

A Framework for Virtual Testing of ADAS

Jinwei Zhou, Roman Schmied, and Alexander Sandalek
Johannes Kepler University Linz

Helmut Kokal
Automotive Testing Inc

Luigi del Re
Johannes Kepler University Linz

ABSTRACT

Virtual testing of advanced driver assistance systems (ADAS) using a simulation environment provides great potential in reducing real world testing and therefore currently much effort is spent on the development of such tools. This work proposes a simulation and hardware-in-the-loop (HIL) framework, which helps to create a virtual test environment for ADAS based on real world test drive. The idea is to reproduce environmental conditions obtained on a test drive within a simulation environment. For this purpose, a production standard BMW 320d is equipped with a radar sensor to capture surrounding traffic objects and used as vehicle for test drives. Post processing of recorded GPS raw data from the navigation system using an open source map service and the radar data allows an exact reproduction of the driven road including other traffic participants. The proposed framework automatically generates the recorded and post processed environment within the simulation and enables testing of ADAS strategies by identification and implementation of a detailed vehicle model of the test vehicle. Further, connection of the simulation environment to an engine test bench allows for HIL testing and additional performance evaluation of an ADAS by e.g. measuring engine emissions or fuel consumption. Additionally, the approach easily allows extensions in terms of sensor stimulation and automatic traffic object generation based on real world measurements.

CITATION: Zhou, J., Schmied, R., Sandalek, A., Kokal, H. et al., "A Framework for Virtual Testing of ADAS," *SAE Int. J. Passeng. Cars – Electron. Electr. Syst.* 9(1):2016, doi:10.4271/2016-01-0049.

INTRODUCTION

The effort spent in the development of Advanced Driver Assistance Systems (ADAS) has increased exponentially within the last years. The scientific community and the automobile industry raises lots of funds to investigate and implement systems in vehicles which should assist a driver in different traffic situations by taking over essential driving functions such as braking and accelerating with objectives like reducing the risk of accidents [1, 2], increasing traffic flow [3, 4], or increasing several performance criteria [5, 6] etc.

Whereas the main focus in research lies on the functionality and performance of ADAS, industry of course sets the main focus on safety. Both aspects need an extensive testing procedure because the requirements are increasing continuously as traffic situations are becoming more and more complex. Also, road traffic regulations and road signs differ from country to country but an ADAS must follow those rules independently from a specific location.

On the way to implementing an ADAS in production standard vehicles, field and real world testing are necessary. Nevertheless, those tests consume a lot of time and money which is the reason why

methods that allow a reduction of field test hours obtain high attention. Virtual ADAS testing environments represent an approach to achieve this objective by evaluating assistant systems in simulation or with hardware-in-the-loop (HIL) experiments.

The work in [7, 8] presents the development and evaluation of ADAS in general by using a simulation environment. In [7] additionally a human-machine interface is introduced by means of a driving simulator. This enables the assessment of ADAS and their implementation on human drivers within safe and reliable conditions. The interaction between ADAS and human drivers has also been examined in [9] by introducing a game-based human factor analysis.

Extension of simulative ADAS testing by considering HIL experiments has been proposed in e.g. [10, 11, 12]. Coupling of a simulation environment to a dynamic engine test bench indeed costs more money compared to simulation only but has the advantage that performance measure like fuel consumption or engine emissions can be captured precisely. An additional requirement for HIL testing of ADAS is that the algorithms and processing must be real time capable to be executed online. Other works investigate the entire

process from virtual testing to real world application, see e.g. [13, 14]. In those works various platforms and software products are combined to an integrated workflow.

The approach presented in this paper describes a framework for virtual HIL testing of ADAS. Thereby, the focus is set on generating a realistic and reliable traffic environment for the device under test. Based on real world measurements, captured by basic sensors, it is possible to generate such scenarios. The measurements allow reproduction of environmental conditions within a simulation tool, namely *IPG CarMaker*. Via a map service and some additional functions coordinates captured in real world can be transformed to a virtual road. Modeling and implementation of the test vehicle within the simulation environment enables virtual testing of a specific ADAS. Additionally, a connection to a real engine test bench using *AVL InMotion* allows for precise measurement of various ADAS performance criteria, as mentioned above.

