Determining road profiles and tire loads using virtual iteration and tire models for multi body simulation

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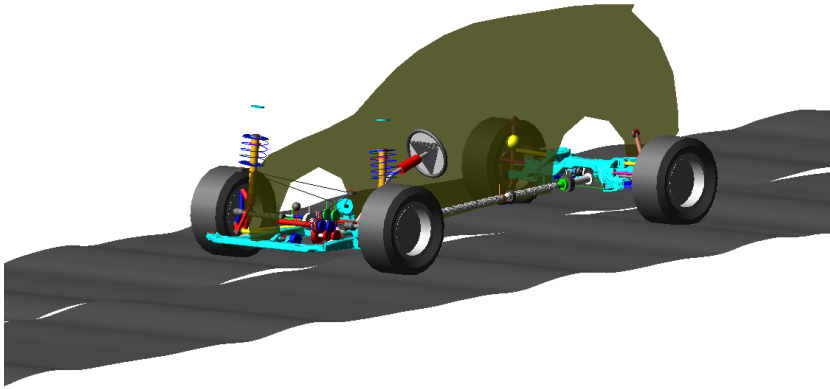
automotive CAE Grand Challenge 2017
April 5–6, 2017

Determining road profiles and tire loads using virtual iteration and tire models for multi body simulation

Content

- Overview of road load simulation methods
- Method of virtual iteration for determining vehicle loads
- Generation of an effective road profile
- Generation of a 3D road profile via virtual iteration



Workflow of load generation for CAE

measurement data of vehicle

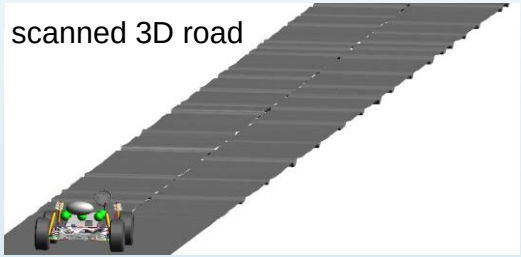
apply WFT forces

measurement data of vehicle

virtual iteration FEMFAT LAB vi

poster excitation

3D road simulation



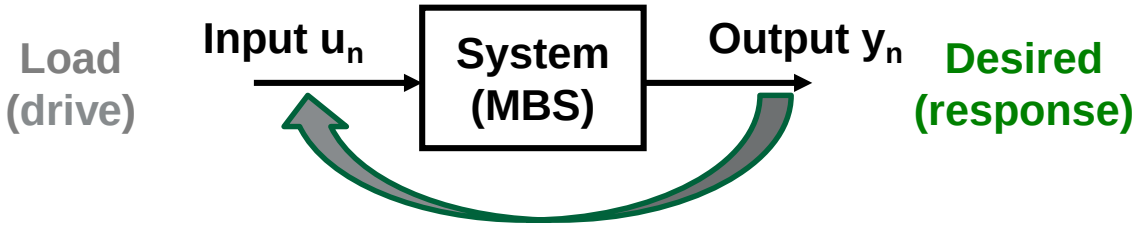
3D road simulation

interface loads or model coordinates

FE-model of component

durability analysis FEMFAT max

Method of virtual iteration



Inverse non-linear problem

find load for given response

Drive

High effort or not measureable

- Forces (external)
  - WFT
  - Load cell
  - Strain gauges
- Displacements (absolute)

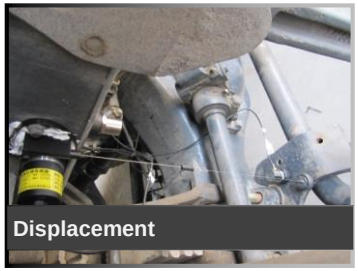
Response

Often simply and cheaply measureable

- Accelerations
- Displacements (relative)
- Strains
- Forces (internal)

