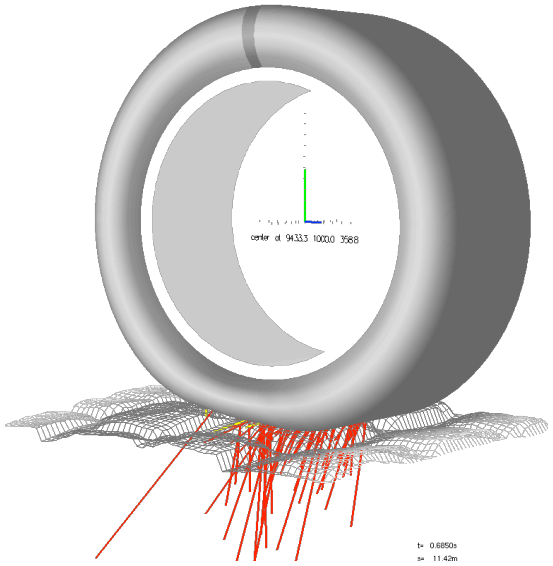
cosin
scientific software

New High Performance Stiff and Deformable Digital Roads for *FTire*

Gerald **Hofmann** and Michael **Gipser** @ cosin scientific software

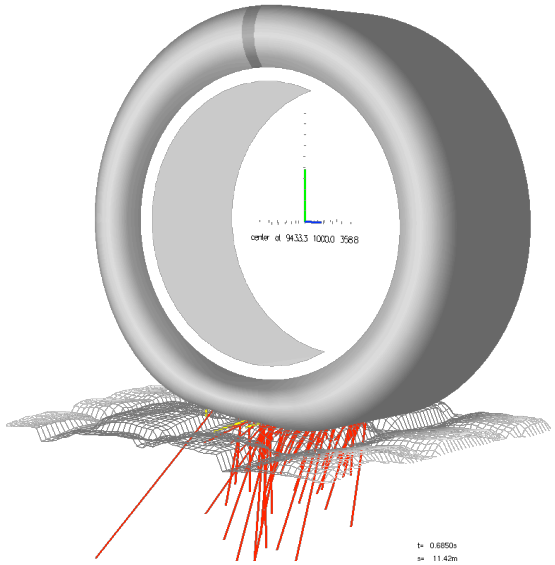


HyperWorks Technology Conference 2010
Novi, MI, April 27-29, 2010

FTire: Higher frequency, short wavelength tire model

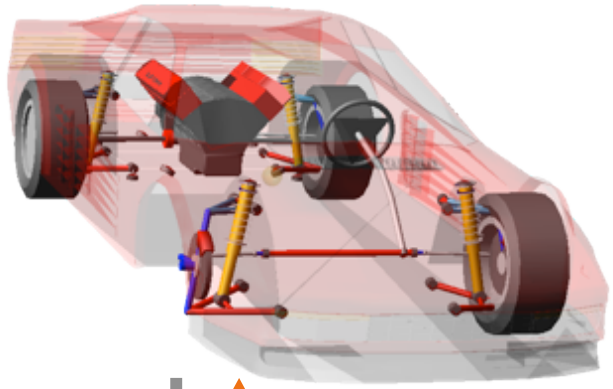
cosin scientific software

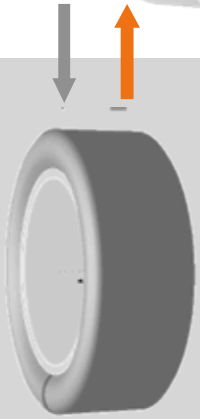
- Structural dynamics based, full 3D nonlinear in-plane and out-of-plane tire model for simulation of belt dynamics, local pressure distribution in the contact patch, rolling resistance, side-wall contact, large camber angles and misuse scenarios.
- Suitable for a frequency range up to 200Hz, excited by short surface wavelength, mass imbalance, non-uniformity or irregular tread patterns.
- Very fast and flexible. Orders of magnitude faster than explicit FE models.
- Simulation of imbalances by inhomogeneous mass distribution and local wear.
- Belt temperature distribution model
- Available in the Altair HyperWorks Partner Alliance



Vehicle / Tire / Road Interfacing

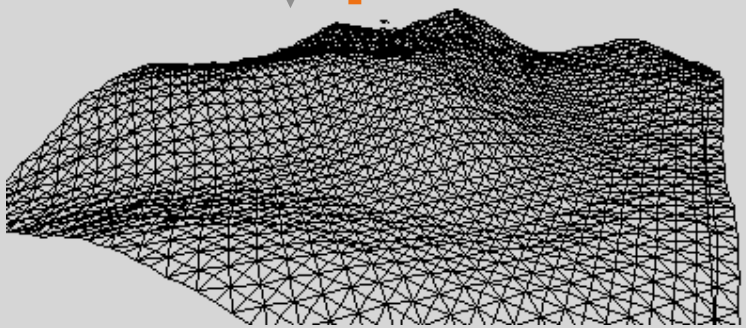
cosin
scientific software





cosin tire interface (CTI)

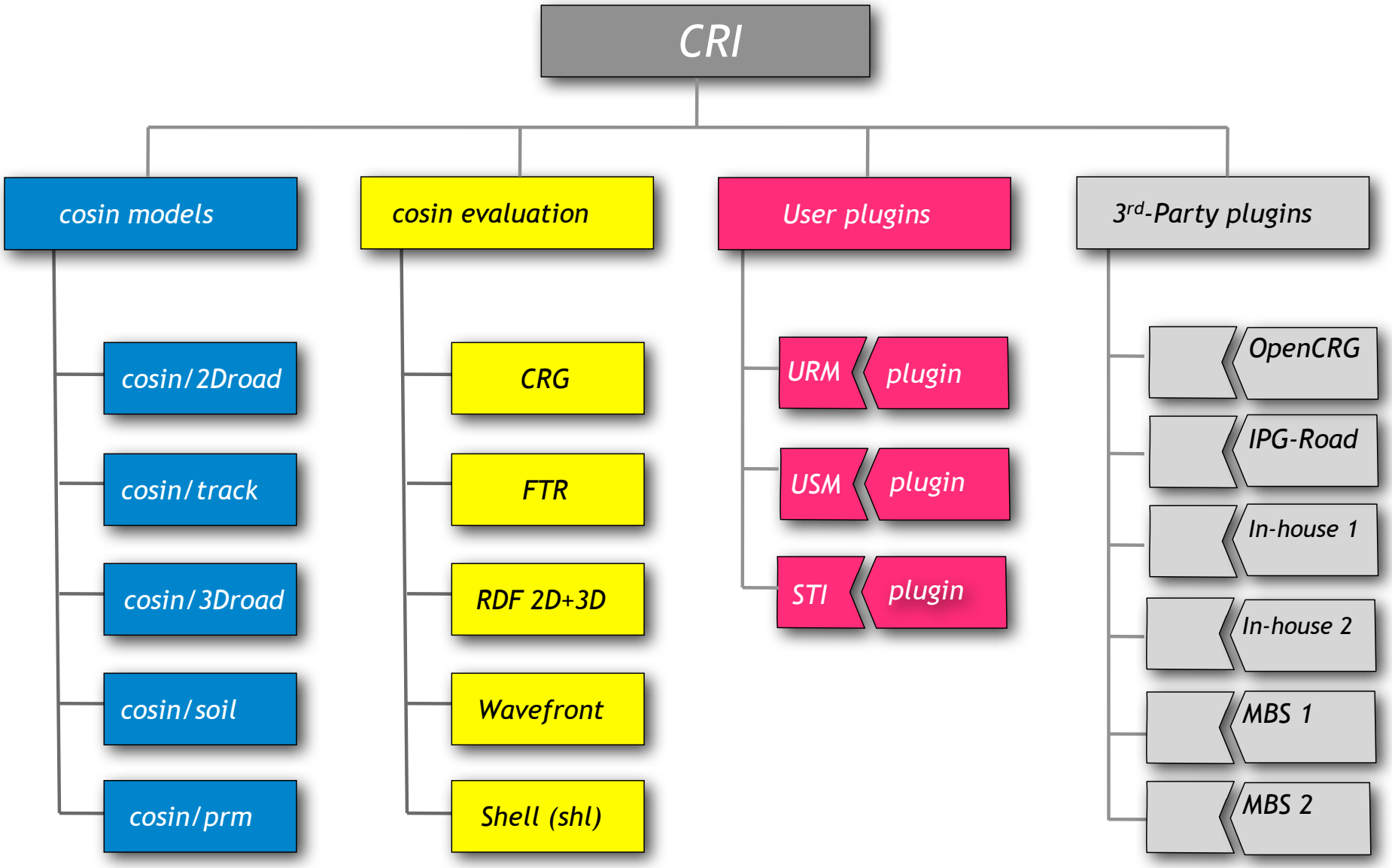
cosin road interface (CRI)



FTire interface

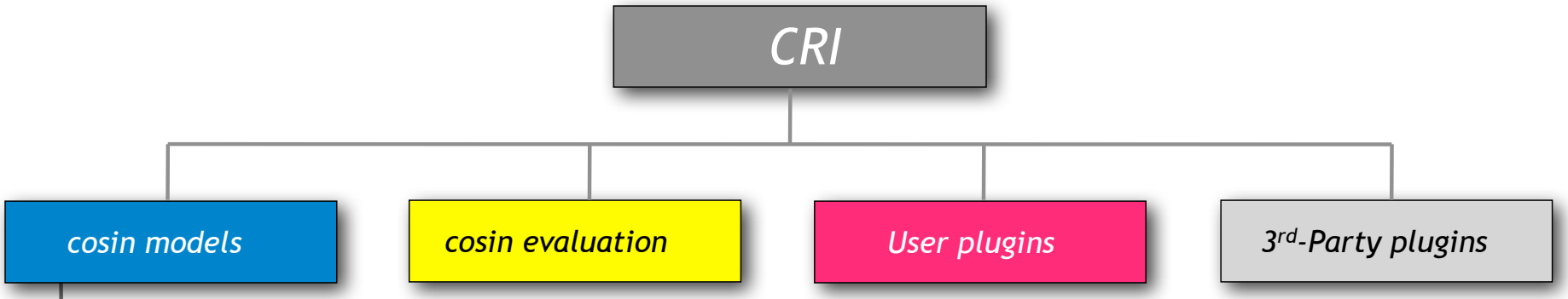
CRI: Gateway to Road Models and Interfaces (1)

cosin
scientific software



CRI: Gateway to Road Models and Interfaces (2)

cosin scientific software



cosin/2Droad

analytical 2D and 3D rigid road surface description: single obstacles, rotating drum with cleats, hydro-pulse, stochastically uneven roads ..

cosin/track

analytical road center line description: straight line, clothoid, circle, mean banking angle, lane number, lane width, animation data ..

