Fast and Simple Printing of Graded Auxetic Structures

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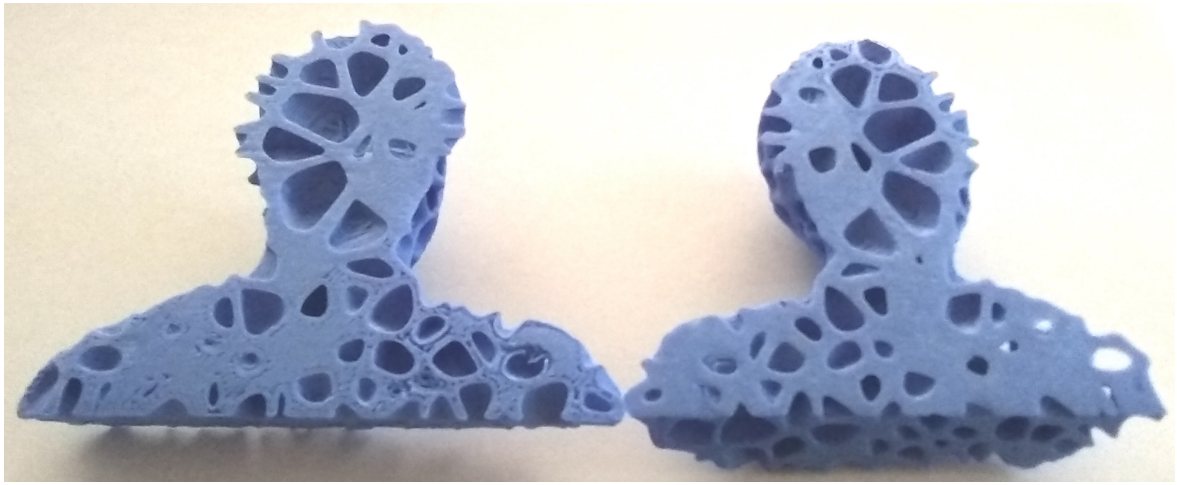
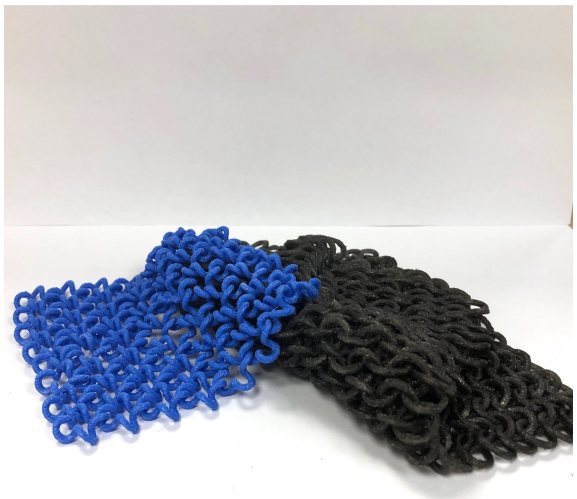
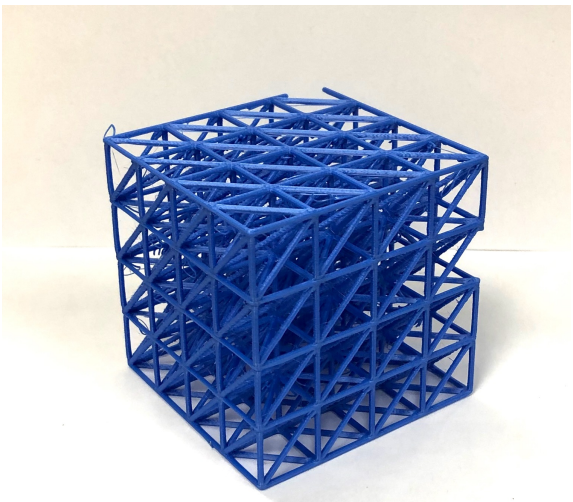
Outline

Printing Metamaterials

- "Complexity for free"?
- Difficult to manufacture with other methods
- But, difficult to model







