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

Please contact Chuck Farrar (farrar@lanl.gov, 663-5335) for more information.

- **Fall 2009 UCSD courses (Instructor)**
  - **Foundation of Solid Mechanics (MAE231A/SE271, Vlado Lubarda), M/W/F 3:00-3:50 pm**
  - **Detection Theory (ECE 254, William Hodgkiss), Tu/Th 9:00-10:20 am**
  - **Array Processing (ECE 251DN/SIO207D, William Hodgkiss), Tu/Th 10:30-11:50 am**
  - **Finite Element Methods in Solid Mechanics I (MAE 232A/SE 276, Yuri Bazilev), Tu/Th 12:00-1:20 pm**
  - **Fluid Mechanics I (MAE 210A, Daniel Tartakovsky), Tu/Th 4:30-5:50 pm**
- **EI Quarterly Tutorial**
  - **Residual Stresses by Mike Prime (W-13, LANL)**
    - **1:00-5:00 pm, October 21st, 2009, Wednesday**
    - **TA03, Bldg 4200, Suite 100 (1st floor—IMMS)**
- **Engineering LDRD-DR Lesson Learned & FY11 Strategy Planning Session**
  - **12:00-3:00 pm, October 29th, 2009, Thursday**
  - **TA-00, Bldg.1325, Rm201 (Pecos conference room)**

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Engineering Institute

UCSD Jacobs School of Engineering | Los Alamos National Laboratory

LA-UR-09-06077

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.

Contact:
Engineering Institute Leader
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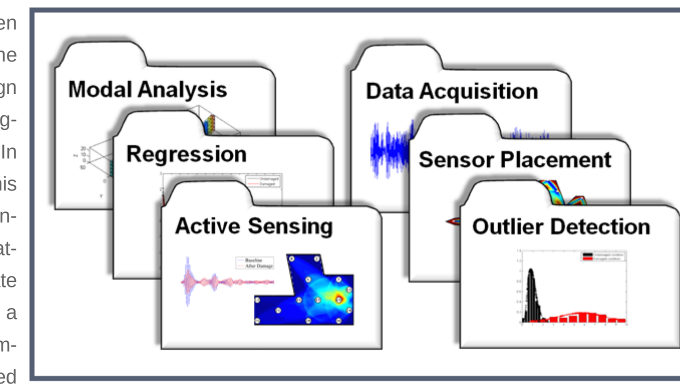
SHMTools, a modular data-processing software package

Structural Health Monitoring (SHM) is the process of observing a structure over time, identifying a damage sensitive feature in the observations, and performing a statistical analysis of these features to determine the health of the structure. Structures include examples from mechanical, civil, and aerospace engineering systems. The observations consist of periodically sampled dynamic response measurements from an array of sensors deployed on the structure. Damage sensitive features are extracted through modeling of baseline structural observations, while the subsequent statistical analysis leads to quantitative information about the current state of the observed structure.

Statistical pattern recognition is a research topic in engineering, statistics, computer science, and even the social sciences. The topic covers the design of systems that recognize patterns in data. In the area of SHM, this process typically involves recognizing patterns that differentiate data collected from a structure in its undamaged and damaged states. Statistical pattern recognition appeals to researchers in the area of SHM because of the ability to quantify and automate the decision making process in the presence of uncertainty. This ability leads to the design of integrated hardware and software systems that can continuously monitor a structure's health.

In the past, several tools have been developed at LANL in an effort to provide accurate and quantitative SHM. The original LANL toolbox, DIAMOND is a graphical-user-interface (GUI) driven MATLAB toolbox for experimental modal analysis, finite element model updating, and damage identification based on changes in modal properties. This toolbox was developed in the mid 1990's. With a shift in paradigm from global modal parameter based damage identification to statistical pattern recognition based SHM , another tool was also developed, referred to as DIAMOND II. Like its predecessor, this software is a collection of functions based in MATLAB that are assembled to provide SHM data interrogation tools.