The paper is structured as follows: First, a general description of the approach is given presenting the main idea. Afterwards, the individual components are described in detail. Starting with the vehicle measurements, the measurement equipment and data recording the paper goes on with explaining the digital map and virtual traffic environment generation. Finally, the workflow of the proposed framework is demonstrated with a test example, namely the virtual HIL testing of an Adaptive Cruise Control (ACC) system.

GENERAL DESCRIPTION OF THE FRAMEWORK

Most of the ADAS requires field test, which is expensive, unpredictable and time consuming. For proven in use arguments and a confidence level of 70%, 480×10⁶ kilometers are required for Automotive Safety Integrity Level A (ASIL A) [15]. And some scenes are too dangerous or even illegal to be tested on a real field test. Therefore it is more efficient and beneficial to test an ADAS in a virtual environment. In this approach the real driving environment will be reproduced in a simulated environment, so that ADAS can be tested for different driving situation and the simulation results can be compared with the real measurements.

The following flow chart, Figure 1, explains the approach: From test vehicle measurements via virtual environment (road) generation up to ADAS testing.

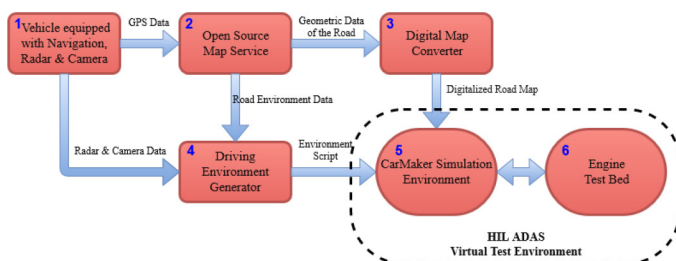


Figure 1. Flow Chart from test vehicle measurements up to ADAS testing

In block 1, the navigation system records the trace of the test drive as GPS data points of limited accuracy. The recognizable road environment, such as speed limits, traffic signs, is obtained by a vehicle integrated camera and profiles and trajectories of other traffic participants are captured with a radar sensor.

In block 2, these GPS raw data, obtained from block 1, will be post processed and located in the real world map with the help of some open source map service, so that the accurate road geometrical shape and detailed road environment can be obtained from digital geographical map directly.

In block 3, the geometric data, obtained from block 2, are converted into a digitalized road map, which can be directly loaded by simulation software.

In block 4, a script generates a virtual traffic environment based on the road environments and traffic environments data, obtained from block 1 and block 2.

In block 5, both digitalized road and road environment script are imported into *IPG CarMaker* to build a virtual simulation environment, which can be used in cooperation with engine test bed (block 6) to construct the so called hardware-in-the-loop (HIL) virtual test environment for ADAS validation.

The approach thus provides several conveniences, e.g.:

- The scenarios for ADAS validation rely on real data and therefore represent realistic testing conditions
- Repeatability is guaranteed within the virtual testing framework
- HIL experiments allow a detailed analysis of additional performance criteria such as fuel consumption, engine emissions etc.
- Effect of sensor stimuli/errors can be implemented and tested extensively within the framework
- Performance of an ADAS can be compared to the one obtained from a human driver who did the test drive
- Critical or important situations can be extracted from measurement data and be analyzed in detail within the virtual test environment

In the following, the individual parts of the framework will be explained to get a closer insight into the approach.

VEHICLE MEASUREMENTS

As mentioned in the introduction the approach is based on real world measurements to obtain realistic traffic situations within the virtual test environment afterwards. For this, a test vehicle is used which is equipped with just very few standard sensors.

Test Vehicle and Equipment

The vehicle itself is a production standard BMW 320d with a 4 cylinder 2l engine. It is equipped with an adaptive cruise control (ACC) system and access to the vehicle's CAN-bus is available.

Additionally, a *Continental* radar sensor is mounted on the front end of the vehicle which is able to detect up to 40 objects within its range. The sensor comes with two ranges, a close-up range up to 60m with a total coverage angle of 56° and a far range up to 200m with a coverage angle of 17°. Figure 2 illustrates the ranges and resolution of the utilized radar sensor. The sensor measures the relative longitudinal and lateral positions, velocities and accelerations of each detected objects and provides classification parameters like identifiers, object category etc.