Functionally Graded Objects

Natural materials

e.g. plant cells, bone, skin

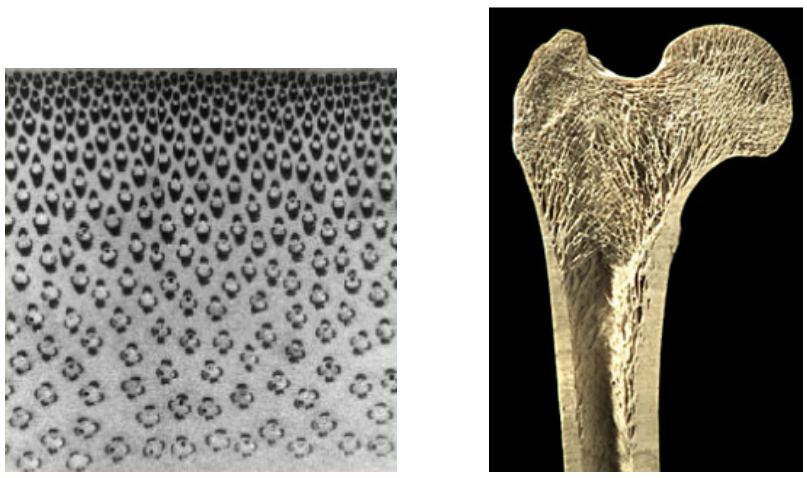


Figure 1: *Left:* Bamboo internal structure [4] *Right:* Human femur internal structure (Photo by Paul Crompton © University of Wales College of Medicine [1])

Artificial materials

Energy absorption, tailored deformation, anisotropic properties

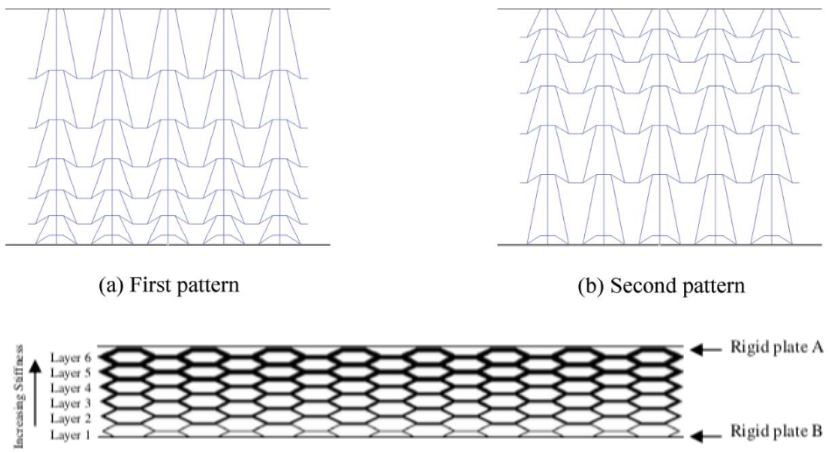


Figure 2: *Top:* [5] *Bottom:* [2]

Functionally Graded Objects

Pros:

- Expanded design space
- More parameters for optimization
- Unique material properties

Cons:

- Harder to manufacture (especially traditionally)
- Harder to design
- Harder to simulate

