ADAS & Automated Driving

Development and validation of advanced driver assistance systems and automated driving functions with virtual test driving
For advanced driver assistance system tests
- Autonomous emergency braking systems
- Lane-keeping systems
- Electronic stability control systems
- Evasive steering assist systems
- Speed assist systems and adaptive cruise control (ACC)
- Pedestrian and cyclist detection
- Side collision avoidance systems
- Adaptive headlights
- Cooperative V2X applications
- etc.

For automated driving function tests
- Perception
- Sensor data fusion
- Localization
- Trajectory planning and control
- Actuator control
- Training data generation
- etc.
**Safe. Intelligent. Automated. The automotive future.**

**Develop and validate advanced driver assistance systems and automated driving functions by means of virtual test driving with the CarMaker product family**

Today’s automotive trends such as safety, connectivity and digitization, or new sustainable mobility concepts, have one thing in common: assistance systems and automated driving functions that turn the vehicle into a data center on wheels. In order to make these trends a reality, their underlying systems need to be powerful and, above all, safe. This requires an enormous development effort as an unprecedented number of test scenarios needs to be taken into account.

The increasing complexity of functionalities in modern vehicles impacts these test scenarios in various ways, thereby increasing the number of test variations. Millions of kilometers therefore need to be driven in real-world test runs to bring the systems to market. This, however, is downright impossible.

Only by complementing real test drives with virtual test driving can these challenges be met. The CarMaker product family enables tests of individual functions and entire system networks in realistic, reproducible scenarios with a virtual prototype, long before a real prototype becomes available. CarMaker can be used to validate the whole event chain, from perception and sensor fusion, the generation of an environment model, decision-making and trajectory planning right up to actuator technology and its implementation.

Accurate, real-time capable sensor and vehicle dynamics models required to test ADAS and automated driving functions are included in the software as well. These deliver signals from the environment and are capable of modeling realistic effects on the driving performance.

CarMaker offers a software environment incorporating models for the road, traffic, environment, driver as well as the vehicle with all its subcomponents, which also allow individual parameterization. In addition, a variety of interfaces enables the integration of the user’s models or real hardware.

**Your benefits at a glance**

- **Streamlined scenario generation**
  - Combination of different sources such as map data, real road measurements and traffic scenarios
  - Reproducible test scenarios
  - Extensive test catalogs to rapidly cover a large part of the test scope

- **Integration platform with open interfaces**
  - Integration of component models as well as of own vehicle models
  - Coupling with middleware applications such as ROS

- **Virtual prototypes following the concept of purpose-driven fidelity**
  - Easy parameterization of the virtual prototype using the Vehicle Data Set Generator
  - Exchange of existing prototypes with other departments
  - Seamless integration into the development process
Holistic testing throughout the entire development process

Seamlessly conduct your tests in the virtual world with a high level of detail. Our CarMaker product family enables the efficient, reproducible and automated development, testing, verification and validation of your advanced driver assistance systems and automated driving functions.

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Same simulation workflow

Model -in-the-loop

- Integrate existing models, processes and tools already in the earliest stages of development via interfaces such as MATLAB Simulink/CarMaker

Software -in-the-loop

- Execute the control unit code in a virtual ECU via coupling with middleware such as ROS or FMI before the hardware is available

Hardware -in-the-loop

- Test the entire hardware component or ECU before the real vehicle is available
- Test interactions/networks of the components within the virtual prototype

Vehicle -in-the-loop

- Reproducibly test critical and complex scenarios in the real vehicle without risk
- Benefit from the advantages of both virtual and real-world test methods
Introduction

The simulation workflow in detail

In all stages of the development process (MIL, SIL, HIL, VIL), the same simulation workflow is guaranteed. Build your models and systems, integrate them into virtual prototypes and conduct automated tests in scenarios. A precise analysis of results lets you draw conclusions regarding potential improvements.

Virtual prototype
- Your ADAS or AD system
- Sensor models
- (Sub-)system models
- ...

Scenario
- Road and infrastructure
- Traffic
- Environment
- ...

Test automation and execution
- XIL
- Scenario variations
- HPC/cloud
- ...

Results
- Evaluation
- Post-processing (big data analytics)
- ...

If required, optimization/feedback

Adopt the automotive systems engineering approach and test your virtual prototype as a whole vehicle with CarMaker. In closed-loop tests, the systems can complete entire development, test and validation cycles up to the final approval of the respective function or component.

The parameterization of test scenarios including roads with infrastructure, traffic and the corresponding ambient conditions is straightforward and allows for flexibility.

Test automation allows you to rapidly vary the large number of scenarios to be validated in every stage of the development process (MIL, SIL, HIL, VIL). Using cloud-based solutions or high-performance computing enables the parallel execution of test scenarios in no time.

The subsequent analysis of results and post-processing sheds light on the functionalities, potential parameter optimization and further need for testing.
Building the virtual prototype according to requirements

Different sensor model classes for maximum flexibility and efficiency

The prime components for testing ADAS and automated driving functions in a virtual prototype are the interfaces between the systems and the environment – the sensor models.

