209), *Jan. 05*.
- Th. Fraichard. Motion Planning for Autonomous Car-like Vehicles. *ERCIM News*, 42, *July 00*.
- Th. Fraichard and I. Mazon. Projet Sharp: Robotique en Environnement Réel. *Bulletin de l'Association Française d'Intelligence Artificielle*, 27, *Nov. 96*.

9.2. Seminars for General Audiences

- *A robot on trial*, mock trial of a futuristic robot as part of the *Transfo* digital festival, *Jan. 19*. This successful event attracted around 200 participants
- *Introduction to Robotics*, lecture to high school students in Jerusalem (IL), *March 16*.
- *Introduction to Robotics*, lecture primary school students in Jerusalem (IL), *Nov. 13*.
- *How do robots move*, lecture to high school teachers in the framework of the "Informatique au Lycée" initiative, *May 13* [Video Part 1 & Part 2].
- *How does a robot move*, lecture to high school students in Voiron (FR) in the framework of the "Informatique au Lycée" initiative, *Apr. 13*.
- In October 2010, I organized a *Robotics Show* in the 2010 edition of the Fête de la science at INRIA Grenoble Rhône-Alpes. This two-day event was very successful and attracted over 300 participants.
- *Outils pour la conduite automatique*, In'Tech seminar, Antibes, *June 04*.
- *Systèmes de transport Intelligents*, Colloquium of the Institut Français de Navigation, Paris, *Mar. 04*.

9.3. Invited Seminars for Academic Audiences

- *Formal methods will not prevent self-driving cars from having accidents*, Forum Méthodes Formelles, Toulouse (FR), *Oct. 17* [Video].
- *Will the driver seat ever be empty?*, Bar Ilan Univ., Ramat Gan (IL), *Oct. 13*; Ariel Univ. (IL), *June 13*; Tel Aviv Univ. (IL), *June 13*; Technion, Haifa (IL), *Apr. 13*; LAAS Lab., Toulouse (FR), *Dec. 12*; Ben Gurion Univ., Be'er Sheva (IL), *Dec. 12*.
- *The Difficulty of Safely Navigating Dynamic Environments.*, Ariel Univ. (IL), *Dec. 09*.
- *Safe Autonomous Navigation in Open and Dynamic Envts.*, Univ. of Karlsruhe (DE), *Jul. 09.*
- *Trajectory Generation for Trajectory Deformation*, Ariel Univ. (IL), *Dec. 08*.
- *Motion Safety in Dynamic Environments*, Swiss Polytechnic Federal Inst., Zurich (CH), *Jan. 08*.
- *Dynamic Environments and Safe Motions*, Ariel Univ. (IL), *Dec. 07*.
- *Safely Navigating Dynamic Environments*, Simon Fraser Univ., Vancouver (CA), *Dec. 07*; Carnegie Mellon Univ., Pittsburgh (US), *June 07*.
- *Motion Safety for Mobile Robots*, INRIA Grenoble Rhône-Alpes, *Feb. 07*.
- *Safe Motion in Dynamic Environments*, Univ. of Zaragoza (ES), *June 06*.
- *Safe Motion Planning in Dynamic Environments*, LAAS Lab., Toulouse (FR), *Jan. 05*.
- *Motion Planning in Uncertain Environments*, INRIA Grenoble Rhône-Alpes (FR), *Nov. 04*.
- *Tools for Autonomous Navigation*, SungKyunKwan Univ., Seoul (KR) *Oct. 04*.
- *Inevitable Collision States: a Step Towards Safer Robots*, Tokyo Univ. (JP), *Dec. 02*.
- *From Path to Motion Planning*, Riken Inst., Saitama (JP), *Oct. 02*.
- *Advanced Motion Planning Tech. for Robotic Vehicles*, Nanyang Tech. Univ., Singapore, *Jan. 01*.
- *Continuous-Curvature Path Planning for Car-Like Vehicles*, Riken Inst., Saitama (JP), *Nov. 99*; Tsukuba Univ. (JP), *Nov. 99*.
- *Planning Continuous-Curvature Paths for Car-Like Robots*, Univ. of Brasilia (BR), *Nov. 98*.
- *Car-Like Robots and Moving Obstacles*, Carnegie Mellon Univ., Pittsburgh (US), *Jan. 94*.
- *Planification de mouvement en environnement dynamique*, LIFIA Lab., Grenoble (FR), *Apr. 93*.
- *Path Planning For Nonholonomic Vehicles in Structured Worlds*, LAAS Lab., Toulouse, *Mar. 91*.
- *Motion Planning in a Multi-Agent World*, Artificial Intelligence Lab., Bruxelles (BE), *Jul. 90*.

10) Eléments divers / *Other relevant information*

1. Patents

- The work with Christophe Coué on the Bayesian Occupancy Filter has yielded a French patent by INRIA: #FR0552735, *Procédé d'assistance à la conduite d'un véhicule et dispositif associé (Sep. 09)*, `http://bases-brevets.inpi.fr/fr/document/FR2890773`.
  The transfer aspects for this patent are covered in *Key Contribution #4*.
- The work with Marco Polo Cruz Ramos has yielded a Mexican patent by the Technològico de Monterrey: #MX/E/2012/082045, *Rampa retractil automatica para carga y descarga (Dec. 12)*. It was later extended for an international submission *(May 14)*: `http://www.google.com/patents/WO2014069976A1`.
  Mexican partners are currently working on the transfer aspects for this patent.

2. Activité de conseil

A l'initiative du Cluster Coboteam de la région Auvergne-Rhône-Alpes et en lien avec le service Transfert pour l'Innovation et Partenariats (STIP) de l'INRIA Grenoble Rhône-Alpes, j'ai commencé une activité de conseil à titre privé pour la société EDAP TMS basée à Lyon (http://www.edap-tms.com). Cette société est à la fois pionner et leader sur le marché de la lithotritie extracorporelle, *i.e.* la fragmentation des calculs rénaux par des ondes de choc acoustiques. Je leur apporte mon expertise en matière de gestion de collision dans le développement de leur nouveau prototype de plateforme de traitement des calculs urinaires.

3. Retour sur candidature DR2 2018

Pour mémoire, j'ai été admissible en 6ème position ex-aequo au concours DR2 INRIA 2018. Le retour officiel que j'ai reçu vis-à-vis de l'échec de ma candidature DR2 2018 était le manque de publications/visibilité quant au versant "Mouvement socialement acceptable" de mon programme de recherche. Je me suis donc efforcé en 2018 de corriger ce défaut.

En ce qui concerne mon travail sur la notion d'attention, ce travail qui avait bien commencé (une première publication en 2014 qui avait été nominée pour le Best Paper Award dans la conférence *IEEE Int. Symp. on Robot and Human Interactive Communication (RO-MAN)* – conférence de **rang A** d'après la classification établie par le GdR Robotique dans un document datant de 2015), a malheureusement pris beaucoup de retard suite à la grave maladie qui a frappé Rémi Paulin, le doctorant impliqué dans ce travail. Cette maladie l'a empêché de travailler pendant près de deux ans. Malgré ces difficultés, nous avons finalement réussi à obtenir de bons résultats et Rémi a pu achever et soutenir sa thèse en mars 2018. Les conditions ne nous ont cependant pas permis de publier pendant la durée de cette thèse, notre priorité étant de la mener à terme. En 2018, j'ai donc porté mes efforts sur la publication des résultats obtenus. Ces efforts se sont concrétisés par une première publication dans un workshop associé à la conférence de **rang A+** *IEEE-RSJ Int. Conf. on Intelligent Robots and Systems 2018 (IROS)*, puis une double soumission à la conférence de **rang A+** *IEEE Int. Conf. on Robotics and Automation 2019 (ICRA)* et à la revue *IEEE Robotics and Automation Letters (RA-L)*[11]. Ces deux soumissions ont été couronnées de succès.

Mon travail sur la notion d'effort avec le doctorant Jose Grimaldo Da Silva Filho a quant à lui été valorisé en 2018 par une publication à la conférence de **rang A** *IEEE Int. Symp. on Robot and Human Interactive Communication (RO-MAN)*.

[11] RA-L ayant été crée en 2016, elle n'a pas été classée par le GdR Robotique. On peut imaginer qu'elle aura un classement similaire à sa revue équivalente *IEEE Trans. on Robotics (TRO)* qui est de **rang A+**.

Formulaire 2 — DESCRIPTION SYNTHÉTIQUE DE L'ACTIVITÉ ANTÉRIEURE
Form 2 — SUMMARY OF YOUR PAST ACTIVITY

Robotics and **motion** are the two keywords that best capture the scope of my research activities. Central to my work is **motion planning** that can be defined as follows: given a model of a robot and a model of its environment, find out the motion that will take the robot from, say, A to B. The ability for a robot to move is fundamental and as such, this topic has been largely addressed in the past fifty years. Because of its complexity, it remains an important research topic in the robotic community.

I will distinguish two stages in my career, they are characterized by their primary application targets.

1. In the first stage, from my PhD to 2010, I have focused on wheeled mobile robots in general and **self-driving cars** in particular. Accordingly, I tackled all the constraints corresponding to such robots, *i.e.* (1) robotic systems subject to kinematic and dynamic constraints, and (2) environments featuring static and moving obstacles whose future behavior is uncertain. This is certainly the most challenging problem when it comes to motion planning.
2. The second stage started in 2011 when I decided to shift my focus to **service robots**, *i.e.* robots that performs useful tasks for humans or equipment excluding industrial automation application[12]. This definition encompasses a broad family of robotic systems for both personal and professional use and I narrow my focus to **mobile service robots that interact with people**. As we will see later on, the coexistence of robots and humans adds novel and challenging dimensions to the motion issue.

My main contributions concerning self-driving cars are presented in the following sections, thematically rather than chronologically. As for my activities concerning service robots, they will be presented and discussed in Form 4–*Research Program*.

1. Path Planning

Path planning focuses on the geometric aspects of motion planning: it aims at computing the geometric curve that will take the robot from A to B without colliding with the fixed obstacles around.

