Use of Driving Simulators within Car Development

Johannes Colditz[1], Ludger Dragon[1], Rüdiger Faul[1], Darko Meljnikov[2], Volkhard Schill[3], Thomas Unselt[4] and Eberhard Zeeb[3]

DaimlerChrysler AG

[1] Mercedes Car Development; Dept. Vehicle Dynamics, Simulation and Analysis

[2] Truck Group; Dept. CAE Active and Passive Safety

[3] Group Research and Advanced Engineering; Dept. Driving Simulators
Daimlerstr. 143, 12277 Berlin

[4]Group Research and Advanced Engineering, Dept. Human Factors

Abstract

Since 1985 DaimlerChryslers moving base driving simulator has been permanently improved and his role has changed from a basic research tool to a widely accepted tool within DaimlerChryslers predevelopment and development process for driver assistance systems, human machine interfaces as well as chassis systems. Nowadays it is extensively used for driver acceptance and driver behavior tests with normal drivers as well as for drive dynamic assessments done by expert test drivers. Because we can not check ride aspects at the Berlin handling simulator we added last year a new ride simulator, based in our Sindelfingen facility. This new tool is very important in context with our new development process which contains a so called "Digital Prototype".

In our paper we describe the current functionalities of our handling simulator in Berlin, especially our latest improvements regarding night time and in town driving, and of our newly installed ride simulator. Furthermore we give examples of simulator studies conducted to quantify benefits of driver assistance systems at cross roads and of drive dynamic assessments, allowing the subjective rating of new chassis system in an early development process with digital prototypes and a first optimization even before real hardware prototypes are build up.

Introduction

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In this paper we describe the main functional extensions of our driving simulators in Berlin and Sindelfingen. Namely we have improved the imaging system of our moving base simulator in Berlin, allowing very realistic night time drives with variable headlight functionalities of the own car. The newly installed ride simulator, based on an electrical hexapod was already used within the development process of the currently introduced new C-class model.

In the second part of the paper, as an example for a typical experiment with normal test drivers, the reconstructions of real accident situations at road crossings in town and out of town are shown. To show the usage of our simulator facilities for driving dynamics analysis and development we give two examples from heavy truck as well as from passenger car development allowing the subjective rating of new chassis system in an early development process with digital prototypes and a first optimization even before real hardware prototypes are build up.

Functional extensions of DC's driving simulator facilities

Visual system for realistic night time drives

The current image genaration system of the Berlin driving simulator uses a Evans&Sutherland Renderbeast PC-cluster consisting of 18 Simfusion 6500q PCs and the commercial VegaPrime visualization software [1]. VegaPrime does not provide adequate headlight functionalities, so that it was necessary to enhance the software. As software solution a vertex shader and a pixel shader technology was used. Textures were created out of light distributions from existing headlight, using standard light measurement utilities. These textures then are read in the visualization software.

The well known method using projected textures isn't accurate enough. To create utmost realistic lighting effects the shader technology that is available in all state of the art computer graphic boards does create better results. But the shader capability of the Simfusion PC's is not powerful enough. Therefore new high-end COTS PC's -each with two NVIDIA Quadro FX 5500 SLI boards- are integrated in the visualization cluster. Only the three front channel PC's are replaced, the far side channels and the rear channel are not affected. The integration of pixel and vertex shaders into the VegaPrime environment turned out to be a challenge but eventually it did work pretty well.

The requirement for the headlight simulation is not only to appear realistic, but show the most current light technology that is used by Mercedes-Benz. The interface for that purpose should be easy to adopt for new lighting technologies. Standard light measurement tools are used to create a texture of the light distribution. This texture is read into the shader extension. Several different textures, e.g. high beam and low beam, are simultaneously available in the software. The switching between the different textures happens without any delay.
The installed solution allows a very realistic visualization of head lights as shown as an example in Fig. 1 It allows an easy installation of different light textures, e.g. for typical halogen or xenon light distributions.

Fig. 1: Approaching a construction area with high beam (left) and low beam (right) head lights.

