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# Isogeometric analysis of trimmed NURBS-surfaces in LS-DYNA

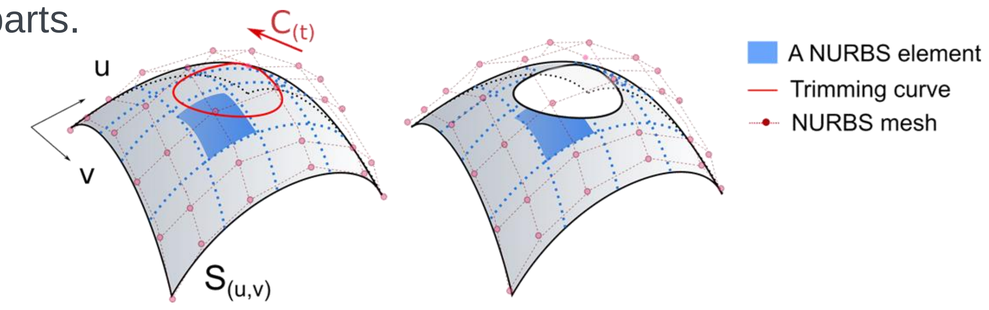
## Motivation

The isogeometric analysis aims at integrating the design and analysis process by using the same model based on NURBS surfaces. However, the application of isogeometric analysis to trimmed surfaces turns out to be a great challenge. This thesis deals with the examination of the capability of isogeometric analysis on trimmed surfaces in the commercial finite element software LS-DYNA. Treatment methods as well as the quality of the analysis of the trimmed models are to be presented.

## Theory of trimming and integration rule of trimmed NURBS surfaces

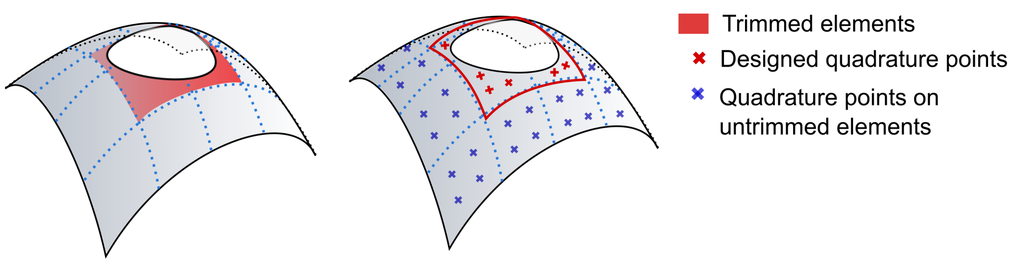
### Trimming in parametrical space

Trimming is an approximation method in which the trimming curve $C_{(t)}$ turns the NURBS surface $S_{(u,v)}$ into valid and invalid parts.



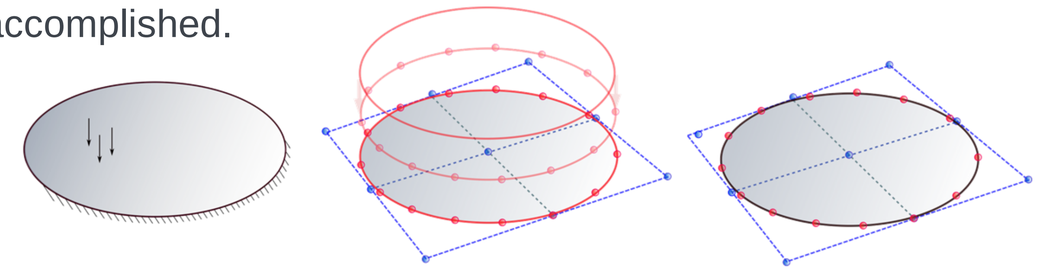

### Quadrature design of trimmed elements

After trimmed elements on the NURBS surface are detected, the point elimination algorithm is applied for designing quadrature points on the trimmed elements. This enables isogeometric analysis on trimmed surfaces.

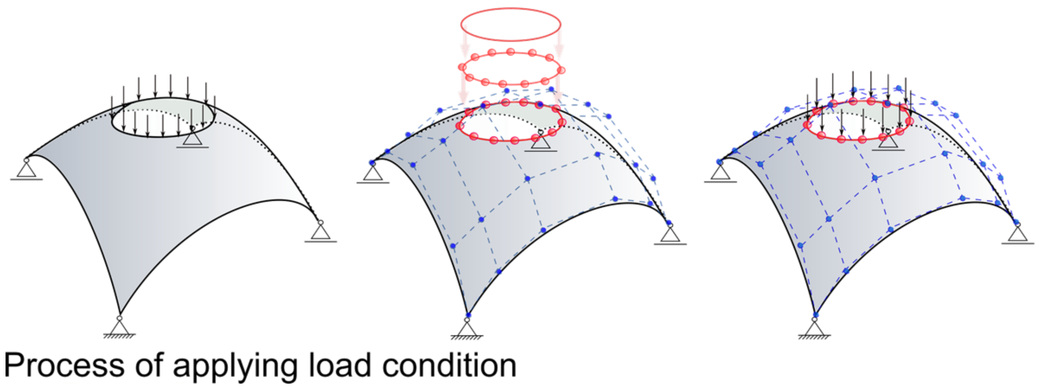



## Model generation in LS-Prepost

The application of load or kinematic boundary conditions on trimming curves can be achieved in LS-DYNA by using a card which inserts extra nodes to the NURBS surfaces. By setting certain constraints onto the 6 DOFs, the corrosponding behaviour between the nodes and the NURBS surface is accomplished.



