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DESIGN AND OPTIMIZATION OF SELF-FOLDING SPACE STRUCTURES CONSIDERING LARGE DEFORMATION

Abstract

Emerging manufacturing techniques provide unprecedented design freedom that traditional design methods do not entirely utilize. Therefore, sophisticated design tools are needed that take advantage of the increased flexibility of these manufacturing techniques to realize parts with complex geometry at acceptable cost. Topology optimization being one of these tools is used in this work to automate the design process of self-folding 3D smart structures undergoing large deformation. A gradient-based level-set topology optimization approach is adopted to describe the geometry evolving throughout the optimization process. The eXtended Finite Element Method (XFEM), an immersed boundary technique, is employed to predict the structural response using a well-resolved geometry representation and spatial discretization. A large-strain mechanical model together with higher-order finite elements is utilized to capture the physical behavior of self-folding structures where self-actuation is caused by internal swelling-strains. The complex geometries and non-intuitive material layouts resulting from the optimization process are then fabricated and tested via direct 4D printing. During this additive manufacturing approach, a pre-programmed expansion strain is directly printed into certain parts of the structure eliminating the need for mechanical or thermal training to generate self-folding. After an in-depth discussion of the modeling and optimization approach, examples of optimized self-folding space structures are presented and comparisons against direct 3D printed samples are made.