cosin/3Droad

cosin Regular Grid Roads: efficient storage, evaluation and analysis of high resolution road surfaces, including OpenCL-accelerated implementation

cosin/soil

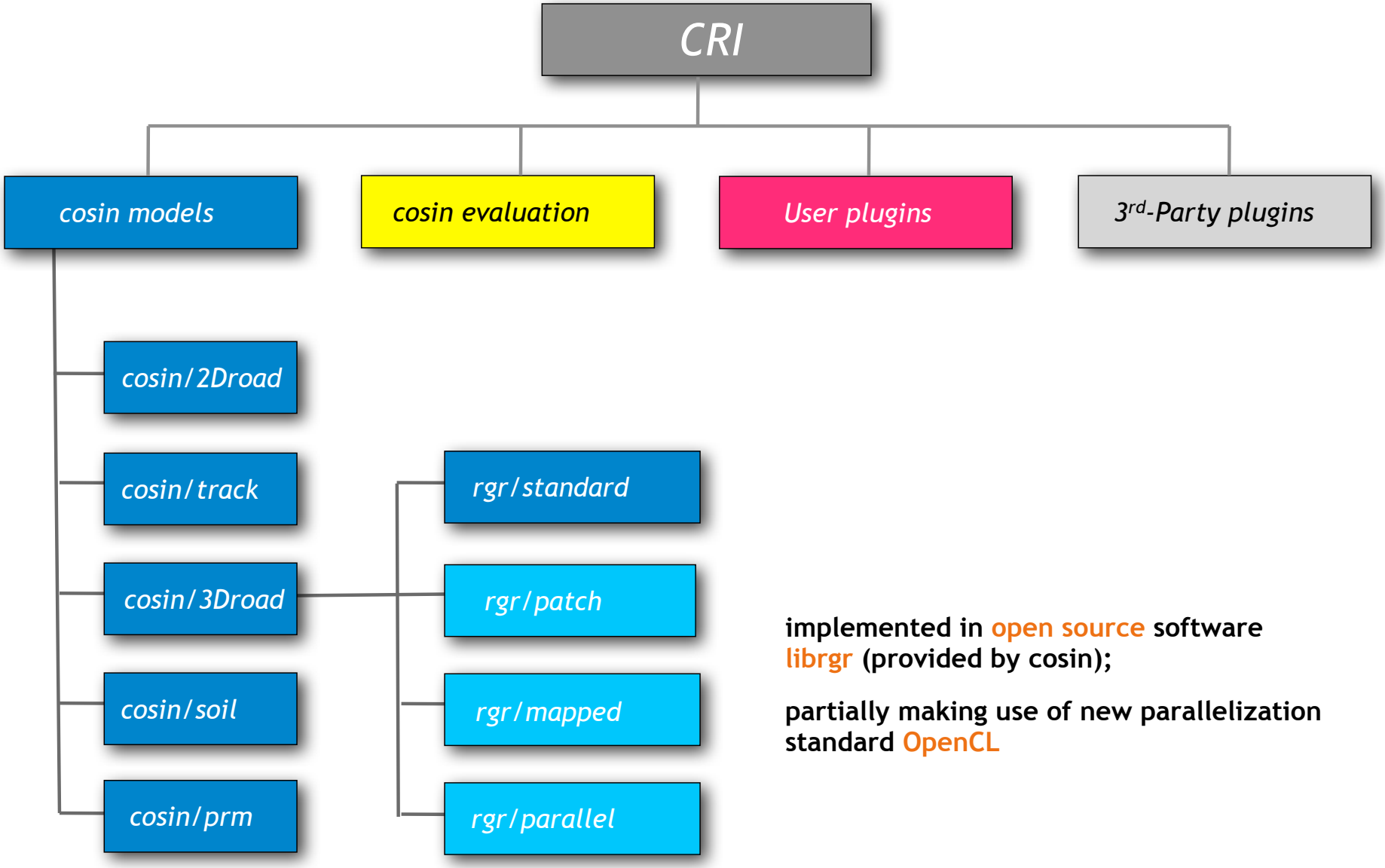
cosin Soft Soil Model: Cosin's internal soft soil model. Software structure and interfaces to tire model completed, *physical model under development*

cosin/prm

cosin Particle Road Model: Cosin's granular material road surface model, making use of massively parallel GPU computations. *Under development*

CRI: Gateway to Road Models and Interfaces (3)

cosin
scientific software

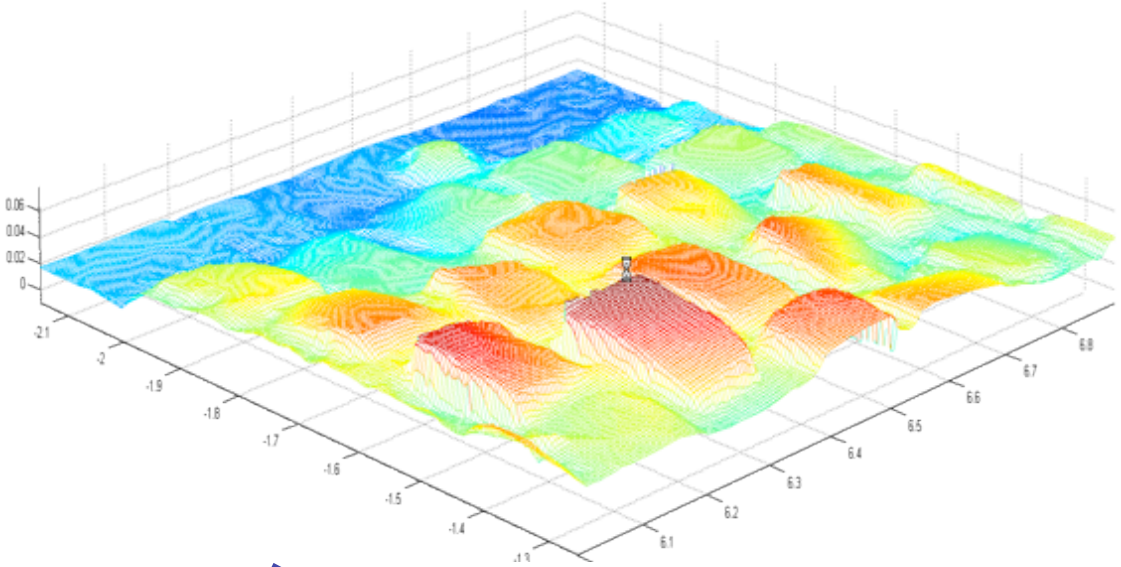


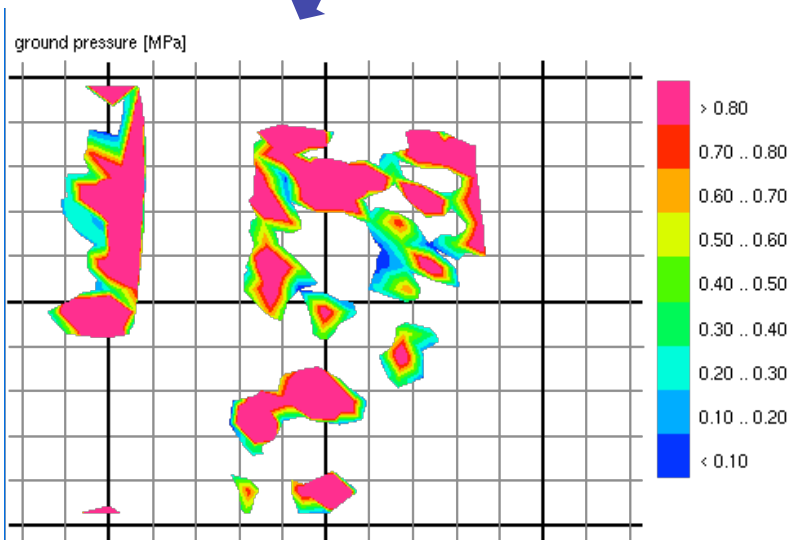
implemented in open source software librgr (provided by cosin);

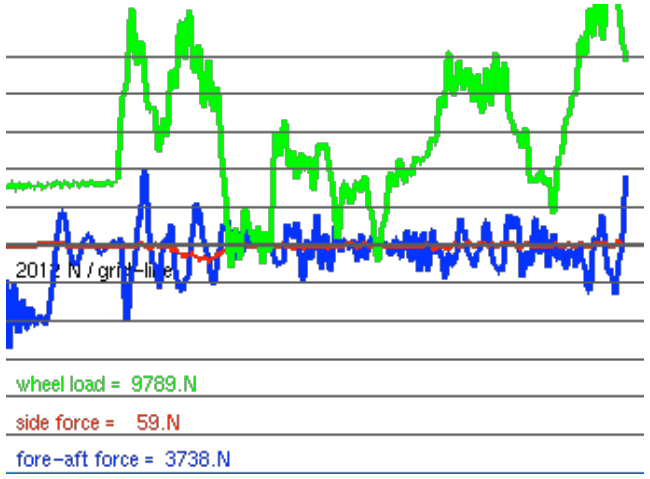
partially making use of new parallelization standard OpenCL

