

SST: COLLABORATIVE PROJECT - SELF-SUPPORTING WIRELESS SENSOR NETWORKS FOR IN-PROCESS AND IN-SERVICE INTEGRITY MONITORING

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Soundar Kumara



San-Gook Kim



Xiang Zhang



Satish Bukkapatnam



PROJECT OBJECTIVES

- To investigate the scientific principles of how to harness information from a large network of self-sustainable sensors for quality and integrity monitoring in engineering systems, especially those at the core of the manufacturing and service enterprises
- Two facets of this objective are:
 - To fabricate self-sustainable wireless sensors
 - To develop a framework to analyze the distributed sensor data
- Vision: Integrity monitoring of large manufacturing and service infrastructure



IMPACT AND UNIQUENESS

- Integration of MEMS-based sensors with an energy harvesting device and RF transducers for the applications of the self-sustainable sensor networks.
- Deciphering information from sensor signals, including scenarios where signal to Noise Ratio (SNR) is low for effective monitoring using conventional approaches, so that anomalies including damage are detected in their incipient stages.
- Integration of information from a large network of such sensors in the form of compact models that, have been theoretically proven to yield robust estimates of damage and degradation in complex systems.
- Survivability of complex sensor networks

APPROACH AND TASKS

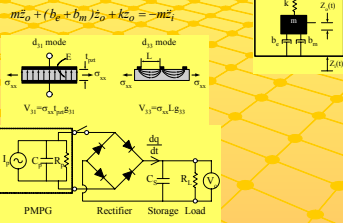
- Task 1: SENSOR DESIGN:** To design and fabricate miniature wireless RF sensors that can harvest energy from the ambient environment (e.g., from acoustic waves). The investigation is done in two stages:
 - Device fabrication and their characterization
 - To integrate them as a part of a large sensor system consisting of components for power generation, sensor and RF transmission
- Task 2: SENSING PRINCIPLES DERIVATION:** To decipher information buried in the feeble signals from a network of self-sustainable sensors, and to synthesize models for monitoring in-service integrity of large complex systems.
- Task 3: PERFORMANCE ASSESSMENT:** To validate the new framework by assessing the performance, through lab and some field experiments, for in-service integrity monitoring of pipeline infrastructure.

SENSOR DESIGN

- Energy Harvesting Principles
- PMPG Sensor Design
- Sensor Fabrication
- Component Integration

Energy Harvesting

- Seismic vibration of electromechanical damped mass



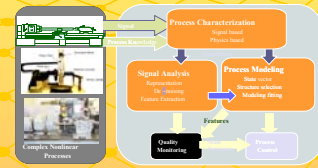
Sensor Design and Fabrication

- Schematic
- SEM of the fabricated PMPG device with bond pads
- Stress Control Cantilevers (a) PZT/ZrO₂/SiO₂(thermal), (b) PZT/ZrO₂/SiO₂(PECVD) (c) PZT/ZrO₂/SiO₂(PECVD)/SiNx



SENSING PRINCIPLES

- Real-world systems including various manufacturing machines and processes are complex Nonlinear stochastic dynamics
 - nonstationarity, bursts and intermittencies in sensor data
- Models and representations capturing this complexity are imperative for effective monitoring and control
- Sensor-based approaches provide an automated and cost-effective way to Assure quality in manufactured products
 - quality specifications have shrunk by 3 orders since 1940's
 - Manage nation's engineering and information assets.
 - maintenance currently costs exceed \$1 Trillion per year

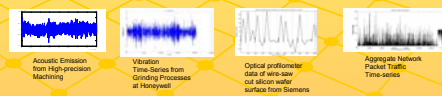


Sensor-based Modeling

- Augments the statistical and qualitative reasoning foundations of conventional monitoring technologies with nonlinear dynamic systems theory
- Captures this complex process dynamics from sensor signals in the form of Customized multi-scale representations and Formal nonlinear stochastic differential-difference equation (in SDE) models

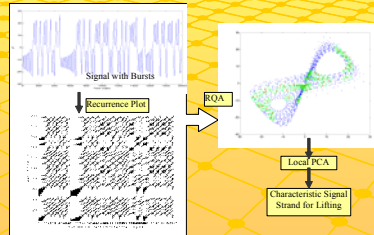


- Applications
 - Traditional and Emerging Manufacturing Machines and Processes
 - Process stability, Degradation, Product surface monitoring
 - Structural health monitoring, Network traffic monitoring, Dynamics characterization

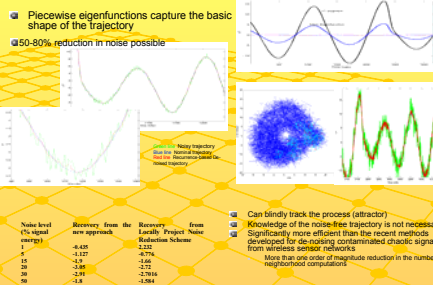


Blind Process Identification

- Data from wireless sensors tend to have poor SNR for analysis using conventional methods
- Strandlets: Piecewise eigen representation
 - Builds on our previous work on customized multi-scale representations



Results



EDUCATION ACTIVITIES

- Two New Courses Developed
 - Multi-Scale System Design and Manufacturing (at MIT)
 - RFID and RF Sensing Applications in Manufacturing Systems (at Oklahoma State)
- Laboratory for Sensor Networks and Complex Systems Monitoring Research

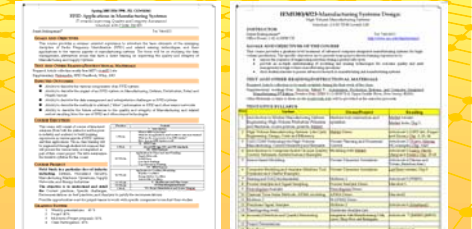
Multiscale Design and Manufacturing

- Created and offered in Fall 2004



RFID and RF Sensing Applications in Manufacturing Systems

- Seminar Course to be offered in Spring 2005 at Oklahoma State
- Builds on Fall 04 course focusing on Sensor based modeling (Enrollment: 20 students, including 2 from underrepresented groups, 1 undergraduate and 4 from regional manufacturing companies)
- Participation from CELDI members that include Halliburton and Walmart as well as a few defense agencies anticipated
- Course focus will be on the impact of these technologies on quality and integrity improvement



INDUSTRY AFFILIATIONS

- Possible collaborations are being explored with the following companies and agencies
 - US Department of Transportation
 - Procurement of line pipe samples for the experimentation test bed
 - Intelligent Automation Inc.
 - Dissemination of the new sensing principles for prognosis applications in commercial and defense sectors

PLANNED ACTIVITIES

- PMPG sensor manufacturing for temperature and strain measurement
- Pipeline integrity monitoring test-bed development
- Distributed computing platform of sensor data integration
- Methods for fast process identification and feature extraction
- About 1000 Sq. Ft. Lab space sanctioned in Advanced Research and Technology Center at Oklahoma State University
- Leveraging Grant from CELDI an NSF IU/CRC