Ride simulator

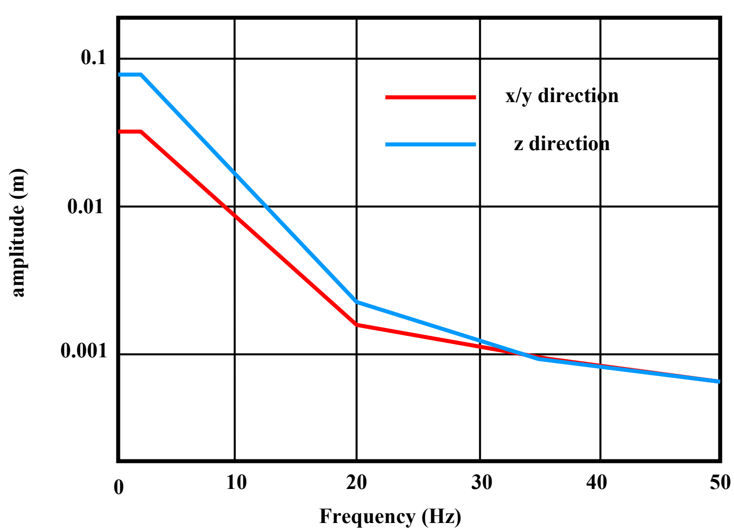

Fig. 2: Required vibration amplitudes for driving comfort studies.

At the Berlin driving simulator we are not able to perform studies concerning the comfort behavior of chassis systems, because of the frequency limitations of the dome structure and the hydraulic hexapod [2]. For such studies it is necessary to induce vibrations with small amplitudes below 200 mm but within the frequency range up to 50 Hz to the car cabin or the driver's seat. A typical spectral requirement for chassis comfort studies is shown in Fig. 2.
Therefore we developed and installed a special ride simulator. A photo of it is shown in Fig. 2. Two car seats are mounted on a platform which is based on an electrical hexapod system from Moog-FCS. The motion envelope of the platform is about ± 250 mm in x and y direction and ± 200 mm in z-direction. Rotational degrees of freedom are about ± 6 degrees for yawing, pitching and rolling. Maximum acceleration values of ± 10 m/s^2 for a payload of 800 kg are achieved. The hexapod system is mounted on a large concrete foundation of 250 tons weight which is isolated against the foundation of the building by air suspensions. In front of the seats a flat video screen is installed to display the front view of a driving scenario.

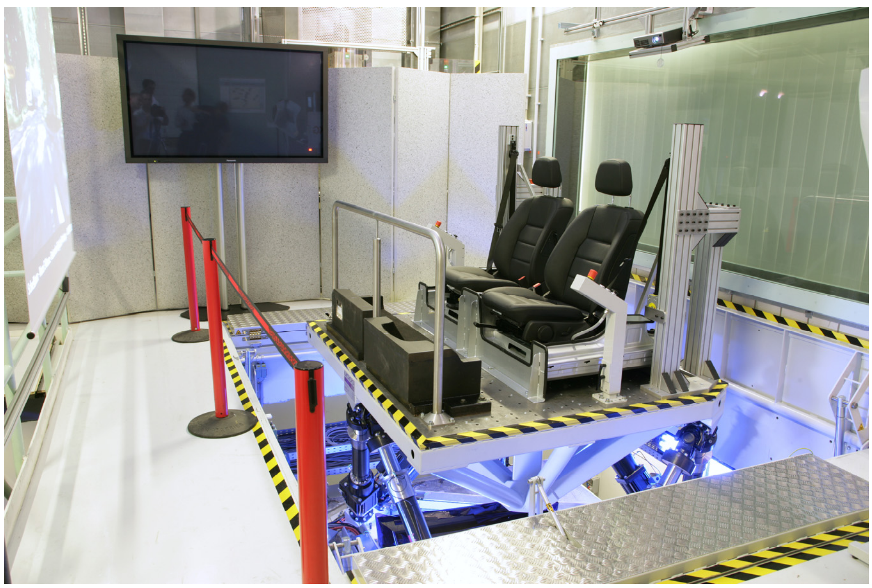

Fig. 3: Photograph of DCs ride simulator.

In contrast to the handling simulator the subjects are not integrated in the loop They are fully passive like passengers. So they are completely focused on the ride quality estimation without any deflection through driver duties.
Off line simulations made a big advancement in the last few years so that we are now able to simulate any vibration in all degrees of freedom in any position of a non existing car with the help of multi-body simulations and digitized road services. These simulation results than can be replayed with the Ride Simulator and specialists as well as decision makers can rate the actual stage of development and decide in which direction further development efforts should go to give our customers an optimum in the conflict of the objectives ride and handling for the next car generation.

Example of experiments

Analysis of drivers reactions in typical road crossing accidents

Accident reconstruction

To avoid crossroad accidents through the benefit of future driver assistant systems it is necessary to analyse this accident type and driver reactions in critical driving situation at crossroads in detail. Therefore we reconstructed the scene and the driving maneuvers of real life crossroad accidents [3] which were found to be representative for this group of accidents adapted from the GIDAS [4] accident data base.

