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A Wireless Data Acquisition Network Designed for Structural Health Monitoring Software Algorithms and Active Sensing

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This research demonstration highlights a wireless sensor network system with integrated hardware/software Structural Health Monitoring (SHM) capabilities jointly developed by Motorola Labs and Los Alamos National Laboratory to address the shortcomings experienced when attempting to execute SHM statistical pattern recognition algorithms on COTS hardware. We demonstrate: (1) an Embedded System Platform tailored specifically to needs of the SHM application, (2) Distributed Control and Actuation via the use of PZT patches for both sensing and actuation, or "active sensing", (3) Dynamic Tasking and Control via the ability to change the computational process on the sensor node in real-time from the host node, (4) Damage detection, estimation, and tracking by comparison to "healthy" damage state data stored at the local sensor node, and (5) In-Network Processing which allows energy conservation and enables use of the low-power, low-data rate Zigbee protocol.

Structural Health Monitoring (SHM) is the process of implementing a damage detection strategy for aerospace, civil, and mechanical engineering infrastructure. It involves the observation of a system over time using periodically sampled dynamic response measurements from an array of sensors, the extraction of damage-sensitive features from these measurements, and statistical analysis of these features to determine the current state of system health. For long term SHM, the output of this process is periodically updated information regarding the ability of the structure to perform its intended function in light of the inevitable aging and degradation resulting from operational environments.

(1) The Motorola embedded system platform (Figure 1) consists of: (a) a single board computer where SHM procedures are implemented to provide true processing power in a compact form, (b) a custom DSP board with six A/D converters to gather raw time-series data from structure-mounted PZT sensors and four D/A converters to provide a calibrated input force via structure-mounted PZT actuators, (c) a Motorola neuRFon^{tm} wireless network board to relay structural status information across the network to an adjacent node or a central host (Figure 2). Each board is modular and coupled through TCP/UDP protocols, which makes the system extensible and adaptable to a wide variety of SHM applications.

(2) Distributed control and actuation (Active Sensing) is achieved via the incorporation of high-resolution A-D converters that locally process the data from multiple structure-mounted PZT patches and D-A converters that provide a calibrated input force to the structure at several locations (Figure 3).

(3) Dynamic tasking and control of the sensors is achieved via a collection of data interrogation software algorithms assembled to form a SHM process through a GUI. This allows the user to construct an application-specific SHM process for transmission in real-time to specific sensor nodes (Figure 4).

(4) The assembled SHM process is then able to autonomously monitor the system and identify the onset of damage. The damage identification procedure is based on the statistical analyses of time series data measured from a distributed sensing system located on the structure.

(5) A neuRFon^{tm} PAN coordinator collects already processed data from the sensors distributed on the portal structure, while the MS1000 gateway box displays the status of each node in the network, thus indicating the overall health of the portal structure from any IP-addressable display device. By computing the overall "healthy" or "damaged" status at each individual sensor node, the network bandwidth and energy required to transmit the essential information to a host is minimized.

Figure 1. Motorola Wireless Data Acquisition Module

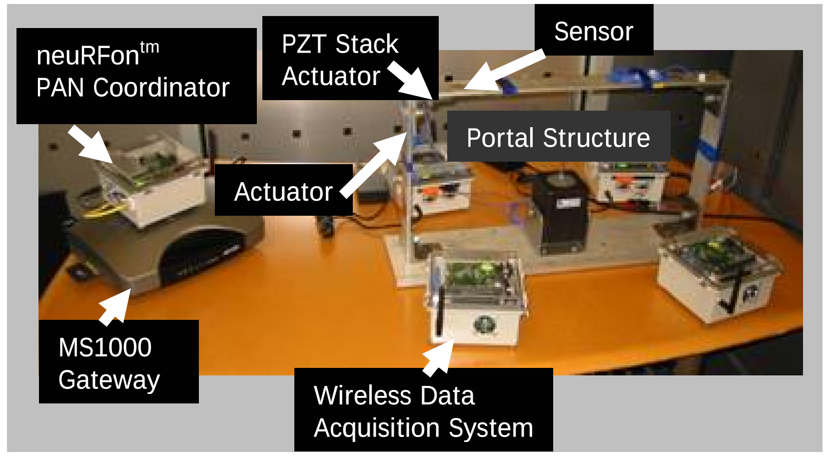

Figure 2. Complete SHM system to be demonstrated, monitoring the joint of a portal (doorway) structure.

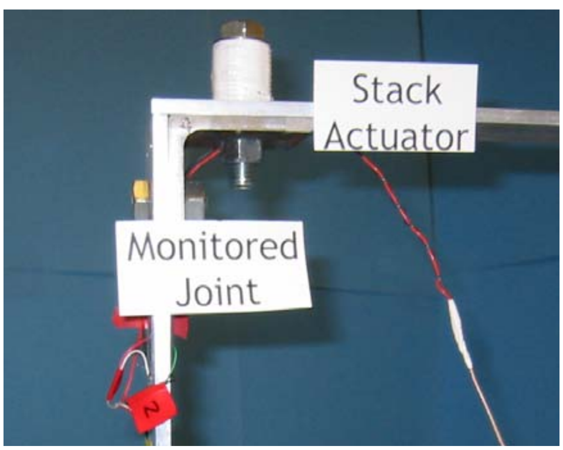

Figure 3. Portal Structure showing PZT Stack Actuator, and the joint monitored with PZT-based sensors/actuators.

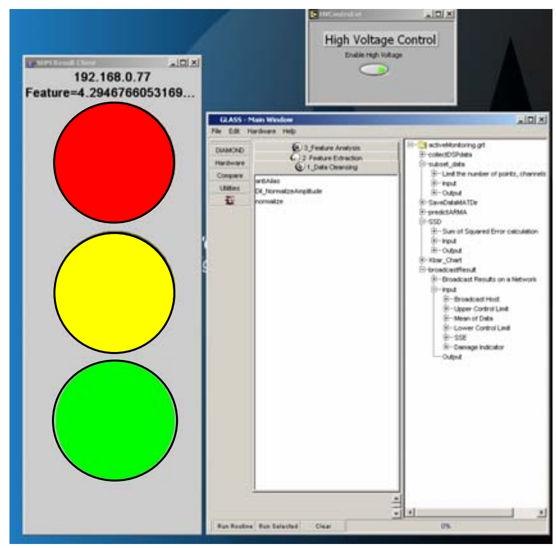

Figure 4. Screen capture of LANL GLASS/DIAMONDII statistical pattern recognition software.