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Structural Health Monitoring Based on Wireless Sensor Network for Smart Building

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Abstracts

The aim of this project is designing a MEMS based Structural damage cause through various factors, through some Sensors as a single node. This Sensor node is placed in the critical points in various places in the building through we make a network and the sensor monitored data is transmitted through Wireless Sensor Network. Structural damage is pre-detected, then it automatically alert the environment and also take necessary step to avoid big disaster that going to occur.

Keyword: MEMS sensor, Vibration sensor, Temperature Sensor, Pressure sensor, GSM, Zigbee.

Introduction

Safety plays a major role in today's world and it is necessary that good safety system be implemented in places of Structural Health Monitoring of buildings.

The Sensor nodes detects the maximum threshold level, at the same it calculate where the structural damage is occurring and remaining time that the building can withstand further damage. Then we send an interrupt through WSN from microcontroller, based on that we can control some appliances in host section.

A Wireless Sensor Node (WSN) is implemented in Golden Gate Bridge (GGB). Its length is 200feet. The Structural damage is measured at low cost by using the wireless Sensor Network.

Structural Health Monitoring proposed the new solutions by using Wireless Sensor Network to meet the requirements.

In this bridge have 64 nodes. They are located over the main span and tower. It collects the ambient variations of data at 1 KHZ rate. The part of data is collected reliably from the sensor node network with the bandwidth of 441B/s.

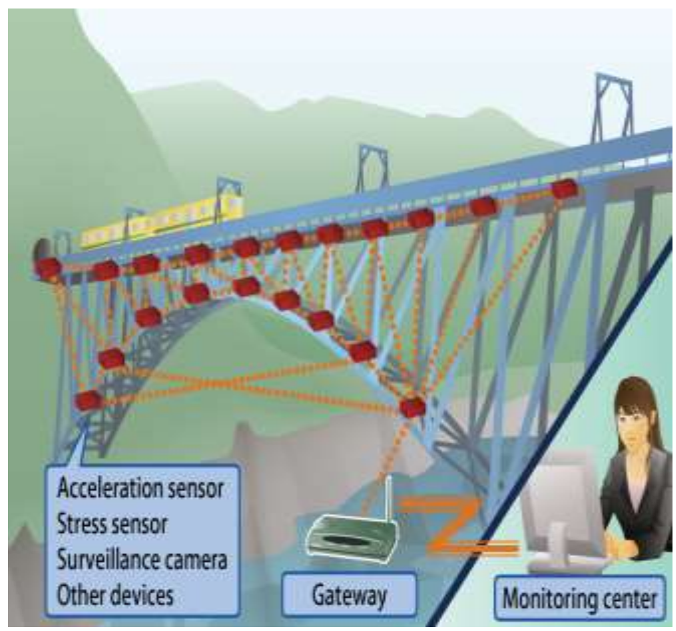

Fig 1: Health Assessment structure of Bridge

[1] A Structural Health Monitoring system uses the techniques to provide continuous information about the state of structures. Structural Health Monitoring systems can prevent the structural failure of the critical structures such as bridges, dams and skyscrapers.

The information from the sensors is integrated into structural analyses and failure models to predict the remaining life time of the building. The diagnostic and

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prognostic components of the Structural Health Monitoring based on materials engineering and applied mechanics.

[2] The thin and long holes are placed in galleries used for installing small measuring devices such as sensors. The effects of the shape, size and orientation of open – hole galleries are experimentally determined. Due to the irregularities whose spacing is greater than sampling length around the galleries are reduced load bearing area and reduced fibre volume caused by an abnormal enlargement is occur in the module and strength properties decreases with increasing gallery diameter.

The galleries are aligned in 0º direction is compared to the applied load in 90º direction. High percentage of applied load thickness is distorted by galleries at 90º direction. These sensors are used to compare the composite structure properties with space.

[3]-[4] Piezo Electric Fiber (PEFSs) composite sensors are made from micro – sized lead zirconate Titanate (PZT). It has many advantage such as highly flexible, easily embeddable, have compatibility with composite structures. Piezo Electric Fiber as embedded sensors will continuously monitor the stress/ strain levels and health conditions of composite structures.

