Developments on the Electronic Horizon

An integrated development environment for map-based driver assistance systems

Modern, map-based driver assistance systems are one way to solve the challenges posed by the road traffic of tomorrow. Efficient development of these systems requires a tool chain featuring flexible and configurable access to map data throughout all development phases. To meet the challenges of the tasks involved, NAVTEQ and dSPACE have coordinated their development tools.

The Road Traffic of Tomorrow

The automobile industry will face great challenges in the future. High traffic density, driver stress and information overload are making it increasingly difficult to drive and keep the general overview in traffic. On top of this, due to demographic change the number of older road users will increase. This is why road safety is a major focus of numerous discussions, as is the reduction of CO_2 emissions.

Motivation for Driver Assistance Systems

Modern driver assistance systems are an important way to solve these challenges. They help the driver keep track of the traffic, and can contribute significantly toward greater safety and reduced energy consumption. Many of today's driver assistance systems require a reliable detection of the vehicle environment. Information from radar, video, or ultrasonic sensors is the foundation of numerous applications such as adaptive cruise control, lane departure warning systems, and parking assistants. In the future, advanced driver assistance systems (ADAS) will intervene in the driving process more intensively and autonomously. For example they will influence braking and steering maneuvers, which will give drivers even more support in traffic.

Map-Based Driver Assistance Systems

One fundamental concept of advanced driver assistance systems is to capture not only short range information from the vehicle environment but also long range data on the road ahead based on high-quality digital maps and the current vehicle position. This detailed knowledge of the road ahead, such as slopes, road curvatures and speed limits, opens up the potential to create numerous new applications that enhance driving safety and CO_2 reduction. Predictive cruise control, overtaking and curve speed warning assistants, and intelligent concepts for energy and thermal management ("Looking forward", BMW Group, page 14), are just some examples. In general, these systems are called map-based advanced driver assistance systems (map-based ADAS).

Fundamentals: The Electronic Horizon and the Most Probable Path

To make information on the road ahead available to driver assistance

Map-based driver assistance systems utilize map attributes for the road ahead (i.e., of the most probable path) and predictively control various vehicle functions.

Four major factors govern how mobility will evolve in the future: environment, safety, traffic and demographics.

systems, an electronic horizon is needed which can be evaluated during driving in real time. The electronic horizon is a kind of virtual sensor that uses map data from a digitalized road map, the current vehicle position, and the vehicle's direction of travel to provide attributes of the roads ahead. This includes topographical data such as slopes and curvatures, and information on the traffic infrastructure such as traffic signs and the number of lanes.

The electronic horizon is periodically broadcast by a horizon provider via the associated vehicle bus. For this, the horizon provider constantly calculates the route along which the vehicle will likely travel. This route is called the most probable path (MPP). If the driver has selected a route in the satellite navigation system, that route is used as the MPP. If navigation is not activated, various heuristics are used to determine the MPP. These algorithms use static map attributes as well as dynamic

> The dSPACE tool chain supports the seamless development of map-based driver assistance systems.

vehicle states, such as the speed or a direction indicator signal. This method is also applied if a special cost-optimized elctronic control unit (ECU) without a user interface is being used instead of a satellite navigation system. The driver assistance functions receive the attributes from the electronic horizon and evaluate them. For example, a predictive energy management system uses data on slopes and speed limits, while adaptive headlight systems and curve speed warning assistants evaluate the road curvature.

NAVTEQ/dSPACE Tool Coupling

The right tools are needed to quickly implement new concepts, try them out in a vehicle, and test the production software. NAVTEQ and dSPACE have coordinated their efforts and have created an integrated development and test environment for map-based driver assistance systems.

NAVTEQ ADAS RP Development Environment

The ADAS Research Platform (ADAS RP) from NAVTEQ is a development environment for map-based driver assistance systems that runs on Windows® PCs. ADAS RP provides basic functions such as the visualization of maps, route planning and the indication of the vehicle position in respect to the digital map. It also serves as a horizon provider and sends the MPP and all the selected attributes for example via a network service. The ADAS RP development environment can be adapted to application-specific requirements by plug-ins, for example, to send the MPP via a proprietary protocol.

