Multidisciplinary Modular Courseware Development in Structural Health Monitoring Systems

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Introduction

A multidisciplinary group of faculty members at the University of Missouri-Rolla is developing modular courseware in infrastructural health monitoring systems. The field of infrastructural health monitoring is one of the areas of engineering where knowledge, which has been heretofore compartmentalized in several different engineering disciplines, must be integrated into a functional unit because the application crosses disciplinary boundaries. A successful understanding and application of the concept of structural health monitoring depends on an in-depth appreciation of structural modeling, assessment methodology, smart sensors and materials, signal processing techniques, monitoring and diagnostic techniques, and discrimination methods. This area is truly interdisciplinary in nature and the students trained in single disciplinary environment were unprepared to perform at a high level in multidisciplinary infrastructure projects. A recent workshop on integrated research for civil infrastructure, funded by the National Science Foundation, concluded that there is a need for new curricula to better prepare engineers and project managers for rapidly changing and ever demanding infrastructure environment.

At the University of Missouri-Rolla (UMR), the research on infrastructural systems has been identified as one of the six emphasis areas on the campus. We have developed significant research capabilities and the state-of-the-art experimental facilities for structural control and health monitoring of infrastructural systems. The primary objective of the effort is to integrate the research results with curriculum development in the multidisciplinary area of structural health monitoring systems for the benefit of the students in Civil, Electrical, Nuclear, Mechanical, Aerospace Engineering and Engineering Mechanics. The technology needs of the students will be met with the content and material of the proposed two-course sequence in structural health monitoring. The overall goals for curriculum development are:

(i) Development of modular courses for introduction of health monitoring concepts to senior undergraduate and graduate students.

(ii) Development of a multidisciplinary two-course sequence in health monitoring systems utilizing instructional and laboratory modules

(iii) Insertion of new modular courses in the existing curricula

(iv) Project-based learning with hands-on laboratory experience and introduction of capstone design projects

(v) Development of multimedia-based innovative educational delivery systems

(vi) Stimulation of critical thinking and effective communication

Innovations in Curriculum Development

To accomplish the curriculum development objectives, we are developing a two-course sequence of multidisciplinary courses in the infrastructural health monitoring systems. These courses are designed to provide students with a firm grasp of the sensing technologies and integrated health monitoring techniques. These courses also balance theory and application, classroom lectures and multimedia courseware, laboratory and team design projects in a multidisciplinary environment. The courses are team taught and at the senior-elective/graduate level and will be jointly listed in the departments of civil, electrical, nuclear, and mechanical and aerospace engineering and engineering mechanics

To accommodate the diverse backgrounds of students in the interdisciplinary courses, we will present the course material in the 4-week modular form. In each semester, the students are required to enroll in three sequential modules as described below. Students will select the appropriate module depending on their backgrounds, picking the module that brings them up to speed on material that other students may already have had in their major field of study.

Course I: Sensing Technologies for Structural Health Monitoring Systems

The First course will introduce the concepts of structural health monitoring systems, various sensing technologies and project-based health monitoring techniques. A detailed syllabus is given below:

- Introduction and importance of health monitoring systems *1 week*
- Typical examples *1 week*
- Remedial work (offered in parallel in different time slots) *4 weeks*
  - Module I: Review of Structural Modeling and Finite Element Models (for Electrical and Nuclear Engineering students)
  - Module II: Review of Signals, Systems and Data Acquisition Systems

- Module III: Sensors for Health Monitoring Systems (all students) *4 weeks*
- Module IV: Health Monitoring/Diagnostic Techniques (project based) (all students) *4 weeks*
- Review and examinations *2 weeks*

Module I: Review of Structural Modeling and Finite Element Models
This module is a remedial work for electrical and nuclear engineering students. The main topics are modeling for damage and collapse behavior of buildings and bridges, finite element modeling, theoretical prediction of structural failures.

Module II: Review of Signals, Systems and Data Acquisition Systems
This module is a remedial work for civil, mechanical, and aerospace engineering and engineering mechanics. The main topics are frequency and time domain representation of systems, Fourier transforms, modeling from frequency response measurements, D/A and A/D converters, programming methods for data acquisition systems.

Module III: Sensors for Health Monitoring Systems (all students)
Acoustic emission sensors, ultrasonic sensors, piezoceramic sensors and actuators, fiber optic sensors and laser shearography techniques, and imaging techniques.

Module IV: Health Monitoring/Diagnostic Techniques
Project-based health monitoring techniques will be introduced in this module. Vibration signature analysis, modal analysis and neural network-based classification techniques will be utilized to demonstrate the techniques.

Course II: Integrated Health Monitoring Systems
This course will build on the first course. The second course will be emphasized using integrated techniques for the damage detection and location. The syllabus for this course is given below. This course will also be team taught by two professors. A number of case studies and guest lectures by the industrial and government laboratory team members will be included in this course.

- Introduction and case studies *2 weeks*
- Module V: Intelligent Health Monitoring Techniques *4 weeks*
- Module VI: Information Technology for Health Monitoring *4 weeks*
- Module VII: Project-Based Integrated Health Monitoring Methods *4 weeks*
- Review and examinations *2 weeks*

16 weeks

Module V: Intelligent Health Monitoring Techniques
Neural network classification techniques, extraction of features from measurements, training and simulation techniques, connectionist algorithms for anomaly detection, multiple damage detection, and case studies.

Module VI: Information Technology for Health Monitoring
Information gathering, signal analysis, information storage, archival, retrieval, security; wireless communication, telemetry, real time remote monitoring, network protocols, data analysis and interpretation.

Module VII: Project Based Health Monitoring Techniques
In this module the health monitoring techniques based on case studies will be introduce. Practical aspects of testing large bridges for structural assessment, optimal placement of sensors, structural integrity of aging aircraft/multistory buildings, and condition monitoring of heavy machinery. Every student is expected to study integrated health monitoring of at least two case studies.

Conclusions

A two-course sequence with three modules in each course has been developed and successfully taught. The interdisciplinary research projects and common laboratory provided an unique opportunity for significant interactions between the students from different disciplines. These courses were very popular amongst the students working in multidisciplinary areas.