Designing and Making Mechanism-Based Metamaterials

USC Viterbi Department of Mechanical Engineering, SHINE 2022

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USC Viterbi School of Engineering

SHINE Summer High School Intensive in Next-Generation Engineering

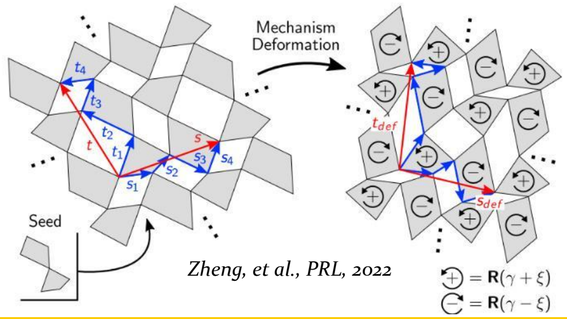
Introduction

Mechanism-based metamaterials are carefully structured materials that consist of stiff and flexible elements, where the stiff elements can deform rigidly about the flexible element in a continuous way. Unlike natural materials, they derive their properties from the design structure rather than the base of the material. These attributes allow researchers to make highly complex structures that can be used for purposes such as emergency shelters, solar cells, soft robots, etc.

Miura-ori

Objective & Impact of Professor's Research

Prof. Plucinsky's research involves creating the fundamental principles of mechanical metamaterials using origami and kirigami as examples. The work done in this lab aims to help other researchers with their interdisciplinary studies by providing the general math theories for such structures.



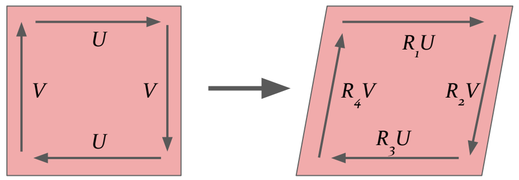
Zheng, et al., PRL, 2022

Methods

Simulating 2D Metamaterials

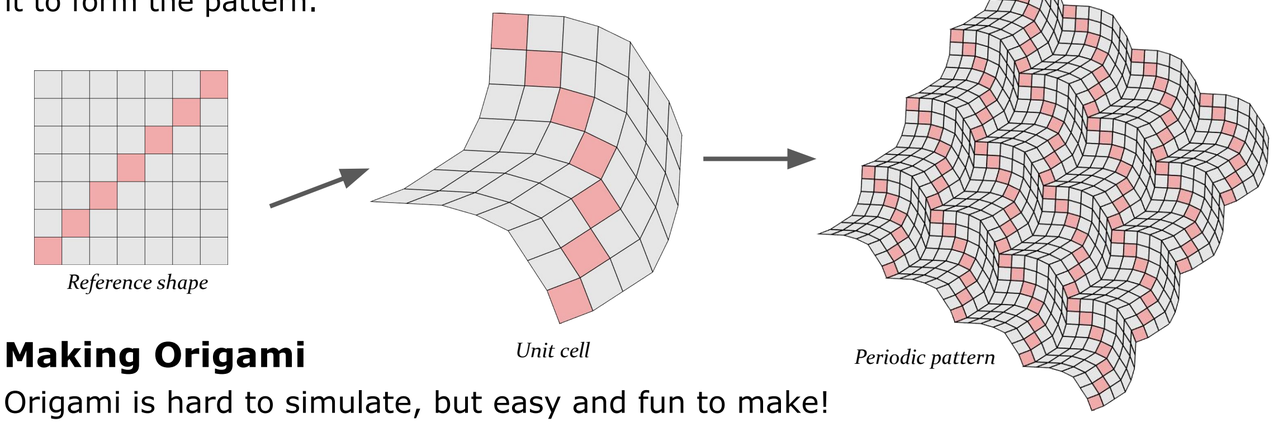
Basic Motif:

Parallelograms are interesting shapes because they can deform into other parallelograms while maintaining their side measures. This property can be used to make periodic patterns, which are an example of mechanical metamaterials.



$$(R_1 - R_3)U + (R_2 - R_4)V = O$$

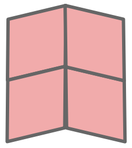
I developed a custom program in MATLAB that generates a periodic pattern based on certain angles of rotation inputted by the user. Starting with a reference shape, the program creates the unit cell of the pattern, then it makes copies of it to form the pattern.



Reference shape *Unit cell* *Periodic pattern*

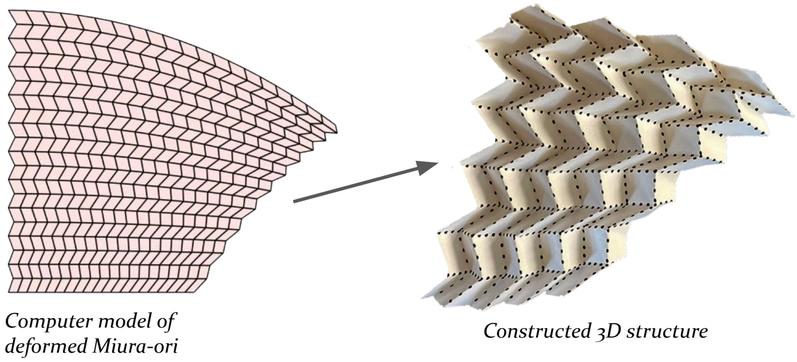
Making Origami

Origami is hard to simulate, but easy and fun to make!



This is a famous fold called the Miura-ori. Its stiff elements are the panels, and its flexible elements are the sides/folds. Note that the panels are parallelograms.

The Miura-ori is foldable and collapsible because the panels are equal parallelograms, but how about patterns where the panels are *almost* parallelograms?



Computer model of deformed Miura-ori *Constructed 3D structure*

After observing the deformed version, it can be concluded that the pattern is foldable but not collapsible. However, it can still be bended into different looking shapes just like the regular Miura-ori.

Next Steps & Advice for Future SHINE Students:

SHINE exposed me to curriculum that's ahead of my grade level, so I plan to use the math concepts I learned to help me through my future high school years. For college, I want to pursue a major in an engineering-related field, so I hope to use this experience to help me with my STEM journey.

Advice to Future Students:

I strongly recommend you to have strong fundamentals in the STEM-related classes you take. It will help you in SHINE even though you may not exactly use the concepts you learned during school.

Acknowledgements

I'd like to sincerely thank Prof. Paul Plucinsky and my mentor Yingchao Peng for having me in their lab and teaching me about the math behind origami. I am also extremely grateful for my parents who supported me throughout my STEM journey. Lastly, I want to thank Dr. Mills, my center mentor Marcus, and the SHINE team for making this opportunity possible.

References:

Zheng, Yue, et al. "Continuum field theory for the deformations of planar kirigami." Physical Review Letters 128.20 (2022): 208003.