Major scientific contributions- period 2005 -2009

Contribution 1 :   Description and implementation of a research project on "robots in human environments"

I firstly proposed the research theme "robot sharing the human living space" during an European brainstorming meeting in Brussels in Brussels in March 2002; This meeting was organized during the preparation of the FET (Future Emerging Technology) call for projects "Beyond Robotics". I then developed a research program to bring out this key theme and to make initial contributions to this important scientific challenge. This research program is the foundation for the creation of e-Motion team. From the scientific point of view, this challenge leads one to deeply revisit the traditional approaches which are not fully adapted to the processing of uncertainty and complexity constraints coming from real world applications. Our research work is now based on the combination of Geometric & Topological models with the Probabilistic models based on the concept of "Bayesian Programming". It should be noted that this scientific challenge to develop robots sharing the human living space is now featured as a highlight in the Strategic Plan 2008-12 of INRIA.

Impact

- This new approach has allowed us to obtain original scientific results and these results were published in major conferences and journals in the domain (http://emotion.inrialpes.fr/laugier), Moreover this work also resulted in patents and validation. (see Contribution 5 and Webpage http://emotion.inrialpes.fr).

- This new scientific position with the results obtained has allowed us to obtain contracts from national research Progam (ANR / Predit ...), European Union (BIBA, BACS IP, IP PREVENT ...) as well as important R&D contracts with large companies in the field of automotive industry (Toyota Europe, Denso Japan, and Renault in particular).

- Another aspect of the visibility and interest from our scientific community to these new approaches, lies in the success of 8 workshops on "perception, navigation, and decision in dynamic environment", which I co-organized since 2005 in the two major robotics conferences IEEE ICRA and IEEE IROS (see Contribution 4). I also helped set up in 2004 with Alberto Broggi (Univ. Parma) and U. Nunes (Univ. Coimbra) under the IEEE RAS, a Technical Committee on "Autonomous Ground Vehicles and Intelligent Transportation Systems" which is very active and received an award in 2006 (see http://tab.ieee-ras. Org/).

- I was invited to give several plenary lectures on the theme of "robots sharing the human living space" in various international scientific events (see Contribution 4).

Contribution 2 :   Concept of "Bayesian Occupancy Filter" for robust perception

 The robust perception of the environment is a fundamental prerequisite to enhance the assisted driving system for the current complex situation caused by the road and urban environment, and the presence of the vulnerable (pedestrians, cyclists ...) . The difficulties posed by these environments are not fully controlled, making current perception techniques not sufficiently stable and therefore difficult to use in active driving safety products. The main obstacle to the robustness of these systems comes from insufficiently dealing with uncertainty (incompleteness of data, measurement errors, uncertainties in the physical world), temporary occlusions, and explicit consideration of the probable evolution of the dynamic environment of the vehicle (ie prediction of the probable future movements of targets observed).

The concept of Bayesian Occupancy Filter (BOF) we developed provides an initial response to these technological issues. The basis of this concept was originally developed by a Ph. D. student (C. Coue) for filtering and data fusion of different sensors in dynamic environments subject to various sources of

uncertainty (measurement errors, inaccuracies, uncertainties ...). The principle is developed to apply a Bayesian filtering on a discretized probabilistic model which integrates both the spatial and time dimension (e.g. speed), this filter takes explicit account of the historical measures, a probabilistic model of sensors and the uncertainty and the dynamics of observed targets.

This work has resulted in 3 publications in international journals (ISRR, IJVAS, IJISR). It also helped establish industrial cooperations including our Probayes start-up and major groups in the field of automotive industry (Toyota Europe, Denso Japan, and Hitachi). This work has also resulted in two patents. (see Contribution 5).

Contribution 3 : Concept of "prediction" and "probabilistic risk assessment"

The robust perception of a dynamic environment is not enough to make a safe navigation decisions. We must also interpret this data based on the current context, the most probable evolution of this environment in the near future, and risks incurred by the controlled vehicle. These aspects, however, very important for the safe movement in a dynamic open environment, have hardly been addressed by our scientific community. To take into account this new problem, we developed two complementary approaches aiming firstly to **predict the most probable future movements** of observed mobile objects (vehicles, pedestrians), and secondly to conduct a **continuous evaluation of collision risk** as a function of contextual and perceptual data.

