EXPLICIT ISOGEOMETRIC CRASH ANALYSIS

ON TRIMMED NURBS-BASED MULTI-PATCH CAD MODELS IN LS-DYNA.

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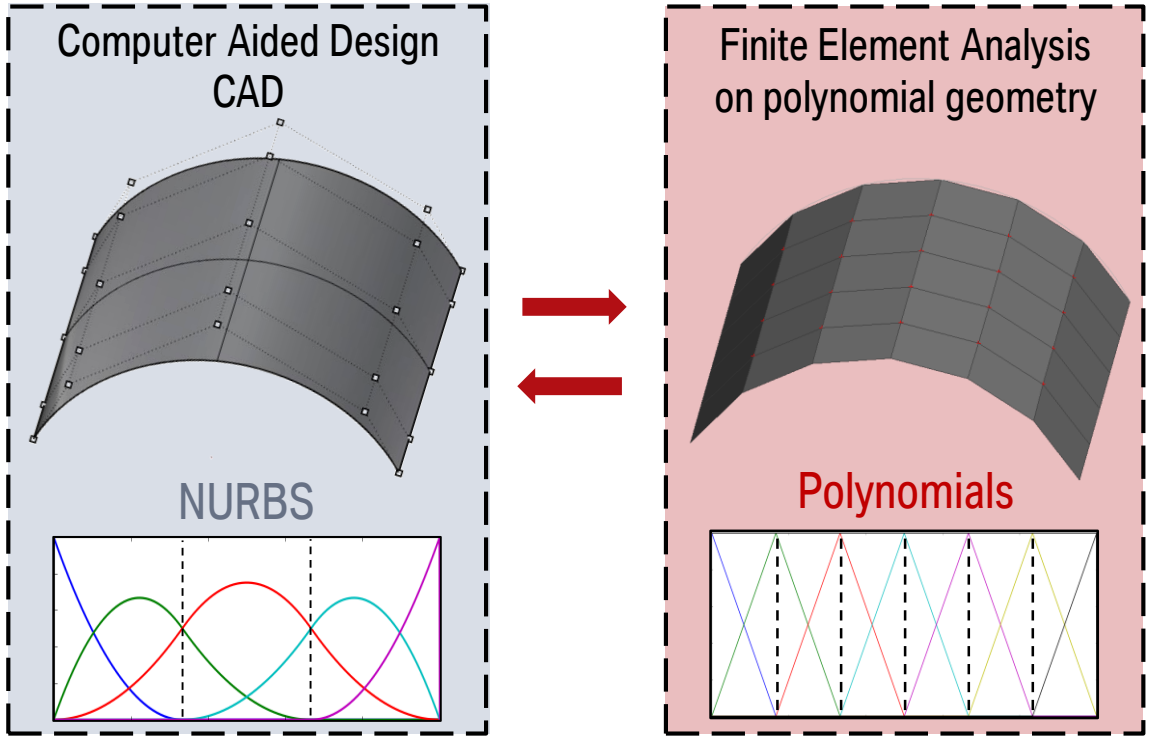
WHAT IS ISOGEOMETRIC ANALYSIS (IGA)?
OUTLINE.

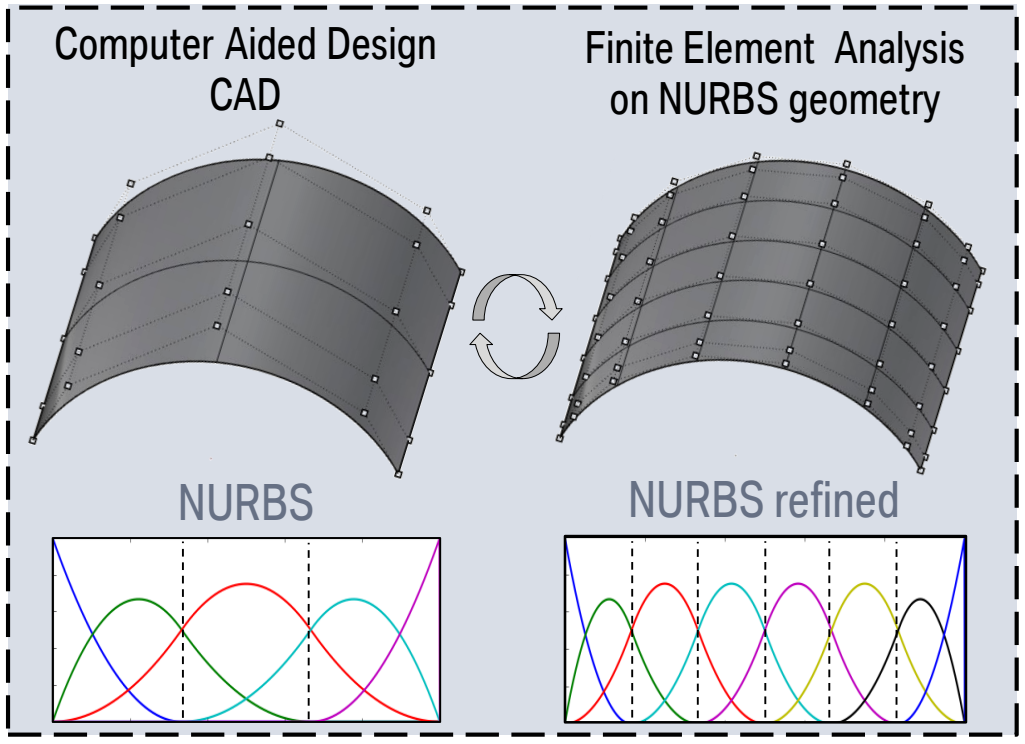
NURBS = Non-Uniform Rational B-Splines

Conventional Finite Element Analysis (FEA)



- Change in geometry description
- Time- & labor-intensive conversion process

Isogeometrische Analysis (IGA) [1]



- Simulation directly on CAD model
- Finite Element Analysis with new basis functions

