Thesis Title:
*Autonomous Driving in Realistic Traffic Situations: from “Safe Driving Assist” to “Fully Autonomous Driving Co-pilot”*

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Keywords: Open and dynamic environments, Uncertainty, Bayesian inference, Situation awareness, Prediction, Continuous collision risk assessment, Motion Safety, Risk-based navigation decision.

PhD thesis context
- Long-term collaboration between INRIA and Toyota Motor Europe (TME), including experimentations performed on an equipped vehicle Lexus provided by TME.
- INRIA Grenoble Rhône-Alpes, e-Motion research team led by Dr. Christian Laugier.

Technical context, State of the Art and Background
Autonomous driving in realistic traffic situations remains a challenging problem for future cars. The DARPA Urban challenge in 2007 has clearly shown that such a challenge could reasonably be addressed according to the recent progresses in the fields of perception and of autonomous navigation for unmanned vehicles. Yet the safety issues and scalability problems had still to be solved. The current Google Car project tries to deal with these important issues. Recent progresses in the field of Bayesian perception, Bayesian Risk assessment, and Safe navigation in dynamic environments shall enable to potentially attain the related objectives in the coming years.

Navigating safely in a dynamic, open, and uncertain environment requires the combination of three important complementary functions:

i. A *continuous interpretation of the state of the environment* (both current state and its likely evolution).

ii. A *continuous evaluation of the collision risk* (i.e. probability of collision in the near future) according to the chosen driving decisions and to the scene characteristics and moving participants

iii. A *decision making function* taking into account the outputs of the two previous functions and involving an *on-line motion planner* having the ability to avoid the choices leading to probabilistically inevitable collisions in the near future.

Until now, this problem leading to tightly combine the three abovementioned topics has received a few significant contributions from the robotics community, in particular concerning important issues such as prediction, risk assessment, and safety.

INRIA (partly in the scope of the cooperation with Toyota) has pioneered work on these closely related topics. In particular, we have developed models aiming at improving driving safety by combining *robust perception techniques* (including efficient and robust detection and tracking algorithms using our Bayesian Occupancy Filter (BOF) approach [7]), with *cognitive functions for making predictions and for continuously evaluating the risk of collision* [1]. We have also developed models and algorithms for controlling the *intentional navigation and maneuvers* of a non-holonomic autonomous vehicle [5,6,8], for making *safe navigation decisions* based on an on-line motion planner paradigm taking into account both the risk of collision (Risk-Based Motion Planner [3]) and an evaluation of the unsafe states to be avoided using potential obstacles motions prediction (Learn and Predict paradigm [4]).

The related research work was accomplished by the INRIA e-Motion research team, and it has already led to six PhD theses [1-6] and numerous publications, for example [7-11].
PhD thesis subject

Research work
The proposed PhD work shall focus on the development of models and methods for autonomous driving in realistic driving situations. The proposed approach is to combine, to adapt, and to improve our previous methods for Collision risk assessment, Risk-based planning/navigation, and Probabilistic safety evaluation. The objective is to design and to implement on the TME-INRIA experimental vehicle, an intelligent controller having the abovementioned properties and providing the vehicle with the capability to navigate safely in some selected realistic driving situations.

In other words, the main objective of the PhD work shall be to continuously monitor the collision risk level, in order to provide a risk-based navigation function having the capability to operate safely in open and dynamic traffic environments. The data which will be used by the embedded system includes history of observations, geographic information (GIS), contextual cognitive/semantic information, and learned knowledge about the nominal behaviors of surrounding moving entities. The output of the system will represent the best safe navigation trajectories to execute during the next period of time.

The research work will be executed in two mains steps:
1. Design and implement a Safe Driving Assist system to be tested on the current TME-INRIA experimental platform. In this step, the situation awareness module and the navigation decision module will explicitly take into account the constraints coming from the traffic code (including possible violations of the traffic rules by some other traffic participants).

2. Integrate the previous Safe Navigation Assist system with a car controller, in order to provide the experimental vehicle with Autonomous Driving capabilities allowing the execution in realistic traffic situations of some selected maneuvers such as emergency braking, lane change, overtaking, obstacle avoidance… The type of maneuvers to be considered will be selected during the first 6 months of the work, after technical discussions with TME.

Experimental validation & TME-INRIA experimental platform
The PhD candidate will use our state-of-the-art experimental platform on the TME-INRIA equipped vehicle to conduct tests. The car is currently equipped with the following sensors: a stereo camera, two lidars, a radar, an inertial measurement unit coupled with a GPS, and an odometry measurement unit; a removable GPS RTK device mounted on the top of the vehicle might also be used for some ground truth validation. The TME-INRIA experimental platform will be modified by TME for giving access to the acceleration, braking, and steering controls.

We also plan to add a 3D laser scanner (e.g. a Velodyne) for improving the cartography, the 3D localization, and the detection and tracking embedded functions.

The experiments concerning the Safe Navigation Assist system (first step) will be executed on various roads (highways and other roads), using the TME-INRIA experimental platform.

The first autonomous driving experiments will be performed on some private test tracks. Autonomous Driving experiments in more realistic traffic situations will be executed in a second step in tight cooperation with TME and with the Toyota Research Center located in USA.

The acquisition of experimental data from the on-board sensors is achieved on-line by means of a dedicated middleware that runs on an on-board computer with a Graphics Processing Unit (GPU). The required data acquisition and data processing modules are developed by INRIA in the scope of both an internal INRIA
development project (ArosDyn) and the INRIA-TME Research and Development agreement abovementioned. The ROS middleware has also been recently integrated on the TME-INRIA Platform.

Required competences for the PhD candidate
The ideal candidate shall possess strong analytical skills and creativity, as well as knowledge in stochastic processes, decision making, perception and robotics. She or he must have experience in software development in C++ language in Linux. The PhD candidate shall be capable of working autonomously on assigned tasks. The work will require a team work and the capability to perform experiments with an equipped experimental car. The knowledge of CUDA and Boost libraries will be appreciated. The initial experience or knowledge of the Robotics library ROS and the fluency in English will be an advantage.

Application
Please send your Curriculum Vitae, List of Publications (if applicable) and presentation letter to Dizan Vasquez: alejandro-dizan.vasquez-govea@inria.fr

Bibliography and additional information