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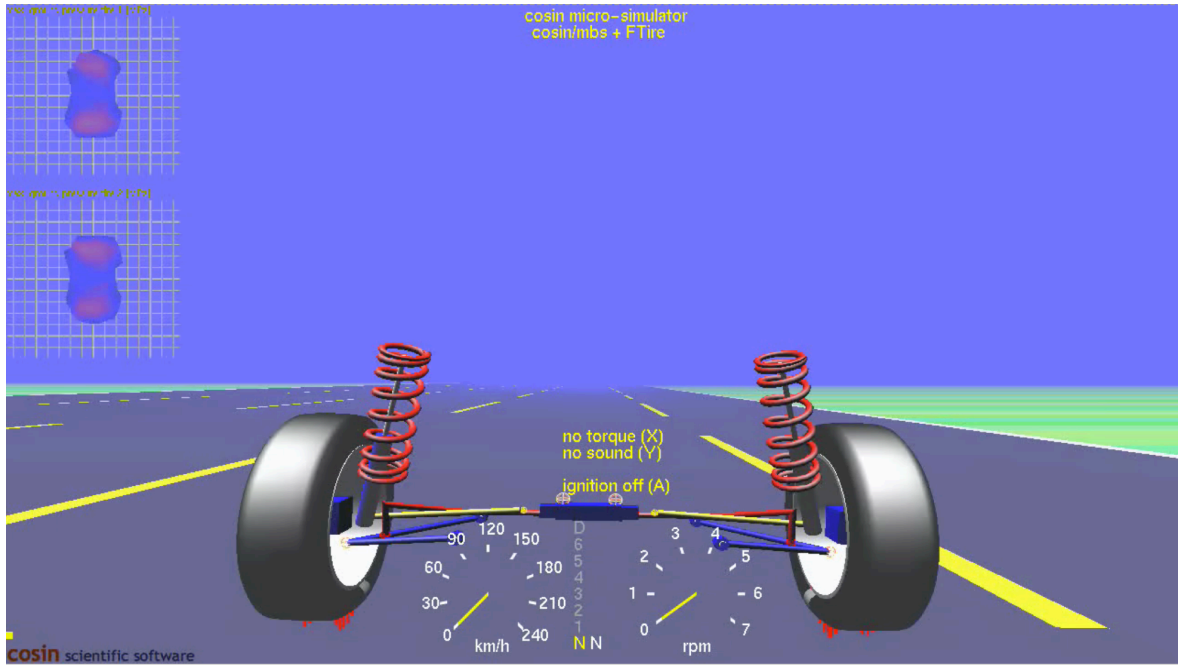
INTERNATIONAL VI-GRADE USERS CONFERENCE

Milano, May 8-9, 2018



FTire on the Driving Simulator

Michael Gipser
Mario Baumann
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Modifications for FTire/realtime, single instance

model extensions deactivated

- ➜ misuse
  - bottoming
  - side-wall contact
  - rim-to-road contact
- ➜ flexible rim
- ➜ air cavity

extra output only off-line

- ➜ animation
- ➜ plot data
- ➜ structure distortion
- ➜ contact patch states

solver improved

- ➜ smarter contact search
- ➜ efficient Jacobian update

resolution reduced

- ➜ longer internal time step
- ➜ less segments
- ➜ less contact elements

- ➜ no changes in interface
- ➜ no changes in data file
- ➜ speed mode selectable either in tire data file or by calling solver

Modifications for FTire/realtime, parallel computation

multi-threading organized by calling solver

- ➜ no changes in *FTire* or *CTI*
- ➜ achievable speed-up limited, highly depending on solver strategy and model topology

parallelization on CTI level

- ➜ 1 core / tire instance
- ➜ synch every global time step (1 ms)
- ➜ nearly no overhead
- ➜ maximum speed-up
- ➜ requires changes in the way the solver calls tire models

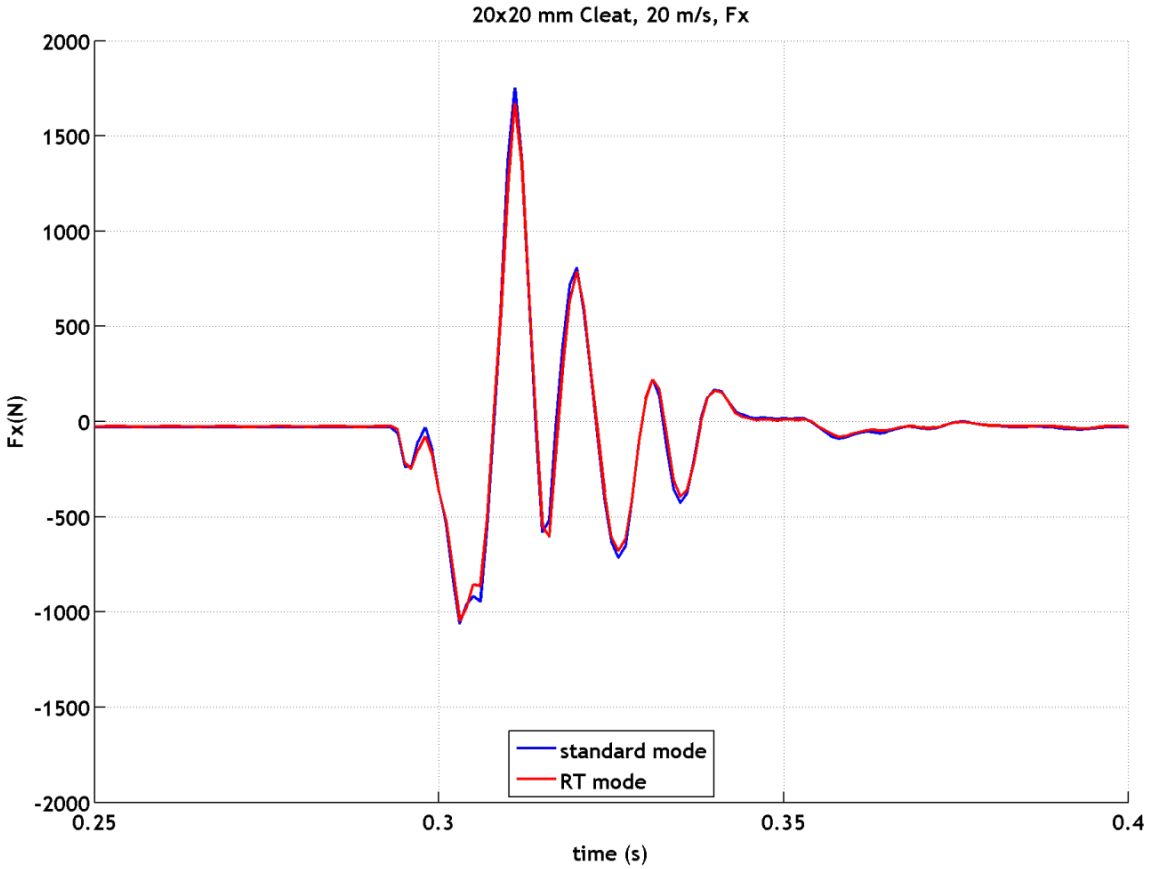
CTI/server

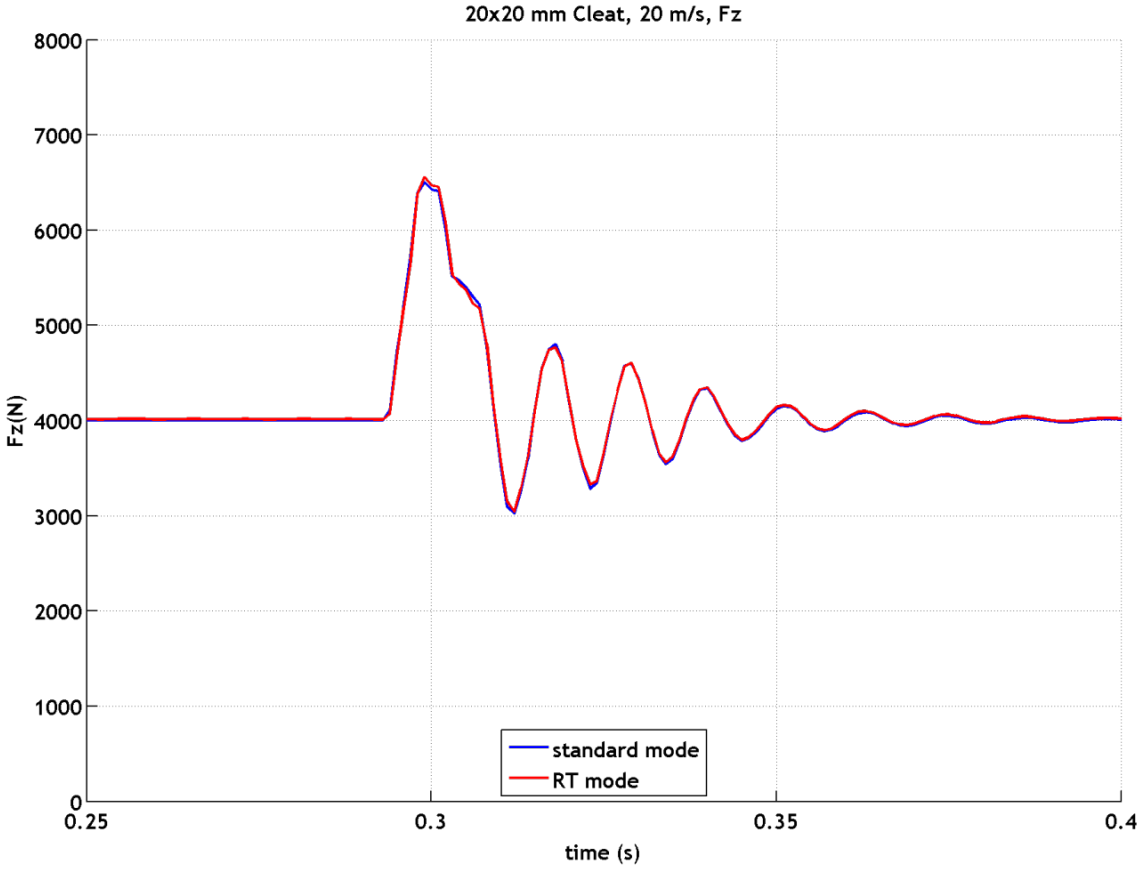
- ➜ server-based solution for hard real-time
- ➜ dedicated machine with real-time OS
- ➜ exchange of rim states and forces/moments via UDP or other fast protocol

➜ all *FTire* speed modes and model extensions are 100 % thread-safe,
including all road models (except RGR in case of dynamic patch swapping)

