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ICRI Project Update – Contact Benchmark

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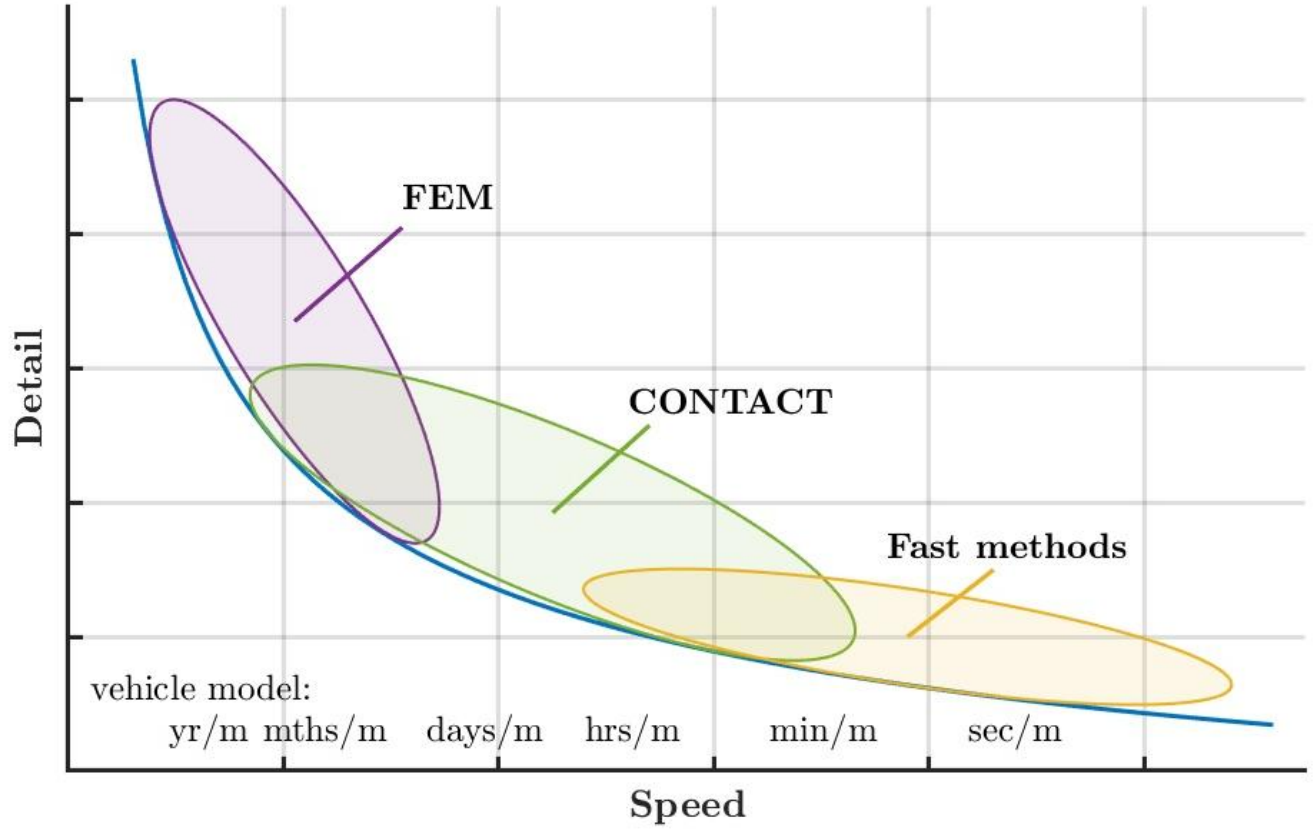
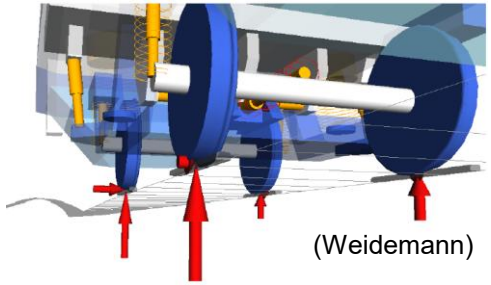
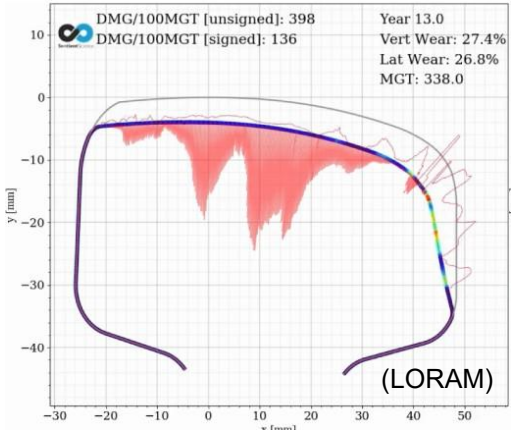
ICRI workshop, Tokyo, Sep 22, 2025

