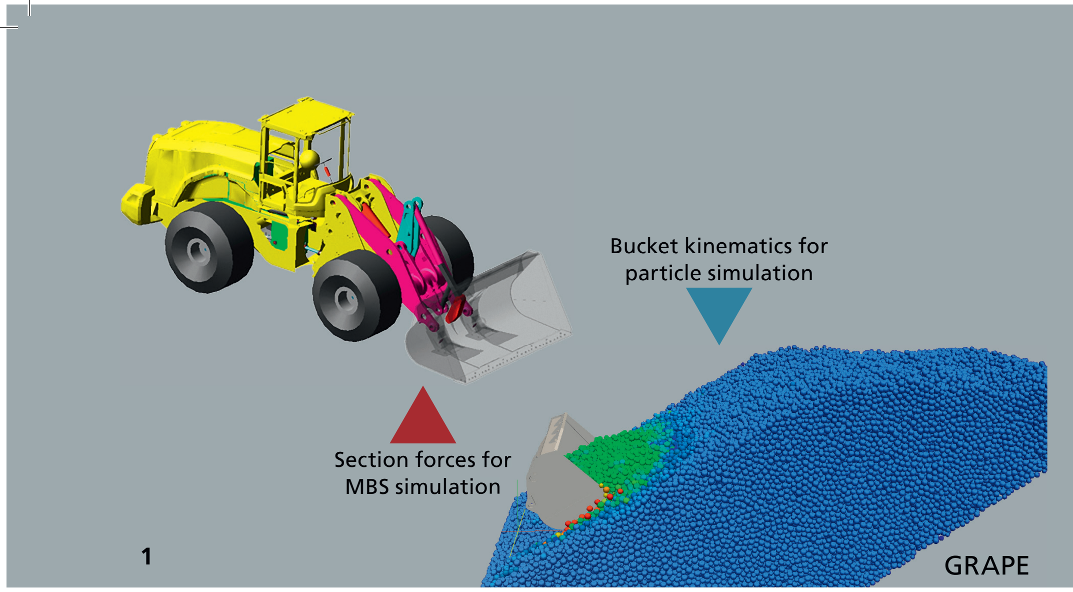
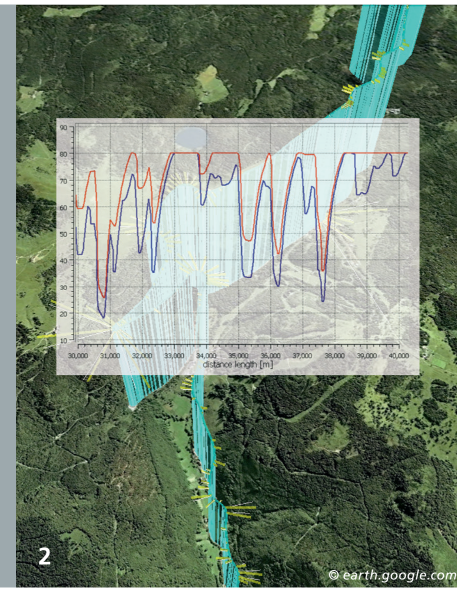




1 Soil and material simulation

2 Curvature and slope along a route

Soil and material simulation

With GRAPE (GRAnular Physics Engine) the ITWM offers a proprietary operational DEM software (Discrete Element Method) for particle simulation of granular materials. For practically relevant particle sample sizes about 150.000 particles, fast computation is achieved (realtime factor < 100) but even so forces are predicted correctly.

The model is parameterized via standardized tri-axial tests with optional validations via McKyes tests – both well-established methods in soil mechanics. By elaborate parameterization, the simulations not only yield correct material flows but also proper force feedbacks on terraforming tools (with respect to problem-inherent fluctuations). Moreover, GRAPE can be utilized in co-simulation scenarios via standardized Functional Mockup Interface (FMI) and Simulink S-functions.

Simulation of usage variability

Statistical methods play an important role during design and assessment of mechanically loaded components as well as for estimating fuel consumption and emission of a vehicle in its real field usage. Initially, the usage variability needs to be described and modelled according to the combination of different users and different environments. Which road types are used by a Van in Eastern Europe in a mainly city-dominated application? What is the distribution of upward and downward slopes and what is different compared to Western Europe?

Such and similar questions are treated systematically at Fraunhofer ITWM based on statistical methods and a geo-referenced database. Amongst other things, this comprises the simulation of usage scenarios (e. g. commuters in France) using VMC® methods, the geo-referenced evaluation of data measured on public roads (VMC® GeoLDA), and the extrapolation of such data to expected load distributions in the field (U·Sim).

The department Mathematical Methods in Dynamics and Durability develops methods towards the solution of all these tasks, executes application projects, and offers corresponding software solutions.

