Computational Homogenization for Inverse Design of Surface-based Inflatables

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Abstract

We present a computational design framework for surface-based inflatables, which are composed of two thin sheets joined along a sparse set of fusing curves. During inflation, the unfused areas separate to maximize enclosed volume, while the fusing curves control both out-of-plane expansion and in-plane contraction. By spatially varying the fusing pattern, we can create structures with incompatible contraction ratios, resulting in metric frustrations and buckling into doubly-curved equilibrium states that balance the inflation pressure forces and elastic forces stored in the sheets. To design these structures, we develop a numerical homogenization method with a novel deformation parametrization, enabling efficient evaluation of bending and stretching stiffness for inflated unit cells with arbitrary fusing patterns. By applying the homogenization algorithm, we create a database of fusing patterns with a wide range of material properties. Finally, we incorporate this database into an inverse design optimization framework to create lightweight yet structurally sound inflatable structures that closely approximate freeform target shapes.

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