Virtual Reality for Automated Vehicles: Coupling virtual testing with real dynamic performance

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Summary

The introduction of Automated Driving technologies is settling advanced software development to the automotive industry. This causes a clash between two highly different approaches for software based product development: the flexibility found in the ICT domain and the robustness of the automotive techniques. Coupling both approaches is also needed to achieve lower development costs and faster implementation in best-selling cars. The objective is then to develop a tool coupling both simulated perception inputs and real dynamic inputs allowing flexible development process at a lower cost. This tool can be compared to a virtual reality device to feed all the perception sensors of the vehicle while the vehicle is operating in a real environment (i.e. dynamic platform).

1 Automated driving: the mobility solution and challenge

Automated Driving technology is foreseen to be one of the major technological challenges in the upcoming years. It is expected to be key to achieve a higher level of safety, fulfilling the environment objectives established in the EC white paper for transport 2011-2020[1] and increasing comfort, social inclusion and accessibility[2]. Several studies revealed the outstanding economic impact projected for automated driving for the years to come ranging up to €71bn in 2030[3] and the estimated global market for automated vehicles is expected to achieve 44 million vehicles by the same year[4].

1.1 Automated vehicles development and validation costs

It is said that to fully validate an automated vehicle it would take 100 million kilometres of testing (0.67 astronomic units or 5.6 light minutes). Considering that Automated Vehicles are foreseen as one of the main pillars of future mobility, this would mean the deepest crisis in history for the automotive industry.

The current approach of the automotive industry is based on the V-Model, where the validation phase takes place at the final steps. This validation phase can make use of four main validation tools: Hardware-in-the-loop (HIL), virtual test drives, test tracks and public roads.

HIL simulators allow developers to validate new hardware and software automotive solutions, respecting quality requirements and time-to-market restrictions. However, as a simulation tool, it lacks the realism that real road testing provides.

Virtual test drives try to close the gap between simulated and real world testing (e.g. [5]). They take the functionality closer to the real world and this requires ground-truth data through very realistic test scenarios and accurate sensor and vehicle models. Nevertheless, the dynamics of the vehicle are tangentially contemplated through models and consequently real road tests are still required. On the other hand, a huge amount of scenarios and test cases can be defined and executed in order to validate software development, taking the logic system to the limit without safety risks.

A next validation step is the use of test tracks. Very close to real road testing, it allows the safe validation of functions before going to public roads with mixed traffic. However, the complexity of new development lines i.e. advanced ADAS and AD (SAE levels 2 to 5) require many km of testing in several scenarios, and consequently, higher associated time and human efforts.

The final stage before fully validating and verifying the system are public road tests. This is the most realistic development stage but a great maturity of the system is required. Nevertheless, some factors as user acceptance must be assessed through FOTs before getting to the production stages.

1.2 Automotive engineering and software engineering

The three tools mentioned previously refer to the final stage of the V-model, the traditional, well defined and conceived to fulfil the development cycle of automotive hardware and software applied to functionalities and the division of work in working groups or external suppliers. Additionally, functional safety standards (ISO26262) are aligned with the V-Model to allow the development of safe systems.

However, Automated Driving brought new technologies to the automotive industry, such as computer vision or even machine learning, traditionally much closer to the Information and Communication Technologies (ICT) area. In the ICT domain, the common development approach is completely different and follows different approaches as the AGILE methodology. This method enables high flexibility and adaptation when requirements and specifications are loosely defined as it enables multiple iterations during the development of a function, service or app during the whole development process.

2 Novel idea presented: Coupling virtual testing with real dynamic performance

We presented two main challenges posed by the introduction of Automated Driving technologies in the automotive industry: the need to reduce development and validation costs and the need to couple two very different development approaches, the V-model and AGILE.

The concept consists in integrating a virtual environment, quite similar to the ones used in the virtual test drives, with proving ground tests. As shown in Fig. 1:, the full sensing capability of the vehicle is connected to the virtual environment and the acting potential (braking, steering, etc.) is directly interacting with the test track (dynamic platform). This approach would provide a limitless flexibility in terms of different scenario implementation while assessing the performance under real dynamic conditions.

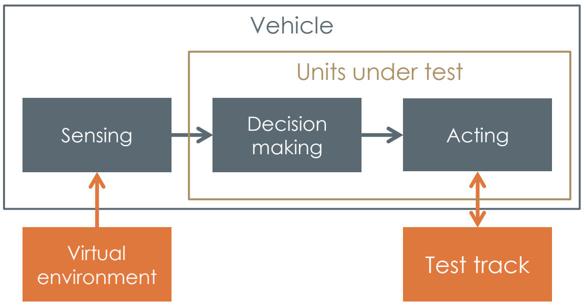

Fig. 1: Concept architecture

Although the subsystems tested using this tool are the control module and the actuator systems of the vehicle, a strong focus is put on the acting systems. This is due to the fact that the acting systems of a vehicle (steering and braking) are at a much higher level of development than the decision making systems. In fact, this would also allow testing new decision making systems into existing vehicles.

