

Subjective Perception and Evaluation of Driving Dynamics in the Virtual Test Drive

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ABSTRACT

In addition to the analysis of human driving behavior or the development of new advanced driver assistance systems, the high simulation quality of today's driving simulators enables investigations of selected topics pertaining to driving dynamics. With high reproducibility and fast generation of vehicle variants the subjective evaluation process leads to a better system understanding in the early development stages.

The transfer of the original on-road test run to the virtual reality of the driving simulator includes the full flexibility of the vehicle model, the maneuver and the test track, which allows new possibilities of investigation. With the opportunity of a realistic whole-vehicle simulation provided by the Stuttgart Driving Simulator new analysis of the human's thresholds of perception are carried out. The thresholds give general information about the perception of vehicle body motion, which are caused by road unevenness or bumps and transferred over the vehicle body to the occupants.

Furthermore, the resulting vehicle body motion due to such road impacts is analyzed in the simulator. Based on real test runs on the autobahn the vehicle's body motion is measured after overrunning the road unevenness and exactly implemented in the driving simulator. For more detailed evaluation the excitation is divided into single impulses according to the vehicle's degrees of freedom. In the present case rolling and yawing motion are considered separately. The driver can modify amplitude and phase of the single impulses by control elements to get an immediate subjective impression of the resulting vehicle motion. A detailed five-mass vehicle model, synthesized road profiles and measured road excitations provide the basis of this analysis to obtain more realistic results. With this method new objective criteria can be derived to enhance the basic design of driving dynamics.

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INTRODUCTION

New Advanced Driver Assistance Systems and the increasing number of vehicle derivatives pose a challenge to the present chassis development process. In addition to the conventional developmental possibilities of simulation and test runs, the driving simulators are used more and more frequently to generate a better understanding of the entire system. With the aid of the driving simulator the subjective evaluation of driving dynamics leads to additional knowledge in early stages of the development process. With this knowledge important decisions can be finalized sooner which involve a reduction of prototypes and the saving of costs and time [1]. As a result the implementation of the driving simulator to the simulation process complements the tool chain by the subjective evaluation (Figure 1).

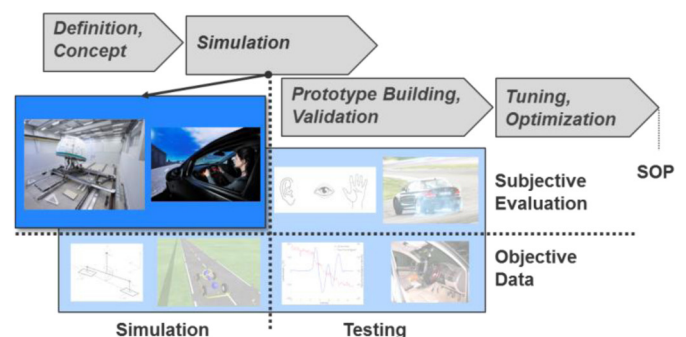


Figure 1. Subjective evaluation based on driving simulator tests complements the tool chain in the early stages of the development process.

The quality of today's simulators allows analyses regarding certain topics of driving dynamics. As is generally known, the exploration of the vehicle's full capability or analyses of lateral dynamics in combination with longitudinal motion are partly practicable. However, certain topics, e.g. high speed stability, crosswind and primary ride are particularly suitable for investigation including the simulator [2]. Real on-road test drives are often severely restricted by permanently changing test conditions. Influences like wetness, temperature and crosswind can affect the results of the test runs. In the simulator high reproducibility and fast generation of variants modifications of the chassis setup are immediately noticeable and assessable by the driver. This benefit makes the optimization of chassis setup and the comparison of vehicle variants pass more quickly.

Such applications using a driving simulator require a specific control of the simulator's movement. The simulator has to ensure the motion calculated by the vehicle model. In the Stuttgart Driving Simulator (Figure 2) the vehicle movement is provided by the xy-table and the hexapod which result in eight degrees of freedom. To fulfill the target movement the lateral motion of the hexapod is combined with the lateral motion of the xy-table in consideration of an optimized amplitude response [3]. Furthermore a predictive motion cueing algorithm is applied. The algorithm calculates the dome's optimal position and enables a maximum dynamic range for the test run [4].

While transferring the scenario to the simulation environment an important aspect represents the vehicle model used for simulation. Basically, the model reproduces the vehicle's behaviour. The structure of the model has to include an appropriate level of complexity. A low level of model complexity does not allow a realistic driving impression caused by insufficient simulation accuracy [5]. An exact model, however, can cause enormous computing time and violates the real-time capability.



Figure 2. Stuttgart Driving Simulator with xy-table and hexapod (8 dof)

In the context of this work the Stuttgart Driving Simulator is used to analyze the driving dynamics and the primary ride comfort. The implementation of the virtual driving scenario rests on the exact reproduction of the vehicle body motion and the subjective driving impression. In detail the vehicle motion during the overrunning of

single events, e.g. autobahn unevenness, bridge joints and road bumps is evaluated. Particularly the resulting coupling of yawing and rolling motion is investigated. Admittedly, evaluation processes generating objective criteria in frequency domain are already available. But these processes do not consider short single events, primarily apply to harmonic sines and are partly applicable to the reality [6]. Altogether, there are insufficient investigations about the objectification of the detailed vehicle body's motion due to such single events. In addition to that, new criteria to objectify this combined vehicle movement shall be determined in the simulator.

The subjective perception plays a major role when using the driving simulator for driving dynamics applications Knauer [6] investigates thresholds of perception by masking a randomized and unequal excitation with a stochastic road spectrum. His investigations only refer to vertical and longitudinal acceleration located at the driver's seat. To obtain further information new fundamental investigations about the perception thresholds concerning lateral dynamics are realized.

IMPLEMENTATION OF THE DRIVING SCENARIO

The following investigation shows necessary steps to generate a most realistic driving impression in the simulator. This is crucial for making the driver immerse in the virtual reality which is a prerequisite for realistic driver behavior and subjective assessment. Therefore, seven experts form a group to carry out the test runs. All subjects are experienced with the driving simulator. The researched autobahn scenario bases on driving at high speed over 180 km/h. Depending on the autobahn surfaces single events like road unevenness, bridge joints and road bumps represent significant impulses. Due to these impulses the characteristics of the chassis components, the kinematics and elastokinematics initiate a vehicle body motion. In particular the combination of the resulting yawing and rolling motion increasingly influences the driver's assessment. Especially at high speed cornering up to 0.3 g and overtaking maneuvers these impacts have a bearing on secure feel and vehicle's stability [1].

Generally, such conspicuous single events will have a strong influence on the drivers' subjective impression and assessment which is a result of their selective perception. If there are memorable events between several test vehicles, the absolute differentiation between test vehicles becomes easier [6]. According to the experience of many test drivers continuous and monotonic excitations are adapted by the driver and make the subjective comparison of the ride comfort more difficult.

Principle of Driving Dynamics Evaluation in the Simulator

Fundamental differences, as compared with the common vehicle evaluation process on road are resulting from analysis in the simulator (Figure 3). Instead of the real test vehicle a simulation model is responsible for the vehicle's reaction. An advantage is the full access to the model's output data and parameters from chassis components and assemblies. Changing components or their