Need for fast contact algorithms

Trade-off speed versus detail



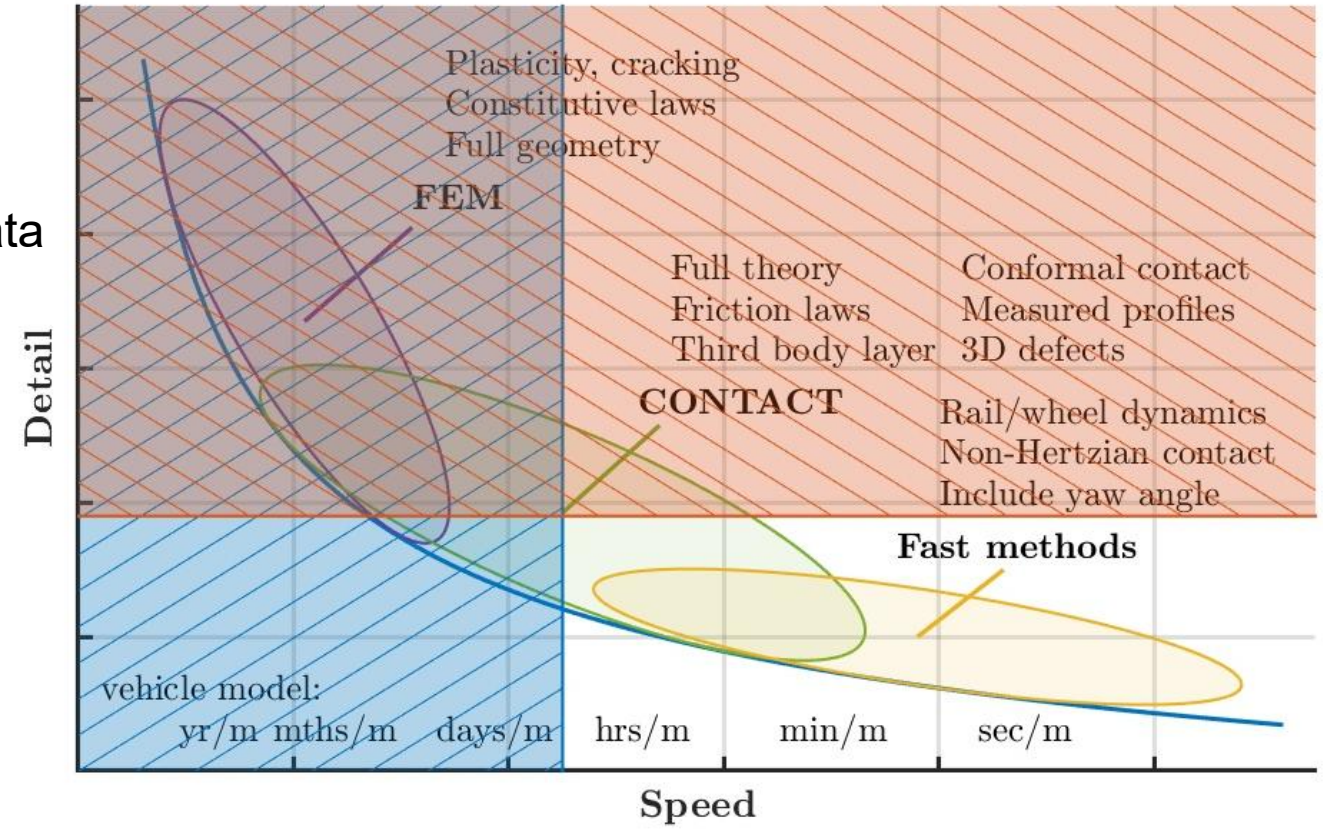


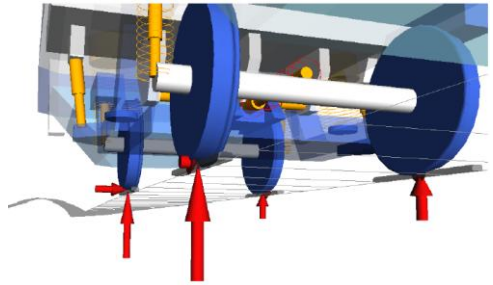


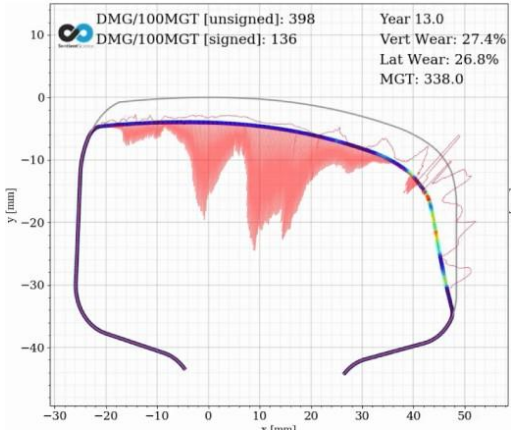
Wheel-rail contact: trade-off speed versus detail

