Universität Stuttgart
Fakultät für Bau- und Umweltingenieurwissenschaften

Yuan Song

Coupling of one dimensional elements with isogeometric shell elements

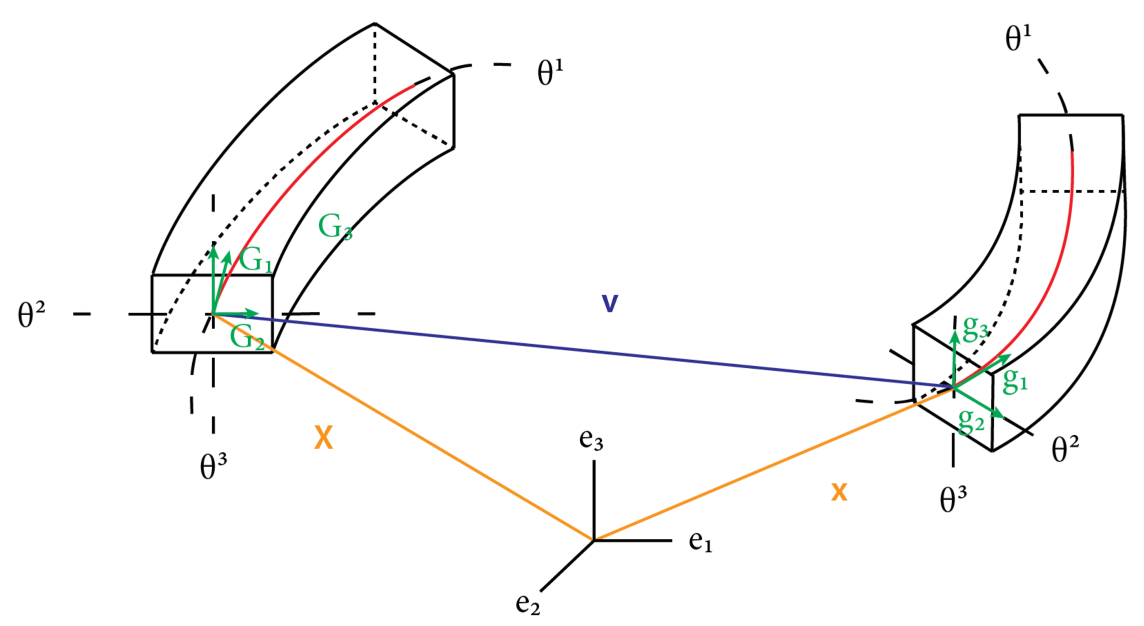
Motivation

The integration of adaptability into building envelopes is one possibility to increase the energy-efficiency of buildings. As the plants are the excellent examples of efficient kinetic structure, in this thesis the simulation of Venus Flytrap snap based on the isogeometric analysis is executed.

The present biological study has demonstrated, that the elongation of some cylinder cells actuates the high speed movement of the Venus Flytrap leaf. In order to reproduce the movement and understand its mechanical principle, the one dimensional membrane element will be implemented in NumPro and coupled with the existing three dimensional shell element. Considering of the advantage of the isogeometric analysis, the geometry of the target element will be defined through NURBS.

Formulation of one dimensional membrane element

The formulation of the one dimensional membrane element, which is used for the isogeometric analysis, is derived through the dimension reduction of the existing Kirchhoff-Love shell element formulation. Analogues to the formulation of the Kirchhoff-Love shell element, the displayed curvilinear coordinate system is chosen for the element parent domain.



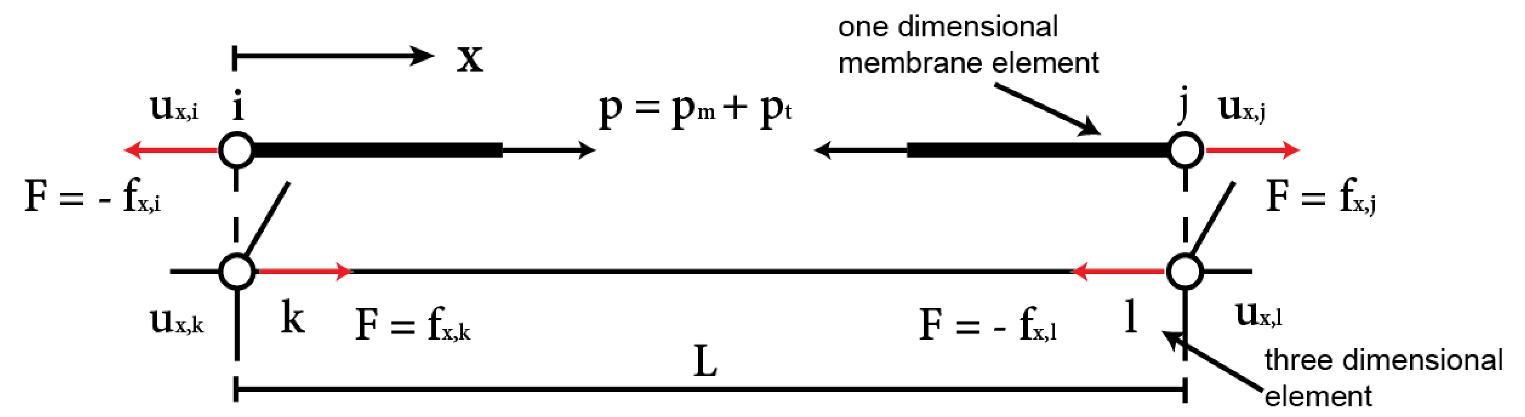
The chosen local curvilinear coordinate system for the formulation of the target element

