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Using Self-Excited Template Dynamics and Root-Finding Algorithms for Sensor Design

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ABSTRACT:

I describe a new approach to dynamic sensor design that characterizes the steady-state sensor behavior in terms of a mapping onto a subset of degrees of freedom of a template nonlinear dynamical system with self-excited dynamics. The mapping is computed using a root-finding algorithm that can be made insensitive to the use of unmodeled actuators to drive the sensor dynamics. The sensor gain, as captured by the sensitivity of the components of the mapping to a parameter of interest, may be tuned by modifying parameters of the template system, without any changes to the sensor itself. An example application to mass sensing using a single, forced, linear, mass-spring-damper oscillator illustrates the general approach. The results show that the root-finding algorithm may be initialized without knowledge of the system damping or the properties of the unmodeled actuator and converges rapidly over a range of parameter values.

BIOGRAPHY:

Since January 2024, Harry Dankowicz is Professor and Chair of Mechanical Engineering in the A. James Clark School of Engineering at the University of Maryland, College Park. He graduated from KTH Royal Institute of Technology in Stockholm, Sweden, with an M.Sc. in Engineering Physics in 1991 and, subsequently, from Cornell University with a Ph.D. in Theoretical and Applied Mechanics in 1995. Following a post-doctoral and research associate appointment at KTH between 1995 and 1999, he joined the Department of Engineering Science and Mechanics at Virginia Polytechnic Institute and State University, where he remained until 2005 when he became a faculty member in the Department of Mechanical Science and Engineering at the University of Illinois at Urbana-Champaign. Between 2016 and 2021, he served as Associate Dean for Graduate, Professional and Online Programs in The Grainger College of Engineering. Starting in May 2021 and through December 2023, he served as Program Director for the Dynamics, Control and System Diagnostics Program in the Division of Civil, Mechanical, and Manufacturing Innovation at the National Science Foundation. Dankowicz is a Fellow of the ASME and a recipient of a PECASE award from the US National Science Foundation and the Fred Merryfield Design Award and Archie Higdon Distinguished Educator Award from the ASEE. He conducts dynamical systems research at the intersection of engineering, math and physics. This work involves studying a wide range of complex systems that are governed by differential equations and learning the behavior of those systems through theory and experiments. His research efforts further seek to make original and substantial contributions to the development and design of existing or novel devices or methodologies that capitalize on system nonlinearities for improved system understanding and performance. He is the lead developer of the Matlab-based COCO package for bifurcation analysis and design optimization and author of textbooks on multibody mechanics and visualization, chaotic dynamics in Hamiltonian systems, and parameter continuation techniques.