No Time

No Data

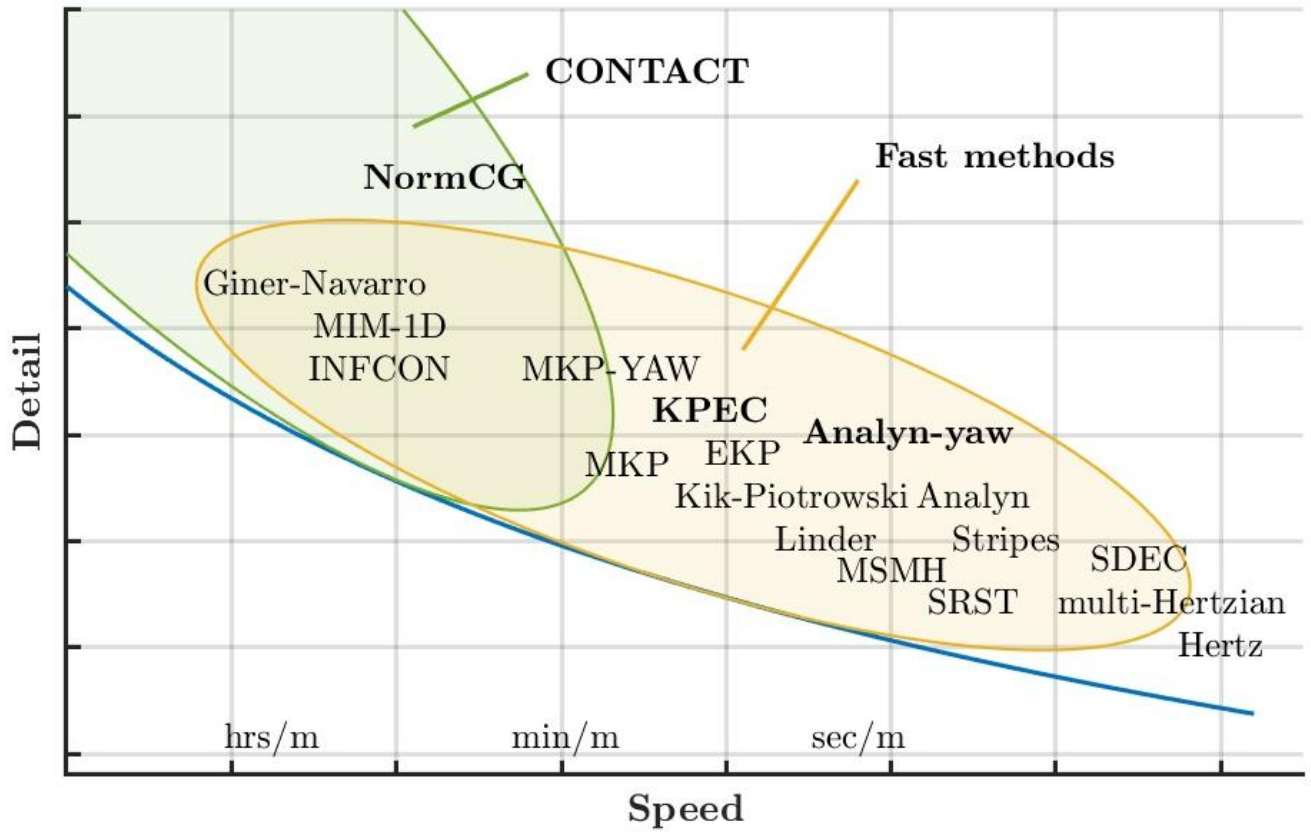






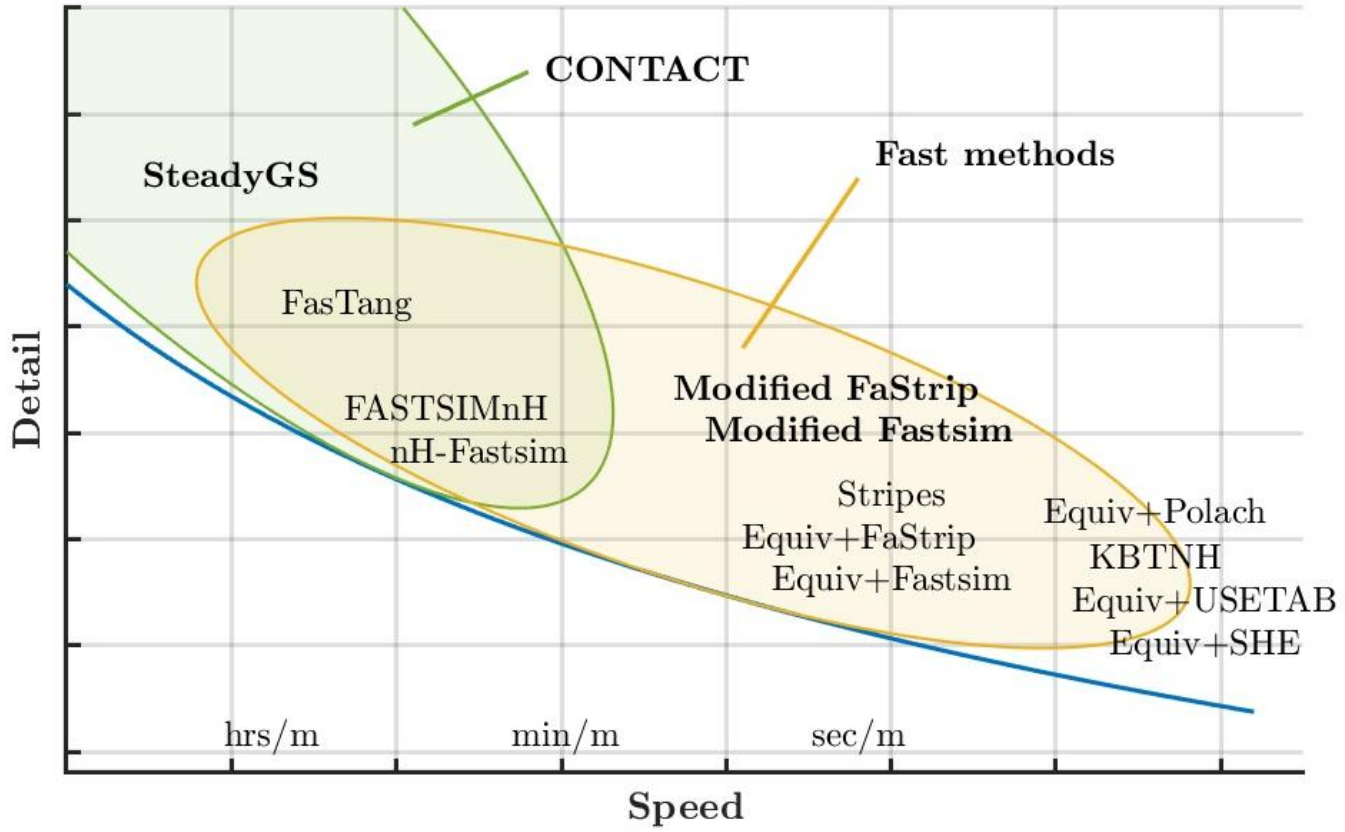
Normal contact solution

Analytical,
Semi-Hertzian,
Virtual interpen.,
Strip elements,
…



Tangential contact solution

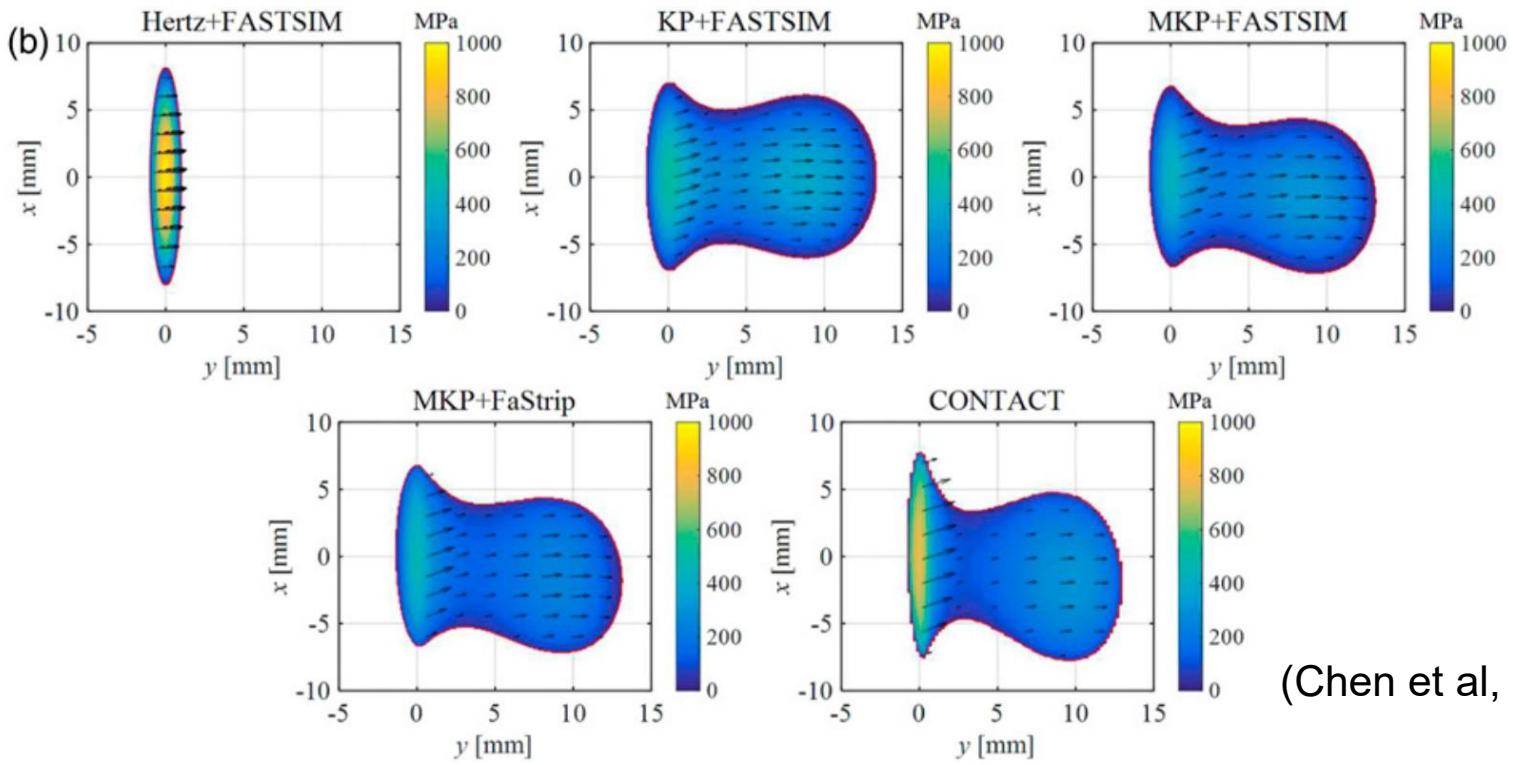
Table-based,
Equivalent ellipse,
Fastsim/FaStrip,
Blending,
Non-Hertzian flex.



Normal contact – Comparison of algorithms