My first contribution to path planning has to do with **nonholonomy**. The problem is to compute path for robots that take into account the nonholonomic constraints that restrict their motions[13]. When I started to work on this topic, path planners would compute paths made up of circular arcs and straight segments. But, to follow such paths accurately, a car-like robot has to stop at each segment-arc transition to reorient its wheels. To address this issue, I developed CC-Steer, a path planner for car-like robots that compute paths satisfying a number of properties, *e.g.* continuous curvature, that guarantees that such paths can be *tracked accurately with a guaranteed minimum velocity*. This work started with the PhD of Alexis Scheuer whom I supervised [Sch98]. To begin with, we addressed the case of a car moving forward only. I later addressed the case of the car moving both forward and backward [15]. This contribution is detailed in *Key Contribution #3*.

My second contribution to path planning has to do with **path robustness**. The challenge here is to compute paths whose execution can be guaranteed to succeed in spite of the uncertainty affecting the control and the sensing of the actual robot. Robustness in motion planning was addressed first in the context of assembly tasks with manipulator arms (70's), mobile robots were considered later (90's). Given the intrinsic complexity of robust motion planning, simplifying assumptions would usually be made, *e.g.* omnidirectional point robot, perfect sensing. Such assumptions could seriously reduce the applicability to real problems of the solutions proposed. To address this issue, I introduced nonholonomic constraints in robust path planning and proposed novel robust path planning solutions for car-like vehicles subject to sensing and localization uncertainty (odometric drift). The challenges here were (1) to consider realistic sensor models, and (2) to establish uncertainty evolution models adapted to nonholonomic robots. This work started with Raphaël Mermond's PhD [87] using geometric uncertainty evolution models. Later, during the post-doc of Alain Lambert, we shifted to probabilistic models [84].

2. Trajectory Planning

A trajectory can be thought of as a path with a time history, it specifies where the robot should pass but also when and how. Trajectory planning is in order as soon as you have to deal with dynamic constraints. Dynamic constraints come in two flavors: those related to the robot's dynamics, *e.g.* bounds on its velocity/acceleration, and those related to the environment, *i.e.* the moving obstacles. Given my target application, *i.e.* self-driving cars, I had to consider both type of constraints simultaneously. When I started to work on this topic during my PhD [150], I could locate only two research works (of limited interest) dealing with both type of dynamic constraints [O'D87, FS89]. The intrinsic complexity of such trajectory planning problems certainly explained this situation.

The primary contribution of my PhD was to introduce and show how the **state-time space** framework could be used to tackle complex motion planning problems featuring robots subject to kinematic/dynamic constraints and moving in dynamic

[12] ISO 8373:2012 definition.

[13] Consider a wheel, it must always move in a direction perpendicular to its rotational axis, this is an example of a nonholonomic constraint.

environments. In a sense, the state-time space (STS) is for trajectory planning the equivalent of the classical configuration space that is used for path planning.In STS, part of the constraints at hand (dynamics and moving obstacles) are represented uniformly as forbidden regions and trajectory planning boils down to finding a curve in the free part of STS. Accordingly, standard path planning techniques can be adapted to solve the problem at hand. This work was finalized by an article published in Advanced Robotics [20]. At the time of my PhD, the high dimensionality of STS was a limiting factor. However, the advent of randomized motion planning techniques in the late 90's has changed the situation dramatically: suddenly, it became possible to efficiently handle high dimensionality spaces [KSLO96, LK01]. STS then became the natural framework to address trajectory planning problems with dynamic constraints as indicated by the number of research works using STS that have appeared since then, *e.g.* [FDF01, HKLR02, vdBO04].

When a motion is planned in an environment featuring moving obstacles, it must be temporally anchored. In other words, it must start at a prescribed time and every position along the motion must be reached by the robot at the time prescribed. Temporal anchoring is required to ensure no collision with the moving obstacles. In these circumstances, the motion planning process is subject to a hard real-time constraint henceforth called **decision time constraint**: the time available to plan the motion is upper-bounded by the duration between the current time and the time at which the motion is supposed to start. If it were possible to set the start time arbitrarily, that would not be a problem. It is not the case unfortunately: among moving obstacles, a robot cannot remain passive since it runs the risk of being hit. In spite of its importance, the decision time constraint was strangely absent from the works on motion planning in dynamic environments. My first contribution here has been to make this constraint explicit. Now, given the intrinsic complexity of motion planning, there is little hope that an arbitrarily low decision time constraint can ever be met. Having acknowledged that, my second contribution was to propose **partial motion planning** (PMP) as an answer to this issue. PMP is an interruptible motion planning scheme: when the decision time is over, PMP returns the best motion it has computed so far, it may be partial only though and not go all the way to the goal but, at least, PMP ensures that the decision time constraint is met (and that the safety of the robot is not compromised). Of course, PMP has to be called repeatedly until the goal is reached. At each cycle, the partial motion produced is passed to the robot for execution. An important aspect of PMP is that planning is done over a finite **planning horizon**. Let us note that the key features of PMP have now become standard practice when it comes to trajectory planning in dynamic environments. I introduced PMP in 2001 [Sha01], the first application of PMP was made in collaboration with Frédéric Large, a PhD student of my former team E-MOTION [Lar03, 70]. Later, I furthered this work with Stéphane Petti's PhD [Pet07], it involved experiments on a real vehicle [13].

3. Motion Safety

The aforementioned decision time constraint is such that, if it is violated, the safety of the robot is compromised. This observation led me to consider more carefully what motion safety could mean for a robot, it prompted me to introduce and investigate the novel concept of **inevitable collision state**. This contribution is detailed in *Key Contribution #1*.

4. Dynamic World Modeling and Future Prediction

As part of my work on self-driving cars, I have enlarged the field of my activities in order to address problems that concerns the models that motion planning requires as input, *i.e.* the model of the environment and its future evolution. My first contribution here concerns the **modeling of dynamic environments**, it is detailed in *Key Contribution #4*. My second contribution has to do with **future motion prediction**, it is detailed in *Key Contribution #2*.

References

[FDF01] E. Frazzoli, M. A. Dahleh, and E. Feron. Real-Time Motion Planning for Agile Autonomous Vehicle. In *Proc. of the American Control Conf.*, Arlington, VA (US), June 2001.

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[vdBO04] J.P. van den Berg and M.H. Overmars. Roadmap-based motion planning in dynamic environments. In *IEEE-RSJ Int. Conf. on Intelligent Robots and Systems*, Sendai (JP), October 2004.

Formulaire 3 — CONTRIBUTIONS MAJEURES
Form 3 — MAJOR CONTRIBUTIONS

The contributions I have chosen to present here offer a mix of scientific contributions, technology development and industrial transfer. The contributions that did not make it here are briefly described in Form 2–*Summary of your past activity*.

- Scientific contribution:
  1. **Inevitable Collision States (ICS)**, a formal concept to address motion safety.
- Scientific contributions and software technology developments:
  2. **Growing Hidden Markov Models (GHMM)**, an HMM extension applied to long-term future motion prediction.
  3. **CC-Steer**, a steering method for nonholonomic systems.
- Scientific contribution, software technology development and industrial transfer:
  4. The **Bayesian Occupancy Filter (BOF)**, a software framework for sensor-fusion and dynamic environment modeling.
- Software and hardware technology development:
  5. **Parkview**, a platform for the interpretation of complex dynamic scenes.

Details about the software developments related to those contributions will be found in Form 5–*Complete list of contributions*, §3. BOF has yielded an industrial transfer which is detailed in Form 5–*Complete list of contributions*, §4.

Video sequences illustrating different aspects of these contributions can be found on the webpage:

http://thierry.fraichard.free.fr/research

Key Contribution #1: Inevitable Collision States

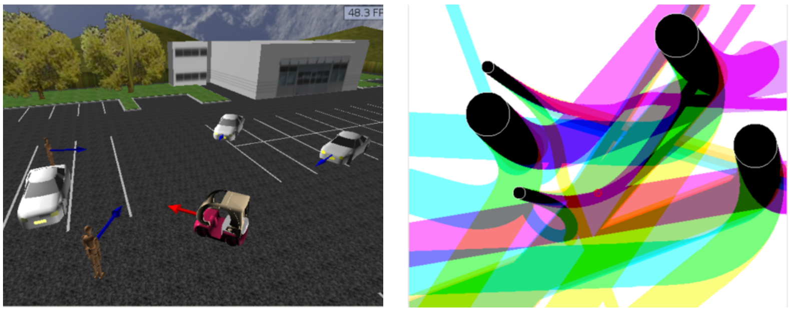


Figure 3.1 – (left) a driving situation involving fixed and moving obstacles; (right) the corresponding Inevitable Collision States (black areas in the 2D position plane of the 5D state space of the robot).

1. Description de la contribution / *Description of the contribution*

An **Inevitable Collision State (ICS)** for a robot is a state such that, no matter what the future trajectory of the robot is, a collision eventually occurs. Besides offering new insights into the complexity of safely moving in dynamic environments, the ICS concept is the key to designing autonomous robot for which **motion safety is guaranteed**.

2. Contribution personnelle du candidat / *Personal contribution of the applicant*

The ICS concept stems from a reflection I had in the mid 00's about the motion safety of robots. I formalized this concept on my own and established all the theoretical properties that are now synthesized in my latest report on this topic [140].

3. Originalité et difficulté / *Originality and difficulty*

Motion safety is a term commonly used in Robotics but never defined. Interestingly, I showed that state-of-the-art collision avoidance schemes are in fact unsafe in dynamic environments [56]. The ICS concept helps in understanding key aspects of motion safety guarantees (or lack thereof) in real-world situations, it allowed me to state **motion safety laws**. I was also able to show that absolute motion safety is impossible to achieve in the real-world and advocated instead the use of weaker **motion safety levels** that can be guaranteed, *e.g. passive safety*[14] and *passive friendly safety*[15]. Characterizing the ICS set is a complex problem that remains largely open. In practice however, the properties I have established in [16] have permitted the design of the first ICS-checker, *i.e.* an algorithm that checks if a given state is an ICS [49]. It is the key to navigation schemes with guaranteed motion safety properties. In this respect, I believe my work around the ICS concept is groundbreaking.