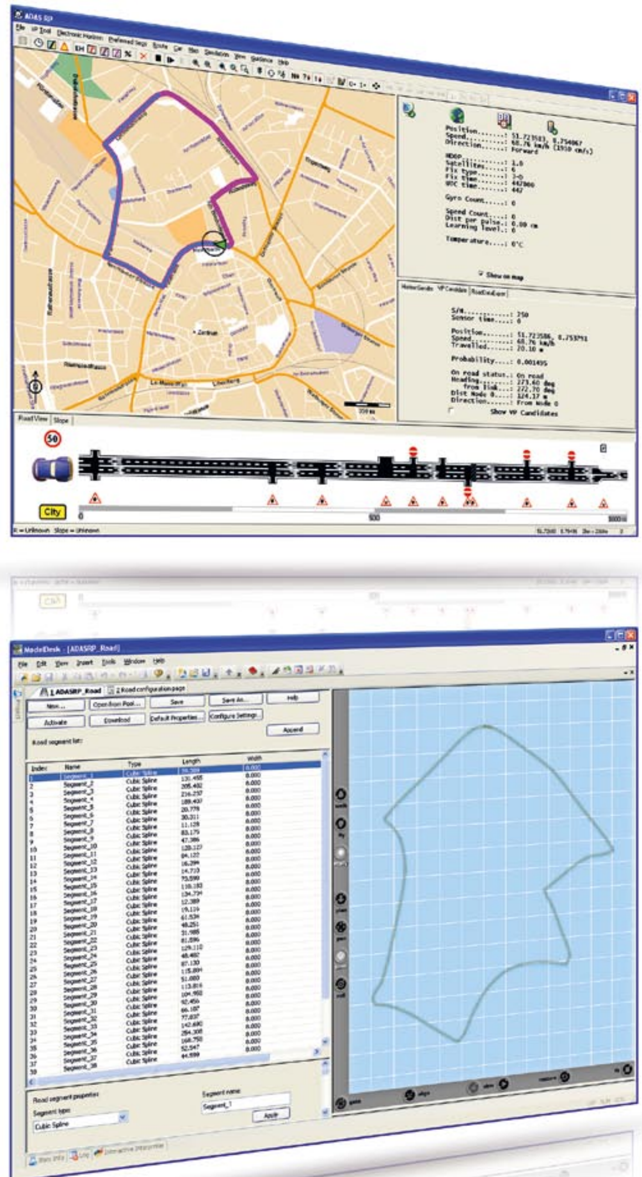
dSPACE Tool Chain for Map-Based Driver Assistance Systems

The dSPACE tool chain supports the major development phases in the model-based software development of map-based driver assistance systems. A specially created Simulink® blockset performs data exchange with ADAS RP and can be used for PC simulations and for real-time applications. The supported development phases include the following:

- Function development and offline simulation on a PC with the Automotive Simulation Models (ASM) and the ModelDesk parameterization software
- In-vehicle rapid control prototyping (RCP) with MicroAutoBox or AutoBox
- ECU testing by hardware-in-the-loop (HIL) simulation with the dSPACE Simulator and ASM

Coupling the Development Tools

The dSPACE tools are coupled to ADAS RP by file export and by the User Datagram Protocol/Internet Protocol (UDP/IP). For example, a navigation route can be exported as a road for the driving simulation. During simulation (PC/HIL) or rapid control prototyping, data is exchanged bidirectionally via UDP/IP. The receiver function blocks of dSPACE's ADAS RP blockset provides the Simulink model the electronic horizon received by the ADAS RP. The sender function blocks transfer the vehicle position simulated by ASM as GPS coordinates to ADAS RP. In an RCP application, sender function blocks take the information on the vehicle position, which was received by the vehicle's sensors, and transfer it to the ADAS RP. ■



A route from NAVTEQ ADAS RP (above) is exported as a route to dSPACE ModelDesk (below).

Sinisa Durekovic, NAVTEQ

We would like to thank Sinisa Durekovic of NAVTEQ for his kind support in producing this article. Mr. Durekovic is in charge of application-specific further development of ADAS RP at NAVTEQ in Sulzbach (Taunus), Germany.

Application Examples:

An Integrated Development Process for Map-Based Applications

Function Development and PC Simulation

The Task

In model-based function development, new ECU functions have to be tried and tested in a virtual environment at an early stage. Map-based assistance systems need a virtual vehicle and a virtual environment consisting of roads and, if necessary, other road users .

