Integration of Wireless Structural Control into Curriculum through Arduino Microcontrollers

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Design Approaches for Civil Structures

• Traditional Design Technique
  • Static approach
  • Resist gravitational loads throughout structure lifetime
  • Increase the stiffness

• Modern Approach through Structural Controls
  • Dynamic approach
  • Use of auxiliary devices
  • Enchantment of integrity through vibration control
Applications

Kajima Shizuoka Building, Shizuoka, Japan

I-35 Walnut Creek Bridge, OK

Dongting Lake Cable-Stayed Bridge, Hunan, China

Eiland Bridge, Kampen, Netherlands
Motivation for Wireless Control
AKA Wireless Sensor-Actuator Network (WSAN)

• Cost per sensor > $5000
  • Wiring
  • Labor

• Sustainable – energy-efficient

• Embedded platforms suitable for Internet of Things
Wireless Sensing with Arduino - XBee

• Working “Out-of-box”
• Based on IEEE 802.15.4 Standard
• Designed for sensor and control networks
• Used for applications that require:
  • Low Power Consumption
  • Low Data Rate
  • Network Security
# Zigbee VS Other Protocols

<table>
<thead>
<tr>
<th>Market Name</th>
<th>ZigBee™</th>
<th>---</th>
<th>Wi-Fi™</th>
<th>Bluetooth™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>802.15.4</td>
<td>GSM/GPRS, CDMA/1×RTT</td>
<td>802.11b</td>
<td>802.15.1</td>
</tr>
<tr>
<td>Application Focus</td>
<td>Monitoring &amp; Control</td>
<td>Wide Area Voice &amp; Data</td>
<td>Web, Email, Video</td>
<td>Cable Replacement</td>
</tr>
<tr>
<td>System Resources</td>
<td>4KB - 32KB</td>
<td>16MB+</td>
<td>1MB+</td>
<td>250KB+</td>
</tr>
<tr>
<td>Battery Life (days)</td>
<td>100 - 1,000+</td>
<td>1 - 7</td>
<td>.5 - 5</td>
<td>1 - 7</td>
</tr>
<tr>
<td>Network Size</td>
<td>Unlimited (2&lt;sup&gt;64&lt;/sup&gt;)</td>
<td>1</td>
<td>32</td>
<td>7</td>
</tr>
<tr>
<td>Bandwidth (KB/s)</td>
<td>20 - 250</td>
<td>64 - 128+</td>
<td>11,000+</td>
<td>720</td>
</tr>
<tr>
<td>Transmission Range (meters)</td>
<td>1 - 100+</td>
<td>1,000+</td>
<td>1 - 100</td>
<td>1 - 10+</td>
</tr>
<tr>
<td>Success Metrics</td>
<td>Reliability, Power, Cost</td>
<td>Reach, Quality</td>
<td>Speed, Flexibility</td>
<td>Cost, Convenience</td>
</tr>
</tbody>
</table>
Evaluation of Low-cost Wireless Sensors for Real-time Estimation of Reference-free Displacements for Railroad Bridges
Use of Arduino for Impact Detection

Collision is inevitable!
Redundancy is not ensured!
Costly visual inspection!
Use of Arduino for Impact Detection

Reactive Remote Sensing
Grand Challenges of Arduino

• Very cheap!?  
  • Affordable system  
  • Limited Computation

• Slow Penetration  
  • Limited to hobbyist  
  • Growing community

• Limited use by the companies  
  • Monetization of entry-level solution
Solution through Education

• Integration of Arduino into curriculum
  • Arduino is a good fit for active learning

• Cultivate next generation engineers open to new technologies

• UNM is a minority university.
Why is Active Learning essential in Education?

Contemporary classroom research has shown that active learning techniques can lead to greater knowledge retention than traditional lecture methods. The diagram illustrates this point by comparing the percentage of material retained over time between lecture and active learning methods. According to McKeachie, Teaching tips: Strategies, research and theory for college and university teachers, Houghton-Mifflin (1998), active learning strategies can significantly enhance student engagement and comprehension.
Active Learning with Arduino

Students **solve** problems, **answer** questions, **formulate** questions of their own, **discuss**, **explain**, **debate**, or **brainstorm** during class or within lab environment.
Hands-on Arduino-in-the-Loop

- Simulate systems in real-time
- Understand how Arduino works
- Acquire and produce sensors data
- Develop control algorithms
Wireless Arduino Systems

- Rapid development
- Rapid deployment
- Rapid testing
- RAPID LEARNING
Conclusions

- Collecting data with wireless systems saves a lot of money.
- Structural control through wireless systems promises longer lifetime.
- Integration of Arduino–based systems into curriculum will conceive new generation of engineers.
CE 597 – Structural Control Systems
Syllabus Fall 2016

Instructor:       Dr. Ali I. Ozdagli
Office:          CENT 3500
Email:           ozdagli@unm.edu
Office Hours:    By appointment, please email me
Course Web Site: TBD
Lecture Time:    TBD
Room: TBD

Text: No official text will be used. To make frequent use of the suggested references.

Reference:
Random Vibe by Vennard and Fleisch
Dynamics of Structures by Clough and Penzien
Structural Dynamics by Clough.

Description: This course provides an introduction to the design of structural modification devices and systems that are being used within structural engineering. Applications will span multiple disciplines that deal with structural systems. The systems to be discussed include, but are not limited to, seismics, damping devices, mass dampers, waveguide materials. Fundamental concepts to be taught include the performance of these systems will be discussed including sensors, data acquisition, earthquake dynamics, control-strategy interactions and Modal signal processing systems. Passive, active, and semiactive systems will be discussed, in terms of modeling, simulation, performance and recent implementations for each class of systems. Computer simulations of structural systems and laboratory experiments will be included.

Homework: Homework must be submitted to the instructor by noon on the due date unless otherwise noted. Homework should be clear and neat; there is no requirement to use special paper. Homework will consist of both written problems and computer projects. Many of these will require the use of computer programs including MATLAB.

Exams: There will be two exams. During exams one 8.5 x 11”-sized paper (one side only) may be used as a reference. Calculators may be used. No other materials are allowed. Cell phones must be stored inside bags during all exams.

Project: Homework should be clear and neat; there is no requirement to use special paper. Homework will consist of both written problems and computer assignments. You are always welcome to use computer programs including MATLAB to complete or verify your results.

Grades: Grades will be assigned based on the following weighting:
Room I 25%  Room II 25%
Homework 25%  Project 25%
Course grades will be assigned based on the discretion of the instructor. No pre-determined scale is used.

Classroom Environment: I wish to encourage a professional classroom environment based on basic courtesy and mutual respect. It is important to be on time and come prepared to fully participate in discussions.

Academic Honesty: Faculty and student working together can promote a fair and positive work environment. All students are expected to conduct themselves in an ethical manner. Students are permitted and encouraged to discuss homework assignments together, but should do their own work when preparing a problem solution (i.e., writing of a solution manual or another student's work is explicitly prohibited). Plagiarism is to be completed without unauthorized assistance. Any student caught cheating on an assignment or exam will receive a zero on that assignment or exam and will receive a grade of "F" for the course.

Emergency Procedures: In the event of a major campus emergency, course requirements, deadlines and grading procedures are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Please check the University News website for information about changes in this area.
Thank You for Your Attention
The Active Learning Continuum

Simple
- Pause Procedure
- Class discussion
- Minute Paper
- Think-Pair-Share
- Pro-Con Grid

Complex
- Problem-based learning
- Cooperative learning
- Experiential Learning

Short, low-risk

Longer duration, higher-risk

(Bonwell & Sutherland, 1996)