Auxetics

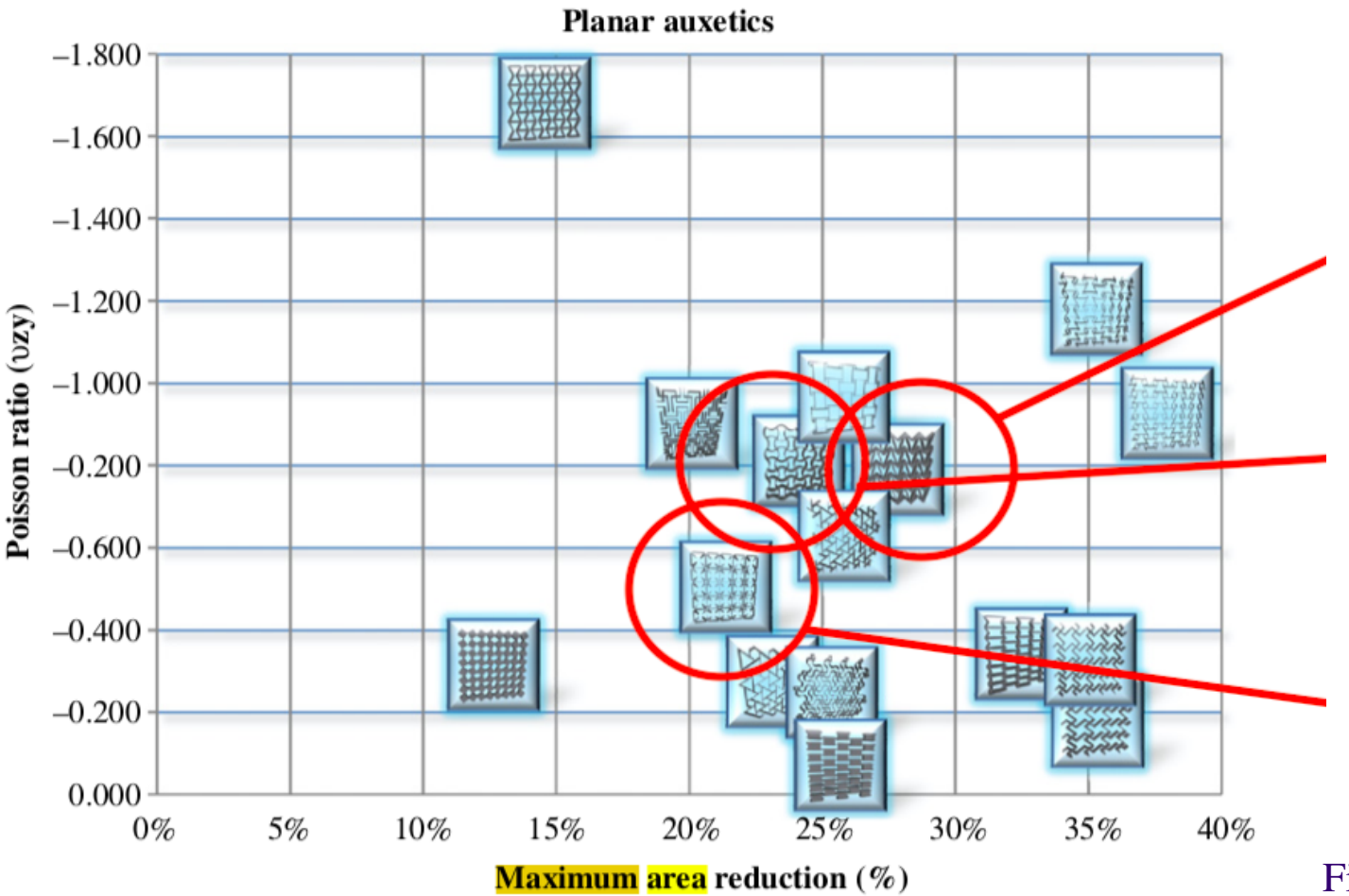


Figure 3: [3]

