VANDERBILT
School *of* Engineering

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

Seminar

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"MEM-MODELS: A NEW HYSTERESIS MODEL CLASS FOR PATH-DEPENDENCY, INTERNAL DAMAGE, & RECOVERY"

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ABSTRACT

Dr. Leon Chua postulated "the missing memristor," a fourth basic circuit element, which he later extended to include memcapacitors and meminductors, all based on nonlinear state-space formulation. After applying mechanical-electrical system analogies, my collaborators and I studied the mechanical counterparts of memristors, memcapacitors, and more, which we used to form a new family of hysteresis models called mem-models. Our work reveals that these models facilitate constitutive modeling, system identification, control, and reduced-order modeling with new physical insights and improved computational efficiency.

Our research on mem-models uncovered new concepts such as the time integral of strain, called strain absement, which augments the traditional concepts of strain and strain rate. This work has shown that strain absement relates to the damage variable in continuum damage mechanics. Mem-models thus deepen the understanding of complex material behaviors and system responses subjected to repetitive dynamic loads. Using new state variables and the hybrid dynamical system framework that we have introduced to mem-models, we have developed robust and efficient numerical solvers for reduced-order modeling.

I present a qualitative Mullins-effect model relevant to soft materials as an example of how mem-models can offer a new thought-provoking means of introducing path-dependency, internal damage, and recovery into a model, while providing both insight and parsimony. A helical fluid inerter, a novel device in earthquake engineering, and a clayey soil specimen under fatigue loading are among applications using real-world data, which are directly contributing to infrastructure renewal.

BIOGRAPHY

Dr. Jin-Song Pei is an Associate Professor in the School of Civil Engineering and Environmental Science at the University of Oklahoma, Norman, Oklahoma. Dr. Pei is also on the graduate faculty in the School of Electrical and Computer Engineering at the University Oklahoma. She received her Ph.D. in Civil Engineering and Engineering Mechanics from Columbia University, while her B.Eng. and M.Eng. degrees in Structural Engineering were obtained from Xi'an Jiaotong University, Xi'an, China and Nanyang Technological University, Singapore, respectively.

Dr. Pei's research interests are multidisciplinary, centering on modeling nonlinear dynamical systems using real world data measurements. She focuses on theoretical development and numerical analysis for mathematical problem formulation, signal processing, nonlinear system identification, and reduced-order modeling. The broad utility of her work is in structural, mechanical, aerospace, and biomechanical engineering to enable damage detection, damage prognosis, control, digital twin, and more. Besides mem-models, Dr. Pei has made a novel contribution to interpretable machine learning (IML) for nonlinear function approximation, and is the sole principal investigator for a new three-year NSF BRITE project.