The Structural Health Assessment/ monitoring is the concept is widely used in various infrastructure ranges from bridges to skyscrapers. The process of implementing the damage identification module with civil and mechanical infrastructure is referred as structural Health Monitoring. It observes the structure of the building periodically to determine the current status of the building.

Before the Wireless Sensor Network, health monitoring of the structure is manually checked periodically. So the values are not accurate. And also MEMS sensor only used to monitor the structure. It is used to get only the axis of the building.

In the system person should require the knowledge about the following

- Detection of the damage in the structure
- Location of the damage
- Identify the type of damage

Signal processing and statistical classification is necessary to convert the data information from sensor to monitoring section. To improve the accuracy of the values, vibration, and pressure and temperature sensor is integrated with MEMS.

Data Acquisition, Normalization and Cleansing

Data acquisition involves the selection of excitation methods, sensor types, number of sensor location and transmitter hardware. The intervals at which data should be collected and transferred to the consideration must be addressed.

Data can be measured under varying conditions for damage identification process. As it applies to SHM, data normalization is the process of separating changes in sensor reading caused by damage from those caused by varying operational and environmental conditions.

Normalization is the measured responses by the measured inputs. Environmental change or operational variability is a drawback in SHM, so we normalize the data to compare with environmental or operational cycle. Variability of data changes the environment, test conditions and data reduction process. Monitoring of the acquisition process includes identification and minimized the variation occurred in data. Only appropriate measurements are required to validate the data.

Data cleansing is the process of selectively choosing data to pass or reject from the selection process. It is usually based on knowledge gained by every persons directly involved in the data acquisition. If the sensor node is loosely mounted, then the data from the particular sensor is detected. Then the signal is rejected from the selection process. Signal processing techniques such as filtering and re-sampling can play a vital role in data cleansing procedures.

Finally, the above three methods of SHM process should not be static. The gained information from the selection process and statistical model development process will provide information about changes that can improve the data acquisition method.

Feature Extraction and Data Compression

SHM process receives the data about distinguish between damaged and undamaged state of structure. The feature extraction of damage identification is application specific. Feature extraction method is based on correlating quantities, such a vibration amplitude or frequency of the degrading system.

The analytical tools are used to perform numerical experiments where the defects are found through computer simulation. Damage accumulation testing is

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degradation of the realistic loading condition under the study of significant structural components of the system. It can be used to identify appropriate features also. This process involved in induced-damage testing, fatigue testing and temperature cycling to accumulate certain types of damage.

The operational implementation and diagnostic measurement technologies needed to produce more data than traditional uses of structural dynamics information. Data will be gathered from a structure over an extended period of time in an operational environment. Robust data reduction techniques are developed to retain feature sensitivity.

Embedded system overview

Microcontroller are widely used in Embedded System products. The use of embedded system is to reduce power consumptions and space. This can be achieved by integrating more functions into the CPU. I/O, ROMs are integrated with embedded processor for low power consumption. An Embedded System has a combination of hardware & software to perform a specific function. Software is used for providing features and flexibility. And hardware (Processors, Memory...) is used for performance & security. It is a special purpose system in which the computer is completely replicated by the device it controls.

The core of any embedded system is formed by one or several microprocessor or micro controller programmed to perform a small number of tasks. The general purpose computer, which can run any software application, the user chooses, the software on an embedded system is semi-permanent, so it is called firmware.

Proposed monitoring in building

In this system the MEMS, Pressure, Temperature & Vibration Sensors are arranged in a single node. Sensor nodes are the key element for gathering information about smart environment.

These sensor nodes includes

- Easy installation
- Self identification
- Self diagnosis
- Reliability
- Time coordination with other nodes

In this building the number of nodes is replicate as increasing the coverage area. The gathered information of Sensor nodes are transmitted through Zigbee module to the monitoring center.