In order to generate a highly detailed, realistic environment model, different sensor models with various fields of view based on distinct technologies are used that capture the environment including roads and traffic.

CarMaker offers three sensor model classes containing sensor models of varying levels of detailing, which are suited to address a variety of issues in system development.

Real-time capable sensor models with different levels of modeling are the basis for the efficient virtual testing and validation of automated driving functions
**Ideal Sensor Models**

**Does the system work in general, excluding detection errors in perception?**

Ideal sensors are independent of the sensor technology used, they are easy to parameterize and deliver ideal object lists.

- Suitable for proof of concept, rapid prototyping, general function development and function tests in early stages of development

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**HiFi Sensor Models**

**Does the system typically function, i.e. in everyday use with realistic sensor input?**

High-fidelity sensors factor in technology-dependent physical effects and therefore the technology's characteristics. The delivered object list contains the same errors that an object list from a real sensor would include.

- Suitable for function development, e.g. whenever detailed object lists with technology-dependent effects are required, or for tests of the developed function and its robustness

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**Raw Signal Interfaces**

**Does the system function together with the sensor components?**

The Raw Signal Interface delivers raw signals that a sensor control unit requires for perception. It models detailed, relevant physical effects of the considered technology on signal propagation in the environment.

- Suitable for the development and tests of components or signal processing algorithms

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**Your benefits at a glance**

- **Purpose-driven fidelity**
  - A high level of performance already in early stages of development
  - Highly accurate sensor modeling according to requirements and the focus of the test
- **Easy modeling of real sensors**
Visualizing the virtual world

High-quality visualizations are crucial for human drivers when testing vehicle dynamics or human-machine interfaces. For ADAS to make decisions during a test drive, or for object classification and interpretation fed from the camera-based sensors mounted on the vehicle, detailed visualizations are required as well.

IPGMovie – The visualization tool in CarMaker

Observe what is happening with accuracy – the visualization tool IPGMovie enables you to individually define the optical input for camera-based systems and make it visible at once. Setting different points of view, visualizing various lens types, modeling reflections and the sun’s position, lighting effects caused by headlights and many other features deliver realistic image data for tests of camera-based systems.
Coupling with third-party visualization software

Thanks to the openness of our simulation solution CarMaker, coupling the systems with another visualization software such as rFpro is easy. This allows you to use photo-realistic high-definition models of public roads and OEM test tracks for your scenarios.

Generating synthetic data to train AI algorithms

Virtual test driving also enables you to train and test deep learning algorithms. Safely generate and precisely label reproducible, synthetic data as well as data from dangerous scenarios. By drastically reducing the need for manual labeling, you also achieve savings in time and costs.

Your benefits at a glance

- Problem identification and solving by simulating in real time
- High-end visualization of camera-based functions with realistic input
- Safe testing of dangerous scenarios to train AI algorithms
- Semantic segmentation for AI-based systems training
**Generating realistic scenarios**

Our software enables you to realistically and precisely model scenarios with various vehicle types and their dynamic properties, the driver behavior, infrastructure and the environment in dynamic traffic situations within the virtual world. Thanks to the clearly structured user interface, all models allow for fast and easy parameterization for virtual test driving with a high level of detail.

**Road and infrastructure**

Realistic road characteristics and geometries lay the foundation for realistic test scenarios for virtual test driving. This makes solid validation tests of driving functions in the virtual prototype possible in the first place. For a fast and efficient generation of the required test scenarios, CarMaker offers a range of options for road generation and infrastructure design.

**Manual generation using the Scenario Editor**

Use the Scenario Editor to manually generate and configure scenarios. Here the focus is on the straightforward definition of road networks and the easy configuration of scenarios including buildings and traffic signs. Any changes to the scenario can be supported by graphics, making this process easy to perform and comprehensible for the user.
Import of map data
When you need to use road networks in scenarios that are not simply realistic but real, you have the option of integrating road networks from map data such as HERE ADAS RP and subsequently adding road users and infrastructure.

Import of real measurement data
The closest correspondence with reality is achieved by importing measurement data of large-scale road networks together with their properties. Data from our partners, e.g. 3D Mapping Solutions or atlatec, can be exported to ROAD5 format to be used in CarMaker.

Your benefits at a glance
- The Scenario Editor enables the easy generation of individual scenarios from scratch and gives you full control of the scenario
- Importing map data or real measurement data allows you to integrate real scenarios into the virtual environment
- Choose from different methods to achieve your objectives according to your individual needs
Traffic

In addition to the road model, test scenarios need to be equipped with realistic traffic behavior. Physically correct traffic behavior is a prerequisite for testing camera-based functions, for instance, to ensure that the object detection algorithms are confronted with realistic input data.

Our software also offers a range of options for generating traffic.

Manual use of the traffic model

The traffic model enables you to generate individual scenarios that require the dedicated control of individual traffic objects such as vehicles, cyclists, pedestrians or animals with realistic movement patterns.

Random traffic in the Scenario Editor

Using the function “random traffic” you can generate a large number of traffic objects in the Scenario Editor. Integrating your own traffic objects is possible as well. Here, the interaction between the objects plays a key role. Traffic density, vehicle types and the assignment of different routes can also be defined.