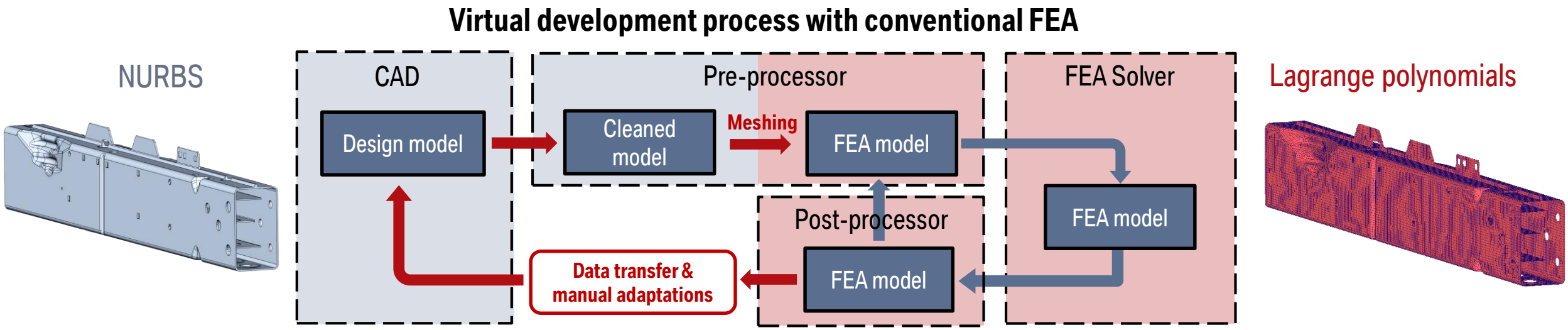
[1] T.J.R. Hughes, J.A. Cottrell, Y. Bazilevs, Isogeometric analysis: CAD, finite elements, NURBS, exact geometry and mesh refinement, Comput. Methods Appl. Mech. Eng. 194 (2005) 4135–4195.

CONTENT

1. Motivation for IGA: CAD/CAE Integration.
2. IGA for Industrial CAD Models.
3. Explicit IGA for Crash.
4. Conclusion & Outlook.

CONTENT

MOTIVATION FOR IGA: CAD/CAE INTEGRATION.



FEA Model generation
- Takes several weeks
- Time- and labor-intensive

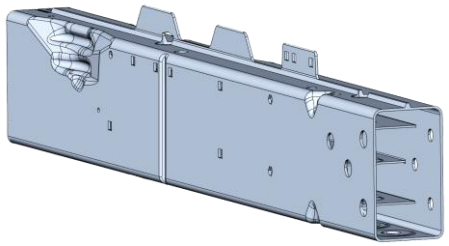
Multiple design cycles
- Synchronization CAD/CAE
- Communication between departments

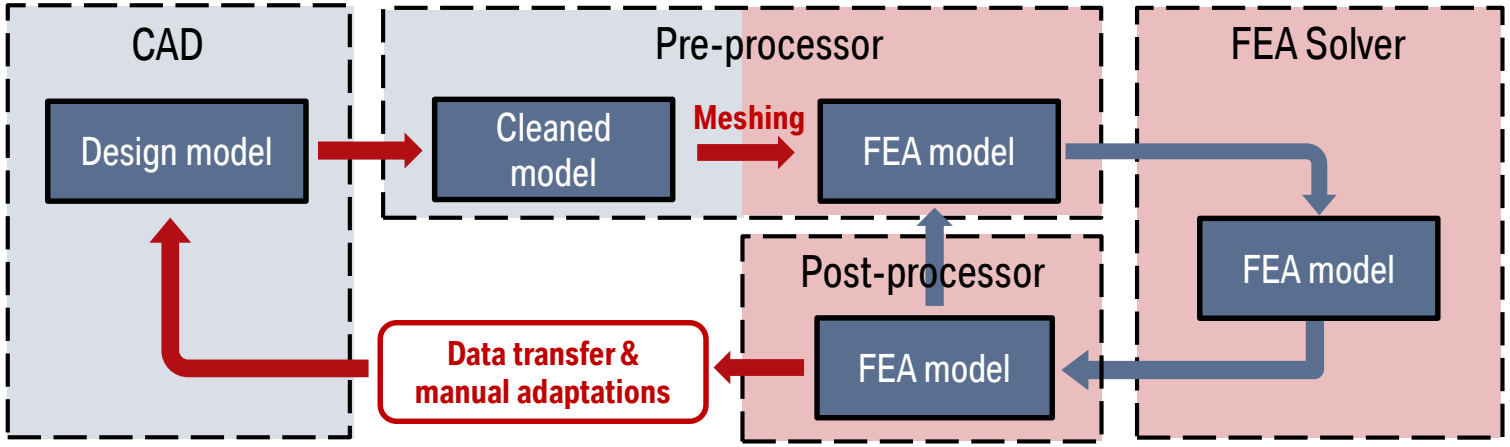
Transfer CAE → CAD
- Manual Adaptations on CAD model
- Time- and labor-intensive

MOTIVATION FOR IGA: CAD/CAE INTEGRATION.

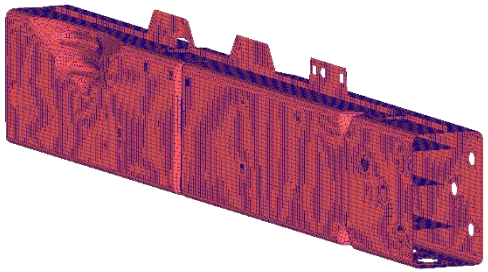
Virtual development process with conventional FEA

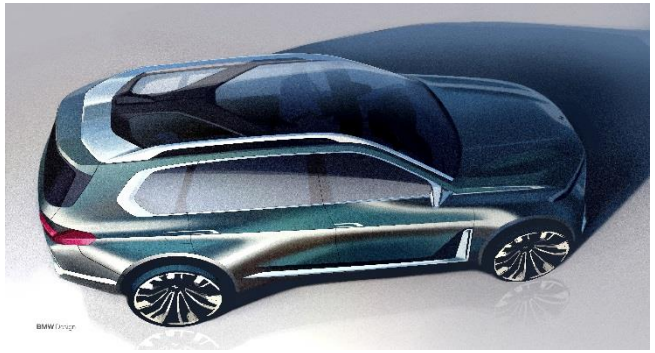
NURBS





Lagrange polynomials





GOAL

Develop our cars faster and more efficient!