Recently, the EI researchers from LANL and UCSD, led by E. Flynn, S. Kpotufe, E. Figueiredo, have designed and integrated a new SHM software, referred to as "SHMTools". The concept was for software that would allow a user to assemble statistical pattern recognition functions into a SHM process in the same manner as assembling a puzzle. The project developed from simple graphical interfaces to a modern piece of software that provides easy user interaction, expandability, and is easy to maintain. The package provides a set of functions organized into modules according to the three primary stages of SHM: Data Acquisition, Feature Extraction, and Damage Detection. Data Acquisition functions provide basic services for standard SHM related data acquisition tasks, and include interfaces to common data acquisition hardware. Feature Extraction functions perform application-specific dimensionality reduction on the acquired raw data in order to enhance the identification of system changes due to damage and deemphasis changes due to environmental and operation variability. Finally, the Damage Detection functions work to classify the extracted features through machine learning.

The design of the package is very modular. This design, along with a set of standardized parameter formats, makes it easy to assemble and test customized SHM processes. In addition, various assembly points are provided: these are a set of command line and GUI tools that can be used to navigate the package and assemble custom detectors by combining pieces from various modules.

SHMtools will be made available for free by EI. It is the beginning of a larger effort to collect and archive proven approaches to SHM for re-use by the research community. Therefore, the package includes various algorithms with source codes, along with structural data to serve as benchmarks for the evaluation of algorithms. The package also includes extensive documentation to help users get acquainted not only with the functionality, but also with state-of-the-art approaches to structural health monitoring.

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)

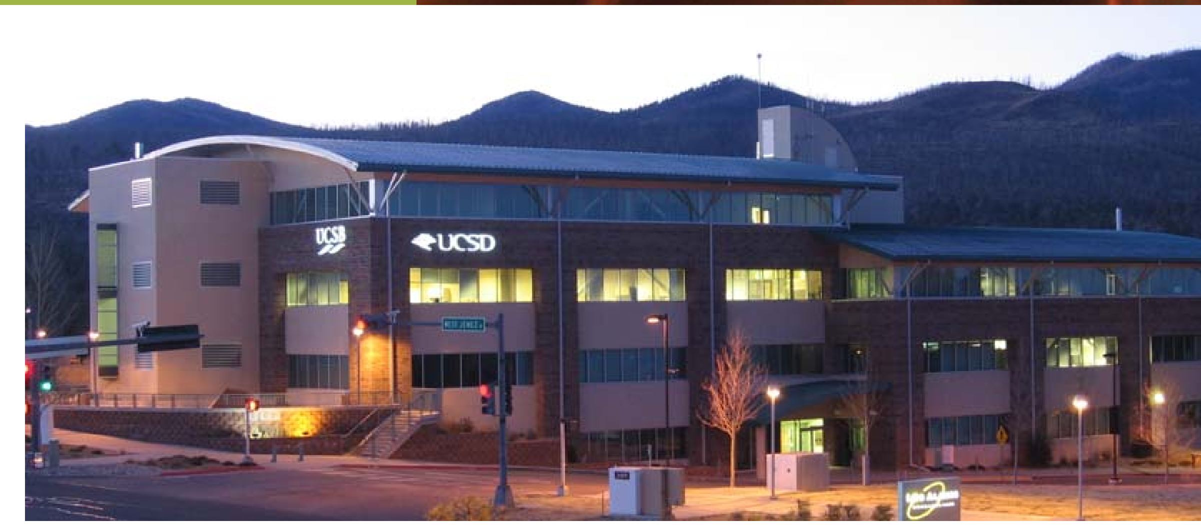
SHiMmer: A wireless embedded platform for active ultrasonic SHM analysis

The adoption of wireless sensor networks (WSNs) in advanced Structural health monitoring (SHM) systems has increased significantly in the last few decades. The usage of distributed intelligent devices facilitates reducing human intervention. An important limiting factor for the adoption of battery powered WSNs is their reduced average lifetime resulting from both energy intensive measurement and computational tasks. The design of a standalone embedded system for active SHM represents a challenging problem, especially considering both the required accuracy in generating and collecting SHM signals and system energy requirements.

