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Integrating Physical Intelligence with Artificial Intelligence: Autonomous Design and Manufacturing of Emerging Material Systems

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ABSTRACT:

Achieving superior performance in future material systems hinges on optimizing the heterogeneity of materials and structures. However, the design and fabrication of such advanced systems present significant challenges, requiring the integration of knowledge across multiple domains—including materials science, manufacturing, structural mechanics, and design optimization. This talk introduces a paradigm shift toward unifying "physical intelligence" with artificial intelligence (AI) to realize "embodied intelligence" in material systems. By combining data-driven generative design with physics-based modeling and simulation, we enable seamless integration of predictive materials modeling, advanced manufacturing, and design optimization—accelerating the development and deployment of next-generation materials. We will present state-of-the-art design methodologies that leverage statistical inference and AI techniques for the design of nano- and microstructured materials and programmable metamaterials responsive to external stimuli, covering methods such as machine learning, mixed-variable Latent Variable Gaussian Process (LVGP) modeling, Bayesian optimization, differentiable simulation, topology optimization, and generative design. The talk will also highlight recent advances in digital twins for autonomous co-design and manufacturing, using additive manufacturing as an example to showcase how these tools are transforming the landscape of intelligent material systems.

BIOGRAPHY:

Dr. Wei Chen is the Wilson-Cook Professor in Engineering Design and Chair of Department of Mechanical Engineering at Northwestern University. Directing the Integrated DEsign Automation Laboratory (IDEAL- http://ideal.mech.northwestern.edu/), her current research involves the use of statistical inference, AI, and uncertainty quantification techniques for design of emerging materials systems including microstructural materials, metamaterials and programmable materials. She serves as the Design Thrust lead for the newly funded NSF Engineering Research Center (ERC) on Hybrid Autonomous Manufacturing, Moving from Evolution to Revolution (HAMMER), where she works on digital twin systems for concurrent materials and manufacturing process design. Dr. Chen is an elected member of the National Academy of Engineering (NAE) and American Academy of Arts and Sciences (AAA&S). She served as the Editor-in-chief of the ASME Journal of Mechanical Design, the Chair of the ASME Design Engineering Division (DED), and the President of the International Society of Structural and Multidisciplinary Optimization (ISSMO). She currently serves as the chair of the ASME Mechanical Engineering Department Heads Executive Committee (MEDHEC). Dr. Chen is the recipient of the 2025 ASME Barnett-Uzgiris Product Safety Design Award, 2022 Engineering Science Medal from the Society of Engineering Science (SES), ASME Pi Tau Sigma Charles Russ Richards Memorial Award (2021), ASME Design Automation Award (2015), Intelligent Optimal Design Prize (2005), ASME Pi Tau Sigma Gold Medal achievement award (1998), and the NSF Faculty Career Award (1996). She received her Ph.D. in mechanical engineering from the Georgia Institute of Technology in 1995 and her MS in mechanical engineering from the University of Huston in 1992.