4. Validation et impact /*Validation and impact*

My ICS-related papers are regularly cited by the latest works on safe navigation (as of today, more than 1150 citations). In the wake of the development of self-driving cars, there is a growing awareness of the necessity to design navigation strategies with motion safety guarantees. Passive safety has de facto become the default motion safety level and passive friendly safety begins to spread, *e.g.* [PYG+17, MGVP17].

5. Diffusion/*Dissemination*

Following the initial journal article presenting the ICS concept [16], the progress in the development of the ICS has been documented in a series of publications in the major international conferences [33, 34, 36, 40, 44, 45, 48, 46, 49, 57, 75] and journals [4, 6, 13] in the field. I have also organized the first two workshops on this topic[16] and edited a special issue on motion safety for the Autonomous Robot journal [121].

References

[MGVP17] S. Mitsch, K. Ghorbal, D. Vogelbacher, and A. Platzer. Formal verification of obstacle avoidance and navigation of ground robots. *Int. Journal of Robotics Research*, 36(12), 2017.

[Pet07] S. Petti. *Partial Motion Planning Framework for Safe Navigation in Dynamic Environments.* PhD thesis, Ecole Nat. Sup. des Mines de Paris, July 2007.

[PYG+17] D. Phan, J. Yang, R. Grosu, S. Smolka, and S. Stoller. Collision avoidance for mobile robots with limited sensing and limited information about moving obstacles. *Formal Methods in System Design*, 51(1), August 2017.

[14] If a collision is inevitable, the robot will be at rest.

[15] If a collision is inevitable, the robot will be at rest and the colliding object could have avoided the collision, had it decided to.

[16] http://safety2010.inrialpes.fr and http://safety2011.inrialpes.fr.

Key Contribution #2: Growing Hidden Markov Models

Figure 3.2 – (left) the long-term future motion prediction problem; (center) set of pedestrian trajectories observed on a parking lot; (right) GHMM prediction of the future behaviour of the currently observed pedestrian (estimation of the state at time $t + 10$ and of the goal state).

1. Description de la contribution / *Description of the contribution*

The **Growing Hidden Markov Model (GHMM)** is a tool to predict the long-term future behaviour of moving objects. It learns the typical motion patterns of the moving objects in a given environment using observed trajectories as input. Once learned, the patterns are used to predict the future behaviour of the moving objects and their goals.

2. Contribution personnelle du candidat / *Personal contribution of the applicant*

I initiated the work on future motion prediction topic during the Master of Dizan Vasquez [Vas03]. The development of GHMM has been done in the scope of his PhD that I supervised [Vas07].

3. Originalité et difficulté / *Originality and difficulty*

Unlike most motion prediction techniques that learns off-line, GHMM learns new motion patterns in an on-line and continuous fashion, it can also perform learning and prediction in parallel. One distinctive feature of GHMM is that both the structure and the parameters of the corresponding HMM can be learned simultaneously. This property is obtained thanks to the use of a Self-Organizing Topological Map. Accordingly, GHMM is suited to tackle any pattern recognition problem for which there is a topological equivalence between a continuous state space and the corresponding observation space.

4. Validation et impact / *Validation and impact*

GHMM has been validated on the ParkView platform (see *Key Contribution #5*) and used in E-MOTION, *e.g.* [Tay09, Ful09]. Following Dizan Vasquez's post-doc in the Autonomous Systems Lab. of the Swiss Federal Inst. of Technology (ETH) in Zürich, GHMM has been used there in their self-driving car. GHMM has also been selected by the Field Robotics Center of Carnegie Mellon University as a benchmarking tool for motion prediction. Finally, let me emphasize that Dizan Vasquez received the **European Robotics PhD Award** in April 09.

5. Diffusion / *Dissemination*

GHMM's development has been documented in a series of publications in the major international conferences in the field: [51, 60, 58, 68] and in book chapters in the *Springer STAR* series [113, 114]. It culminated in two articles published in the top ranking international journals *Int. Journal of Robotics Research* [7] and *IEEE Trans. on Intelligent Transportation Systems* [8]. As a recipient of the 2009 European Robotics PhD Award, Dizan Vasquez's PhD has been published as a book in the *Springer STAR* series [Vas10]. Dizan Vasquez has packaged an open-source distributable version of GHMM[17].

References

[Ful09] C. Fulgenzi. *Navigation autonome en environnement dynamique utilisant des modèles probabilistes de perception et de prédiction du risque de collision.* PhD thesis, Inst. Nat. Polytechnique de Grenoble, Grenoble (FR), June 2009.

[Tay09] C. Tay. *Analysis of Dynamic Scenes: Application to Driving Asisstance.* PhD thesis, Inst. Nat. Polytechnique de Grenoble, Grenoble (FR), September 2009.

[Vas03] D. Vasquez. Estimation de mouvement des obstacles mobiles: une approche statistique. Master's thesis, Inst. Nat. Polytechnique de Grenoble, Grenoble (FR), September 2003.

[Vas07] D. Vasquez. *Aprentissage incrémental pour la prédiction des mouvements de piétons et de véhicules.* PhD Thesis, Inst. Nat. Polytechnique de Grenoble, February 2007.

[Vas10] D. Vasquez. *Incremental Learning for Motion Prediction of Pedestrians and Vehicles*, volume 64 of *Springer Tracts in Advanced Robotics*. Springer, 2010.

[17] https://github.com/dichodaemon/ghmm

Key Contribution #3: CC-Steer

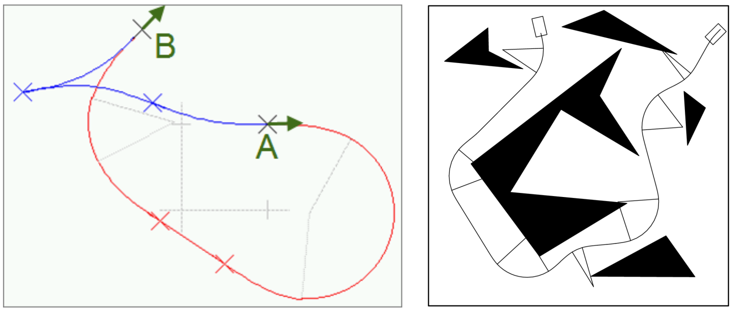


Figure 3.3 – (left) CC-Steer on its own; (right) coupled with a generic motion planning scheme.

1. Description de la contribution / *Description of the contribution*

Nonholonomic Path Planning is a branch of path planning concerned with robots that are subject to kinematic constraints that restrict their motion[18]. **CC-Steer** is a nonholonomic path planner designed for car-like systems, it computes paths made up of straight segments, circular arcs and clothoidal transitions.

2. Contribution personnelle du candidat / *Personal contribution of the applicant*

The development of CC-Steer started in the scope of the PhD of Alexis Scheuer whom I supervised [Sch98]. To begin with, we addressed the case of a car moving forward only. I later addressed the case of the car moving both forward and backward with two interns: Richard Desvigne [85] and Pierre Billiau. I finalized the scientific work with an article published in the IEEE Trans. on Robotics [15]. I also wrote the final version of the software, the code is about 6000 lines long.

3. Originalité et difficulté / *Originality and difficulty*

When we started to explore path planning for cars, path planners would compute paths made up of circular arcs and straight segments. But, to follow such paths accurately, a car would have to stop at each segment-arc transition to reorient its wheels. To address this issue, we designed CC-Steer that compute paths that satisfy the following properties: (1) continuous curvature, (2) upper-bounded curvature (to account for the steering angle limits), and (3) upper-bounded curvature derivative (to account for the steering velocity limits). Accordingly such paths can be *tracked accurately with a guaranteed minimum velocity*. On top of that, we have established that CC-Steer verifies a topological property that ensures that it is *complete* (in the sense that it can connect arbitrary pairs of configurations) and that, when it is used within a general motion-planning scheme, it yields a *complete collision-free planner*. Finally, the length of the paths computed *converges towards the optimum* when the curvature derivative increases. As of today and to the best of my knowledge, CC-Steer remains the only steering method verifying all the aforementioned properties.

4. Validation et impact / *Validation and impact*

CC-Steer has been used within E-MOTION and also IMARA in Paris [13]. In the wake of the publication of my work on continuous-curvature path planning, I have been regularly contacted by researchers interested in this software. I am aware of two publications wherein CC-Steer has reportedly been used [SL03, PA05].

5. Diffusion / *Dissemination*

The progress in the development of CC-Steer has been documented in a series of publications in the major international conferences in the field: [80, 85, 90, 91, 94]. It culminated in an article published in the top ranking international journal *IEEE Trans. on Robotics* [15]. The CC-Steer software package is available on request as an Open-Source software.

References

[PA05] J. Peng and S. Akella. Coordinating multiple robots with kinodynamic constraints along specified paths. *Int. Journal of Robotics Research*, 24(4), April 2005.

[Sch98] A. Scheuer. *Planification de chemins à courbure continue pour robot mobile non-holonome.* PhD Thesis, Inst. Nat. Polytechnique de Grenoble, Grenoble (FR), January 1998.

[SL03] A. Sanchez Lopez. *Contribution à la planification de mouvements en robotique: approches probabilistes et déterministes.* PhD Thesis, Université Montpellier II, Montpellier (FR), July 2003.

[18] Consider a wheel, it must always move in a direction perpendicular to its rotational axis.

Key Contribution #4: Bayesian Occupancy Filter

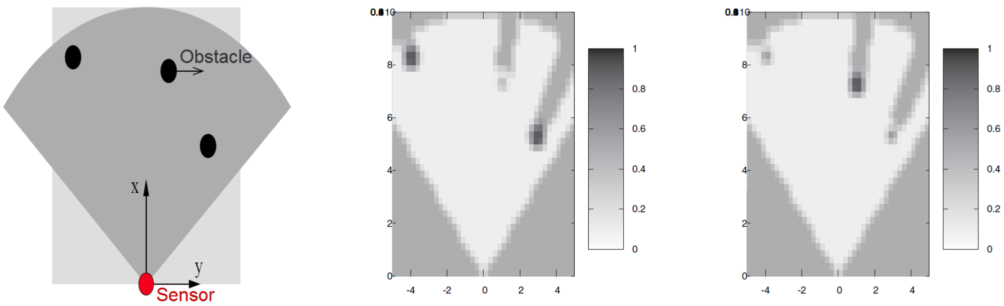


Figure 3.4 – (left) situation observed, the sensor observations are given as $\{x, y, \dot{x}, \dot{y}\}$. The moving obstacle is moving to the right at unit speed; (center and right) occupancy probabilities for two slices of the 4D grid: $\{\dot{x} = 0, \dot{y} = 0\}$; $\{\dot{x} = 0, \dot{y} = 1\}$.

