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A Guidance Scheme for Full Car Dynamics Simulations

The performance of active vehicle control systems, such as anti-lock brakes, in a virtual prototype driven along a course can be tested by Hardware-in-the-Loop (HIL) experiments linked to full car dynamics simulations in real time. For investigation of optimal car-driveability, guidance of the virtual prototype at its driving limits is of great interest. We suggest a guidance scheme for nonlinear real time control of the position of the center of gravity of the full car model along a desired path.

1. Introduction

Every major auto manufacturer and most major automotive suppliers must use *virtual prototyping* to cut time and cost and to improve design quality. In order to "test drive" entire vehicles in the computer, realistic models of the car, the driver, and the environment (course of road, weather) are required.

The virtual car is described by mechanical systems taking into account the effects of applied and inertial forces [4,5,6]. The car model consists of multi-body systems of the car structure, the powertrain, the steering mechanism, and the axle kinematics. Also, proper tire models are very important. The numerical simulation of the full motion behavior is done by solving large-scale systems of ordinary differential or differential-algebraic equations [7]. Here, we use the special purpose method VEDYNA [3] enabling vehicle dynamics simulation in real time [5] as required for HIL applications.

A tailored and parameterized road model for VEDYNA has been developed and implemented in [8]. Hereby, a realistic road can already be obtained with relatively few parameters, although the level of detail can be adapted. This realistic road model is suitable for real time simulation.

2. Online control of the virtual car

For guiding the center of gravity of the full car dynamics model along a nominal path on the virtual road, we have developed a nonlinear position control law [8,9]. The nonlinear controller is based on a reduced car model, namely a single track model, and the theory of nonlinear system decoupling and control [2]. Inputs are the current position of the center of gravity of the full car model, and its set point position. Outputs are the front lateral force and the longitudinal force which have to be achieved by appropriate steering angle and brake or gas pedal position.

The visualization of numerical results for the virtual test drive of a midsize car on a course with partially icy pavement is given in the next section. Here, set point for the position of the center of gravity of the car travels along the center stripe of the closed test course. The velocity profile along the nominal path is determined online (cf. [9]) depending on four parameters describing the car and the risk taking willingness of the driver: maximum longitudinal acceleration $a_{l,\max} = 3.5\,[\mathrm{m/s^2}]$, maximum longitudinal deceleration $a_{l,\min} = -9.81\,[\mathrm{m/s^2}]$, maximum lateral accelaration $a_{y,\max} = 7.2\,[\mathrm{m/s^2}]$, and maximum speed $v_{\max} = 200\,[\mathrm{km/h}]$.

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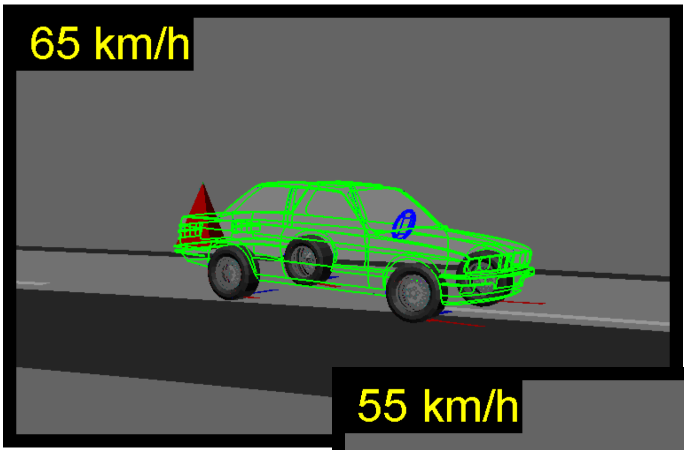
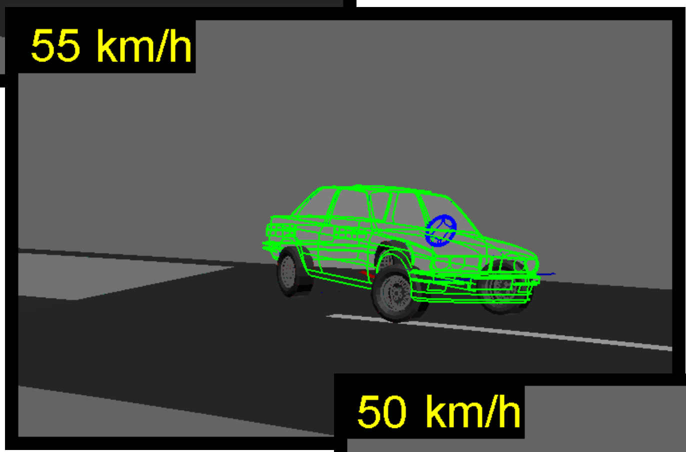
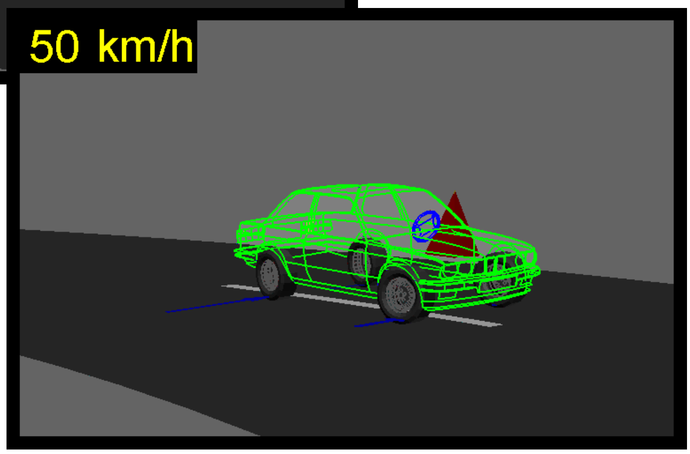
3. Numerical results for a virtual test drive







The developed guidance scheme is applied to the test drive of a virtual prototype of a midsize car. The partially icy pavement causes the car to skid. However, the virtual driver, i. e., the developed online controller of the full car dynamics simulation, keeps the car on the road even in this critial situation at the driving limits.

4. References

1 Chucholowski, C.; Vögel, M.; von Stryk, O.; Wolter, T.-M.: Real time simulation and online control of cars: the moose test and similar handling and driveability investigations. To appear in: Lecture Notes in Computational Science and Engineering, Proc. Intern. FORTWIHR Conf., München, March 16-18, 1998.

2 Mayr, R.: Verfahren zur Bahnfolgeregelung für ein automatisch geführtes Fahrzeug. Dortmund: Universität, Diss. 1991.

3 N.N.: VEDYNA User's Guide. TESIS Dynaware GmbH, München, 1997.

4 Popp, K.; Schiehlen, W.: Fahrzeugdynamik. Stuttgart: Teubner, 1993.

5 Rill, G.: Simulation von Kraftfahrzeugen. 1. Aufl. Braunschweig: Vieweg, 1994.

6 Schiehlen, W.: Multibody Systems Handbook. Berlin: Springer, 1990.

7 Simeon, B.; Führer, C.; Rentrop, P.: Differential-algebraic equations in vehicle system dynamics. Surv. Math. Ind. **1** (1991) 1–37.

8 Vögel, M.: Fahrbahnmodellierung und Kursregelung für ein echtzeitfähiges Fahrdynamikprogramm. Diploma Thesis, München: Technische Universität, Lehrstuhl für Höhere Mathematik und Numerische Mathematik, 1996.

9 Vögel, M.; von Stryk, O.: Online guidance and control of full car dynamics simulations. In preparation.

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