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A Computational Platform for Optimal Design of Deformable Polyhedral Structures

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Abstract

Deformable polyhedral structures have many potential engineering applications. While perhaps the most common applications are in robotics, e.g., to implement locomotion, polyhedral structures can be used as reconfigurable structures to support antennas, provide shelter, as reconfigurable machines, or as mechanisms used in flow control or flow management. Mobility of deformable polyhedra has been the subject of numerous investigations, as is the case currently in the area of collision detection, fueled by the explosion of interest in computer games and the broad availability of raw computer power available from inexpensive GPUs. Extensions into origami design and tensegrity structures make the literature on polyhedral structures particularly interesting and the study of deformable polyhedra a vibrant research topic. In this work we study the modeling and control of deformable polyhedral bar and plate structures. The goal is to develop a general platform for investigation of deformable polyhedral structures and their optimal design and control, starting from very general data, i.e., a graph representation. Starting from configuration X(0), the objective is to bring the structure to configuration X(t) without stretching (or, depending on the application, without wrinkling). Optimal configurations are application-dependent. To motivate the work, we focus on structures used to support communication antennas for a controlled angle of incidence, but the formulation is useful in other contexts, including locomotion and flow control, and designs motivated by these criteria are explored as well. In addition to structural topology and member sizing, the optimization involves the optimal number and location of actuators, and of passive stiffening components. In most applications the structure is used for containment and protection, and therefore additional considerations involve strength and workspace constraints. In addition, energetic considerations are also included to manage the energy required to effect the transformation from X(0) to X(t).