A MODELLING TECHNIQUE FOR FAST COMPUTER SIMULATIONS OF CONFIGURABLE VEHICLE SYSTEMS

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Summary In this paper the vehicle is modelled by a non perfect multi body system. The specific structure of a vehicle is used to minimize the computational effort. The model is separated into subsystems having a functional skeleton and consisting of several configurable modules. A modified implicit Euler-Algorithm guarantees sufficient accuracy and stability even in combination with third party modules.

MODELLING CONCEPT

The vehicle model is separated into subsystems describing the vehicle framework, the steering system and the drive train, Fig. 1. Each subsystem has a functional skeleton and consists of several configurable modules.

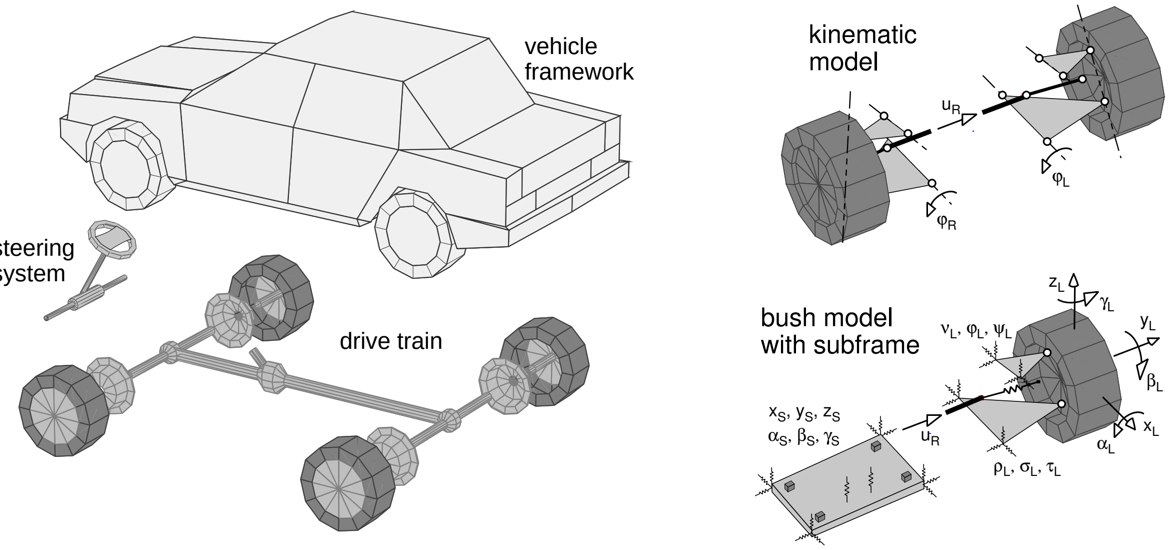


Figure 1: Vehicle Structure and different Axle Modules

The steering system consists at least of the steering wheel, a flexible steering shaft and the steering box which may also be power-assisted. The drive train model is generic. It combines front wheel, rear wheel and all wheel drive. The dynamics of the engine torque may be modelled quit simply by a first order differential equation or by using the enhanced engine torque module en-DYNA developed by the TESIS Company. Tire forces and torques are generated either based on the tire model TMeasy, [3] or by external tire modules, ig. [4]. The vehicle framework consists at least of a rigid or a flexible chassis module and the axle suspension. At present the flexible chassis module takes into account the first torsional mode only. For comfort simulations the vehicle framework can be extended with an elastically suspended engine and passenger models. A lot of different axle suspension modules are available. Pure kinematic axle models overlayed by quasi-static compliancies result in the fastest executables. More enhanced suspension models consider the essential compliances in the bushings and include the subframe. Each suspension model uses simple characteristics or external modules to describe the forces produced by spring damper elements.

EQUATIONS OF MOTION

By neglecting small inertia terms the equations of motion can be derived separately for each subsystem. Via Steering forces and tire forces and torques the subsystems are still coupled to each other. The velocity state of the vehicle chassis and the elastically suspended engine can be described by a specific set of generalized speeds, cf. [1]. Thus the equations of motion for the vehicle framework can be written as a set of two first order differential equations.

