Real Time Simulation of Heavy Trucks using SIMPACK

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SIMPACK User Meeting 2001
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• FKFS is a non-profit-making foundation, located in Stuttgart / Germany since 1930
• close co-operation with Stuttgart University
• 120 employees in 2001
Major Fields of Work

- Internal Combustion Engines
- Automotive Engineering
- Mechatronics and Software
Overview

- Introduction
- Using SIMPACK for Real Time Simulation
- RT Models of Truck / Trailer Vehicle Dynamics
- Application Example: Driving Simulator
- Application Example: Active Suspension
- Portability and HIL aspects
- Conclusion and Outlook
Product requirements

executable specification

software prototyping

software-in-the-loop

man-in-the-loop

software implementation

hardware-in-the-loop

development step

testing method

production code generation

Scope of Regard
Modelling and simulation objectives:

- Use of identical simulation models for offline and real time simulation
- Use of modern software tools with automatic code generation, no manual coding
- Integration of measured parameters into the simulation, e.g. tyre properties
- Portability of simulation models between different Real Time Hardware and Operating Systems !!!
Coupling for Real Time Applications

MATLAB / SIMULINK

ASCET-SD

FKFS Tool Chain

INTEC

TTP-Plan

TTP-Build

STATEMATE MAGNUM

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CANULINK

TTTech
Symbolic Code Interface

(F77, F90, C)

- Interface code
- C libraries
- Target specific make files

Automatic code modification tool

MATLAB / SIMULINK

Real Time Workshop

Executable program running on a real time computer

C-code

target specific
C compiler / linker

EXE

Offline simulation in SIMULINK
Real Time Capable Truck Models in SIMPACK
Tractor / trailer model with rigid chassis
9 bodies, 28 DOF + 7 rheonomic drives

- sub-structure "tractor"
- sub-structure "trailer"
- Load movement (rheonomic)
- "fifth wheel"
- suspension: leaf or air springs, dampers, stabilisers
- externally calculated tyre forces (FKFS “REAL TIRE” model)
- elastic hitch, tow-bar with contact algorithm

Tractor / trailer model with rigid chassis
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Semitrailer train model with rigid chassis
8 bodies, 29 DOF + 3 rheonomic drives

Coupling gear (3 DOF)
Load movement (rheonomic)
Truck model, 2 rear axles, elastic chassis, cab suspension
7 bodies, 20 DOF + 3 rheonomic drives

load movement (rheonomic, 3 axes)

chassis torsion

cab suspension (3 DOF)
Structure of SIMULINK / SIMPACK vehicle models

measured tire behaviour and steering kinematics FKFS "REAL TIRE"

Integration of SIMPACK truck models in SIMULINK

steering wheel torque

tire forces

driving resistance

aero-dynamics

vehicle dynamics

power train

driver

vehicle motion

tire print movement

steering angle

delta_H

M_H

F_R

X_V_R

v_Veh

F_F

M_PT

embedded SIMPACK MBS

Drive

M_PT

delta_H

Drv

driver

F_F

F_R

v_Veh

FKFS "REAL TIRE"
### SIMPACK/SIMULINK Truck model execution times
on Industrial PC based Real Time Computers (single processor)

<table>
<thead>
<tr>
<th>Model Type</th>
<th>DOF/Rheo</th>
<th>ODE Solver</th>
<th>Min. Step Size on IPC (AMD Athlon 1000 MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td>28/7</td>
<td>Runge-Kutta 2(^{nd}) order (Heun)</td>
<td>1.6 ms</td>
</tr>
<tr>
<td><img src="image2.png" alt="Diagram" /></td>
<td>29/3</td>
<td>Runge-Kutta 2(^{nd}) order (Heun)</td>
<td>1.7 ms</td>
</tr>
<tr>
<td><img src="image3.png" alt="Diagram" /></td>
<td>20/3</td>
<td>Runge-Kutta 2(^{nd}) order (Heun)</td>
<td>1.4 ms</td>
</tr>
<tr>
<td><img src="image4.png" alt="Diagram" /></td>
<td>35/7</td>
<td>Runge-Kutta 2(^{nd}) order (Heun)</td>
<td>1.8 ms</td>
</tr>
</tbody>
</table>

AMD Athlon 1800+, **expected:** 1.8 ms
Application example: Real Time Driving Simulator
**FKFS Lab Driving Simulator**

- Powertrain and vehicle dynamics simulation
- Investigation of steer-by-wire concepts
- Interactive software testing (e.g., vehicle dynamics control)

**Application example:**
Real Time Driving Simulator

**3D graphics**

Real Time Computer with vehicle model

- Pedals
- Gear shift lever
- Steering unit
- Parameter variation
- Instrument panel
FKFS Lab Driving Simulator: Active Steering Unit

- Steering torque up to 16 Nm, dynamics: < 20 ms
- Sensors for steering angle and speed
- 3 phase servo motor for torque generation
- Interface to real time simulation computers

Tire and steering simulation model
Application example: Real Time Driving Simulator
• Real time implementation of a software prototype
• Test of active suspension components using a test bench connected to a Real Time vehicle model

Controller Software (ASCET SD)

Vehicle dynamics and powertrain model (SIMPACK / SIMULINK)

- Real time implementation of a software prototype
- Test of active suspension components using a test bench connected to a Real Time vehicle model

Application Example: Active Suspension
Kinematic loops and elasticities in Real Time Simulation

Application Example: Active Suspension

- Special Real Time User Routines
  - kinematic and elastokinematic wheel suspension systems
  - steering transmission incl. steering elasticity

-> no kinematic loops, full precision, integration speed up, ...
FKFS Universal Measuring Vehicle for Tire Properties

Lateral force vs. slip angle and wheel load

Lateral force stiffness vs. camber angle / wheel load

Measurement of Tire Properties on Real Roads
Portability issues:

- Transformation of SIMPACK Symbolic Code to pure ANSI-C enables porting of combined SIMPACK/SIMULINK models to different Real Time hardware and Real Time operating systems

- Portability tested on:
  - Industrial PC System (XPC Target RT kernel)
  - VME / Power PC computer (Lynx OS)
  - dspace DSP/alpha combo (reduced model complexity)

- Porting to any other platform is possible if computing power and memory are sufficient

- Embedded SIMPACK RT models are also fully functional in offline simulation with MATLAB/SIMULINK (running under MS Windows)
**Conclusion**

- Since 1999 SIMPACK is used at FKFS for creation of real time capable vehicle dynamics models
- Embedding of SIMPACK into SIMULINK expands modelling techniques to a wider range
- Driving simulator and Hardware-in-the-Loop applications for trucks and passenger cars have been realized using SIMPACK combined with SIMULINK
- Code efficiency is sufficient to run complex SIMPACK models in Real Time on single processor hardware

**Further Activities**

- Advanced modelling of elastic suspension parts for Real Time Simulation
- Realization of a Hardware-in-the-Loop simulator for truck vehicle dynamics control (“ESP”)