1. Description de la contribution / *Description of the contribution*

The **Bayesian Occupancy Filter (BOF)** is a software framework for robust perception of dynamic environments. It combines probabilistic occupancy grids[19] with Bayesian Filtering techniques. Unlike standard occupancy grids, BOF maintains a 4D grid featuring the objects' position and velocity.

2. Contribution personnelle du candidat / *Personal contribution of the applicant*

My primary contribution to BOF stems from my role as the coadvisor of the PhD of Christophe Coué [Cou03]. His PhD was supported by the European project FP6-IST-12224 **Carsense** *[Jan. 00–Dec. 02]*. As the leader of a workpackage within Carsense, I pushed for the development of the deliverable that would become the prototype of BOF. BOF has been patented by INRIA (`http://bases-brevets.inpi.fr/fr/document/FR2890773`), I am coinventor for this patent.

3. Originalité et difficulté / *Originality and difficulty*

Reliable and efficient perception and modeling of dynamic outdoor environments is a challenging problem that has been largely addressed in the past 20 years (it still is). Adding the velocity dimension to the occupancy grid was one of the distinctive feature of BOF. The use of Bayesian Filtering techniques helped to increase the robustness with respect to occlusions, appearances and disappearances of objects. BOF also allows the straightforward fusion of the information acquired through different sensors. BOF can be used for any application requiring the ability to detect, track moving objects and predict their future motion.

4. Validation et impact / *Validation and impact*

The work around BOF yielded an industrial transfer with the Probayes company, a start-up born of E-MOTION, my former team[20]. As of 2009, INRIA has granted Probayes the exploitation licence for the BOF technology. BOF is now part of Probayes' solution technology called *Smart Sensors*, one of the three solution technologies offered by the company. BOF has been an important asset for Probayes, it provided the company with the opportunity to obtain a series of contracts related to automotive safety with major players of the automotive industry: Toyota, Denso and Hitachi.

5. Diffusion / *Dissemination*

The progress in the development of BOF has been documented in a series of publications in the major international conferences in the field: [76, 77, 78, 79] and in a book of the *Springer STAR* series [112]. It culminated in an article published in the top ranking international journal *Int. Journal of Robotics Research* [14].

References

[Cou03] C. Coué. *Modèle bayésien pour l'analyse multimodale d'environnements dynamiques et encombrés: application à l'assistance à la consuite automobile en milieu urbain.* Phd thesis, Inst. Nat. Polytechnique de Grenoble, December 2003.

[19] That models the environment as a discrete grid with occupancy probability attached to each cell.

[20] `http://www.probayes.com`

Key Contribution #5: ParkView

Figure 3.5 – The ParkView platform: Parking lot — Cameras — Map server.

1. Description de la contribution / *Description of the contribution*

ParkView is an experimental platform combining hardware and software aspects. It was developed in the scope of the French Project ROBEA **ParkNav** *[Oct. 02–Sep. 05]*. ParkView comprised seven video cameras observing the parking lot of the INRIA Grenoble Center. The video streams were merged and interpreted in order to feed a *Map Server*, *i.e.* a module providing in real-time a model of the parking lot combining information about its structure and the moving objects (position and velocity).

2. Contribution personnelle du candidat / *Personal contribution of the applicant*

I was the project manager responsible for the design of the platform. I selected and supervised the two engineers, Frédéric Hélin and Eric Boniface, and the post-doc, Fernando De La Rosa, that worked on the platform during the 2002-2006 period. As the leader of the ParkNav project, I was also in charge of the coordination with the partners of the project. A total of 16500 lines of code including comments have been written for ParkView.

3. Originalité et difficulté / *Originality and difficulty*

The Map Server was the novelty of ParkView. At the time, there was no such technology available. Detecting and tracking moving objects in outdoor situations was challenging (it still is). It required to adapt laboratory image-processing techniques to the harsh requirements of an outdoor environment. Integration was also an issue: the components provided by the partners were prototypes that had to be redesigned in order to fit the requirements of the application. At the end of the project, the platform was fully operational, it was used afterward to support research activities in Grenoble.

4. Validation et impact / *Validation and impact*

The people involved in ParkView were all the partners involved in the ParkNav project, namely:

- LAAS-CNRS Toulouse, Robotics and Artificial Intelligence group.
- INRIA Grenoble and Rennes: E-MOTION, LAGADIC, MOVI and PRIMA teams and SED support group.

LAGADIC, MOVI and PRIMA brought their image-processing expertise. LAAS-CNRS and E-MOTION used the information provided by ParkView as input for their research in motion prediction (E-MOTION) and autonomous navigation (E-MOTION and LAAS-CNRS). Joint experiments in autonomous navigation were successfully carried out [73].

5. Diffusion / *Dissemination*

Two webpages have been set up to respectively describe the ParkView platform and the ParkNav project (`http://emotion.inrialpes.fr/parknav` and `http://emotion.inrialpes.fr/parkview`). Two reports document the engineering work produced [Bon06, Hel03]. After the end of ParkNav, the ParkView platform was kept alive by E-MOTION to support its own research activities (future motion prediction, autonomous navigation in dynamic environments). It was also used by PRIMA (detection and tracking of moving objects). The platform was decommissioned in 2008.

References

[Bon06] E. Boniface. Gestion d'une plate-forme de vidéo-surveillance à usage robotique: modélisation d'un environnement dynamique. Mémoire de fin d'études, Conservatoire Nat. des Arts et Métiers, Grenoble (FR), March 2006.

[Hel03] F. Helin. Développement de la plate-forme expérimentale parkview pour la reconstruction de l'environnement dynamique. Mémoire de fin d'études, Conservatoire Nat. des Arts et Métiers, Grenoble (FR), July 2003.

Formulaire 4 — PROGRAMME DE RECHERCHE
Form 4 — RESEARCH PROGRAM

Étant donné l'organisation d'Inria, tout chercheur, ou toute chercheuse, a vocation à être affecté(e) dans une équipe-projet. Un candidat, ou une candidate, indique donc généralement dans son dossier de candidature l'équipe-projet dans laquelle il ou elle souhaite être affecté(e). Il est dans ce cas fortement recommandé de prendre préalablement contact avec la ou le responsable de l'équipe-projet souhaitée.

Il est néanmoins aussi possible de déposer une candidature sans préciser a priori une équipe-projet d'accueil. Dans ce cas, si la candidate ou le candidat est déclaré(e) admissible, une ou plusieurs équipes d'accueil pourront lui être proposées entre la phase d'admissibilité et la phase d'admission. Cette proposition d'affectation se fera en prenant en compte les aspirations de la candidate ou du candidat, celles des équipes, et la politique scientifique d'Inria.

Dans le cas où la candidature a lieu dans une équipe-projet, le candidat ou la candidate est invité(e) à expliquer dans son programme de recherche son intégration dans l'équipe-projet souhaitée.

Dans le cas où l'équipe-projet n'est pas choisie au moment de la candidature, le candidat ou la candidate n'est pas tenu(e) de détailler son intégration. Il ou elle peut néanmoins, sans que cela soit une obligation, indiquer des noms de chercheurs ou de chercheuses avec qui il ou elle pourrait collaborer en cas de recrutement.

☒ Je souhaite candidater dans l'équipe-projet, ou les équipes-projets suivante(s) : PERVASIVE

☐ Je ne souhaite pas choisir d'équipe-projet pour l'instant. En cas d'admissibilité, je serai contacté(e) par le président du jury pour discuter de possibles équipes d'accueil.

Given Inria's organization, any researcher should be assigned to a project team. A candidate therefore generally indicates in his or her application file the project team to which he or she wishes to be assigned. In this case, it is strongly recommended to contact the leader of the desired project team beforehand.

However, it is also possible to submit an application without specifying a priori a host project team. In this case, if the candidate is declared eligible, one or more host teams will be proposed between the eligibility phase and the admission phase. This assignment proposal will be made taking into account the aspirations of the candidate, those of the teams, and Inria's scientific policy.

In the case of an application in a project team, the candidate is invited to explain in his or her research program the integration in the desired project team.

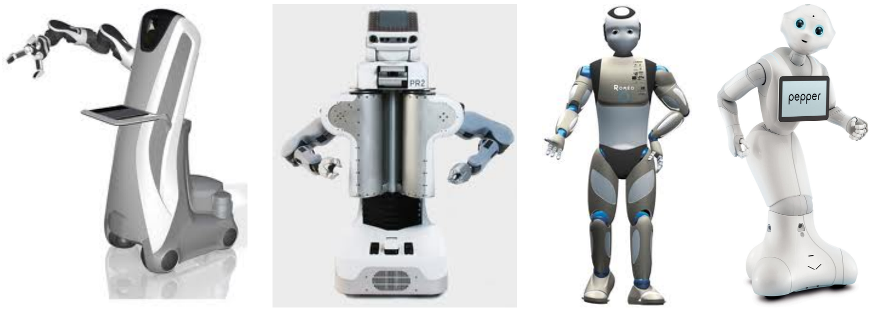
In the case when the project team is not selected at the time of the application, the candidate is not required to detail his or her integration. However, he or she may, without this being an obligation, indicate the names of researchers with whom he or she could collaborate in the case of recruitment.

☐ *I would like to apply for the following project team(s) : . . . .*

☐ *I prefer not to choose a project team for the moment. If I am considered eligible, I will be contacted by the president of the jury to discuss possible host teams.*

Intitulé du programme de recherche / *Title of research program*: **Human-Robot Motion**

1. Motivations



(a) Care-O-Bot (b) PR2 (c) Romeo (d) Pepper

Figure 4.1 – Examples of service robots designed to move around and interact with people.