Measurement signals for virtual iteration


Acceleration


Displacement


Strain – twist beam


Strain – ball joint

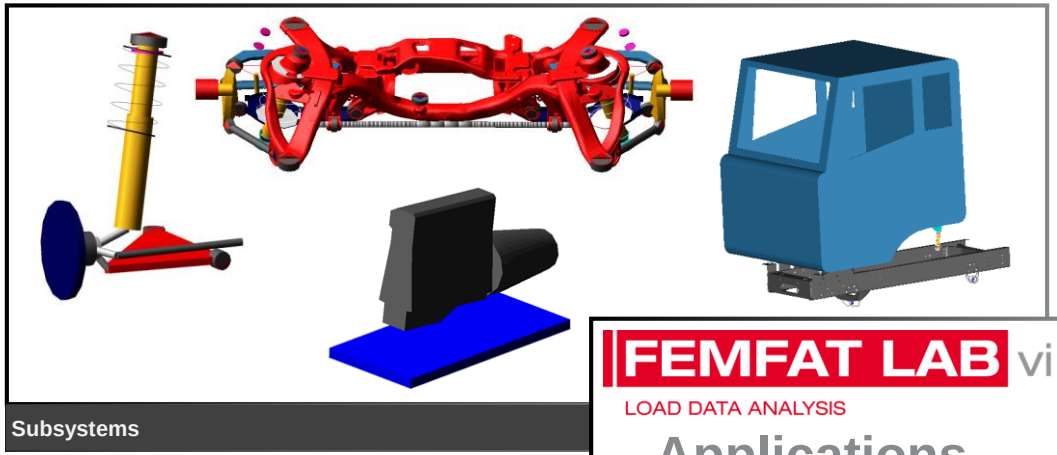

Load cell


Wheel force transducer

Typical responses

- Accelerations
  - 1-axial
  - 3-axial
- Displacements
  - Draw wire displacement sensor
- Frame torsion
- Strains (directly/calibrated to forces)
  - Axle
  - Ball joint
  - Link
  - Rod
  - Spring
  - Stabilizer
- Load cells
  - Mount
- Wheel force transducers

Applications of virtual iteration



Subsystems

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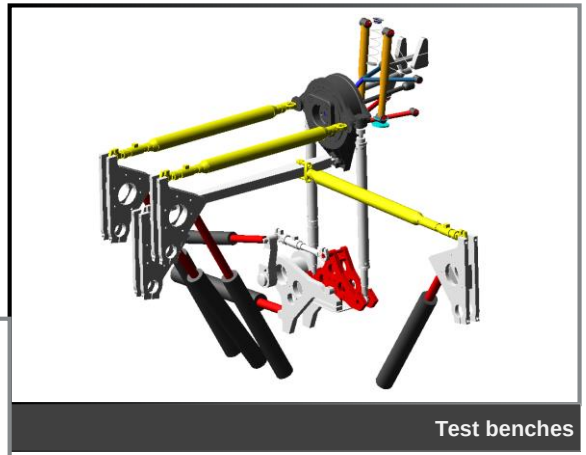
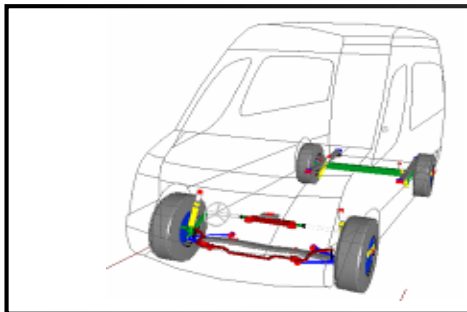
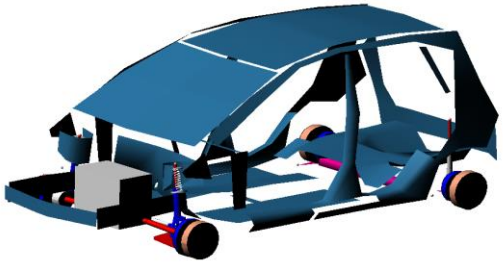
LOAD DATA ANALYSIS