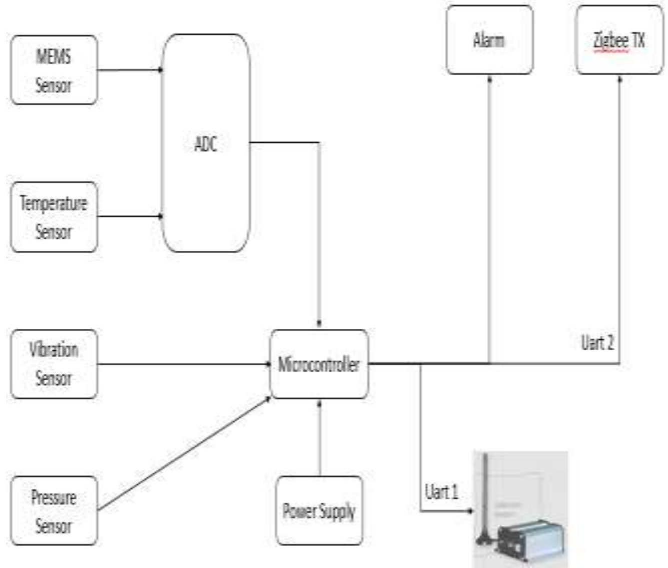

Fig 2: Hardware Architecture Diagram

In this block diagram,the MEMS(Micro Electro Mechanical System),Temperature sensor(LM35),Vibration sensor(Piezo electric sensor)and Pressure sensor are used.For these constant of 3.3vdc supply is given to the circuit.Microcontroller(ARM LPC2148) is connected with the MEMS,temperature sensor,pressure sensor,vibration sensor.

In ARMLPC2148, the signals are converted from Analog to Digital signals.Any variation adapt from the fixed value in the sensors,that is indicated by the alarm and also to the Zigbee transmitter.From these the signals are received by the receiver.The receiving signals variation is indicated by the alarm and also by the computer interface.

MEMS Sensor

[7],[9]Micro-electromechanical systems (MEMS) is a technology that combines computers with tiny mechanical devices such as sensors, valves, gears, mirrors, and actuators embedded in semiconductor chips.

Among the presently available uses of MEMS or those under study are:

- Global position system sensors that can be included with courier parcels for constant tracking and that can also sense parcel treatment en route

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- Sensors built into the fabric of an airplane wing so that it can sense and react to air flow by changing the wing surface resistance; effectively creating a myriad of tiny wing flaps

- Optical switching devices that can switch light signals over different paths at 20-nanosecond switching speeds
- Sensor-driven heating and cooling systems that dramatically improve energy savings

- Building supports with imbedded sensors that can alter the flexibility properties of a material based on atmospheric stress sensing

Vibration Sensor
A Vibration sensor is a device that uses the piezoelectric effect, to measure changes in pressure, acceleration, strain or force by converting them to an electric charge.

Pressure Sensor
[18] A pressure sensor measures pressure, typically of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area.

A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed. For the purposes of this article, such a signal is electrical. Pressure sensors can also be used to indirectly measure other variables such as fluid/gas flow, speed, water level, and altitude.

Temperature Sensor
The LM35 series are precision integrated-circuit temperature sensors, with an output voltage linearly proportional to the Centigrade temperature. Thus the LM35 has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling.

Zigbee Module
ZigBee[10],[13] is the only standards-based wireless technology designed to address the unique needs of low-cost, low-power wireless sensor and control networks in just about any market. Since ZigBee can be used almost anywhere, is easy to implement and needs little power to operate, the opportunity for growth into new markets, as well as innovation in existing markets, is limitless.