Road Surface / Contact pressure / Road Loads

cosin
scientific software

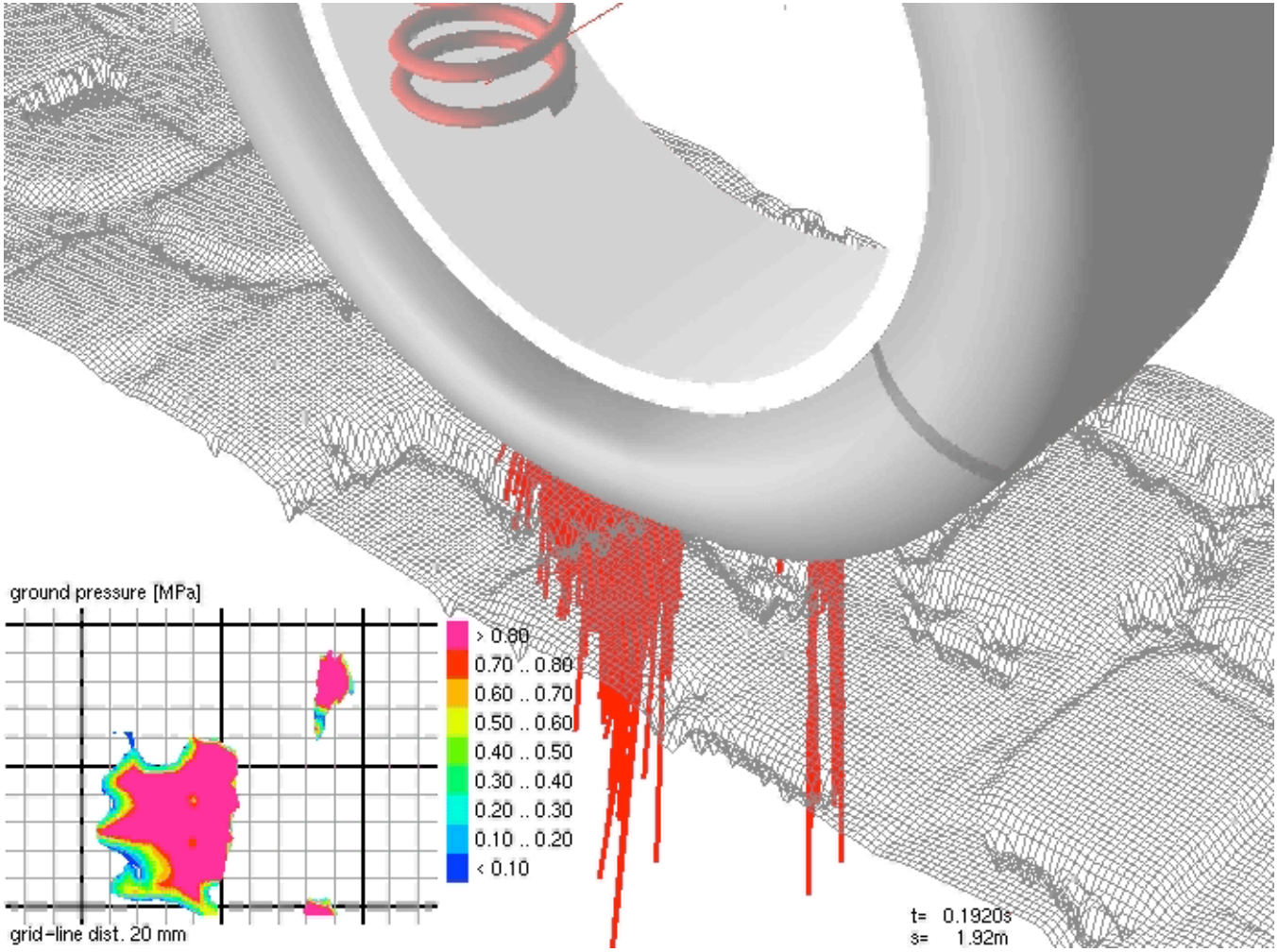






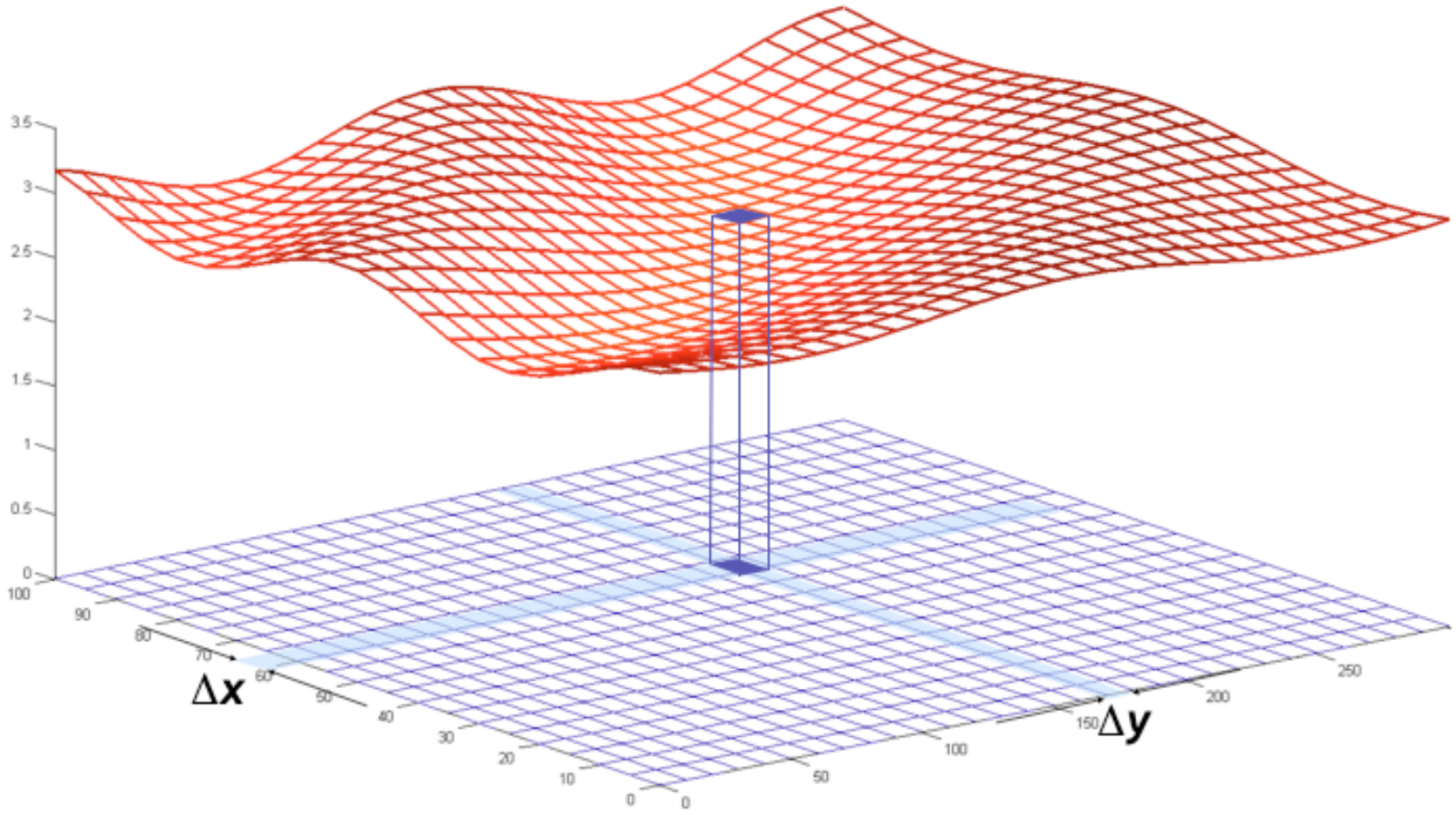
Road Surface / Contact pressure / Spindle Loads

cosin
scientific software



RGR road surface description

cosin
scientific software



RGR idea: equidistant mesh avoids searching for active triangle
Grid index can be computed directly

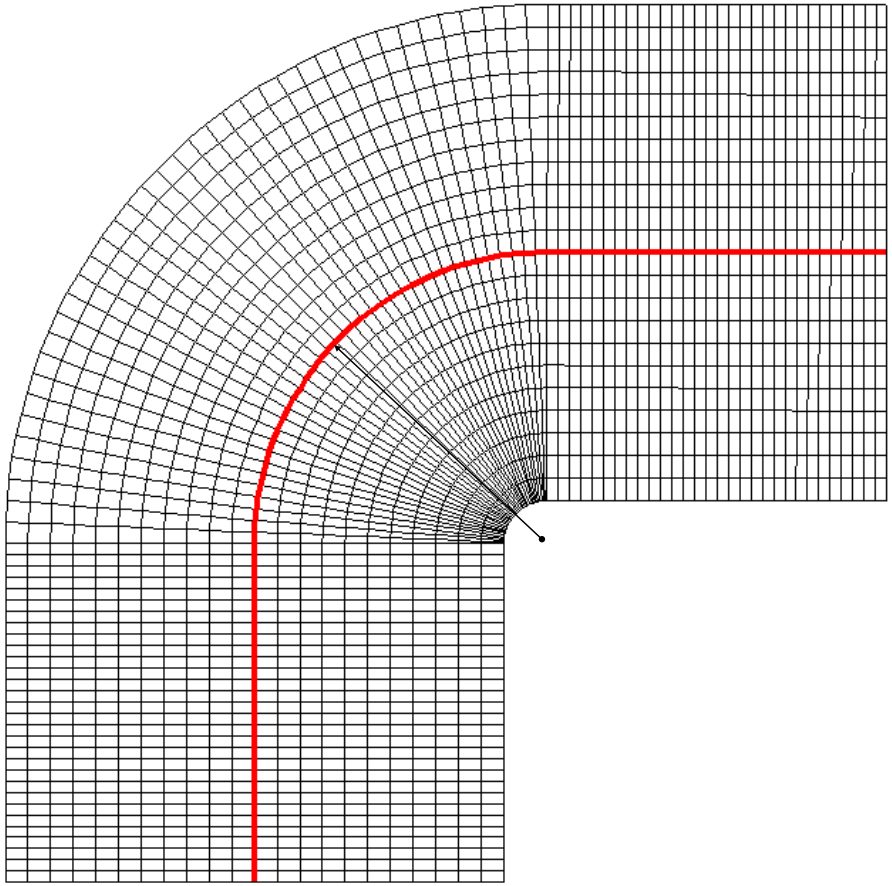
RGR Roads: Features

cosin
scientific software

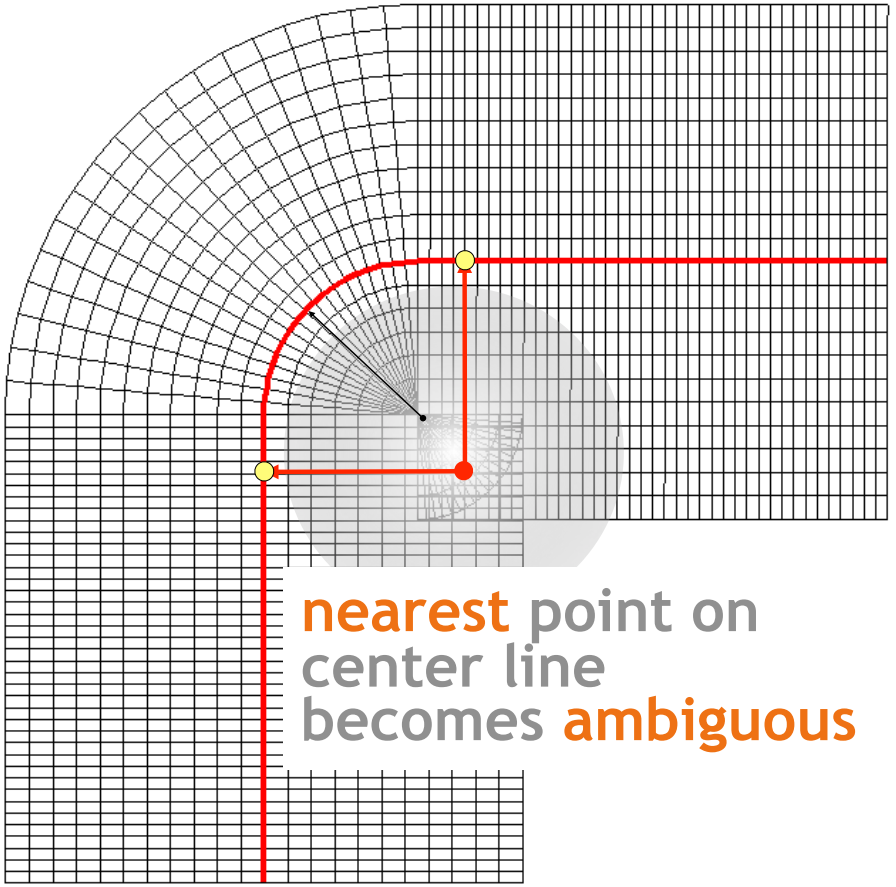
- are evaluated with **highest efficiency** and **accuracy**
- no search for active triangles
- are available both in **ASCII** and **binary** format
- have **lossless compression**
- **dynamic patch loading** for virtually unlimited grid sizes
- minimum loading time
- may have a **curvilinear center line**
- can **export center line** for driver models

Maximum Center Line Curvature

cosin
scientific software



center line
curvature radius >
½ RGR width



center line
curvature radius ≤
½ RGR width

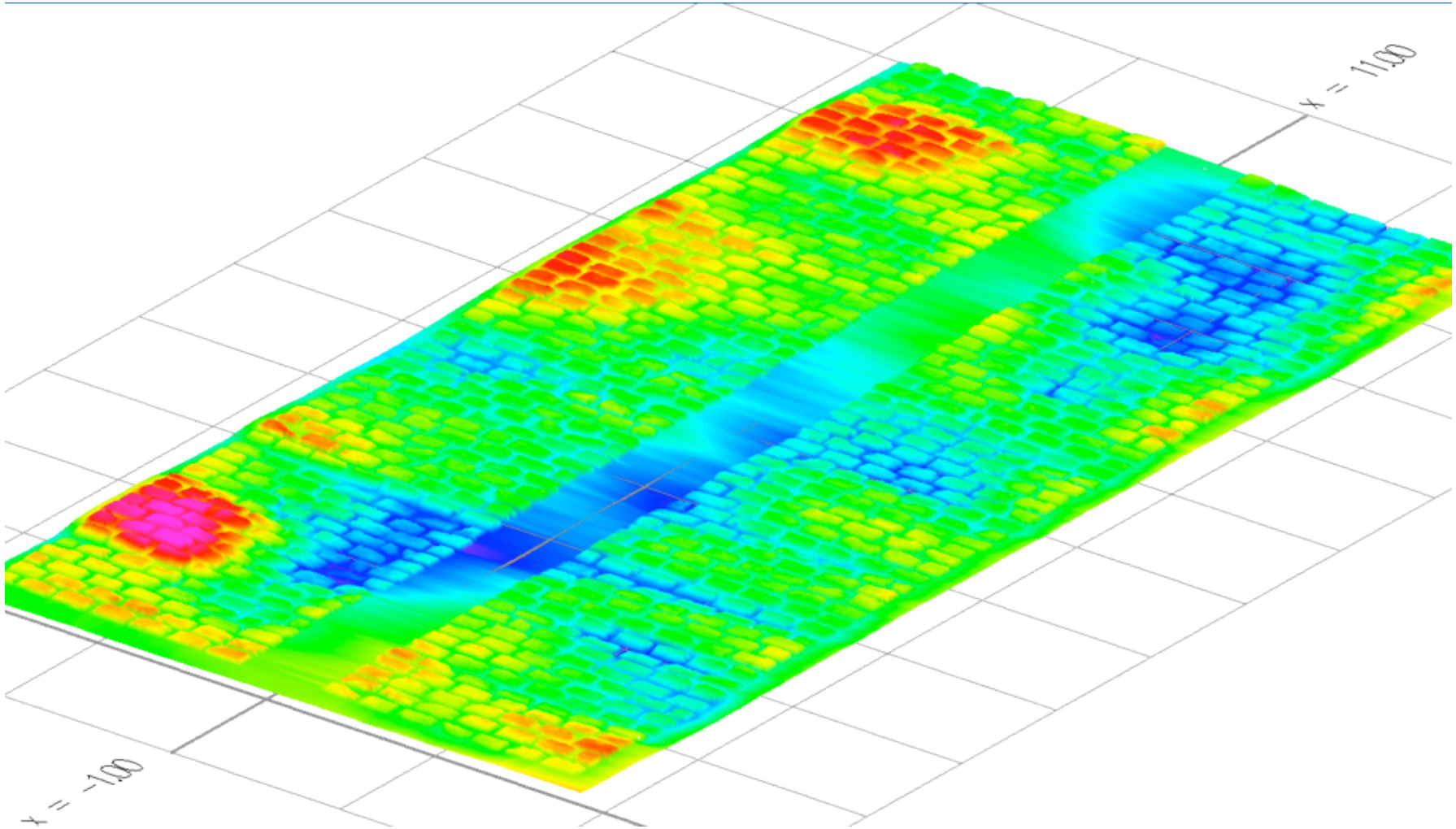
RGR Tools

cosin
scientific software

- 2D visualization (single tracks)
- 3D visualization, meshed or rendered
- generation of RGR roads out of any other supported road model
- generation of RGR roads out of 2D spectral density formula expression
- generation of RGR roads out of *z=f(x,y)* formula expression
- generation of RGR roads out of image data
- processing of RGR roads:
  - smoothing
  - compression
  - coarsening
  - filtering
  - ASCII -> binary
  - Binary -> ASCII
  - splitting into patches
- generation of shl-files for road graphics in calling solver