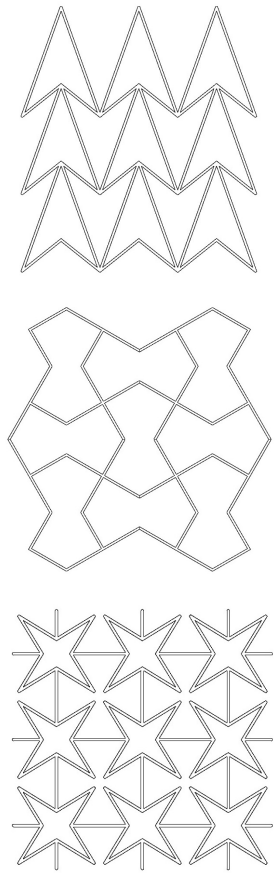
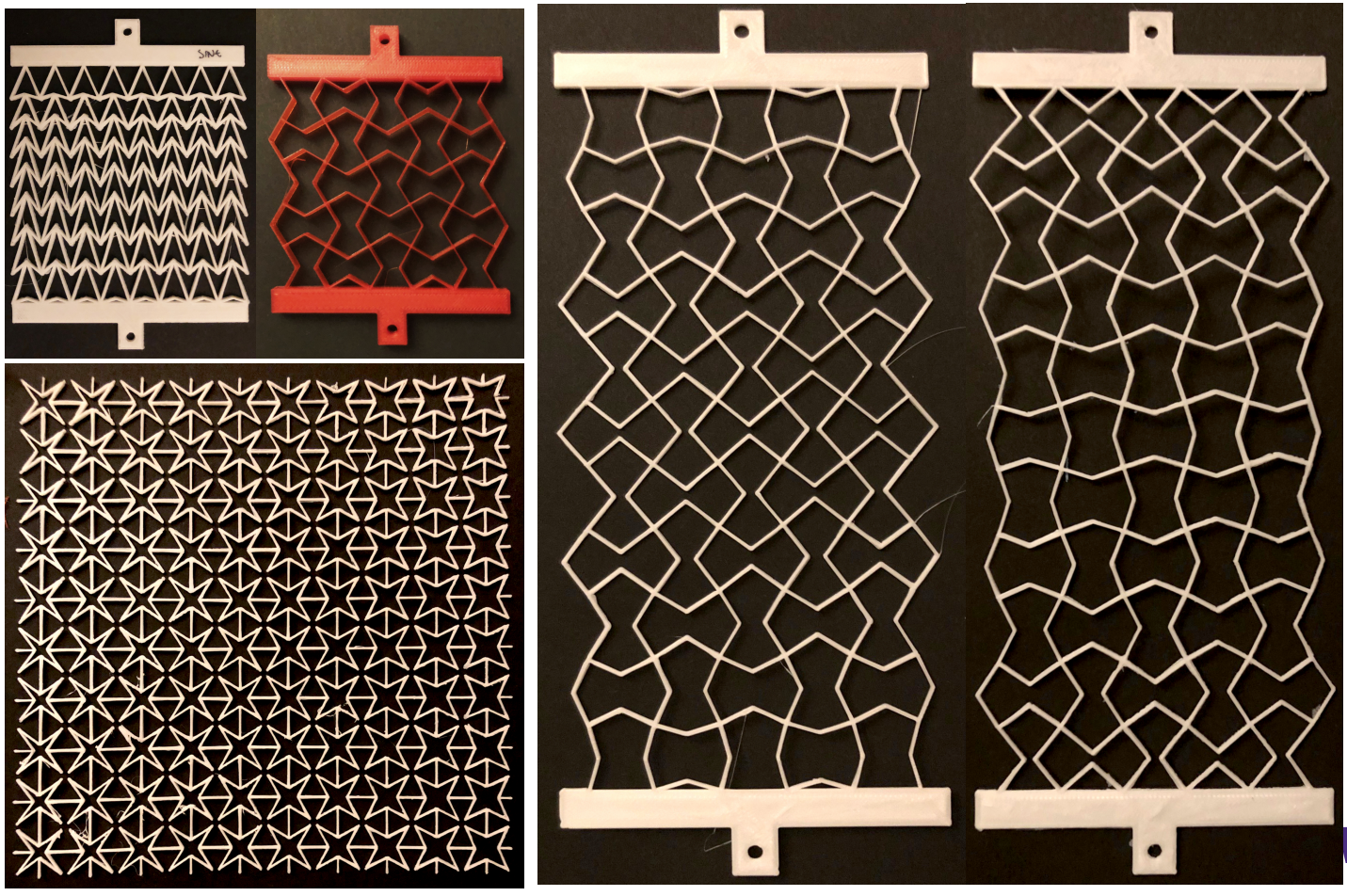


