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FORWARD DYNAMICS ALGORITHM FOR ORIGAMI-FOLDED DEPLOYABLE SPACECRAFT STRUCTURES

Abstract

An emerging area in the field of spacecraft deployable structures takes inspiration from origami folding techniques to stow planar structures with large area relative to the spacecraft bus, such as solar arrays, star occulters, and antenna. A central challenge for this concept is modeling the deployment dynamics and designing the deployment actuation of the folded structure and spacecraft system. Here, the system dynamics modeling is approached using multi-body tools and the deployment actuation is designed using strain energy hinges at the fold lines. Strain energy deployment enables a free deployment that does not need an external actuation truss, cables, or a motor, simplifying the mechanical design of the system.

This paper develops an algorithm for generating the equations of motion of origami-folded spacecraft structures. The dynamics model is derived using the Articulated Body Forward Dynamics algorithm and the Augmented Approach for closed-chain constraints. These algorithms provide a computationally efficient base from the literature from which to build an algorithm that is tailored to the challenges of origami-folded systems. This multi-body approach was originally developed for complex robotic manipulator systems. In this paper, the approach is adapted and generalized for any origami pattern that only contains four-node vertices.

Origami fold patterns with repeating structure, such as the Miura-Ori and Scheel patterns, are considered. These patterns share the common property of having no more and no less than four panels meeting at each vertex. Previous work by the authors studied the four-panel base unit in detail, treating the system as two serial chains on a free-flying spacecraft bus subject to a single loop constraint. The algorithm is now expanded in two key aspects to generalize the approach. First, the two serial chains are expanded to have any number of panels in each chain, where each additional set of panels is subject to a new loop constraint. Second, the algorithm is also expanded such that any number of serial chains, or rows of a pattern, can be modeled. Then, given just the node graph designating how the panels are connected, the algorithm will generate the equations of motion of each hinge in the system. Modeling a rigid body system with a large number of loop constraints such as the origami-folded structure will exerience error growth across the constraints. Error growth as the number of rigid bodies in the system is increased is studied, and error control methods on the loop constraints are discussed.