Anecdotal – Typically restricted to isolated cases

- How large are differences?
- How representative are test-cases?



(Chen et al, 2023)

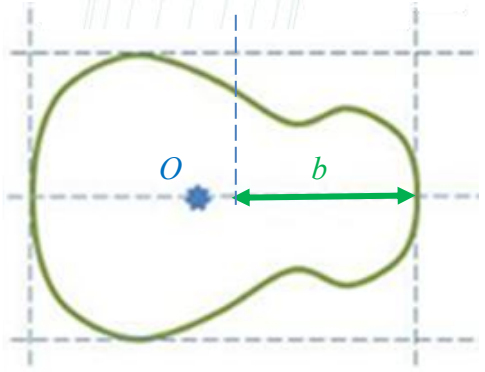
“On-line” benchmarking approaches

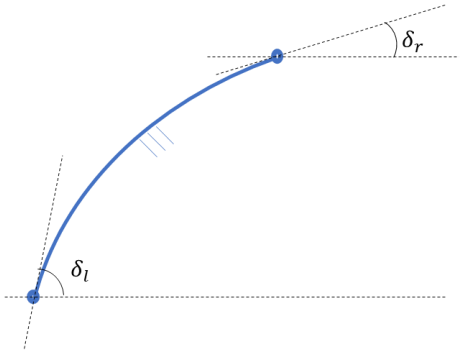
Contact algorithms embedded in vehicle dynamic simulation

+ Pro: see how differences work through

– Con: difficult to see where differences come from.

