C02

3D structural puzzle - Numerical Multi Scale Shape and Topology Optimisation Methods to Additively Manufacture Optimal Structures from Optimised Pieces

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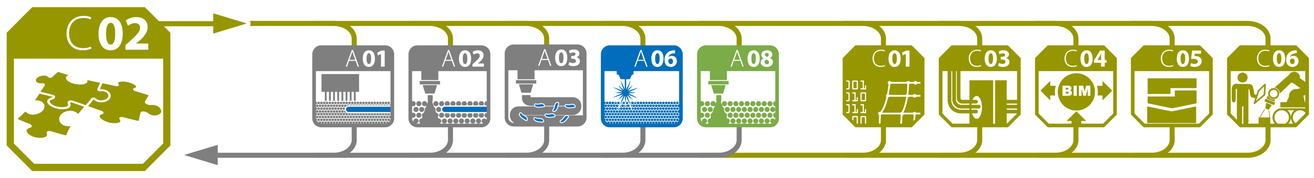
Summary



This project deals with additively manufactured structures considered as large 3D puzzles and multi scale optimisation aspects. Based on Vertex Morphing, numerical methods for supporting a holistic, simulation based multi scale optimisation tool chain will be developed. The goal is to create optimised individual structural pieces which are assembled to form an overall optimal structure. Additive manufacturing is the ideal mean of greatest potential to combine industrial efficient production with individual design and structural layout. The methods will be developed and tested with prototype products and processes in close cooperation.

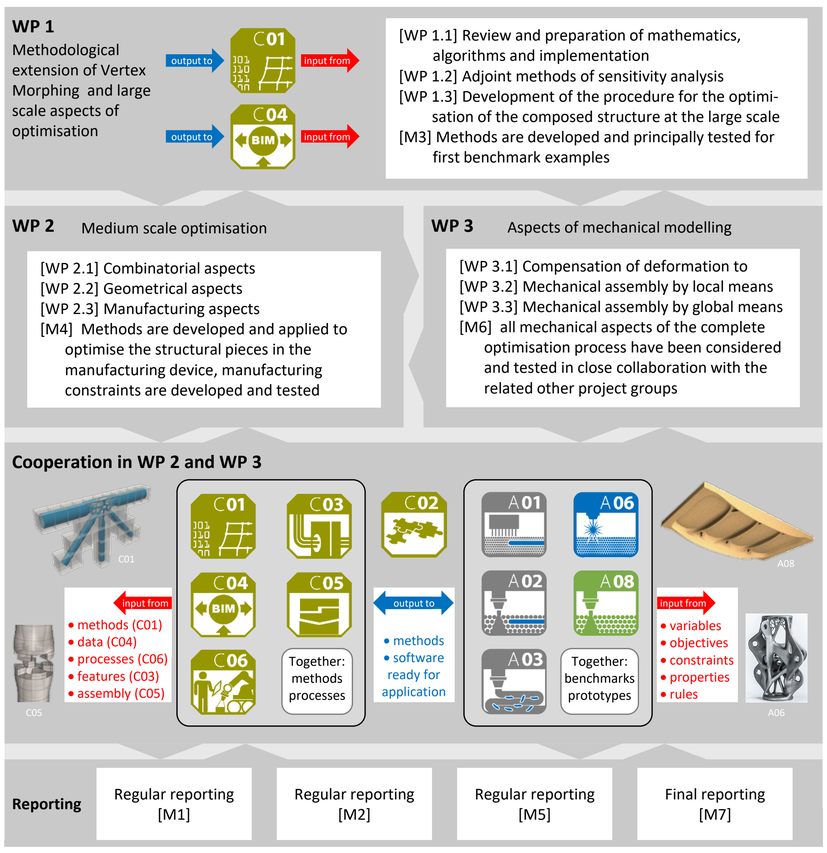
Research Question

- Based on Vertex Morphing develop and implement numerical methods
  - for free-form shape optimisation
  - for supporting a complete simulation based multi scale optimisation tool chain
  - to integrate industrial production and individual design.
- Which span from
  - the first tentative form finding and further optimisation of the large, complete structure (large scale)
  - through the optimal decomposition into structural pieces and the detailed optimisation of those pieces (medium scale)
  - to specifications and constraints of the printing process (small scale).
- Joint potential of simulation, optimisation, and AM will be exploited for structures of innovative shapes.

