SHM Short Course

Structural Health Monitoring Using Statistical Pattern Recognition

A 2-Day Short Course for Aerospace, Civil and Mechanical Engineers

The University of Tokyo, Tokyo, Japan, December 3-4, 2010
Offered at the same venue after the APWSHM2010
(http://www.smart.k.u-tokyo.ac.jp/APWSHM2010/)

Structural Health Monitoring Using Statistical Pattern Recognition will introduce engineers to the most recently developed techniques for detection and location of damage in structures by changes in their measured dynamic properties, in addition to the historical motivation and development of the methods. The course will cover the theory, application, and computerized implementation of this technology. Many **real-world** examples and results will be presented from the fields of aerospace, civil, and mechanical engineering. The application of techniques involving **statistical pattern recognition** will be emphasized.

Course Goals

Upon completion of this course, attendees will be able to:

- Describe structural health monitoring as a problem in statistical pattern recognition
- Describe and classify the primary methods of structural health monitoring, with their associated advantages and disadvantages
- Describe the historical and current real-world applications of damage identification in the aerospace, civil, and mechanical engineering fields
- Summarize current an emerging sensing technologies being used for structural health monitoring
- Discuss the primary practical implementation issues

Course Outline

See the following agenda.

Course Instructors

Dr. Charles Farrar, Los Alamos National Laboratory
Prof. Michael Todd, University of California – San Diego
Dr. Gyuhae Park, Los Alamos National Laboratory

SHM Short Course (12/3-4) Registration Fee

	Early-bird Registration before 9/30	Normal Registration 10/1-11/22	Late Registration on and after 11/23
REGULAR	¥22,000	¥25,000	¥27,000
STUDENT	¥12,000	¥15,000	¥17,000

Payment

Please pay the SHM Short Course (12/3-4) Registration Fee along with 3rd APWSHM 2010 (11/30-12/2) Registration Fee using the same Registration Form.

STRUCTURAL HEALTH MONITORING USING STATISTICAL PATTERN RECOGNITION
The University of Tokyo

Day 1		Day 2	
Time	**Lecture Topic**	**Time**	**Lecture Topic**
09:00-10:30	**1. Introduction (Farrar)** -Motivation for SHM -NDE vs SHM -Statistical pattern recognition paradigm -Fundamental Axioms -Operational evaluation	09:00-10:00	**8. Damage Sensitive Features I (Farrar)** -Feature selection criteria -Summary of features reported in the literature -Basic statistics - Waveform/Image Comparisons
10:30-11:30	**2. Data Acquisition I (Todd)** - Sensor network components - Sensor performance metrics - Signal conditioning issues - Sensor network paradigms - Sensor Fusion - Excitation	10:00-11:00	**9. Damage Sensitive Features II (Todd)** -Physical model parameters -Data-Based model parameters -Residual errors from model predictions
11:30-11:45	**Break**	**11:00-11:15**	**Break**
11:45-13:00	**3. Data Acquisition II (Todd)** - Aerospace Sensors (Accels, Strain Gages, Fiber Optic, PZT, Acoustic) - Telemetry/Recording - Power (Energy Harvesting) - Sensor/Excitation optimization - Emerging Sensing Technologies	11:45-13:00	**10. Statistical Modeling: Supervised and Unsupervised Learning Methods (Farrar)** -Hypothesis Testing -Statistical Process Control -Machine Learning -Regression Analysis
13:00-14:00	**Lunch**	**13:00-14:00**	**Lunch**
14:00-15:00	**4. Embedded Sensing: Piezoelectric Active sensing (Park)** - Introduction to Piezoelectric Materials - Impedance Methods - High frequency response functions - Active sensors for Lamb waves - Integrated SHM with Active sensors - Sensor Self-diagnostics	14:00-15:00	**11. Optimization Procedures (Todd)** -Sensor Optimization -Input Optimization for active sensing -Bayesian risk analysis
15:00-16:00	**5. Embedded Sensing: Guided Wave Propagation (Park)** -Lamb wave theory -Phase & group velocity -Application to delamination detection on composite structure- -Application to crack detection in metallic structure	15:00-16:00	**12. Data Normalization (Farrar)** -Environmental/ operational effects on SHM -Modeling environmental effects -Look-up table technique -Machine learning approaches -Experimental design
16:00-16:15	**Break**	**16:00-16:15**	**Break**
16:15-17:00	**6. Embedded Sensing: Acoustic Emissions (Park)** -Sensing systems -Data Analysis -Performance comparison and discussion -Applications to aerospace structures	16:15-17:30	**13. Aerospace Examples (Todd)** - Usage Monitoring - Rotorcraft HUMS systems - Shuttle Modal Inspection Program - Composite fuel tanks
17:00-18:00	**7. Introduction to Statistical Inference (Farrar)** -Review of basic statistics -The need for statistical models in SHM -Supervised vs unsupervised learning -Group classification -Regression modeling -Outlier analysis -Monte Carlo/Bootstrap methods	17:30-18:15	**14 Software Demonstration (Park)** - Software overview - HOPS - SHMTools/ mFUSE - Validation data **15. Closing Remarks (Farrar)** - Fundamental Axioms of SHM - Other sources of information - Course Survey