Figure 4: "Arrow", "Bow", and "Star" structures

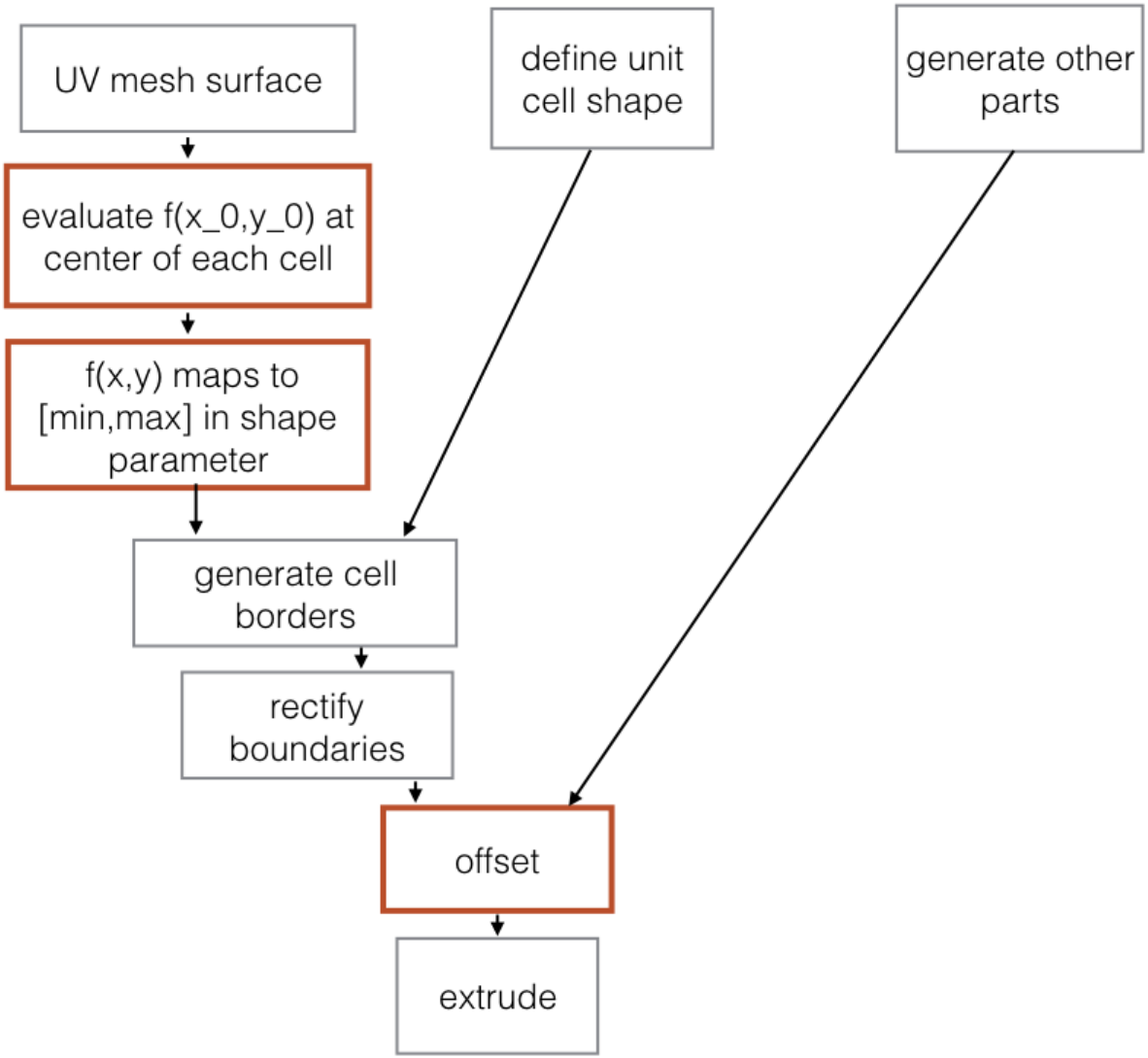
Project

Goal: To develop parametric tools for quickly generating printable graded auxetic (negative Poisson's ratio) structures