FTire/realtime, Cleat Test Accuracy in Time Domain

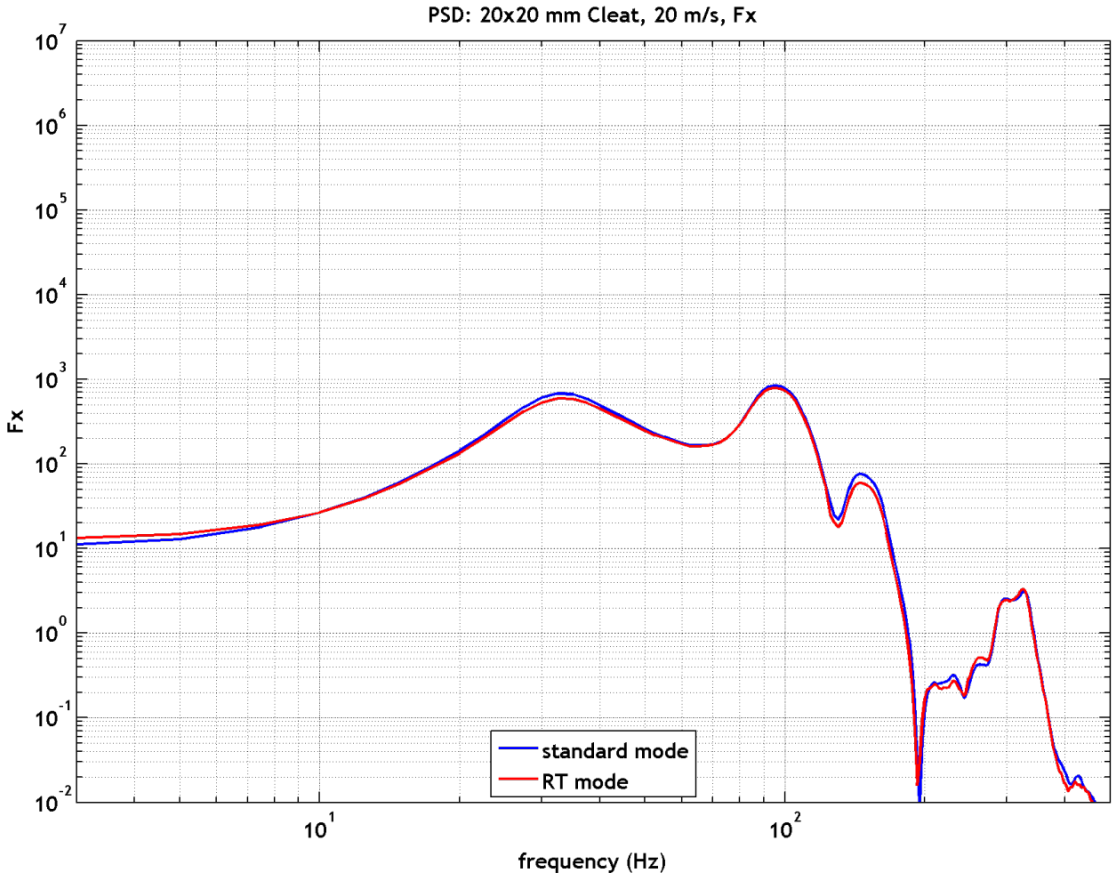
Barely loss in accuracy: single obstacle (20 x 20 mm cleat, 20 m/s). Time domain

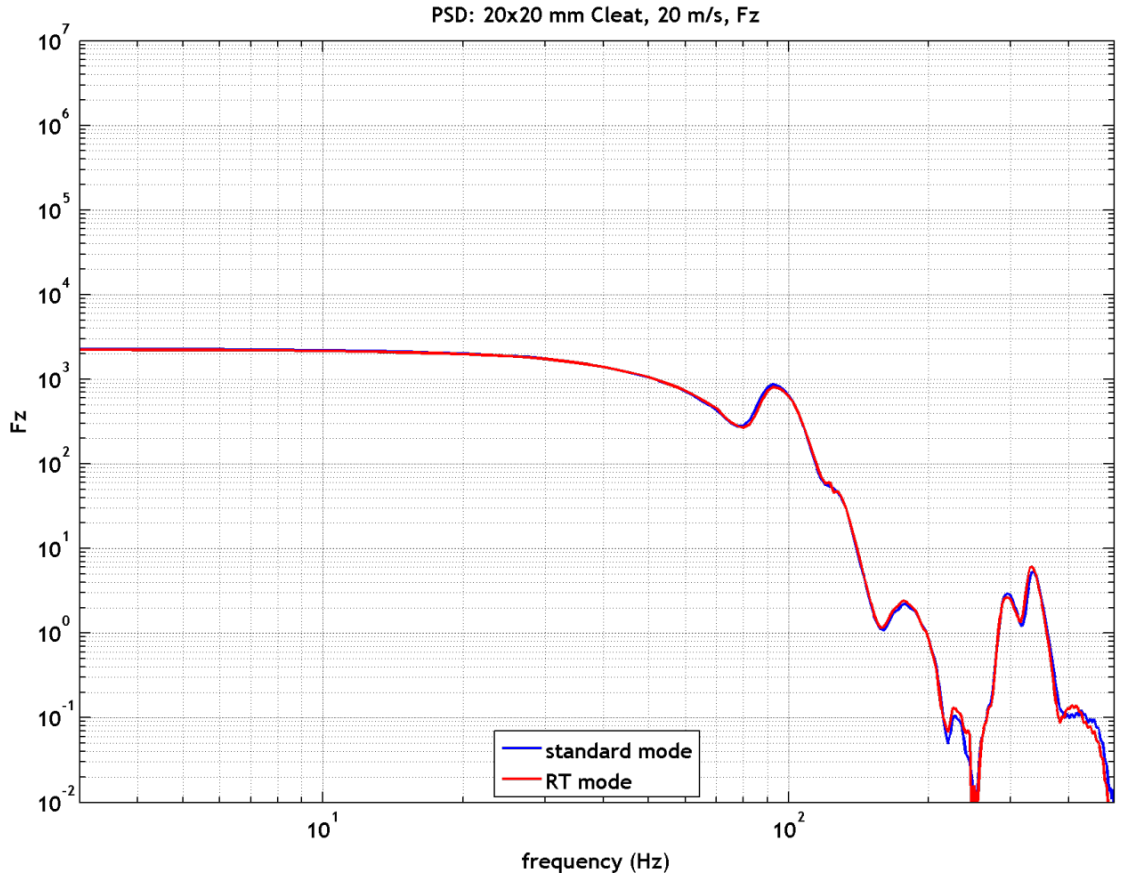




FTire/realtime, Cleat Test Accuracy in Frequency Domain

Barely loss in accuracy: single obstacle (20 x 20 mm cleat, 20 m/s). PSD





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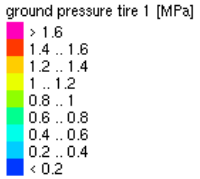
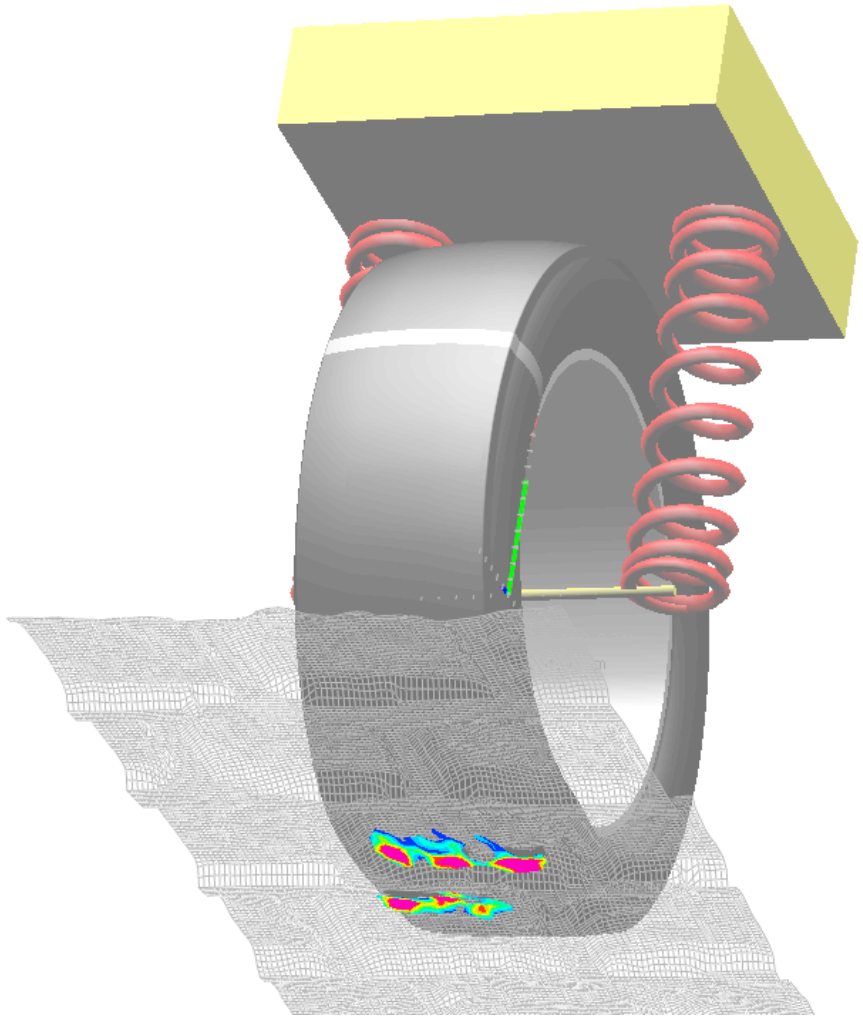
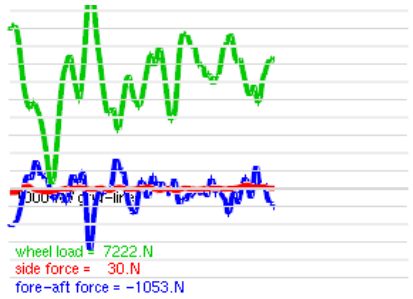
FTire/realtime, Accuracy on Real Road