Development Environment

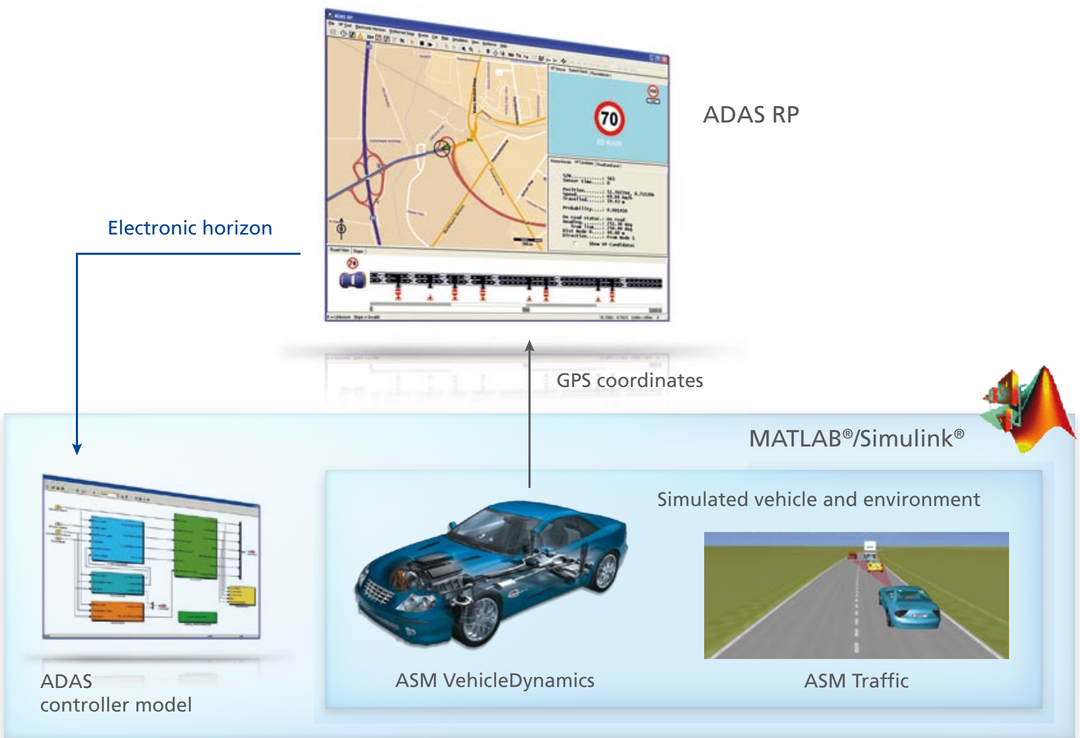
ASM VehicleDynamics is an open MATLAB/Simulink model. It is equipped with the ModelDesk parameterization software to enable the vehicle, roads, and maneuvers to be defined and configured. The ADAS RP development environment provides the electronic horizon. The two tools are coupled by a network service and can run together on one Windows PC.

Roles and Signals

A route defined in ADAS RP is exported to ASM VehicleDynamics for use as a road in simulation. During the driving simulation, the vehicle follows the road at a variable speed that is determined by the maneuver. Its position is sent to ADAS RP cyclically in the form of GPS coordinates. ADAS RP computes the electronic horizon for these coordinates and sends it to the simulation model. The attributes are available to the ADAS algorithm for evaluation.

The Benefits

- Map data used in early development phases
- Driving simulations on realistic roads



