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An Industrial Workbench for Test Scenario Identification for Autonomous Driving Software

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Abstract—Testing of autonomous vehicles involves enormous challenges for the automotive industry. The number of real-world driving scenarios is extremely large, and choosing effective test scenarios is essential, as well as combining simulated and real world testing. We present an industrial workbench of tools and workflows to generate efficient and effective test scenarios for active safety and autonomous driving functions. The workbench is based on existing engineering tools, and helps smoothly integrate simulated testing, with real vehicle parameters and software. We aim to validate the workbench with real cases and further refine the input model parameters and distributions.

I. INTRODUCTION

Testing of unsupervised autonomous driving (AD) features is a grand challenge for the automotive industry, since the variation of scenarios to test is extremely large and it might therefore be difficult to get sufficient scenario coverage within available testing budget when relying on live testing only [1]. To utilize available resources, virtual testing and simulations is a primary industry concern, according to a recent survey [2]. However, simulation only is of limited assistance for auto makers; they must smoothly bridge the virtual software model-in-the-loop to the final testing with the real vehicle-in-the-loop. Industrial workbenches have been presented [3], [4] but since they are not fully open nor standardized, there is a need for further development of autonomous driving test benches.

We therefore designed a workbench for efficient test scenario identification for autonomous driving software, integrated with the industrial development process and products.

We have set up an industry-academia collaboration project between Volvo Cars and Swedish universities to design a workbench consisting of three interconnected tools, as shown in Figure 1 (left): a Requirement and Verification Management Tool for embedded systems; SPAS, a proprietary simulation platform for Active Safety (AS); and modeFrontier, a multi-disciplinary design optimization platform. Further, we define a workflow, see Figure 1 (right), first generating an initial test database from the system specifications and standards, second optimizing the model to identify the most critical scenarios.

II. RELATED WORK

A number of simulation platforms are available for autonomous driving, either open source or commercial. Despite that many of them are similar from a functional perspective, one may differ from the others regarding the simulation

engine, scripting language used, or the capability to support specific sensor types, operating systems, and the X-in-the-loop integration [5]. CARLA, an open-source simulator, enables 3D visualized urban environments for autonomous driving, where the road, weather, vehicle dynamics, pedestrians, and sensor suites can be modeled [6]. Airsim, another open source simulator, that simulates both vehicles and drones, enables both software-in-the-loop and hardware-in-the-loop for physically and visually realistic simulations [7].

To make the tools more integrated, main automotive manufacturers are developing their own products for validation, verification, testing and simulation [5]. For example, Opel developed their toolchain for simulation-based identification of critical scenarios [3]. Analogously, Volvo Cars developed their SPAS platform, to serve the development and testing of different AS/AD systems. The primary advantages of proprietary toolchains are, that they maintain full control of the design and implementation of them, and can flexibly adapt as well as to deploy a new iteration for any specific feature integration. Further, it enables tight integration of their product software in their simulation environments. However, as development of tools and test rigs are costly, cross-company initiatives exist, for example presented by Solmaz and Holzinger [4].

III. TOOLS AND WORKFLOW

A. Requirement and Verification Management Tool

The Requirement and Verification Management Tool is a development platform for embedded systems with a strong foundation in the automotive industry. The tool is used for specifying and maintaining the requirements, architecture designs, test solutions and other type of system specifications for vehicle features, as well as the test results that measure the coverage and fulfilment of the requirements.

B. SPAS Platform

SPAS is a simulation platform for integration and testing, based on MATLAB/Simulink and developed by Volvo Cars. The platform is used as the model-in-the-loop testing platform for early verification of Active Safety (AS) and Autonomous Driving (AD) functions at Volvo Cars.