Belgian block road (10 m section, 80 km/h, 6 kN, non-linear quarter-car model, unsprung mass 600 kg)







contact elements: force vectors
t = 0.3660s

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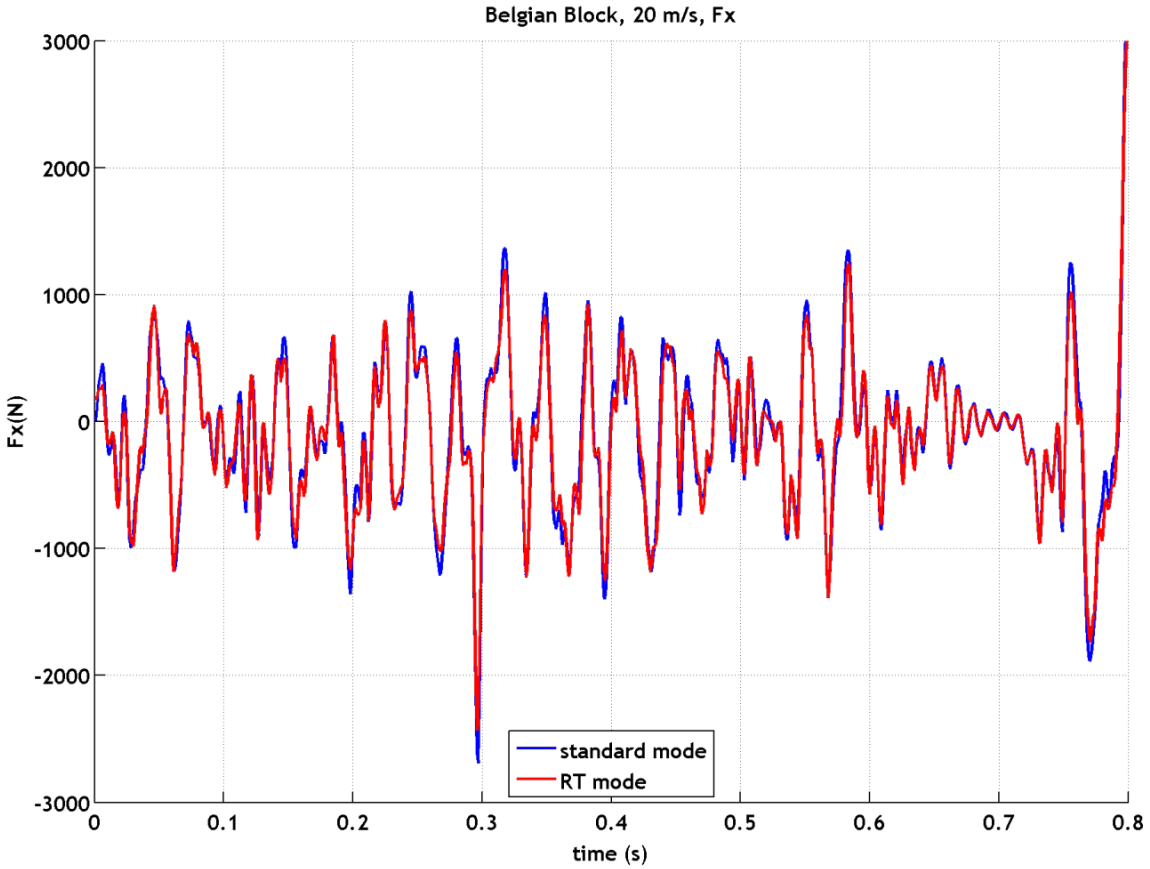
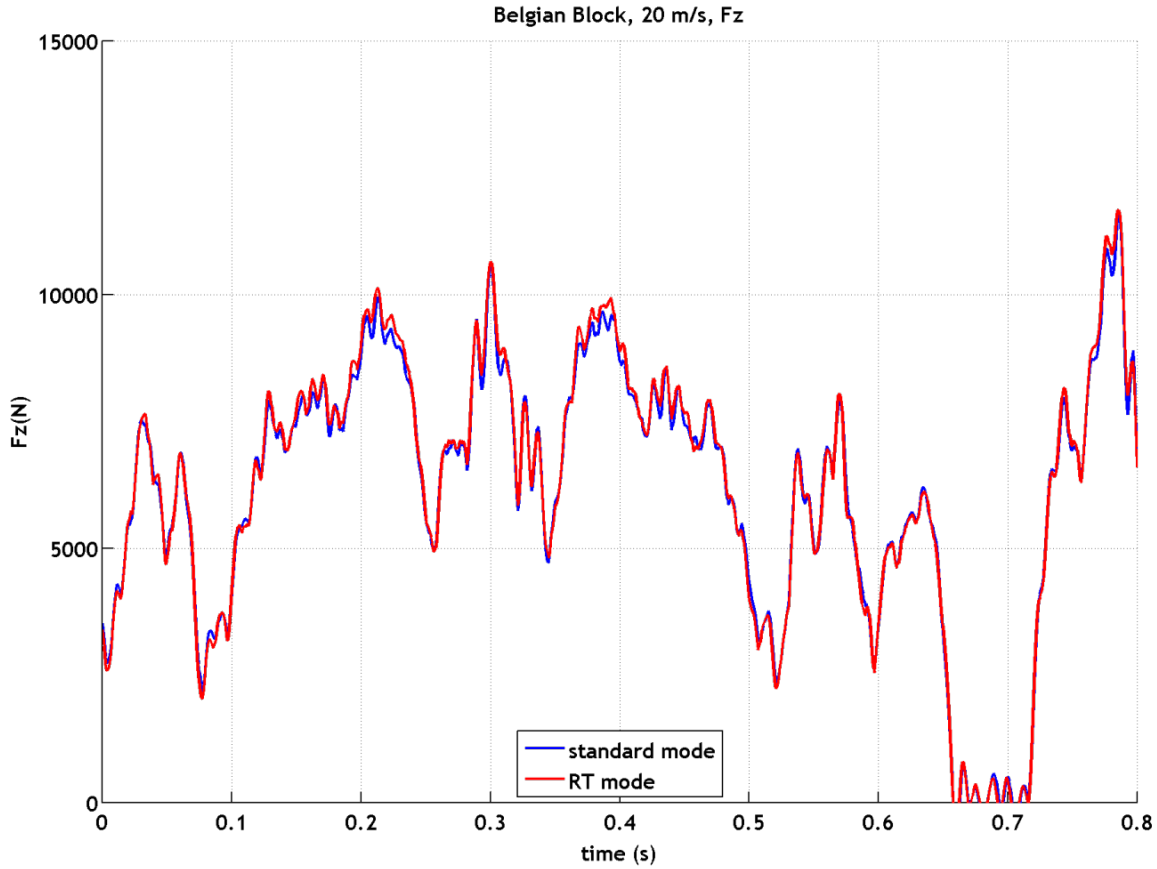
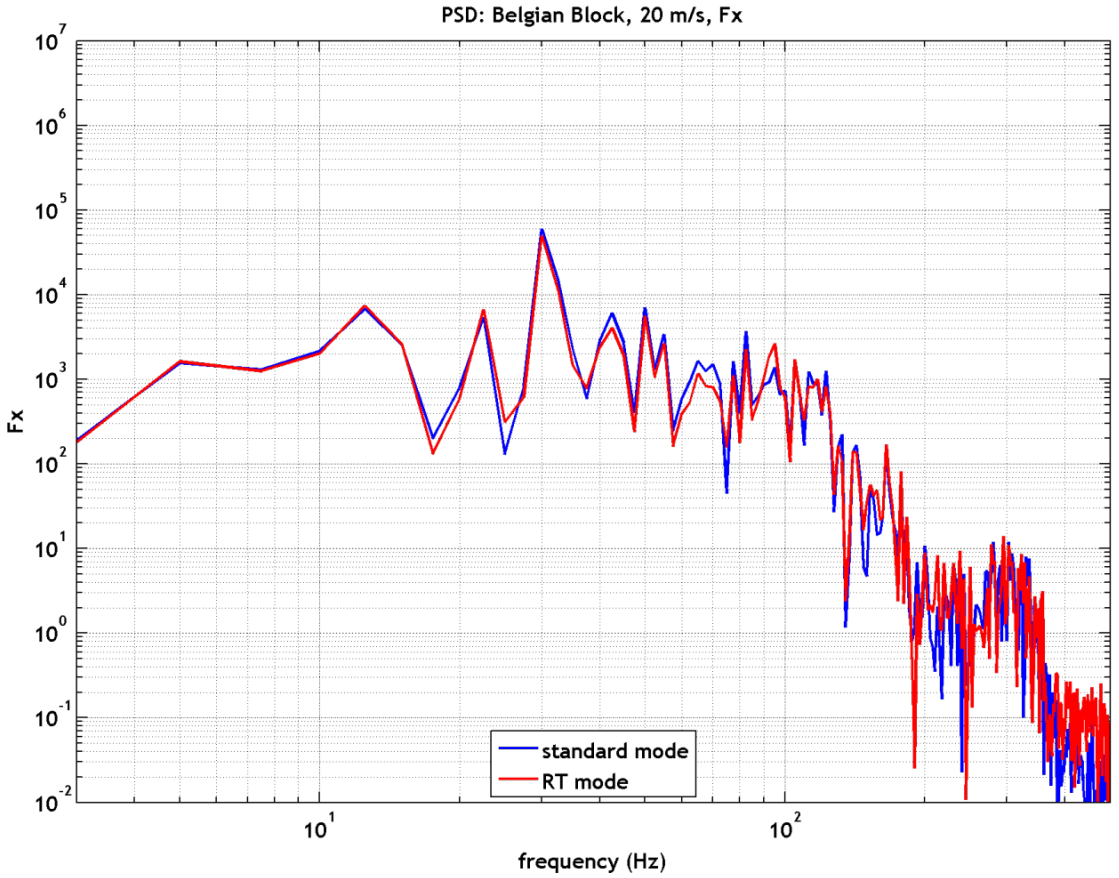
FTire/realtime, Accuracy on Real Road in Time Domain

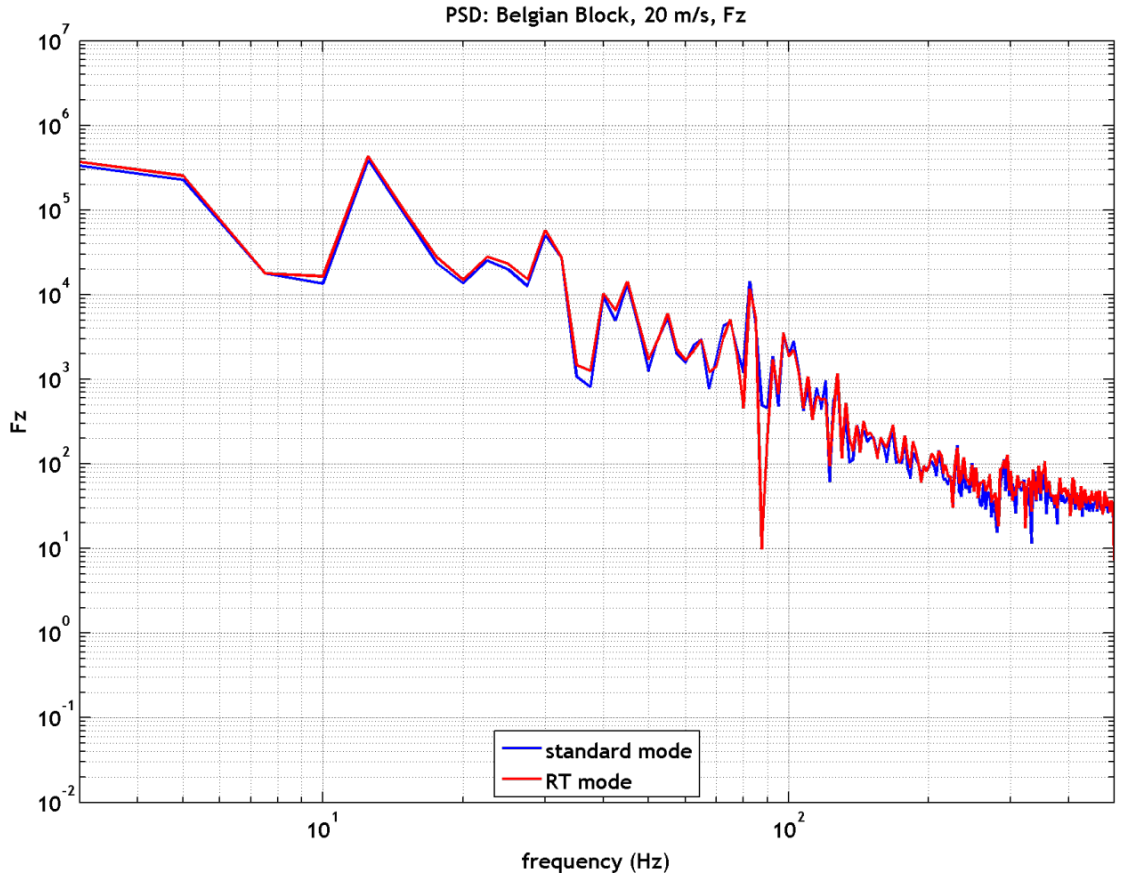
Barely loss in accuracy: durability road (Belgian block, 20 m/s). Time domain





