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PROCEEDINGS

Hierarchical Tessellation Enables Programmable Morphing Matter

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ABSTRACT

Shape-morphing materials present promising avenues for mimicking the adaptive characteristics of biological organisms capable of transitioning between diverse morphologies. However, existing morphing strategies through pre-arranged localized strain and/or cut/fold patterns have a limited range of achievable geometries, and the morphed structures usually have low stiffness due to the intrinsic softness of underlying materials. To overcome these challenges, we are inspired by the inherently non-monolithic architectures in living organisms, e.g., the nacre or bone consisting of stiff building blocks joined by the weak interfaces, which endow creatures ingenious shape-morphing abilities and tunable mechanical properties through collectively assembling, sliding, rotating, and separation of rigid blocks. Herein we introduce an inverse-design framework via tessellating target 3D geometries at two different levels: kirigami tessellation at the global level and particle tessellation at the local level, referred as "hierarchical tessellation." Upon actuation, general 3D geometries such as varying curvature and asymmetry, and tunable stiffness can be reversibly achieved by assembling rigid tessellated building blocks from a 2D surface. We demonstrate its applications with an interactive lamp, a protective rescue channel, and the smart actuation with electrothermal actuators. Our framework provides guidelines for designing programmable matter with high morphing capabilities and respectable mechanical robustness for multiscale applications.

KEYWORDS

Morphing matter; programmability; hierarchical tessellation; particle assemblies; tunable mechanical properties

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