Title

SEI 2: Embedded Wired and Wireless Seismic Networks for Structural Health Monitoring

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Embedded Wired and Wireless Seismic Networks for Structural Health Monitoring

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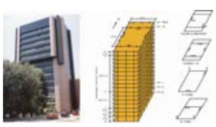
(http://factor.gps.caltech.edu)

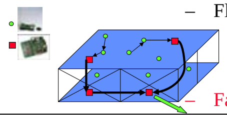
Introduction:

Results from data analysis and predictive modeling using a wired seismic network is guiding the design of a state-of-the-art wireless network for structural health monitoring.

Wired UCLA Factor seismic network

The wired network is a testbed for predictive modeling for use in designing a wireless network for structural health monitoring. Changes in the mode shapes and frequencies are observed in the modeling results for strong ground shaking and for hypothesized damage patterns. Wireless untethered devices whose design is guided by the data analysis can significantly increase the spatial resolution of structural response to earthquakes.





First-generation software system: Wisden

- Wireless sensor network-based data acquisition system
- Allows continuous sampling and reliable logging of time-synchronized structural response data
- Flexibility in deployment
  - Nodes self-organize into a multi-hop network.
  - Nodes can be inserted into and removed from network dynamically
- Fast, low-cost installation

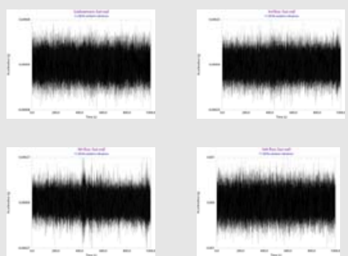
Problem Description:

There are common, serious hardware and software limitations in wireless networks for engineering structures that preclude the measurement and detection of many types of useful signals.

Common limitations:

HARDWARE

- Digitizers are ≤ 16-bit and cannot record low-amplitude vibrations
- Sensors have noise levels that are too high, esp. for low frequencies
- Vibration data cannot be calibrated or validated
- Digitizers cannot record 3 components at required sample rates for long periods



ACTUAL TESTING AND DESIGN

- Node layout is not usually based on structural health monitoring data analysis needs
- Wireless networks are rarely tested in full-scale, operational structures
- Sensors cannot be easily redeployed in multi-scale layouts
- Data flow is linear from sensor to digitizer only

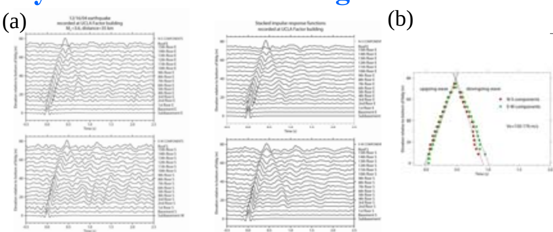
Proposed Solution:

We examine waveform, spectral, and modal data, and numerical modeling results to determine system requirements for a high performance structural health monitoring wireless network.

Types of measurements to identify the occurrence of a significant event or structural damage

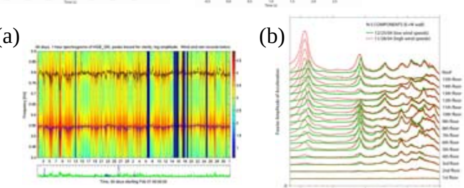
- Wave propagation properties
  - Impulse response functions (a), travel times (b), and attenuation
  - Stack the dense data for higher signal-to-noise ratios

(a) (b)



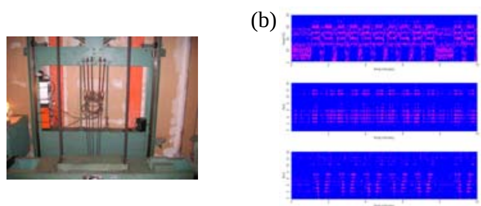
- Spectral properties
  - Frequency changes during high-amplitude and low-amplitude shaking events (a)
  - Use of low-amplitude ambient vibration data to identify temporal variations (b)
  - High- and low-amplitude wind data (b)

(a) (b)



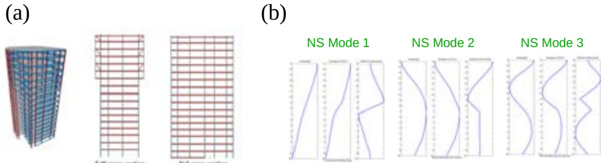
- Non-seismic excitation
  - Elevator counterweight motions recorded by temporary seismometer within wide frequency range (a)
  - Example of predictable excitation to induce location-dependent response (b)

(a) (b)



- Predictive modeling
  - Build computer model of structure (a)
  - Use numerical modeling results to examine changes in properties (e.g., mode shape changes) as signature of significant event or o damage (b)

(a) (b)



- **Need a high density of nodes with flexible placement**
- **Need processing at 3-comp nodes at ≥ 500 sps; low power consumption**
- **Need better than 16-bit devices, lower noise esp. at low frequencies**
- **Need multi-scale analysis and easy, multi-scale deployments**