Process of applying kinematic boundary condition

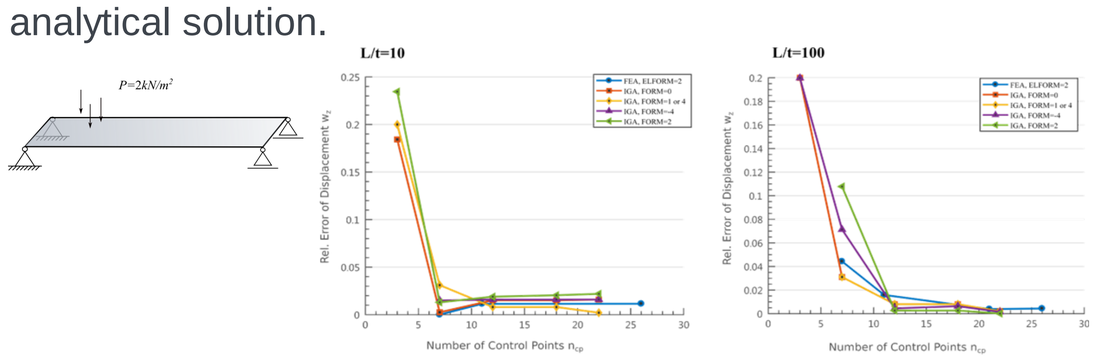


Process of applying load condition

## Numerical examples

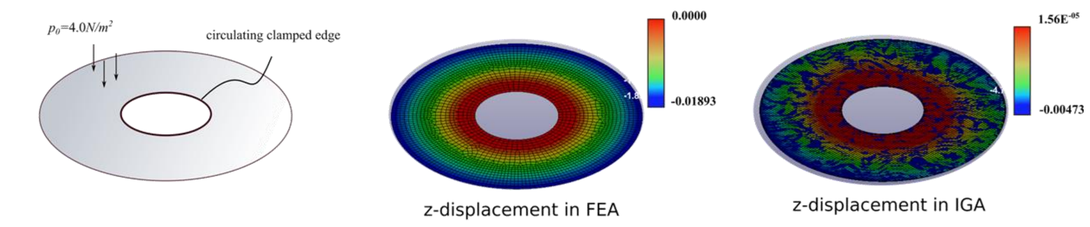
### IGA on untrimmmed surfaces

IGA application on untrimmed structures shows satisfactory results. Choosing different formulations of the same shell model in LS-DYNA provides varying differences when compared to an analytical solution.

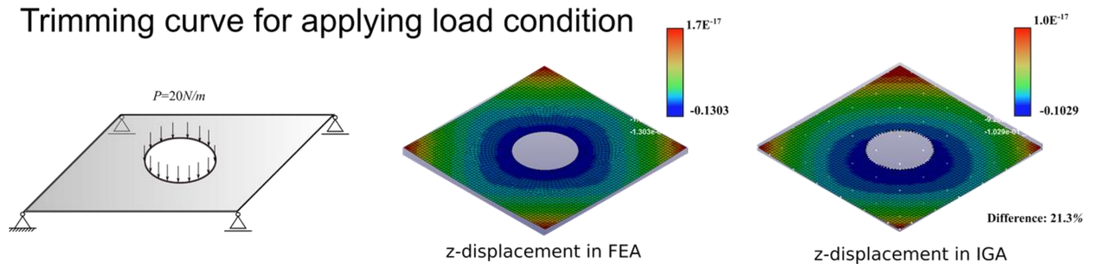



### IGA on trimmmed surfaces

Trimming curve for applying kinematic boundary condition




Trimming curve for applying load condition




## Conclusion

- Time consuming manual treatments on trimmed NURBS surfaces are needed for providing IGA models which are suitable for analysis.
- IGA applications on trimmed surfaces achieve unsatisfactory results.
- Choosing of IGA shell formulation affects the quality of solutions in a, so far, not comprehensible way.

## Literature

Nagy, Attila P.; Benson, David J.: On the numerical integration of trimmed isogeometric elements. In: Computer Methods in Applied Mechanics and Engineering (2015)

Marussig, Benjamin; Hughes, Thomas J. R.: A Review of Trimming in Isogeometric Analysis: Challenges, Data Exchange and Simulation Aspects. In: Archives of Computational Methods in Engineering (2018)

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