Applications



Test benches

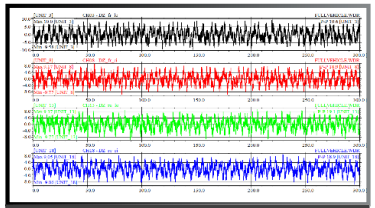




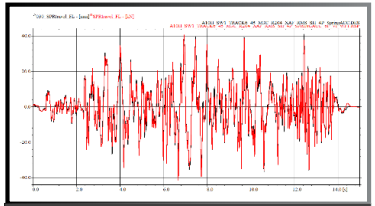
Full vehicles

Workflow of virtual iteration

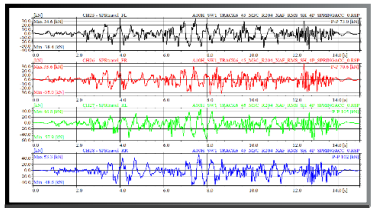
Iteration process



1. Noise



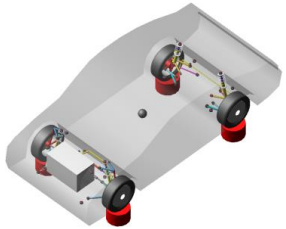
6. Response = desired



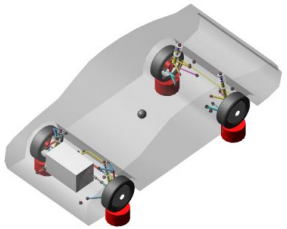
5. Response

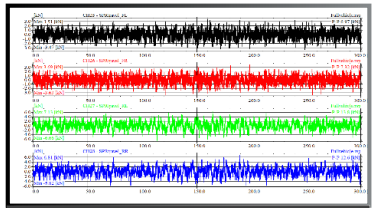
u_{Noise}

y_{Noise}



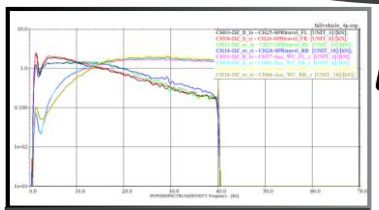
$u_{n+1} = u_n + F^{-1}\,(y_{Desired} - y_n)$





