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MEM-MODELS FOR HYSTERESIS MODELING: THEORETICAL FOUNDATION AND APPLICATIONS

Abstract

Dr. Leon Chua postulated "the missing memristor", a fourth basic circuit element, who also developed the theory of memristive systems. The theory involving memristor devices and memristive systems was extended to include memcapacitors and meminductors, thereby introducing a new model class called "mem-models". This nonlinear state-space model class is the foundation of the present study. By applying the well-known mechanical-electrical system analogies, the mathematics of mem-models is transferred to the setting of engineering mechanics, resulting in mechanical counterparts of memristors, memcapacitors, and more. This transfer is nontrivial, for example, a new concept and state variable called "absement", the time integral of deformation, emerges. We identify some recent examples of "mem-dashpots" and "mem-springs". In addition to a "zero-crossing" condition, we highlight the role played by discontinuities in the model and/or the excitation, the combination of which enables mem-models to produce numerous hysteresis patterns. We derive new properties and develop new modeling techniques so that this new family of hysteresis models can facilitate system identification and control, deepen the understanding and possibly unify the modeling of hysteresis (Pei et al. 2015, Pei et al. 2017, Pei 2018). A partial model for concrete, and qualitative models for shape memory alloy (SMA), rubber, and the Mullins effect are presented first as application examples to show how mem-models put forth a new thought-provoking means of introducing path-dependency, internal damage, and recovery into the modeling. Finally, mem-models for a helical fluid inerter, a novel dynamic device that displays challenging hysteresis responses, are presented. We again reveal how mem-models can be made to capture subtle and complex physical behaviors, while staying insightful and parsimonious.

Tutti gli interessati sono invitati a partecipare.

Prof. Walter Lacarbonara

Roma, 8 Ottobre 2019

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Short Bio

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 has years of practical engineering and development experience in the United States of America, Singapore and China. In particular, she practiced at Weidlinger Associates, Inc., Cambridge, MA.

Dr. Pei received the NASA JPL Faculty Research Program award in 2016 and 2017 (twice) to work with Group 352G (Dynamics Environments) on data-driven pyroshock response prediction, and a Center for Academic Partnerships (CAP) award to work with Group 347D (Mobility and Robotic Systems) on improving the modeling fidelity of complex aerospace systems with mem-models from December 2018 to January 2019. Dr. Pei just visited Los Alamos National Laboratory (LANL) to work at Engineering Institute for the second time. From January to June 2018, Dr. Pei was a visiting professor at the Institute of Structural Engineering of ETH Zürich engaging in both teaching and research. Dr. Pei held a visiting professorship at Eindhoven University of Technology (TU/e), Netherlands, under a Netherlands Organisation for Scientific Research (NWO) travel grant from August to September 2019. In October 2019, Dr. Pei will be visiting Professor Walter Lacarbonara at Sapienza University of Rome, Italy. Dr. Pei's research centers on theoretical development and numerical analysis for data processing and nonlinear system identification. Modeling nonlinear dynamical systems is inherently challenging; however, it is necessary in that it has broad utility in many engineering disciplines.