The New Dynamic Driving Simulator at DLR

Reiner Suikat

Institute of Transportation Systems, German Aerospace Centre (DLR)

Lilienthalplatz 7, D-38108 Braunschweig

Tel.: +49-531-295-3434, Fax: +49-531-295-3427

E-Mail: reiner.suikat@dlr.de

Abstract

The DLR Institute of Transportation Systems is conducting research in driver's behaviour and interaction with advanced and future driver assistant systems. It has recently built up a large motion based simulator to be able to simulate driving situations and new assistance functions with a very high degree of realism. This paper will describe in detail the requirements and design ideas of the new simulator and show some first impressions of the simulator in operation.

The simulator is a motion based system with a high quality large field of view projection system and carries a full vehicle cabin. An innovative hexapod design with the hydraulic cylinders hinged at the upper rim of the projection system delivers a very large motion envelope within only six meters ceiling height. Another benefit of the novel design is that the rotation point is lying in a plane below the actuator hinges, which promises a big advantage for tilt coordination.

A modular rear-projection system with nine channels equipped with high resolution DLP-projectors offers a field of view of 270°x40° and a total resolution of about 8500x1240 pixels. The use of a rear projection system guarantees an unobstructed projection even with a large cockpit.

The simulator is driven by a real passenger car, a VW Golf. This increases the driver's impression of reality dramatically. All driver control inputs are available via the vehicles bus-systems plus special sensors. A high quality steering force simulation enhances the controllability of the simulator.

Introduction

The DLR Institute of Transportation Systems is conducting research in driver's behaviour and interaction with advanced and future driver assistant systems. To this end the institute operates a Driver Assistance Lab consisting at the moment of a Virtual Reality Simulator and a research vehicle to measure driver's behaviour, the ViewCar. Recently a large motion based simulator has been added to be able to simulate driving situations and new assistance functions with a very high degree of realism. This simulator is operational since April 2005 and currently motion tuning is taking place.

This paper will describe in detail the requirements and design ideas of the new simulator and show some first impressions of the simulator in operation.

Driver Assistant Lab

The main research task to be supported by the driving simulator is the development and evaluation of future driver assistance functions and HMI concepts. The Institute of Transportation Systems is focusing on the interaction of the driver with such systems and the functional and safety issues resulting from this interaction. Hence a strong focus is on experiments with real drivers. Only a limited amount of such experiments can be carried out on the road in real traffic for well known reasons: Cars equipped with such systems are not available or admitted to participate in traffic, it is very difficult to precisely control the scenarios and there is always a high risk involved. Therefore the institute is operating a multi-stage research infrastructure, the Driver Assistance Lab. The components of this lab cover the entire chain from gaining fundamental knowledge about driving up to evaluating assistance functions in real traffic.

The ViewCar, a research vehicle equipped with a variety of sensors to record the driver's actions and the traffic scenario, is used to answer the fundamental question how certain types of drivers behave in certain situations and what assistance needs can be derived from that. This vehicle is in operation since 2003 and has helped to increase the knowledge about drivers significantly. It can also be used to evaluate driver's interaction with passive assistance systems.

Figure 1 ViewCar®

A three stage infrastructure is planned for the actual evaluation of active assistance systems, allowing evaluation of concepts and prototypes at different degrees of maturity. First evaluations of new concepts can be carried out in the Virtual Reality Lab, a three sided cave using stereo projection and a very simple mockup for driving. Displays can be simulated in the virtual environment, so that concepts can be evaluated with real driver-in-the-loop tests without having to build a prototype. The second stage is the driving simulator described in this paper, which is designed to reach a very high degree of realism and immersion so that the actions of the drivers are as close as possible to what the drivers would have done in real traffic. This simulator features a full vehicle to drive the simulator and hence assistance systems need to be build as prototypes before being evaluated. Finally assistance functions will be evaluated in real traffic using a research vehicle equipped with drive-by-wire controls. This vehicle is planned to enter service in mid 2006.

Figure 2 Virtual Reality Lab

The DLR driving simulator

Figure 3 DLR driving simulator

Requirements

The main design requirements for the driving simulator follow from the basic philosophy of the Driver Assistance Lab. First the simulator must fit seamlessly into the research infrastructure. This means that as many components (software and hardware) as possible shall be common to the other parts of the lab. The second requirement is that the simulation shall have an extremely high degree of realism, so that the results of simulation studies may be considered valid. A third requirement is a flexible configuration, so that new assistant systems can be integrated into the simulator easily and efficiently.