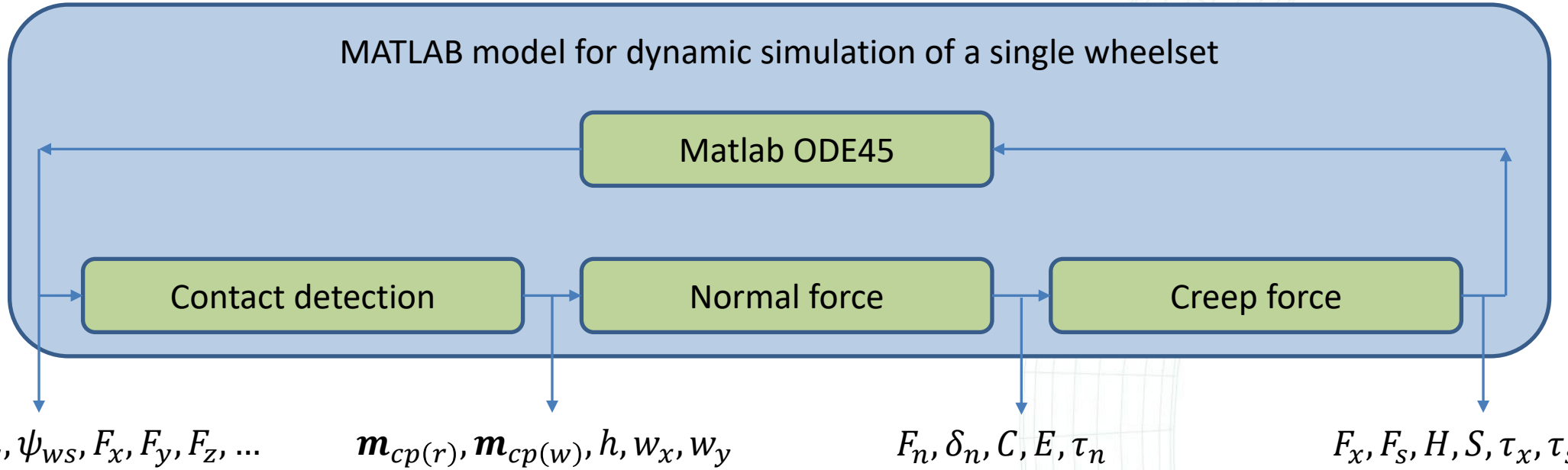
1. (Shackleton, 2008) Manchester contact benchmark: 21 positions + equilibrium equations
   – Anecdotal results
2. (Liu, 2025a) “Effects of conformality”: Single wheelset in curve: speed, radius, force balance
   – Instability
3. (Liu, 2025b) “Indicators non-ellipticity/conformality”: Single wheelset and full vehicle
   – Differences from MBS (Simpack EEC method)





On-line evaluation using a test harness in Matlab

Using a Matlab program for a single wheelset – developed further and ready for testing

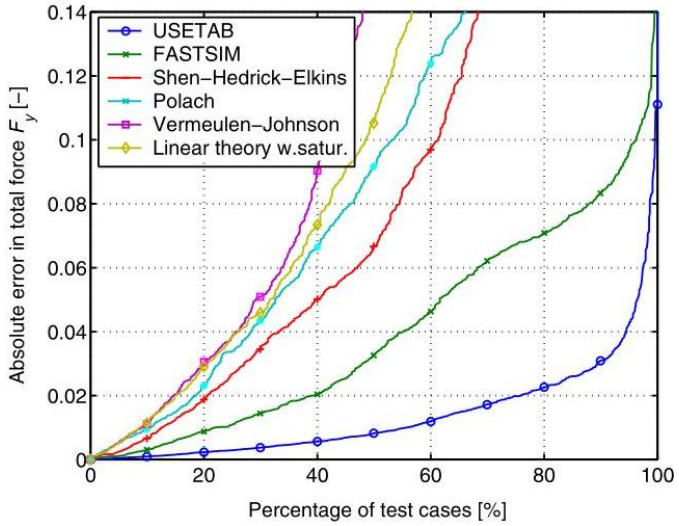


“Off-line” benchmarking approaches

Contact algorithms run in isolation

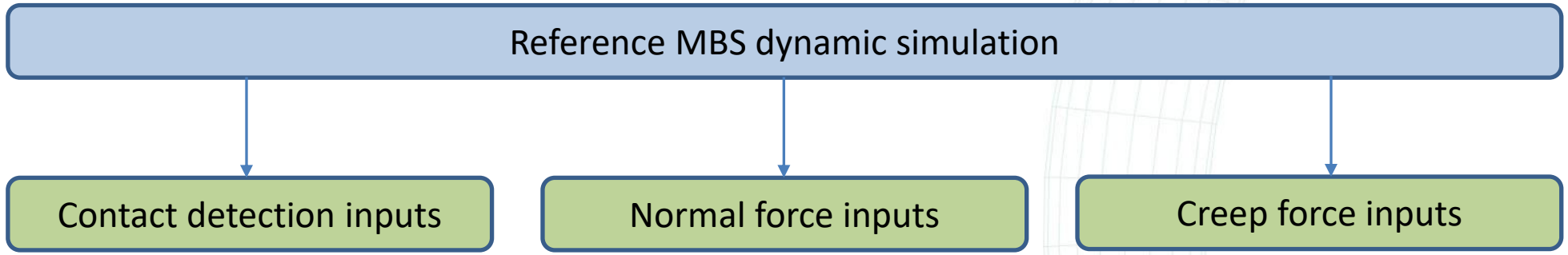
+ Pro: detailed comparison of contact algorithms
– Con: difficult to predict relevance of differences.