EI researchers at UCSD (T. Mollov, D.Dondi, led by Prof. T. Sinunic Rosing) has recently developed a new active-sensing platform, SHiMmer, which is a standalone embedded system designed for active ultrasonic SHM. SHiMmer comprises three boards: a digital board based on a ADI BlackFin DSP for data analysis and wireless networking board running a custom Linux-based OS, an analog board that manages 16 independent channels and generates high-voltage active SHM pulse for piezoelectric active sensors, and a power manager board that collects energy from a solar energy harvester, stores the energy into a Supercapacitor, generates the required power supply and manages a Li-Ion battery acting as back-up energy reservoir. The Figure below shows the SHiMmer development board for preliminary laboratory tests.

SHiMmer implements the active-sensing SHM measurement following two procedures, Actuation and Sensing, which are performed recursively over all the possible pairs of piezoelectric sensors. During the Actuation, the actuation SHM signals are custom generated by the DSP, amplified by the analog board up to 30 V, and transmitted to the structure selecting 1 of the total 16 piezoelectric sensors. During sensing, the structural responses are selectively collected through each of the remaining 15 sensors, filtered through an anti-aliasing block, amplified by the analog board up to ±1V, and acquired by the digital board up to 25 MSPS. Due to the high-voltage amplification and high sampling-rate acquisition, Actuation and Sensing procedures are high energy consuming activities, representing a significant and irreducible part of overall SHiMmer power requirement.

Moreover, SHM data analysis requires the DSP to perform several digital averaging, filtering, fast Fourier transform and convolution operations on the full set of acquired SHM data increasing the required power budget. The adoption of the ADI BlackFin represented the optimum trade-off between high-performance and low-power characteristics. The former due to a very efficient design of the core targeted to high speed complex data analysis; the latter due to the native dynamic voltage and frequency scaling (DVFS) algorithm, which allows reducing both the core voltage and frequency. Based on the DVFS capability, the system has been designed to select three different working modes. The reduction of BlackFin core voltage and frequency allows saving about 30% of the DSP energy consumption between the two active modes. The adoption of DVFS and the two different modes of operation is crucial to allow the proposed task scheduler to allocate the set of SHM tasks on the optimum core working condition.



Student Highlight—Stuart Taylor

Stuart Taylor is a PhD student with the Engineering Institute in UC San Diego's Department of Structural Engineering, and an NSF Graduate Research Fellow. Before completing his B.S. and M.S. degrees in Mechanical Engineering at the University of Houston, Stuart was a summer student in the Los Alamos Dynamics Summer School in 2003, where he investigated delamination in carbon fiber composite plates and first became interested in damage detection and structural health monitoring. Stuart came to the Engineering Institute as a post-master's student in 2007, when he began developing wireless sensor nodes for SHM. Stuart started his PhD work in 2008 under Professor Michael Todd, and he is currently conducting research in SHM and wireless sensing at the Engineering Institute. Stuart plans to leverage his Master's work in algorithmic development for damage detection to implement SHM systems on wireless sensor networks with distributed computational and decision-making capabilities.

In addition to damage detection and wireless sensor nodes, Stuart enjoys swing dancing, trail running, and taking his wife Laura on motorcycle rides.

EI Quarterly Tutorial—Residual Stresses

Mike Prime, WT-13, LANL
Wednesday, October 21, 2009
1:00—5:00 PM, National Security Education Center, 100

Residual stresses are the stresses existing in a body that is free of external loads. They are left behind by most manufacturing processes. Just like applied stresses, they contribute to failures caused by fatigue, fracture, stress corrosion cracking, distortion, etc. But they can be particularly insidious because they are ubiquitous, offer no external evidence of their existence, and they are difficult to predict or measure.

This tutorial, aimed at a general technical audience, will answer a broad set of practical questions on residual stresses. How do they arise? Why do we care and when do we not care? How do we measure residual stresses? How do we predict their effect on failures? How do we manipulate residual stresses to our benefit? Many practical examples will be used to illustrate these issues.

If interested, please contact Chuck Farrar, farrar@lanl.gov. The training seminar may be used to meet Professional Engineering License Continuing educational requirement. Certificates will be provided for attending the seminar.

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 (CCS-3)
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)