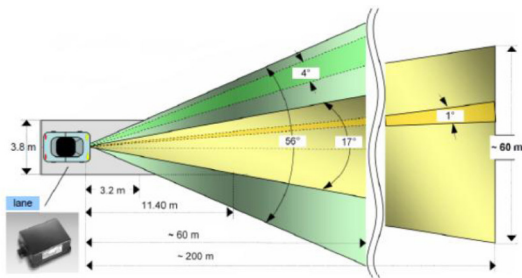


Figure 2. Illustration of the radar sensor's range and resolution in the close-up and the far range.

A *dSpace* rapid prototyping system is used to capture signals from the CAN-bus as well as those from the radar sensor and integrated camera online. The GPS raw data signals are provided via the CAN-bus, too.

GPS Raw Data recording

The GPS raw data of the vehicle's current location is obtained from the navigation device through the vehicle's CAN-bus and recorded by *dspace*. With the sampling frequency of 10 Hz, the location of the vehicle is recorded in form of matrix, consisting of longitude, latitude and altitude.

Vehicle Modeling

Virtual testing of ADAS requires the implementation and parametrization of a vehicle within the simulation environment. In order to make measurement and simulation/HIL results comparable, modeling of the test vehicle is necessary. Various parameters can be taken from data sheets, others must be obtained experimentally. The most important ones which are considered in this work are the coefficients for the longitudinal friction coefficients and a gear shift model.

The friction parameters can be estimated using standard techniques like coasting experiments. The gear shift model is obtained by analyzing various test drives in different driving situations. Thereby, it can be obtained that shifting in the automatic gear box mainly depends on the vehicle's velocity and the engine torque. Figure 3 illustrates gear shift operations depending on these two quantities. It can be observed that the gear shift behavior can be approximated using piecewise linear functions. Further, Figure 4 depicts a comparison of measured and modeled gear box recorded in a test drive.

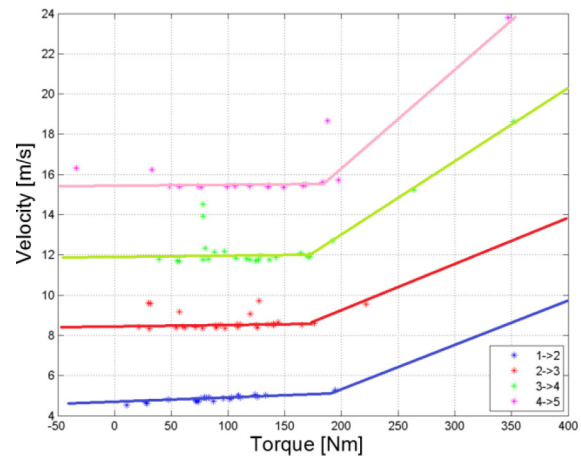


Figure 3. Measurement (stars) and model (solid) of gear shifting operations depending on engine torque and the vehicle's velocity.

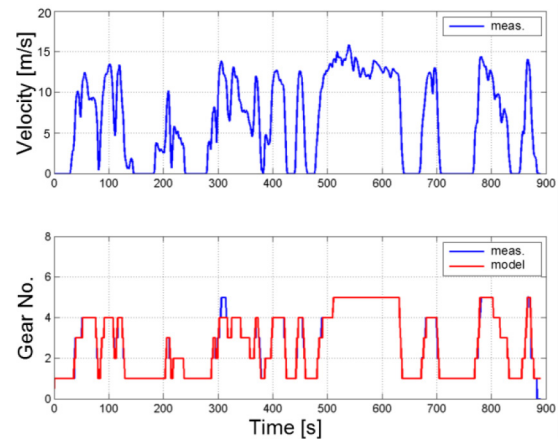


Figure 4. Evaluation of the gear model by means of a test drive in an urban traffic environment.

DIGITAL MAP GENERATION

In order to reproduce environmental conditions obtained on a test drive, firstly, the trace of test drive has to be identified and the road geographical shape has to be reconstructed as exactly as possible.

The navigation system is integrated with the so-called map-matching algorithm (with on-road-lock), correcting the GPS data dynamically and projecting the detailed driving trace onto the nearest road or even a traffic lane. But the GPS raw data (containing longitude, latitude and altitude) recorded from the navigation system is normally of limited accuracy (10 meters), with redundancy and with noise, which is not suitable for reconstructing the roads of test drive. On the other hand, the radar system can't recognize all the objects or road environments yet, so we have to detail the road scene with help of some map service, which provides much useful information along the roads, such as lane number, traffic sign (with its location) and so on.