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London Workshop on the Control of Cyber-Physical Systems

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http://controls.ame.nd.edu/mediawiki/index.php/London_CPS_Workshop

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Cyber-Physical Systems (CPS)

-As computers become ever-faster and communication bandwidth ever-cheaper, computing and communication capabilities will be embedded in all types of objects and structures in the physical environment.

-***Cyber-physical systems (CPS)*** are physical, biological and engineered systems whose ***operations are monitored, coordinated,* controlled *and integrated by a computing and communication core***.

-This intimate coupling between the cyber and physical will be manifested from the nano-world to large-scale wide-area systems of systems. And at multiple time-scales.

-Applications with enormous societal impact and economic benefit will be created. Cyber-physical systems will transform how we interact with the physical world just like the Internet transformed how we interact with one another.

-**We should care about CPS because our lives depend on them**

Technological and Economic Drivers

- The decreasing cost of computation, networking, and sensing.
- A variety of social and economic forces will require more efficient use of national infrastructures.
- Environmental pressures will mandate the rapid introduction of technologies to improve energy efficiency and reduce pollution.
- The need to make more efficient use of health care systems, ranging from facilities to medical data and information.

Some Applications

Medical care and health

- Pacemakers, infusion pumps, medical delivery devices, connected to the patient for life-critical functions

- Life-supporting micro-devices, embedded in the human body; wireless connectivity enabling body area sensor nets; mass customization of heterogeneous, configurable personalized medical devices, and natural, wearable sensors (clothing, jewelry) and benignly implantable devices

Energy

- Centralized generation, Supervisory Control and Data Acquisition (SCADA) Systems for transmission and distribution
- Systems for more efficient, effective, safe and secure generation, transmission, and distribution of electric power, integrated through the smart grid; smart ("net-zero energy") buildings for energy savings; systems to keep nuclear reactors safe

Transportation and Mobility

- Vehicle-based safety systems, ABS, traction and stability control, powertrain management; precision GPS-enabled agriculture
- Vehicle-to-vehicle communications for enhanced safety and convenience ("zero fatality" highways), drive-by-wire, autonomous vehicles; next generation air transportation system (NextGen); autonomous vehicles for off-road and military mobility applications

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Manufacturing

- Computer controlled machine tools and equipment; robots performing repetitive tasks, fenced off from people
- Smarter, more connected processes for agile and efficient production; manufacturing robotics that work safely with people in shared spaces; computer-guided printing or casting of composites, design for manufacturabillity, programmable foundries

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Materials and other sectors

- Relatively few, highly specialized applications of smart materials– predominantly passive materials and structures
- Sustainable mass production of "smart" fabrics and other "wearables" with applications in many areas; Actively controlled buildings and structures to improve safety by avoiding or mitigating accidents; electronics provide versatility without recourse to a silicon foundry; emerging materials such as carbon fiber and polymers offer the potential to combine capability for electrical and/or optical (hence NIT) functionality with important physical properties (strength, durability, disposability

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PCAST Report

Leadership Under Challenge:
Information Technology R&D in a Competitive World
An Assessment of the Federal Networking and Information Technology R&D Program
President's Council of Advisors on Science and Technology
August 2007

New Directions in Networking and Information Technology (NIT)

Recommendation: No 1 Funding Priority:
NIT Systems Connected with the Physical World

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CPS Workshops

· Workshop on "High Confidence Medical Device Software and Systems (HCMDSS)", June 2 - 3, 2005, Philadelphia, PA.
· Workshop on "Aviation Software Systems: Design for Certifiably Dependable Systems", October 5-6, 2006, Alexandria, TX.

· Workshop on "Cyber-Physical Systems", October 16-17, 2006, Austin,TX.
· Meeting on "Beyond SCADA: Networked Embedded Control for Cyber Physical Systems", November 8-9, 2006, Pittsburgh, PA.
· Workshop on "High-Confidence Automotive Cyber-Physical Systems," April 3-4, 2008, Troy, MI
· Workshop on "High-Confidence Transportation Cyber-Physical Systems: Automotive, Aviation & Rail," Nov 18-20, 2008, Tyson's Corner, VA
· Workshop on "Developing Dependable and Secure Automotive Cyber-Physical Systems from Components," March 17-18, 2011, Troy, MI

· CPS Week, 2008 (St. Louis), 2009 (San Francisco), 2010 (Stockholm), 2011(Chicago), 2012 (Beijing), 2013 (Philadelphia)

Series of topical workshops under NSF sponsorship started in 2006.

