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A complete framework for developing and testing automated driving controllers

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Abstract: Intelligent vehicles have improved their highly and fully automated driving capacities in the last years. Most of the developments are driven by the fast evolution of embedded systems for the acquisition, perception and communication modules. However, the fast growing of the automated vehicle market demands modern tools for validation, integration and testing of these new embedded functionalities, specially related to Advanced Driving Assistance Systems (ADAS). In this paper, a testing methodology for validation of path planning and control algorithms for current and future automated vehicles is presented. A high degree of modularity and adaptability have been considered in the design of the proposed method. It is based on a software tool for vehicle modeling, called Dynacar, which allows a good trajectory definition, cooperative maneuvers interaction and virtual validation. Different types of vehicles, scenarios (i.e.: urban, interurban, highways under different environmental conditions) and controllers can be tested. Moreover, Hardware-In-the-Loop configuration (i.e. electronic control units) can be also tested. Simulation results show a good performance in the implementation and configuration of urban scenarios, using different controllers in the proposed framework.

Keywords: Intelligent transportation systems, control architectures in automotive control, simulation, control validation, control testing.

1. INTRODUCTION

Nowadays, Advance Driver Assistance Systems (ADAS) and automated driving capacities are becoming a reality in mass-produced vehicles Policy (September 2016). These systems contribute to the reduction of accident rates on highway and urban scenarios, due to human driver errors. The validation of these new functionalities, and the remarkable complexity they involve, requires modern tools to integrate and test new scenarios and vehicles.

Different simulation environments are rather related to the acquisition, perception and communications stages, as in Bounini et al. (2015). Other approaches are focused in model identification (Dias et al. (2015)), based on real data from an instrumented vehicle. However, from the control point of view, almost exclusively linear longitudinal models have been considered for low speeds controllers, where the main applications include parking and adaptive cruise control.

In the automotive industry, virtual testing considerably contributes in the cost reduction of the validation and testing stages of the new intelligent functionalities, as have been presented in the DESERVE project (Kutila et al. (2014)). The goal is to develop and adjust control algorithms without the need of constantly testing them in real scenarios all the time, due to legislation limitations.

Since the development process and the validation of the embedded controller are becoming more complex, a solution for testing the modules of decision makers, path planning and control is needed. Based on the general architecture for automated vehicles used by most of the researcher groups and the automotive industry around the world González et al. (2015), in this paper, a testing framework for the validation of decision, planning and control algorithms is presented. The approach considers the 6 main stages: acquisition, perception, communication, decision, control and actuators, and the automation levels defined in SAE J3016 standard SAEJ3016 (2014) for automated driving. The solution allows a real time performance, based on software and hardware module independence. This is a valuable advantage for testing certain ADAS functions with on-board ECUs for modern vehicles, and even to emulate the setup from data acquisition sensors, as in Differential GPS. Our approach is useful to validate, first in simulation and then using HIL methods, the most common individual and cooperative maneuvers (i.e.: overtaking, intersections, merging, roundabouts, platooning, etc).

The rest of the paper is organized as follows: a review of simulation tools for automated vehicles is provided in Section II. Details of the implementation of the Dynacar simulator are also given. Section III explains the proposed testing framework. Validation and tests results are described in Section IV. Finally, conclusions and future works are listed in Section V.

2. CURRENT STATE OF MODELING AND SIMULATION ENVIRONMENTS FOR ADAS

As discussed in the introduction, vehicle simulators are very valuable for validation and testing of new functional-

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ities for automated driving. In order to increase security and safety of new algorithms, more accurate dynamic models in simulation environments are needed in the automotive research and industry.

Robust dynamic models, based on a correct environment modeling, will lead a reduction of development cost of the new ADAS. In this section, a description of the most relevant simulators available on the market is presented.