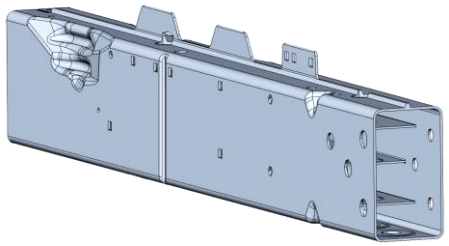
→ Reduce model generation effort
→ Facilitate data transfer
→ Avoid out-of-sync problems

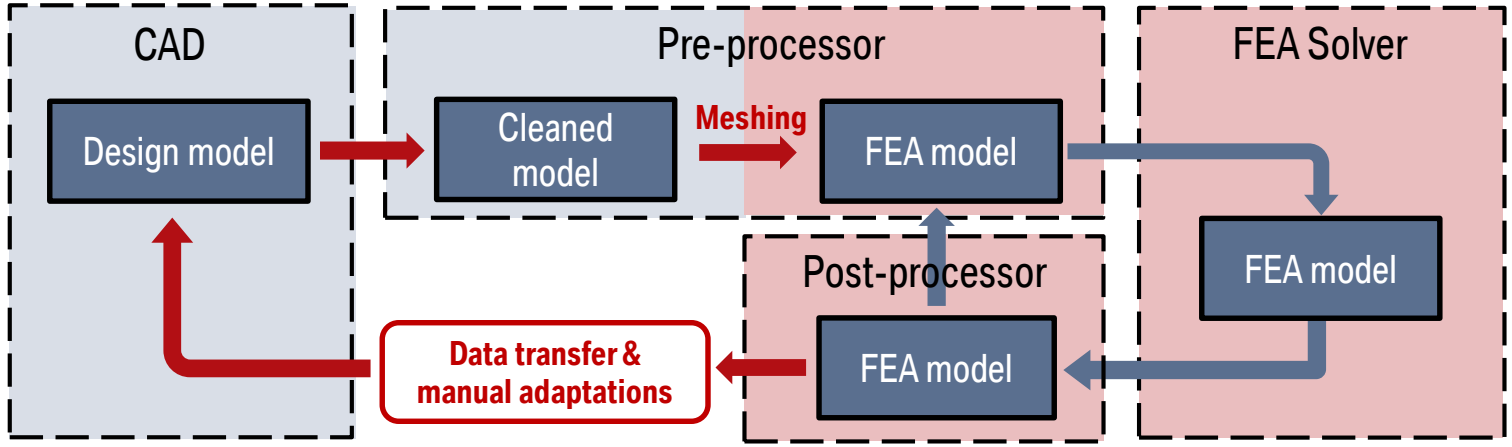
- CAD/CAE integration
- Consistent data management
- Isogeometric Analysis

MOTIVATION FOR IGA: CAD/CAE INTEGRATION.

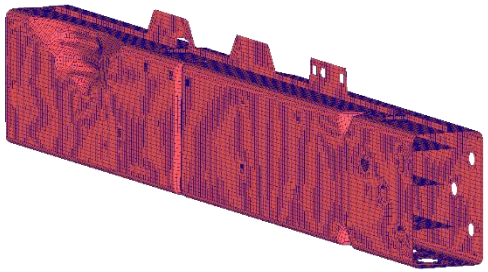
Virtual development process with conventional FEA