Measured Belgian Block Road (1)

cosin
scientific software



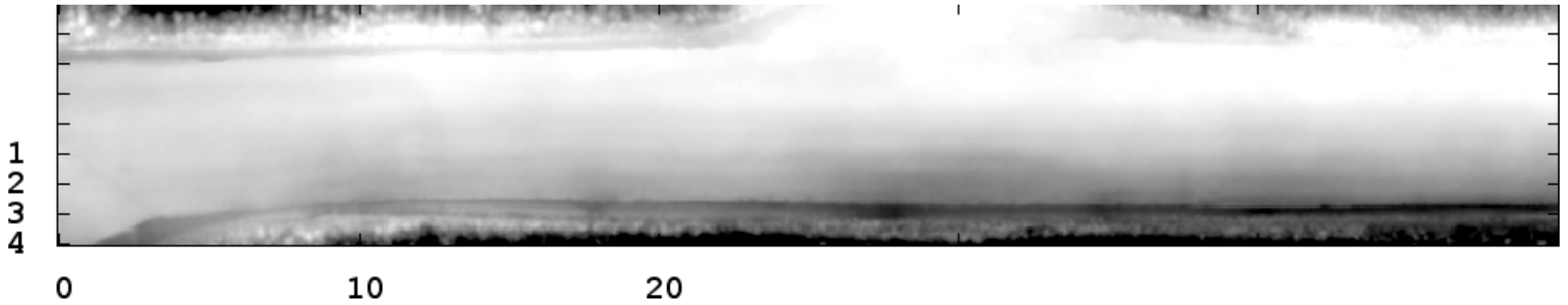
Road surface measurement

cosin
scientific software

Courtesy of MAN Nutzfahrzeuge AG
Research & Development (ERTV)

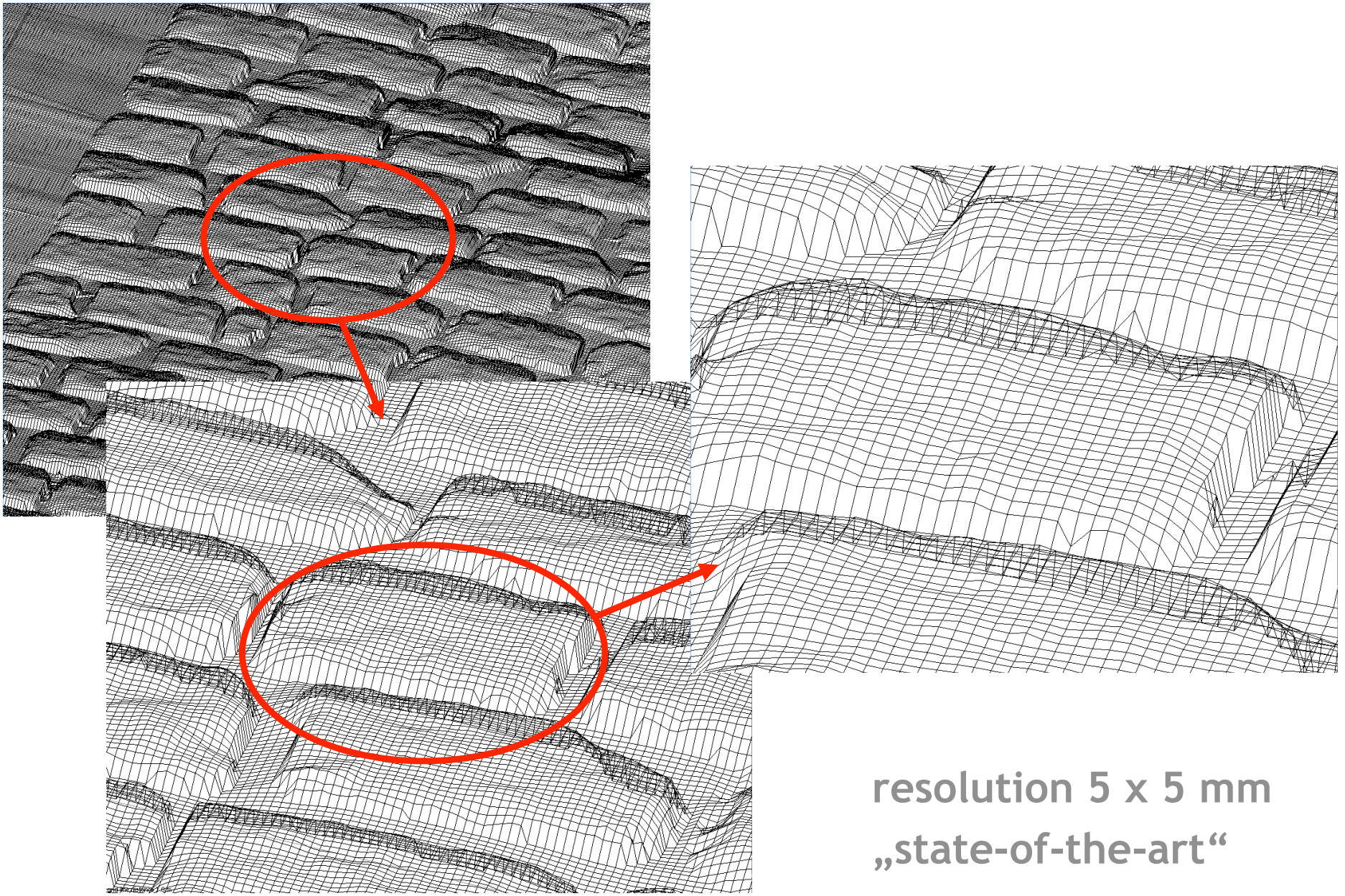
3D Mapping

www.3D-Mapping.de



Measured Belgian Block Road (2)