Fraunhofer-Institut für Techno- und Wirtschaftsmathematik ITWM

Fraunhofer-Platz 1
67663 Kaiserslautern
Germany

Contact
Dr. Klaus Dreßler
Phone +49 631 31600-4466
klaus.dressler@itwm.fraunhofer.de

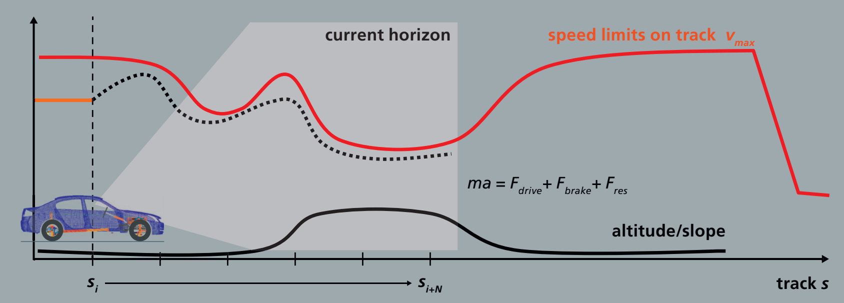
www.itwm.fraunhofer.de

mdf_flyer_FUMI_DE-EN

Fraunhofer ITWM

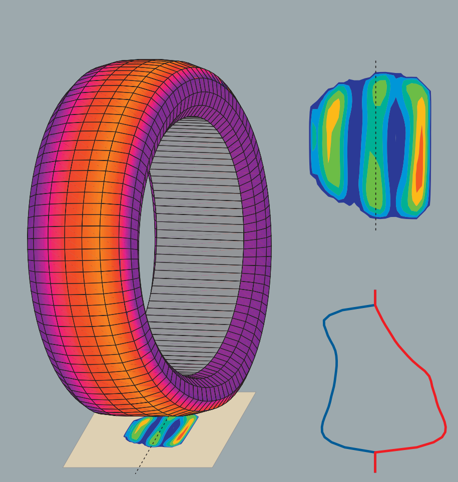
FRAUNHOFER INSTITUTE FOR INDUSTRIAL MATHEMATICS ITWM

VEHICLE – ENVIRONMENT – HUMAN INTERACTION

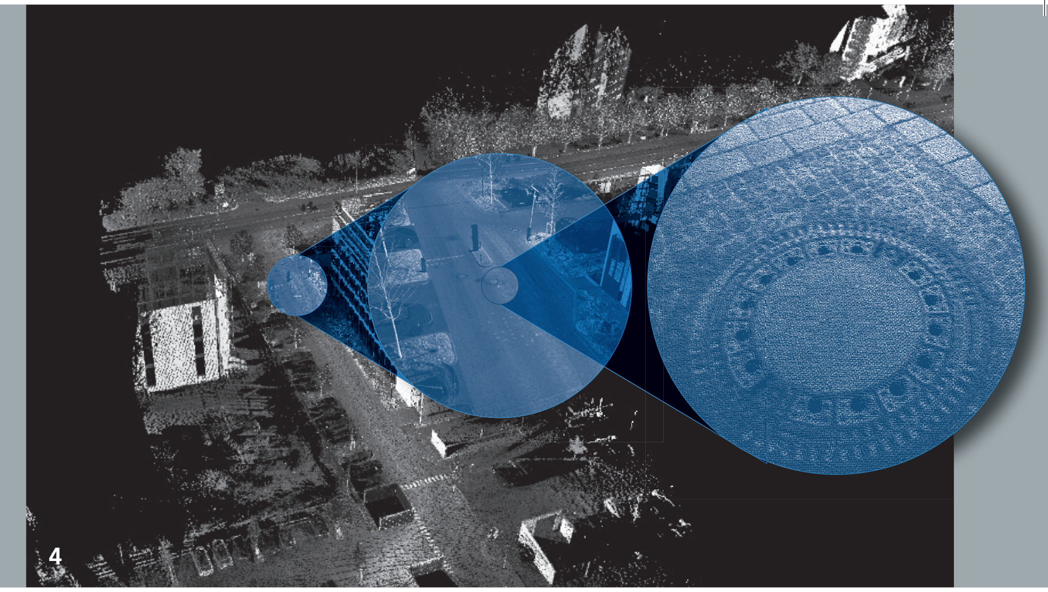


1

2



3



4

Simulation based engineering (often called computer aided engineering/CAE) is a key part of all vehicle engineering processes. It is about assessment, optimization and validation of vehicle physics and functional performance based on mathematical (CAE-) models and simulation. 'Transient' attributes like durability, reliability, fuel consumption and emission require the simulation and accumulation of highly variable maneuvers and usage-scenarios. For this type of simulation a good model of the vehicle is not sufficient, however, the simulation of the 'boundary conditions' i. e. 'the interaction with the rest of the world' is needed as well. In particular, we need good models for the road network, topography, road conditions, traffic, tires and driver's behavior. Most important, validation processes for such vehicle properties require statistically qualified test and simulation scenarios, which capture the real usage variability of loads, consumption and emission. Since 2010, our team at Fraunhofer ITWM is working on these topics systematically in the framework of the Fraunhofer Innovation Cluster 'Vehicle-Environment-Driver Interaction'. Since 2016 the innovation cluster is an integral part of the Fraunhofer High Performance Center 'Simulation- and Software-Based Innovation'.

