Challenges in Control

A tribute to LIDS and Sanjoy

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Proceedings
IBM Scientific Computing Symposium
Control Theory and Applications

SESSION 1: Theory and Computations I
1 Optimal Programming and Control
   — Arthur E. Bryson, Jr.
2 Toward a Theory of Difficulty of Computation in Optimal Control
   — R. E. Kalman
3 Some Aspects of the Relationship of Dynamic Programming to the Calculus of Variations
   — Stuart E. Dreyfus

SESSION II: Theory and Computations II
4 On Certain Differential Games
   — L. S. Pontryagin
5 Applications of Liapunov Stability Theory to Control Systems
   — J. P. Lasalle
6 Stability of the Optimal Control Problem
   — Lawrence Markus

SESSION III: Industrial Processes
7 Application of Optimal Methods to Control of Industrial Processes
   — J. H. Westcott
8 Control Theory and Applications in Chemical Process Control
   — Theodore J. Williams
9 Control Problems in Papermaking
   — K. J. Åström
10 Control Problems in Automobile Traffic
   — Denos C. Gakis
11 Application of Control Theory to Biological Systems
   — Fred S. Grodins
12 Minimum-Fuel Impulses for Space Trajectories
   — Lucien W. Neustadt

SESSION IV: Special Processes
13 Discontinuous Variational Problems
   — H. Gardner Moyer
14 Optimal Control and Convex Programming
   — J. B. Rosen
15 Stochastic Problems in Control
   — W. M. Wonham
A Perspective

➤ Emergence
   Drivers: World War II
   Formation of the field
   The Servomechanisms Laboratory 1940

➤ The Second Phase
   Drivers: Space race, computer control
   Subspecialization: …

➤ The Third Phase?
   Drivers: Complex networked systems,
   Safe embedded systems
   Autonomy
   Recover the holistic view
Control Everywhere
The Power of Feedback

- Accurate systems from imprecise components
- Reduce effects of disturbances and component variations
- Regulate, stabilize, and shape behavior
- Drawbacks:
  - Risk of Instability
  - Sensor noise is fed into the system
A Third Phase?

- Drivers: embedded systems, networks, biology, physics, economy ...
- Autonomous distributed systems
- Sensor and actuator rich systems
- Provable safe design and reconfiguration
- Can the holistic view be recovered?
Physics

- Nobel Prizes
  Dahlén 1912
  van der Meer 1984
- Instruments mega to nano
- Turbulence
- Quantum and molecular systems
Feedback is a central feature of life. The process of feedback governs how we grow, respond to stress and challenge, and regulate factors such as body temperature, blood pressure, and cholesterol level. The mechanisms operate at every level, from the interaction of proteins in cells to the interaction of organisms in complex ecologies.

Mahlon B Hoagland and B Dodson The Way Life Works Times Books 1995
The CS Barrier

Control

- Feedback, Stability, ODE, PDE
- Moderate complexity
- Robustness

Computing

- Logic, languages, DES, FSM
- High complexity, abstractions
- Architecture

The controller
The Physics Barrier

Blockdiagrams ODEs
Mass, energy, momentum
Block diagrams unsuitable for serious physical modeling
Automotive Climate Control

- Audi, BMW, DaimlerChrysler, 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.
Summary

➢ Control is a vital dynamic field
➢ Networked embedded systems
➢ Autonomy and safety
➢ The educational challenge
➢ Recover the holistic view
Sanjoy’s Half Plane

Thanks for all your contributions!
Continue to deepen insight and understanding!