cosin
scientific software

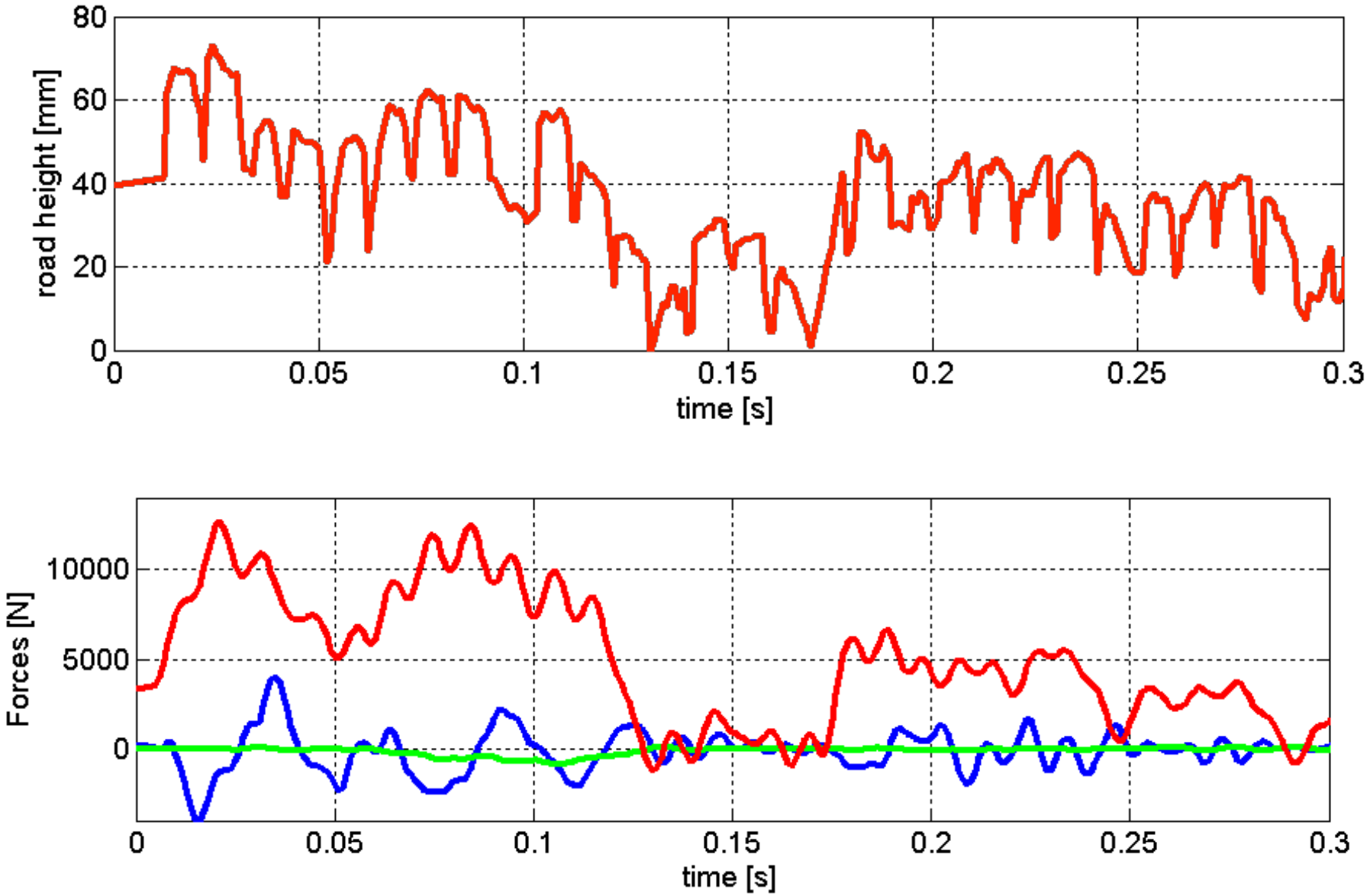


resolution 5 x 5 mm

„state-of-the-art“

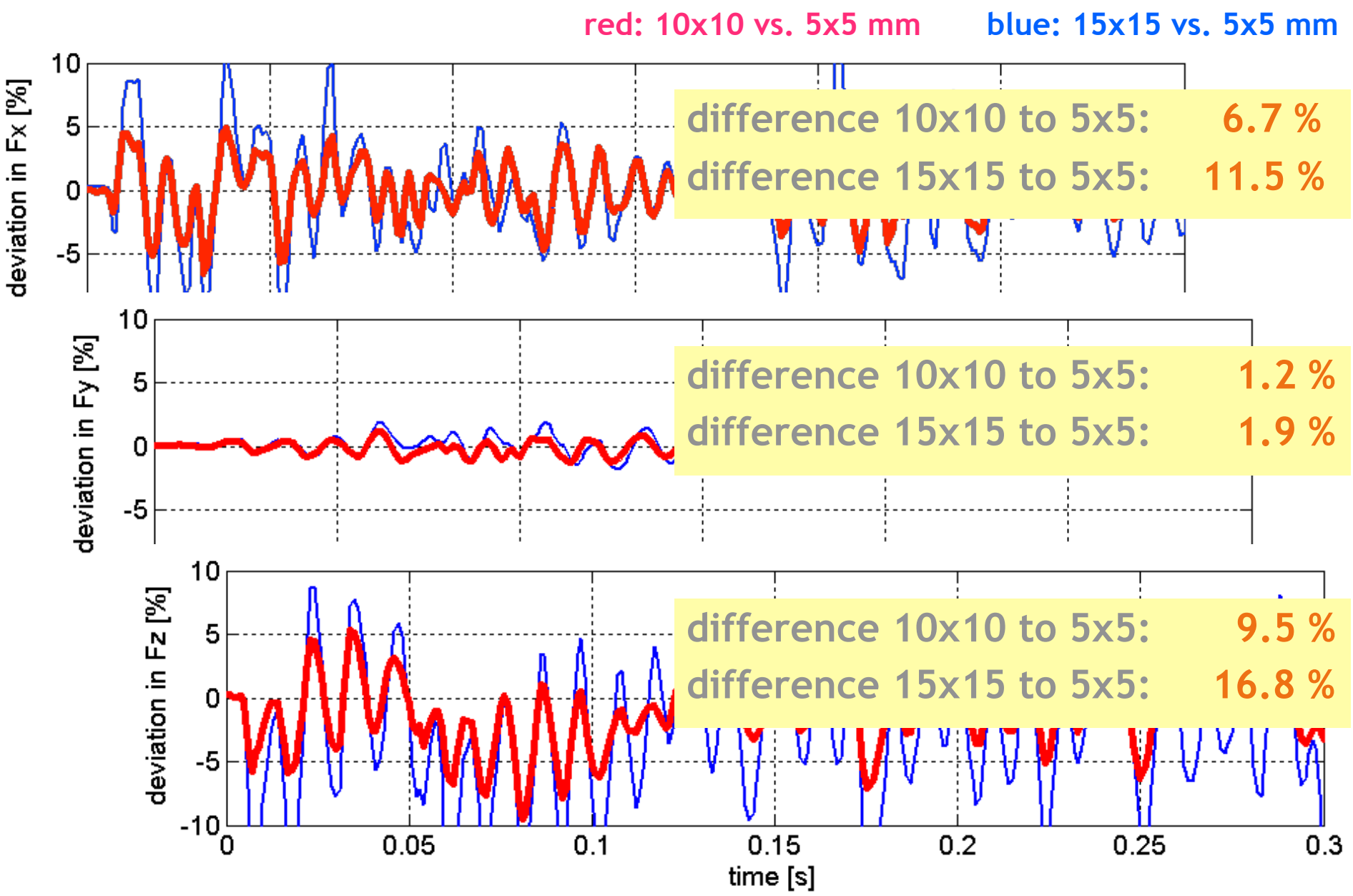
Predicted Road Load On Belgian Block

cosin
scientific software



Predicted Road Load On Belgian Block: Road resolution

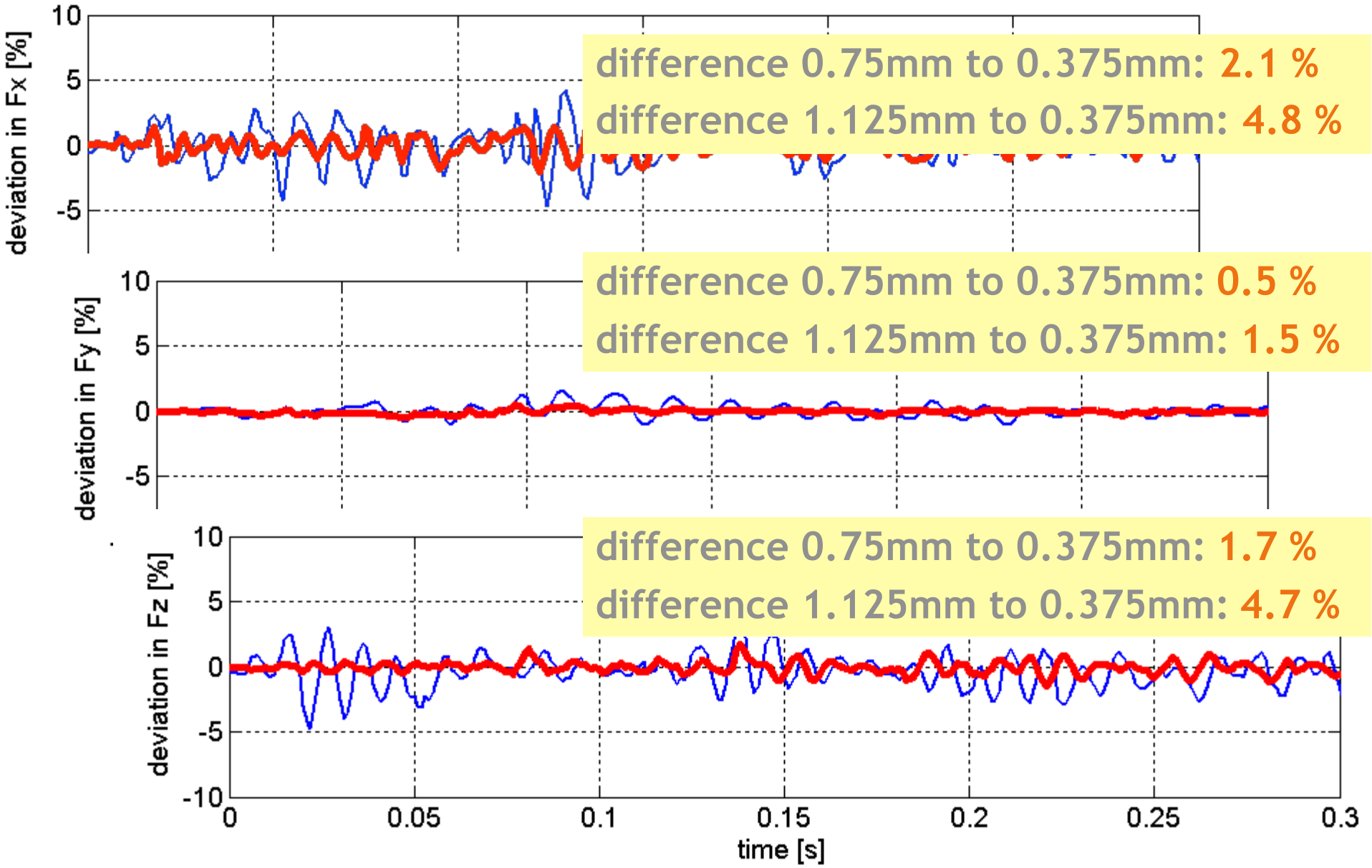
cosin
scientific software



Predicted Road Load On Belgian Block: Tread resolution

cosin
scientific software

red: 0.75 mm vs. 0.375 mm blue: 1.125 mm vs. 0.375 mm



difference 0.75mm to 0.375mm: 2.1 %
difference 1.125mm to 0.375mm: 4.8 %

difference 0.75mm to 0.375mm: 0.5 %
difference 1.125mm to 0.375mm: 1.5 %

difference 0.75mm to 0.375mm: 1.7 %
difference 1.125mm to 0.375mm: 4.7 %

cosin
scientific software

Efficiency Comparison for Belgian Block Road File Formats

	Triangulated Road 3D TeimOrbit	RGR ASCII data file	RGR binary data file	RGR binary data file + curved center line
# nodes	1.487 mio	1.487 mio	1.487 mio	1.487 mio
# triangles	2.968 mio	-	-	-
file size	153.74 MB	12.88 MB	5.80 MB	6.02 MB
memory amount	237.80 MB	5.80 MB	5.80 MB	5.91 MB
file loading time	95.75 s	0.73 s	0.21 s	0.28 s

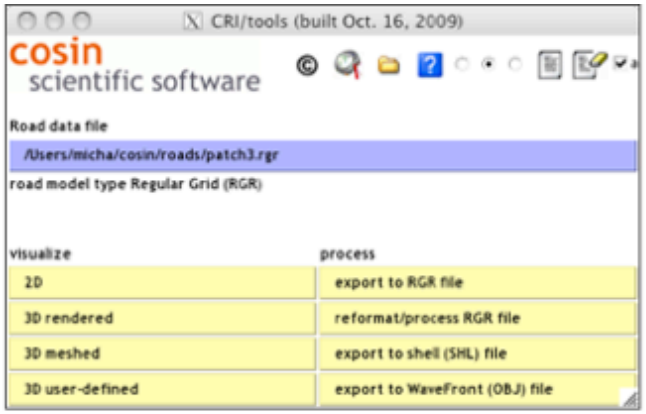
CPU Time for 1 Mio Road Evaluations

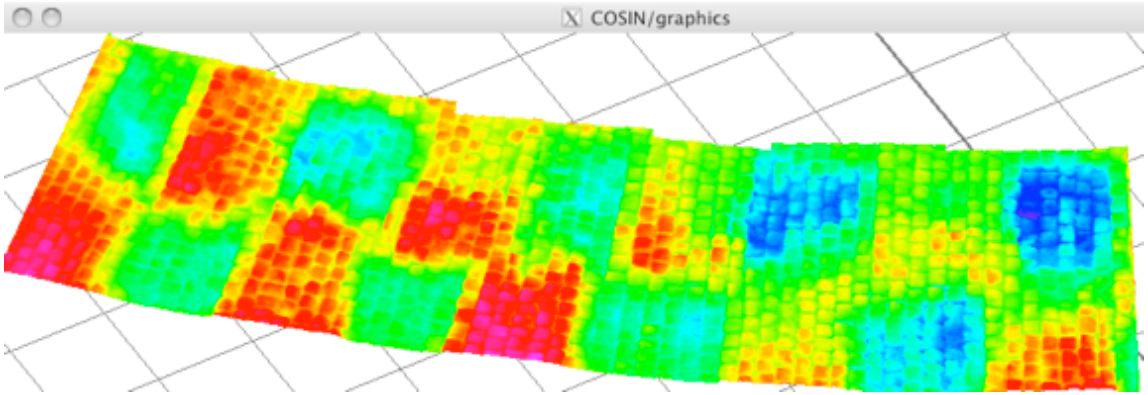
mean evaluation point distance	Triangulated Road 3D TeimOrbit	RGR ASCII data file	RGR binary data file	RGR binary data file + curved center line
0.001mm	0.826 s	0.203 s	0.203 s	0.556 s
0.01mm	0.984 s	0.203 s	0.203 s	0.556 s
0.1mm	2.98 s	0.203 s	0.203 s	0.556 s
1mm	23.2 s	0.203 s	0.203 s	0.556 s
10mm	222 s	0.203 s	0.203 s	0.556 s

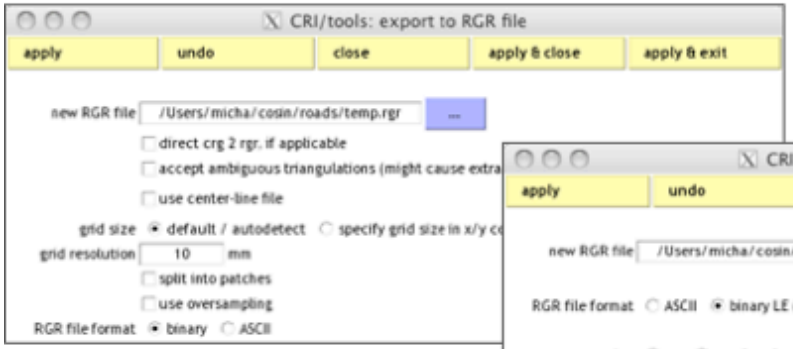
CPU Time for Simulation on Belgian Block Road

tread blocks per segment	total number of tread blocks	road evaluations per s	total CPU time per s with RGR road	total CPU time per s with TRIA road
20	1600	4.15 mio	6.8 s	551 s
30	2400	5.80 mio	7.9 s	564 s
40	3200	7.45 mio	8.9 s	567 s
50	4000	9.11 mio	10.1 s	574 s
60	4800	10.76 mio	11.3 s	576 s