My research project is concerned with **service robots** with a particular focus on **mobile service robots that interact with people (MSR)**. The stakes involved in Service Robotics are not only scientific but also economical and societal. In the past fifteen years, Service Robotics has grown into a dynamic sector of activity and it is expected that it will keep on gaining importance. On the societal front, with the aging of our societies, it will become essential to improve the quality of life of our senior citizens and Service Robotics can offer valuable solutions. Fig. 4.1 depicts examples of MSR I am focusing on, they are the size of a person and can move in large environments. My vision is to have such a MSR navigate gracefully in the crowd of a shopping mall in order to pick up a parcel from a store counter before delivering it to its recipient. As deceptively simple as this scenario may appear, it is full of scientific challenges that are yet to be solved.

2. Scientific Goals

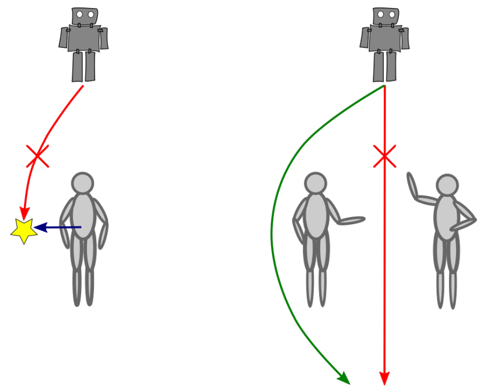


Figure 4.2 – Human-Robot Motion in a nutshell: (left) *safe* and (right) *acceptable* motions.

For a MSR, **mobility** is an essential problem, it must be able navigate freely in its environment. To that end, it has to address all the standard problems pertaining to autonomous navigation, *e.g.* world modeling, localization, motion planning, motion control. However, the presence of people adds a novel dimension to mobility: people are not geometric obstacles that can be treated like pieces of furniture. Social, cultural and psychological rules govern how people move among their peers. Besides those rules, the motion of a person is largely influenced by the non-verbal cues, *e.g.* velocity, gaze direction, that are sent by others (and vice versa). Through its motion, a person can signal that it wants to pass or join a group. In other words, motion constitutes a form of non-verbal interaction. These different aspects constitutes are at the heart of my research program. I have coined the term **Human-Robot Motion (HRM)**, with reference to Human-Robot Interaction (HRI), to refer to the study of how MSR should move among people. Whereas HRI covers how robots interact with people in the broad sense of the word, HRM can be viewed as the subdomain that focuses on mobility issues. HRM is about designing MSR whose motions, while remaining **safe**, are deemed socially **acceptable** from a human point of view (Fig. 4.2). I believe this is the key to the acceptance of MSR in our daily lives.

3. State of the Art

Although MSR have moved among people as early as 1997, it is only in 2004 that people have started to be treated as social entities and not objects [AIK$^+$04]. The review of the robotic literature on HRM shows that the main concept that has emerged is that of **social spaces**, *i.e.* regions of the environment that people consider as psychologically theirs [LE11a]. Such social spaces are characterized by the position of the person, *e.g.* “Personal space”, or the activity it is currently engaged in, *e.g.* “Interaction Space” and “Activity Space”. The most common approach in HRM is to define costmaps on such social spaces: the higher the cost, the less desirable it is to be there. The costmaps are then used for navigation purposes, *e.g.* [SMUAS07, SCG+08]. Social spaces are of course relevant to HRM but they have limitations. First, it is not straightforward to define them; what is their shape or size, especially in cluttered environments? Second, it seems obvious that there is more to acceptability than geometry only: the appearance of a robot and its velocity will also influence the way it is perceived by people. Finally, social spaces can be conflicting because when a robot needs to interact with a person, it is very likely that it will have to penetrate a social space.

4. Scientific Challenges, Research Areas and Methodology

My long-term objective is to establish the foundations of HRM in order to design robots that safely move in a manner that respects the context, expectations, social conventions and cognitive abilities of humans. It is interesting to note that the requirements of HRM actually fit the **Ambient Intelligence** paradigm that builds upon a network of systems with sensing, processing and acting capabilities, and that are endowed with a number of properties such as context awareness, anticipation and adaptivity [ZEBD98, AHS01]. Such properties are desirable for HRM and my ambition is to investigate to what extent Ambient Intelligence models and techniques, *e.g.* Johnson-Laird Situation Model [JL98], can be adapted to tackle HRM. It is this goal that has motivated my joining first the PRIMA and then the PERVASIVE team. Following the Ambient Intelligence paradigm, HRM can be decomposed in three scientific challenges that have to be solved, they correspond to as many research axes:

RA_1: Understanding human activities and intents.
RA_2: Identifying and modeling interaction rules.
RA_3: Planning and acting in a social context.

Appropriate and socially compliant interactions requires the ability for real time perception of the identity, social role, actions, activities and intents of humans (RA_1). Such perception can be used to dynamically model the current situation in order to understand the context and to compute the appropriate course of action for the robot depending on the task at hand (RA_3). Performing such interactions in manner that respects and complies with human social norms and conventions requires models for social roles and norms of behavior (RA_2).

HRM implies specific investigations that will distinguish it from standard Ambient Intelligence research. First, the *interaction rules* of RA_2 are those concerning human motion, identifying them means mining knowledge from social sciences such as psychology, sociology, anthropology and the like. Once a promising concept has been identified, it must be modeled in a way which is suitable for RA_3's purpose, which can be challenging. Second, the *actions* of RA_3 are robotic actions that are far more complex than, say, raising the temperature in a room. Such actions will have to satisfy the interaction rules identified in RA_2 while being safe. Solving the challenges of RA_2 and RA_3 is the main priority of my program. As for RA_1 which is primarily a perception problem (and a challenging one for that matter), I am planning to be a “consumer” of results obtained elsewhere, possibly through active collaborations with experts in this area. Finally, let me emphasize that, whatever the candidate solution selected, it will have to be evaluated and tested in experiments involving an actual robot and actual persons which adds to the overall complexity. Let me also emphasize that social sciences being “soft”, it may happen that a promising candidate solution based on an appealing theory may end up being totally inadequate.

5. Results Obtained

This section summarizes what I have done since I joigned PRIMA in 2012 and started to work on HRM (my corresponding publications from 2012 onward are cited with numbers).

5.1 Safety

Safety is an important aspect of HRM, needless to say that the people around MSRs must be safe.

First, I have continued my work around Inevitable Collision States and Motion Safety Levels [4, 34, 33, 123, 30, 3, 21].

Second, in the scope of the PhD of Matteo Ciocca whom I co-advise with Pierre-Brice Wieber (INRIA Grenoble Rhône-Alpes), we have started to explore safety for legged robots. The novelty here is that it requires to consider both **collision and fall avoidance**. In line with my previous work on safety for self-driving cars, we seek to develop walking strategies for which collision and fall avoidance can be guaranteed, several results have already been obtained [28] and [106, under submission].

Third, I have started to investigate if **Viability Theory** [ABSP11] can be used in practice for safety purposes. The concept of viability is more general than Inevitable Collision states, it allows to consider different motion constraints besides collision avoidance such as velocity or visibility constraints. In the scope of the PhD of Muhammad Bouguerra, several results have been obtained and validated by a recent journal article [31, 2].

5.2 Acceptability

Acceptability is the challenging aspect of HRM since a definition of what is an acceptable robot behavior from a human point of view is still lacking. After reading a lot of social sciences articles, I have identified several promising research directions, they are outlined in the next paragraphs along with the results obtained so far.

– Attention. In 2013, in collaboration with Patrick Reignier (INRIA Pervasive), we have decided to explore if human **attention** can be useful for HRM. Using an existing computational model of human attention [MGBR06], we have proposed the novel concept of **attention field**, *i.e.* a predictor of the amount of attention that a robot would receive from a person in a given situation. The attention field can then be used to decide what the robot should do depending on its current task [124] and [32, nominated for Best Paper Award]. Later, in the scope of the PhD of Rémi Paulin, we have developed a novel *computational model of the human visual attention*, it estimates how a person's attentional resources are distributed among the elements in their environment. Based upon the attention field, we have defined different **attentional properties** for the robot's motions such as distraction or surprise. The relevance of the attentional properties for HRM have been demonstrated on a proof-of-concept **acceptable motion planner** on various case studies where a robot is assigned different tasks. It is shown how to compute motions that are non-distracting and non-surprising, but also motions that convey the robot's intention to interact with a person [Pau18, 26]. The results obtained have been validated by a recent journal article [1].

– Effort. From 2016 onward, in the scope of the PhD of Jose Grimaldo Da Silva Filho, we have started to explore how **collision avoidance effort** should be shared between a robot and a person when they interact. Until now, the robot would make all the effort which could yield unrealistic robot behavior. Our working hypothesis is that effort should be shared among the robot and the person in order to obtain more acceptable robot behaviors. This research is carried out in collaboration with Anne-Hélène Olivier (INRIA MimeTIC) and Julien Pettré (INRIA Rainbow). We benefited from their expertise on the analysis of observed human walkers engaged in dyadic interactions in order to determine how effort is shared between two walkers. First results are presented in [29, 27] and [107, under submission].

– Social Comparison. Following my stay at Bar Ilan University, I have decided to explore if **Social Comparison Theory** [Fes54] can be used to address navigation in crowds, *i.e.* a particular instance of HRM. This is a challenging problem that remains largely open and I would like to explore if Kaminka's cognitive models [FK10] can be useful. This work is expected to start in 2019 [21] in collaboration with Jose Ernesto Gomez Balderas (GIPSA Lab.). We will explore whether human visual cues can be combined with the Social Comparison Theory in order to address robot motion in crowds.

6. Perspectives

On both the safety and acceptability fronts, the research directions I am engaged in need to be furthered. As mentioned earlier, costly and time-consuming experiments involving actual robots and actual people will be required to validate the results obtained so far. Besides, I have no doubt that new research directions will appear in the future, especially on the acceptability front.

