Ingenieurfakultät Bau Geo Umwelt

WindForS Wind Energy Research Cluster

WINSENT Wind Science & Engineering Test Site in Complex Terrain

High-fidelity aero-elastic simulation of structures interacting with wind

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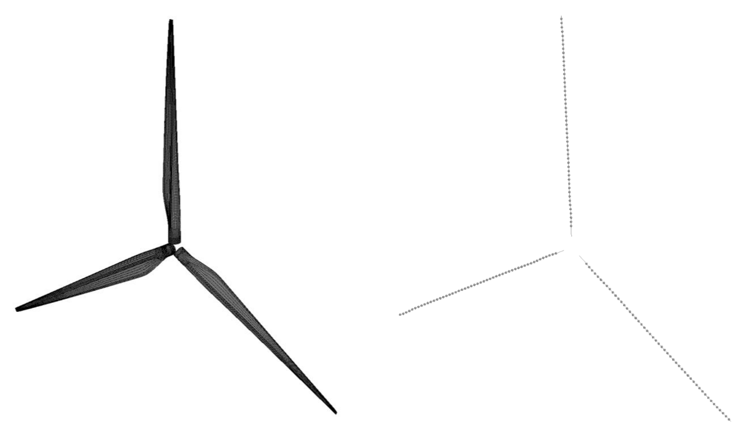
High-Fidelity Structural Modeling and Simulation

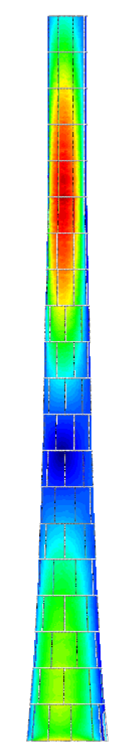
The study of complex wind effects especially needs to be assessed as constructions are pushed to the limit and are thus typically out of the range of engineering experience and standards. Current trends besides wind turbines comprise of high and slender buildings, long and flexible bridges as well as a revival of light-weight structures in general. This tendency to build lighter and more slender is also supported by the availability of new, high-strength materials. The resulting constructions are prone to complex wind response and an in-depth study has to be carried out for assessing wind-induced phenomena.

State of the art computational methods for simulating and quantifying the effects of wind represent a main field of research at the Chair of Structural Analysis. It is in response to the necessity of relying more and more on numerical methods for solving challenging problems which have gained significant ground in the academic and industrial community over the last decades. This is backed up by the rapidly increasing computing power.

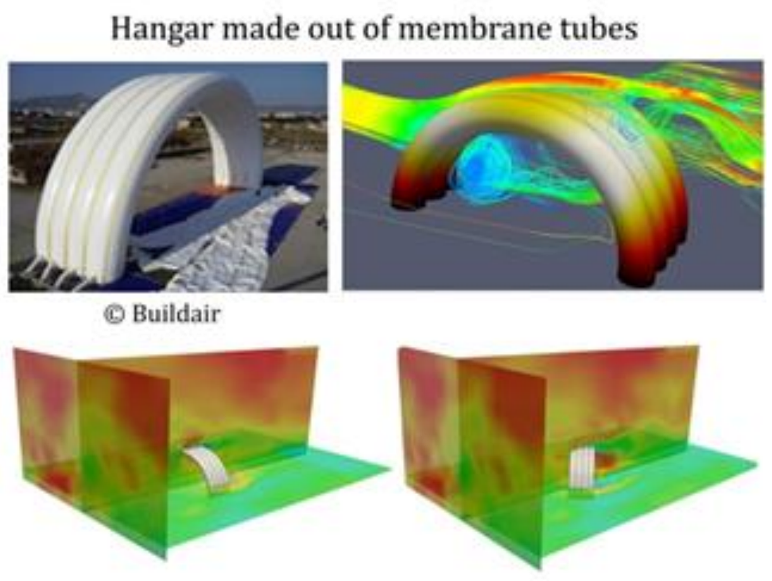
Wind Engineering is a completely interdisciplinary field which involves meteorology, fluid mechanics, structural dynamics, statistics and probability theory, geographic information systems and some other branches. Although aerodynamics is one of the pillars of wind engineering, many of the applications in wind engineering are non-aeronautical. For structural engineers the evaluation of wind loads on constructions is the most important task and the clear goal is to design a safe and economical structure. A good understanding of fluid and structural mechanics is the necessary background for understanding the interaction between wind flow and civil engineering structures.