2D and 3D visualization

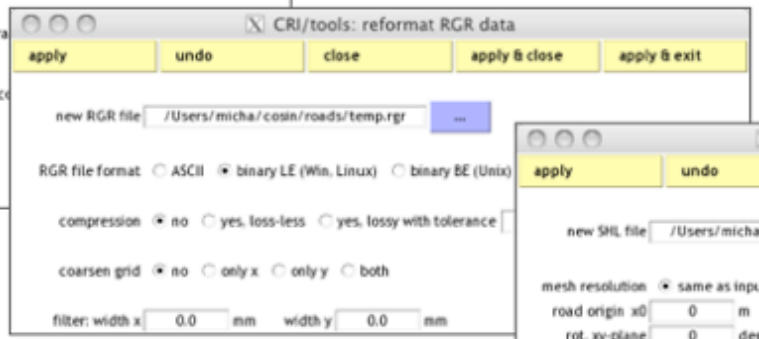




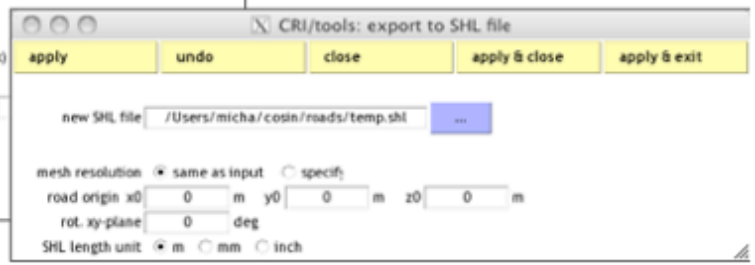


RGR file generation

RGR file processing

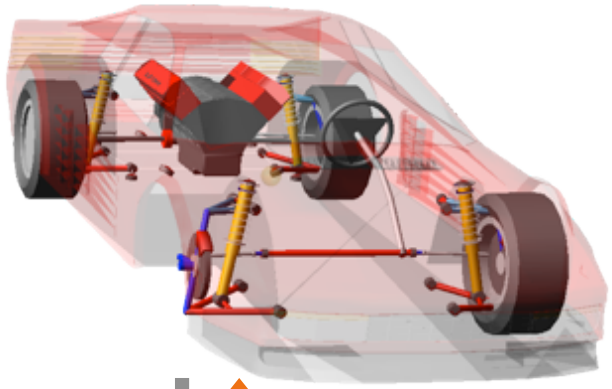


SHL and WaveFront file generation



Vehicle / Tire / Road Interfacing

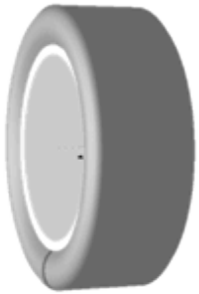
cosin
scientific software



vehicle model

rim position and velocity

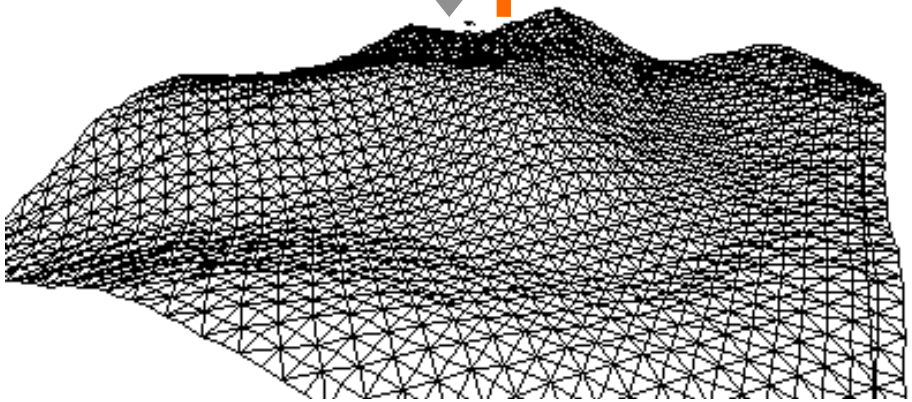
spindle forces and moments



tire model

distributed contact forces

detailed surface geometry



soil model

User Soil Model Programming Interface (2)

cosin scientific software

```
void soil_model_interface ( double  x0
                          , double  dx
                          , uint    nx
                          , double  y0
                          , double  dy
                          , uint    ny
                          , double  phi
                          , double* Fx
                          , double* Fy
                          , double* Fz
                          , double* z
                          , double* vx
                          , double* vy
                          , double* vz
                          , double* mu
                          , int     tire_handle
                          , int     calling_mode
                          , double  dt
                          , char*   soil_model_data_file
                          )
{
  /*  calling_mode = 0:
         initialize soil model instance
      calling_mode = 1:
         call the soil model which applies the contact forces and updates its
         state variables according to time-step dt; compute and return new
         grid elevations and velocities for soil-model instance
      calling_mode = 99:
         terminate model instance                                          */
  ...
}
```

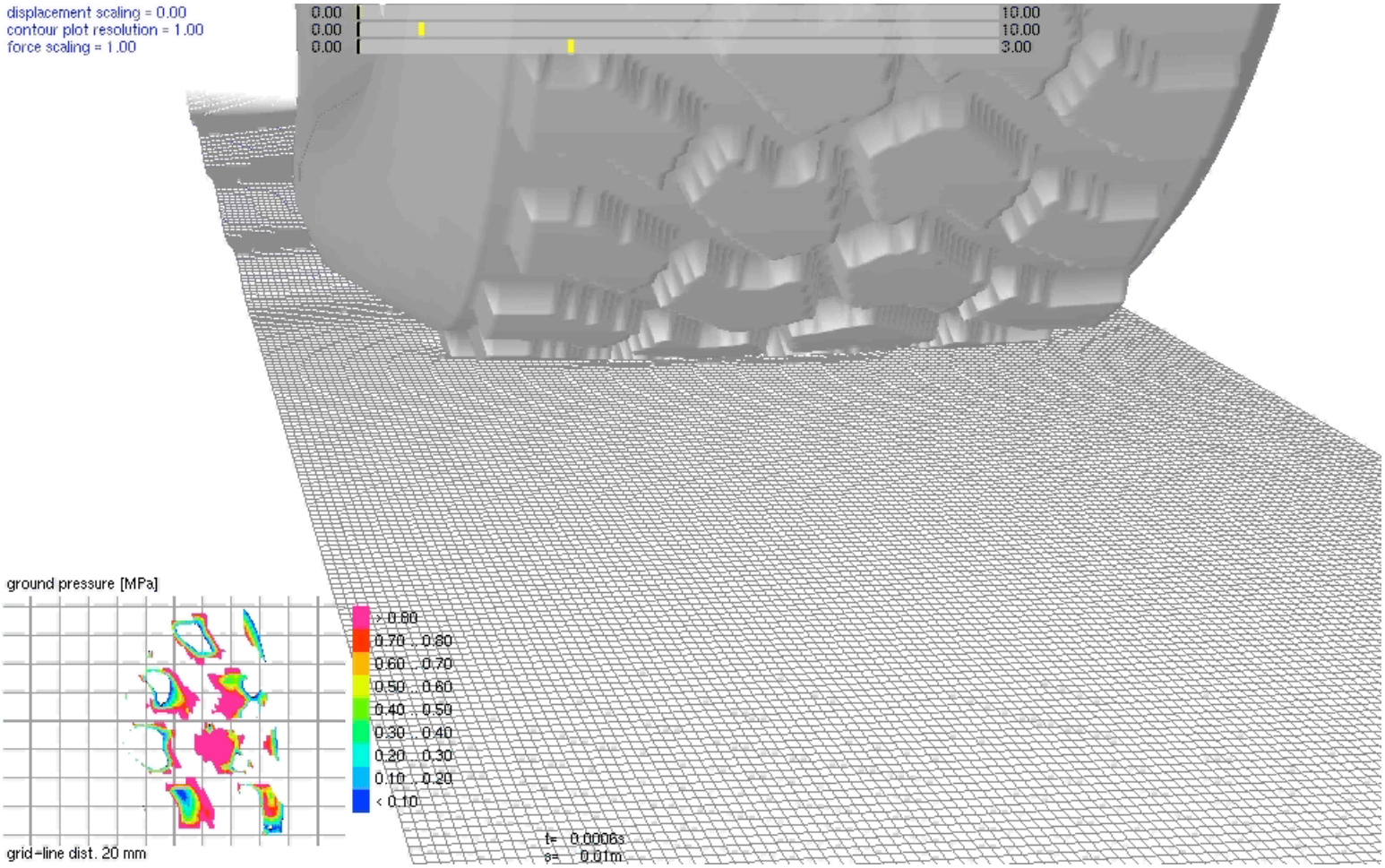
Sampling grid parameters

Applied forces (in)

Road surface state (out)

Simulation With Internal Soft Soil Model

cosin
scientific software



CRI/Tools: RGR File Generation (1)

cosin
scientific software

COSIN/roadtools: generate new road data file

apply | close | apply & close | apply & exit

generate RGR file

- from other road data file
- from 2D power spectral density (PSD)
- from image file
- from x/y-formula

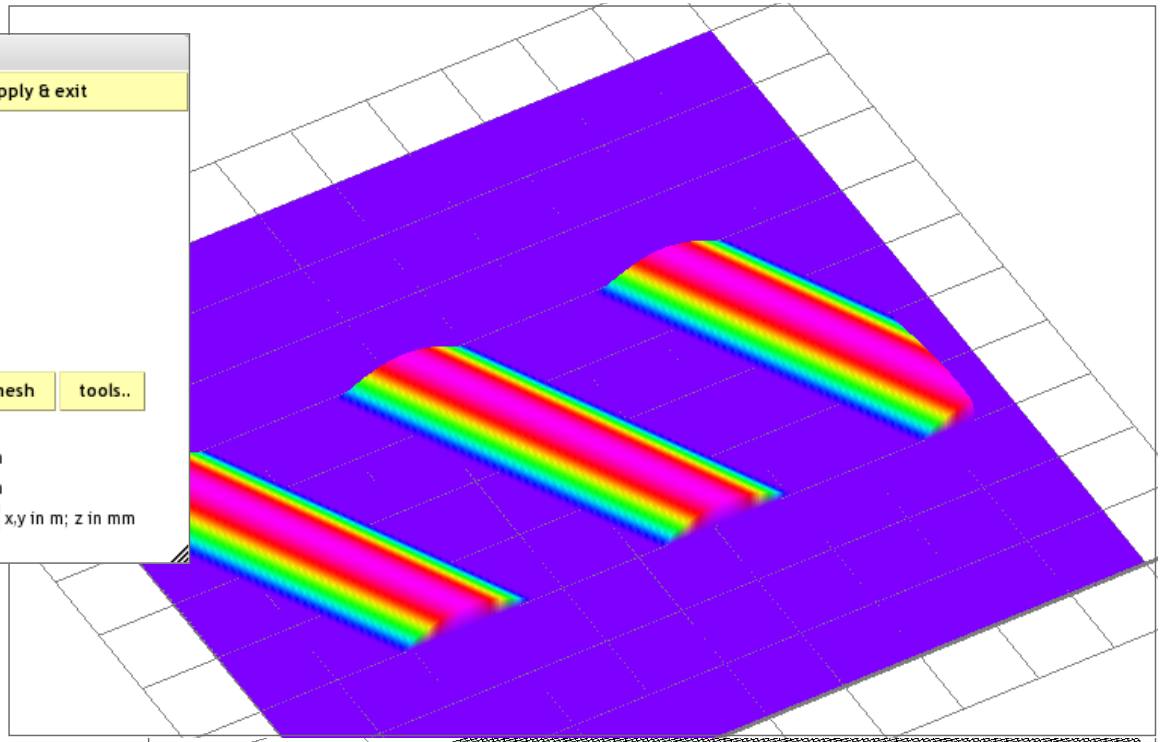
generate RDF center-line file

- from COSIN track data

new RGR file: /Users/micha/work/temp.rgr | ... | show | mesh | tools..

xmin	0	m	dx	50	mm	xma›	10	m
ymin	0	m	dy	50	mm	yma›	10	m

z(x,y) = p1*100* max(0,sin(p2*x+p3*y) * (x>0.5 & x<9.5 & y>3 & y<7)) x,y in m; z in mm



