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

Dr. Puneet Singla
Pennsylvania State University, United States

MODEL BASED CONTROL OF DEXTEROUS TENSEGRITY ROBOTS

Abstract

To further extend our reach into outer space and prepare planetary bodies for human arrival, the need for autonomous agents with dexterous manipulation capabilities is imminent and imperative. On one hand, the difficult challenge of constructing large-scale space habitats demands exceptional dexterity and reactivity to external forces. On the other, high payload costs remain a significant hurdle, requiring robotic structures with low mass and high packaging efficiency. Building upon recent results that the tensegrity is a minimal mass structure subject to a stiffness constraint, we exploit the modularity of tensegrity to design a lightweight, adaptable alternative to traditional robotic manipulators.

Tensegrities comprise a collection of axially loaded compressive members (bars or struts) stabilized by a network of tension members (strings or cables), resulting in flexible structures which can be pre-stressed and actively controlled to manipulate assets and resources in outer space. Historically, tensegrity dynamics packages have suffered from difficulties centered on the efficiency and scalability of the tensegrity's multi-body equations of motion. Recently, Goyal and Skelton showed that tensegrity system dynamics can be represented compactly in matrix form, enabling efficient simulation and model-based control of tensegrity structures. Leveraging the vector-based dynamics model, a state feedback controller is developed to guide the end effector of a tensegrity manipulator along a desired reference trajectory. We define the control variable as the string force density to make the governing equations of motion linear in the control variable. This allows the required string force density to be solved for linearly at each time step by solving a convex linear programming problem. This closed-loop approach lays the foundations needed for highly dexterous manipulators that are both lightweight and compliant to external loads.

The developed control law is implemented in simulation on a new type of tensegrity robotic manipulator. Using self-similar iterations, we design a novel robotic manipulator based on the traditional T-bar tensegrity structure. Trajectories are designed to showcase the entire reachable space of the manipulator. A study is conducted to evaluate both mass efficiency and actuator effort throughout the maneuver of the T-bar manipulator. Results show that tensegrity provides a suitable framework to design lightweight structures with dexterous manipulation capabilities.