As an example Fig.4 shows a comparison of a real road crossing in the city of Dresden (left) with the image of the crossing (right). Buildings, trees, traffic signs, etc. are placed in a very similar position as in reality and even parking vehicles are added in the some manner as in the real accident situation.

Fig. 4: Comparison of real (left) and reconstructed (right) road crossing.

In addition to the rebuilding of the static vicinity we also reconstructed the complete accident situation, e.g. the maneuvers of other vehicles involved in the accident out off the accident report.

Simulator experiment and results

For the simulator experiment a 60 km long test track consisting of rural and urban road parts was used. The duration of the test drive was about 40 minutes. Within the test track two critical road crossing situations where integrated. 50 subjects of both sexes and with an age between 20 and 65 drove within the experiment only once each. In case that the driver had an accident the experiment was not continued. Accidents themselves were not displayed realistically to avoid extreme stress situations for the test drivers. Beside the driving dynamics data of the car we also recorded the head and the eye movement of the drivers before and during the road crossing situations. The evaluation of the glance behaviour provides details on the driver attention during the approach to crossroads.

Drivers were also asked after the situations how they experienced the situation and how they reacted.
One goal of the experiment was to find out if and how in the simulator critical road crossing situations in principal could be realistically reproduced. This could be approved for all investigated situation.
Additionally it was found that test drivers tend to drive more careful in the simulator as in reality. If they have to pass more than one critical situation within the test drive they tent to react in advance, even before real risks are visible. Despite this fact, brake reaction of most of the subjects during the critical situation itself was found to be insufficient to avoid the accident. Thus brake assistant systems will have a potential benefit to reduce the accident rate at crossroads.

Assessment of heavy truck handling and steering performance

Real time simulation models for trucks

Especially with trucks and their variety of axle and trailer configurations, it is an efficient approach to use a multi body system (MBS) tool for model definition. DaimlerChrysler Commercial Vehicles use the MBS tool Simpack to build up detailed dynamic vehicle models including flexible parts like the frame, leaf springs and axles. With the same tool, it is now possible to create efficient real time truck models represented by ordinary differential equations instead of DAE and to integrate them via Code Export into target systems such as the driving simulator or hardware-in-the-loop test rigs. Based on this process, different truck configurations are available at the driving simulator: a semitrailer truck as well as solo trucks with three and with two axles.
To meet real time conditions, some model simplifications are necessary. A semitrailer truck has twelve tires. For each tire, the contact to the driving simulator road surface model has to be calculated. At the moment, it is not possible to perform twelve contact calculations in addition to the model calculation within 1 ms step size. So it is necessary to combine the three semitrailer axles into one axle model and to generate a tire data set for the semitrailer tires which behaves like the sum of the three tires. In the same way, the double tires at the rear axle are combined into one tire model with the properties of the double tire. With the resulting six tires, the simulation is fast enough for real time simulation including road contact. Of course, the simplified models are validated with the detailed MBS models of the vehicles and with vehicle measurements.

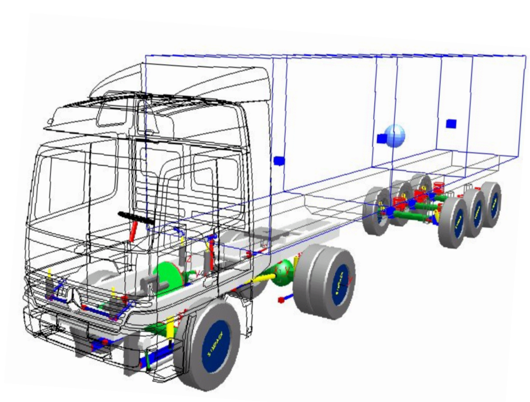

Fig. 5: Schematic of semitrailer truck.

All real time truck models have rigid axles with 2 or 3 DOF relative to the frame, a front axle with a steering DOF for each wheel, a torsional frame elasticity between front and rear axle, a cabin with its suspension, and a power steering model with friction, damping and play. The models provide a realistic vehicle response and steering torque at handling maneuvers.

