New Innovative Technologies for Cyber Physical Societal Scale Systems: Top Down Meets Bottom Up

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Chess Review
October 4, 2006
Alexandria, VA
Steady Pace of Technology Push

• A period of tremendous advances in the 20th century: automotive, aerospace, nuclear, micro-electronics, communications and computing, the world wide web, photonics, MEMS.

• Technology push continues apace
  - Information Technology
  - Nano-technologies
  - Bio-technologies
  - Convergence of computing and communications
  - Neuronal and other human machine interfaces
Opportunities Abound

- Engineering is now poised to reach outwards to bring technology in at least two different areas in addition to the traditional window into the physical sciences: mathematics, physics, chemistry and statistics:
  - Social Sciences: especially Business, Law, Public Policy
  - Biological Sciences: especially Molecular and Cell Biology, Surgical and Clinical Departments, Neuronal technologies and imaging, Psychology, and Prosthetics, Public Health

- Big challenges are in multi-disciplinary projects

- Aspirations of the engineering community in terms of impact have grown: bigger projects, seeing projects through incubation to uptake by industry and society
Societal Needs

- **New (Renewed) Critical Infrastructures**
  - Transportation
  - Water
  - Electricity
  - Cyber, financial, e-government
  - Oil and Gas

- **Energy (cf. Moniz and Deutsch reports)**
  - Alternative Sources: solar, hydrogen, bio-fuels
  - Decentralized generation and consumption
  - Nuclear fuel
  - Demand Side: HVAC, ...
Societal Needs

• Health Care
  - Rapid bug to drug
  - Better sensing and monitoring
  - Better delivery using ICT
  - Telemedicine/telesurgery
  - Tissue Engineering/Prosthetics

• Homeland Security
  - Less vulnerable and recoverable infrastructures
  - Command and control for reconstituting damaged infrastructures
  - Security with privacy in information exchange and gathering
Societal Needs

- National Security
  - Unmanned vehicles (UXVs)
  - Human centered automation
  - Networked Systems (GIG)
  - Embedded Software and Systems
  - Propulsion
  - Space access, exploration

- Data Storage, Query and Retrieval
  - "Semantic Web"
  - Multi-modal data annotation, query
  - Search beyond Google
  - Data integrity, provenance and privacy
New Challenges from NAE 2020

- Fresh Water Shortages
- Ageing Infrastructure
- Energy Demands
- Global Warming
- New Diseases (pandemics)
- Security
- Globalization
CYBER-PHYSICAL SYSTEMS

- Societal Systems need the best new technologies incorporated into them.
- Societal Systems = Cyber Physical Systems need to be
  - Embedded
  - High Confidence
    • Correct by Construction
    • Fault tolerant
    • Resistant to attack
  - Evolvable (able to accept new technologies)
    • Fusion of bio, info, nano
  - Integration of social, economic and legal considerations
# Mote Evolution

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<th>Mote Type Year</th>
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<th>( \text{Telos} ) 2004</th>
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<td>Microcontroller</td>
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<td>Wakeup Time (µs)</td>
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<td>Radio</td>
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<td>CC1000</td>
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<td>Receive Power (mW)</td>
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<td>Transmit Power at 0dBm (mW)</td>
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<td>Power Consumption</td>
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<td>Total Active Power (mW)</td>
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<td>27</td>
<td>44</td>
<td>89</td>
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<td>Programming and Sensor Interface</td>
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<td>Expansion</td>
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<td>USB</td>
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<td>no</td>
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</table>
Sensor Web Applications Taxonomy

- Understanding phenomena: Data collection for offline analysis
  - Environmental monitoring, habitat monitoring
  - Structural monitoring
- Detecting changes: Thresholds, phase transitions, anomaly detection
  - Security systems, surveillance
  - Wildfire detection
  - Fault detection, threat detection
- Real-time estimation and control:
  - Traffic control, building control, environmental control
  - Manufacturing and plant automation, power grids, SCADA networks
  - Service robotics, pursuit evasion games, active surveillance, search-and-rescue, capture, telesurgery

"Vistas in Cyber Physical Systems", S. Sastry
Ubiquitous Computing and Comms: instrumenting the world
Next Generation SCADA/DCS: Cyber Control of our Physical Infrastructures

- Our critical physical infrastructures depend on SCADA and DCS. SCADA and DCS depend on the gathering, monitoring, and control of information from distributed sensing devices.
- The advent of advances in wireless network embedded systems for distributed sensing devices and software, present an opportunity for a new generation of secure critical physical infrastructures.

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The Demand Response (DR) Project
California Energy Commission (CEC)

What kinds of technology do you need so that your utility can send you a price signal every 15 minutes?

