Engineering Institute

UCSD Jacobs | School of Engineering — Los Alamos NATIONAL LABORATORY

this issue

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The Engineering Institute

The Engineering Institute (EI) is a collaboration between LANL and the University of California at San Diego (UCSD) Jacobs School of Engineering whose mission is to develop a comprehensive approach for 1) conducting mission-driven, multidisciplinary engineering research and 2) recruiting, revitalization and retention of the current and future staff necessary to support LANL's national security missions.

The components of the Engineering Institute are 1) the Los Alamos Dynamic Summer School 2) a joint LANL/UCSD degree program, 3) joint LANL/UCSD research projects, 4) annual workshops, and 5) industry short courses.

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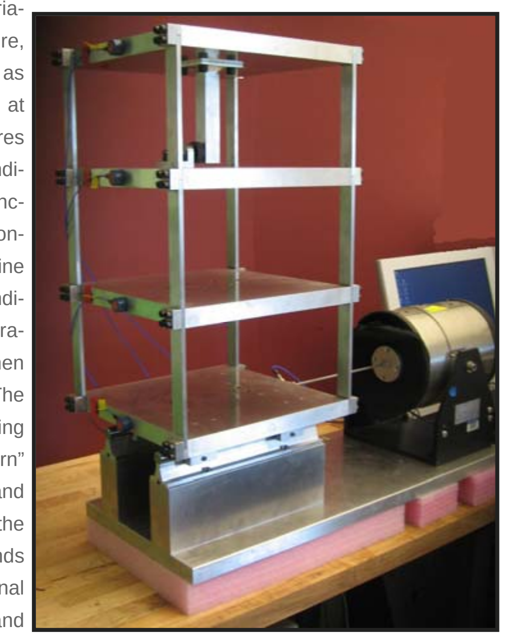
Structural Damage Identification under Varying Operational and Environmental Conditions

Real-world structures are subjected to operational and environmental condition changes that impose difficulties for detecting and identifying structural damage. In fact, separating changes in sensor readings caused by damage from those caused by varying operational and environmental conditions is one of the biggest challenges for transitioning structural health monitoring (SHM) technology from research to practice.

Currently, there are two well-known approaches to separate changes in damage-sensitive features caused by changing operational and environmental conditions. The first approach consists of measuring the parameters related to operational and environmental variations such as live loads, temperature, wind speed, and/or moisture levels, as well as the structural response at different locations. Then, the features corresponding to the baseline condition can be parameterized as a function of these operational and environmental conditions. Herein baseline condition refers to those state conditions acquired under varying operational and environmental effects when the structure is undamaged. The second approach consists of applying machine learning algorithms to "learn" the influence of the operational and environmental conditions from the response data. This approach intends to eschew the measure of operational and environmental variations and pave the way for data-based models applicable to systems of arbitrary complexity.



Several machine learning algorithms have been tested, such as the ones based on Mahalanobis square distance (MSD), auto-associative neural network, factor analysis, singular value decomposition, and principal component analysis. In particular, the MSD-based algorithm has an advance because under certain circumstances, the MSD values from the baseline condition follow a chi-square distribution that might be used to establish confidence intervals for feature classification.

Additionally, in the feature extraction process, a novel algorithm has been proposed for feature extraction in structures under varying operational and environmental conditions. It uses the state-space reconstruction to infer the geometrical structure of a deterministic dynamical system from observed response time series at multiple locations. This algorithm uses a multivariate auto-regressive model of the baseline condition to predict the state space, where the model encodes the embedding vectors rather than scalar time series.

The applicability of those algorithms has essentially been demonstrated in a base-excited three-story frame structure tested in laboratory environment to obtain standard data sets from an array of sensors under several structural state conditions. It should be emphasized that this structure is not a scale model of any prototype system, but rather it was designed as standard test bed for SHM validation studies. Tests were performed with varying stiffness and mass conditions with the assumption that these sources of variability are representative of changing operational and environmental conditions (e.g. changing mass might represent varying live loads and changing temperature will influence stiffness properties on a structure). Damage is simulated through nonlinear effects introduced by a bumper mechanism that induces a repetitive, impact-type nonlinearity. This mechanism intends to simulate, for instance, the cracks that open and close under dynamic loads or loose connections that rattle.

Finally, notice that most of these algorithms have been incorporated into a software package called SHMTools, which is regarded as the beginning of a larger effort to collect and archive proven approaches to support the SHM process. A modular function design and a set of standardized parameter formats make it easy to assemble and test customized SHM process.

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EI Annual Workshops

EI hosts an annual workshop with focus on the broad areas of predictive modeling, advanced sensing and information technology. The reports from these workshops are available on our website. We also work with other LANL organizations to co-host workshops. For more information, please contact Chuck Farrar at farrar@lanl.gov, 663-5330.

