Improving the Resilience of Structures through Active Curvature Modulation

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Abstract

Plant shoots and roots optimize their access to resources like water, light, and nutrients through tropic movement-by turning toward preferred directions via variations in intrinsic curvature. We explore the enhanced efficiency of structures imitating plant tropism with the aid of rotary actuators driven by standard PID (proportional-integral-derivative) controllers. The study of actuated chains, fixed at one or both endpoints, reveals fundamental differences between under-actuated, fully actuated, and "overactuated" systems, and also sheds light on the role of controller parameters in optimizing stability and responsiveness. In addition to turning toward prescribed directions, we also investigate how decentralized curvature modulation along a chain can eliminate bending by converging to a funicular shape without explicit knowledge of external loads or the target shape. These findings open the possibility of designing adaptive structures responding to time-dependent loads by active shape control.

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