Finally, I currently belong to the PERVASIVE team which will terminate in 2020 when its leader, James Crowley, retires. 2019 will be the opportunity to define a new project-team. Because I firmly believe in the importance of HRM, I will push for a new project-team centered on this problem to emerge. To that end, I have recently started discussions with researchers from the Lab. d'Informatique de Grenoble (LIG) and the Lab. Grenoble Images Parole Signal Automatique (GIPSA).

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Formulaire 5 — LISTE COMPLÈTE DES CONTRIBUTIONS[22]
Form 5 — COMPLETE LIST OF CONTRIBUTIONS[22]

1. Publications caractéristiques/*Representative publications*

Selecting only three representative publications is not an easy task but here they are:

1. R. Paulin, T. Fraichard, and P. Reignier. Using Human Attention to Address Human-Robot Motion. IEEE Robotics and Automation Letters (RA-L), Feb. 2019. Selected for presentation at IEEE Int. Conf. on Robotics and Automation (ICRA).
   http://hal.inria.fr/hal-02013578 *Topic: Human-Robot Motion*
2. S. Bouraine, T. Fraichard, and H. Salhi. Provably Safe Navigation for Mobile Robots with Limited Field-of-Views in Dynamic Environments. Autonomous Robots, 32(3):267–283, Apr. 2012.
   http://hal.inria.fr/hal-00733913 *Topic: Motion safety*
3. D. Vasquez, T. Fraichard, and C. Laugier. Growing Hidden Markov Models: a Tool for Incremental Learning and Prediction of Motion. Int. J. Robotics Research, 28(11-12):1486–1506, Nov. 2009.
   http://hal.inria.fr/inria-00430582 *Topic: Motion prediction*

2. Publications

Publication Type	Count	A+	A
International Journals	20	5	6
Peer-Reviewed International Conferences	81	51	19
Non Scientific Journals	4	-	-
Book Chapters	13	-	-
Editorial Works	2		1
Total	119	56	27
Δ wrt. DR2 2018	+5	+2	+2

Table 5.1 – Publication count by type and ranking.

In 2015, the GdR Robotique (French Research group in Robotics) issued a report ranking the different international journals and conferences relevant to the Robotics community. Table 5.1 summarizes my publications by type and ranking when it applies (for top categories A+ and A). It also indicates the number of papers published since last year's DR2 competition.

The results of my work are regularly published in the main international conferences in Robotics, e.g. *IEEE Int. Conf. on Robotics and Automation (ICRA) and IEEE-RSJ Int. Conf. on Intelligent Robots and Systems (IROS). I have also published chapters in reference book series,* e.g. *Springer Lecture Notes in Computer Science (LNCS) and Springer Tracts in Advanced Robotics (STAR), and articles in the top international journals in the Robotics field,* e.g. *Int. Journal of Robotics Research (IJRR), IEEE Trans. on Robotics (TRO), IEEE Robotics and Automation Letters (RA-L) and Autonomous Robots (AURO).*

Research Topic	Publication Period	Citation Count
CC-Steer	*[96-04]*	~1000
Bayesian Occupancy Filter	*[02-08]*	300+
Growing Hidden Markov Model	*[03-11]*	~500
Inevitable Collision States	*[03-present]*	1150+

Table 5.2 – Consolidated publication impact by research topic (source Google Scholar, Feb. 2019).

Beyond the number of articles published and the quality of the publishing places, I believe it is more important to consider their impact on the scientific community (if any) via their citation record. As of today, Google Scholar credits me with ***4700+ citations and a h-index of 38****. Table 5.2 summarizes the citation count for each one of my Key Contributions (count limited to publications whose citation number is greater than my h-index).*

Let me also point out that a recent survey on motion planning in dynamic environments [MS18] cites nine of my papers relevant to this topic, i.e. *about 10% of the references cited there.*

2.1 Revues internationales/*International journals*

[1] R. Paulin, T. Fraichard, and P. Reignier. Using human attention to address human-robot motion. *IEEE Robotics and Automation Letters (RA-L)*, February 2019.

[2] M. Bouguerra, T. Fraichard, and M. Fezari. Viability-based guaranteed safe robot navigation. *J. Intell. Robot. Syst.*, November 2018.

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[4] S. Bouraine, T. Fraichard, and H. Salhi. Provably safe navigation for mobile robots with limited field-of-views in dynamic environments. *Autonomous Robots*, 32(3):267–283, April 2012.

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3. Développements technologiques : logiciel ou autre réalisation / *Technology development : software or other realization*

3.1 Software Developments

In the scope of my key contributions, different software modules have been developed, they are presented below and evaluated in Table 5.3 using INRIA's auto-evaluation criteria (`http://www.inria.fr/medias/recrutement-metiers/pdf/criteria-for-software-self-assessment`).

Software	Audience	Originality	Maturity	Evolution	Distribution	Design	Coding	Maintenance	Management
	A	SO	SM	EM	SDL	OC-DA	OC - CD	OC - MS	OC - TPM
ICS-Check	1	4	1	1	1	4	1	1	4
GHMM	3	3	2	1	4	2	1	1	4
CC-Steer	3	4	2	2	2	4	4	4	4
Parkview	3	2	3	1	1	3	1	1	4

Table 5.3 – Software self-assessment.

– Key Contribution #1: ICS-Check

ICS-Check is an ICS-checker, *i.e.* an algorithm that determines whether a given state is an ICS or not. It was developed in the scope of the PhD of Luis Martinez [Mar10]. Luis Martinez and I both contributed to the design of the algorithm, he took care of the coding. ICS-Check was for internal use only, it was never meant to be distributed.

– Key Contribution #2: Growing Hidden Markov Models (GHMM)

GHMM is an HMM extension applied to long-term future motion prediction of moving obstacles. It was developed in the scope of the PhD of Dizan Vasquez [Vas07]. Dizan Vasquez and I both contributed to the design of the algorithm, he took care of the coding. Because, we received several requests for GHMM, Dizan Vasquez packaged a distributable version of GHMM (Debian package). It is freely distributed as an Open-Source software and available at `https://github.com/dichodaemon/ghmm`.

– Key Contribution #3: CC-Steer

CC-Steer is a path planning method for car-like systems. It was first developed in the scope of the PhD of Alexis Scheuer [Sch98] and later expanded. Different versions of the software have been developed over the years but I have written the final version with the features described in [15]. The code is about 6000 lines long. The code was meant for internal use only but, over the years, I regularly received requests for CC-Steer. Accordingly, I decided to package the code and I distribute it as an Open-Source software upon request. Much to my surprise, I keep on receiving requests regularly although the software is now relatively ancient, *e.g.* three requests in 2017.

– Key Contribution #5: ParkView

ParkView is a platform for the interpretation of complex dynamic scenes, it comprises hardware and software aspects. On the software front, a *Map Server* has been developed. I was the overall manager of the project and contributed to the design and architectural choices. The coding was done by two contracted engineers and a post-doc (about 16500 lines of code). Parkview has been used first by the partners of the French ParkNav project and later by the members of E-MOTION and PRIMA teams.

3.2 Experimental Platforms

Robotics is ultimately about making actual robots that do things. To that end, I have always pushed to have my research ideas implemented and evaluated on real robots. Getting a robotic platform up and running takes a lot of time and efforts. To test a navigation scheme for instance, one has to take care of aspects such as sensor data processing, robot localization, environment mapping, trajectory following and so forth. The software modules corresponding to these functionalities have to be implemented and integrated in an overall control architecture. This additional work is a time-consuming, difficult to quantify and somewhat unrewarding process[23]. It is nonetheless mandatory if one's want to confront its theories to real-world constraints and validate them. Over the years, four different robotic platforms have been used to test the different motion planning and navigation approaches I have proposed:

(a) **Ligier** electric car: used to test the Fuzzy Logic-based navigation scheme developed in the scope of the PhD of Philippe Garnier [Gar95].
(b) **Koala** mobile robot: used to test the Markov Decision Process-based navigation scheme developed in the scope of the Master of Julien Burlet [Bur04].
(c) **Cycab** electric cart: used to test the Partial Motion Planning-based navigation scheme developed in the scope of the PhD of Stéphane Petti [Pet07].
(d) Bluebotics'automated **wheelchair**: used to test the Trajectory Deformation-based navigation scheme developed in the scope of the PhD of Vivien Delsart [Del10], and the Inevitable Collision State-based navigation scheme developed

[23] In this respect, the assistance of the Service d'Expérimentation et de Développement of INRIA Grenoble Rhône-Alpes must be acknowledged.

(a) Ligier (b) Koala

(c) Cycab (d) Wheelchair

Figure 5.1 – Experimental robotic platforms.

in the scope of the PhD of Luis Martinez [Mar10]. This platform was also used for the workshop of the 2010 edition of the Fête de la science.

4. Impact socio-économique et transfert / *Socio-economic impact and transfer*

4.1 Bayesian Occupancy Filter (BOF)

BOF is a software framework for sensor-fusion and dynamic environment modeling (*cf. Key Contribution #4*). It was developed in the scope of the PhD of Christophe Coué whom I co-supervised along with Dr. Pierre Bessière [Cou03]. The BOF software has been patented by INRIA: “Procédé d’assistance à la conduite d’un véhicule et dispositif associé”, *Sep. 09* (http://bases-brevets.inpi.fr/fr/document/FR2890773). I am coinventor for this patent.

BOF++, an optimized version of the BOF, was later developed in collaboration with Emanuel Yguel and Kamel Mekhnacha from the Probayes company[24], a start-up born of E-MOTION, my former team. BOF++ has also been patented by INRIA (http://bases-brevets.inpi.fr/fr/document/WO2007028932). As of 2009, INRIA has granted Probayes the exploitation licence for the BOF++. The technology transfer was facilitated by the special relationship existing between E-MOTION and Probayes (Pierre Bessière was involved in the creation of Probayes).

BOF is now part of Probayes’ solution technology called *Smart Sensors*, one of the three solution technologies offered by the company. BOF has been an important asset for Probayes, it provided the company with the opportunity to obtain a series of contracts related to automotive safety with major players of the automotive industry: Toyota, Denso and Hitachi.