Events

- **Los Alamos Dynamic Summer School Lecture Series**
  - **Tutorials**
    - July 6 & 7th: **Introduction to Controls**, Matt Bement (XCP-1)
    - July 13-16th, 26th: **Model Validation**, Francois Hemez (XCP-1)
    - July 19-21st: **Nonlinear Dynamics**, Doug Adams (Purdue University)
  - **Guest Lectures**
    - July 1st: **Engineering Issues for Orthopedic Surgery,** Michael Meneghini (U. of Connecticut)
    - July 6th: **Predictive Process Dynamics,** Matt Bement (XCP-1)
    - July 8th: **Acoustic Control of Rocket Payload**, Kevin Farinholt (AET-1)
    - July 13th: **Aerospace Structural Dynamics**, Nick Lieven (U. of Bristol, UK)
    - July 15th**: Piping Vibrations**, Klaus Kerkhof (U. of Stuttgart, Germany)
    - July 21st: **Wireless Sensing Systems for Health Monitoring and Control of Civil Structures,** Jerry Lynch (University of Michigan, Ann Arbor)
    - July 22nd: **Reconfigurable Systems for Automated and Remote Non-Destructive Evaluations,,** S. Gareth Pierce (University of Strathclyde, UK)
    - July 27, 29th: **Satellite Dynamics: Alexis and Forte Satellite**, Tom Butler (INST-OFF)

These lectures are open to all LANL staff and students. Staff members can use the tutorials and guest lectures to meet the continuing education credit requirements needed to maintain a professional engineer's license. We will issue certificates of attendance to staff for the purpose of documenting attendance in order to verify PE continuing education requirements. All lectures will be held in Suite 100 (IMMS) or Suite 300 in the Research Park building. For more information, contact Kathie Womack, 663-5206.

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UCSD Course Sequences

Signal Processing
Digital Signal Processing
Array Processing
Detection Theory
Parameter Estimation
Stochastic Processes
Sensor Networks
Random Processes

Embedded Systems
Introduction to Embedded Systems
Software for Embedded Systems
Validation and Testing of Embedded Systems
Design Automation and Prototyping for Embedded Systems

Parallel Computing
Large Scale Computing
Parallel Computation

Controls
Linear Systems Theory
Nonlinear Control Systems
Approx Identification and Control
Applied Structural Control

NDE/SHM
Experimental Mechanics and NDE
Structural Health Monitoring

Structural Dynamics
Structural Dynamics
Advanced Structural Dynamics
Nonlinear Mechanical Vibration
Random Vibrations
Wave Propagation in Elastic Media
Wave Propagation in Continuous Structural Elements

Applied Mechanics
Theory of Elasticity
Theory of Plasticity/ Viscoelasticity
Structural Stability
Solid Mechanics for Structural and Aerospace Engineering
Mechanics of Laminated Composite Structures

Computational Mechanics
Numerical Methods
Finite Element Analysis I & II
Computational Fluid Dynamics
Model Verification and Validation

If you are interested in having any of these classes or a class sequences offered at LANL, please contact Kathie Womack (Womack@lanl.gov, 663-5206)

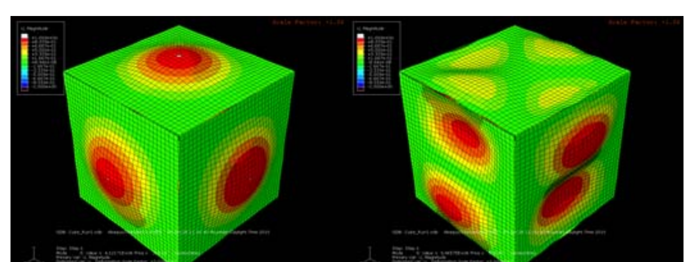
2010 Los Alamos Dynamic Summer School

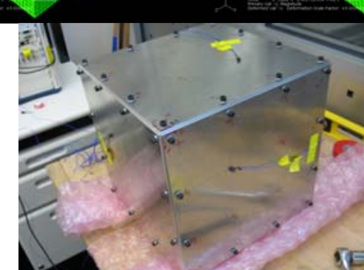
A 9-week program of Los Alamos Dynamic Summer school (LADSS) has started on June 7th. The Los Alamos Dynamics Summer School (LADSS) was created in 2000 to be an innovative, proactive approach to increase the number of excellent U.S. citizen students attending graduate school in engineering and to introduce them to LANL as a potential future employer. The LADSS is designed not only to benefit the students through their educational experience, but also to make the students aware of career possibilities in defense-related industries after they have completed their graduate studies.

