ME 8043114 Automatic Control

Lecture 12: Control History & Summary

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Lecture Outline

- History of Control
- Course Summary

History of Automatic Control

James Watt (1736-1819)

Scottish engineer

Steam engine with flyball governor

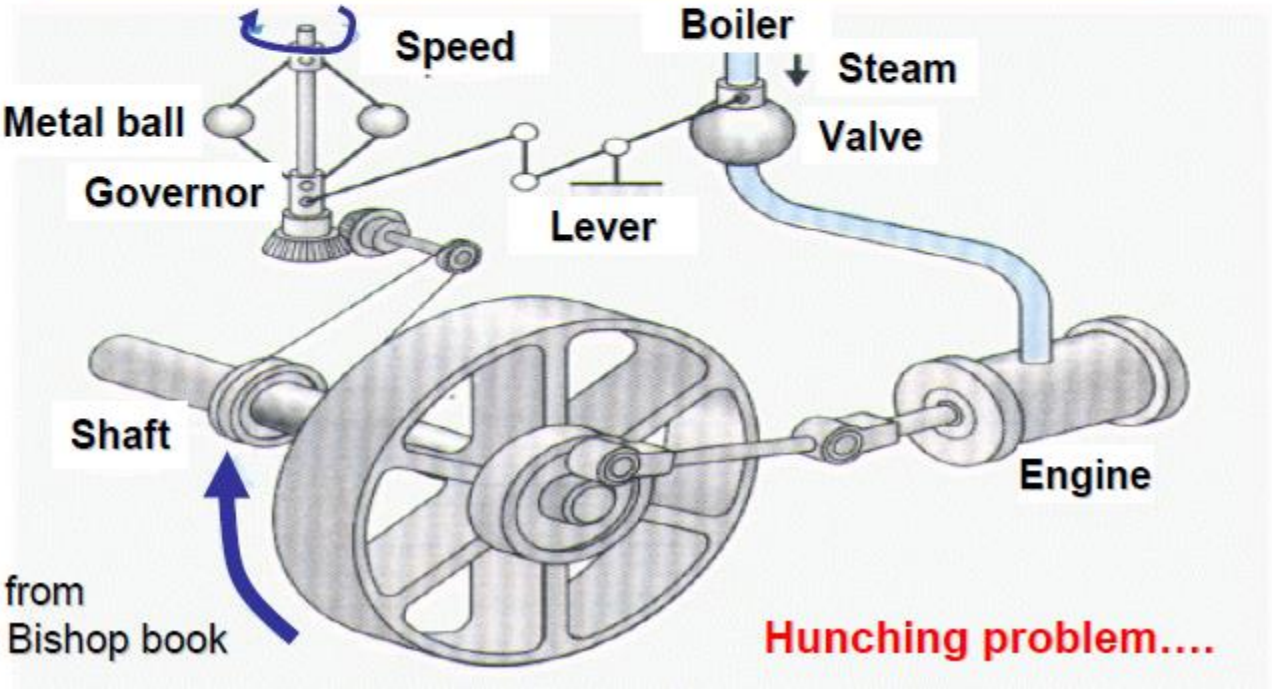
Year: 1788

- The key innovation to Industrial Revolution
  - Steam locomotive
  - Steam boat
- Birth of Feedback Control and Control Engineering



Steam engine with flyball governor

Flyball governor forces the engine to operate at a constant speed.



History of Automatic Control

James Maxwell (1831-1879)

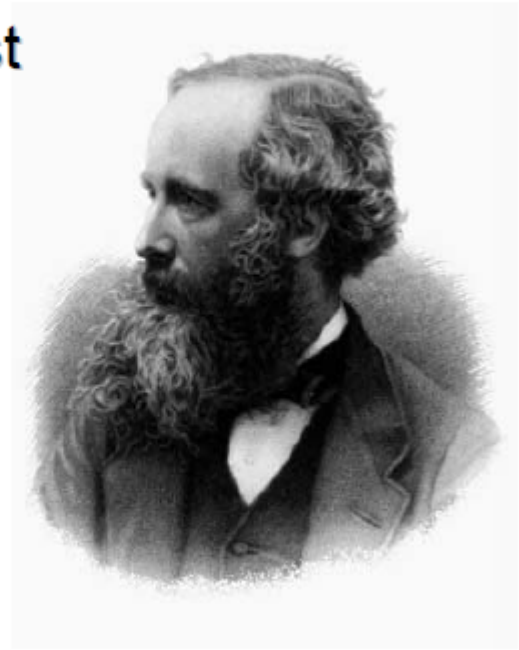
Scottish mathematician & physicist

University of Cambridge

A famous paper *"On governors"*

Year: 1868

- Analysis of stability for a 3rd-order differential equation
- Birth of Control Theory
- Special case of Routh-Hurwitz stability criterion