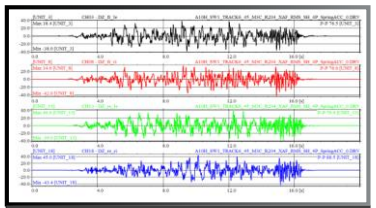
2. Response of noise

$$F = \frac{y_{Noise}}{u_{Noise}}$$



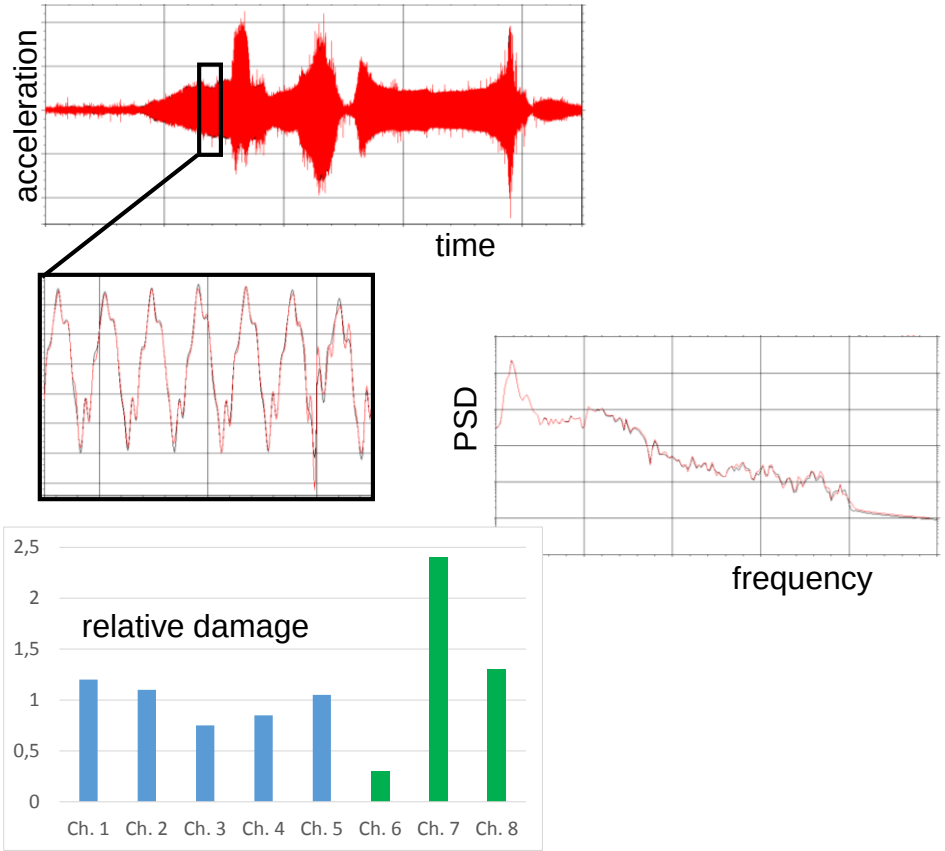
3. Transfer function

$u_0 = F^{-1}\, y_{Desired}$



4. Drive signal

Typical results of virtual iteration

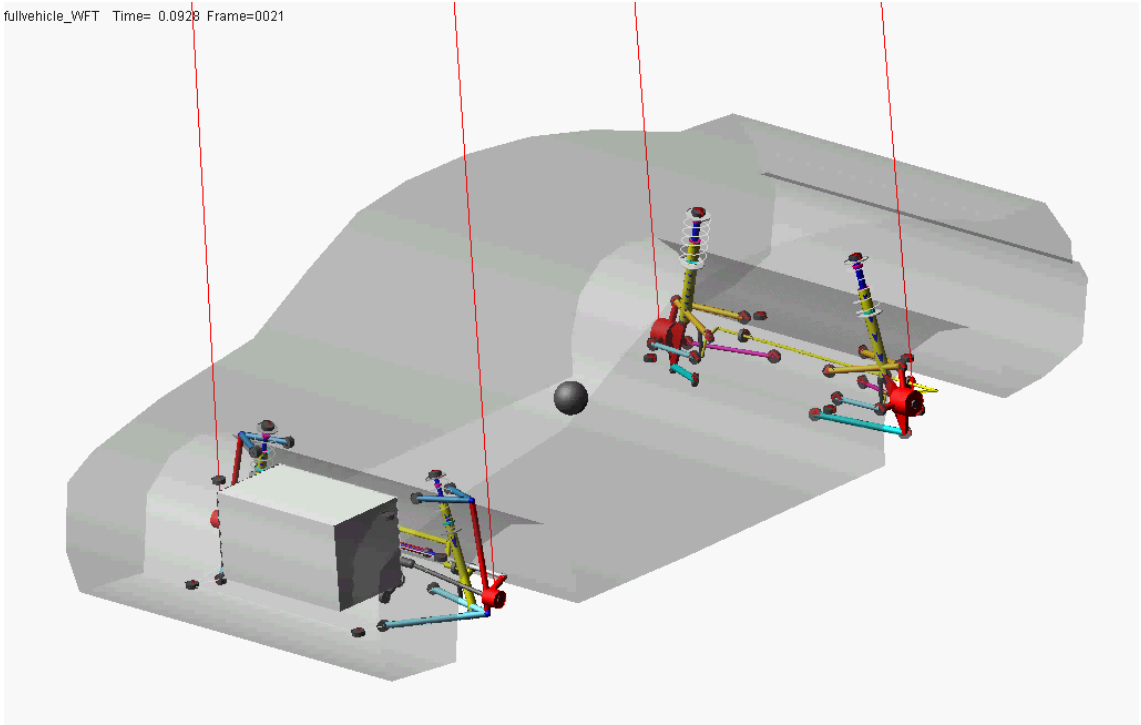


Result check during virtual iteration process

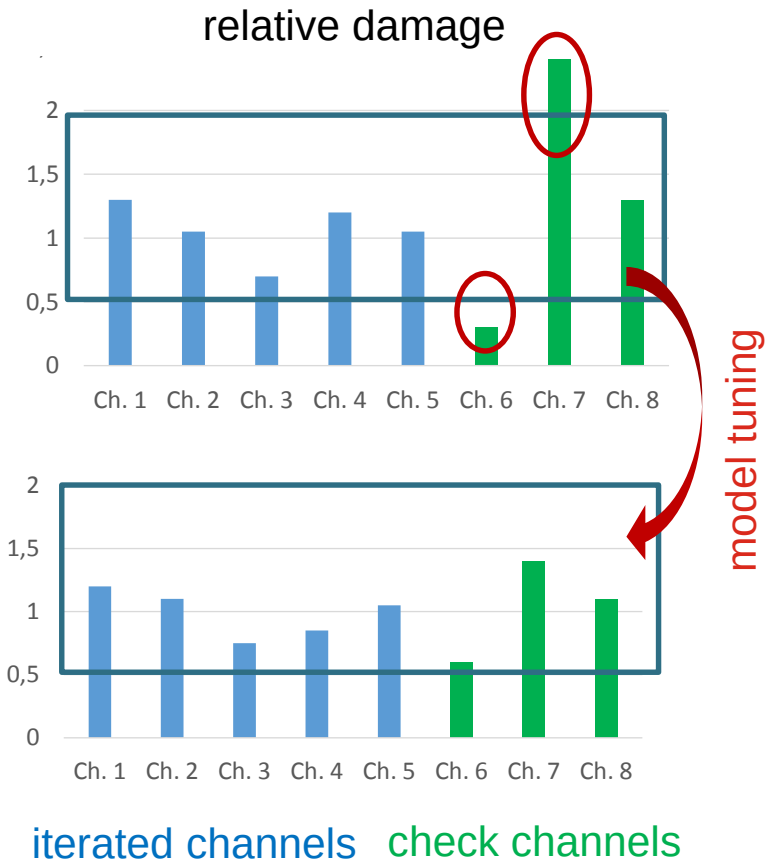
- signals in time domain (quality check)
- peak-to-peak values of signals in time domain (quantity check)
- signals in frequency domain (PSD)
- relative damage value of simulation compared to measurement
  - range-count classification of time signals
  - damage calculation based on Miner-elementary synthetic SN-curve