Course Instructors

Charles R. (Chuck) Farrar, Ph. D., PE (farrar@la-dynamics.com)

Chuck Farrar is the President of Los Alamos Dynamics. Chuck Farrar has 27 years experience as a technical staff member, project leader, and team leader at Los Alamos National Laboratory. He is currently the director of The Engineering Institute at Los Alamos National Laboratory. While at Los Alamos, he earned a Ph.D. in civil engineering from the University of New Mexico in 1988. The first ten years of his career at LANL focused on performing experimental and analytical structural dynamics studies for a wide variety of systems including nuclear power plant structures subject to seismic loading, and weapons components subject to various portions of their stockpile-to-target loading environments. Currently, his research interests focus on developing integrated hardware and software solutions to structural health monitoring problems and the development of damage prognosis technology. The results of this research have been documented in over 300 refereed journal articles, book chapters, conference papers, Los Alamos Reports and numerous keynote lectures at international conferences. In 2000 he founded the Los Alamos Dynamics Summer School. His work has recently been recognized at Los Alamos through his reception of the inaugural Los Alamos Fellows Prize for Technical Leadership and by the Structural Health Monitoring community through the reception of the inaugural Lifetime Achievement Award in Structural Health Monitoring. He is currently working jointly with engineering faculty at University of California, San Diego to develop the Los Alamos/UCSD Engineering Institute with a research focus on Damage Prognosis. This initiative is also developing a formal, degree-granting educational program in the closely related areas of validated simulations and structural health monitoring. Additional professional activities include current appointments to associated editor positions for the *Int. Journal of Structural Health Monitoring* and *Earthquake Engineering and Structural Dynamics*, and the development of this short course that has been offered more than 20 times to industry and government agencies in Asia, Australia, Europe and the U.S. In January of 2007 he was elected to Fellow of the American Society of Mechanical Engineers.

Gyuhae Park, Ph. D. (gpark@lanl.gov)

Gyuhae Park received his Ph.D. in Mechanical Engineering from Virginia Tech in 2000. He is currently a technical staff member at Los Alamos National Laboratory. His prior appointment includes Research Scientist at Virginia Tech, where he served as a PI of the support from National Science Foundation, NASA, and Honeywell Space Systems. His recent research focuses on applications of impedance-based methods and Lamb wave propagations for structural health monitoring (SHM), active sensor self-diagnostics, and self-repairing structural systems with an emphasis on the use of active materials. He is also interested in the development of energy harvesting and wireless energy delivery systems, which can provide the required electrical power for wireless SHM sensing system. Part of his research also concerned with integrating sensing hardware directly with data-interrogation software and developing integrated, multi-scale diagnostics systems to result in more efficient SHM solutions. He has published more than 47 referred journal articles, 4 book chapters, and more than 130 conference proceedings. He is currently serving as an associate

editor for the Journal of Intelligent Material Systems and Structures. Finally, he received the Structural Health Monitoring Person of the Year Award at the 2007 International Workshop on Structural Health Monitoring that was held at Stanford University.

Michael Todd, Ph. D. (mdt@ucsd.edu)

Mike 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 Associate Professor. To date, he has published 40 journal papers, two book chapters, over 120 conference papers and proceedings, and has 4 patents. His main research areas are in applying nonlinear time series techniques (such as chaotic interrogation) to vibration-based structural health monitoring, 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. With partners at Los Alamos National Laboratory, he helped create the country's first graduate degree program in structural health monitoring, damage prognosis, and validated simulations at UCSD, and he serves as Campus Director of the subsequent Engineering Institute. He has won the 1999 Alan Berman NRL Publication Award, the 2003 and 2004 NRL Patent Award, was a 2004-2005 UCSD 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 also serves on the editorial board of *Structural Health Monitoring: An International Journal.*