1. (Vollebregt, 2011) “Assessment of simplified methods”: 3220 cases
   – restricted to Hertzian geometry, tangential problem
2. (Vollebregt, 2021) “Detailed wheel/rail geometry”: 4000 wheel profiles
   – restricted by choice of vehicles, loads, wheel profiles
3. (Vollebregt, 2025) “Assessment of non-Hertzian algorithms”: 9600 cases
   – restricted to CONTACT, mat-file outputs



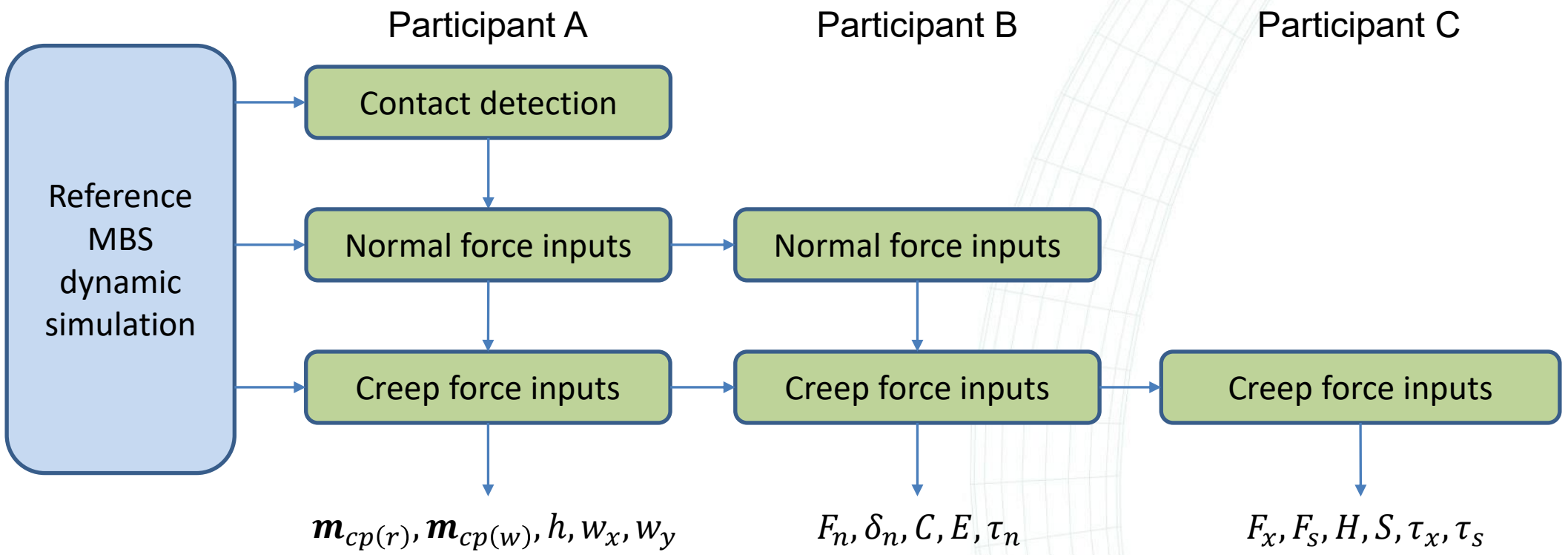
Off-line evaluation using a reference run

- Using 2 vehicles (freight, passenger),
- Create X scenarios (curvature, speed, w/r profiles, irregularities)
- Run vehicle dynamics simulation with reference model
- Extract time-series outputs, for participants' contact calculation



Offline evaluation using a reference run

Participants choose where to enter the benchmark – comparison of Simpack with CONTACT (Liu, 2025b)



Statistical approach – new test-set for non-Hertzian contact

(Vollebregt, 2025) – Starting from the Manchester contact benchmark

1. Using new S1002 wheel and UIC60 rail profiles
2. Using $F_z = 10\text{kN}$ per wheel
3. Using $\mu = 0.30$ (top of rail), $\mu = 0.20$ (gauge face) to avoid wheel unloading
4. Using 40 lateral positions y_{ws}
5. Using 6 coefficients f_ψ: $\psi_{ws} = f_\psi \cdot y_{ws}$, effect of curve radius