• Small cheap radios (PicoRadios)
• Small cheap sensors to measure temperature etc. that are made by our Berkeley Sensor and Actuator Center
• Small cheap computers not running conventional PC OS but a tiny operating system to run thermostats etc. (TinyOS)
• How to control your appliances from wireless signals
• Try to run all this without batteries (energy scavenging)

Source: Prof. Paul Wright
2. New Meter conveys real-time usage, back to service provider
3. Wireless beacons throughout the house allow for fine grained comfort/control
Privacy Issues in Sensor Webs

• What privacy rules, practices, & technologies promote better security?
• What level of security is necessary to promote privacy and confidentiality?
• How can we achieve appropriate levels of investment in security to ensure appropriate levels of actual security?
• When is necessary to access private information in order to provide security?
  - What technical tools, legal policies, practices are necessary to control or monitor such access?
ICT for Health Care Delivery

- We spend $2 T per year in health care (16% of GDP).
- 10% of population over 60 expected to grow to 25% by 2030.
- 55-60% of hospital health care is labor (source: Kaiser Permanente)
- Huge opportunities to make a difference in continuous monitoring (tele-medicine) for chronic conditions, elder care.
- Electronic Medical Records infrastructure implementation: need to work with (Cal) RHIO (Regional Health Information Offices), Medicare, VA and providers (billing of telemedicine services), and privacy/security.
Healthcare Information Technology

- Rise in mature population
  - Population of age 65 and older with Medicare was 35 million for 2004
- New types of technology
  - Electronic Patient Records
  - Telemedicine
  - Remote Patient Monitoring
- Empower patients:
  - Access to own medical records
  - Control the information
  - Monitor access to medical data
- Regulatory compliance

Table compiled by the U.S. Administration on Aging based on data from the U.S. Census Bureau.

Percentage of Population over 60 years old
Global Average = 21%
United Nations • “Population Aging • 2002”
Unintended Consequences: Electronic Medical Records

Source: Dan Masys Vanderbilt

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Privacy and regulatory issues

- Health Insurance Portability and Accountability Act of 1996 (HIPAA)
    - Right to access their medical records
    - Right to request amendments, accounting of disclosures, etc.
  - HIPAA Security Rule (2005): requires healthcare organizations to
    - Protect for person-identifiable health data that is in electronic format

- Complexity of privacy
  - Variable levels of sensitivity: “sensitive” in the eye of multiple beholders
  - No bright line between person-identifiable and “anonymous” data

- Complexity of access rights and policies
  - Simple role-based access control is insufficient
  - Governing principles: “need-to-know” and “minimum disclosure”
Information Technology for Assisted Living in Homes (ITALH)

- Telemedicine is part of our approach
- It also includes smart monitors and sensors
  - Detect and alert the user and/or care providers of
    - Accidents
    - Acute illness
    - Deterioration of condition
  - This will allow the user to remain at home in a safe and secure environment and delay the transition to group care facilities
The ITALH System

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Smart Sensors in the environment and on the people

- The monitors and sensors include embedded software systems which can autonomously detect events of concern, e.g.:
  - **Wearable sensors**
    - Fall sensors
    - Heart rate or pulse monitors
  - **Stationary sensors**
    - Motion detectors
    - Camera systems

- On their own, we can not expect to have sufficient accuracy, however in combination they will
Components: Gateways

- **Mobile gateway**
  - Using mobile telephones, with Symbian OS and Bluetooth wireless for wearable sensors
  - Data interface and alert activated systems have been developed
  - This allows user to have continuous monitoring away from home as well
  - Currently targeting SMS for signaling, voice for communications, video conferencing in the future
Intelligent infrastructures

- Energy
- Water
- Health Care

- Cyber-infrastructure
- Natural Disasters
- Transportation

For intelligent infrastructures, CHESS provides the leverage for:
- Reusable technology - hardware platforms (motes) Common elements - sensors, MEMS-sensors,
- Common software - TinyOS, TinyDB, Deluge, Drain,...
- Common labs
  - Testbeds at Berkeley (Soda, Etcheverry, Cory)
- Common infrastructure is raising all boats
Intelligent infrastructures

• CHESS advances have reduced the cost, size, and power consumption of micro-sensors and wireless interfaces. Software and database tools are shared between all the sub-projects in “intelligent infrastructure”

• Systems can:
  - Sense phenomena at close range
  - Be embedded into environment
  - Perform monitoring
  - Inferencing: next challenge
  - Control: will need to be “silver bullet”

• These systems are revolutionizing
  - Energy and water management
  - Environmental monitoring
  - Emergency response scenarios
  - Medical services

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From Sensor Webs to Cyber Physical Systems

From Monitoring

To Control

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Concluding Remarks

• Need to build on success in Hybrid and Embedded Systems, Network Embedded Systems, Cyber TRUST systems.

• Cyber physical systems: societal scale systems with high confidence needs: compositional design of complex systems.

• Need to integrate societal considerations: security, usability, economics and privacy considerations into technology agenda.

• Modular curriculum elements needed for industry, engineering and social sciences.