There are two main parts in the SPAS environment, namely the SPAS basic model and the AS/AD software. The SPAS basic model includes models of the environment, driver,

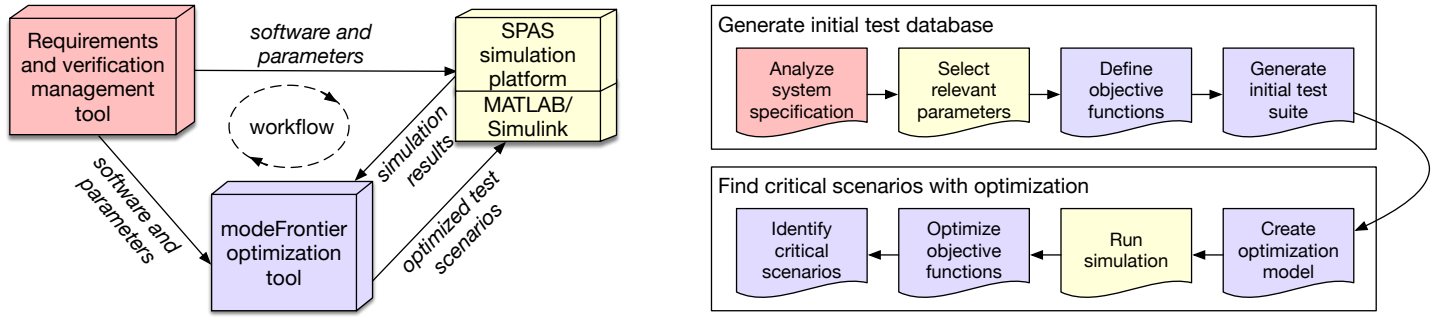


Fig. 1. Overview the test scenario identification workbench, consisting of interconnected tools (left) which are used in the workflow (right)

powertrain, transmission, driveline, chassis, brakes, steering, electrical system, and vehicle system control modules. The AS/AD software is the implementation of the driving function, which will eventually be deployed in production vehicles.

C. modeFrontier

modeFrontier is a tool for process automation and optimization in the engineering design process. It offers a graphical approach to build an optimization model with a variety of built-in applications and external programs for MATLAB, Java and Python etc. modeFrontier also provides visualization and statistical analysis tools to visualize the optimization process and interpret the optimization results.

D. Scenario Identification Workflow

The test scenario identification workflow has two main phases, *Generate initial test database*, and *Find critical scenarios with optimization*. An overview of the workflow is presented in Figure 1 (right).

The first task in the workflow is an initial *system specification analysis* in the Requirement and Verification Management Tool, where the system requirements, design and test artefacts are created and maintained. Next, *relevant parameters and objective functions* for SPAS are selected based on systematic research of the system specifications and industrial standards, like ISO-16787 [8]. *Parameters* are quantifiable properties of the driving scenarios and are crucial for the performance of the system functionalities. *Objective functions* are the measurements that can be tracked or computed during the autonomous drive maneuver, to indicate the performance of the system functionalities in regards to efficiency, accuracy and safety etc. Last in the first phase, an *initial test suite* is generated in modeFrontier, based on the selected parameters.

In the second phase of the workflow (lower right part of Figure 1), the *modeFrontier optimization model* is created to automate the rest of the process including, the SPAS *simulation* of the initial test scenarios, recording the simulation results, and *optimizing the objective functions* using search algorithms in modeFrontier. The solutions evolve through optimization of the objective functions by analyzing the existing results and exploring the parameter space. The last task in the workbench is to *identify critical scenarios* from optimization results where a criticality threshold is defined for the objective

functions. Thus, any scenarios that are beyond the threshold are considered critical.

In contrast to other scenario-based test benches for autonomous vehicles [1], [3], our workbench is generic, which means the driving function, simulation platform, parameters and objective functions are exchangeable. Thus, the workbench can, in principle, be used for critical scenario identification for any driving functions, and is not subject to a particular technique or simulator that is intended. In addition, our workbench automates the critical scenario identification process, which does not require expert involvement to develop, or deploy the workbench as well as to extract scenarios, and thus outperforms the others in simplicity and efficiency. Our further work includes validating the workbench with real cases and refining the input model parameters and distributions.

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