Rough road response of full vehicle – poster excitation

Full vehicle response based on iterated loads



Model improvements



Possible full vehicle model improvement

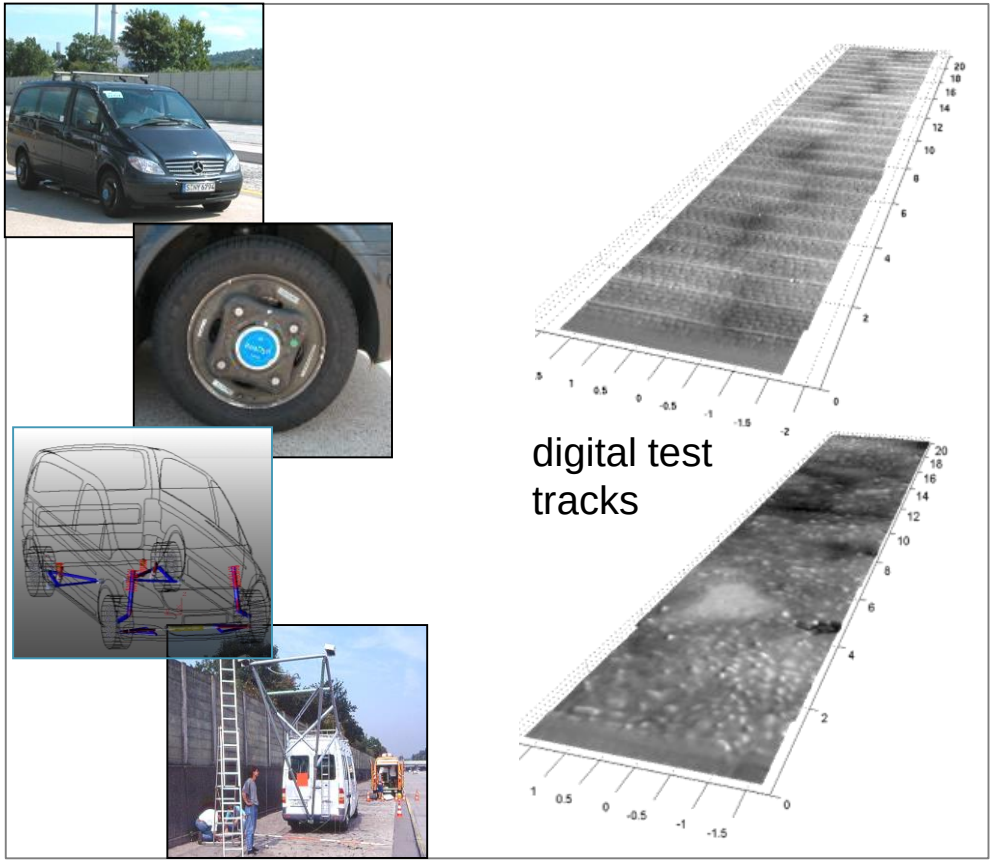
- Correlation to K&C measurements
- Component / subsystem measurements
  - stiffness and damping
  - inertia
  - modes
- Simulation and comparison to dynamic response e.g. obstacle crossing

Model tuning during iteration process

- Additional check channels not used for iteration process
- Check channels out of target range
  -> model tuning and iteration repeat