History of Automatic Control

Edward Routh (1831-1907)

English mathematician (born in Quebec)

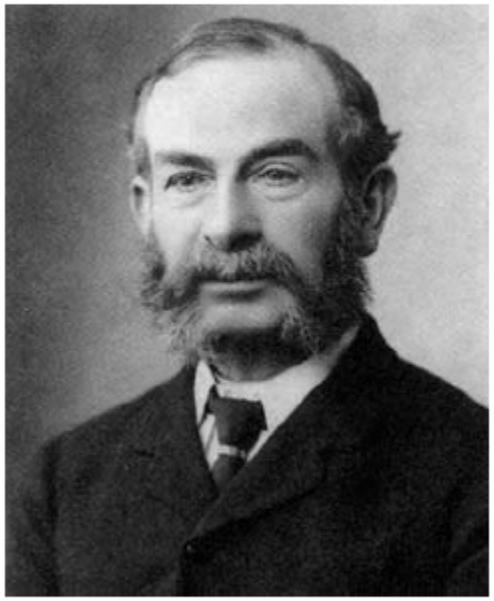
University of Cambridge

Routh stability criterion

Year: 1877

- Analysis of stability for ordinary differential equations
- Equivalent to Hurwitz criterion

(What you learned is Routh's criterion.)



History of Automatic Control

Adolf Hurwitz (1859-1919)

German mathematician

ETH Zurich

Hurwitz stability criterion

Year: 1895

- Analysis of stability for ordinary differential equations
- Equivalent to Routh criterion, but presented in a different form



History of Automatic Control

Aleksandr Lyapunov (1857-1918)

Russian mathematician

University of Saint Petersburg

Stability analysis

Year: 1892

- Lyapunov method
- Applicable to nonlinear, time-varying systems, too.

(Normally taught in *Nonlinear Control Course*.)



History of Automatic Control

Harold S. Black (1898-1983)

American electrical engineer

Bell Telephone Laboratories

*Negative **feedback** amplifier*

Year: 1927



- Long-distance telephone service by eliminating
  - Distortions (disturbance rejection)
  - Noises (noise rejection)
- It can be unstable…. (Nyquist!)

History of Automatic Control

Harry Nyquist (1889-1976)

American research engineer

Bell Telephone Laboratories

Nyquist stability criterion

Year: 1932

- Stability of feedback amplifiers
- Frequency domain (Earlier stability analyses are in time domain.)
- Cauchy's theorem in complex function theory



History of Automatic Control

Hendrik W. Bode (1905-1982)

American research engineer

Bell Telephone Laboratories

Bode plot (1938)

Feedback amplifiers (1945)

- Sensitivity
- Bode integral formula
- Frequency domain feedback design and analysis



History of Automatic Control

John Ziegler (1909-1997)

American process control engineer

Taylor Instruments

Ziegler-Nichols tuning rule (1942)



Nathaniel Nichols (1914-1997)

Mathematician

Taylor Instruments, MIT

Ziegler-Nichols tuning rule (1942)

Nichols chart (1947)



History of Automatic Control

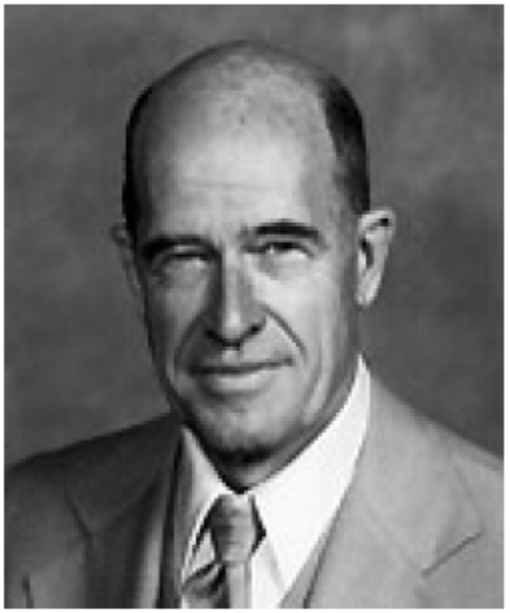
Walter R. Evans (1920-1999)