Barely loss in accuracy: durability road (Belgian block, 20 m/s). PSD





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FTire/realtime, Accuracy in Damage Number Prediction

Percental deviation in pseudo damage number

between fastest real-time mode and standard speed mode on Belgian block road

Damage Exponent = 3

	F_x	F_y	F_z
40 km/h, 3 kN	12.6 %	-16.3 %	-0.6 %
40 km/h, 6 kN	0.2 %	13.6 %	-1.5 %
80 km/h, 3 kN	-3.4 %	-5.1 %	-1.4 %
80 km/h, 6 kN	-5.9 %	-15.8 %	0.7 %

Damage Exponent = 5

	F_x	F_y	F_z
40 km/h, 3 kN	19.9 %	-30.6 %	-1.0 %
40 km/h, 6 kN	-1.5 %	30.4 %	-2.7 %
80 km/h, 3 kN	-5.0 %	-8.2 %	-1.8 %
80 km/h, 6 kN	-11.0 %	-26.6 %	3.0 %

Damage Exponent = 7

	F_x	F_y	F_z
40 km/h, 3 kN	28.5 %	-41.2 %	-1.4 %
40 km/h, 6 kN	-2.5 %	48.9 %	-3.8 %
80 km/h, 3 kN	-6.7 %	-12.0 %	-2.4 %
80 km/h, 6 kN	-16.2 %	-35.7 %	5.7 %

Relevance of load cases / channels

percentage of single damage number relative to maximum damage number in a group

Damage Exponent = 3

F_x	F_y	F_z
2.8 %	< 0.001 %	33.6 %
15.4 %	< 0.002 %	44.8 %
1.7 %	< 0.001 %	54.0 %
9.0 %	< 0.003 %	100.0 %

Damage Exponent = 5

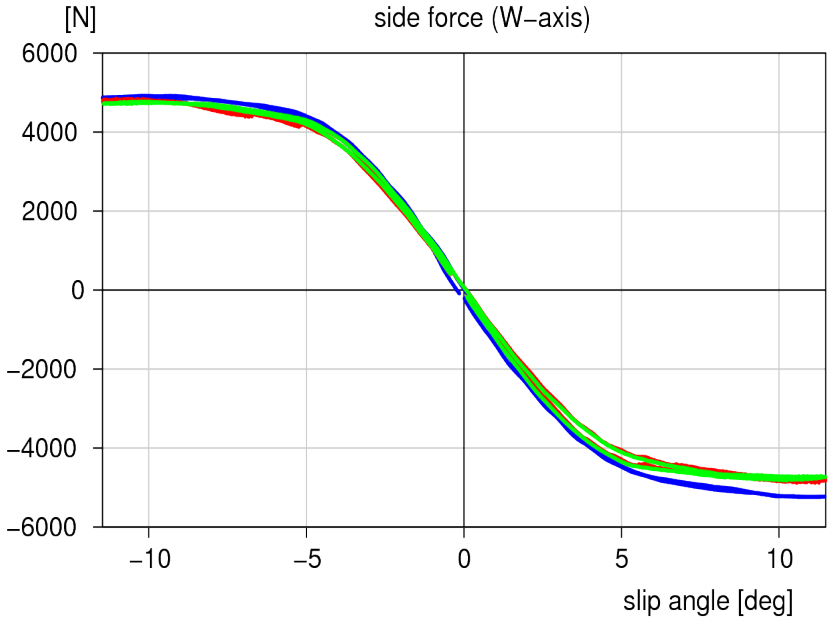
F_x	F_y	F_z
0.2 %	< 0.00001 %	12.2 %
3.0 %	< 0.00001 %	18.9 %
0.1 %	< 0.00001 %	36.2 %
1.5 %	< 0.00001 %	100.0 %

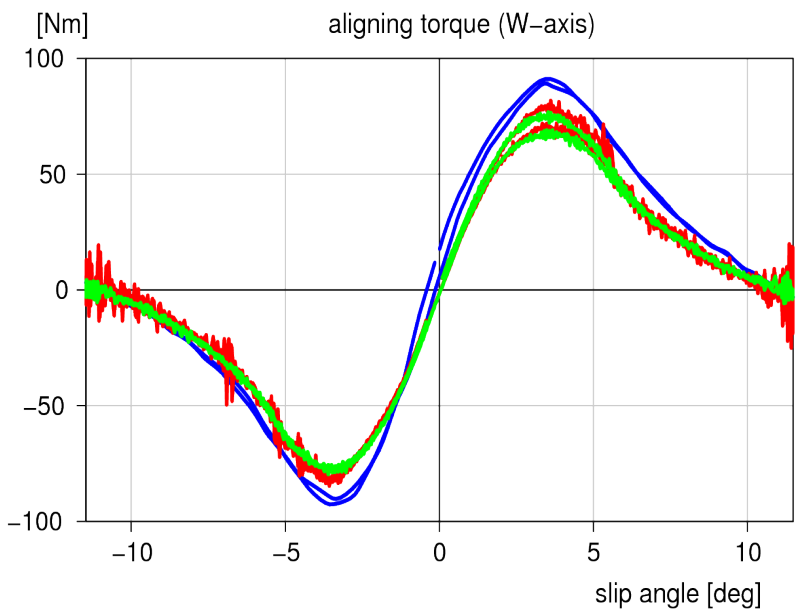
Damage Exponent = 7

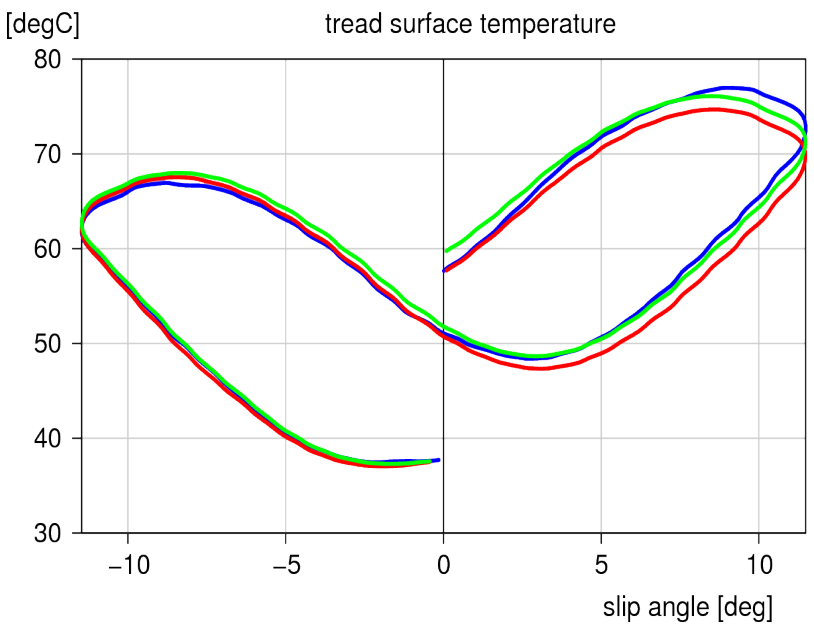
F_x	F_y	F_z
< 0.01 %	< 0.00001 %	4.7 %
0.7 %	< 0.00001 %	8.5 %
< .007 %	< 0.00001 %	25.9 %
0.27 %	< 0.00001 %	100.0 %

FTire/realtime, Accuracy in Steady-State Handling and Temperature

Barely loss in accuracy: Surface temperature @ slip angle sweep







Measurement
FTire Real-Time
FTire standard

2 deg/s, 5 kN

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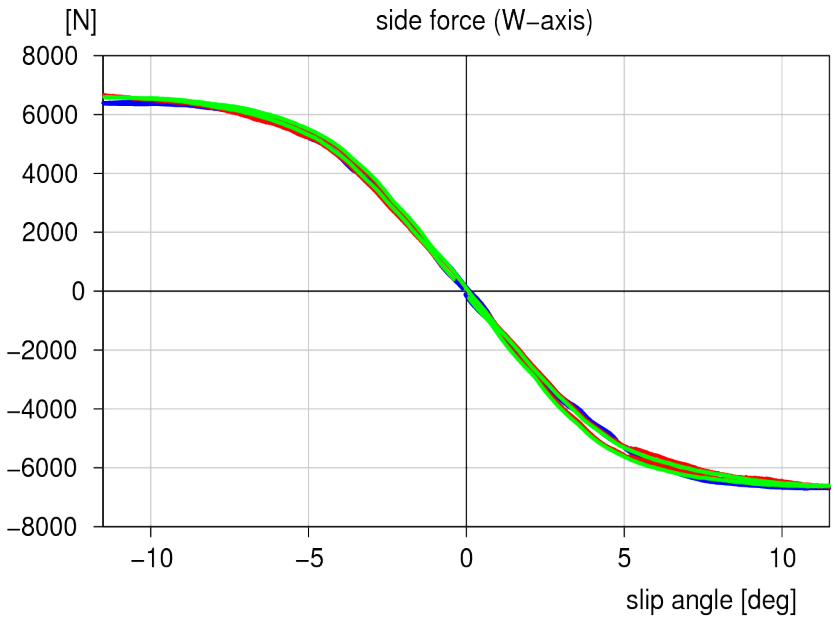
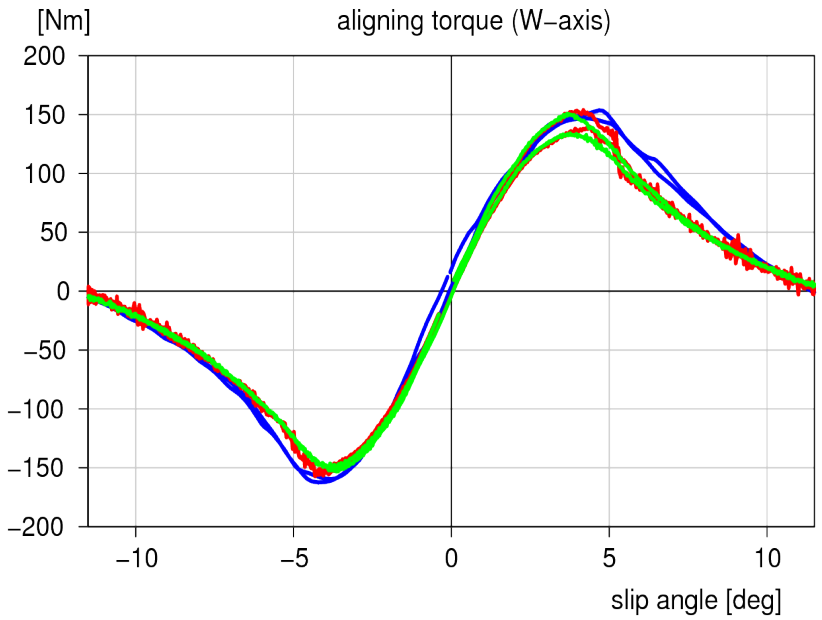
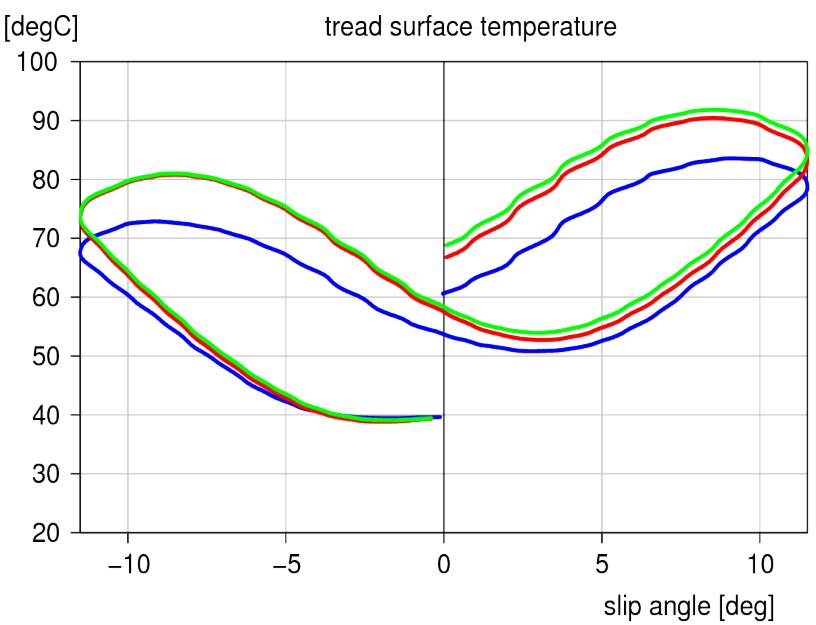
FTire/realtime, Accuracy in Steady-State Handling and Temperature