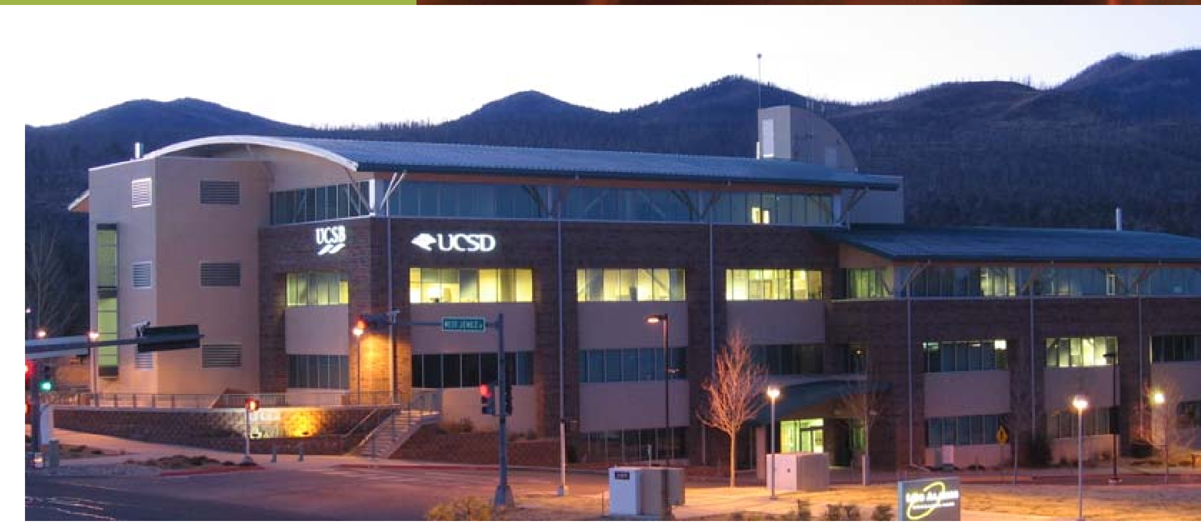
The selection of the LADSS students nationwide is a very competitive process as the mean of the GPA of the students is higher than 3.8/4.0. The summer school activities include four basic elements: 1) lectures on fundamental engineering topics, 2) a distinguished lecturer series on “cutting edge research”, 3) a mini-project consisting of a modal test, finite element analysis, model correlation and validation of a small test structure 4) a research project related to the LANL’s engineering technology focus, which results in a conference paper and presentation. The lectures and tutorials for LADSS are open to all LANL staff and students.

The schedule is posted in the EI website and provided in pg.4 of this newsletter. Staff members can use the guest lectures to meet the continuing education credit requirements needed to maintain a professional engineer’s license.

This year, there are 15 students participating in the summer school, each involved in one of the following research efforts, i) Vibration testing and SHM of wind turbine blades, ii) Dynamic characterization of satellite components, iii) Performance comparison of fiber optic sensing, iv) Development of polymer chips in medical diagnostics, and iv) Periprosthetic fracture vibration testing.







Student’s Highlight— Eloi Figueiredo

Eloi Figueiredo is a PhD student in the Department of Civil Engineering of the University of Porto (FEUP), Portugal, that has collaborated with the Engineering Institute (EI) for three years, under the supervision of Dr. Charles R. Farrar (INST-OFF) and Prof. Joaquim A. Figueiras (FEUP). He completed his B.S. and M.S. degrees in Civil and Structural Engineering at FEUP. In 2007, he received the “Prof. Doutor Joaquim Sarmento Award” to distinguish the best Master’s student that finished in the academic year of 2006-2007.

During his Master’s study, he installed permanent SHM systems on bridges in Portugal, which allowed him to gain sensitivity to some SHM challenges, such as the effects of the operational and environmental variations on the structural responses. Therefore, in 2007, he started the PhD in order to apply and develop data-driven statistical models to remove changes in the extracted features caused by damage from changes caused by operational and environmental variability. His dissertation work and some of data are publically available in the EI website.

Eloi also participated in developing the EI’s SHM software package, “SHMTools”, which will be released in September 2010. Besides his work, Eloi enjoys travelling and good foods.

A new postdoc at EI—Christopher Stull

Christopher Stull joined the Engineering Institute in May as a postdoctoral research associate after earning his Ph.D. in structural engineering at Cornell University. Working with Dr. Christopher Earls, Chris's dissertation focused on a model-based approach to structural health monitoring, wherein inverse problem-solving strategies are employed to infer damage within structural systems. More recently, his efforts have focused on contextualizing these problems within a probabilistic framework through the application of techniques from Bayesian inference. Branching from his work in SHM, Chris’s efforts at LANL will include: (1)supporting the development of shape reconstruction algorithms of sonar arrays for the Office of Naval Research, (2) conducting verification and validation studies of nuclear material models, and (3) examining resilience issues in high performance computing (HPC) systems. The latter topic will entail the development of methodologies that are able to predict faults within HPC systems, as well as methods to treat any errors emanating from these faults.

Advisory Board for EI

The EI has formed an internal advisory board to help guide its educational and research activities. The purpose of this Board is to maximize the positive impact the EI’s recruiting, training and retention activities have on LANL engineers and maximize the number of line organizations impacted by these activities.

The roles and responsibilities of the EI Advisory Board include

- Represent their respective line organization’s needs in terms of recruiting, training and retention to the EI staff.
- Guide the collaborative research projects and educational activities of the EI
- Help to define other EI activities such as workshops and development of proposal writing teams
- Bridge a gap between line organization and EI for summer internships, for post-doctoral research appointments, or for staff hiring.

The following members will serve on this advisory board for a two-year period,

Frank Addessio (T-3)
Don Hush (ISR-2)
Doug Kautz (WCM-2)
Thomas Mason (W-6)
Evelyn Mullen (IAT-DO)
R. Alan Patterson (MST-DO)
Ray Guffee (AET-1)
Daniel Rees (AOT-RFE)
Angela Mielke (ISR-3)