Challenges in Control of Buildings

K. J. Åström
Mechanical Engineering
UCSB
Introduction

- Potential for saving energy
- Strong national and public interest
- Interesting useful technology around the corner
- Networking, modeling, control
- Changing view on life time cost
1. Introduction
2. Long ago and far away
3. A control odyssey
4. Challenges
5. Conclusions
Digital Control of HVAC Systems Lund 1968-78

- Computer control expected to be cost effective
- Modeling and digital control
- Why HVAC
Research Drivers

- Department structure and philosophy
- Modeling dynamics from experiments – system identification
- Computer control
- Exploit networks
- Interactive software systems ↑ !! ↑ !!
Why HVAC and How

- Possibility to have significant impact
- Slow process dynamics
- Initial contacts, seminars
- Networking, masters theses
- Joint courses with industry↑ !!
System Characteristics

- Inexpensive low cost actuators and sensors
- Nonlinearities, friction, backlash, and hysteresis
- Dynamics changes with time and operating conditions
- Simple controllers PI
Milestones

- Networked experiment
- Networked digital control
- Collaboration with start up
- PhD and Masters Theses
- Industrialization
- Ideas for new research auto-tuning
Auto-tuning
Build intelligence into the controller
Some Observations

- Systems change with seasons
- Many simple loops
- Personnel
- Commissioning and operation
- Interactive software for CC
- Remote supervision and energy monitoring
Technology Transfer

- Industrial collaboration courses
- Startup and industrial consolidation
- Networking and the Wallenberg group
- Current situation
Lessons Learned

- Long range view and funding
- Broad student participation
- Technological opportunities
- Industrial collaboration
- Networking
- Flexibility, watch for opportunities
Why did we quit?

- Department philosophy
- One PhD became Professor in Civil Eng (Building Systems)
- Technology changes
- Time to move on
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Control Emerges

- Drivers: gun control, radar ...
- Block diagrams, transfer functions
- Design tools: graphical
- Analog computing
- Holistic view of theory & applications
- Wide spread education
The Second Phase

- Drivers: space, computer control, mathematics
- Rapid growth of subspecialties
- Optimal, stochastic, nonlinear, ...
- Computational tools
- Impressive development of theory
- Holistic view was lost
The Third Phase?

- Drivers: embedded systems, networks, biology, physics, ...
- Autonomy, distribution
- Exploding applications
- Hardware and software platforms
- Can holistic view be recovered?
The Power of Feedback

- Precise systems from imprecise components
- Reduce effects of disturbances and component variations
- Regulate, stabilize, shape dynamics
- Main drawback: Risk of Instability
- Measurement noise is fed into the system
Process Control
Discrete Manufacturing
Consumer Electronics
Vehicles
Biology

- Schrödinger 1944
- Wiener 1948
- von Neumann 1958
- Bellman Mathematical Biosciences 1967
- Understanding dynamics and control crucial
- Biomedical engineering
- Systems Biology
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New Challenges

- Systems rich in sensing and actuation
- Systems with a high degree of autonomy: adaptation, learning and cognition
- Control of/over networks
- Architecture for safe embedded systems
Building Control

Design & Energy Analysis

Windows & Lighting

Natural Ventilation

Indoor Environment

Sensors, Networks, Communications, Controls

Elevators

Safety

HVAC

Vibration damping
Drivers for Change

- Energy costs, green buildings
- Public awareness global warming
- Building codes and standards
- Changes in business structure
Two city council committees voted to require that all major commercial and residential developments slash projected energy and water use, ... placing the city at the cutting edge of an international movement to address the global warming effects of buildings.

The average green building saves 36% in energy and cuts greenhouse gas emissions by 40% and solid waste by 70%
The Systems Perspective

In the past steady increases in knowledge has spawned new micro-disciplines within engineering. However, contemporary challenges – from biomedical devices to complex manufacturing designs to large systems of networked devices – increasingly require a systems perspective.
Modeling and Simulation

There will be growth in areas of simulation and modeling around the creation of new engineering “structures”. Computer-based design-build engineering ... will become the norm for most product designs, accelerating the creation of complex structures for which multiple subsystems combine to form a final product.

NAE The Engineer of 2020
Automotive Climate Control

- Audi, BMW, DaimlerCrysler, Volkswagen and their suppliers have standardized on Modelica
- Suppliers provide components and validated Modelica models based on the AirConditioning library from Modelon
- Car manufacturers evaluate complete system by simulation
- IP protected by extensive encryption

Picture courtesy of Behr GmbH & Co.
UCSB Ideally Positioned

- Long tradition in multidisciplinary research
- Major strength in control, dynamical systems, computing and fluids
- CCDC an excellent platform for multidisciplinary work
- Good long time experience of working with industry
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Conclusions

- A good time to look at control of buildings
- The systems challenge
- Modeling
- Network control
- Rich in sensing and actuation