Barely loss in accuracy: Surface temperature @ slip angle sweep





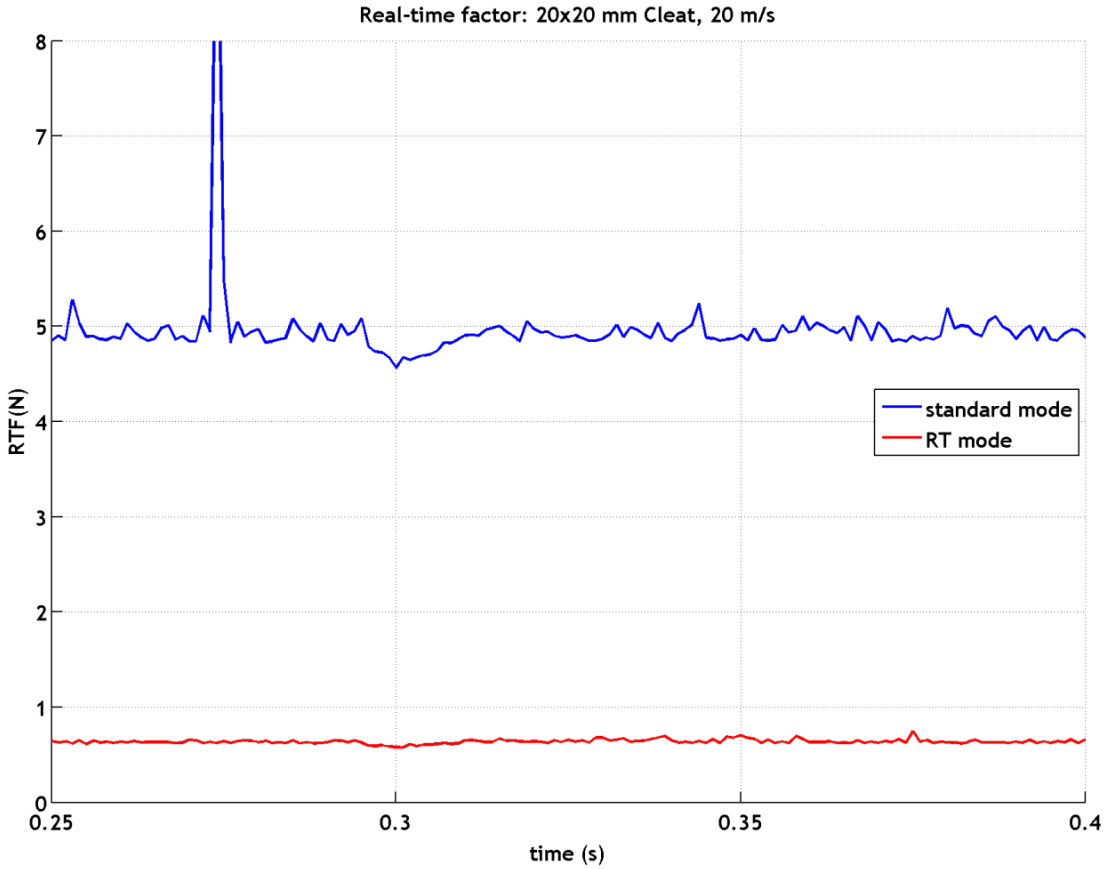


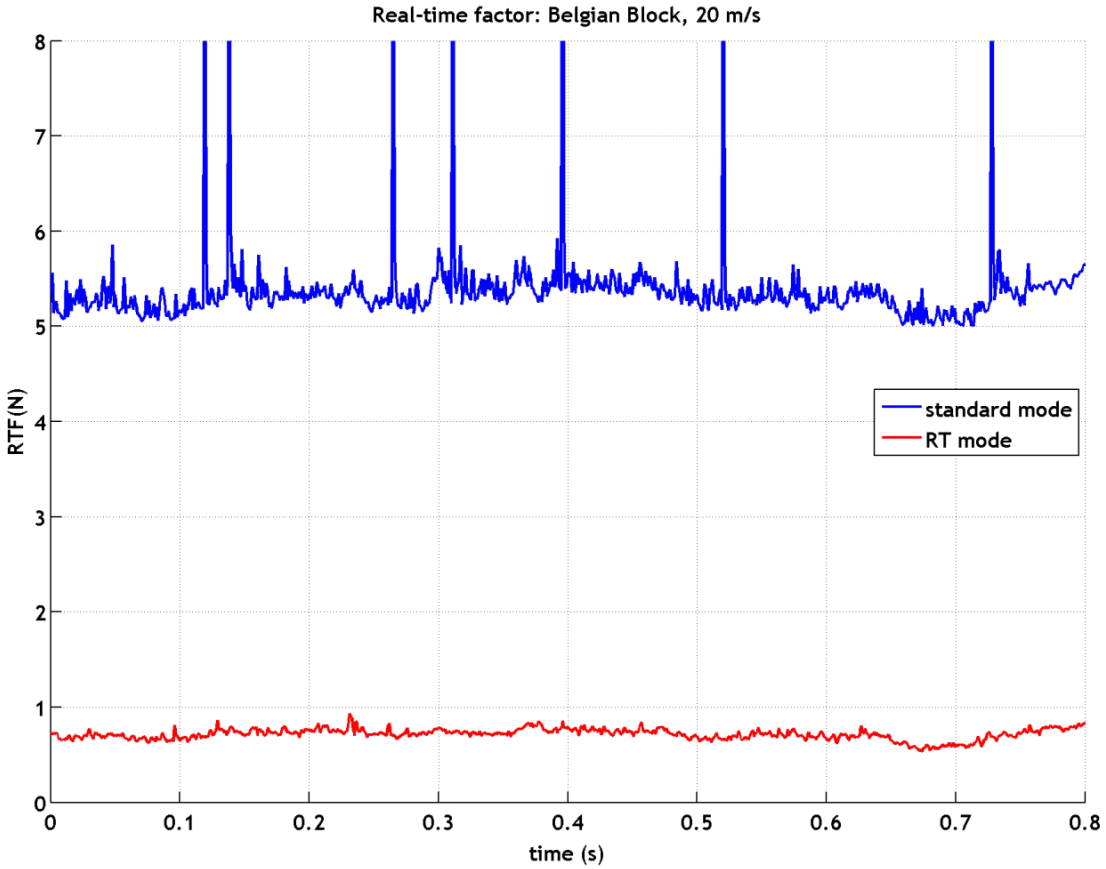
Measurement
FTire Real-Time
FTire standard

2 deg/s, 7 kN

FTire/realtime: Hard Real-Time Reliability

Reliability of achieved real-time factor for hard real-time





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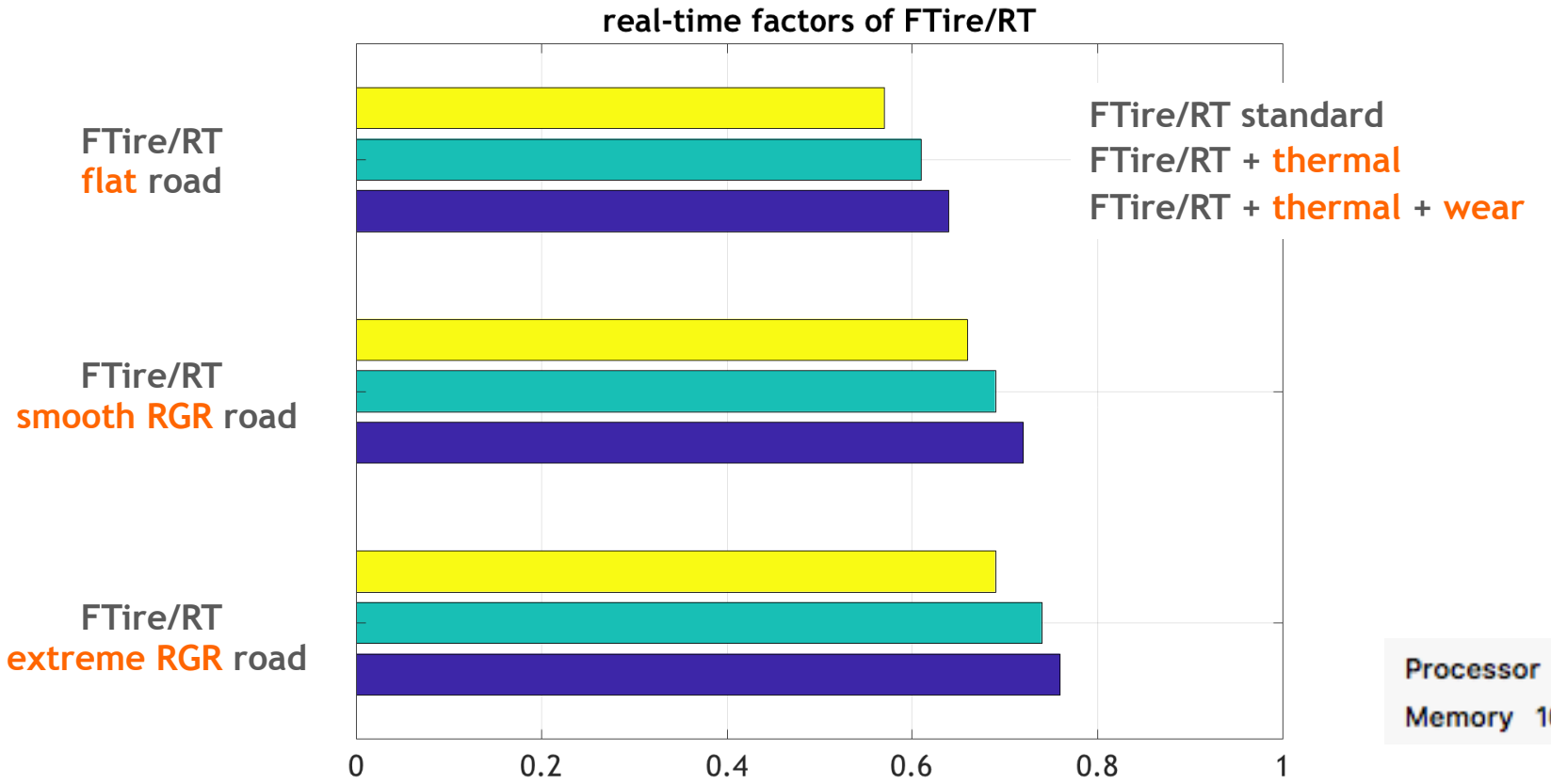
FTire/realtime Efficiency in Real-Time Mode