Examples for effective road profile

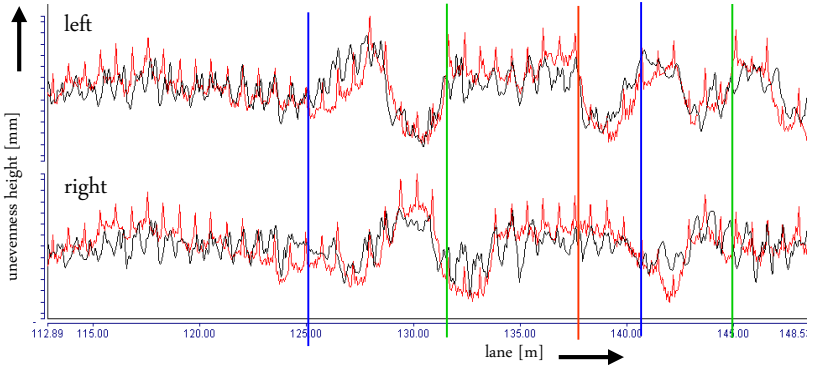
Virtual iteration of a van – comparison of road profile



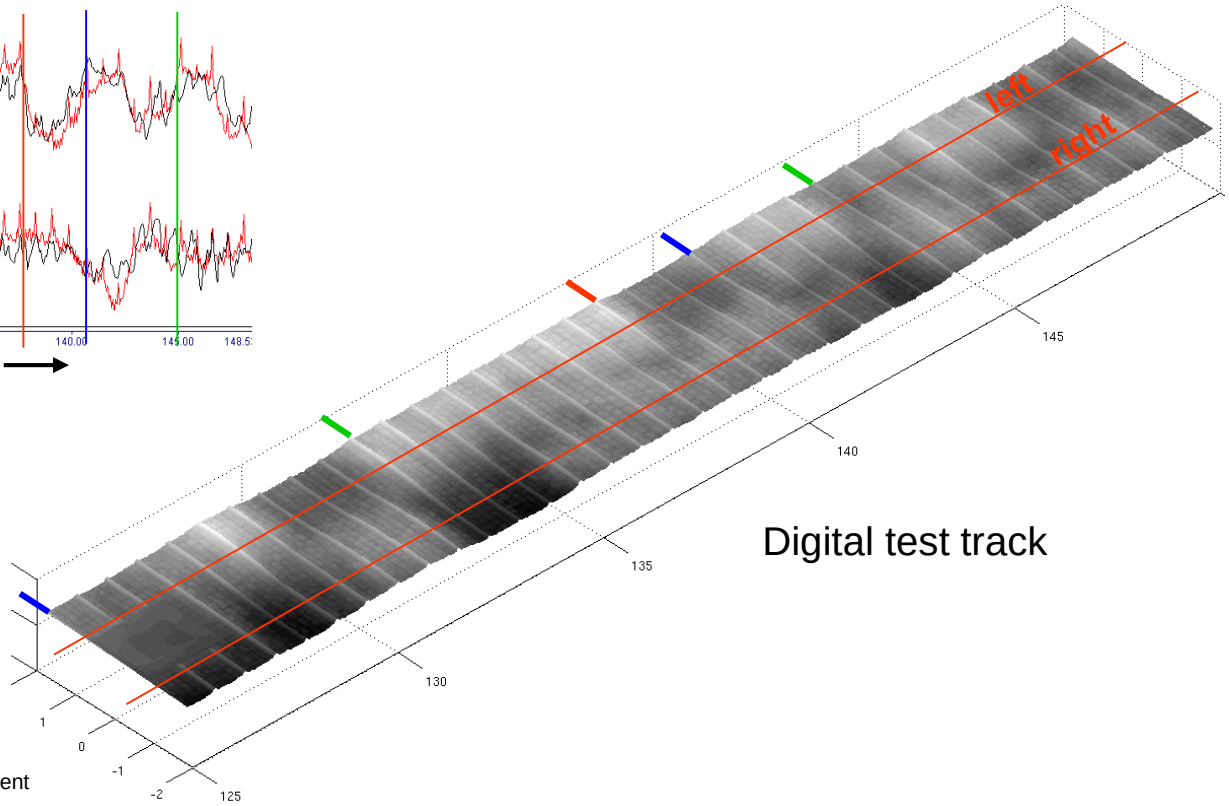
- Goal:
  Computation of „effective road profile“
- Desired (measurements):
  - 4 vertical wheel forces
  - 4 spring travels
- Excitation (virtual iteration):
  Vertical displacements with 4 poster
- Compare the results of the drives with the measured road profile (longitudinal sections of road surface)

