COMBINED MOTION OF A HEXAPOD WITH A XY-TABLE SYSTEM FOR LATERAL MOVEMENTS

Jürgen Pitz [1], Minh-Tri Nguyen [1], Dr. Gerd Baumann [2], Prof. Dr. Hans-Christian Reuss [1]

(1) University of Stuttgart, IVK, Pfaffenwaldring 12, 70569 Stuttgart, Germany
{juergen.pitz, minh-tri.nguyen, hans-chrisitian.reuss}@ivk.uni-stuttgart.de

(2) FKFS, Pfaffenwaldring 12, 70569 Stuttgart, Germany
gerd.baumann@fkfs.de

Abstract – In this paper, a new model based approach to combine the lateral motion of a hexapod with the lateral motion of a xy-table is described. The proposed method allows using maximum dynamic range with an optimized amplitude response while having large lateral movements. As an example for this approach, studies of driving under natural crosswind in the Stuttgart Driving Simulator are presented.

1. Introduction

Driving simulators have an increasing influence in research and development in the automotive industry. They are configured for investigation of vehicle dynamics as well as for development of advanced driver assistance systems.

The common shape of driving simulators as hexapod is more and more extended with additional motion systems or replaced by other concepts. For the design of the Stuttgart Driving Simulator at IVK, shown in Fig.1, the focus was placed on a wide range of possible applications. Therefore the hexapod is mounted on a xy-table which allows 10 m linear motion in vehicle longitudinal and 7 m in lateral direction. The drives of hexapod and table system are designed completely electric. In sum this system has eight degrees of freedom [Bau1].

To control the motion system, a Classical Washout Algorithm for an 8 DOF simulator is implemented by default. As described in [Fis1], the command signal is split into different frequency bands. The best possible representation of acceleration is achieved by using each degree-of-freedom in accordance with its dynamic possibilities. Considering acceleration in the vehicle lateral direction, high-frequency signals are generated with a lateral motion of the hexapod. Mean frequencies are represented by motion of the y-table and low-frequency contents up to stationary accelerations by a rolling motion of the hexapod. Many different driving situations can be simulated with this classical algorithm. The xy-table has a positive effect on the perception of acceleration in the dome. Longitudinal or lateral accelerations can last longer until the tilt of the dome begins.

Fig. 1. Total view of the Stuttgart Driving Simulator

Because of its dimension, the motion system is able to represent small lateral movements without using tilt-coordination. These occur, for example, under the influence of crosswind or while changing the lane on a motor way. The position of the simulator then correlates with the position of the vehicle on the road. For this purpose, all degrees-of-freedom can be controlled by a simulation computer, so that the Classical Washout Algorithm is unused.

2. Method description

By using only one component of the motion system, a linear amplitude response of the acceleration of such lateral movements might be achieved and the influence of the motion system can be minimized. The hexapod alone is too small for this type of excitation. As described in [Bor1] it is possible to use only the y-table. Due to the low dynamic of this part of the rail-system, this alternative has limitations which have a negative effect on the phase behavior of the simulator. The best result is obtained from the combined use of both systems. The rail system is used to realize a large space for movement and the hexapod to achieve a high dynamic range.

The presented method exploits the maximum performance of the y-table and uses the hexapod to compensate the resulting difference between set-point and actual position of the y-table. For this compensation the exact actual position, velocity and acceleration of the y-table are necessary.

This data is provided by the motion system. It transmits them to the real-time computer, which controls the simulator. The sampling rate of this transmission is too low for a satisfying result. Due to noise, the signals have to be filtered for further use, which results in negative effects on time behavior.

To determine the position of the y-table without using the measured signals from the system, the dynamic behavior of the y-table is modeled with a transfer function. This transfer function can be implemented on a real-time-target directly to determine the difference between desired and actual position. This difference is used as input signal to a pilot control to actuate the hexapod. With this method, the hexapod can compensate the occurred discrepancy.

As the dynamic behavior of the y-table is equivalent to a low-pass filter, a 2-way frequency crossover is formed as known from classical algorithms (see above). In classical algorithms this crossover is not influenced by the transient response of one part of the motion system. The presented proposal integrates the transient behavior of the y-table into the algorithm to create a matching low-pass-filter in order to achieve a linear amplitude over a wide frequency range with the combination of hexapod and y-table. In addition a pilot control for the other degrees-of-freedom is used to improve the system behavior.

3. Applications

An adequate example to use the described approach is the simulation of driving under natural crosswind conditions as described in [Kra1]. An interdisciplinary team within IVK and FKFS works together, to find methods, how aerodynamic and driving dynamics modifications can directly be experienced by development engineers in the Stuttgart Driving Simulator. Based on real on-road measurements, the scenario for driving under the influence of stochastic crosswind is transferred to the simulator.

For simulation of the lateral vehicle dynamics an enhanced single-tack model is used, which very well reproduces the transient behavior in the relevant frequency range. Based on unsteady wind tunnel measurements a model of transient aerodynamics is developed. Both models have to be real-time capable.

With this development platform, the influence of stochastic crosswind on the driving behavior is simulated. The driver inside the simulator has the task, to keep the vehicle on the lane.

With respect to driving dynamics it is necessary to reproduce the reality in the simulator as accurately as possible. However, it is more important to resolve different vehicle characteristics in the same way as in reality. To determine the perceptibility of characteristics, different variations of model parameters are implemented to evaluate the modified driving behavior immediatly. First results show that even small parameter variations are perceptible by the drivers.

4. Conclusion and Outlook

Because of the satisfying results with the presented application, the approach to couple the two lateral degrees-of-freedom of the Stuttgart Driving Simulator will be used for other applications as well. The focus will be initially on high dynamic maneuvers such like double lane change and slalom.

5. References

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