ME Seminar

The Quest for Mechanical Sentience: Design of Responsive Structures via integration of Topology Optimization, Smart Materials & 4D Printing

Anurag Bhattacharyya, Senior Opto-Mechanical Design Engineer, KLA Corporation, USA

ABSTRACT

Transformative structures have the ability to change their shape, performance and properties which can be explored to develop the next generation of sensors and actuators that are energy efficient and compact. In this talk, I will explore the development of a computational design optimization framework, fabrication using 4D printing and experimental validation of the shape adaptive characteristics of structures that can sense external stimulus and actuate automatically into target shapes. I will present a novel optimization framework for optimal design of structures exhibiting memory characteristics by incorporating shape memory polymers (SMPs). SMPs are a class of memory materials capable of undergoing and recovering applied deformations. A time-dependent adjoint sensitivity formulation implemented through a recursive algorithm is used to calculate the gradients required for the topology optimization algorithm. Multimaterial topology optimization combined with the novel thermo-mechanical programming cycle is used to optimally distribute the active and passive SMP materials within the design domain. This allows us to tailor the response of the structures to design them with specific target displacements, by exploiting the difference in the glass-transition temperatures of the two SMP materials. I extend the computational capabilities by developing a hierarchical design framework and experimental method for design and synthesis of material-based morphing mechanisms capable of achieving complex pre-programmed motion. The optimization framework leveraged five different types of kinematic structures, designed via topology optimization, each capable of generating a single type of motion when exposed to an external stimulus. A genetic algorithm with collision and manufacturing-based constraints was leveraged to optimally distribute the kinematic structures along a geometry to achieve a tailored global motion. By combining active and passive materials, the algorithm can encode the desired movement into the material distribution of the mechanism. I demonstrate this new capability by de novo design of a 4D printed self-tying knot. This method advances a new paradigm in mechanism design that could enable a new generation of material-driven machines that are lightweight, adaptable, responsive, and easily manufacturable by additive manufacturing. The ability of these structures to sense and actuate when exposed to an external stimulus make them an ideal candidate to develop the next generation of energy efficient and multifunctional sensors/actuators.

ABOUT THE SPEAKER

Anurag Bhattacharyya is a senior opto-mechanical design engineer at KLA Corporation where his work is focussed on design and optimization of systems for laser scanning and semiconductor inspection applications. Previously, he worked as a computational design engineer at Lawrence Livermore National Laboratory (LLNL) and Research Scientist at Palo Alto Research Center – SRI International working at the intersection of computational structural design, machine learning, additive manufacturing, and high-performance computing. His specialization is in developing computational design and optimization frameworks for smart materials/nonlinear materials optimized for 3D/4D printing techniques. Anurag obtained his Ph.D. and M.S. degree in Aerospace Engineering from the University of Illinois Urbana Champaign. He received his B.Tech. degree in Mechanical Engineering from the National Institute of Technology, Durgapur, India. In 2013, he was the sole recipient of the CERN summer research fellowship from the Mechanical Engineering department at NIT Durgapur.

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