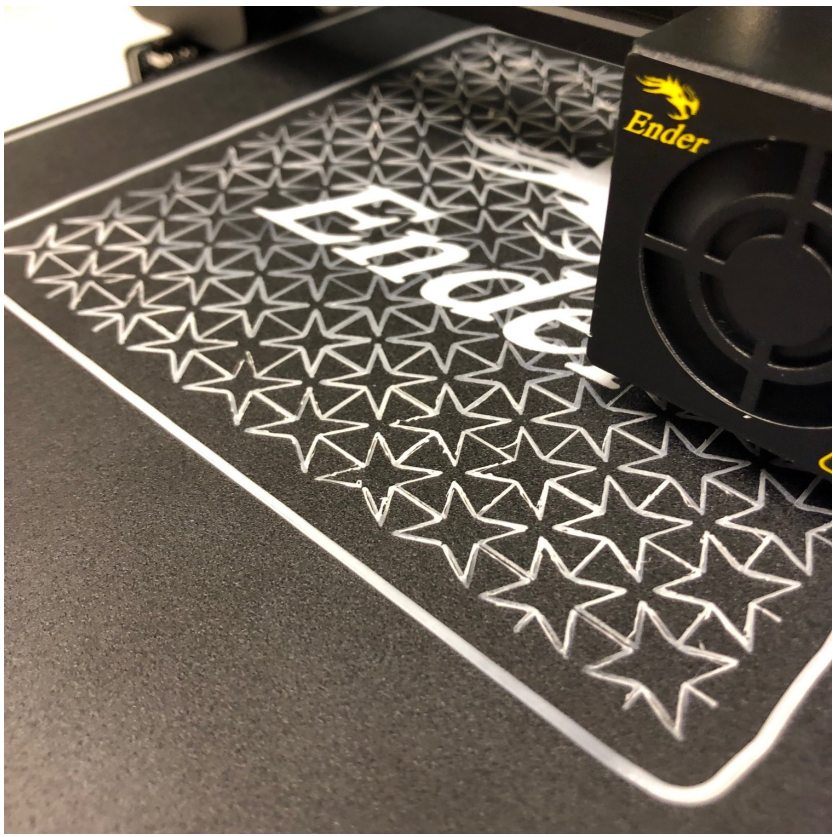


Algorithm: Parametric Generation

- Grasshopper for Rhino 3D: a visual language for parametric solid modeling
- Offsetting with the package Clipper [6]
- This will be on Github soon!



Printing



- Commercial FDM printer: Creality Ender 3
- Magnetic removable print bed
- PLA and NinjaTek Cheetah TPU
- Sliced in Cura
- Layer height .2 mm

An Example

The Model

- 4 x 14 arrow cells, 15 mm in each direction
- $f(x, y) = |\sin(2\pi y)|$
- Min offset 20%, max offset 80%
- $l = .23$ mm (one print bead)
- $h = 5$ mm
- Model generated in 11.8 seconds