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Grenoble, le 25 Février 2006

Rapport de Monsieur C. CANUDAS DE WIT
Sur le dossier de Monsieur Thierry FRAICHARD
En vue de l'obtention de l'Habilitation à Diriger des Recherches
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Le mémoire présenté par Thierry Fraichard en vue de l'obtention de son habilitation à diriger les recherches traite de la problématique de la planification du mouvement, et plus spécifiquement de la planification des chemins et trajectoires des véhicules et robots mobiles.

Son travail couvre diverses problématiques en lien avec l'axe principal de sa recherche qui concerne la planification des mouvements ; planification des chemins (invariant au temps), planification des trajectoires (indexées par rapport au temps), robustesse, prise en compte des contraintes dynamiques et modélisation de l'environnement.

Une première série de travaux concerne donc le problème de planification des chemins. Ceci concerne les méthodes pour construire des « courbes » (trajectoires dans le plan) compatibles avec la dynamique des modèles étudiés (ici on se limite aux modèles cinématiques des véhicules qui négligent les forces physiques issues des énergies cinétiques, tels que les accélérations, et les forces de Coriolis, etc.). Ces modèles sont relativement simples mais ils conservent certaines des caractéristiques principales, comme les restrictions (contraintes) non-holonomiques, qui prescrivent le glissement dans certaines directions du mouvement. Ce problème, posé par d'autres auteurs, a été résolu par diverses méthodes de planification, dont quelque unes issues des propriétés de contrôlabilité de ces modèles. Une contribution importante de l'auteur de ce mémoire concerne l'extension des résultats de Reed & Sheep au cas de la planification des trajectoires avec des gradients continus. Ceci permet la planification des mouvements sans « arrêts » lors des passages entre les droites et les courbes. Ces travaux sont complétés par des études traitant le problème de la robustesse de la planification des chemins issue des incertitudes de localisation. La solution proposée consiste à concevoir un chemin robuste (avec des modèles de chemin idéal) évitant les obstacles dont le positionnement et la géométrie sont connus d'avance.

Une deuxième série de résultats concerne le problème de planification des trajectoires (un chemin avec une signature temporelle particulière), avec des contraintes du type dynamique (i.e. des mobiles). Ce problème est abordé par l'extension du vecteur d'état en introduisant le temps comme une variable additionnelle (espace états-temps). A partir de cette formulation, la recherche d'une trajectoire est donc effectuée par des algorithmes de recherche des graphes. Dans la mesure où cette planification peut-être réalisée « hors-ligne », il est possible de contourner les problèmes de complexité (issues des algorithmes de recherche de graphes) par des méthodes de recherche probabilistiques. Néanmoins, les applications aux robots mobiles nécessitent une planification « en-ligne » qui prenne en compte des contraintes temps réel rendant ces algorithmes inaptes pour des prédictions à des horizons finis et courts. Une réponse à cette difficulté est apportée par la méthode de planification de mouvement partiel, qui consiste à planifier de façon itérative un mouvement dans un horizon de temps plus court (planification partielle) à fin de prendre en compte les évolutions des contraintes dynamiques. Enfin, une dernière partie de ces travaux concerne la modélisation de l'environnement par des modèles de Markov cachés, méthode qui a été validée expérimentalement.

Les travaux mentionnés ci-dessus forment un ensemble très cohérent de résultats dans la thématique de planification des mouvements. Les sujets étudiés sont traités avec beaucoup de soin et de profondeur. Ceci n'est pas nécessairement reflété dans son document (peut-être un peu trop synthétique), mais les articles mis à notre disposition permettent cette conclusion. Parmi les travaux présentés, plusieurs contributions sont munies de simulations, ou bien mieux encore, de validations expérimentales. Ceci montre l'intérêt qui est donné à l'aboutissement des algorithmes à des applications concrètes.

Pour ce qui concerne l'originalité de la démarche de recherche dans le domaine de la planification des mouvements et la maîtrise du sujet, je constate avec plaisir que les travaux de Thierry Fraichard sont d'un grand niveau scientifique. La valeur et le nombre des publications sont largement suffisants. Son engagement dans la formation et l'encadrement des jeunes chercheurs (5 Doctorants, 8 masters, et plusieurs stages) est très satisfaisant.

En conclusion, le dossier de Thierry Fraichard est très complet et équilibré. Il ressort qu'il a réussi dans son travail scientifique, dans sa tâche d'enseignant, et dans la gestion des projets. Pour ces raisons, c'est avec un grand plaisir que j'exprime un avis très favorable pour que Thierry Fraichard puisse présenter ses travaux en vue d'une habilitation à diriger des recherches.

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Rapport établi par
Jean-Paul Laumond, DR CNRS
sur le document intitulé

Contributions à la planification de mouvement

de **Thierry Fraichard**

en vue de l'obtention du diplôme d'habilitation à diriger des recherches (INP Grenoble)

Pour rebondir sur l'avant-propos du document interrogeant la forme que doit prendre « une HDR », je trouve que Thierry Fraichard a choisi le bon équilibre qui permet facilement au rapporteur d'analyser son travail selon les critères demandés.

La production scientifique de Thierry Fraichard porte sur la planification de mouvements en robotique et comprend trois grands temps, à fort recouvrement. Très familier avec les deux premiers pour être en contact régulier avec Thierry Fraichard, j'ai découvert le plus récent en lisant le document.

Le premier temps est dominé, dans une suite logique de son travail de thèse, par l'étude de la planification de mouvement en robotique mobile. Ce travail conduit à la fin des années 90s porte en premier lieu sur un point technique critique : comment élaborer des méthodes locales qui rendent compte, au delà de la simple contrainte de roulement sans glissement, de la continuité de la courbure tout en préservant les qualités désirées de commandabilité locale en temps petit (dans sa version géométrique) ? Ce problème a été abordé par plusieurs équipes de recherche dans cette période par le biais de la commande optimale, sans succès. Thierry Fraichard a proposé une méthode basée sur la combinaison de clothoïdes dont il prouve formellement qu'elle constitue une méthode locale effective pour la planification de mouvement, approximant des trajectoires optimales en longueur de Reeds et Shepp. Cette méthode a été intégrée dans un module logiciel mis à disposition de la communauté et utilisé. La contribution a pris étrangement du temps, puisqu'elle n'a été publiée en revue qu'en 2004, alors que les idées principales étaient présentes dans la thèse d'A. Scheuer dès 1998. En parallèle à ce travail, Thierry Fraichard a abordé la question de la robustesse des chemins planifiés avec prise en compte des incertitudes dues aux dérives en phase d'exécution. Il s'agissait là d'établir des lois de propagation d'incertitudes propres à la prise en compte du roulement sans glissement, alors que la plupart des travaux dans ce domaines à l 'époque considéraient des systèmes holonomes.

Dans un deuxième temps, Thierry Fraichard s'est intéressé à la planification de mouvement en environnement dynamique. Sa contribution ici a été d'étendre les travaux reposant sur l'exploration de l'espace des configurations augmenté de la dimension temporelle à celle de l'exploration de l'espace des états du système augmenté de cette même dimension. Il est à noter que Thierry Fraichard laisse quelque peu en suspend cette modélisation que les méthodes déterministes peinent à exploiter, alors qu'elle sera reprise par d'autres par le biais des méthodes probabilistes de planification qui sont en pleine expansion à cette époque. La deuxième contribution porte sur l'introduction de méthodes de planification de plans partiels, une idée intéressante avec un potentiel qui mériterait d'être ancré dans des applications réelles. Plus aboutie est la contribution formelle sur la sûreté avec le développement de techniques de calcul d'états de collisions inévitables. Le cadre formel étant posé, elle offre un bon potentiel à l'approfondissement de développements algorithmiques.

Plus récemment, Thierry Fraichard aborde une problématique quelque peu en rupture avec ses contributions précédentes et curieusement intitulé « modélisation de l'environnement ». Alors que le lecteur s'attendrait sous ce titre à voir apparaître la dimension sensori-motrice indispensable à l'intégration des techniques de planification sur des systèmes robotiques réels autonomes, il s'agit en fait d'un contexte tout à fait différent et original (qui aurait mérité d'être exposé avec plus de clarté). Le problème est celui de la planification de mouvement dans un environnement dynamique dont l'observation doit permettre, par apprentissage, de dégager des lois générales de mouvements pour les mobiles, lois générales que chaque mobile, pris individuellement, pourra considérer dans son processus propre de planification (on pense à des piétons dans des zones urbaines, à des environnements de parking par exemple). L'exploration de ce nouveau thème de recherche repose sur des modes probabilistes de représentation de la connaissance à la base de mécanismes d'apprentissage. Il fait d'ores et déjà l'objet d'un article soumis à IJRR ce qui témoigne de la dynamique que Thierry Fraichard souhaite apporter à ce thème qui renouvelle heureusement l'activité que je connaissais.

De manière globale, la production scientifique de Thierry Fraichard est créative et de bonne qualité. Il est présent de manière systématique et régulière dans les deux grandes conférences IEEE du domaine que sont ICRA et IROS. Visiblement, la décision de passer l'habilitation a eu l'effet positif de renforcer une stratégie de publication en revues internationales.

Sur le fond, Thierry Fraichard conduit son activité à la frange de la théorie et de la pratique, deux dimensions sur lesquelles il semble hésiter, privilégiant parfois un peu trop le formel au détriment du pratique. Les problèmes posés sont souvent pertinents. Ils gagneraient à s'appuyer sur un ancrage plus résolu dans des réalisations pratiques (certaines existent pourtant mais le document ne les met étrangement pas en évidence).

Dans la même logique, Thierry Fraichard a une bonne activité contractuelle (un projet franco-coréen, un projet Robea, un projet franco-mexicain qu'il coordonne tous trois, et une participation à de nombreux contrats du projet), il est présent sur le plan de l'animation (comité d'organisation d'IEEE IROS en 1997), il fait partie des comités de programme de ICRA et IROS, ... sans qu'il soit possible d'isoler un « pic » ou deux qui lui permettraient de gagner une meilleure visibilité au plan international.

L'activité d'enseignement et d'encadrement, son implication dans le laboratoire sont bonnes.

