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THICK-PANEL ORIGAMI INSPIRED SINGLE-LOOP 7R MECHANISM FOR RECONFIGURATION SATELLITE SYSTEMS

Abstract

Modular reconfigurable satellites offer a promising approach for on-orbit servicing by enabling the dynamic adjustment of multiple functional modules into optimal configurations tailored to specific mission requirements. Traditional reconfiguration methods typically rely on the separation and reconnection of satellite modules, leading to an increased number of actuators. The large number of connected structures between modules can escalate system complexity and reduce overall reliability.

This paper presents the development of an electromechanical system designed to achieve the desired functionality by incorporating a novel origami-inspired hinge mechanism that directly addresses structural constraints. A single-loop 7R mechanism, inspired by thick-panel origami, is introduced to facilitate multi-configuration transformations within satellite systems. Additionally, the actuator configuration is analyzed and optimized to enhance operational efficiency. The primary contributions of this study are as follows:

First, a single-loop 7R mechanism inspired by thick-panel origami is proposed to enable various configuration transformations. The kinematic model of the mechanism is analyzed using Denavit-Hartenberg (D-H) parameters and screw theory. The motion bifurcation characteristics and singular positions are derived, providing a comprehensive framework for optimizing actuator configurations.

Second, the reconfigurable satellite is designed using seven triangular prism modules, with a hinge mechanism tailored to the proposed single-loop 7R mechanism. In conventional thick-panel origami structures, folding patterns are designed along ideal crease lines, without considering hinge structural properties or actuation methods. To address this limitation, a novel hinge mechanism is proposed, incorporating quarter gear elements to prevent collisions among panels, particularly in regions with multiple collinear crease lines. The hinge design provides one degree of freedom and uses pivots for easy motor actuation.

Third, to improve actuator efficiency and reduce system complexity, the impact of various actuator configurations on the mechanism's performance is analyzed. A configuration strategy is developed for efficient actuation, utilizing three actuators to enable transformation between four distinct shapes. This methodology provides a generalizable approach to balancing motion controllability and energy efficiency in reconfigurable mechanisms.

Experimental validation of the prototype demonstrates the successful reconfiguration of the satellite system into four distinct shapes—cube, cuboid, rhomboid, and triangular prism—using only three actuators, thereby showcasing the system's efficiency and versatility. This work advances the design of reconfigurable satellite systems by introducing novel mechanisms and structures, while optimizing actuator configurations, offering new architectural possibilities for future on-orbit servicing and exploration missions.