Bio-inspired shape optimization for structural resistance

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Abstract

Structural resistance poses a complex challenge, with the shape of the structure emerging as a critical factor. Shape optimization plays a vital role in mechanical performance design, ensuring efficient material usage and preventing structural issues. Drawing inspiration from the evolution of natural structures, this thesis delves into bio-inspired shape optimization using isogeometric analysis. The thesis is structured into four main parts: (1) Framework development: A comprehensive framework for bio-inspired shape optimization using isogeometric analysis is discussed. (2) Inspiration from trees: Trees serve as the inspiration resource, leveraging the axiom of uniform strains—a governing principle of tree design—to optimize structures and avoid material overloading or under-utilization. (3) Formulation of bio-inspired criteria: bio-inspired criteria for both deterministic and stochastic shape optimization are formulated. The method is validated through 2D and 3D examples, with comparisons between bio-inspired and classical criteria. (4) Comparison of Results: The results obtained from obtained from based on bio-inspired stochastic design criteria, bio-inspired deterministic design criteria, and classical stochastic design criteria are compared. Key findings include: (1) Shapes generated based on bio-inspired criteria exhibit smooth and refined contours resembling those found in nature, significantly enhancing structural resistance. (2) The resulting strain field for bio-inspired criteria demonstrates greater homogeneity compared to classical criteria, indicating that designs based on bio-inspired criteria are optimal rather than just feasible solutions. This suggests an increased lifespan for the structure. (3) Classical stochastic criteria can provide an acceptable result to designers, while bio-inspired criteria offer a more preferable outcome. (4)This research introduces new criteria for both deterministic and stochastic design, with de- terministic criteria effectively replacing stochastic criteria in the context of bio-inspired shape optimization.

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