
Optimal Targeted Reconfiguration of Straw-Inspired Elements

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Abstract

Reconfigurable structures having several carefully designed stable configurations have a great potential for diverse applications such as deployable and shape morphing structures, as well as architected materials with configuration dependent mechanical properties. Multistability, allowing to stabilize a structure in different configurations can be achieved by embedding it with elements which have instability regions, such as precompressed elastic beams. A promising multistable elastic element discussed here is inspired by the ‘bendy straw’. Under the assumption of planar deformations, such straw-inspired elements are modelled as arrays of unit-cells having up to four stable equilibria, allowing them to be stabilized in a large number of multi-axial configurations. These elements can be further used to form networks of customized geometries and operative stable configurations, to create complex structures and metamaterials with different configuration-dependent forms and functionalities. For applicability, the transition between different stable configurations of such structures should be done efficiently and with a minimal number of actuators, which raises a challenge of path finding in a highly nonconvex energy landscape. Here we focus on targeted reconfiguration of a single straw-inspired element. For this we begin by setting up the theoretical foundations and introduce a numerical scheme used to describe its mechanical behavior under prescribed relative translational and rotational displacements between its ends. This theoretical model is then validated utilizing an experimental demonstrator consisting of a cantilevered straw, multi-axially actuated by a single XY-Theta stage. Finally, we present an algorithm based on the Nudged elastic band (NEB) method, which is utilized to find the boundary conditions needed to be applied to the straw, for optimal targeted reconfiguration.

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