NURBS



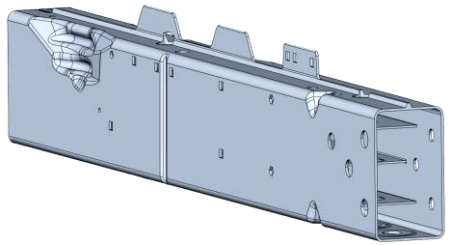


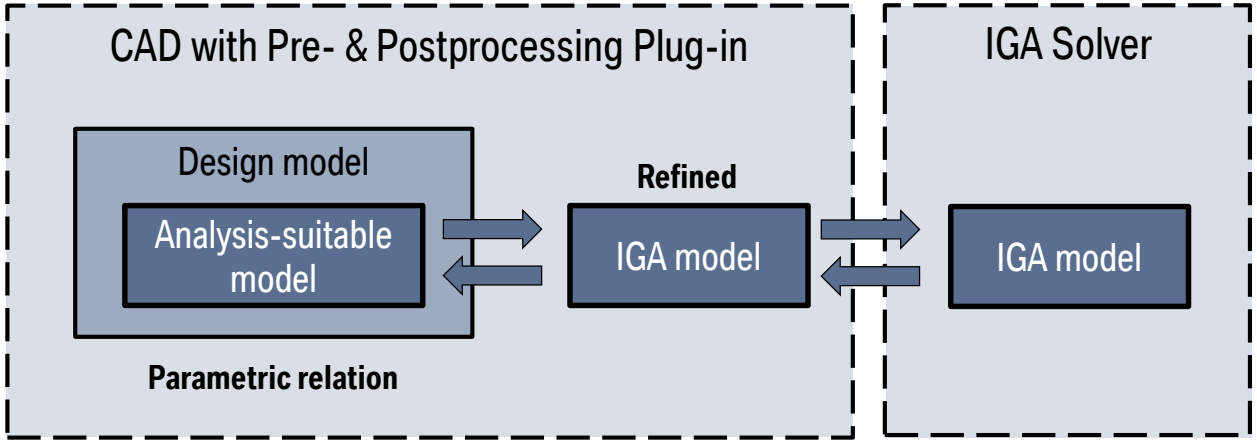
Lagrange polynomials



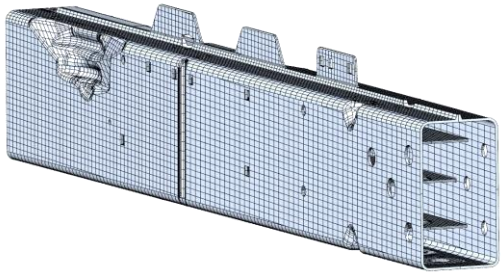
Virtual development process with IGA

NURBS



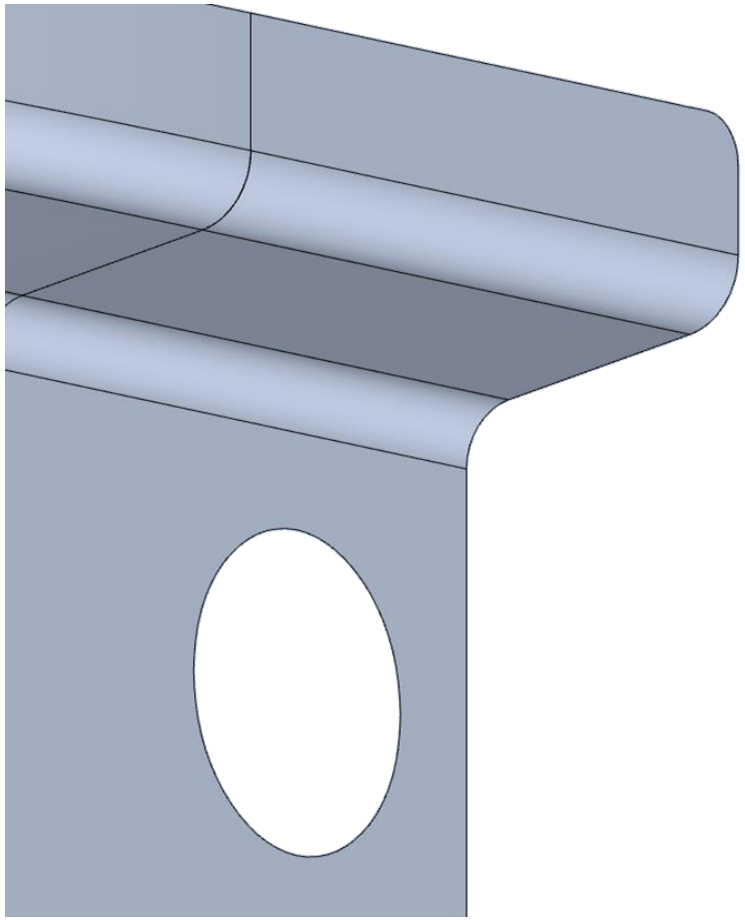


Refined NURBS

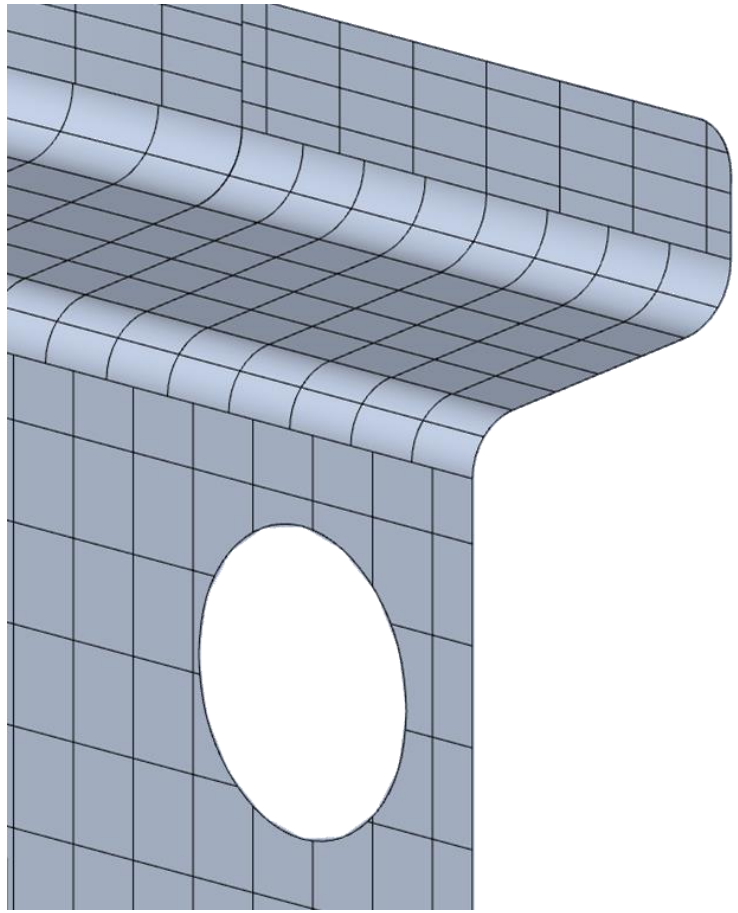


MOTIVATION FOR IGA: CAD/CAE INTEGRATION.
MODEL COMPARISON.