Setup and goals of simulator experiments

Using a heavy truck cabin at the driving simulator, tests are performed together with testing and design engineers and professional truckers to define target values for handling and steering performance of future trucks and to support suspension concept decisions and the specification of parts. For handling maneuvers, a straight, two-lane highway is used. The lateral movement at lane changes is fully covered by the lateral cylinder of the simulator. This leads to a very realistic motion simulation. Small signal steering behavior is evaluated on a narrow, curved country road with oncoming traffic, and additional driving situations like lane grooves are in preparation. The possibility to obtain subjective evaluation of simulation models helps to develop objective target values and to learn which amount of parameter or target value changes is perceptible.
Different pylon patterns like lane change and slalom are positioned on the road during driving at driver's demand, and vehicle variants are changed within some seconds, so that vehicle variants can be compared and assessed very efficiently. Moreover, interesting new variants can be generated quickly based on the ideas that come up during driving. This allows to investigate a big parameter space in a target-oriented way and helps to focus vehicle testing on the most promising parameter combinations. Thus the driving simulator plays an important role in an efficient truck development process.

Passenger car drive dynamic experiments

As described before the digital prototype plays now a fundamental role in the development cycle of new car models in our house. The new C-class of Mercedes-Benz is the world's first production vehicle to be designed and developed based on a digital prototype (DPT) [5]. It is described within 1.2 terabyte !

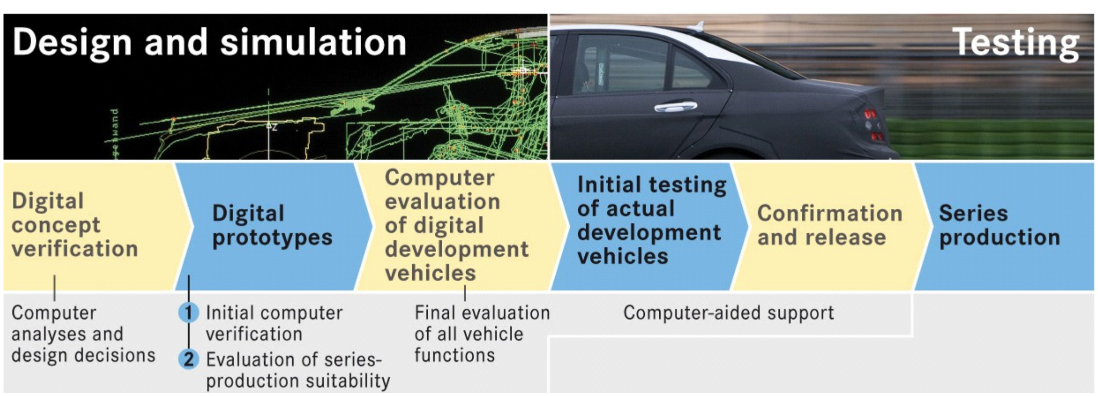

Fig. 6: Development process with digital prototypes in development phase 1.

The development process thereby is divided into two phases, a concept and calculation phase 1 with digital prototypes (see Fig. 6) and a field testing phase 2 with real prototypes.
One important part of the digital prototype is the driving dynamics model, which is modeled in the Mercedes-Benz Car Group with FADYS [6] for driving dynamics and handling as well as DADS for ride simulations. These models of the car were used to perform large amounts of virtual test drives on computers long before the first real prototype is produced. They also can be transferred to our simulators to evaluate the ride and handling behavior of the virtual car subjectively. For rating, comparison and optimization of the handling behavior of different virtual chassis system prototypes, test drivers asses the cornering capabilities, the steering characteristics, the side wide sensitivity etc. by driving typical maneuvers, e.g. slalom or lane changes, or driving along side wind machines at the Berlin driving simulator. Some maneuvers have to be scaled down to about 70 % in the amplitude and in the angular and linear dynamics, due to the dimension of the motion envelope and the dynamical limitations of the simulator, but still allow a good comparison of different parameter sets. In addition to the handling test drives, the same date base is used at the ride simulator described above, to evaluate the driving comfort behavior of the virtual chassis. At the end of the test series the data for the shock absorber characteristics, the spring rates, the steering characteristics etc. are defined as a solid foundation for the subsequent field test phase. During the development of the C-class several thousand test kilometers were driving on the simulators. This helped dramatically to improve the state of maturity of the first hardware prototypes.

Conclusion and outlook

Within DaimlerChrysler the Berlin handling simulator and the Sindelfingen ride simulator are extensively used for driving dynamics assessments, ride assessments as well as for the evaluation of driver assistant systems. To even better integrate driving simulators into the car development process, we have decided to build up a new Driving Simulator Center close to the Mercedes-Benz Development Center in Sindelfingen, which will go into operation in 2009.

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