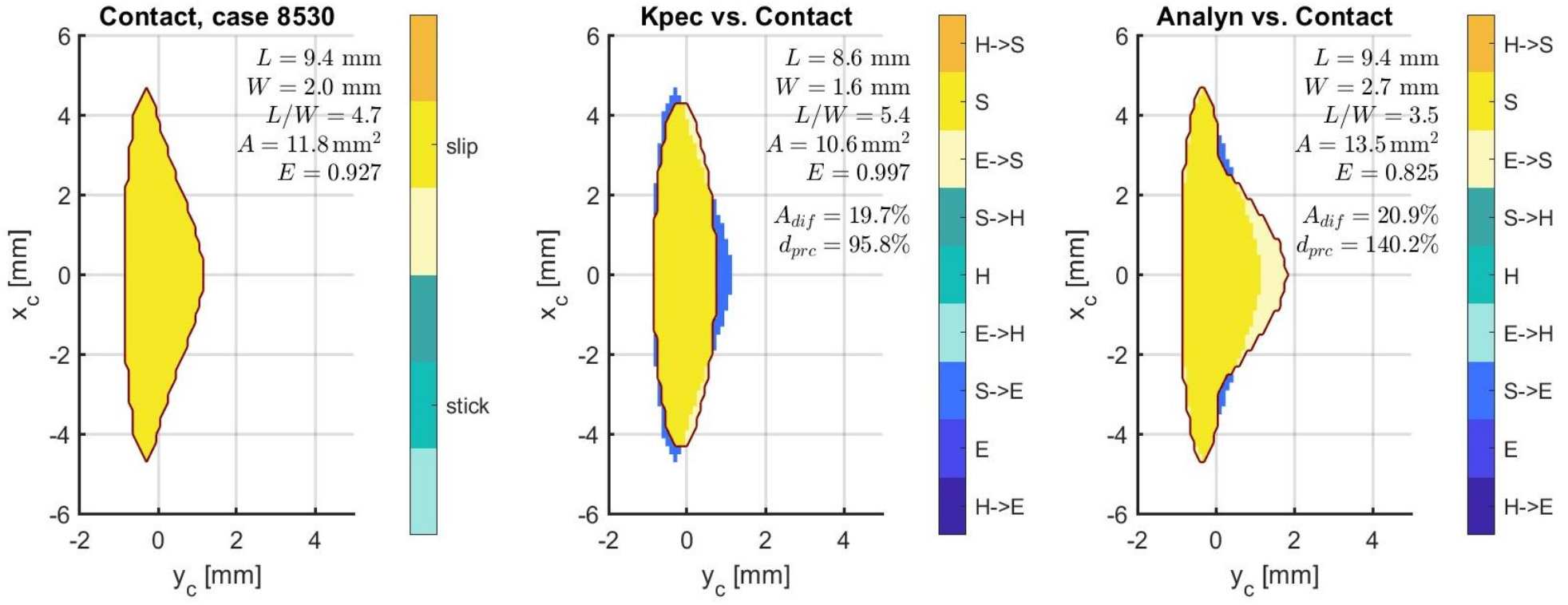
Focusing on one side (wheel) at a fixed wheelset roll angle.

6. Using 8 roll angles $\Delta\phi_r$: effect of cant angle, wheelset roll, rail roll angle
7. Using 5 creepages ξ: effect of curving, acceleration

Creating 9600 instead of 21 test cases

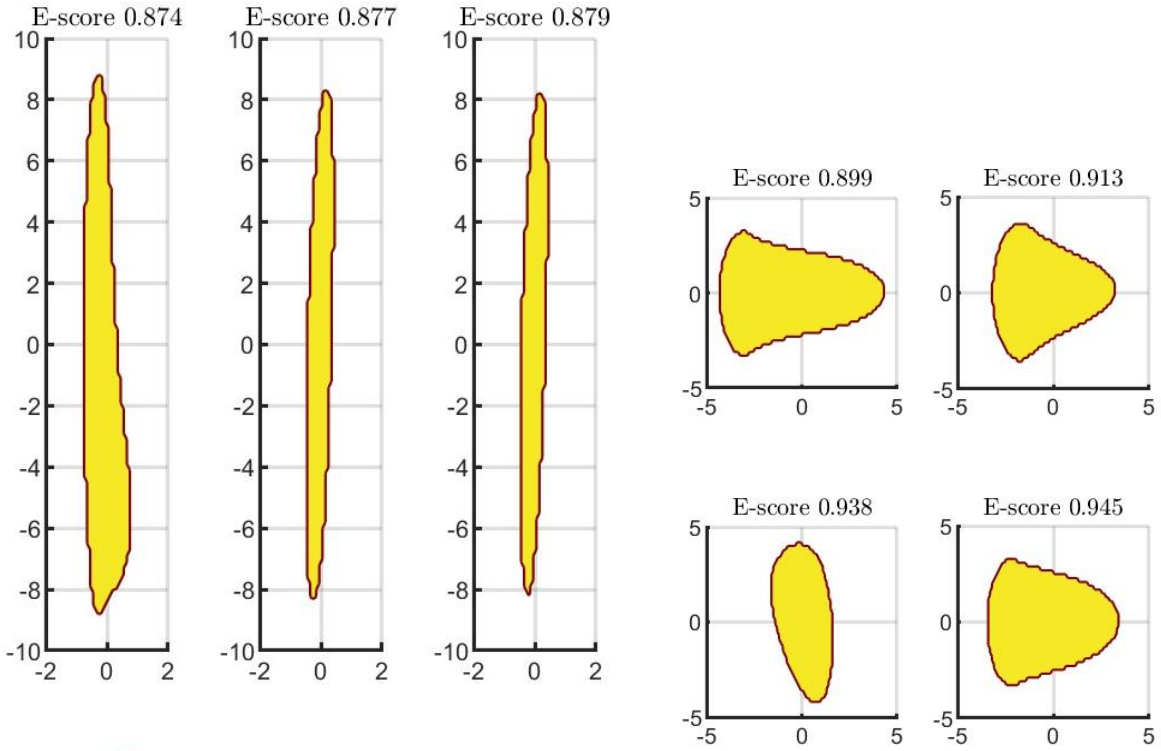
E-score: correspondence to Hertzian ellipse