These basic requirements translate into more detailed requirements for the individual components of the simulator:

1) Commonality
   Hardware- and software-interfaces for assistance systems shall be common to all test platforms (VR-Lab, simulator and research vehicle) where applicable.
   Scenarios and databases shall be exchangeable between VR-Lab and simulator.
2) Realism
   The simulator shall provide a highly immersive environment to the test driver, so that he behaves as if he was driving a real vehicle. This translates into specific requirements for:
   a) Motion
      A motion system supporting high fidelity motion rendering by large amplitudes, high bandwidth and small delays.
   b) Visual System
      A visual system with a large field of view, very high resolution and high quality databases.
   c) Cockpit
      A real vehicle to control the simulator with all cockpit interfaces functioning as expected and high quality steering force feedback.
3) Flexibility
   It shall be possible to change the cockpit easily and also to integrate future assistance systems into the cockpit.

In the following sections we describe what design choices were made to satisfy these requirements.

Motion platform

The design of the motion platform for the DLR driving simulator was driven by two major criteria: The platform should allow large linear motion in x- and y-direction combined with short transport delays and the system should fit into an existing building with a ceiling height of only six meters. Two designs competed for the simulator, an x/y-table combined with a small hexapod and a large "inverted" hexapod. Both were designed to carry the required projection system with a compact passenger car inside.

After careful evaluation the "inverted" hexapod system developed by the Braunschweig based simulator manufacturer Simtec was chosen. In this design the simulator cabin is hanging down in between the actuators, which are hinged to the cabin at the upper rim. While this does require rather large actuators with long travel, the overall height of the system is very small and the simulator settles down to just 50 cm above the ground. The large actuators having a stroke of 2 m allow x- and y-linear motion of ±1.50 m. The motion performance values are summarized in the table below, showing the very high performance of the platform.

Table 1 Simulator motion performance

	Travel	Velocity	Acceleration
x	±1,50 m	±2 m/s	±10 m/s²
y	±1,40 m	±2 m/s	±10 m/s²
z	±1,40 m	±2 m/s	±10 m/s²
pitch	-20 ° / +21 °	±50 °/s	±250 °/s²
roll	±21 °	±50 °/s	±250 °/s²
yaw	±21 °	±50 °/s	±250 °/s²

An additional benefit of this platform design is an improved usability of tilt coordination for simulating enduring accelerations. With a conventional system, having the platform on top of the hexapod, linear travel is required to tilt the platform with the point of rotation at the driver's head. Unfortunately this linear motion is in the same direction as needed for the direct rendering of the acceleration. Hence linear travel and tilt coordination cannot be used at the same time. With the inverted design this is different, since now the point of rotation is actually below the actuator hinges. Hence tilting the platform requires linear travel in the opposite direction.

Motion Cueing

A fundamental problem in driving simulation is the proper control of the motion platform to provide adaequate motion cueing. This is considerably more difficult in driving simulation than in flight simulation and a significant amount of research has taken place in the past. However, there are still numerous questions to be answered and motion cueing for driving simulation is a major ongoing research effort.

The Institute of Transportation System will be an active part of this research and several research activities are planned. Initially however the simulator will be operated with standard washout filters derived from flight simulation using a parameter set derived in a motion tuning phase, which is currently in progress. In the future DLR plans to develop innovative motion cueing algorithms to yield even better motion cueing. To this end the institute has teamed up with several partners in national and European research projects.

Visual system

One significant factor for a good feeling of immersion in a simulator is the visual system. It must provide a large enough field of view and sufficient resolution that the test person can get the required visual cues from it. For the DLR simulator a system with a field of view of 270°x40° has been chosen. It is an nine channel rear projection system with a continuous cylindrical screen. High resolution DLP-projectors (1280x1024 pixel) provide a bright and sharp image totaling some 8500x1280 pixel. Geometry correction and edge-blending is computed within the projectors. The advantage of using a rear projection system is the small height of the overall system and that even large cabins cannot obstruct the view.

A large 40" LCD-display mounted on the back seat serves as rear-view mirror, providing a very realistic impression, since it is actually viewed using the real mirror. Two small 5" high resolution displays are mounted in the side mirrors.

The images are generated using standard PC-hardware, one PC for each channel totaling twelve image generators. The visual software has been developed by DLR using Open SceneGraph and can read a large number of database formats. This software is identical to the visual software used in the VR-Lab.

Figure 4 Projection system and cockpit

Cockpit

The simulator is driven using a complete compact car, a VW Golf. This gives the test driver a very good sense of immersion, since his immediate environment is the real thing. He is surrounded by a complete car with a fully functional user interface. This has been possible by interfacing the cockpit using its CAN-bus system, so that all user actions are available to the software and all instruments can be controlled as expected by the driver. Since the electronics of the cockpit remain intact, even the multi-function buttons on the steering wheel are fully functional.

