Challenges in Developing Intelligent Geosystems (and the pros/cons of interdisciplinary research)

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An interdisciplinary graduate program in the area of Intelligent Geosystems

SmartGeo
COLORADO SCHOOL OF MINES
engineering the way

Road Map

• SmartGeo Applications, Goals, and Challenges
• Custom Hardware
• Trends in WSN Research
• Lessons Learned
• Pros and Cons of Interdisciplinary Research

Intelligent Geosystems
natural or engineered earth systems enabled to sense their condition and adapt to meet their objective

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engineering the way

NSF
Intelligent Earth Dams/Levees

Current State of Practice: Periodic Wired Geophysical Monitoring

Goal: ‘continuous’ monitoring using a (geophysical) WSN

earth systems/structures enabled to sense their environment and adapt to meet their objective

CS/EE Technical Challenges

- unable to integrate geophysical measurement techniques into off-the-shelf mote platforms
- collection of data in a resource constrained environment = use compressive sampling?
- geophysical measurement techniques require localization accuracy at the cm level
- geophysical measurement techniques require time synchronization at the micro-second level
- processing of data (ML and HPC)
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gsMote: geophysical sensing Mote

• geophysical sensors: self potential, seismic, infrasound, resistivity
• High/Low pass hardware filters
• Amplifier
• AVR XMEGA256A microprocessor
• 24-bit off chip ADC
• 64kB FeRAM
• 2-32GB persistent flash storage
• 802.15.4 Radio (900 mHz with 2km range)

gsMote PCB

GeoMoteShield

• geophysical sensors: self potential, seismic, infrasound, resistivity
• Amplifier
• 24-bit off chip ADC
• 32kB RAM
• 32GB persistent flash storage
• GPS
GeoMoteShield with Arduino Fio

- 24-bit ADC
- SD card socket
- GPS
- 32 kB SRAM

Fio

- Geometrics Geode Wired Seismograph (9 channels)
- Arduino + GeoMoteShield WSN (9 motes)
- geophone cluster (27 sensors)
- hammer impact (seismic shot)

Graphs:
- Wired
- GeoMoteShield
- gsMote

Motes 1–9

Time (ms)

0 25 50 75 100

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Motes 1–9

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Motes 1–9

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Motes 1–9

Time (ms)

0 25 50 75 100
Error Results

\[ NRMSE = \sqrt{\frac{\text{mean}((x_{ij} - y_{ij})^2)}{\text{max}(x_{ij}) - \text{min}(x_{ij})}} \]

\( x \): wired system
\( y \): wireless system
for node \( i \), event \( j \)

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Arduinos are programmed in object-oriented C++ (no need to learn nesC).

Arduinos have a huge online support community.

Arduino Fio code is 100% open source and well documented (unlike gsMote and TinyOS).

Arduinos can be easily integrated with many different types of sensors / devices (GPS, ADC, SD card, RTC, LEDs, etc.)
Arduinos can easily support different types of XBee radios (802.15.4, 802.11, 2.4 GHz, 900 MHz, low range, long range).

Arduinos do not have an operating system (unlike TelosB and TinyOS).

Arduinos are NOT low power.

Main Take Away

Arduino: future of applied WSN research?
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- Pros and Cons of Interdisciplinary Research

Inter-disciplinary Research: Pros

- many tough, relevant, real-world research problems exist
- significant funding available for inter-disciplinary research

Inter-disciplinary Research: Cons

- learning the tough, relevant, real-world research problems takes time
- finding the right publishing venue can be difficult
- getting grants can be hard
- communication issues exist

My Students Rule

Recently graduated students: Doug Hakkainen, Brian Hoenes, Aarti Munjal, Marc Rubin, and Kerri Stone

Current Ph.D. Students: Wendy Belcher, James Maher, Thyago Mota, and Henri van den Bulk

Current M.S./Undergraduate Students: Santiago Gonzalez, Kolten Robison, Brandon Rodriguez, and ...