Paper ID: 84300
student

IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures II Development and Verification (Orbital deployable and dimensionally stable structures, including mechanical and robotic systems and subsystems) (2)

Author: Mr. Nate Osikowicz
Pennsylvania State University, United States

Dr. Puneet Singla
Pennsylvania State University, United States

DEPLOYMENT AND REACHABILITY ANALYSIS OF TENDON-ACTUATED STRUCTURAL MODULES FOR AN IN-SPACE ASSEMBLED SEGMENTED REFLECTOR

Abstract

In this paper, we investigate the shape-changing capability of pre-stressable structural modules for in-space assembled reflectors. This work is based upon the tensegrity paradigm, which is a minimum mass structural concept. Understanding the range of equilibrated shapes that a tensegrity structure can achieve is critical for evaluating the structure's ability to perform tasks in shape changing applications. A useful property of tensegrity structures is their ability to change shape between different equilibria. The entire range of achievable shapes, or reachability set, of a tensegrity structure lies on an equilibrium manifold. The process of finding the manifold seeks to find equilibrated shapes under all possible string tensions. Until recently, there has been little investigation into the reachability analysis of tensegrity structures due to the computational bottleneck associated with randomly sampling all possible string tensions. A segmented reflector array could be systematically constructed by appending M individual modules, each with N reachable states, to yield an end-to-end structure with N^M possible configurations. Given this exponential growth, a standard sampling-based approach is not computationally feasible for calculating large multibody reachability sets. In fact, after reaching a certain number of modules, random sampling becomes computationally intractable. To avoid this computational burden, we introduce a new method for approximating reachability sets for modular structures. In this approach, we represent the reachable set as a probability density function and propagate the mean and covariance through forward kinematics to yield a gaussian approximation of the end-to-end reachability set. For an M module system, this reduces the problem into solving M one-dimensional quadrature schemes, avoiding the computational bottleneck that is inherent to random sampling. This new approach enables fast trade-off studies for large multibody systems.

We apply this numerical approach to design a novel tensegrity reflector that can be robotically assembled in space. As a minimum-mass structural module, the tensegrity prism can be packaged efficiently for launch and deployed automatically through closed-loop shape control. A major advantage of this approach is that the internal tension network can be used to stabilize the structure as it is deployed, overcoming a major technical hurdle of other robotically assembled truss concepts. Once assembled, the end-to-end reflector can actively change shape through a range of apertures greater than 15 meters, with the added capability of disturbance rejection by virtue of the internal tension network. With increased aperture and sensitivity, this new reflector concept could enable exciting new capability in remote sensing applications.