Prediction. The approach to the concept of "prediction" was originally developed as part of the thesis Dizan Vasquez, a Mexican PhD student that I co-supervised with Th. Fraichard. This approach combines the functions of learning and decision making based on Markovian process. For this we have developed an extension of hidden Markov models: the "Growing Hidden Markov Model (GHMM)" concept. This work has resulted in several publications in top conferences in the field (IEEE ICRA, IEEE / RSJ IROS, ISRR), two publications in good journals (JMVA and JISR), and two publications in top journals (IJRR and IEEE Transaction on ITS). Dizan Vasquez also won Georges Giralt PhD award 2009 by the European Robotics Network EURON.

Probabilistic Risk Assessment. This approach has been developed as part of the thesis of Christopher Tay Meng Keat and the long-term collaborative project I introduced in 2005 with Toyota Europe. This approach is based on an appropriate combination of a probabilistic estimate of current and future behavior of the observed objects (cars, pedestrians ...) with a probabilistic estimate of the probable trajectories of moving objects. The main originality lies in the combination of a variant model of the hidden Markov model with "Gaussian Process" model. For reasons of business confidentiality and filing patent, little work has been published so far (only the basic concepts in the conference FSR'07). A journal publication is in preparation now that the patent was filed and the PhD thesis has been defended. The relevant patent was filed jointly with Toyota Europe in August 2009 (see Contribution 5).

Contribution 4 : *Scientific communication & organization of scientific events*

- Invited plenary lectures on the theme of "robots sharing human living space" in a panel on the future of robotics conference ICARCV'08 (Hanoi), and as a "keynote speaker" at the conference FSR'09 (MIT , Boston) and AMS'09 Conference (Karlsruhe).

- Other invited conferences: Co-Mobility Workshop (Tokyo, 2008), Tokyo University (2007), Nagoya University (2009).
- Publications of 2 books by Springer-Verlag: "Navigation in Dynamic Environment" in 2007 with R. Chatila, "Probabilistic Reasoning and Decision Making in Sensory-Motor Systems" in 2008 with P. Bessiere and R. Siegwart.
- Publication of 5 special issues of journals (IEEE Transactions on ITS, IJRR, JFR, IJVAS, RAS).
- Organization of the international conference FSR'07 (General Chair); Co-organized with JP. Merlet the international conference IEEE / RSJ IROS'08 (Program Chair).
- Organizations of 7 workshops on "perception, navigation, and dynamic decision environment. These workshops have involved the best researchers and the audience expands from year to year (there were about 50 people in Barcelona in 2005, 70 people in Beijing in 2006, and 90 people in Nice in 2008). They have led to the publication of a book by Springer-Verlag (2007) and a special issue of the journal IEEE Transactions on ITS (2009), a second book and another special issue of journal are being preparation.
- Co-organization of an annual summer school Franco-Mexican countries in Image and Robotics (SSIR) attracting an average of 70 doctoral students from European country and Mexico, some of them did PhDs at INRIA after the summer school. During the period 2005-09, two PhD thesis have been defended in the team, and two are in progress.

Contribution 5 : *Participation in the creation of start-up Probayes SA& Technology transfer*

In 2004 I participated in the creation of the company Probayes SA to promote the Bayesian programming tools developed by our team ("ProBT" library) and develop applications in various fields such as finance, military applications, surveillance, car driving, etc.. The team is still working actively with Probayes on joint projects as well as research activity for which we use Probayes as a carrier for technology transfer (see examples below). A licensing agreement and a cooperation agreement was signed with INRIA for that. Several former doctoral students of the team are now working in Probayes. I am also a scientific consultant of the society Probayes SA.

Bayesian Occupancy Filter.
The first research valorisation is the BOF technology we have patented (see Contribution 2). The initial results and potential of this technology were used to initiate or participate in R & D projects involving industry (Predit Puvame, ANR-Predit LoVe, EU Prevent). Following the great interest of the large companies in the automotive industry (Toyota and Denso), contracts of evaluating BOF technology were introduced, followed by agreements for long term cooperation with these groups. The related work was done in partnership with our start-up Probayes. The BOF software is now integrated into the ProBT library commercialized by the company Probayes, and is used in several applications.

Risk assessment. The second transfer is concerned with "Risk assessment" technology we have also patented with Toyota Europe (see Contribution 3). Like the BOF, the technology transfer is being made with our start-up Probayes and with Toyota as a end-user. The previous agreement of cooperation with Toyota Europe is being renewed and extended, with a loan for 4 years of an experimental luxury vehicle Prius fully equipped with sensors and controls. This work is carried out in synergy with the ADT National INRIA ArosDyn introduced in late 2008.