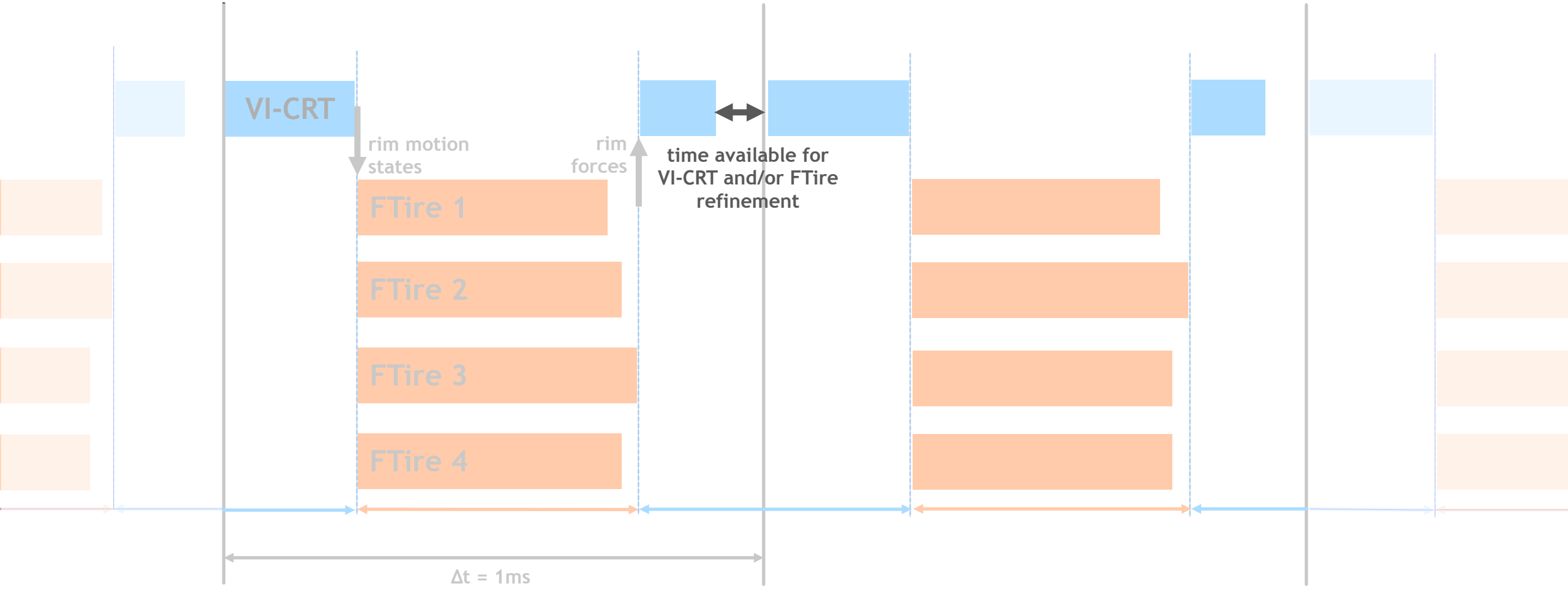
FTire realtime efficiency under different conditions

road contact resolution 1.07 mm x 12.5 mm = 900 contact elements; sample frequency 4.0 kHz

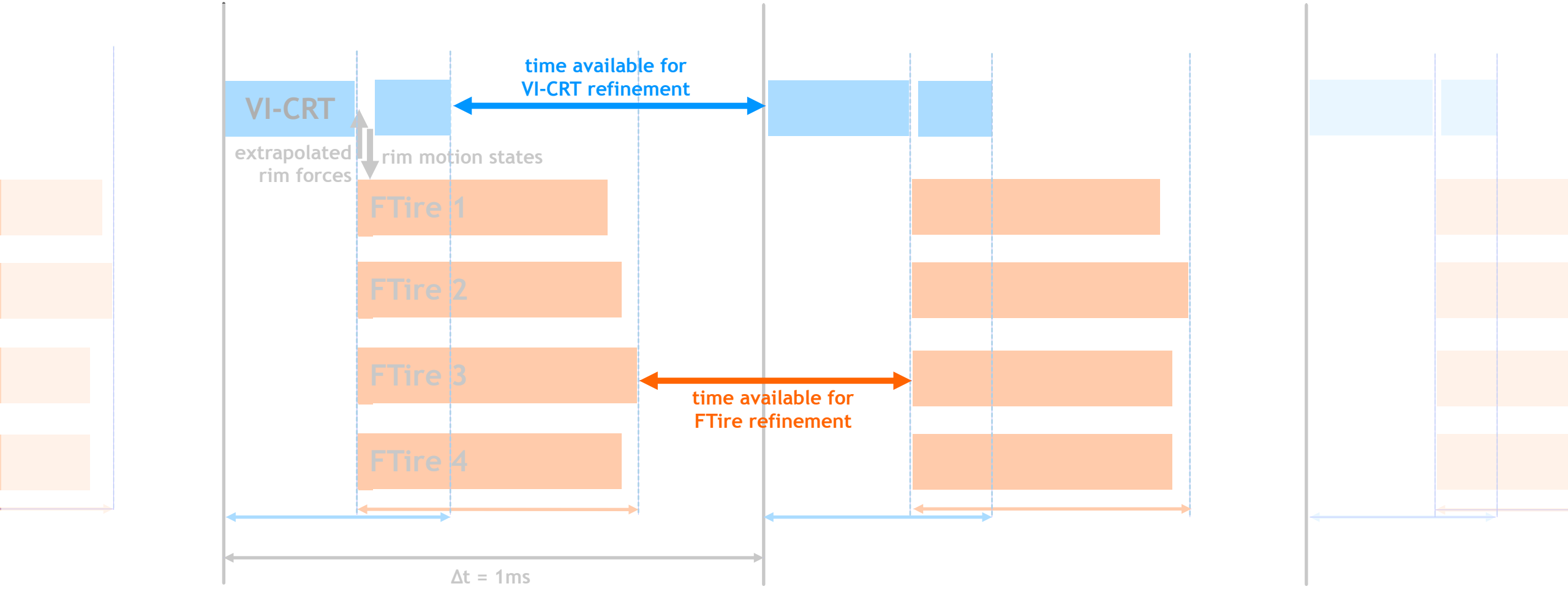


Processor 2,7 GHz 12-Core Intel Xeon E5
Memory 16 GB 1866 MHz DDR3

Cosimulation VI-CarRealTime ↔ FTire: sequential approach, timing chart



Cosimulation VI-CarRealTime ↔ FTire: parallel approach, timing chart



FTire/realtime and Vehicle Model Cosimulation

Cosimulation VI-CarRealTime ↔ FTire

→ both cosimulation methods are available within the same implementation in VI-CarRealTime

→ selection through ‘real-time level’ as specified in the tire data file

Pros and Cons of parallelized cosimulation

- ✔ strongly increased margin for model refinements both and independently in vehicle model and in FTire
- ✔ bidirectional signal exchange only once per time step
- ✔ largely reduced time lag in communication between vehicle model and simulator HW
- ✔ allows to run cosimulation even at 2 kHz instead of 1 kHz, due to FTire's internal 0.25 ms time step

- ✘ slight reduction of numerical stability margin (especially in conjunction with K&C-characteristics based steady-state suspension models)
- ✘ slight degradation of combined model accuracy in frequency domain above about 250 Hz

both impacts potentially reduced by running at 2 kHz instead of 1 kHz

FTire/realtime and RGR Road Model Evaluation

FTire's standard and recommended road model RGR

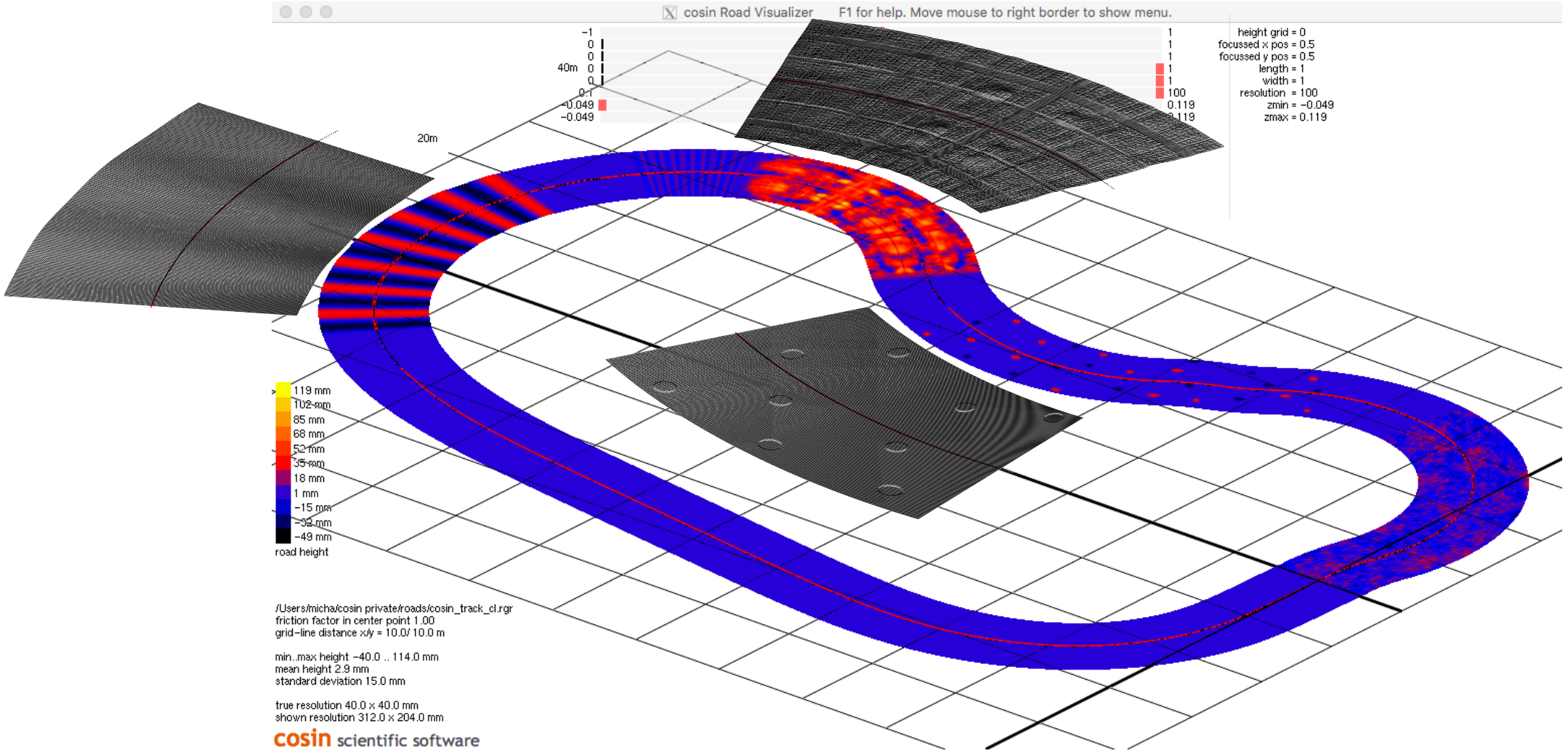
→ FTire/realtime senses the road surface up to 1 mio times per second