Sing V.: Use of virtual iteration in commercial vehicle development
FEMFAT User Meeting 2007

Virtual iteration of a van – comparison of road profile



Red: Measured road profiles
Black: 5th drive (effective road profile)



Digital test track

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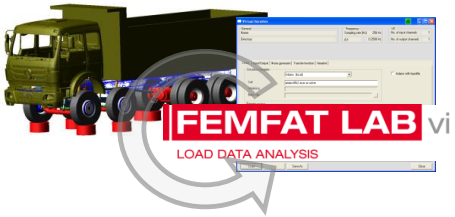
Generating road loads for virtual prototype

vehicle measurement

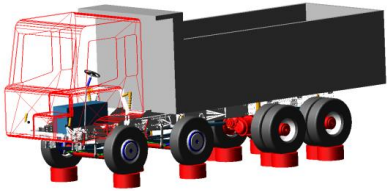
road load data

measurement vehicle



virtual iteration of road surface

MBS-simulation with road surface



new developed vehicle

Transfer of invariant signals to different vehicle

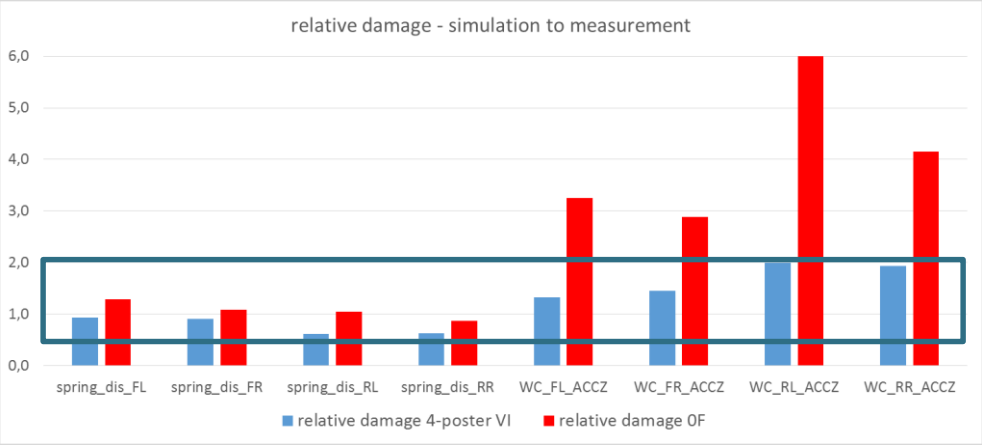
- Identification of effective road surface from poster excitation
- Road excitation can be transferred to similar vehicle

3D Road Iteration

Method of 3D road iteration

Generation of 3D road based on poster signals

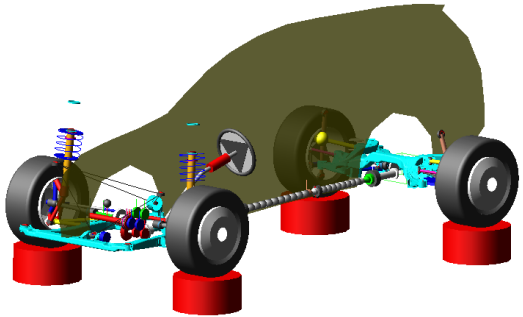
- Virtual iteration of 4-poster within target
- Use 4-poster signals to generate 2-track 3D road profile
- 3D road simulation results out of target
- Improvement necessary



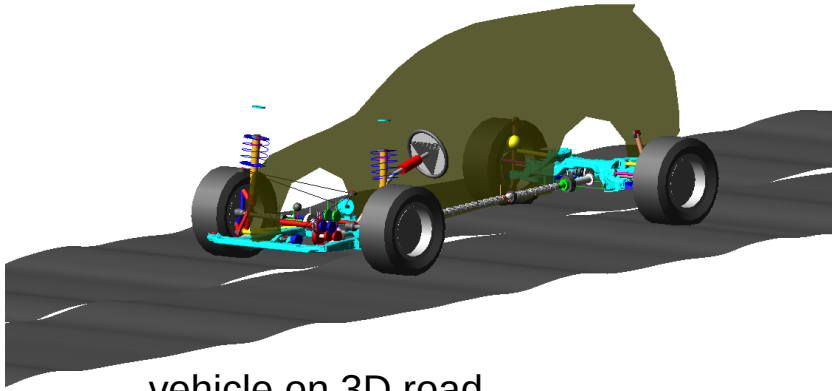
Enhanced process of virtual iteration

- Based on simulation results, 3D road profile is generated each loop
- Road simulation each loop
- Until iterated channels reach target range