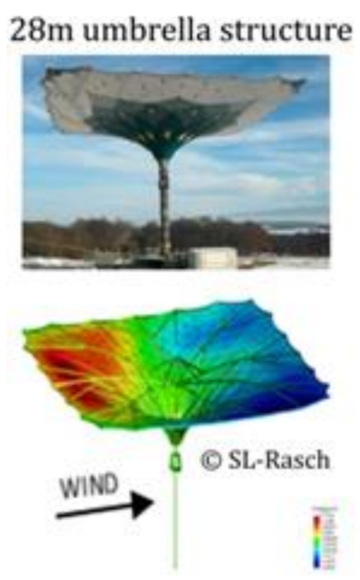


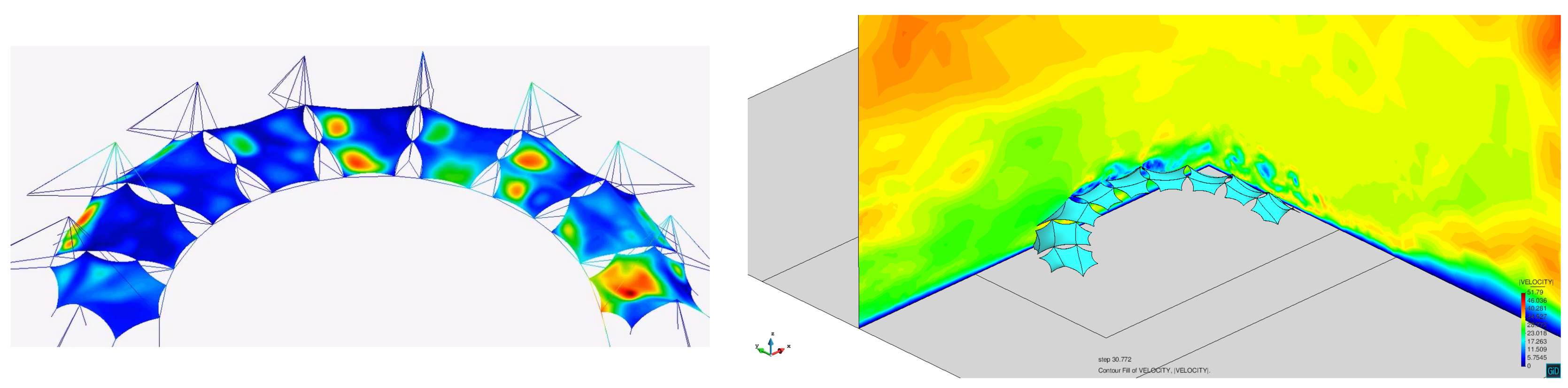
Wind turbine rotors
modelled with shell and beam elements



Steel-Concrete hybrid
wind turbine tower



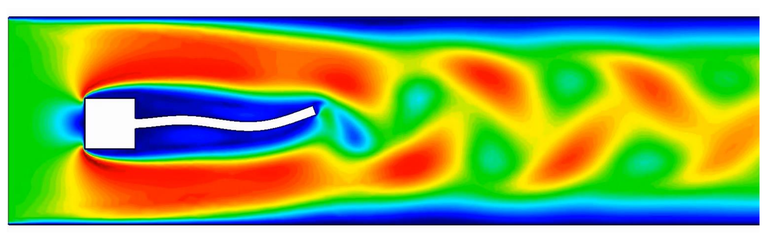




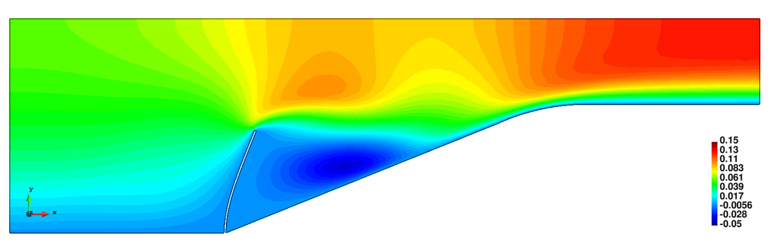
Large scale simulation of the Munich
Olympic Stadion Roof

Fluid-Structure Interaction

Wind turbines are driven by the interaction of wind and the turbine. The influence of the wind on the turbine and also vise-versa has to be taken into account during the simulation to obtain accurate results. This means that the two physical fields fluid (wind) and structure (turbine) can no longer be simulated independently, they have to be coupled in a Fluid-Structure Interaction (FSI) – simulation. Several difficulties arise from the coupling, both on the technical (e.g. data exchange on the interface) side as well as on the physical side (coupled simulation does not converge).
FSI requires Co-Simulation and Mapping techniques.