The steering wheel has been equipped with a torque motor for force feedback which is driven by data from the vehicle dynamics simulation, so that a good feeling for the road can be obtained. High quality force feedback is a major factor contributing to controllability of the simulated vehicle.

Software

The simulator software is designed using a modular concept. The main modules are shown in Figure 5.

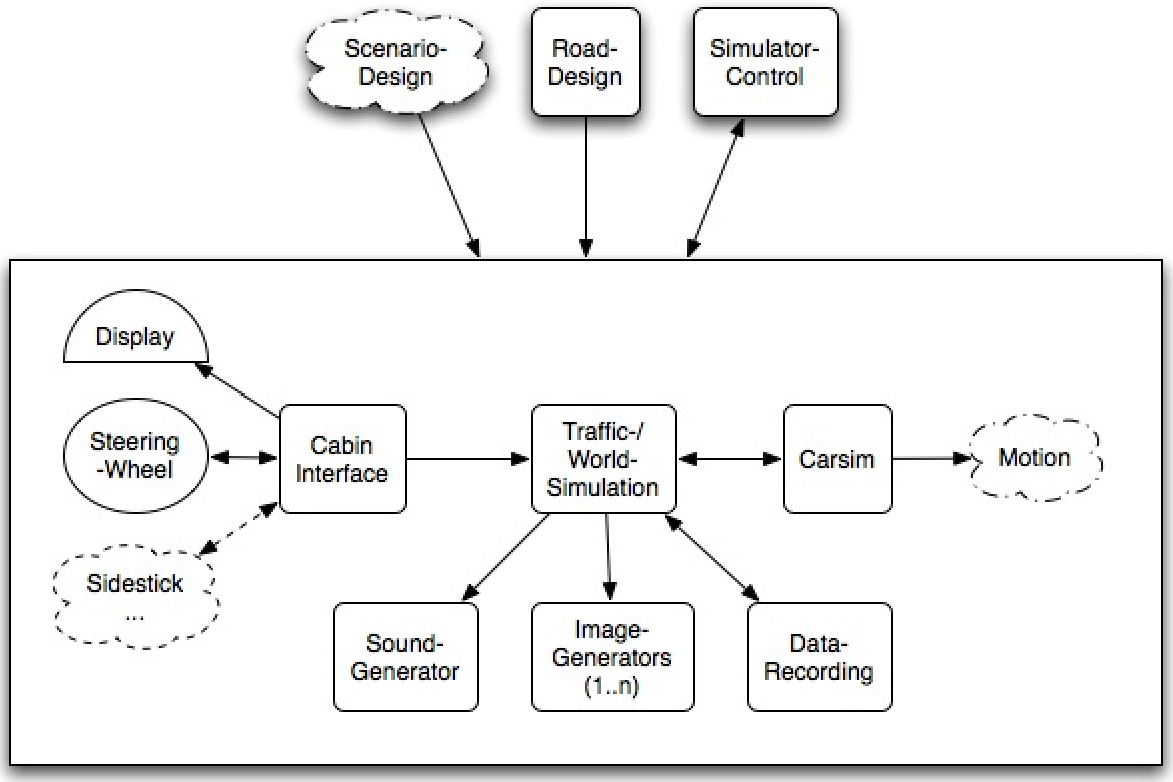

Figure 5 Software Modules

The modular architecture allows optimization/replacement of individual modules without sacrificing overall functionality. The communication core and several other modules have been developed in-house to meet the specific needs of the Driver Assistance Lab infrastructure. Modules available on the market with the desired performance and affordable price have been purchased to accelerate overall software completion. These include the traffic simulation and road design (STSoftware), sound generator (VRTainment) and vehicle dynamics (CARSIM, MSC). The software runs on a PC-cluster with dedicated PCs for most modules. This results in a low cost (compared to high-end graphics workstations) and highly efficient hardware environment.

Conclusion

The DLR Institute of Transportation Systems is developing and evaluating future driver assistance systems. For this purpose it operates a multi-staged research infrastructure to study and assess the driver's interaction with advanced systems and future traffic scenarios. A major component of this infrastructure is a motion based driving simulator, which has beed presented in this paper.

The simulator has been designed to meet three major goals: Compatability with the existing and planned research infrastructure, a very high degree of realism and immersion, and finally a flexible design to be able to integrate new assistance systems easily. A new motion platform concept has been developed for this simulator that promises exceptional motion cueing performance and improved usability. A high end projection system combined with a complete car to drive the simulator add to the realism experienced by the test driver.

After an initial motion tuning phase the simulator will be used for first real experiments near the end of 2005. Being the operator of a major research driving simulator DLR will not only use this simulator as a tool for the evaluation of driving assistance functions, but also actively participate in driving simulation research, in particular in motion cueing.

References

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