A Bayesian Experimental Design Approach to Structural Health Monitoring With Specific Application to Ultrasonic Interrogation of Structures

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Abstract
This presentation introduces a new approach for approaching structural health monitoring (SHM) applications. Starting from a general formulation of Bayes risk, we derive a global optimality criterion within a detection theory framework. The optimal design configuration is then established as the one that minimizes the total computed Bayes Risk (or loss) for the application. While the approach is suitable for many sensing/actuation SHM processes, we focus on the example of active sensing using guided ultrasonic waves by implementing an appropriate general statistical model of the wave propagation and feature extraction process. This example implements both pulse-echo and pitch-catch actuation schemes and takes into account line-of-site visibility and non-uniform damage probabilities over the monitored structure. The design space considers the optimal placement and selection of transducers. We provide a few actuator/sensor placement test problems (within the separate problems of detection and localization) and discuss the optimal solutions generated by the algorithm. Such a scheme allows for proper uncertainty quantification in the design and application process of SHM solutions.

Biography

Michael Todd received his B.S.E. (1992), M.S. (1993), and Ph.D. (1996) from Duke University's Department of Mechanical Engineering and Materials Science, where he was an NSF Graduate Research Fellow. In 1996, he began as an A.S.E.E. post-doctoral fellow, then a staff research engineer (1998), and finally Section Head (2000) at the United States Naval Research Laboratory in the Fiber Optic Smart Structures Section. He joined the Structural Engineering Department at the University of California San Diego in 2003, where he currently serves as Professor of Structural Engineering. To date, he has published over 100 journal papers, five book chapters, over 320 conference papers and proceedings, and has 4 patents. His main research areas are in applying nonlinear time series techniques (such as chaotic interrogation) to structural health monitoring problems, stochastic modeling/uncertainty propagation for structural health monitoring applications, building UAV-enabled RFID sensing systems for structural assessment, developing real-time shape reconstruction strategies for highly flexible structural systems, designing and testing fiber optic measurement systems, and developing noise propagation models for fiber optic measurement systems. Prof. Todd won the 1999 Alan Berman NRL Publication Award, the 2003 and 2004 NRL Patent Award, was a 2004-2005 UC San Diego Hellman Fellow, was an invited speaker at the 2003 National Academy of Engineering Japan-America Frontiers of Engineering Symposium where he was runner-up for the Galbraith Distinguished Lectureship, was nominated for the 2005 SEM Durelli Award, was named to 2005 Academic Keys 'Who's Who in Engineering Education,' was an invited speaker for the 2005 SOM National Building Science and Design Research Symposium in New York, and was a 2004 William J. Von Leibig Center for Entrepreneurism and Technology Advancement fellowship winner. He won the 2005 Structural Health Monitoring Person-of-the-Year Award, presented at Stanford University in September 2005, he was named a 2009 Benjamin F. Meaker Visiting Fellow at the University of Bristol (UK), and he won the 2016 D. J. DeMichele Award in Dynamics from the Society of Experimental Mechanics. He serves as the Managing Editor of *Structural Health Monitoring: An International Journal*.