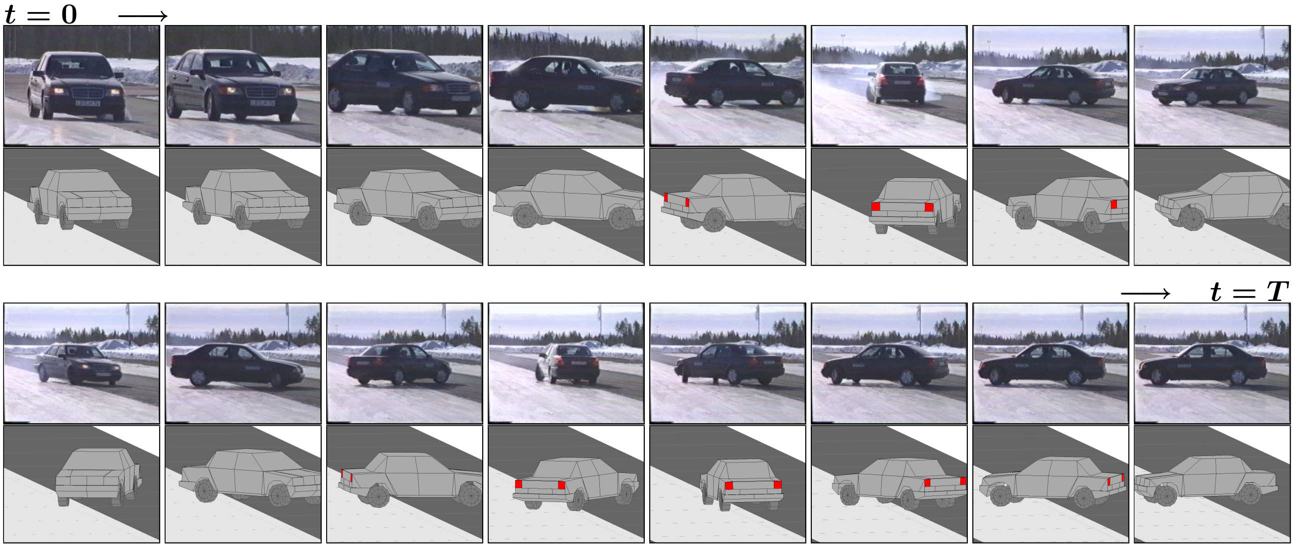
$$K_F(y_F)\,\dot{y}_F \;=\; z_F \quad \text{and} \quad M_F(y_F)\,\dot{z}_F \;=\; q_F(y_F,\dot{y}_F;\,y_S,\dot{y}_S;\,y_D,\dot{y}_D)\,, \tag{1}$$

where y_F is the $n_F\times 1$ vector of generalized coordinates, describing the momentary position of the vehicle framework subsystem, K_F is the $n_F\times n_F$ kinematic matrix, M_F is the $n_F\times n_F$ mass matrix, and q_F is a $n_F\times 1$ vector of generalized forces. The number of generalized coordinates depends on the model complexity. An enhanced vehicle model with an elastically suspended engine, four passengers and bush axle models comes up to $n_F\approx 80$. The coupling to the other subsystems is indicated by the generalized coordinates y_S, y_D and their time derivatives $\dot{y}_S$, $\dot{y}_D$ which denote the momentary state of the steering system and the drive train.
As described in [2] the numerical solution is done by a modified implicit Euler-Algorithm where the specific system properties of a vehicle are taken into account. This algorithm guarantees sufficient accuracy and numerical stability even if the vehicle model is combined via co-simulation with third party modules.

APPLICATION

The presented modelling concept is realized with a MATLAB/Simulink® interface in the product ve-DYNA which in the meantime is applied world wide by automotive companies and suppliers.

$t=0 \quad \longrightarrow$



$\longrightarrow \quad t=T$

Figure 2: Braking on μ-split: Field Test / ve-DYNA–Simulation

A vehicle without an anti-lock system braked on a μ-split surface shows a strong yaw reaction which causes the vehicle to spin around the vertical axis. In Fig. 2 screen shots of a commercial trailer to the EPS-system from the company Robert Bosch GmbH are compared with the results of a ve-DYNA-simulation. Despite of different vehicles and estimated friction coefficients for the dry ($\mu=1$) and the icy part ($\mu=0.05$) of the test track the simulation results are in good conformity to the field test.
Whereas the reproducibility of field tests is not always given a computer simulation can be repeated exactly with the same environmental conditions.

REFERENCES

[1] Rill, G.: Modeling and Dynamic Optimization of Heavy Agricultural Tractors. In: 26th International Symposium on Automotive Technology and Automation (ISATA). Croydon: Automotive Automation Limited 1993.

[2] Rill, G.: Vehicle Modelling for Real Time Applications. RBCM - J. of the Braz. Soc. Mechanical Sciences, Vol. XIX - No. 2 - 1997 - pp. 192-206.

[3] Hirschberg, W; Rill, G. Weinfurter, H.: User-Appropriate Tyre-Modelling for Vehicle Dynamics in Standard and Limit Situations. Vehicle System Dynamics 2002, Vol. 38, No. 2, pp. 103-125. Lisse: Swets & Zeitlinger.

[4] Gipser, M.: Reifenmodelle für Komfort- und Schlechtwegsimulationen. In: Tagungsband zum 7. Aachener Kolloquium Fahrzeug- und Motorentechnik. IKA, RWTH Aachen und VDI 1998.