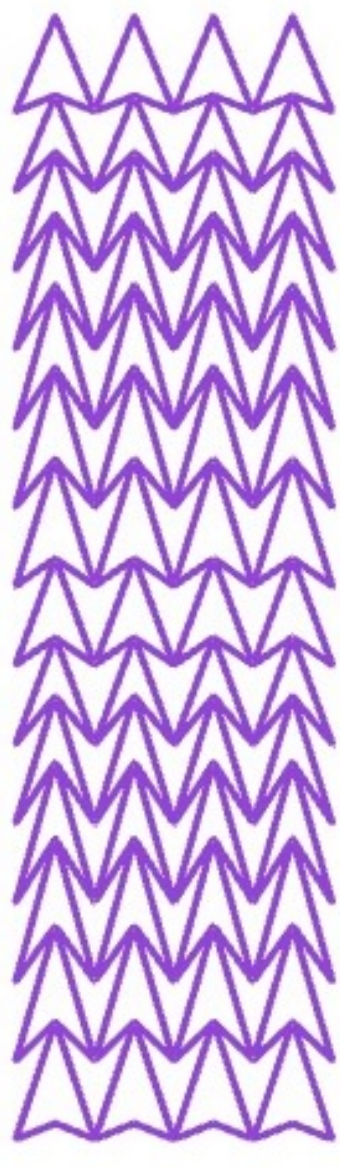


Figure 5: Test part

Simulation

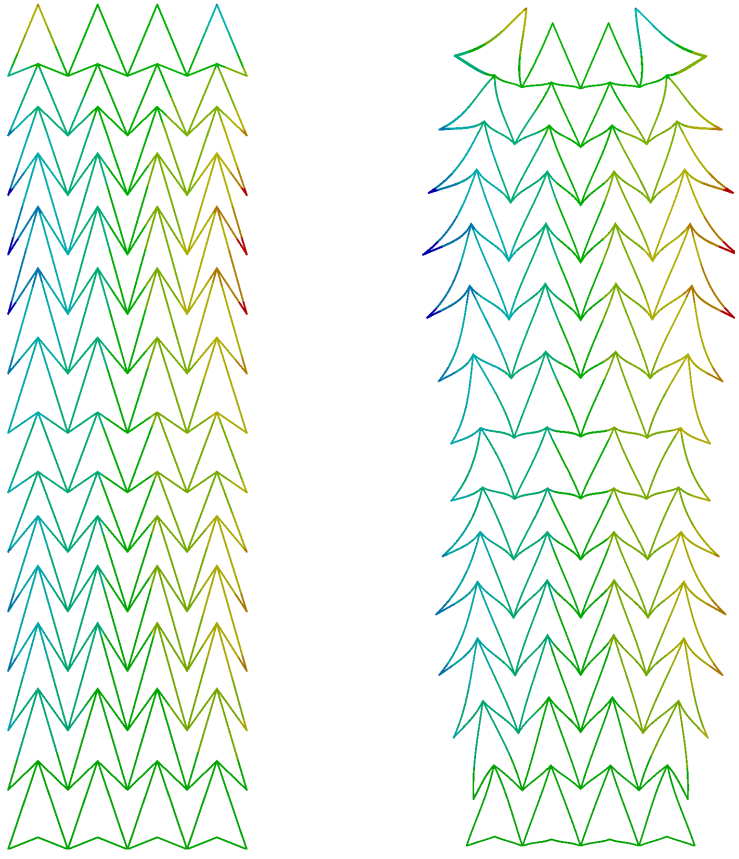
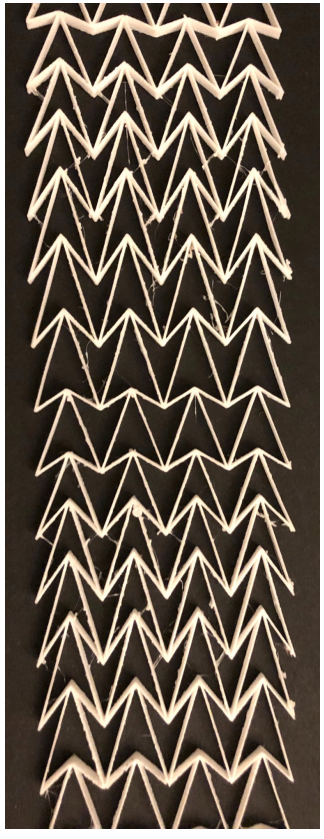
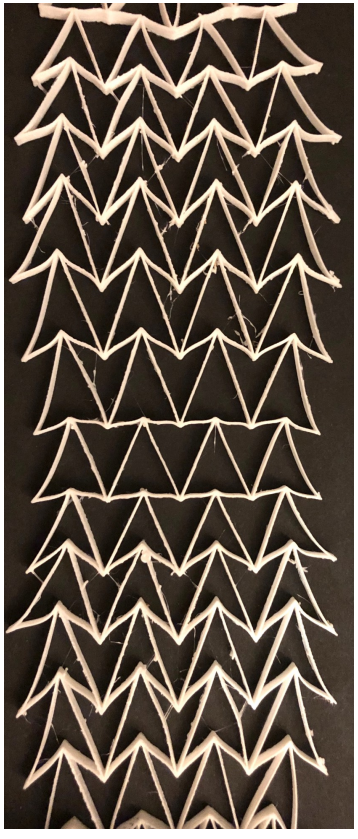


Figure 6: ANSYS ver. 19.2 Academic. Arrow structure with spatial function $|\sin(2\pi y)|$. *Left:* Undeformed *Right:* Under loading in the y direction, pinned in y along the bottom edge.

A Successful Print





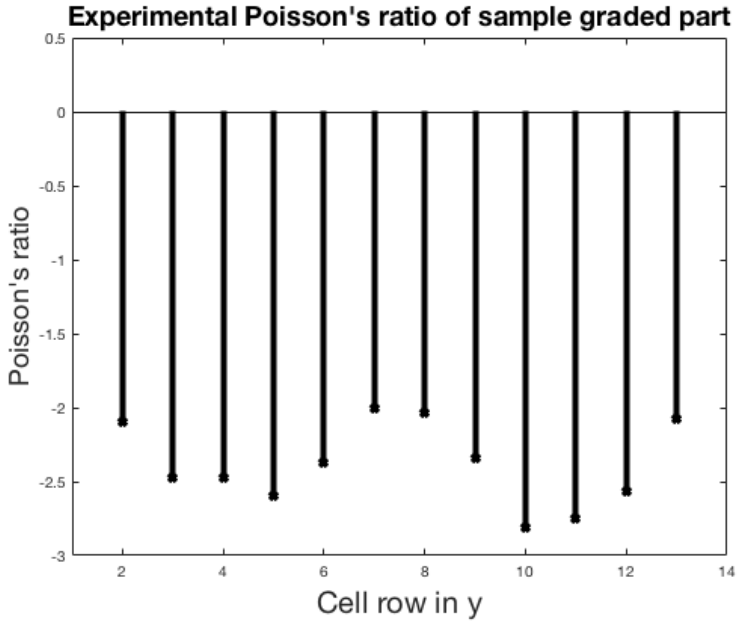


Figure 7: TPU print of the same model. *Left:* Undeformed *Right:* Deformed.

Summary

- A tool for building graded auxetic structures
- Printable models of three 2D auxetic patterns can be generated in ≤ 2 minutes
- Test print agrees with FEA model

Possibilities

- Optimization
- 3D or 2.5D shapes
- Other patterns or more general cellular pattern editing capability

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