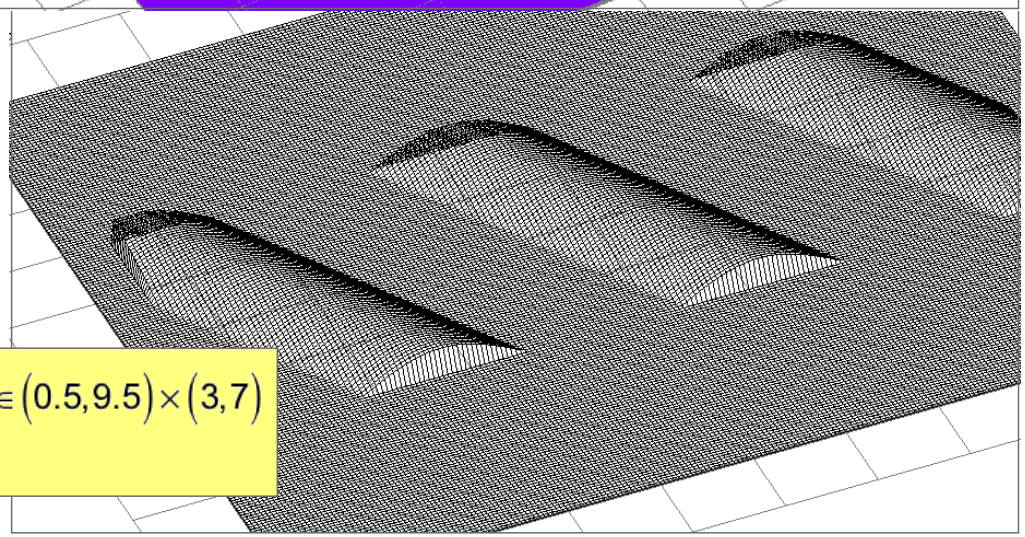
Design Parameters

define modification factors

p1 .. p4 may be used in data files and entry fields, within all arithmetic expressions

reset all sliders to default value 1.0

p1	3.00
p2	1.83
p3	0.94
p4	1.24

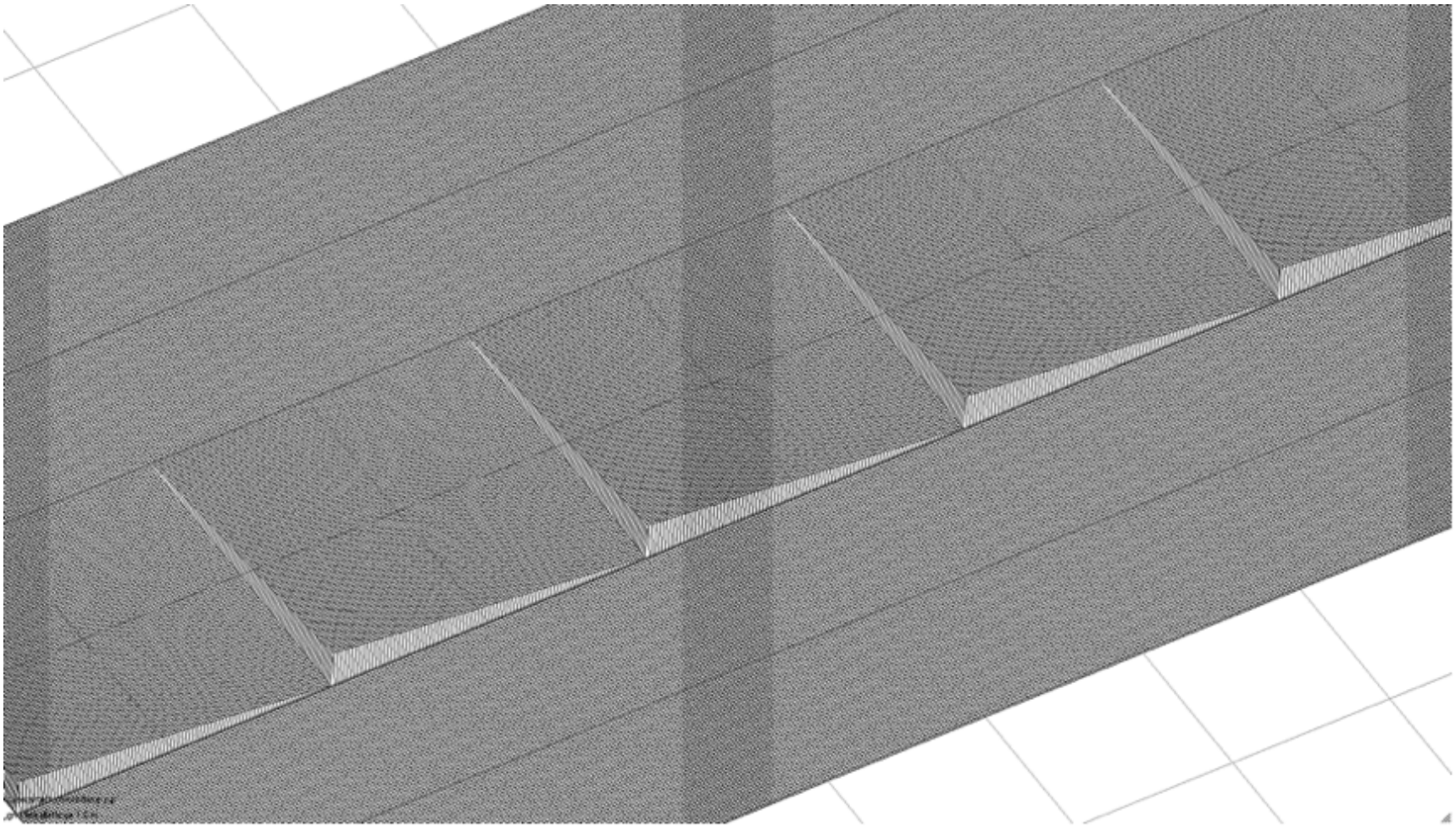


$$z(x,y) = \begin{cases} p_1 \cdot 100 \cdot \max\left(0, \sin\left(p_2 x + p_3 y\right)\right) & \text{if} \quad (x,y) \in (0.5, 9.5) \times (3, 7) \\ 0 & \text{else} \end{cases}$$

CRI/Tools: RGR File Generation (2)

cosin
scientific software

$$z(x,y) = 100 \cdot p_1 \cdot (y > 0 \,\&\, y < p_2) \cdot \mathrm{mod}(x, p_2) \cdot y$$



CRI/Tools: RGR File Generation (3)

cosin
scientific software

COSIN/roadtools: generate new road data file

apply | close | apply & close | apply & exit

generate RGR file

- from other road data file
- from 2D power spectral density (PSD)
- from image file
- from x/y-formula

generate RDF center-line file

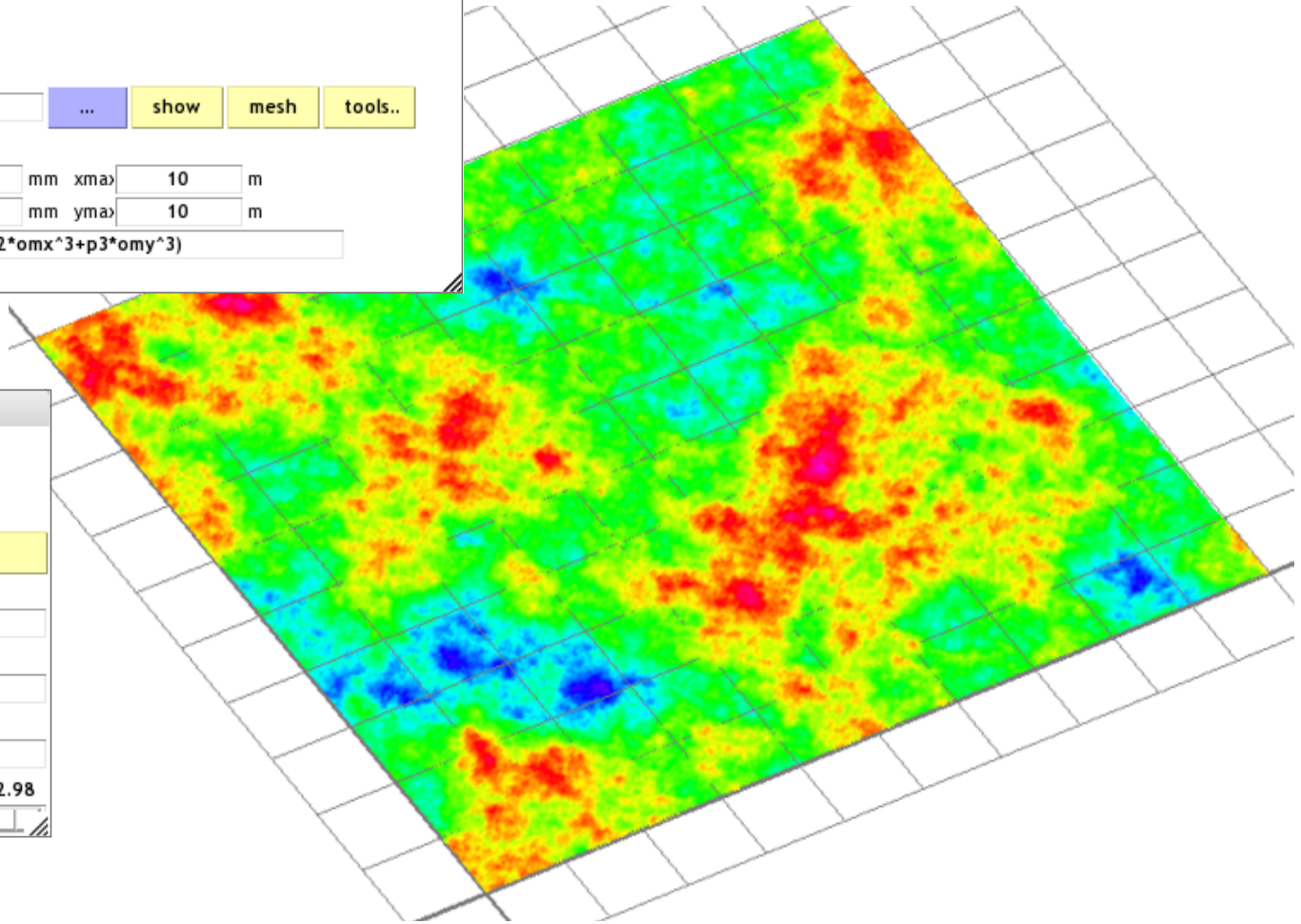
- from COSIN track data

new RGR file [...] show | mesh | tools..

xmin	0	m	dx	20	mm	xmax	10	m
ymin	0	m	dy	20	mm	ymax	10	m

PSD: S(omx,omy) = p1*10/max(0.01,p2*omx^3+p3*omy^3)

$$S\left(\Omega_x,\Omega_y\right)=\frac{10p_1}{\max\left(0.01,p_2\Omega_x^3+p_3\Omega_y^3\right)}$$



