

Engineering Institute

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NATIONAL LABORATORY

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LA-UR-09-02301

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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Designing Intelligence into Wind Turbines

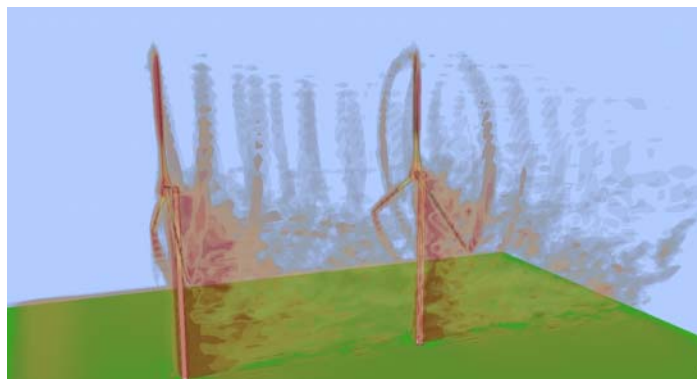
Wind energy in the United States is the fastest growing source of clean, renewable and domestic energy. A recent DOE technical report proposed the potential for meeting 20% of the nation's energy needs through wind power by 2030.

Recently, LANL has chosen a research project, entitled "Designing Intelligence into the Next Generation Wind Turbine," as part of the LDRD-Engineering grand challenge feasibility study. This project is led by Francois Hemez (X-3) and Curtt Ammermann (AET-1) with several staff members across the laboratory from AET-6, CCS-3, EES-16, ISR-3, W-13, CCS-1, P-23 and INST-OFF. This multi-disciplinary program will develop and integrate new physics-based predictive models, advanced sensing technologies, novel data processing techniques, active performance control, and reliability-based decision making algorithms to develop a next generation wind turbine that has more efficient energy conversion capabilities and lower lifecycle costs. Specifically, this project, will develop i) multi-physics modeling capabilities to assess and control the effect of coupled aerodynamic and structural conditions on power output; ii) sensing technologies to measure wind turbine response on multiple time- and length-scales for state awareness, control, and damage detection; and iii) active turbine control to improve efficiency and compensate for structural damage in wind energy applications. These components will be coupled with novel data processing and uncertainty quantification techniques to produce the hardware and software tools necessary to realize a prognosis and control capability for wind turbines.

This research is motivated by one of LANL's national security missions to secure a sustainable energy future by developing renewable energy sources and energy-related technologies. This research will integrate several key engineering components from across the laboratory including structural monitoring, embedded sensing, predictive model-

ling, and active performance and damage control. The successful outcome of this project will significantly improve the current practice of harvesting wind energy and position LANL to bring innovative technology to this rapidly growing area. The developed technology can be also extended to other LANL's engineering applications, including those of weapons engineering and threat reduction.

The multi-disciplinary team consists of recognized researchers whose expertise spans the breadth of composite material damage initiation and evolution modeling/experimentation; structural component and system dynamic simulation; advanced acoustic domain structural health monitoring technologies, such as guided wave monitoring, impedance monitoring and ultrasonic NDE; time series modeling



Windblade simulation results showing turbine-induced vorticity from two turbines in wind field with vertical shear. WindBlade was developed at LANL by Rod Linn and Eunmo Koo (EES-16)

and signal processing; statistical model building; probabilistic model development; model validation and uncertainty quantification; and active vibration and structural control. The team has developed a low-power wireless multi-scale sensing device in the past, which will be evolved for wind turbine applications to truly realize an embedded sensing and processing

capability. The team also developed the HIGRAD/WindBlade atmospheric code (patent pending) for the investigation of a variety of atmospheric phenomena ranging from explosive and passive dispersion to cloud physics. This model will be used as a foundation for predicting and understanding the interaction between the wind turbine and wind loading. The team also brings significant expertise on control system design, including manufacturing process control, self-repairing joint systems, and vibration & structural control.