En clair, le dossier de Thierry Fraichard remplit tous les critères d'une bonne habilitation.

Fait à Toulouse le 25 Février 2006,

Jean-Paul Laumond
Directeur de Recherche CNRS
LAAS-CNRS
7 Avenue du Colonel Roche
31077 Toulouse, France

Jean Claude Latombe
Kumagai Professor
Department of Computer Science
Stanford University
Stanford, CA 94305-9010

Le 3 Mars 2006

Rapport d'Evaluation sur les travaux de Monsieur Thierry Fraichard, candidat à l'Habilitation à Diriger des Recherches

Le domaine principal de recherche de T. Fraichard est celui de la planification de trajectoires pour robots mobiles. Une importante application potentielle est la voiture sans chauffeur. Les contributions de T. Fraichard consistent en représentations et algorithmes nouveaux, qui prennent mieux en compte les contraintes pratiques (obstacles mobiles, obstacles inconnus, incertitudes, non-holonomie, contraintes dynamiques, etc…) que les méthodes antérieures. Dans son domaine de recherche, T. Fraichard a acquis une notoriété mondiale. Ses articles sont fréquemment cités et largement utilisés par d'autres chercheurs.

Les travaux de T. Fraichard forment un tout très cohérent, dans lequel chacune de ses nouvelles contributions s'insère naturellement. Ses travaux les plus marquants sont présentés dans son mémoire. Ce sont :

1. *La planification de chemins à courbure continue pour véhicules non-holonomes*. Les précédents algorithmes de planification construisaient des chemins à courbure constante par morceaux, laissant au module de commande/contrôle le soin de lisser la courbure aux points de discontinuité. En prenant en compte plus de contraintes lors de la planification, la méthode de T. Fraichard facilite le contrôle du robot et améliore la précision du mouvement.

2. *La prise en compte d'environnements dynamiques avec obstacles mobiles*. L'article « Trajectory planning in a synamic workspace : a 'state-time space' approach » (*Advanced Robotics*, 1999) est un article très important qui représente la planification de trajectoire dans l'espace état-temps, au lieu du traditionnel espace de configurations, ce qui permet de prendre en compte à la fois les contraintes dynamiques sur le mouvement du robot (en plus des contraintes de non-holonomie) et la présence d'obstacles mobiles.

3. *La prise en compte du temps de planification*, lorsque celle-ci est faite dans un environnement temps réel. Très peu de résultats sur ce sujet (autres que des techniques purement heuristiques) avaient été obtenus avant les travaux de T. Fraichard. Celui-ci a fait deux contributions importantes : la planification de mouvements partiels, ce qui permet a un robot de commencer à exécuter un plan avant que celui-ci ne soit complètement calculé, et la détection et l'évitement d'états de collision inévitable, qui permet de garantir la non-collision sur une certaine fenêtre de temps.

Par ailleurs, les travaux récents de T. Fraichard sur la prédiction de mouvements par des méthodes de Markov sont très originaux et prometteurs.

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De façon générale, les travaux de T. Fraichard se caractérisent par des choix originaux de bons problèmes et des méthodes de résolution bien adaptées. Ses travaux combinent une bonne connaissance des enjeux pratiques et des analyses théoriques rigoureuses qui font souvent défaut dans ce domaine. Ses publications sont bien présentées, claires, et informatives.

Par ses travaux et publications et par l'expérience d'encadrement qu'il a déjà acquise, Thierry Fraichard a toutes les capacités requises pour conduire des projets de recherche importants et guider avec succès des jeunes thésards. Je considère qu'il mérite tout à fait de recevoir l'Habilitation à Diriger des recherches.

Jean-Claude Latombe

INP de Grenoble

PROCES VERBAL DE SOUTENANCE DU 20/03/2006 A 10h30

ANNEE UNIVERSITAIRE 2005/2006

Etudiant : M. THIERRY FRAICHARD né le : 01/02/1964

Version de diplôme : DHDR Informatique et Mathématiques Appliquées

Lieu de soutenance : Grand Amphithéâtre de l'INRIA Rhône-Alpes - ZIRST - 655, Avenue de l'Europe - 38330 MONTBONNOT-SAINT-MARTIN

La soutenance est publique.

Résultat :

~~Mention :~~

Membres du Jury

Nom	Qualité	Etablissement	Rôle	Signature
M. CARLOS CANUDAS DE WIT	Directeur de Recherche	CNRS GRENOBLE	Rapporteur	
M. JEAN-PIERRE LATOMBE	Professeur	Les Universités de l'Etat de Californie	Rapporteur	
M. JEAN-PAUL LAUMOND	Directeur de Recherche	CNRS TOULOUSE	Rapporteur	
M. JAMES CROWLEY	Professeur des Universités	INP GRENOBLE	Membre	
M. BERNARD ESPIAU	Directeur de Recherche	INRIA RHONE-ALPES	Membre	
M. PHILIPPE JORRAND	Directeur de Recherche	CNRS GRENOBLE	Membre	
M. CHRISTIAN LAUGIER	Directeur de Recherche	INRIA RHONE-ALPES	Membre	

INP Grenoble

RAPPORT DE SOUTENANCE :

Pour sa soutenance d'Habilitation à Diriger la Recherche, Thierry Fraichard a présenté ses contributions à la planification de mouvements avec un exposé remarquable pour ses qualités de synthèse et de pédagogie. Sa présentation était à la fois pertinente pour les spécialistes et abordable, et même intéressante, pour les non-spécialistes. Il a su éviter de se noyer dans les détails de développements formels, et ainsi a pu clairement dégager les grandes lignes des développements de sa carrière de chercheur scientifique. Parmi toutes ses contributions formelles, il a eu le bon goût de sélectionner celles dont l'importance théorique se trouvait associée à un ancrage sur les problèmes pratiques et les verrous scientifiques de la robotique. Pertinentes et bien construites, ses réponses aux questions ont mis en valeur ses qualités de chercheur confirmé et la parfaite maîtrise de son domaine. Pour toutes ces raisons, le jury attribue à Thierry Fraichard la qualification de l'Habilitation à Diriger la recherche.

James L. Crowley

MINISTÈRE DE L'ÉDUCATION NATIONALE, DE LA JEUNESSE ET DES SPORTS

DIPLÔME DE DOCTEUR

(1) INSTITUT NATIONAL POLYTECHNIQUE DE GRENOBLE

(Arrêté du 23 novembre 1988 relatif aux études doctorales)

préparé en collaboration avec (2)

Vu les titres initiaux produits par Monsieur FRAICHARD Thierry
né(e) le 01 février 1964 à SELLIERES (Jura)

Vu les pièces constatant que l'intéressé(e) a présenté en soutenance, conformément aux règlements, à la date du 22 avril 1992 une thèse ou un ensemble de travaux (3) portant sur le sujet suivant : Planification de mouvement pour mobile non-holonome en espace de travail dynamique

devant un jury constitué au sein de (1) l'INSTITUT NATIONAL POLYTECHNIQUE DE GRENOBLE
présidé par Monsieur VERJUS et composé de Messieurs LATOMBE, LAUMOND, BOISSONNAT, LAUGIER, DEMAZEAN

Vu la décision dudit jury prononçant l'admission de l'intéressé(e) avec la mention Très Honorable

LE DIPLÔME DE DOCTEUR DE (1) l'INSTITUT NATIONAL POLYTECHNIQUE DE GRENOBLE

(4) INFORMATIQUE

*est conféré à M*onsieur FRAICHARD Thierry

pour en jouir avec les droits et prérogatives qui y sont attachés.

Fait à Grenoble, le 24 Avril 1995

(5) Le Président de l'INPG
Maurice RENAUD

Signature du titulaire

Vu, pour le Ministre et par délégation,
le Recteur de l'Académie, Chancelier des Universités,
Jean-Paul WATTEAU

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N° 71

(1) Désignation de l'(des) établissement(s) délivrant le diplôme.
(2) Désignation de l'(des) établissement(s) ayant, le cas échéant, collaboré à la préparation du diplôme.
(3) Rayer la mention inutile.
(4) Désignation de la discipline ou de la spécialité (à la discrétion de l'établissement).
(5) Titre(s) de la (des) personne(s) dirigeant l'(les) établissement(s) délivrant le diplôme.

RÉPUBLIQUE FRANÇAISE

R É P U B L I Q U E   F R A N Ç A I S E

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR ET DE LA RECHERCHE

INSTITUT POLYTECHNIQUE DE GRENOBLE

HABILITATION A DIRIGER DES RECHERCHES

Vu le code de l'éducation ;

Vu le décret n° 84–573 du 5 juillet 1984 modifié relatif aux diplômes nationaux de l'enseignement supérieur ;

Vu le décret n°2002–481 du 8 avril 2002 relatif aux grades et titres universitaires et aux diplômes nationaux ;

Vu l'arrêté du 23 novembre 1988 modifié relatif à l'habilitation à diriger des recherches, notamment son article 5 ;

Vu le procès–verbal du jury attestant que l'intéressé a présenté ses travaux, le 20 mars 2006, devant un jury présidé par JAMES L. CROWLEY, Professeur et composé de CARLOS CANUDAS DE WIT, Directeur de Recherche, BERNARD ESPIAU, Directeur de Recherche, PHILIPPE JORRAND, Directeur de Recherche, JEAN–CLAUDE LATOMBE, Professeur, CHRISTIAN LAUGIER, Directeur de Recherche, JEAN–PAUL LAUMOND, Directeur de Recherche ;

Vu la délibération du jury ;

Le diplôme d' **DIPLÔME D'HABILITATION À DIRIGER DES RECHERCHES** INFORMATIQUE ET MATHÉMATIQUES APPLIQUÉES

est délivré à **M. THIERRY FRAICHARD** né le 1 février 1964 à SELLIERES (039)

pour en jouir avec les droits et prérogatives qui y sont attachés.

Fait à Grenoble, le 20 juillet 2009

Le titulaire

L'administrateur général

Paul JACQUET

Le Recteur d'Académie,
Chancelier des universités

Jean SARRAZIN

LE RECTEUR DE L'ACADÉMIE DE GRENOBLE

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