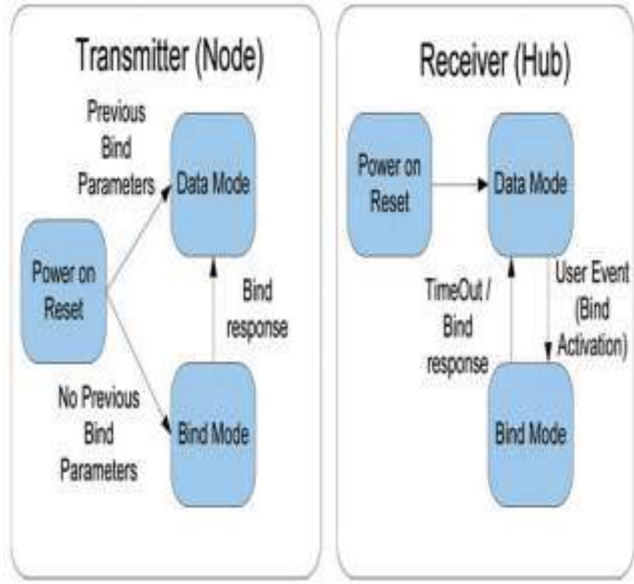

Fig 3: Zigbee Transmitter and Receiver Module

The foundation of every ZigBee standard and specification is the powerful IEEE 802.15.4 physical radio standard operating in unlicensed bands worldwide at 2.4GHz (global), 915Mhz (Americas) and 868Mhz (Europe). It delivers raw data throughput rates of 250Kbs at 2.4GHz (16 channels), 40Kbs at 915Mhz (10 channels) and 20Kbs at 868Mhz (1 channel).

Transmission distances are remarkable for a low-power solution, ranging from 10 to 1,600 meters, depending on power output and environmental conditions, such as other buildings, interior wall types and geographic topology.

When the hub is set in the bind mode sequence, it assumes the network parameters and "listens" to any bind requests from the receiver. When the bind is activated on the node side, it sends out a Hub Bind Request packet and waits for the acknowledgment from the Hub. Both the node and the Hub perform this sequence on different channels until their channels overlap. The timing of the channel hopping is made such that the hub and the node will have multiple channel overlap and thus sufficient binding opportunities.

Once the node receives the acknowledgement from the hub, it stores the parameter data that the hub decides into Flash and then uses this in the data packets that it sends henceforth.

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Monitoring section

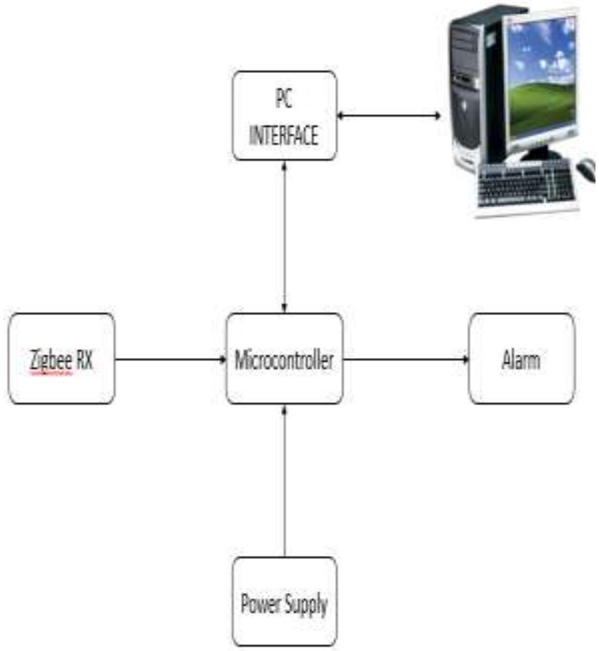

Fig 4: Client Architecture

The gathered information is transmitted through Zigbee transmitter from building to the monitoring section. In the receiver section, the Zigbee receiver is available. It receives the information and displayed it in the monitor.