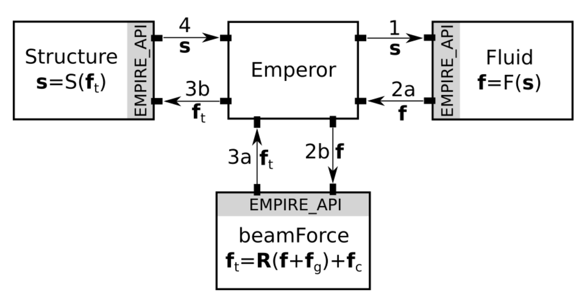


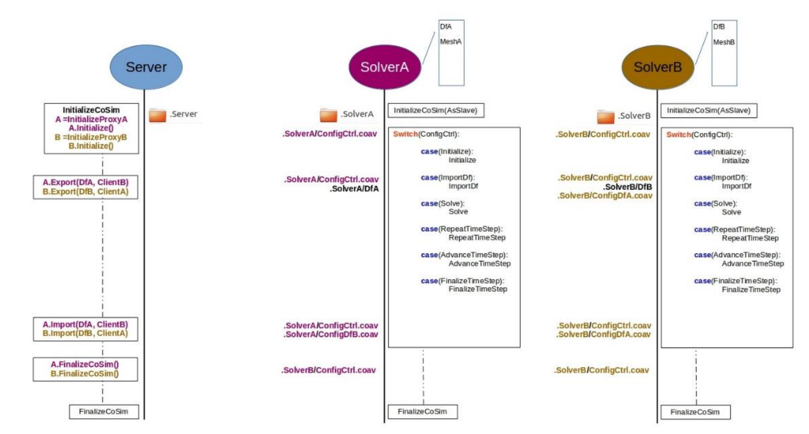
Flexible flag behind obstacle



Flexible flap in channel

Co-Simulation

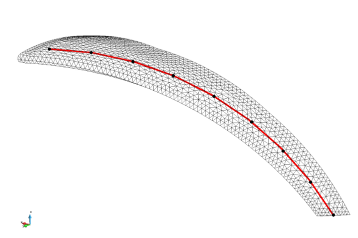




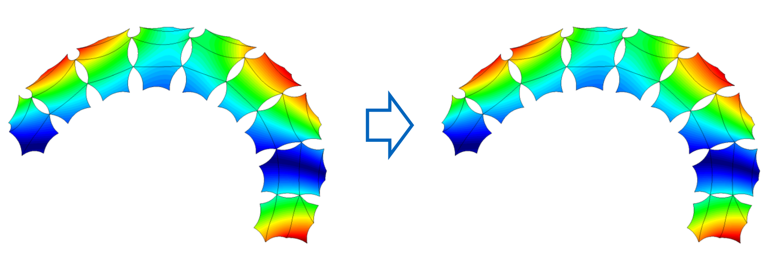
In order to perform multi-physics simulations such as FSI, two or more solvers have to be coupled. This coupling is usually done through a framework or library that is specially designed for the coupling and the data exchange.
They provide adapters for coupling to the data structures of the different solvers and also control the flow of execution. This is usually realized with special communication patters.
They also provide different tools for assisting the coupling such as convergence accelerators.

Mapping

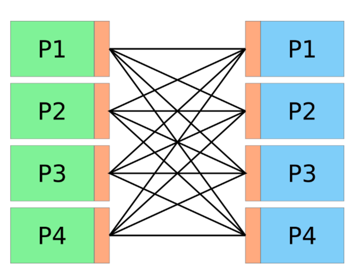
When two or more solvers are being coupled, the discretization of the interface (also known as „wet surface“ in FSI) is typically different for every solver.
This requires the application of „mapping“ methods to convert/translate the information from one side of interface to the other side.
A special focus of research is given to mapping in case of distributed computing on clusters and supercomputers. The main technical challenge is that the data is distributed and not available everywhere.



Line to Surface Mapping



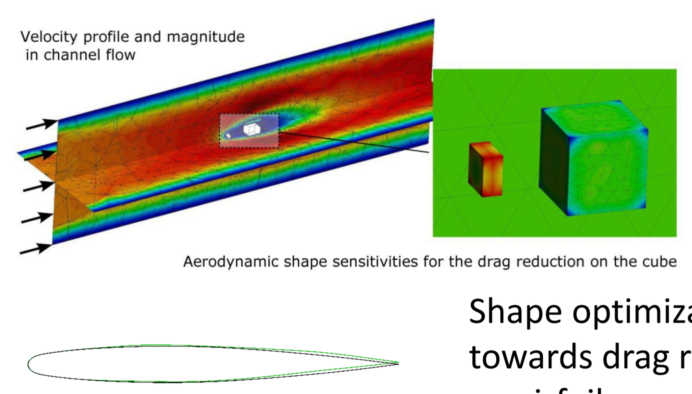
Surface Mapping Olympic Roof



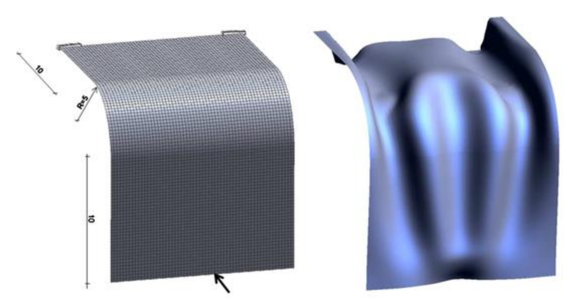
Communication Pattern in
Distributed Computing

Structural Optimization

Optimal design of structures can be achieved by different approaches. The research and application of shape optimization methods is one core topics at the Chair and the so-called node-based shape optimization was developed to be a robust and capable approach which can be applied in various technical fields, such as optimization of shells e.g. in automotive industry or in aero-elastic problems within aerospace applications. In this method, the design variables are typically defined directly by the nodal positions of the Finite-Element model which constitutes a great design space and enables the detection of innovative and non-intuitive optimal designs.



Shape optimization
towards drag reduction of
an airfoil



Optimization of a bent
cantilever