History of Control - Introduction

Karl Johan Åström

Department of Automatic Control LTH
Lund University

Introduction

1. Introduction
2. Practical Information
3. A Thumbnail History
4. The Power of Feedback
5. Summary

Theme: Those who ignore history are doomed to repeat it. Those who cannot remember the past are condemned to repeat it. (George Santayana)

Why bother?

- Fun
- Useful to have a perspective
- Understand how ideas develop
- Understand how fads come and go
- Understand how research communities emerge
- Useful for teaching

Driving Forces

- New Inventions
- New Technology
- “New” Mathematics
- New Applications
- Social factors (War, Revolutions, ...)
- Institutions (DARPA, NSF, EU, VR, Vinnova, ...)
- Organizations (IFAC, IEEE, ASME, AIAA,...)

Useful to get in on the ground floor and to shape the agenda!

Information Sources

- Control is a very young field
- Books
  - History of technology
  - Organizations and companies that celebrate
- History of Technology
  - IEEE, ASME have sections for history
- The Web
- Svensk IT historia `http://ithistoria.se`
  - Svenska dataföreningen, History of Technology KTH

Introduction

1. Introduction
2. Practical Information
3. A Thumbnail History
4. The Power of Feedback
5. Summary

Theme: Those who ignore history are doomed to repeat it.

Practical Information

- Lectures
- Home page
  - Lecture notes references and papers
- Books - Library shelf
  - Look at the books but leave them there
- Exam Project
  - Projects in History of Automatic Control K. H. Johansson, K. J. Åström, TFRT 7561 June 1997
  - Explore trends of control via conferences. Examples: Papers from industry IFAC 1960 vs 2011. Theory vs practice.
  - What is hot? Most popular topics 2011, 2008,...
  - Explore a particular topic
  - You can start now!

Some Questions

- What things are really being used?
- Will PID still be around?
- What is the next branch of mathematics that will be hot?
- What are the emerging applications?
- To distribute or not to distribute?
- Why did not adaptive control really make it?
- Why did auto-tuning succeed?
- PhD free control

Lectures

<table>
<tr><th></th><th></th><th>1940</th><th>1960</th><th>2000</th></tr>
<tr><td>1</td><td>Introduction</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Governors</td><td>|</td><td>|</td><td>|</td></tr>
<tr><td>3</td><td>Process Control</td><td>|</td><td>|</td><td>|</td></tr>
<tr><td>4</td><td>Aerospace</td><td>|</td><td>|</td><td>|</td></tr>
<tr><td>5</td><td>Feedback Amplifiers</td><td>|</td><td>|</td><td>|</td></tr>
<tr><td>6</td><td>Harry Nyquist</td><td>|</td><td>|</td><td>|</td></tr>
<tr><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>7</td><td>Servomechanisms</td><td>←</td><td>|</td><td>|</td></tr>
<tr><td>8</td><td>The Second Phase</td><td>←</td><td>←</td><td>|</td></tr>
<tr><td>9</td><td>The Third Phase</td><td>←</td><td>←</td><td>←</td></tr>
<tr><td>10</td><td>The Swedish Scene</td><td></td><td></td><td></td></tr>
<tr><td>11</td><td>The Lund Scene</td><td></td><td></td><td></td></tr>
</table>

Natural and Engineering Science

- Understand Nature
- Physical Laws
- Isolation
- Reductionism
- Theoretical Physics

- Build Systems
- System Principles
- Interaction
- Systems
- System Theory

Similarities and common ground:

- Connected to the real world
- Extensive use of mathematics
- Instruments and experiments
- Computing

Organizations

- ASME 1880 +120k
  Dynamic Systems and Control Division
  Journal of Dynamic Systems, Measurement, and Control
- AIChE 1908 40k
  - CAST computing & Systems Technology Division
- IEEE 1963, (AIEE 1881, IRE 1912) 400k
  IEEE Control Systems Society
  CS, AC,
- AIAA 1963,(ARS American Rocket Society 1930, IAS Institute of Aeronautical Sciences), 31k
  Information and Command & Control Systems
  Journal of Guidance, Control and Dynamics
- ISA International Society of Automation 1945 30k
- SIAM 1951, 12k
- IFAC 1956,
- FSA Finnish Society of Automation 1953, 1.9k
- NFA Norsk Forening for Automatisering 1958, 1.2k
- ITF Instrumenttekniska föreningen 1961, 1.1k

Compare

Science

- DPG Deutsche Physikalische Gesellschaft 1845, 61k
- AMS American Mathematical Society 1888
- APS American Physical Society 1899, 48k
- Svenska Fysikersamfundet 1920, 0.8k

Engineering

- ASME 1880 +120k
- AIChE 1908 40k
- IEEE 1963, 400k
- AIAA 1963, 31k
- ISA 1945 30k
- FSA 1953 1.9k
- NFA 1958 1.2 k (0.2k companies)
- ITF 1961 1.1k

The Role of Computing

- Dramatic change of what we mean by a solution!
- Vannevar Bush 1927. *Engineering can proceed no faster than the mathematical analysis on which it is based. Formal mathematics is frequently inadequate for numerous problems, a mechanical solution offers the most promise.*
- Herman Goldstine 1962: *When things change by two orders of magnitude it is revolution not evolution.*
- Gordon Moore 1965: *The number of transistors per square inch on integrated circuits has doubled approximately every 18 months.*
- Moore+Goldstine: *A revolution every 10 years!*
- Significant productivity changes, but we have not learned how to capitalize and software does not evolve as fast as hardware

Introduction

1. Introduction
2. Practical Information
3. A Thumbnail History
4. The Power of Feedback
5. Summary

Theme: Those who ignore history are doomed to repeat it.