Application Examples

Rapid Control Prototyping (RCP): In-Vehicle Function Development and Tests

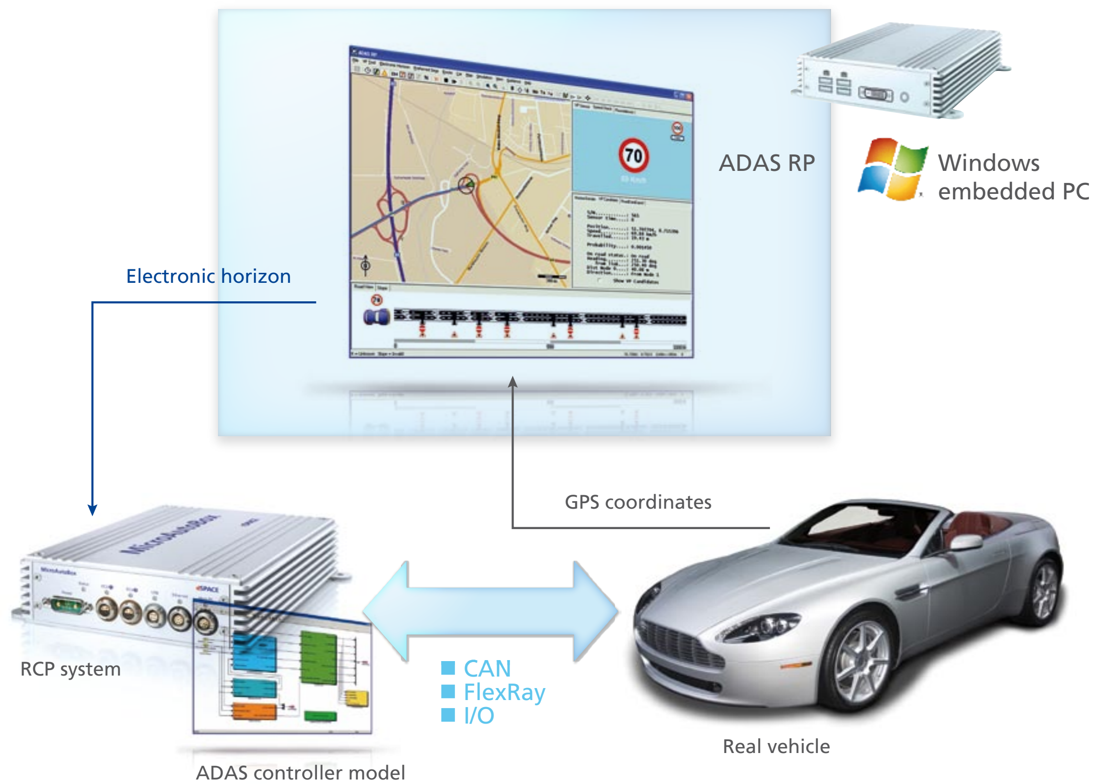
The Task
Developing, testing and optimizing software for map-based ADAS in a vehicle. The ADAS prototype has to be integrated into the vehicle like a real ECU, and communicate with the vehicle's bus systems (such as vehicle CAN). It must be possible to configure the electronic horizon flexibly.

Development Environment
MicroAutoBox and AutoBox are compact prototyping solutions for executing computing-intensive embedded software and integrating it in a vehicle's electrical system. They can be configured with all the interfaces necessary for map-based driver assistance systems. In a typical case, the sensors of the vehicle provide the GPS coordinates. If required, a sensorbox with high-quality sensors for position finding (GPS antennas, gyroscopes) can also be used. ADAS RP evaluates this position data and provides the electronic horizon for the real vehicle position.

Roles and Signals
Position data from in-vehicle sensors or a dedicated sensor box (e.g. from NAVTEQ) is acquired and transferred to ADAS RP. This matches the vehicle's position to the digital map and broadcasts the electronic horizon (MPP + road attributes) once per second. The dSPACE system, which is connected via Ethernet, receives the data and decodes it with the ADAS RP Blockset. The electronic horizon is then available to the algorithm under test on the MicroAutoBox or AutoBox.

The Benefits

- Map-based assistance systems tested and optimized under real driving conditions at an early stage
- Communication tested in the vehicle's electric/electronic system



ECU Testing by HIL Simulation

The Task
As part of the development process, control and diagnostic algorithms of new software versions of the map-based ADAS ECU have to be tested on a HIL simulator. For production release, network tests also need to be performed with the vehicle's ECUs.

Development Environment
Together with the ASM Vehicle Dynamics model, the dSPACE HIL Simulator provides the virtual controlled system for the production-ready ADAS ECU. It can be equipped with all the interfaces and simulation models needed to simulate a complete vehicle and its environment in real time. The electronic horizon is provided by ADAS RP on a Windows PC. ModelDesk is used to parameterize the vehicle model and create roads and maneuvers for the test cases.

Roles and Signals
A road exported from ADAS RP is available on the dSPACE Simulator. The vehicle's position (GPS coordinates), speed, and direction of travel are computed in the simulation model and passed to ADAS RP via Ethernet. ADAS RP calculates the MPP for the vehicle's position and sends it (for example, via CAN) to the map-based driver assistance ECU together with the attributes of the electronic horizon. Thus, the map-based ADAS ECU can be tested in a closed control loop. In addition, the usual test methods for testing ECUs automatically and reproducibly are also available.

The Benefits
- Automated, reproducible test cases
- Function testing and diagnostics testing on the component and network levels