→ preferred method is RGR with straight or curved center-line, using the new high efficiency evaluation method

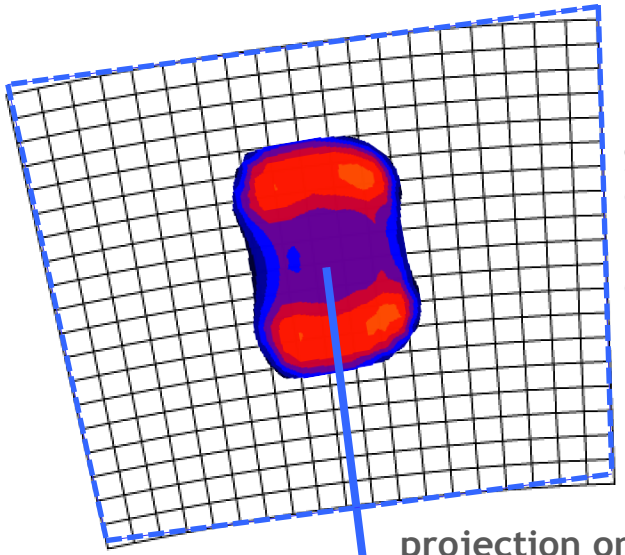
→ 'few clicks' functionality in cosin/tools to create a curved centerline RGR file from every other supported road data format (rdf, OpenCRG, etc.), or from scratch

FTire/realtime and RGR Road Model Evaluation

FTire's standard and recommended road model RGR

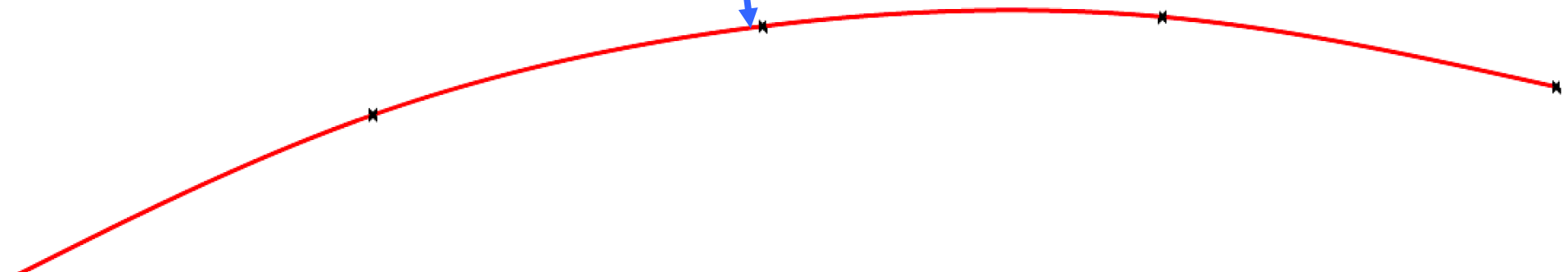


FTire's standard road model RGR with highest efficiency evaluation mode



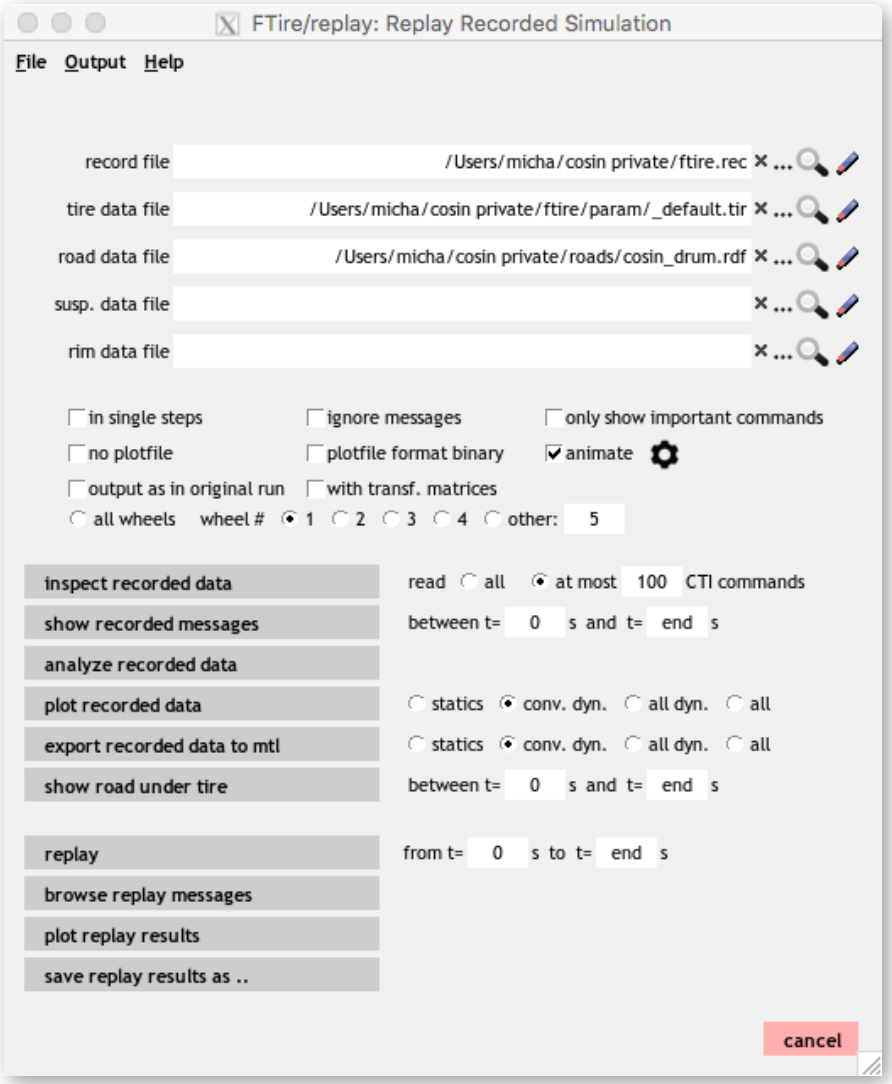
grid distortion due to
curved centerline
linearized near (small)
contact patch

projection onto
centerline only once
per tire and time step,
for footprint center



FTire/realtime postprocessing

- → for efficiency reasons, most of the file output is suppressed in real-time mode
- → however, complete and configurable output including detailed animation can be created offline, using the record file, without requiring the vehicle model



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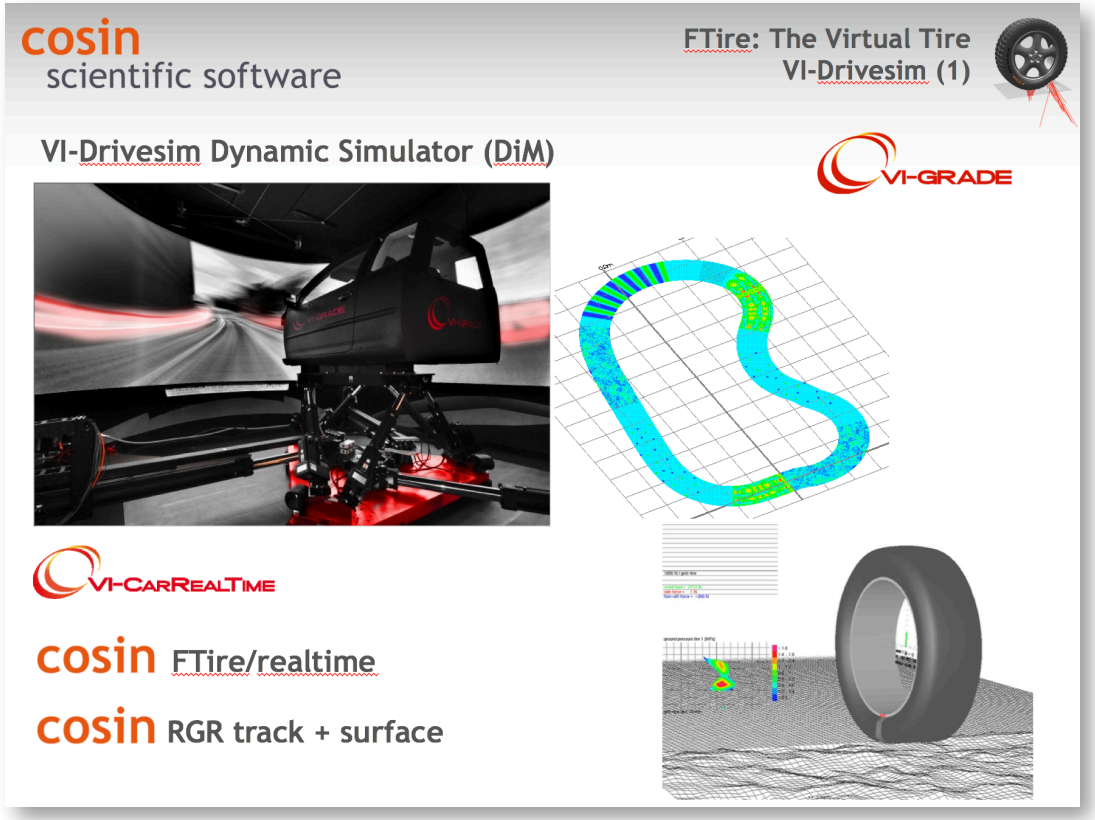
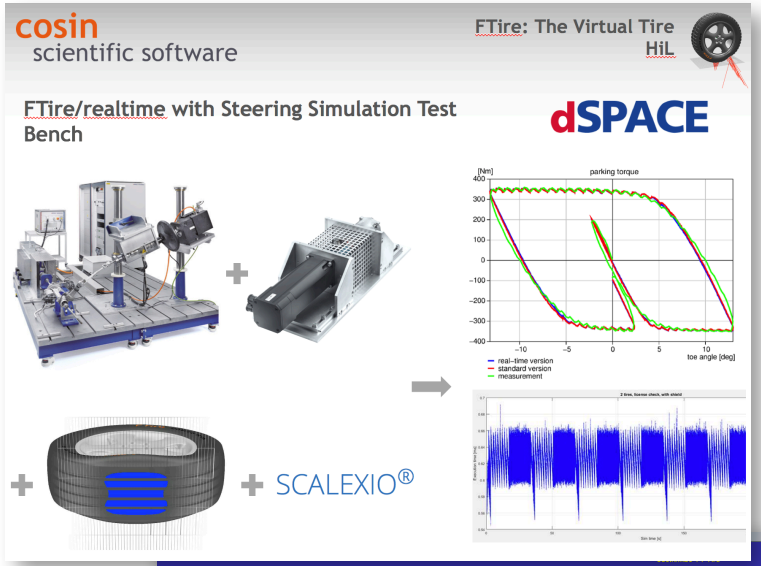
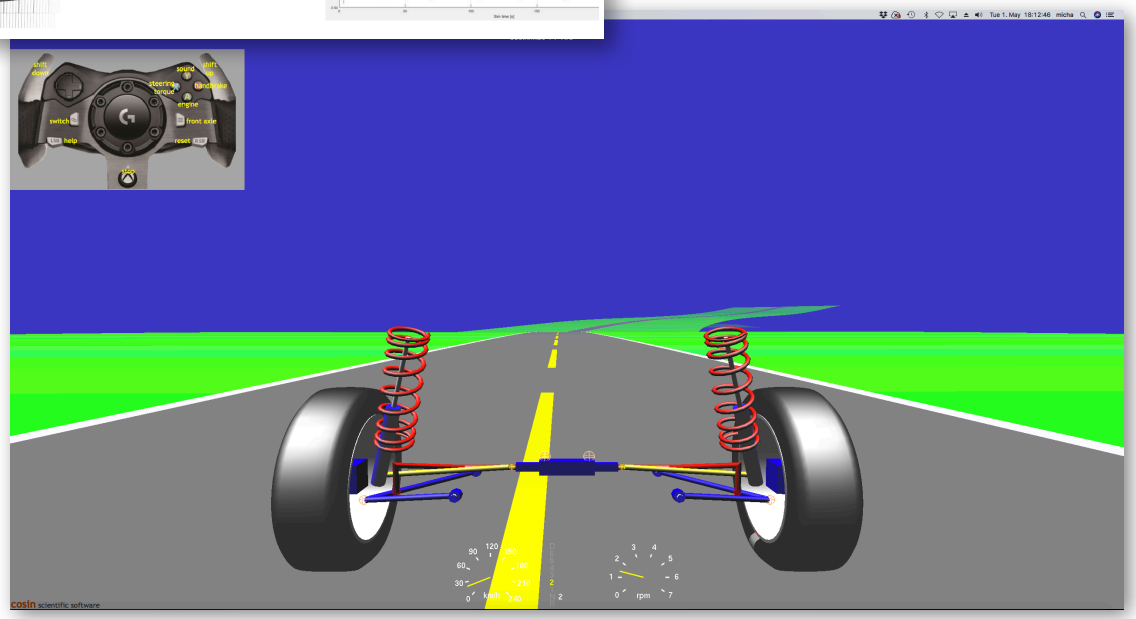
FTire/realtime on Simulators and HiL