Methods

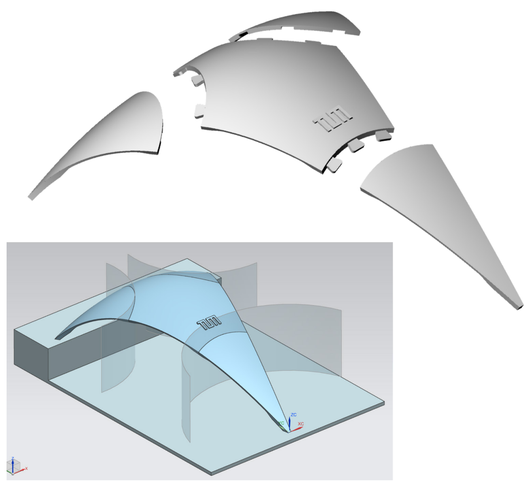
- We are working in the larger field of Computational Mechanics spanning the area between mechanics, mathematics, and computer science.
- We are working on the theory of structural analysis, structural optimisation, numerical methods and computer aided modelling.
- We are experts in developing finite elements for the structural analysis of beams, plates, shells, membranes and solids.
- We develop algorithms for non-linear and multiphysical coupled analysis, form finding, and optimisation, as well as their combinations.
- We develop data models to support the interaction of analysis and computer aided design.
- We are implementing our methods into own and open source software, supporting parallel and high performance computing.
- We rely on long years' experience about tight cooperation with other ambitious groups on large software projects, e.g. KRATOS together with CIMNE.

WPs and Collaboration

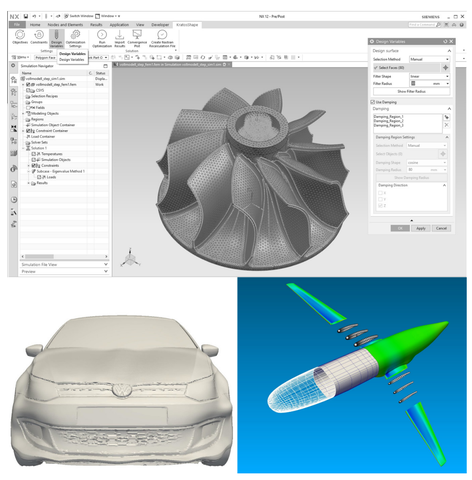


Preliminary Work

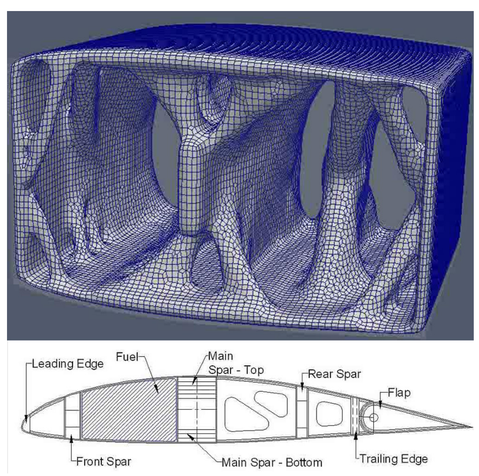
- Extensive experience in the development and application of numerical methods for shape optimisation and form-finding
- The Vertex Morphing method for free form shape optimization
- Topology optimisation, SIMP for 3D-solids
- CAD-FEM integration by the Isogeometric B-Rep Analysis (IGA/IBRA), specific data models, simulation and optimisation
- Own implementations in KRATOS, Carat++, Kiwi3D, SiemensNX Plug-In
- Cooperation with groups of Profs. Kloft and Gehlen in SPP 1542 "Leicht Bauen mit Beton"
- Experiences with composed concrete shells by applying IBRA and optimisation of joint line geometry



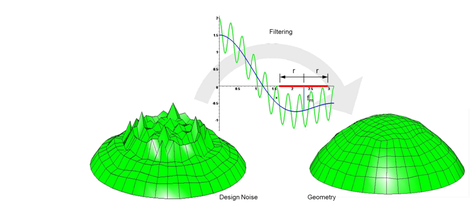
Trimmed IGA modelling and optimisation of composed shell; SPP1542



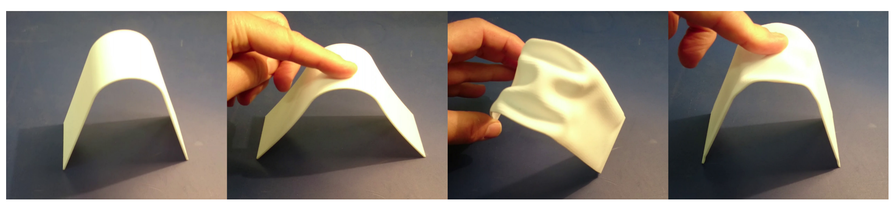
Vertex Morphing applications, SiemensNX PlugIn, Carbody, AeroSpace Shape Opt.



Topology optimization of a wing box, own KRATOS implementation



Vertex Morphing, Filtering of "design noise"



Optimal beads for max. stiffness; Filter radius = bead wave length; No. of design variables >> 1.000; 3D printed prototype; Left: initial shape, Right: optimized shape