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Closed Loop Shape Control for Modular Folded Structures

Project Overview

Discretely assembled cellular structures can produce superior custom mechanical performance, beyond scales offered by most additive or subtractive fabrication methods. The structures we make here at the Center for Bits and Atoms can be designed with custom mechanical properties and anisotropies, blurring the boundaries between material, structure, and mechanism. The geometry of the unit cell (beam or plate lattice) plays a major role in the overall mechanical properties, and it has been demonstrated that plate architectures outperform beam-based ones at the same relative densities.

These cellular structures are attractive for robotics and morphing structures because of their programmable anisotropies and high specific strengths. But, to fully exploit these structures for these applications, we need to have a better understanding of the real-time deformations of the structure, which will enable closed-loop control of the shape of the structure. Unlike rigid structures/mechanisms, which deform at specific joints in known ways, these cellular structures, by design, deform through the entire structure. This continuous deformation is both what makes this material system interesting for robotics applications and difficult to directly deploy, as the state cannot be simply measured by the placement of well-developed linear or rotary encoders.

This IAP, we aim to develop a system that integrates sensing directly into the structures, to measure local deformation and compute the global state of the structures. The goal of this is to provide a physically scalable strategy for the closed loop shape control of continuously deforming structures.

I will be working under the guidance of graduate researcher Alfonso Parra Rubio and Professor Neil Gershenfeld.

Personal Responsibilities & Goals

For this IAP UROP I plan to work on ideating and testing different strategies for sensing and creating models of the structure. Specifically, measuring deformations in the structure by:

a. comparing strain gauges,
b. other resistance based displacement measurements
c. hall-effect sensors and magnets
d. capacitive sensing

Additionally, I will help with the physical design of prototypes regarding

2. The method for connecting the cell geometries
3. Constituent materials for the structures
4. Designing the modules
5. Fabrication of the prototypes

The deliverable for IAP would be a single unit cell or voxel with integrated sensing, calibrated against Instron testing.
A stretch goal could be a small cantilever beam or recreating an existing morphing structure that implements these cells.

Personal Statement

From my history with designing complex origami and interest in robotics emerged this aspiration to see actuated folded structures. This opportunity would not only let me get more practical experience with skills like modeling, controls, sensing, and fabrication, but I would also get to work meaningfully on a project I've always looked forward to.