This study will form the foundation for LANL's new wind energy program development. The team has already submitted three proposals to the recent DOE wind energy RFP on the area of supporting wind turbine research in collaboration with Sandia and National Renewable Energy Laboratory.

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UCSD Course Sequences

Signal Processing

Digital 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 SE 272
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
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)

Structural Health Monitoring, Data Analysis, and Modeling for Ship Structures

The Engineering Institute, in collaboration with staff members from CCS-3 and X-3, is studying the application of machine learning techniques to structural health monitoring (SHM) for U.S. Navy ship structures. The study includes a statistical approach to anomaly detection and a statistical test to identify damage associated with anomalous sensor readings in the presence of varying operational and environmental conditions.

Identifying damage in structures and monitoring its progression can be generally categorized as a *detection and tracking problem*. When applied to ship structures, there are several causes of change that alter the sensor readings, including the structure's internal (e.g. payload, fuel) and external (e.g. wave impact) loading, operational and environmental conditions such as ship speed and weather conditions and, most importantly for this study, damage.

In addition, as the amount of data that floods the analysis engine increases, the development of an adaptive, fast, and efficient data management engine will become of paramount importance. The data management engine should enable a distributed and hierarchical approach to damage detection that: accurately detects anomalies and allocates analysis resources to the detected trouble spots, updates and builds multivariate models in real time, and

records a history of the system as represented in both the evolving sensor models and the multivariate control charts.

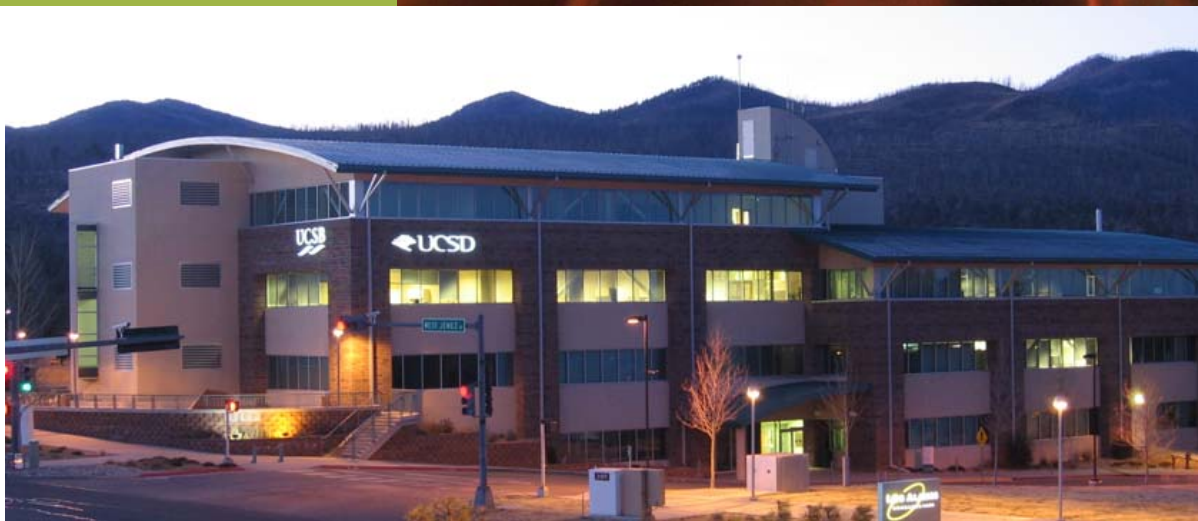
In order to successfully address these challenges, this study uses Support Vector Machines (SVMs) to build nonparametric and nonlinear autoregressive models for the structural response of the boat to the input forces provided by ship operation and the sea conditions. The residual between the SVM model prediction and the measured signal are calculated, and the distribution of residual errors obtained with each sensor model is examined as a damage sensitive feature. Statistical thresholds to detect anomalous sensor behavior are established and the 1% and 99% quintiles for each model residuals are used to define confidence intervals: any residuals outside this interval signal the presence of anomalous behavior. Because an anomalous loading event does not

necessarily imply damage, the distributions of residual errors obtained before the onset of a particular loading event and after the disappearance of event are also examined. If there are statistically significant differences in the residuals errors, the anomaly is assumed to have caused structural damage