Vehicle models for load paths and energy flows

Modern vehicles – passenger cars, trucks, agricultural and construction machines – are highly complex mechatronic systems. Fraunhofer ITWM develops numerical models of such systems, in order to analyze them very efficiently using computer simulation. The system behavior (inner loads, load paths, energy flows between specific subsystems) can be investigated, adapted and optimized in an early stage of the development process. Typically, the base structure of such models is a mechanical system, which is mathematically modelled as multibody system. Subsystems from other physical domains (hydraulics, electrics, electronics, etc.) or controllers can be coupled to such a base structure. Fraunhofer ITWM also develops methods for an efficient simulation of such coupled systems (co-simulation). Couplings to real physical hardware (e. g. for HiL-Tests or interactive simulators) are also considered. In these fields, one is typically faced with strong requirements concerning computational efficiency. At ITWM, one is concerned with specific modelling techniques (appropriate model complexity), coupling schemes as well as specific numerical solvers. In addition to that, monitoring and driver-assistance systems are developed. In this context, machine quantities (speed, mass, etc) are estimated online, i. e., under running and working conditions, and are used, in combination with suitable simulation models, to support the operator in his decision process. To realize this task, methods from nonlinear optimization, optimal control and model predictive control (MPC) are developed and applied.

Interactive simulation

Due to the rapidly increasing level of vehicle complexity not only advanced driver assistance systems are coming up, but even the driving task itself is partially or completely covered by intelligent systems. This is a new important demand on the simulation tool chain and in the development process itself. The driving simulator RODOS® enables our partners to test and assess virtual prototypes and to improve these together with expert operators. Our approach allows very fast iteration cycles in very early stages of the development process. Physical prototypes and field studies are substituted by the use of our interactive simulation tool chain. Typical tests in the simulator are:

- impact of new assistance and automation systems on different skilled operators
- development and test of new human-machine interfaces and new vehicle functions
- derivation of driver and operator models

An important aspect for the generation of interactive simulations is the use of standard engineering tools like Matlab/Simulink®, Simpack®, LMS Virtual Lab®, C++ etc. This ensures that existing and already validated models of our partners can be applied in the interactive simulation. A feedback of model changes can directly be included into the productive processes of our partners. Technical details, such as the unconventional motion system which is based on an industrial robot with 1000kg payload, allows the usage of off-the-shelf cabins for simulation. The extraordinary large hemispherical screen with 10m diameter leads to very realistic simulations.

Tire

In the virtual development process, the assessment and optimization of vehicle suspension and chassis performance are based on the forces that are transferred by the tire from road into suspension. In this load transfer, the tire is one of the most critical components because it has a strong nonlinear behavior and is very difficult to model. ITWM's tire model CDTire supports engineers in almost all analysis scenarios used in modern vehicle development processes within modern multibody simulation tools. Special focus on tire belt dynamics and interaction with 3D road surfaces allows to accurately capture the vibrations in both amplitude and frequency behavior.

CDTire supports different applications by adapting the model complexity in balancing the simulation performance and the problem requirements. The CDTire/3D is a structural 3D shell based bead-to-bead model with sidewalls and belt that separately models all functional layers of a modern tire. Derived from this model are: CDTire/Realtime, which is a hard-realtime capable tire model for ride, comfort and durability applications; CDTire/MF++, which is an enhanced Magic Formula to feature the temperature dependency of an tire and CDTire/NVH, a linearized version of CDTire/3D for usage in FEM based NVH-tools.

Furthermore, within the CDTire family there is a dedicated temperature model CDTire/Thermal to predict the temperature creation and propagation in a tire. This can be coupled with the mechanical tire model CDTire/3D and CDTire/MF++. CDTire is available for the following simulation-tools: MSC.Adams, Simpack®, Altair MotionSolve, LMS Virtual Lab® Motion, Matlab® and Simulink®

Environmental data and road network

In order to analyze usage variability with respect to durability, reliability, and energy efficiency of vehicles, Fraunhofer ITWM provides a geo-referenced database and a variety of corresponding methods. Based on a world-wide digital road map including speed limits, traffic signs, altitude, and climate data, VMC® GeoStatistics analyzes and compares regions and markets or single routes to each other with respect to vehicle relevant properties. This enables extensive options towards an improved evaluation of measured data as well as for planning new measurement campaigns.

The ITWM measurement system REDAR (Road and Environmental Data Acquisition Rover) serves to specifically extend the VMC database. REDAR is a vehicle equipped with an inertial platform incl. DGPS and distance sensor, laser scanners, and high resolution cameras to collect detailed 3D environmental data. The point clouds are used for a close to reality 3D display of scenes and a high resolution road surface sampling. The range of application of the system comprises the interactive driving simulator RODOS®, the techniques for calculating invariant vehicle model excitations, and the already mentioned extension of the VMC database.

1 *Calculation of speed profiles along a route*

2 *Interactive simulation with RODOS® in a point cloud scenario*

3 *Tire simulation with temperature and contact force distribution*

4 *Acquisition of environmental data up to high resolution road surface*