Based on the chosen curvilinear coordinate system and under the assumption that there is no deformation occurring in the cross section, the derivative of the Green-Lagrange strain tensor with respect to coordinate line θ^1, namely B-Operator, also the element stiffness matrix of the one dimensional membrane element, can be deduced. Following the assembly rules, the element tangent stiffness matrix will be added to the global stiffness matrix.

Similar to the standard finite element method, the stress recovery of the target element has been extra implemented.

Discretization of temperature load

To reproduce the movement of the Venus Flytrap leaf, the temperature load is chosen to apply to the membrane element. Because temperature load can generate the similar effect of the elongated cells. As temperature load does not act as a mechanical force. Based on the analysis of thermomechanical effect, the temperature load will be discretized as nodal force and distributed on the corresponding control points. Additionally, because of the specialty of temperature load, the way of stress recovery is different. The generated stress results from the hindrance of the shrunk of the loaded elements.

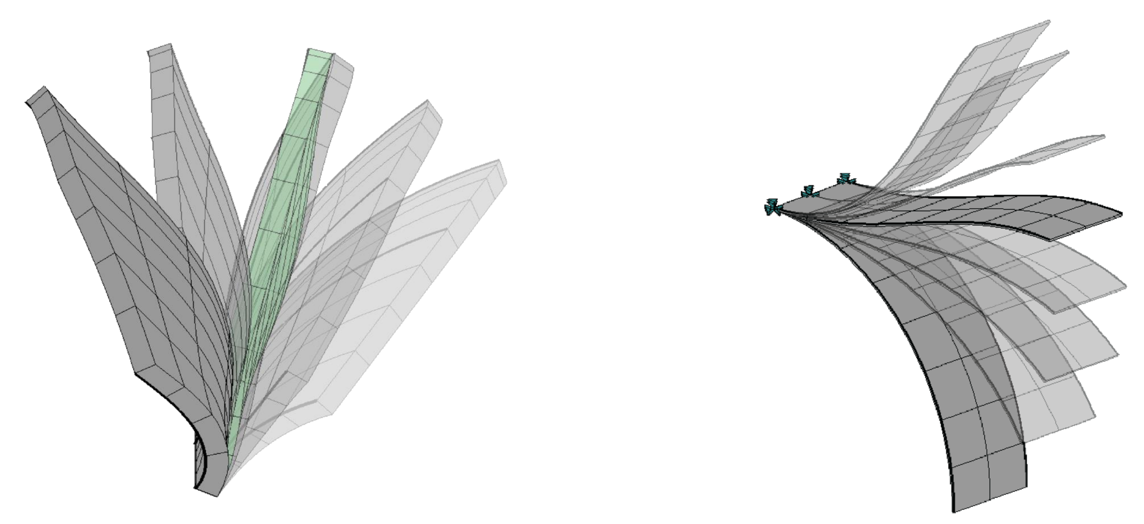


The forces acting on the nodes of the membrane element and hexahedra element, when the membrane element bears temperature load

$$F = EA\frac{u_{x,i}-u_{x,j}}{L} = \underbrace{A\sigma}_{\text{mechanical axial force}-f_m} + \underbrace{EA\alpha\Delta T}_{\text{internal thermal force}-f_t}$$

Numerical examples

The implemented one dimensional membrane element is coupled with the different displayed three dimensional body. And temperature load is applied to the implemented element. Under nonlinear analysis, the three dimensional body deformed as in the figure showed.



The deformed configurations of the numerical examples in different load steps

Literatur

- Song. Y: Coupling of one dimensional elements with isogeometric shell elements
  Institut für Baustatik und Baudynamik, Universität Stuttgart, Masterarbeit,2016

Abschlussarbeit:
Msc. Renate Sachse and Dipl.-Ing. Bastian Oesterle

https://www.ibb.uni-stuttgart.de

Baustatik und Baudynamik