The analysis of the HSV-2 Swift sea trials data shows the difficulty posed by complex signals generated by structures subjected to real-world operational and environmental variability. Nevertheless, the statistical pattern recognition paradigm for SHM has demonstrated its potential to adequately detect damage, particularly when multiple features are used (SVM residual errors and autocorrelation of these residuals) to assess the presence of damage.

This project is supported by Office of Naval Research, and is currently performed in collaboration with Naval Surface Warfare Center, Carderock.





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 Addressio (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)

Engineering Institute Highlight

Kevin Farinholt of the Engineering Institute has been elected to the ASME Adaptive Structures Technical Committee. The committee's charter is to supervise and lead ASME's efforts in the development and applications of smart materials and structures. This includes organizing all of the Society's conferences and deciding which papers are accepted for the presentation and awards. It is made up of 40 members representing university, government, and industry research centers including many of the most well-respected

senior researchers in this field. Kevin has also been elected as a co-chair of the SPIE's conference on Industrial and Commercial Applications of Smart



Structures Technology III. This annual conference concentrates on the insertion of smart structure technology and emphasizes products and integration in advanced technology demonstrations conducted in realistic environments. As a co-chair, Kevin will organize and direct this conference for the next three years.

Kevin's election to the committee and the conference co-chair is a clear indication that his peers recognize the significant research contributions to the field of smart structure related technologies that he has made in his relatively short professional career.

Conference Presentation of Summer School Students

This February, students from the 9th Los Alamos Dynamic Summer school presented their research at the IMAC-XXVII, A Conference & Exposition on Structural Dynamics, held in Orlando, Florida. The papers presented include,

- ◆ "Improving a Turning Process Using Piezoelectric Actuators and Ultrasonic-Assisted Machining," by W. Kruse, P. Radecki, A. Welsh, G. Park, M.T. Bement.
- ◆ "Real-time Dynamic Measurements of a Wind Turbine Rotor Blade Using Modal Filtering," by M. Garcia, G. Reich, Y. Zhu, J. White,

- ◆ "Multi-Transducer System for Energy Harvesting," by J. MacDonald, N.A. Miller, W. Sifuentes, K.M. Farinholt,
- ◆ "Dynamic Characterization of Carbon Foils for Space Flight Applications," by T. Collins, R. Hodge, J. Lee, A. Puckett
- ◆ "Use of a Collocated Piezoelectric Sensor/Actuator for Vibration Control and Structural Health Monitoring," by M.R. Nelis, K.A. Ogorzalek, G. Park
- ◆ "Initial Mechanical Stability of Cementless Highly-porous Titanium Tibial Components," by L. Amer, T.B. Stone, C.P. Warren, P. Cornwell.



EI Annual Workshops

EI hosts an annual workshop with focus on the broad areas of predictive modeling, advanced sensing, and information technology. The reports which are the outcome of these workshops are available in 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.

- **Spring 2009 UCSD courses (Instructor)**
 - ◆ **Verification and Validation of Computer Models Partk II (SE 207B, Francois Hemez), M/W/F 4:00-5:00 pm**
 - ◆ **Digital Signal Processing II (SIO 207C/ECE 251B, William Hodgkiss), Tu/Th 9:00-10:20 am**
 - ◆ **Sensor Networks (SIO 238/ECE 156, William Hodgkiss), Tu/Th 10:30-11:50 am**
 - ◆ **Structural Health Monitoring (SE 265, Charles Farrar), Tu/Th 3:00-4:20 pm**

Engineering Institute News Letter March 2009



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