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Multiscale Method for Mechanical Analysis of Pressure-actuated Cellular Structures with Polygonal Microstructures

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Abstract: This work investigates shape morphing behaviors of the adaptive bio-inspired pressure-actuated cellular structures composed of randomly distributed polygonal fluidic cells. A multiscale method based on the framework of multiscale finite element method is developed to solve the mechanical behaviours of such heterogeneous materials with randomly distributed polygonal microstructure. In this method, the coarse-scale unstructured polygonal elements are firstly used to model the heterogeneous structures with arbitrary microstructural morphologies. And then multiscale base functions are constructed to establish the relationship between the small-scale fluctuations of the microstructures and the macroscopic deformation on the coarse scale mesh. Furthermore, the multiscale method with polygonal elements is extended to predict geometrically nonlinear shape morphing of fluid actuated cellular structures. The co-rotational formulation is integrated to the multiscale method to decompose the geometrically nonlinear motion of the coarse-grid element into rigid-body motion and pure deformational displacements. Several numerical examples about the pressure-actuated cellular structures are presented. The results indicate that the multiscale methods for polygonal microstructures developed in this paper have high accuracy and efficiency.

Keywords: Fluid actuated, Cellular structures, Geometrically nonlinear analysis, Multiscale finite element method, Co-rotational formulation