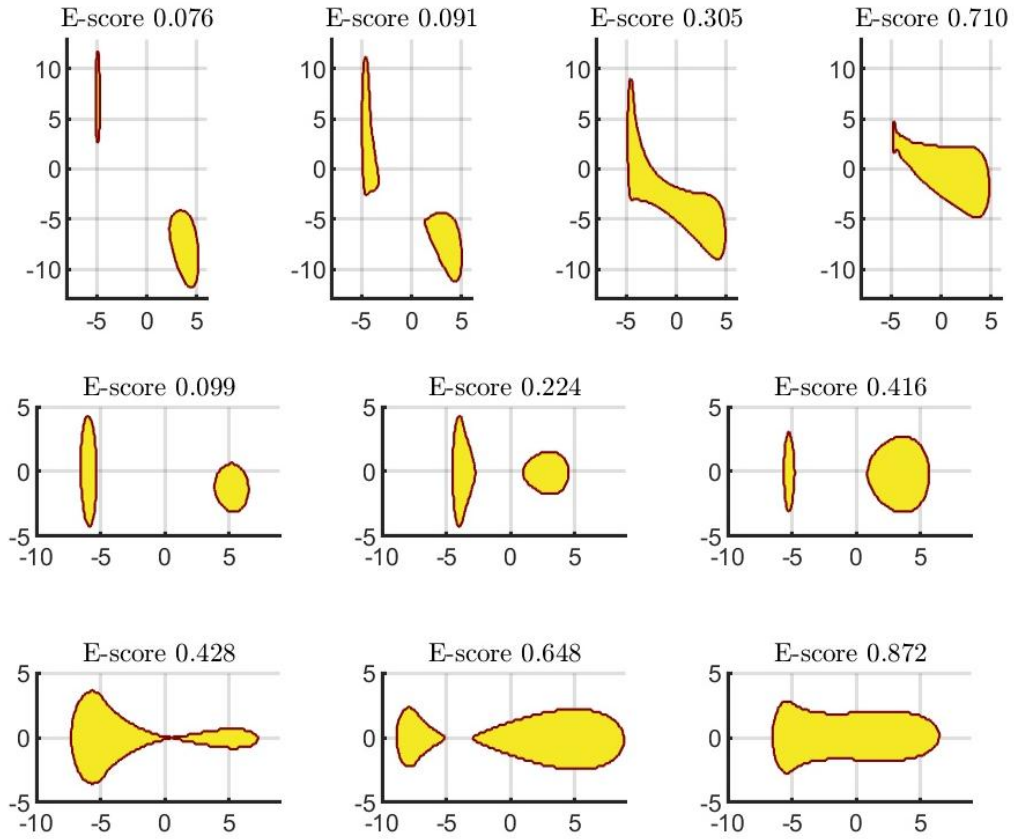
- Typically, KPEC creates more elliptical shapes than CONTACT, whereas Analyn creates more ellipse-deviation.



E-score: correspondence to Hertzian ellipse

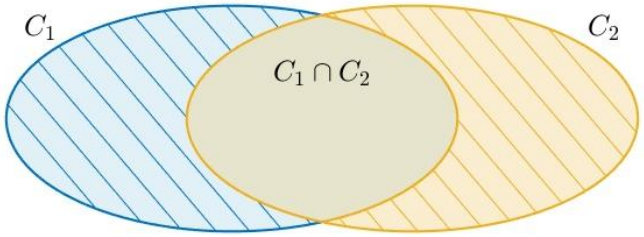
E-score < 0.95 in 9.3% of the test-cases





Tangential contact – Adhesion and slip areas

- Difference of area $|C_1| - |C_2|$: preserves sign, ignores shape & location
- Area of differences $A_{dif} = |C_1| + |C_2| - 2|C_1 \cap C_2|$: captures change in shape & location



	min	mean	max	i80	i95	rms
Relative size of adhesion area $\|H\|/\|C\|$ [−]:						
Contact	0.000	0.175	1.000	0.390	0.786	0.324
Fastsim-ellip - Contact	−0.000	0.083	0.464	0.141	0.199	0.111
Fastsim-parab - Contact	−0.000	0.058	0.401	0.127	0.190	0.091
Fastrip-orig - Contact	−0.088	0.001	0.471	0.026	0.071	0.040
Fastrip-full - Contact	−0.624	−0.007	0.150	0.026	0.067	0.042
Fastrip-modf - Contact	−0.089	−0.001	0.332	0.025	0.068	0.034

- Element divisions from Fastsim-parab are not much better than from Fastsim-ellip.

Assessing results of non-Hertzian contact algorithms

Test-set for statistical evaluation of non-Hertzian contact algorithms

Indicators

- Non-ellipticity index I_{ne}, conformality index I_{cf}
- E-score: correspondence to Hertzian, aligned elliptical shape
- Area of differences: changes in shape and location of contact patches
- Rms of field differences: assess changes in stress distribution

Further work: • evaluate more diverse methods, • for different profiles, • measured profiles, • assess robustness, • conformal contact, • effects of third body layers, …

How to proceed with the ICRI Contact benchmark?

Target outcomes?

- Vehicle dynamics (forces), Wear/RCF (stress distribution)?
- Contact location (ICP/wgt.center), measured profiles (smoothing)?

Target approach?

- On-line using one's own MBS software
- On-line using test harness in Matlab
- Off-line using reference results from MBS
- Off-line using statistical approach

Target scenarios?

- Conformal, third body layers?

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Thank you for your attention.

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