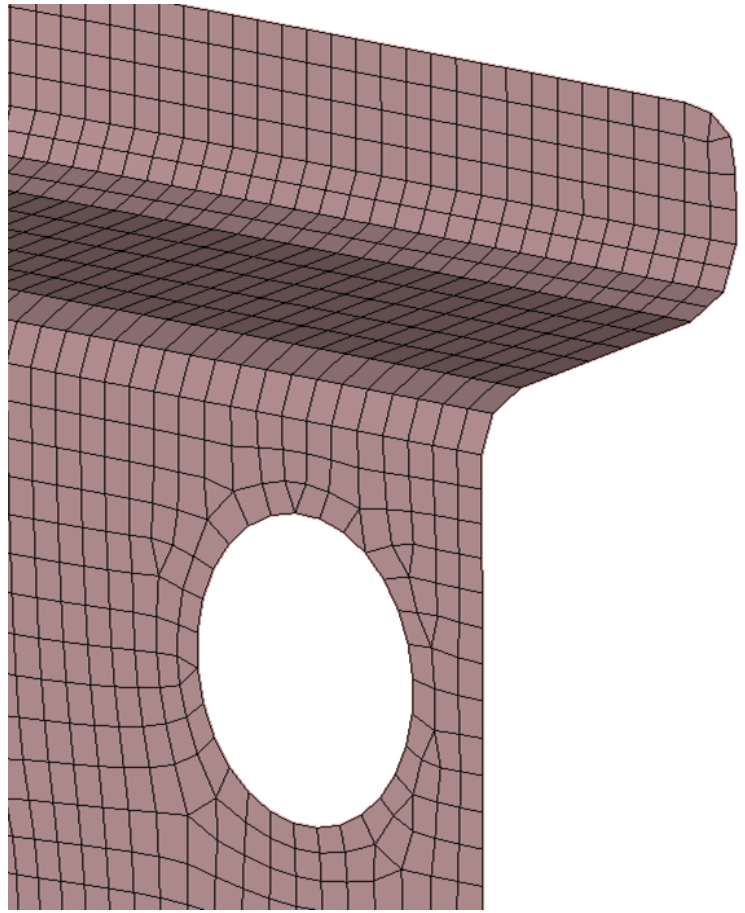
NURBS geometry



NURBS geometry refined for analysis

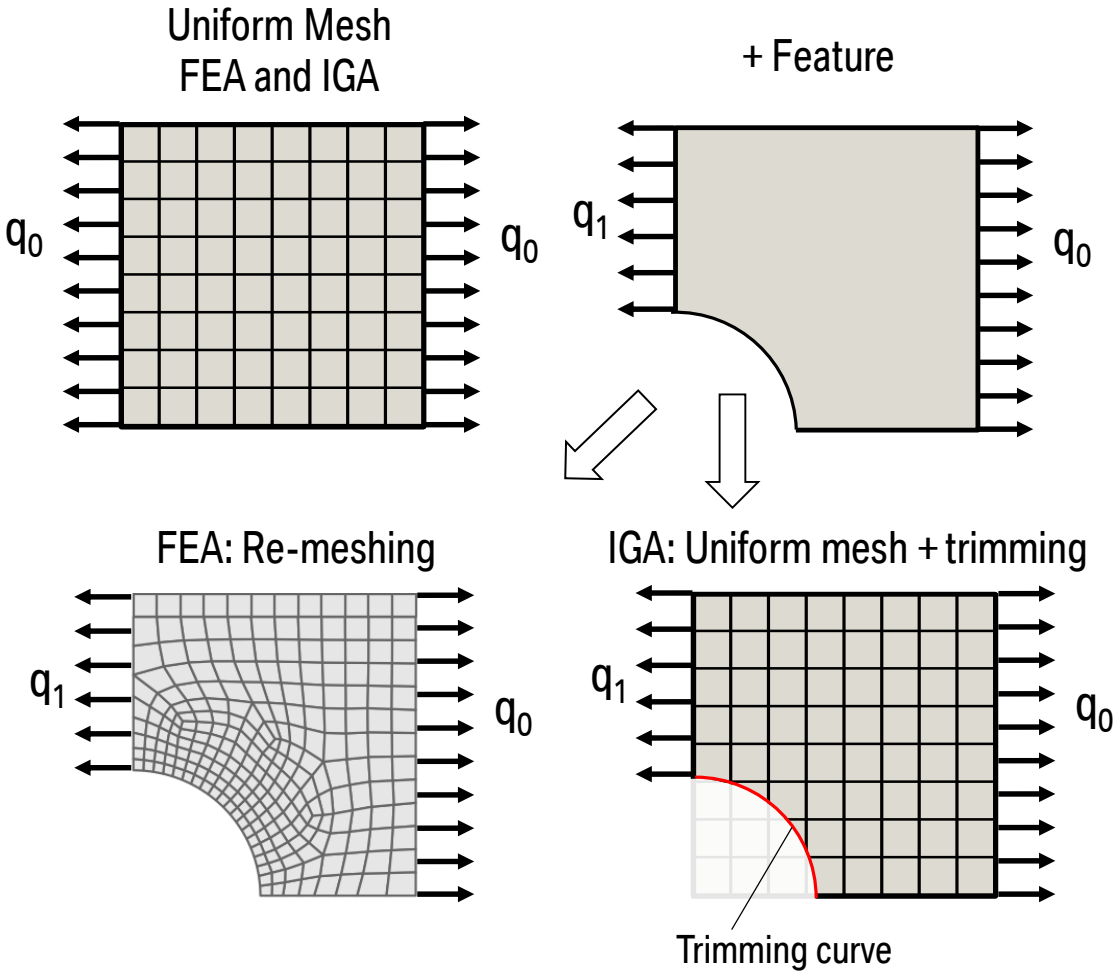


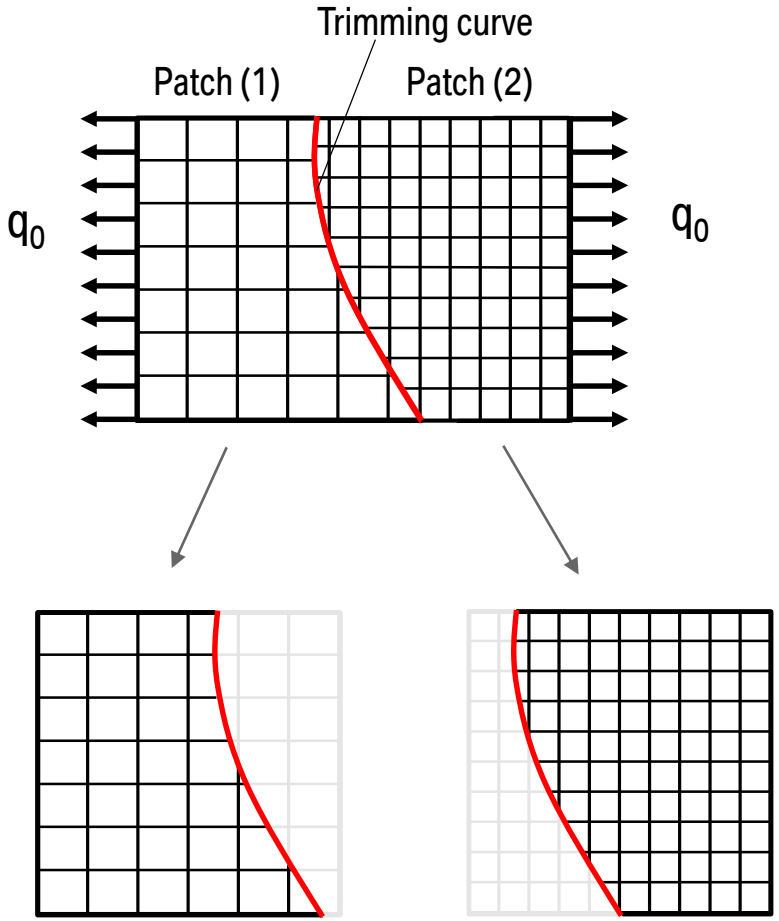
Linear polynomial geometry für FEA



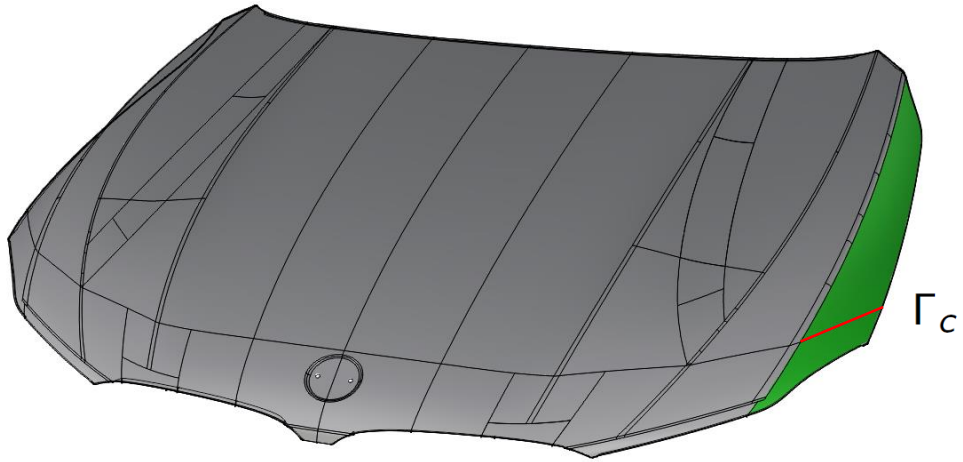
CONTENT

IGA FOR INDUSTRIAL CAD MODELS.
TRIMMING.





