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Exploring Programmability of Architected Soft Materials

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ABSTRACT:

Metamaterials are designed to realize exotic physical properties through the geometric arrangement of their underlying structural layout. Traditional mechanical metamaterials achieve functionalities such as a target Poisson ratio or shape transformation through unit-cell optimization, often with spatial heterogeneity. These functionalities are programmed into the layout of the metamaterial in a way that cannot be altered. Although recent efforts have produced means of tuning such properties post-fabrication, they have not demonstrated mechanical reprogrammability analogous to that of digital devices, such as hard disk drives, in which each unit can be written to or read from on the fly. Here we overcome this challenge by using a design framework for a tileable mechanical metamaterial with stable memory at the unit-cell level. Our design comprises an array of physical binary elements (m-bits), analogous to digital bits, with clearly delineated writing and reading phases. Each m-bit can be independently and reversibly switched between two stable states (that is, memory) using magnetic actuation to move between the equilibria of a bistable shell. Under deformation, each state is associated with a distinctly different mechanical response that is fully elastic and can be reversibly cycled until the system is reprogrammed. Encoding a set of binary instructions onto the tiled array yields markedly different mechanical properties; specifically, the stiffness and strength can be made to span over an order of magnitude. We expect that the stable memory and on-demand reprogrammability of mechanical properties in this design paradigm will facilitate the development of advanced forms of mechanical metamaterials.

BIOGRAPHY:

Tian (Tim) Chen is currently a post-doctoral scientist at the École polytechnique fédérale de Lausanne in Switzerland. He is co-advised by Pedro Reis from mechanical engineering and Mark Pauly from computer science. His research is at the intersection of computational design, material science, solid mechanics and advanced manufacturing. In particular, he is interested in the design of architected matter and transformable matter. His studied Engineering Science as an undergraduate from the University of Toronto in Canada, M.Sc. in civil engineering from Delft University of Technology in the Netherlands, and PhD in mechanical engineering from ETH Zurich in Switzerland where he received the ETH Medal in 2018. Institute for Advanced Systems Engineering Breakthrough Award in 2016. He also leads UW's participation in the Advanced Robotics for Manufacturing Institute, a Manufacturing-USA Initiative, and serves in the Scientific Advisory Committee of the Boeing Advanced Research Center.