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Simulation, Design and Control of Smart Structures

In the case of thin and lightweight structures, the aim of the computational design process is often to minimize weight while constraining various other criteria like stress and deformation. This is not only the dominant goal in the design of aerospace structures. In the civil engineering context, prominent examples are large membrane structures such as tents or roofings. Structural adaptivity and control can be used in this context to further increase functionality, improve usability or to create even lighter structures.

Method

A computational framework and the related algorithms for the virtual design and simulation of smart lightweight structures is presented. Controller design is based on a state space model that is derived from the finite element model. Discrete time control via an optimal linear-quadratic-Gaussian (LQG) regulator is applied.

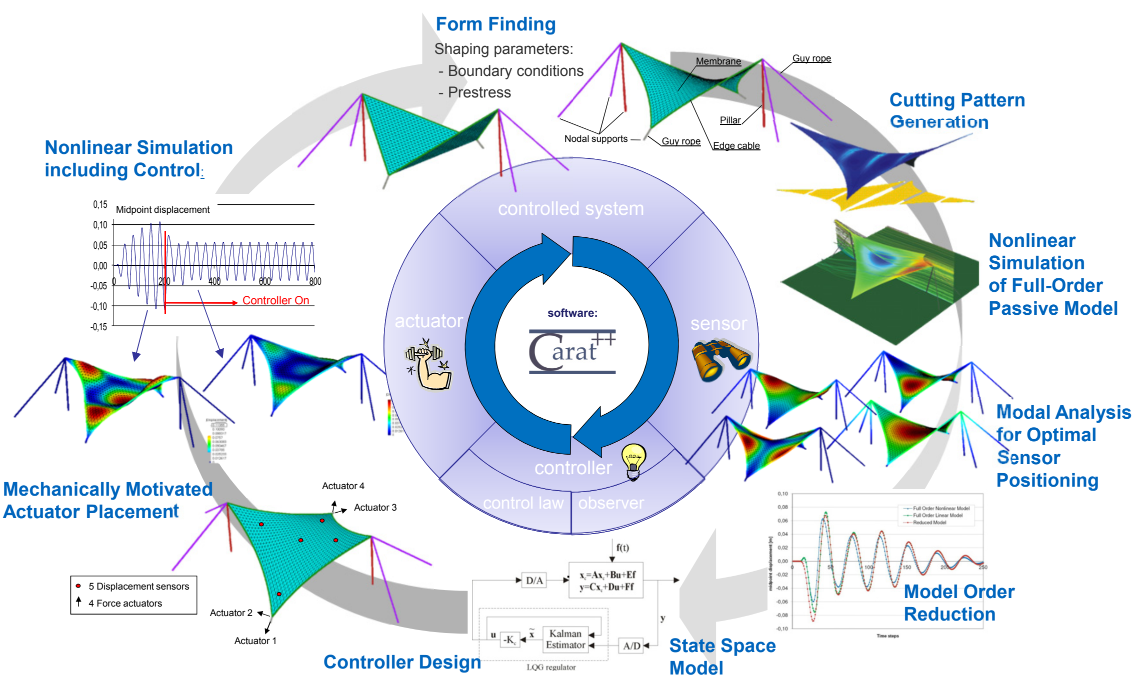
The presented methods of all simulation and design steps are implemented in the in-house software Carat++. The two examples illustrate the design loop for different application scenarios.

Smart Membrane Structures

In this example, active control is adopted for vibration suppression under external loads like e.g. wind.

Form finding is used to determine the optimal structural shape from an inverse formulation of equilibrium. Also the cutting pattern generation is integrated in the design loop in order to consider fabrication effects already in the design stage.

The state space model is derived from the finite element model and preserves the geometrically nonlinear equilibrium state and the prestress effects of the membrane structure.

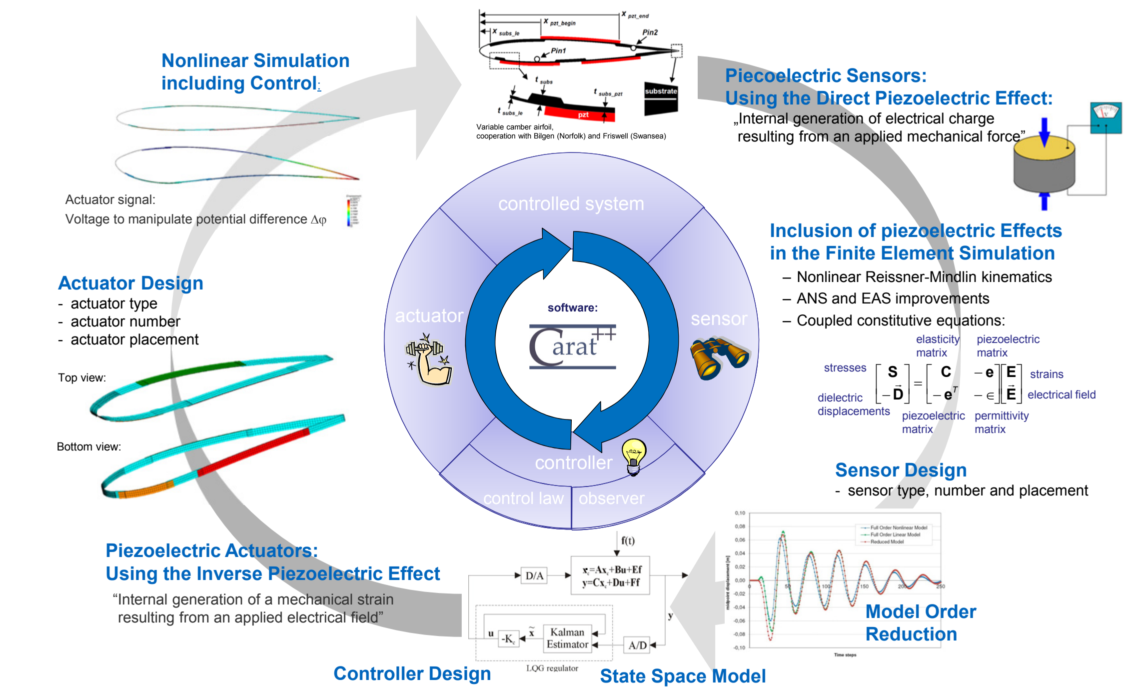


Variable Camber Airfoil

This example presents the virtual design loop for a surface-actuated piezocomposite variable-camber morphing wing structure.

Finite element based optimization with adjoint sensitivities is used to perform optimal actuator placement and to optimize the thickness distribution of the passive structure for efficient control. The constraining factor of this optimization problem is the need for sufficient bending stiffness to sustain shape under aerodynamic loading.

The state space model is again derived from the finite element model.



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