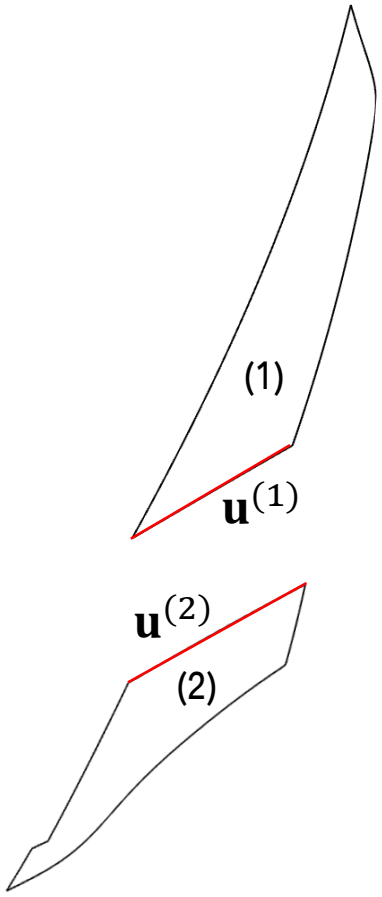
IGA FOR INDUSTRIAL CAD MODELS.
TRIMMING + COUPLING.



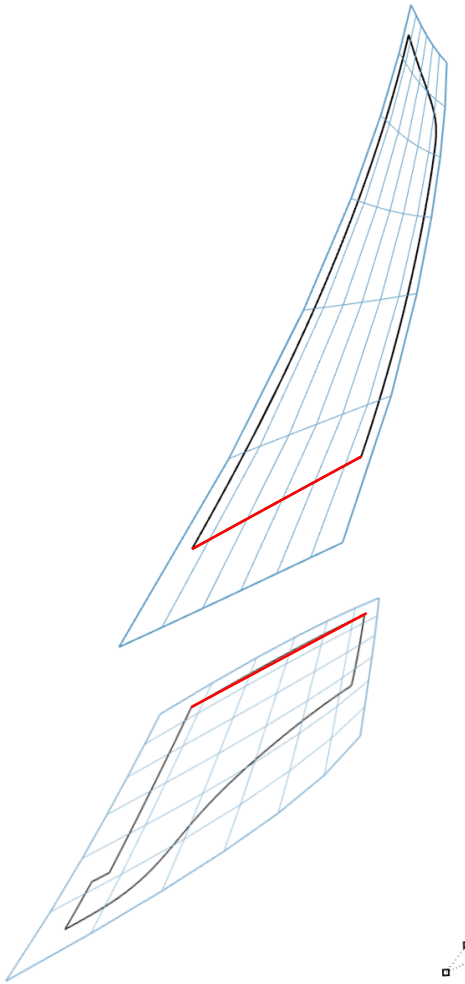
→ Coupling elements for a „weak coupling“ of patches

$$\delta W_p = -\alpha \int_{\Gamma_c} (\mathbf{u}^{(1)} - \mathbf{u}^{(2)})(\delta\mathbf{u}^{(1)} - \delta\mathbf{u}^{(2)})\, \mathrm{d}\Gamma_c$$

