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Metallic Structural Origami: Design Algorithms and Manufacturing of a Folded Plate Lattice Bridge

Project Overview

This project manifests from the synergy of three main ideas: discrete structural origami, architected cellular solids, and plate lattices.

Origami is the inspiration for using sheet stock material to create high load-bearing structures. Manufacturing-wise, the idea of using a 2-D single layer process with embedded 3 dimensional information shows significant potential. With rapid manufacturing, exploring structural origami as an architected cellular solids is achievable as well.

Industry and researchers' interest in low-density, yet high-specific stiffness materials has generated consistent work on architected cellular solids. It has been proven that discreetly assembled cellular solids can perform as ultra light materials with record-setting density-stiffness ratios[1]. Many of these studies, however, only consider beam lattices.

Besides, beam lattices maintain a lower ratio of stiffness to strength than plate lattices at the same relative density. They also show inflexibilities on generating geometries out of a greater range of materials. A different approach is to consider the less-researched plate lattices. Plate lattices with the same relative density to beam lattices have an increased specific stiffness 2.5 times that of their beam lattice counterpart[2].

As a demonstration of the significance of the concepts mentioned above, we aim to design and build a bridge using discretely assembled plate lattices. For the scope of the UROP, we will be leveraging prior research by implementing a specific lattice geometry that can adapt to any outer mold target surface and bears advantageous mechanical properties.

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

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[1] *Reversibly Assembled Cellular Composite Materials*. http://cba.mit.edu/docs/papers/13.09.Science.pdf.

[2] Berger, J. B., et al. "Mechanical Metamaterials at the Theoretical Limit of Isotropic Elastic Stiffness." *Nature News*, Nature Publishing Group, 20 Feb. 2017, https://www.nature.com/articles/nature21075.

Personal Responsibilities & Goals

For this project, I plan to focus on creating a script that generates a 3D structure of plate lattices from an input outer mold surface and to prepare it for manufacturing. This task can be broken down into several segments:

- Learning to Interface with a CAD software like rhino using python scripting
- Designing an algorithm to populate a target surface geometry
- Implement the algorithm into an actionable script
- Unraveling the CAD model into specific 2D surfaces with their generating crease lines
- Translate the 2D files into G-code for CNC milling.

The goal by the end of this UROP opportunity would be to have the working physical models and a strong grasp of the workflow, including the necessary integrations for all the steps from design to prototype.

Personal Statement

While so many of the undergraduate student body seem to have a strong background in STEM fields, I have always found my inspiration and confidence through things related to design and complex origami. This UROP offers a way for me to develop new practical skills that allow me to further pursue design and engineering while also providing the comfort of a familiar theme in an exciting new application.