Date July 16th 2015
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Modeling of foldable metamaterials through finite rotation shell elements

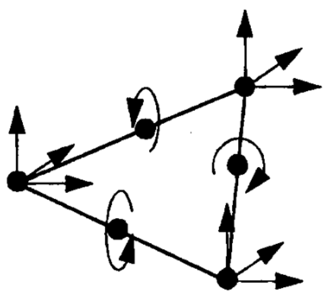
Master of Science project

Abstract

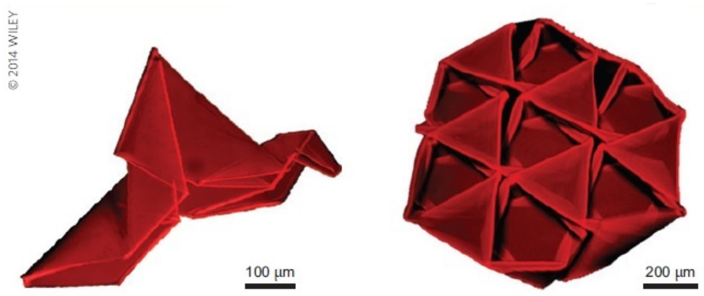
This M.Sc. project consists in the implementation of special shell elements for the computational modeling of foldable metamaterials. The student will implement advanced numerical methods for the optimization of such complex materials within hybrida, a rapidly growing in-house finite element library that is currently being developed at the Structural Optimization and Mechanics (SOM) group.

Introduction Contrary to natural materials, whose behavior is mainly determined by their composition, metamaterials obtain functionality that is not often seen in nature by means of the way they are structured at relatively small length scales. Metamaterials have tremendous potential as they broaden the spectrum of functionalities with new applications that not too long ago were undreamed of. The realm of metamaterials has spread out from its origin in the field of electromagnetism, and regarding mechanical metamaterials alone, many new functionalities have been investigated, including energy absorption, acoustic/phononic wave propagation, heat conduction, and negative Poisson's ratio.

The analysis of foldable metamaterials requires advanced numerical tools. This project aims at implementing special shell elements for the modeling and optimization of folding structures. Figure 1a shows the triangular shell element that is to be implemented, and Figure 1b shows a possible folded microstructure.



(a)



(b)

Figure 1: (a) Nodal dofs of a triangular shell element, taken from [2]. (b) Folded microstructures [1].

Tasks *i)* Conducting a thorough literature review on methodologies used for the modeling of foldable structures using shell elements; *ii)* Implementing the required formulation within hybrida, our in-house finite element library; *iii)* Carrying out the optimization of folding patters in order to achieve a determined functionality; *iv)* Presenting the results and preparing a report that could lead to a peer-reviewed journal publication.

Requirements The student should have modeling experience and basic knowledge of finite element analysis. Python programming experience is recommended.

References

[1] Samuel M. Felton, Michael T. Tolley, ByungHyun Shin, Cagdas D. Onal, Erik D. Demaine, Daniela Rus, and Robert J. Wood. Self-folding with shape memory composites. *Soft Matter*, 9(32), 2013.

[2] F. Van Keulen and J. Booij. Refined consistent formulation of a curved triangular finite rotation shell element. *International Journal for Numerical Methods in Engineering*, 39(16):2803–2820, 1996.