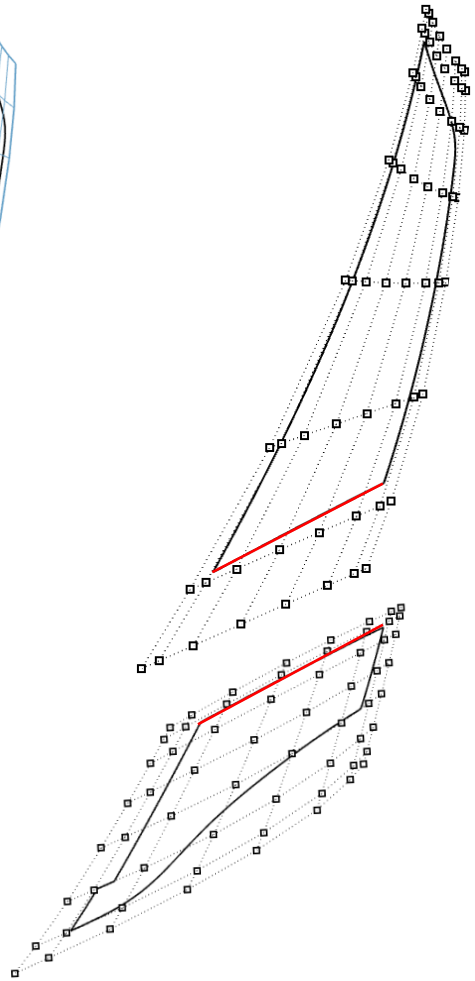
Penalty factor



Trimmed patches



Untrimmed patches with elements

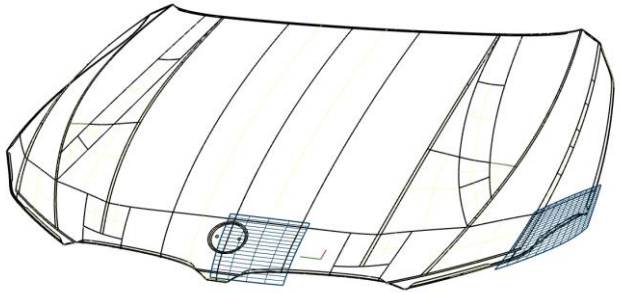


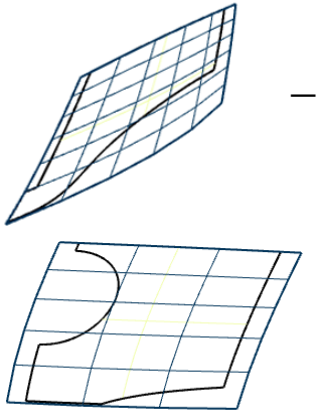
Control points

CONTENT

EXPLICIT IGA FOR CRASH.
COLLABORATION.

BMW GROUP





- Industrial CAD models
  - Closed design loop CAD – CAE
    - → Trimmed NURBS models
      - Crash simulations

IBRA - Isogeometric B-Rep Analysis [2]

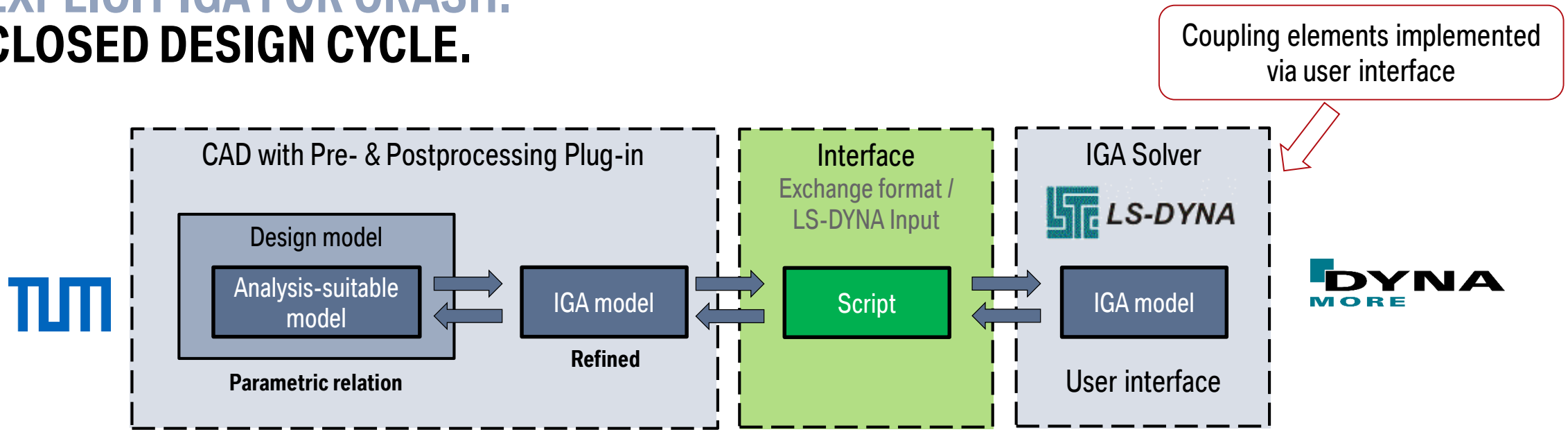
+ Coupling of trimmed NURBS patches
+ Penalty-based B-Rep elements
+ CAD-Plug-in
  + Pre- & Postprocessing
  + IBRA exchange format [3]

LS-DYNA IGA [4] LS-DYNA DYNA MORE

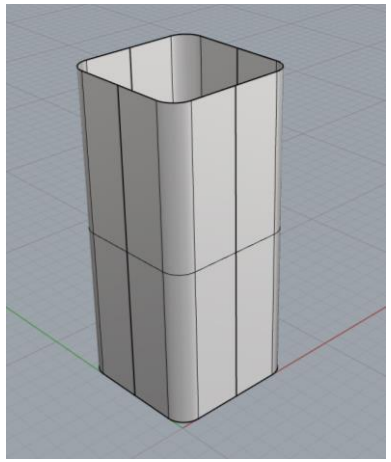
+ Isogeometric elements
+ Trimmed NURBS patches
+ Crash-relevant features
  + Explicit time integration, plasticity, contact,...
+ Hybrid models IGA-FEA

[2] M. Breitenberger, A. Apostolatos, B. Philipp, R. Wüchner, K.-U. Bletzinger, Analysis in computer aided design: Nonlinear isogeometric B-Rep analysis of shell structures, Comput. Methods Appl. Mech. Eng. 284 (2015) 401–457.
[3] T. Teschemacher, A.M. Bauer, T. Oberbichler, M. Breitenberger, R. Rossi, R. Wüchner, K.U. Bletzinger, Realization of CAD-integrated Shell Simulation based on Isogeometric B-Rep Analysis, Adv. Model. Simul. Eng. Sci. 5 (2018).
[4] S. Hartmann, D.J. Benson, Mass scaling and stable time step estimates for isogeometric analysis, Int. J. Numer. Methods Eng. 102 (2015) 671–687.

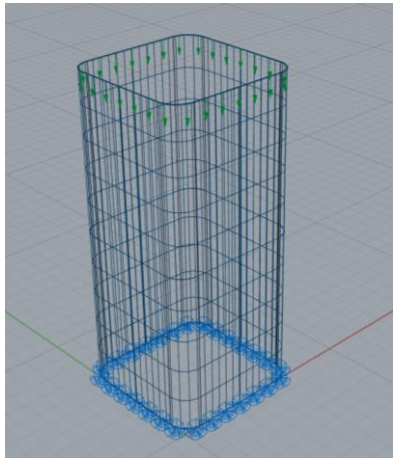
EXPLICIT IGA FOR CRASH.
CLOSED DESIGN CYCLE.