Design Parameters

define modification factors

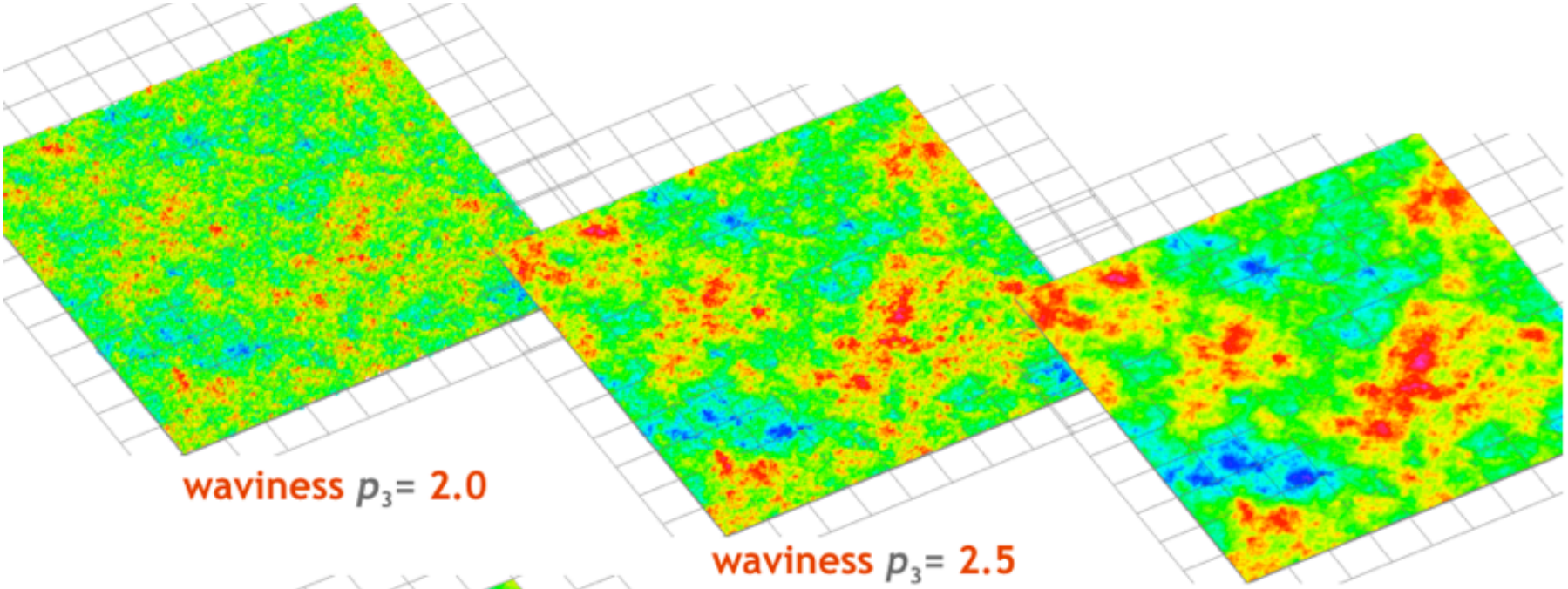
p1 .. p4 may be used in data files and entry fields, within all arithmetic expressions

reset all sliders to default value 1.0

p1	1.39
p2	1.07
p3	1.62
p4	2.98

CRI/Tools: RGR File Generation (4)

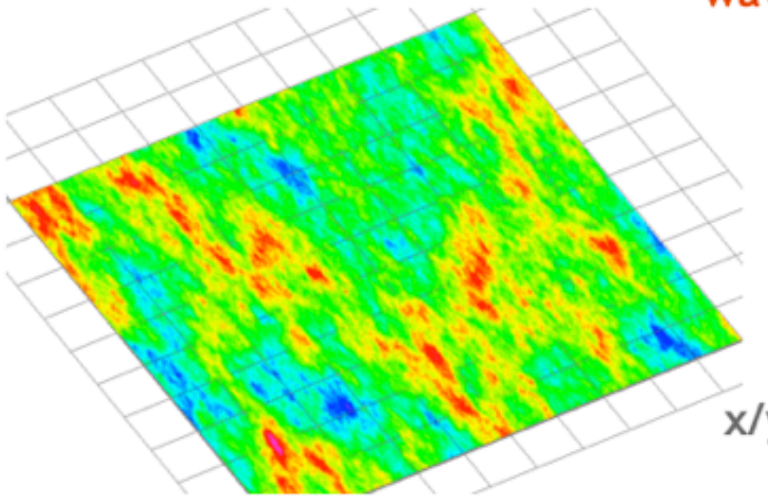
cosin
scientific software



waviness p_3= 2.0

waviness p_3= 2.5

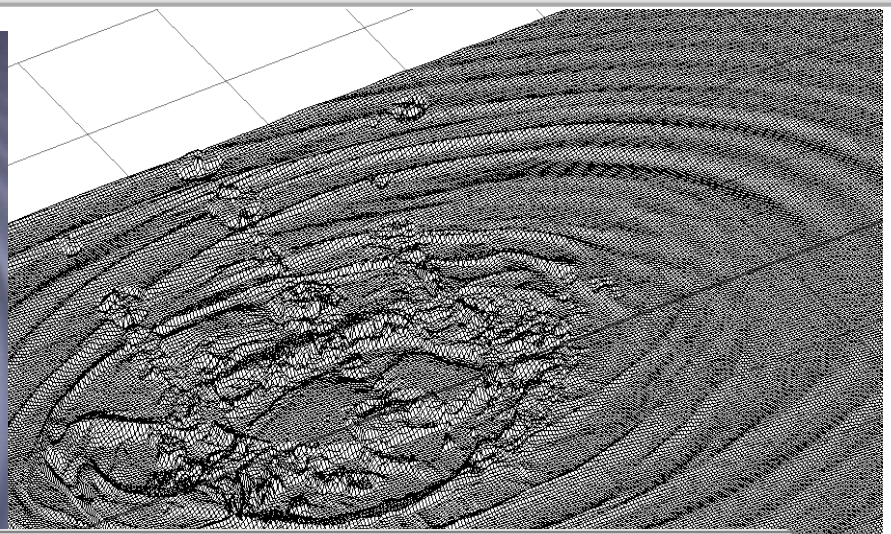
waviness p_3= 3.0

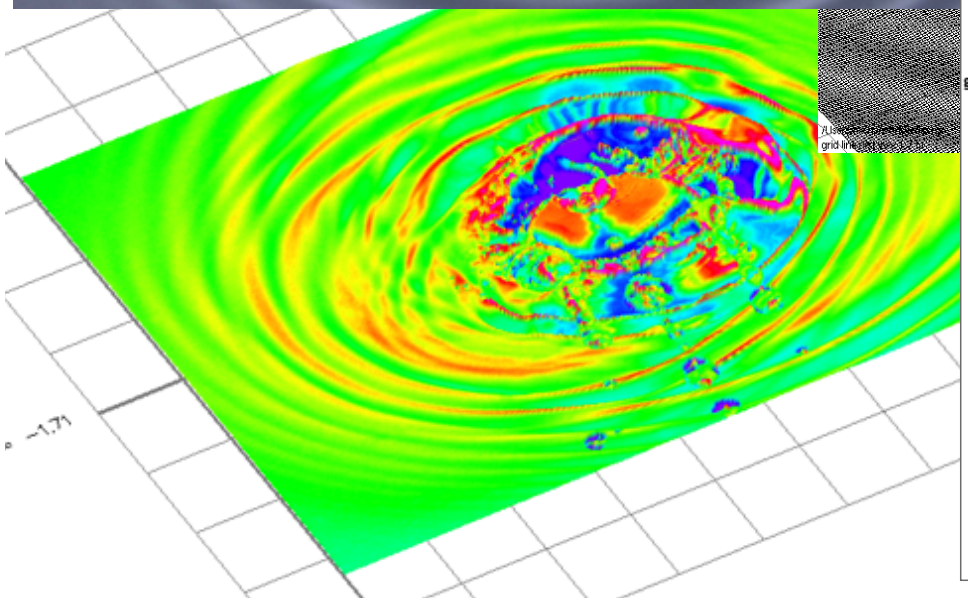


x/y anisotropy factor p_2= 3.0

CRI/Tools: RGR File Generation (5)

cosin
scientific software





COSIN/roadtools: generate new road data file

apply | close | apply & close | apply & exit

generate RGR file

- ○ from other road data file
- ○ from 2D power spectral density (PSD)
- ◉ from image file
- ○ from x/y-formula

generate RDF center-line file

- ○ from COSIN track data

new RGR file: /Users/micha/work/temp.rgr [...] show mesh tools..

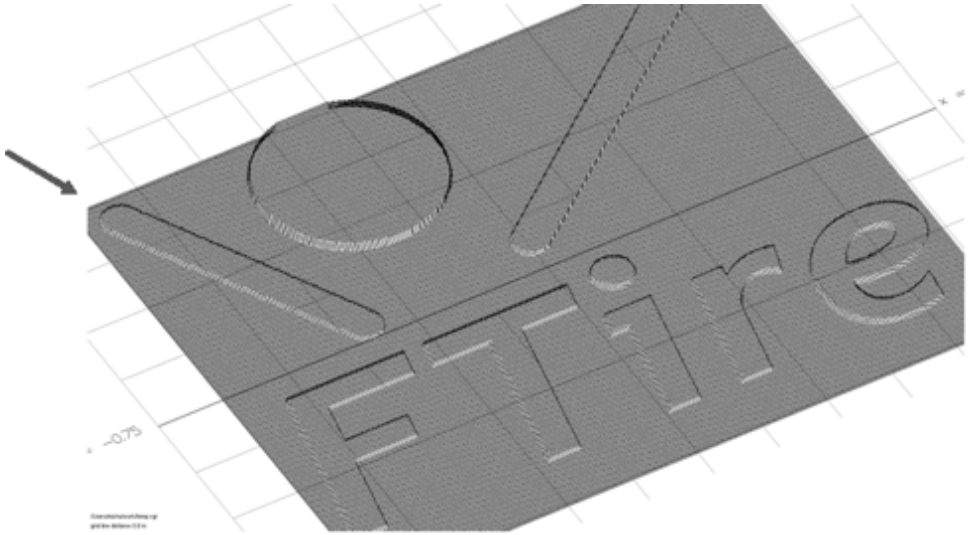
input image file: /Users/micha/ftire_pres/Altair_2009/im [...] show

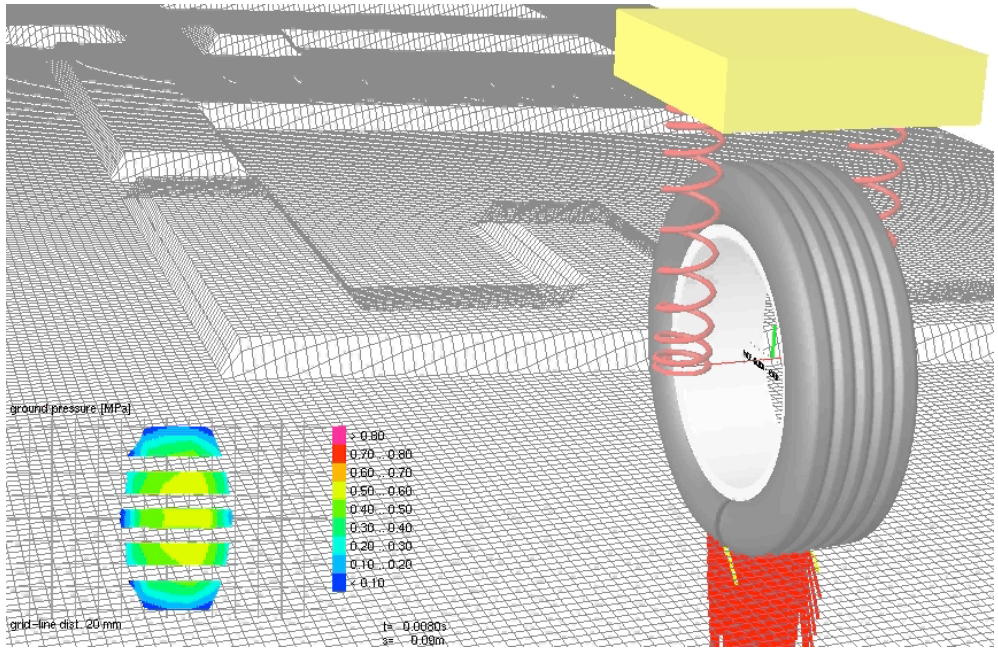
pixel distance: 20 mm

- ○ height values at pure RGB colors; interpolation by RGB superposition
  - 33.33 mm | 33.33 mm | 33.33 mm
- ◉ height values at white and black; interpolation using brightness
  - 200 mm | 0
- ○ height values as general function of RGB values
  - z(r,g,b) = 33.33*(r+g+b) 0<=r,g,b<=1; z in mm

CRI/Tools: RGR File Generation (6)

cosin
scientific software





..thank you for your attention!

CRI, *CTI*, *and FTire* demo versions, papers, animations, documentation, version updates, and more at: www.cosin.eu