American engineer

North American Aviation

Root locus (1948)

- Unstable plants in aerospace control problems
- Difficult to apply frequency response techniques
- Back to characteristic equation and closed-loop poles



Categories of Automatic Control

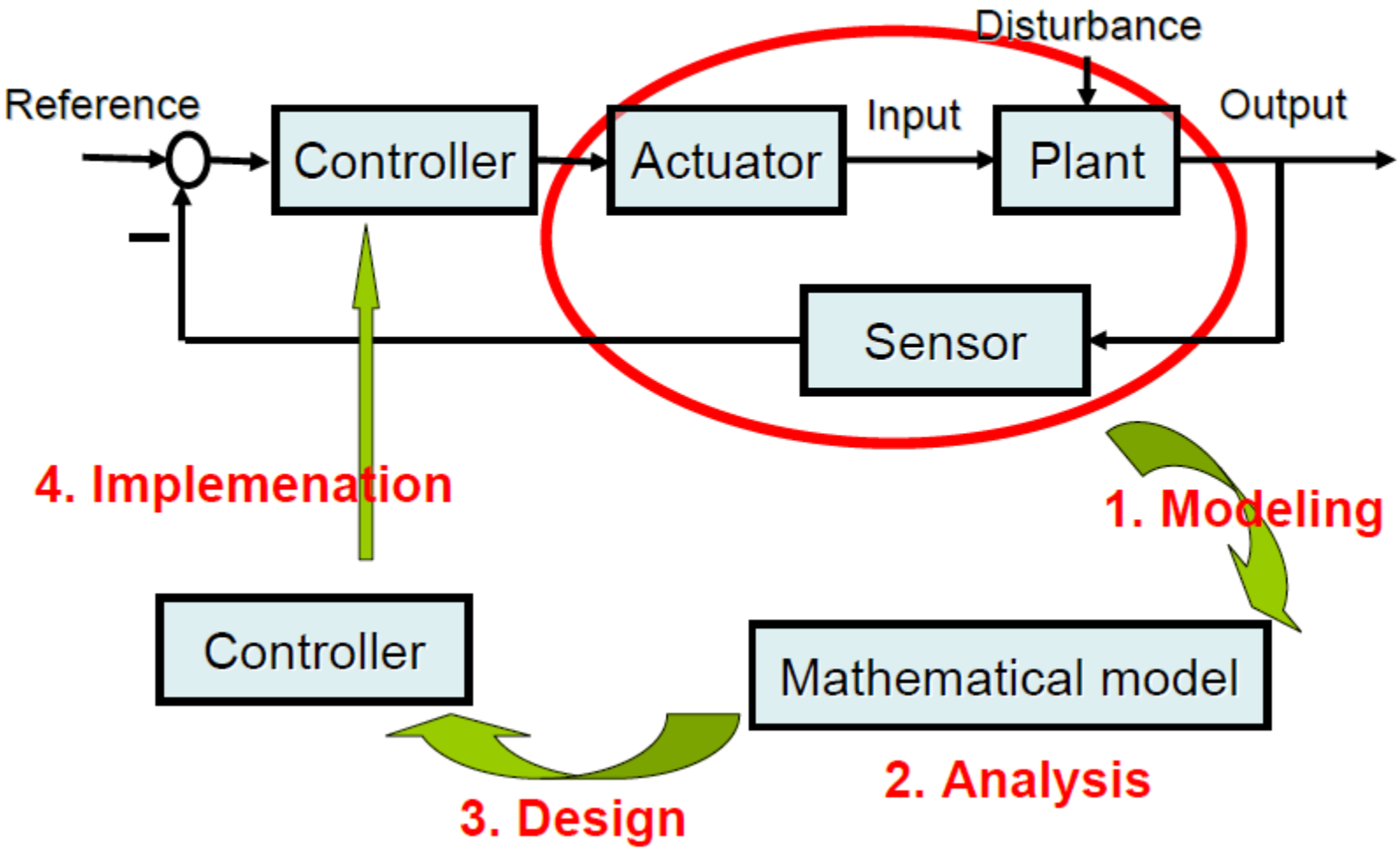
- Classical control (contents in this course)
  - Transfer function
  - Frequency domain
- Modern control (1960-)
  - State-space model
  - Time domain
  - Optimality
- Post-modern control (1980-)
  - Robust control
  - Hybrid control, etc.