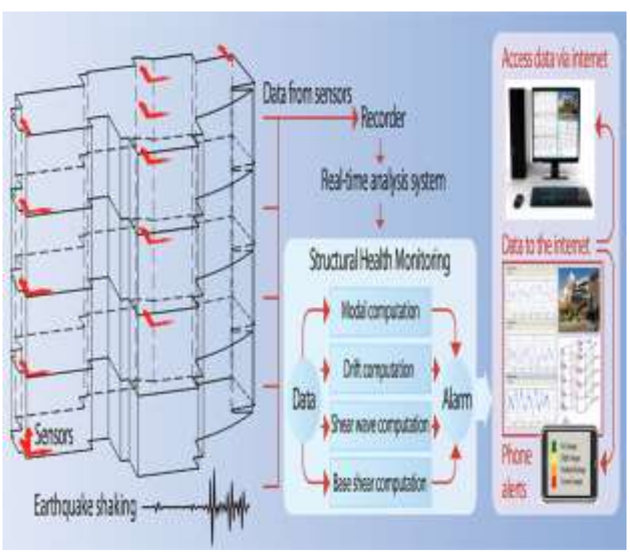

Fig 5: Placement of sensors in building

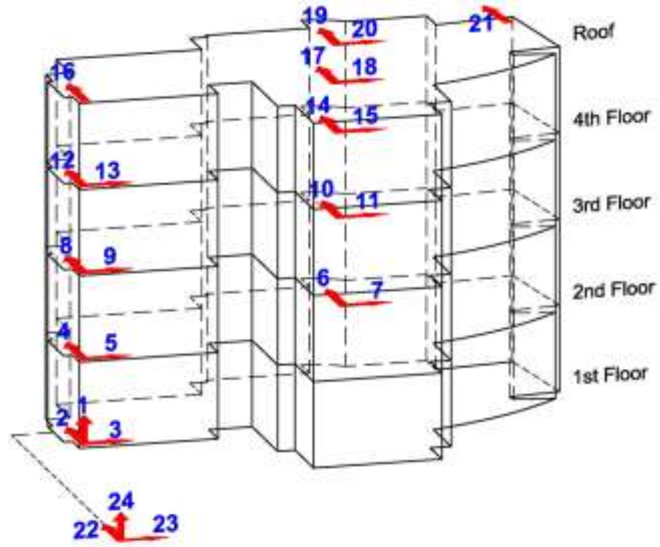

Fig 6: Placement of sensors

In the above structure 21 sensors are implemented in various places of building. These sensors are strategically located in each floor where the maximum building response during a ground shaking is expected, mostly at the edges. Every story has at least two seismic motion sensors oriented horizontally in two orthogonal directions to detect building motion along the reference east-west and north-south directions. Floor rotation around the vertical axis can be computed from the recordings of the two sensors pointing same direction but located at different points. The building also has a tri-axial sensor located on the first floor, which records the input motions in three orthogonal directions at this level. Specifically, the building's instrumentation is designed to record and compute:

- The swaying and twisting of the building
- The time it takes seismic waves to travel from the foundations to the roof
- How the frame of the buildings changed during the earthquake

Performance analysis

In this section, we propose an analytical model to investigate the performance of the proposed system. In this analysis,

- Observe the apparition of transversal cracks a few days after concreting.
- Curvature variations of the building under thermal loading
- Measurements in fresh concrete allowed the prediction of cracking long before the cracks

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became visible and the optimization of the concrete mix for successive pours.

- Temperature monitoring and correlation with the measured strains.
- Verify that no damage is induced to a building due to nearby construction.

The outputs of MEMS, Temperature, Pressure and Vibration Sensors are shown here. This system will provide important information on the structural health of the building. After a significant vibration, its near-real time data analysis capabilities will help to rapidly assess building safety.