Vehicle model for 3D road iteration



vehicle on poster



vehicle on 3D road
left and right track are independent

model description
- damper, bushings non-linear
- suspension parts rigid
- truck frame flexible
- car body typically rigid

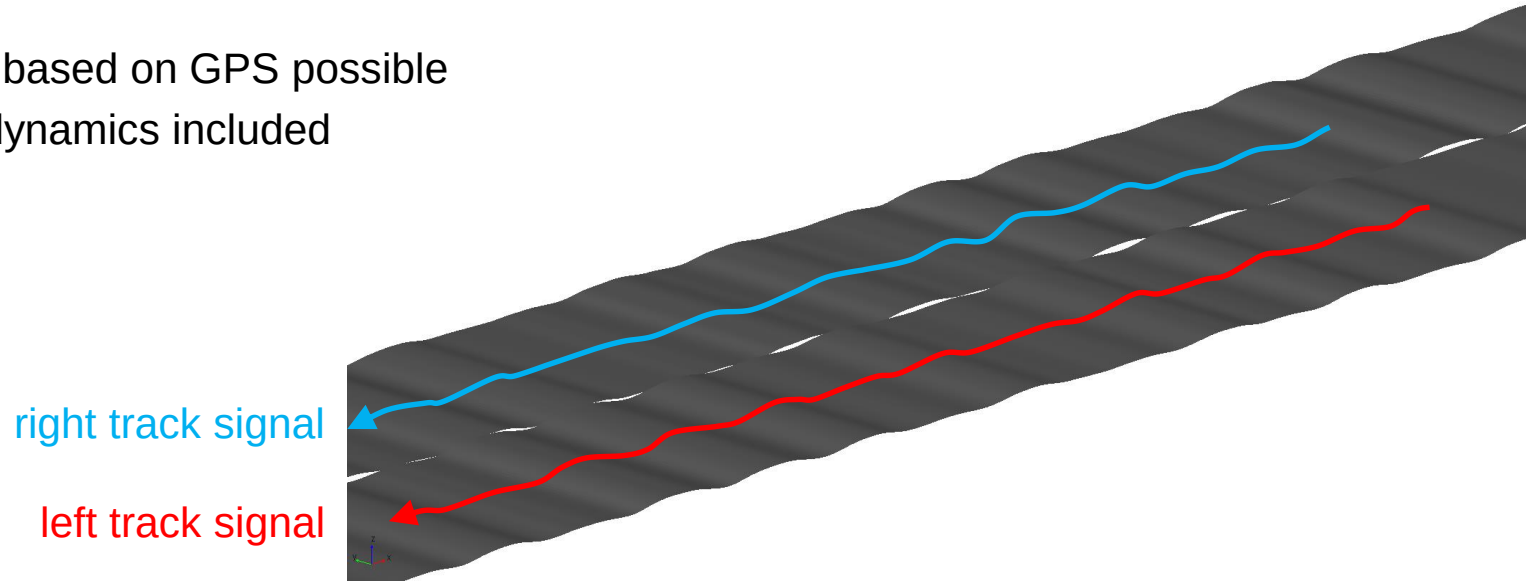
model enhancement
- 3D tire model
- operating powertrain
- driver model necessary

Method of 3D road iteration

Results of 3D road with virtual iteration

- Road profile is generated from time signals
- 3D road profile with independent left/right track

- Road trajectory based on GPS possible
- Global vehicle dynamics included



Summary and conclusion

- Method of virtual iteration usable for various applications
- High accuracy as based on measurement data
- Redundant measurement data allow model verification
- Method of 3D iteration to generate 3D road profile
  - Road scan not necessary
  - Simulation with different vehicle configurations allowed
  - Global vehicle dynamics included, e.g. lateral acceleration from cornering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