A Thumbnail History

- The roots (before 1940)
  Use of feedback in windmills, steam engines, engines, ships, airplanes, process control, telecommunication
- The field emerges (1940 –) Servomechanism theory
  Drivers: World War II, gun control, radar, ...
  A holistic view: theory, simulation and implementation
  Block diagrams, Transfer functions, analog computing
  Spread like wildfire: education, industry, organization
- The second phase (1960 –)
  Drivers: space race, digital control, mathematics
  Subspecialities: linear, nonlinear, optimal, stochastic, ...
  New ideas: state feedback, Kalman filter, ...
  Computational tools
  Impressive theory development, holistic view was lost
- The third phase (2000 –)?
  Drivers: Embedded systems, networks, autonomy
  Exploding applications - Control everywhere
  Can the holistic view be recovered?

Introduction

1. Introduction
2. Practical Information
3. A Thumbnail History
4. The Power of Feedback
5. Summary

Theme: Those who ignore history are doomed to repeat it.

The Power of Feedback

Feedback has some amazing properties, it can

- make a system insensitive to disturbances and component variations,
- make good systems from bad components,
- stabilize an unstable system,
- create desired behavior, for example linear behavior from nonlinear components.

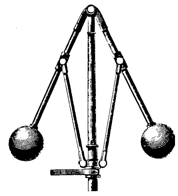
The major drawbacks are that

- feedback can cause instabilities
- sensor noise is fed into the system

Reduce Effects of Disturbances

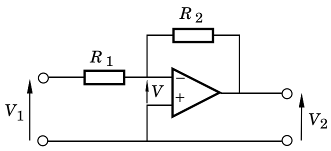
Keep interesting variables constant in spite of disturbances

- Textile mills
- Water turbines
- Power systems
- Machines
- Process control
- Instruments



Good Systems from Bad Components

- Feedback amplifier
- Pneumatic controller
- Motor driven controller
- Hifi amplifiers
- Biological systems



$$G = \frac{V_2}{V_1} = -\frac{R_2}{R_1}\frac{1}{1+\frac{1}{A}\left(1+\frac{R_2}{R_1}\right)}$$

$$A = 10^6,\ \frac{R_2}{R_1} = 100,\ \frac{dG}{G} \approx 10^{-4}\,\frac{dA}{A}$$

Gain is the hard currency, we can use it to buy robustness

Stabilization

- Airplanes
- Bicycle
  Stable because a properly designed front fork creates a stabilizing feedback
- Exotherm reactors
- Missiles
- Nuclear reactors
- Segway

Flight Control

The Wright Brothers knew dynamics (bicycle manufacturers)

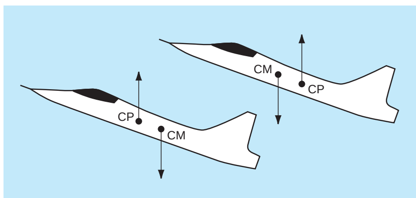
Lecture by Wilbur Wright 1901:

> Men know how to construct airplanes.
> Men also know how to build engines.
> Inability to *balance and steer* still confronts
> students of the flying problem.
> When this one feature has been worked out,
> the age of flying will have arrived, for
> all other difficulties are of minor importance.

The main stream idea at the time was to build stable airplanes. The Wright Brothers built an *unstable* airplane that was *manoevrable*, the Wright Flyer, which first flew on December 17 1903! Sperry's autopilot 1912.

Shaping Behavior

- Stabilization
- Haptics
- Collision avoidance
- Homeostasis
- Goal seeking, extremal control



High performance is obtained by designing an unstable aircraft and using a control system to stabilize the system

Introduction

1. Introduction
2. Practical Information
3. A Thumbnail History
4. The Power of Feedback
5. Summary

Theme: Those who ignore history are doomed to repeat it.

Summary

Control is a young field

Todays references:

- Projects in History of Automatic Control TFRT-7561
- Control Science Evolution Sergio Bittanti CNDC 2008
- The American Automatic Control Council 1957-2011
- Automatisering for å bygge Norge, NFA 2008
- IFAC In Japan - A Report on Japans activity for IFAC 1956-2006
- Historic Control Textbooks, Gertler (ed) Elsevier 2006
- D. J. Kevles The Physicists - The History of a Scientific Community in Modern America. Harvard University Press 1971,...,1995.