Weak points of classical control

- Single-input single-output (SISO)
  (Multivariable (MIMO) control theory)
- Linear time-invariant
  (State-space, nonlinear control theory)
- No optimality in design
  (Optimal control theory)
- No robustness, except GM and PM
  (Robust control theory)

Much more control theory has been, and is being, developed!

Systematic controller design process

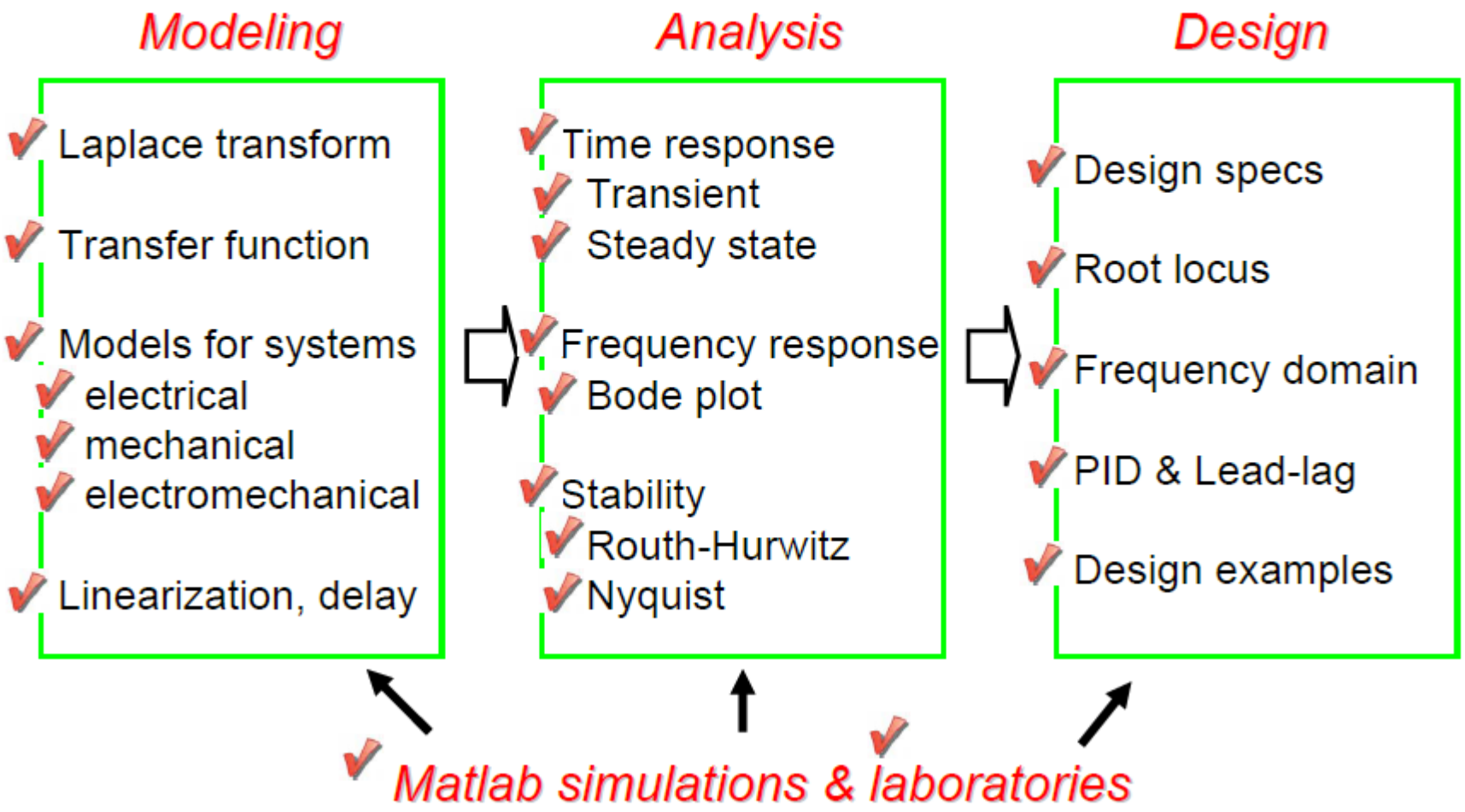


Goals of this course

To learn basics of feedback control systems

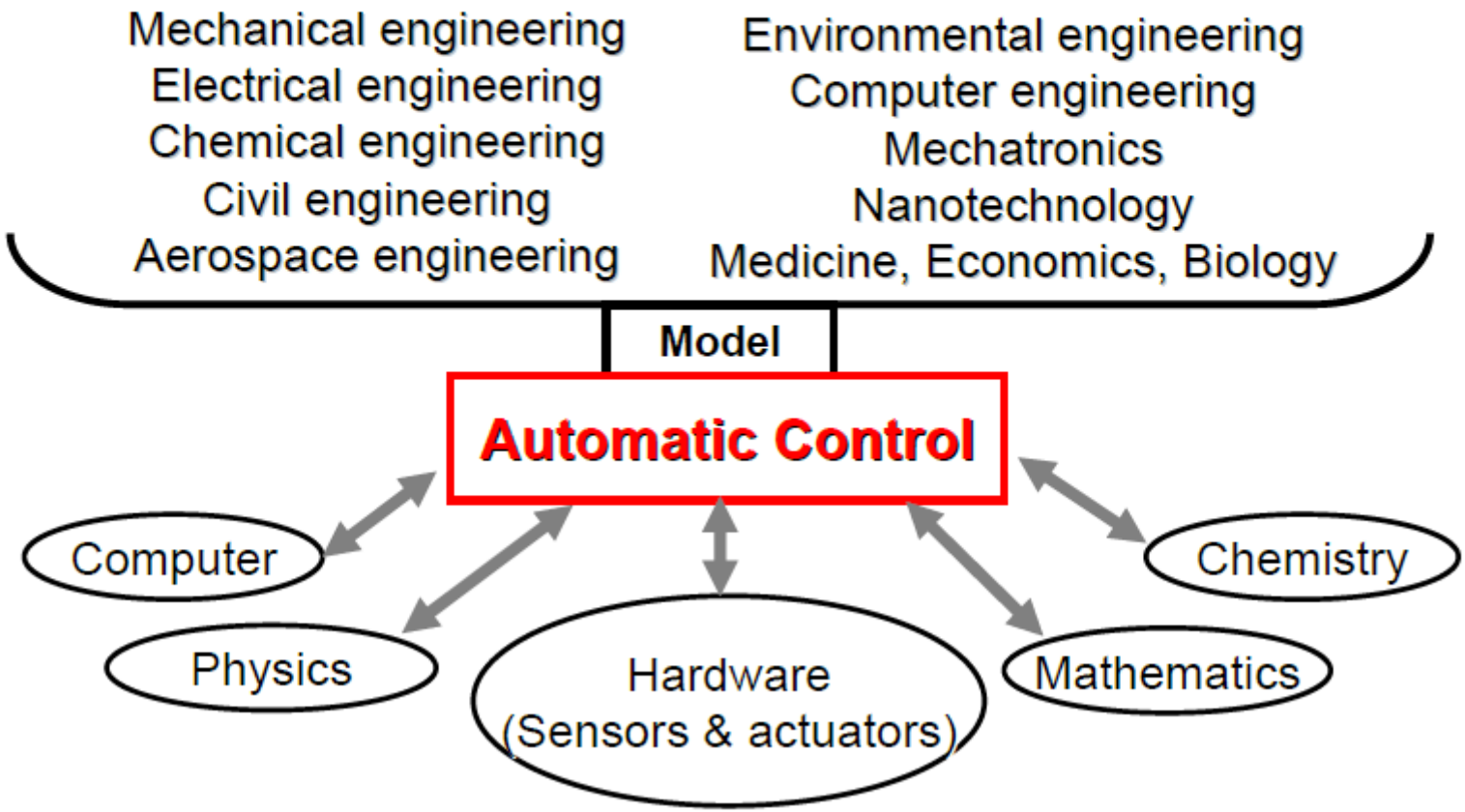
- Modeling as a transfer function and a block diagram
  - Laplace transform (Mathematics!)
  - Mechanical, electrical, electromechanical systems
- Analysis
  - Time response, frequency response
  - Stability: Routh-Hurwitz criterion, Nyquist criterion
- Design
  - Root locus technique, frequency response technique, PID control, lead/lag compensator
- Theory, simulation with Matlab, practice in laboratories

Course roadmap



Summary

Automatic control supports various disciplines!



GOOD LUCK
ON YOUR
FINAL EXAM