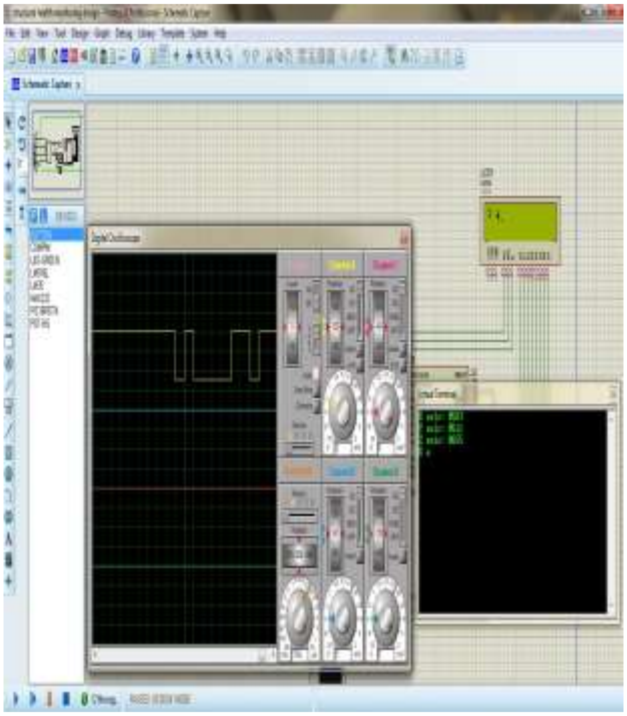

Fig 7: Performance of MEMS Sensor

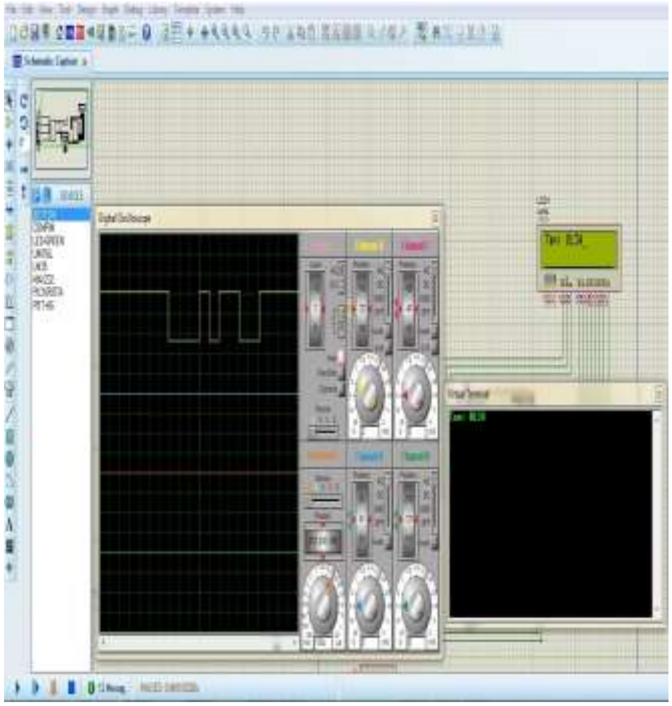

Fig 8: Performance of Temperature Sensor

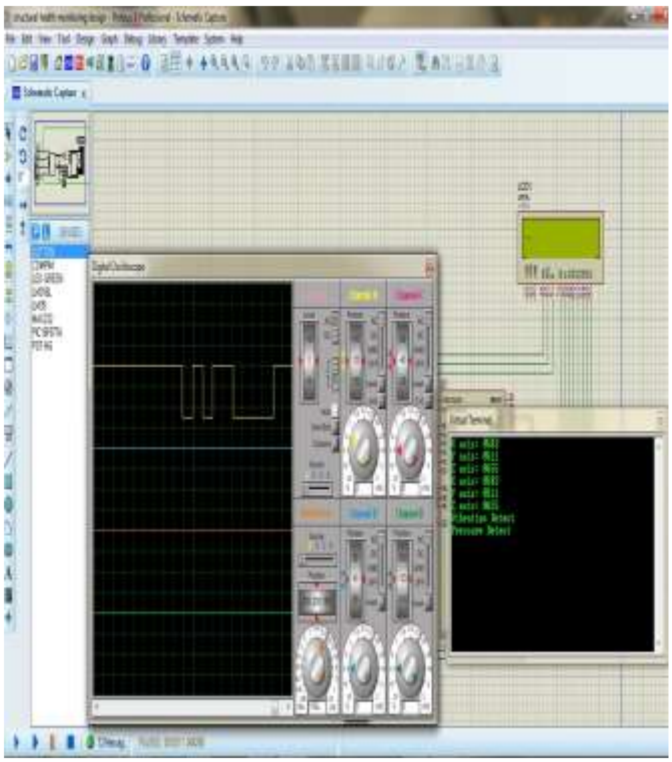

Fig 9: Performance of Sensor nodes

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Conclusion

In this thesis**,** Structural health monitoring technique using multiple sensor nodes has been investigated. The work is to enhance the capability of the conventional impedance based structural health monitoring. The inspection of building structures is currently a visual process. An approach to continuous structural health monitoring techniques based on wireless sensor networks were presented, which provide data from the inside of a structure to better understand its structural performance and to predict its durability and remaining life time. A wireless sensor network system based on MEMS and hybrid sensors is equipped with motes and will be available for a very low budget. Since prototypes are already available, the system is now undergoing an optimization process regarding power consumption, data acquisition and data aggregation, signal analysis and data reduction.

The present results prove that network of sensors are designed as a node can be successfully adopted to improve the safety and reliability of aerospace, civil and mechanical infrastructure by detecting damage before it reaches a critical state. To achieve this goal, technology is being developed to replace qualitative visual inspection and time-based maintenance procedures with more quantifiable and automated damage assessment processes.

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