2.1 Civitec Pro-Sivic

This tool has been designed as a sensor simulator by the company CIVITEC, mainly oriented to perception and ADAS developments. It gives the opportunity to simulate a variety of complex scenarios like intersections, roundabouts, multiple vehicles and pedestrians on the road, and different weather conditions such as rain, fog, snow, brightness and others. Moreover, it has the potential of being connected with RTMaps platform to test new algorithms. Some applications use Simulink/Matlab platform to communicate it with the Pro-SIVIC simulator to test cooperative algorithms on automated vehicles Bounini et al. (2014).

2.2 CarSim and TruckSim

CarSim and TruckSim are products of the Mechanical Simulation Company. They were developed to use dynamics vehicle models, for passenger cars and light trucks, respectively.

This simulator is oriented to validation and ADAS, i.e.: obstacle avoidance algorithm using model predictive control Abbas et al. (2014), robust control for in-wheel motor vehicles Gaspar et al. (2014) and dynamic trajectory generation Hafner and Pilutti (2014).

2.3 Tass international PreScan

PreScan of Tass international is a simulator that is specialized on sensor modeling like GPS, vision, laser, radar, accelerometer and odometry. It is also based on Matlab/Simulink. They have a full spectrum camera simulation for reliable virtual development and validation of automated driving applications Molenaar et al. (2015).

2.4 SCANeR

SCANeR Studio is a software suite for HiL driving simulations. It is developed by OKTAL, and is based on works of the Vehicles Simulation and Perception research group of Renault and works of SERACD.

Several European projects have been used as background for the development of the software, for instance Prometheus, TRaCS (TRuck and Coach Simulator), CARDS (Comprehensive Automobile R&D Simulator).

2.5 SPEOS VRX OPTIS

Based on the previous experience in SPEOS driving simulator platform, OPTIS has developed the SPEOS VRX environment for ADAS and Automated Driving testing. This tool is focused on the acquisition of different sensors embedded in the vehicles. It includes camera, LIDAR, infrared sensors, among others. They also provide a 3D view of the car environment in 360 degrees.

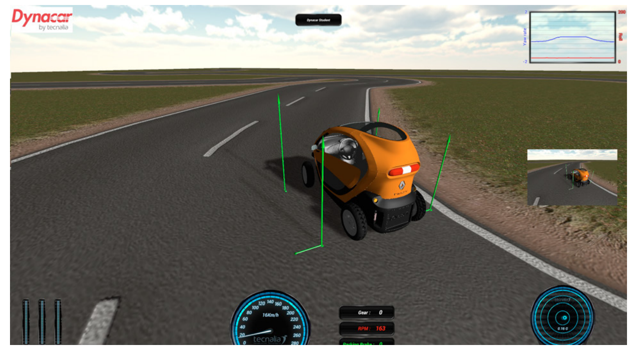

Fig. 1. Dynacar by Tecnalia

2.6 Tecnalia Dynacar

Dynacar (figure 2) is a simulation tool developed by Tecnalia Research and Innovation which provides a real-time vehicle model covering multiple domains. It focuses on vehicle dynamics, providing a high-fidelity vehicle physics simulation basing on a multibody vehicle model. This is combined with a Pacejka tire model and sub-models for elements like the engine, transmission, steering system, braking system, aerodynamics, etc Iglesias (2015).

Dynacar allows real-time and accelerated-time simulations. The real-time capability is very valuable, as, combined with its notable modularity and interfacing options.

This work is based on Dynacar's capabilities, using them to implement automated driving maneuvers. A testing methodology for the validation of control algorithms for future automated vehicles is presented. The modularity and adaptability has been exploited in the design of the proposed method based on the a general control architecture for automated driving presented in González et al. (2015). It enables a good trajectory definition, cooperative maneuvers and virtual validation with different kind of vehicles and scenarios.

3. PROPOSED TESTING ARCHITECTURE

The proposed framework is illustrated in figure 2. It includes a highly representative dynamic model of the vehicle to test automated capacities, as: real-time path generation, control, communication and other algorithms that can be embedded in an ECU.

The apporach presented in this paper has been implemented in Matlab-Simulink, as, besides being widely established in research and industry, it permits to integrate C-code functions and provides convenient interfacing capabilities (figure 3).

The main components of the automated driving environment are: