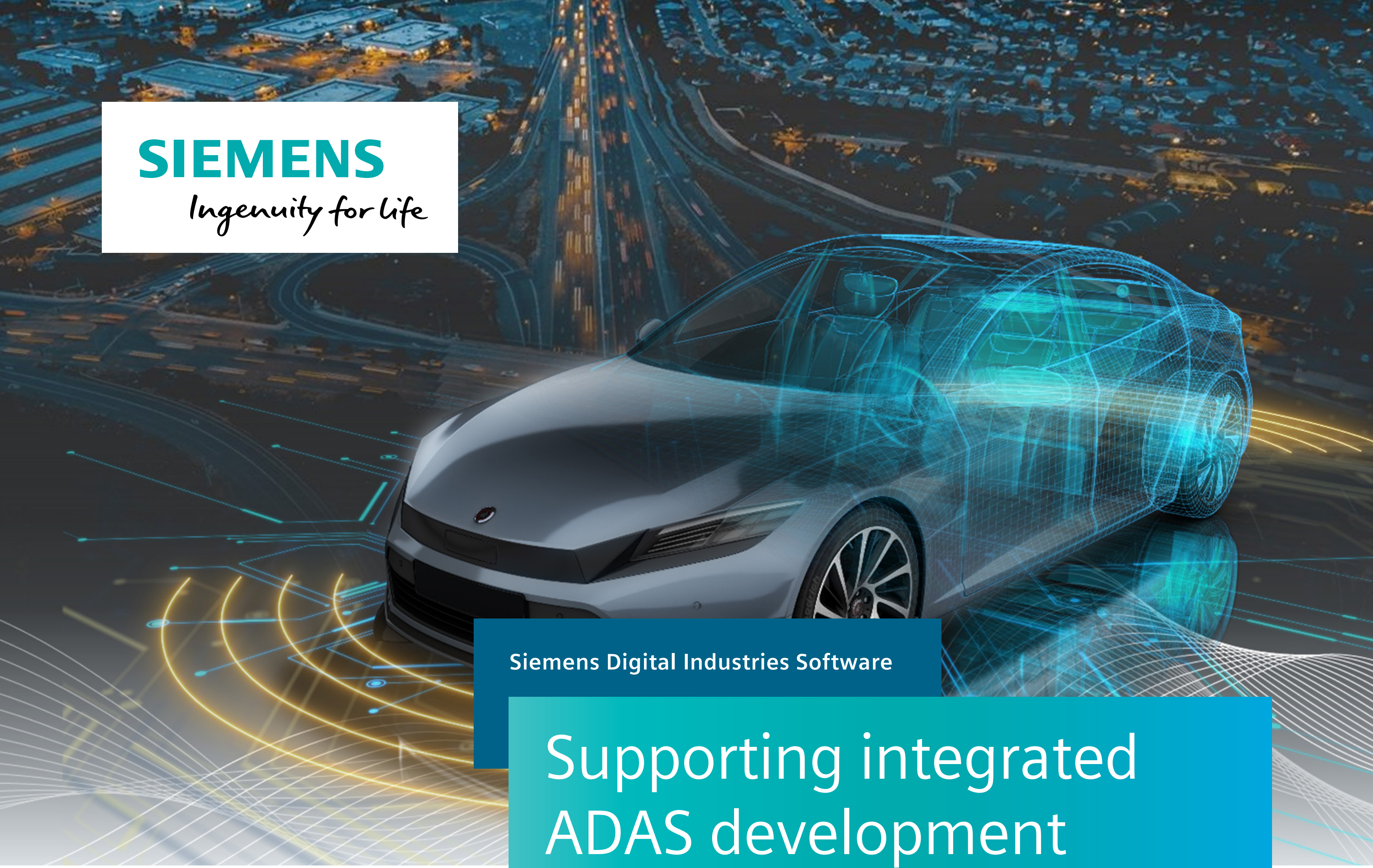

Siemens Digital Industries Software

Supporting integrated ADAS development

Using a mixed-reality framework for verifying safety and comfort

Executive summary

The performance of advanced driver assistance systems (ADAS) depends on the complex interaction between sensors, driving scenes, control algorithms and vehicle dynamics. This gives rise to dynamic scenarios that are difficult to assess, especially in the early stages of development.

ADAS teams often have to deal with developing just part of the system, which makes it impossible to assess its contribution to the full vehicle performance in real-life scenarios. Therefore, the system can only be fully assessed using physical testing at the prototype stage when resolving issues is difficult and costly.

Abstract

Today we observe many issues in existing systems that often do not match driver expectations. For instance, automated emergency braking (AEB) is not always activated properly due to an incorrect perception of the driving scene.[1,2] Also as reported in a recent survey from the American Automobile Association (AAA), lane keeping systems, adaptive cruise control and traffic jam assists fall short of expectations,[3] eventually leading to safety and/or comfort issues.

To support original equipment manufacturers (OEMs) and ADAS systems suppliers in identifying such issues early on, Siemens' Simcenter™ Engineering and Consulting services team has put together a closed loop development framework that allows virtual testing of the full system, even when working on only a part of it. This includes perception, path planning and control actions. Real-life scenarios are defined, including the environment and driving scene, and suitable sensor models are created.

To make the framework most useful to ADAS systems engineers, it is customized to their specific needs. Dedicated libraries of perception, path planning and control algorithms are included. Based on Siemens' significant experience in ADAS systems simulation and testing, relevant scenarios are defined to assess the system in appropriate conditions. A large number of scenarios are evaluated using virtual models from which a subset of more critical ones is identified for verifying and validating the system so you end up with a manageable physical testing program.

The system is plug-and-play as it allows the user to switch from standard components or algorithms to the ones being developed for a specific program. A dedicated vehicle dynamics model is linked to the framework, which provides an accurate response to the system and enables the user to study the comfort aspects of ADAS. It can be turned into a vehicle-specific model if the physical parameters of its chassis are known. When this is not the case (as can be the case for ADAS systems suppliers or when investigating a competitor vehicle), a process is proposed to reverse engineer these parameters based on full-vehicle testing.

Finally, the framework can be opened to physical components to become a genuine mixed-reality application. This is made possible by using middleware such as a Functional Mock-up Interface (FMI) or robotic operating system (ROS), which can interface directly with the physical systems. In this way the physical electronic control unit (ECU), the real sensors, a vehicle simulator and eventually the full vehicle can be consistently tested with virtual models. In the latter case the real physical environment can be enhanced by introducing virtual obstacles, other vehicles or vulnerable road users (VRU), enabling vehicle-in-the-loop (ViL) testing.

Simcenter engineers are adapting the development framework to their customers' needs and supporting them to the full extent possible with this fully integrated closed-loop virtual/physical framework for ADAS systems development.

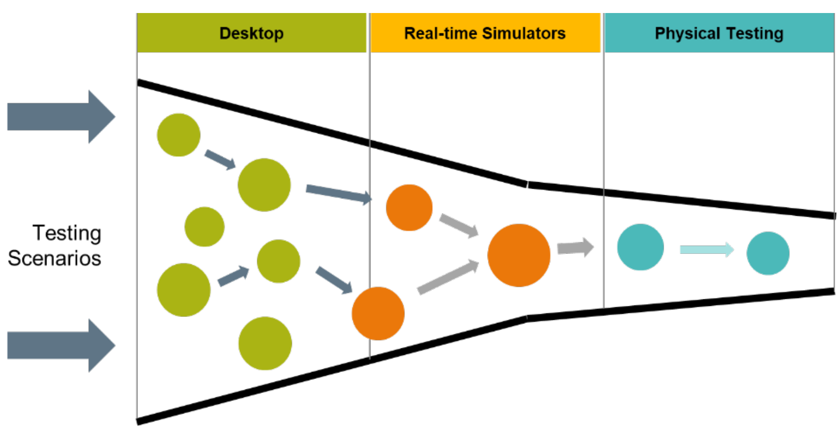

Figure 1. Managing test scenarios from virtual to physical validation.

Development framework overview

The purpose of the development framework is to verify system performance early in the design in a large number of realistic conditions in an integrated fashion according to the principles of a model-based design (MBD) approach.

The system evaluation is supported by dedicated simulation tools such as Simcenter™ software, which is part of the Xcelerator™ portfolio, the comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software. Using Simcenter Prescan™ software enables you to simulate the driving scene, including static (roads, road signs, traffic lights, obstacles) and dynamic environments (various actors), and provides sensor models with different levels of fidelity. Simcenter Amesim™ software enables the user to simulate vehicle dynamics and can be coupled with Simcenter Prescan. Optimization solutions such as HEEDS™ software screen the system performance through multiple scenarios and can support design optimization. In order to define and track systems and software requirements and use consistent test cases during development, a dedicated tool such as Polarion™ software for Automotive is used.

In order to integrate these tools in the system development process for a closed-loop integrated evaluation early in the process, the proposed framework organizes these capabilities around the classical sense-think-act chain, allowing the user to:

- Assess the set of sensors (type, number, location) and develop perception algorithms for an accurate identification of the driving scene
- Evaluate system behavior in real-world driving conditions
- Test and verify the path planning and control strategy and algorithms
- Identify the subset of critical scenarios to be included in the physical verification and validation of the system

In recent years, Simcenter Engineering and Consulting has developed significant experience in perception, path planning and control algorithms for various ADAS and autonomous features. Model-based control algorithms such as model predictive control (MPC) as well as data-driven approaches based on machine learning are included. Scenarios are defined based on experience in supporting the customer's ADAS development using standards and regulations (for example, European New Car Assessment Program (NCAP)) and real-world driving data or by coupling the framework with a traffic simulation tool such as Aimsun software.

Given the high degree of customization, the framework is adapted to the needs of a specific program during a services project and handed over to our customer during a methodology transfer session.

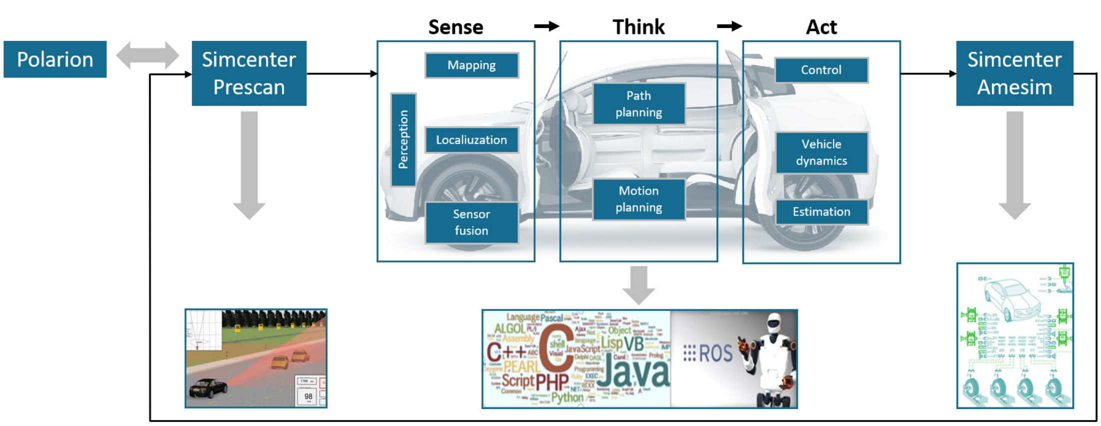

Figure 2. Development framework overview.

Vehicle dynamics considerations

Vehicle dynamics may influence ADAS/AD systems performance significantly. Therefore, it needs to be represented with the right level of fidelity in the process to assess the vehicle state. This depends on the application. The use of a simplistic vehicle dynamics model can lead to an incorrect assessment of the full system, in particular in the case of a highly dynamic maneuver such as significant steering and braking actions. The right level of fidelity must be carefully defined; in many cases we obtain a good compromise for both lateral and longitudinal dynamics using a so-called 15-degrees-of-freedom (DOF) model.

This model approach requires knowledge of some global physical parameters of the chassis. When these parameters are not available, Siemens engineers have developed a reverse engineering method based on a series of tests performed on a full vehicle. If needed, the model can then be completed by dedicated steering or braking system models or using an improved tire model like the Simcenter Tire software MF-Swift.

Another potential use of the vehicle dynamics model is to evaluate comfort in ADAS/AD scenarios. Research activities are ongoing in our engineering team on the comfort performance at large, including driver acceptance of the system (for example, feeling safe). This includes the design of control algorithms according to target driving styles in combination with strict safety boundaries.

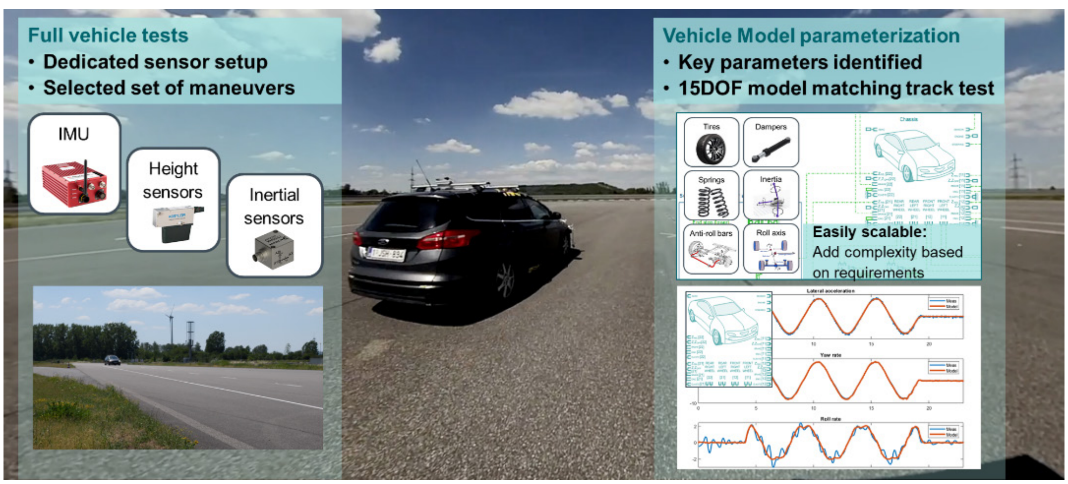

Figure 3. Reverse engineering of vehicle dynamics model.

Mixed-reality testing

Developers of ADAS systems must verify that it behaves well in complex environments and conditions it will face in operation. This leads to a large number of test conditions, including various actors, vehicles and pedestrians, which cannot all be tested using the real vehicle. Using the framework described above, virtual testing is instrumental in managing the verification of the system over a large number of scenarios.

To bridge the gap between virtual and physical testing, the framework allows you to progressively replace some of the simulated components (for instance, sensors, ECUs) with physical components, thereby combining test and simulation in a mixed-reality environment. The integration of the framework with the ROS enables the user to seamlessly exchange physical and virtual parts.

Eventually this leads to a ViL setup in which the real vehicle is driven on a test track where virtual actors (for example, static and dynamic vehicles, obstacles, vulnerable road users, etc.) are introduced using the virtual framework. The vehicle sensors detect the virtual actors as if they were physically present. This provides greater flexibility in setting up all kinds of test scenarios and is being considered by certification authorities as a future mandatory validation step.

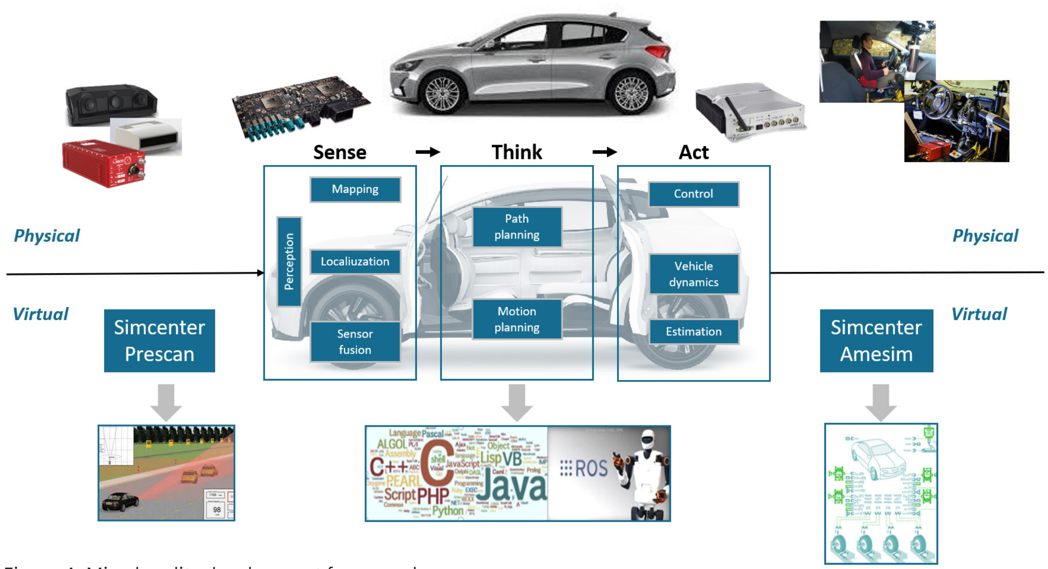

Figure 4. Mixed-reality development framework.

Conclusion

Automotive vehicles include an increasing number of advanced ADAS features that have a great potential to improve safety. However, they also introduce a lot of challenges. The development framework we describe allows you to verify ADAS performance early on to identify real-life perception, planning and control issues. When physical elements of the system become available, it evolves into a mixed-reality testing platform. Simcenter engineers work with OEMs and suppliers to adapt the framework to their needs and programs while leveraging our application know-how.

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