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Newmark Distinguished Lecture

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Origami Engineering

Abstract: We study the geometric mechanics of origami assemblages and investigate how geometry affects behavior and properties. Understanding origami from a structural standpoint allows for conceptualizing and designing feasible applications across scales and disciplines of engineering. We review the basic mathematical rules of origami and use 3D-printed origami legos to illustrate those concepts. We then present a reduced-order-model, which consists of an improved bar-and-hinge model, to simulate origami assemblages. We explore the stiffness of tubular origami and kirigami structures based on the Miura-ori folding pattern. A unique orientation for zipper coupling of rigidly foldable origami tubes substantially increases stiffness in higher order modes and permits only one flexible motion through which the structure can deploy. We couple compatible origami tubes into a variety of cellular assemblages that enhances mechanical characteristics and geometric versatility, leading to the design of structures and configurational metamaterials that can be deployed, stiffened, and tuned. We have designed, fabricated (using DLW, direct laser writing), and tested (in-situ SEM) this metamaterial at the micron-scale. This resulted not only in the smallest scale origami assembly, but also in a metamaterial with intriguing mechanical properties, such as anisotropy, reversible auxeticity, and large degree of shape recoverability. The presentation concludes with a vision toward the field of origami engineering, including origami robots with distributed actuation, allowing for on-the-fly programmability, and other interdisciplinary applications.

Bio: Professor Paulino is the Margareta E. Augustine Professor of Engineering at Princeton University. His seminal contributions in the area of computational mechanics include the development of methodologies to characterize the deformation and fracture behavior of existing and emerging materials; topology optimization for large-scale multiscale/multiphysics problems; variational methods; deployable and adaptable structures; and origami engineering. Recently, he received the Daniel C. Drucker Medal of ASME (2020), the Raymond D. Mindlin Medal of ASCE (2020), and the Reddy Medal from Mechanics of Advanced Materials and Structures (MAMS 2020), and the Eringen Medal form the Society of Engineering Science (SES 2023). He also received the 2015 Cozzarelli Prize from the National Academy of Sciences, "which recognizes recently published PNAS papers of outstanding scientific excellence and originality." He is a member of the US National Academy of Engineering (NAE), and a former President of SES. More information about his research and professional activities can be found at the following link: http://paulino.princeton.edu/