FTire/realtime available for

- ➜ VI-Grade simulators
- ➜ dSPACE HiL
- ➜ cosin/comics simulator







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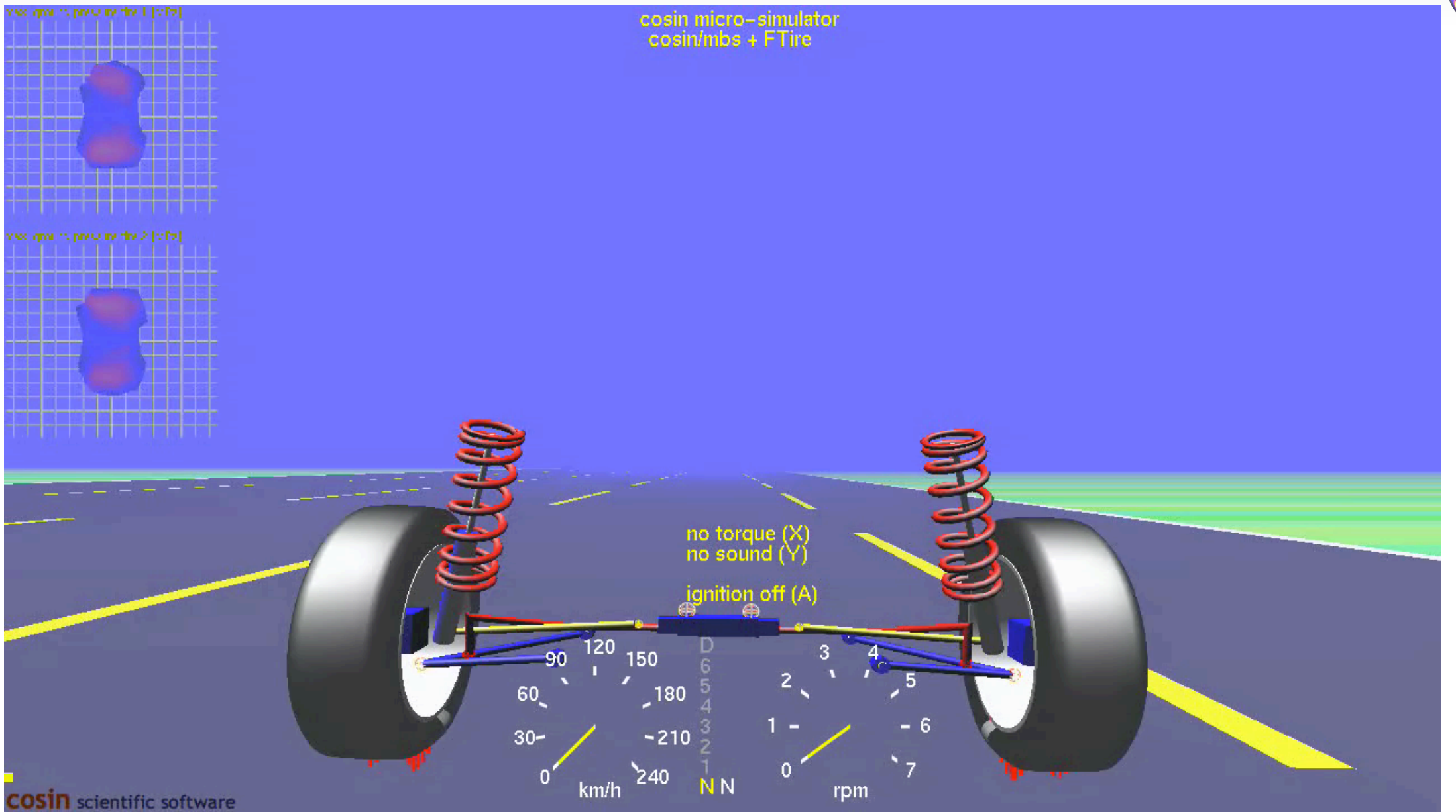
FTire/realtime in cosin/mbs ‘micro simulator’
High Speed Test Track



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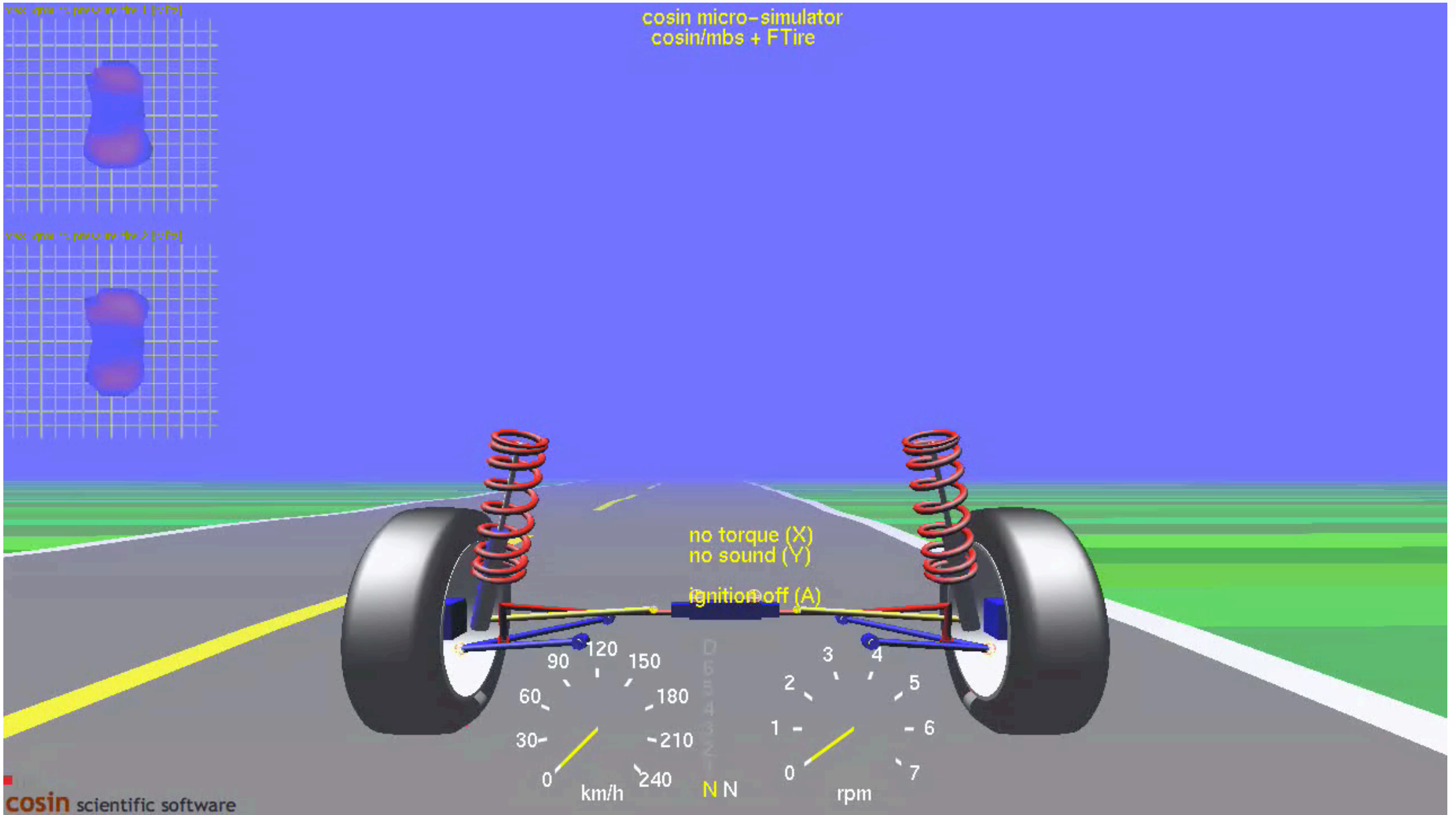
FTire/realtime in cosin/mbs ‘micro simulator’
Bumpy Road at Different Speeds and Sinus Steering Input



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That's it, thanks for listening.

Q & A

FTire papers,
animations, documentation,
version updates:

www.cosin.eu