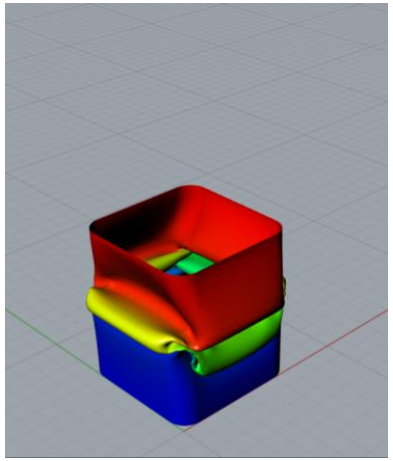
Design



Preprocessing



Postprocessing

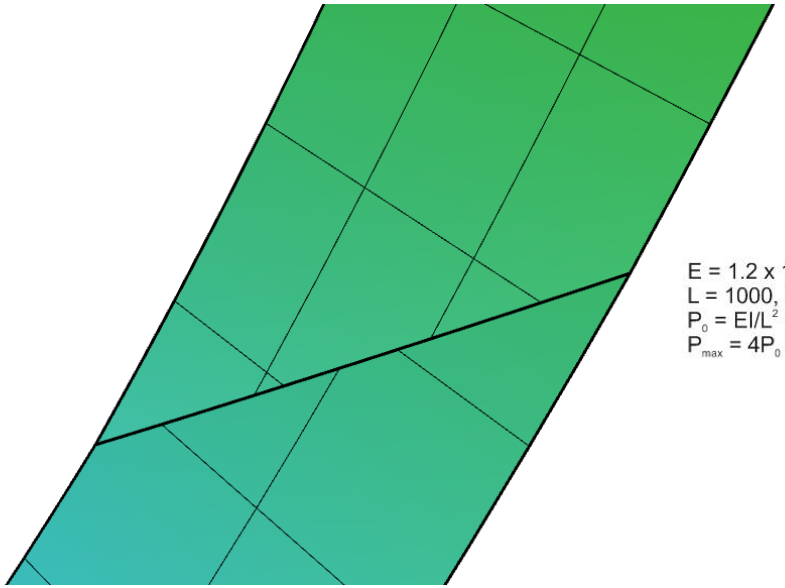


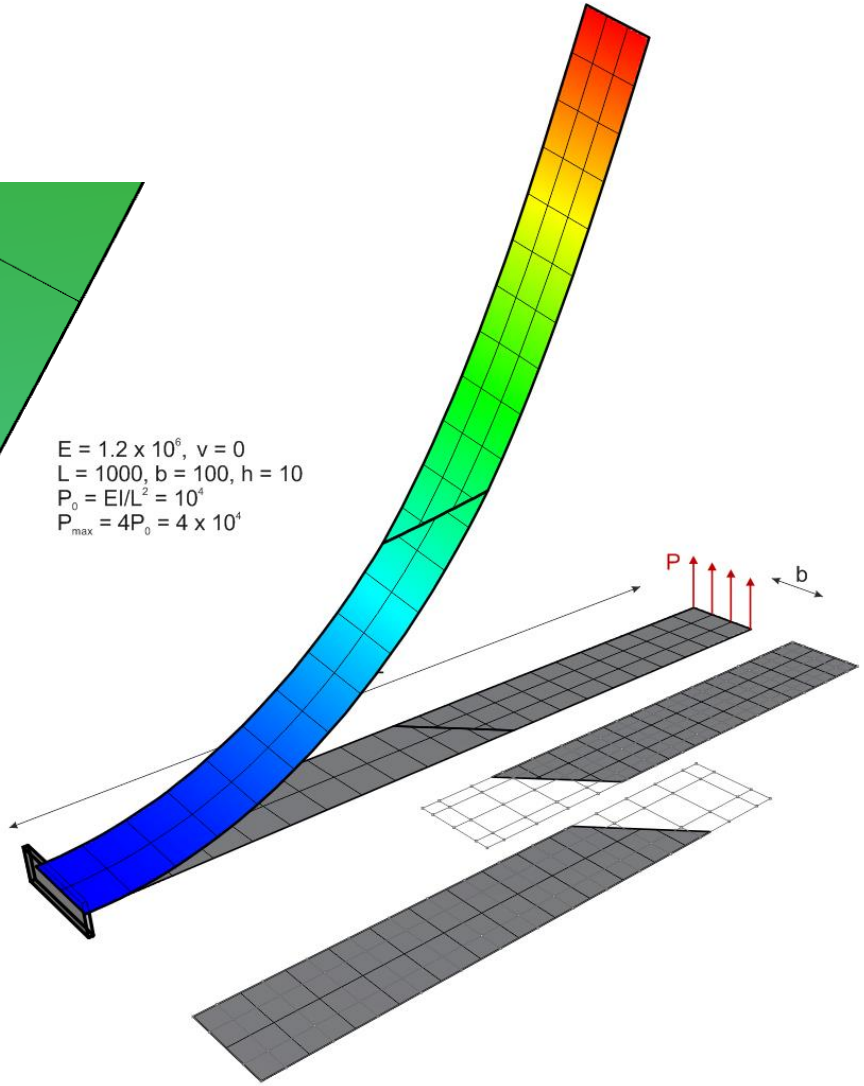
- Full CAD/CAE integration
- Closed design cycle based on NURBS shells

EXPLICIT IGA FOR CRASH.
NUMERICAL RESULTS – CANTILEVER SUBJECTED TO END SHEAR FORCE.

Large deformation benchmark
- Linear elastic material
- Explicit analysis with increasing load
- Trimmed non-matching patches

Conclusion
- Good results for large deformations
- Only minor time step restrictions
- Stabilization of “flying nodes”





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CONCLUSION & OUTLOOK.

Explicit analysis on industrial CAD models
- Coupling of trimmed NURBS surfaces
- Penalty-based coupling elements via user interface
- Explicit time integration, plasticity, contact

CAD/CAE integration
- Design, Pre- & Postprocessing in CAD environment
- Closed design cycles based on NURBS shells
- Faster development process

Next steps
- Basic research on efficiency and robustness
- Guidelines for analysis-suitable design
- Industrial workflow for practical tests at BMW