Coupling with third-party simulation software

The open architecture of CarMaker makes it possible to couple the software with your existing intelligent traffic simulations such as PTV Vissim. This expands the simulation environment and combines CarMaker’s realistic whole vehicle behavior, its many model integration options and sensor modeling with the traffic behavior model of PTV Vissim and its traffic light control.
Digitizing real data

Using ScenarioRRR (Record, Replay, Rearrange), you can record test drives, import traffic objects and play the scenarios back. As the traffic objects are fully integrated in CarMaker, they can be manipulated as usual in order to achieve variations of the recorded scene. We offer this service as part of engineering projects.

Your benefits at a glance

- Reproducible tests in different traffic scenarios:
  - “Realistic” random traffic and generic traffic including individual/“incorrect” road user behavior
  - Full control of the scenario
- Reuse of real traffic scenarios:
  - Function tests in hazardous situations
  - Generation of scenario variations, enabling function robustness tests
- Choice of different methods to achieve goals according to individual requirements

Environment

Weather conditions such as rain, heavy snowfall or fog also have an impact on the proper functioning of advanced driver assistance systems and automated driving functions. The environment model in CarMaker enables you to parameterize different ambient conditions. This allows realistic function tests and, for instance, the early correction of sensor perception errors with virtual test driving.

Your benefits at a glance

- Testing the impact of environmental conditions on the sensor models
- Realistic function tests by modeling sensor perception errors within the simulation
Conducting automated tests

Test Manager is part of the CarMaker product family and ensures stable and automated tests for seamless use throughout the entire development process. You can rapidly compile and parameterize even extensive test series with variations, achieving a wide coverage of the test scope. In addition, you can generate pre-defined test catalogs called Test Ware Packages, which you can vary and execute at any time.

Using pre-defined test packages

Example: Test Ware Package Euro NCAP

Euro NCAP assesses general vehicle safety systems based on occupant protection of adults (drivers and passengers) and children as well as the protection of vulnerable road users such as cyclists or pedestrians. In addition, safety systems incorporating driver assistance and collision avoidance technologies are assessed.

CarMaker offers you the Test Ware Package Euro NCAP including 15 tests with over 130 variations for you to develop emergency brake, speed and lane keeping assist systems in compliance with the Euro NCAP test protocols. The Test Ware Package is updated and adapted to the test protocols on a regular basis.

Precise, fast and parallel simulation

Due to the variety of test scenarios to be validated, solutions are in demand that run as many test drives as possible in the shortest time achievable with concentrated computing power. CarMaker enables parallel simulation in high-performance computing (HPC) mode. This solution allows you to conduct your tests even faster thanks to distributed computing on high-performance hardware, massively reducing computing time and achieving major savings in time and costs. For straightforward parallel computing on a workstation CarMaker offers the “HPC Light” mode, enabling you to simultaneously test new functions in a variety of scenarios with little investment of time. For more complex computer architectures and distributed systems, the usage of an HPC scheduler is possible.

Cloud-based solutions

A cloud-based solution can also be implemented as an alternative to the conventional HPC options. You can run jobs on an external hardware infrastructure, which offers you high flexibility at a relatively low organizational effort since your own hardware is not required.

Your benefits at a glance

- Driving millions of test kilometers in the simulation thanks to easy scalability
- Full coverage of all test cases including rare and dangerous events
- Automated execution and evaluation of tests in all stages of the development process (MIL, SIL, HIL, VIL)
- Openness of the simulation environment for the integration of other software
- Use of prepared Test Ware Packages
Analyzing results and optimizing systems

CarMaker enables the storage of detailed result data of the entire test series as well as of individual test runs. In order to structure the large amounts of data and make use of these for further development, you can automatically export and save the test results after completing your tests. Coupling with big data analysis tools facilitates the evaluation of the reports.

The resulting findings offer insights into any potential performance limits of the systems under test and any required optimizations of individual parameters.

Your benefits at a glance

- Time savings thanks to automated analysis
- Automatic generation of results in illustrative test reports after the tests are completed
- Full traceability thanks to archives of all data used for the simulation as well as the test results

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As a global leader in virtual test driving technology, IPG Automotive develops innovative simulation solutions for vehicle development. Designed for seamless use, the software and hardware products can be applied throughout the entire development process, from proof of concept to validation and release. The company’s virtual prototyping technology facilitates the automotive systems engineering approach, allowing users to develop and test new systems in a virtual whole vehicle.

IPG Automotive is an expert in the field of virtual development methods for the application areas of ADAS & Automated Driving, Powertrain and Vehicle Dynamics. The company’s CarMaker product family is used around the world to address the challenges associated with developing and testing advanced driver assistance and automated driving functions by integrating a highly accurate vehicle model in a realistic environment. In order to generate realistic input data for the functions to be tested, detailed sensor models are stimulated by an environment model of any complexity, comprising elements of infrastructure and road users, while taking relevant environmental influences into account.

IPG Automotive stands for quality, holistic user orientation, efficiency, promotion of innovation and lasting partnership.