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What is a CPS? Can we recognize a CPS when we see it?

- NIT interaction with physical world.
- Digital control in chemical processes half a century old.??
- What is different here is the tight integration of the cyber and the physical parts.
- The specifications play a central role. When demanding, the cyber and physical should coordinate and orchestrate their actions and reactions to achieve desired goals.

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What is a CPS? Can we recognize a CPS when we see it?

- Example from hybrid systems. Train and gate. To minimize time gate is down, stopping cars from crossing, is obtained when the continuous dynamics of the train and the gate are taken into account.
- When there is no heat or energy issue or shared resource issues, there is no reason to worry about reducing the clock speed of the digital device when the control algorithm does not need it, do cross layer design, worry about demanding timing issues in implementing the algorithm
- **So the same system may be regarded as a CPS or not.**

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CPS Challenges

CPS Characteristics

What cyber physical systems have as defining characteristics:

- Cyber capability (i.e. networking and computational capability) in every physical component
- They are networked at multiple and extreme scales
- They are complex at multiple temporal and spatial scales.
- They are dynamically reorganizing and reconfiguring
- Control loops are closed at each spatial and temporal scale. Maybe human in the loop.
- Operation needs to be dependable and certifiable in certain cases
- Computation/information processing and physical processes are so tightly integrated that it is not possible to identify whether behavioral attributes are the result of computations (computer programs), physical laws, or both working together.

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CPS Issues

There is a set of pervasive underlying problems for CPS not solved by current technologies:

• How to build predictable real time, networked CPS at all scales?

• How to build and manage high-confidence, secure, dynamically-configured systems?

• How to organize and assure interoperability?

• How to avoid cascading failure?

• How to formulate an evidential (synthetic and analytic) basis for trusted systems? Certified.

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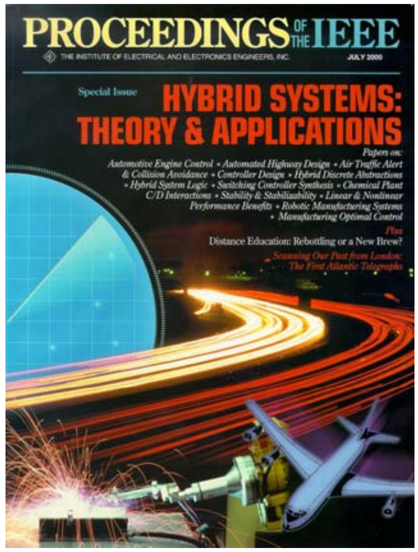

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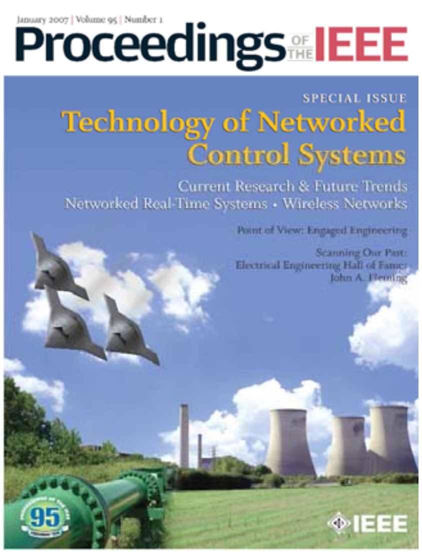

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Connections & Personal Motivation

Linear Feedback Systems

– Polynomial Matrix Descriptions

Autonomous Intelligent Control

- Defining Intelligent Control - Hierarchies - Degrees of Autonomy
- To DES (PN), Hybrid Systems, Networked Control Systems (MB)
- To Cyber Physical Systems

Quest for Autonomy

- Autonomy wrt …. Human in the loop.

The Power of Feedback

– Feedback Transcends Models