The sensing and perception systems are not tested under this concept and two hypotheses can be considered:

- The perception and sensing systems is already validated and working properly. In this case the virtual environment will be directly fed into the perception system so the post processing of the signals is done by the vehicle system itself.
- The perception and sensing system is not validated yet but the expected responses are known. In this case the perception system outputs should be simulated and fed into the vehicle decision system after a post processing of the virtual environment. Several initiatives are are alrealdy working in the standardisation of these sensor outputs.

3 Methodology

The implementation of such tool is not simple as it requires a significant level of understanding of the technologies and of the integration of all the systems. Additionally, a high quality virtual environment is required and will define the effectiveness and ultimately the feasibility of the tool.

This virtual environment should be versatile, allowing to make changes with a high degree of flexibility. This virtual environment should also use (a close to) standard format usable by existing simulators and HW/SW solutions. The testing area should be geographically limited (geofencing) so if the vehicle gets near its GPS defined coordinates a redundant and independent safety system should be able to make the vehicle stop in a safe, controlled way.

The test track(s) should be wide and long enough to allow the reproduction of complex scenarios. The vehicle should have an agreed interface between the control unit and the actuators. The test case would be uploaded to the vehicle under test (VUT) from a remote location in a standardised way.

4 Progress beyond the state of the art

4.1 Technical progress

As explained previously, the current technicques used for automated driving functions development are adapted to the current development approach and each has a specific balance between cost (or development stage) and real-world correlation. In this approach a linear process is taken, from HIL at low sub-system development stages, to validation and finally test track and public roads for final full vehicle testing.

The presented tool would allow to use the same methodology, the same tool for a variety of development stages. Therefore, for a very first software version we could be using the same test set up as the last versions. The virtual set up allows to tune the complexity of the test according to the capabilities of the current development stage while the reliability of the test is maintained by the physical link with the test track.

4.2 Project development

As mentioned previously, the automotive V-model is the traditional and well defined approach and is specifically conceived to fulfil the development cycle of automotive hardware and software applied to functionalities and the division of work in working groups or external suppliers. Additionally, functional safety standards (ISO26262) aligned with the V-Model. However, although it allows certain iterations in some of its stages but penalises heavily having to return to previous stages due to design errors discovered in next stages.

However, using the AGILE approach it is difficult to fragment the process between groups and external providers as the development is considered as one or very few stages (following a holistic approach to the function development). Additionally, (functional) safety is not as well defined as in the V-Model.

The proposed methodology will bring together all the benefits above and close the gap between real road testing and virtual testing while keeping the versatility and convenience of in-lab XIL testing driven by the designed tool

5 Foreseen impact

It is not easy to quantify the current cost of the development of automated vehicles but as mentioned previously is expected to be incredibly high, if the current tools and methods are still used. The main benefit of the testing tool introduced in this paper is that it can be the driver for the introduction of new methodologies and approaches to the automotive industry. It allows to embed specific sotware development technologies into the traditional automotive approach so that a more efficient development can be achieved.

Additionally, it allows to test an increased number of safety critical scenarios with a high degree of safety and reliability achieving a higher level of validation when the vehicle comes out to the public road. The use of the presented tool and the new presented approach would allow to avoid a significant number of incidents in public roads that could have a stong negative effect on corporate image to automakers.

6 References

[1] EUROPEAN COMMISSION
Whitepaper - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system
European Commission
Brussels, 2011

[2] ERTRAC
Automated Driving Roadmap
ERTRAC Task Force "Connectivity and Automated Driving"
Brussels, 2015

[3] KPMG
Connected and Autonomous vehicles - The UK Economic Opportunity
KPMG UK
London, 2015

[4] ALEXANDER, D., GARTNER, J.
Autonomous Vehicles, Self-Driving Vehicles, Autonomous Parking, and Other Advanced Driver Assistance Systems: Global Market Analysis and Forecasts
Navigant Research
Boulder CO, 2013

[5] ROS, G., SELLART, L., MATERZYNSKA, J., VAZQUEZ, D., LOPEZ, A. M.
The SYNTHIA Dataset: A large collection of synthetic images for semantic segmentation of urban scenes
CVPR
2016