Introduction

Robust Control Course

Department of Automatic Control, LTH

Autumn 2011

Any mathematical model is merely an approximation of the real world

After designing controller C for model M, we apply real-world controller implementation C_r to a real-world plant P ...

- $M \neq P$
- $C \neq C_r$

Therefore, we need a "robust" design, namely,

$$\left.\begin{array}{ccc} P & \approx & M \\ C_r & \approx & C \end{array}\right\} \quad \Rightarrow \quad (P, C_r) \approx (M, C).$$

- How to check this? (Analysis problem)
- How to design such a controller? (Synthesis problem)

Short historical note

Early theoretical insights:

Nyquist curve (1932); Bode diagram (1940); Loop shaping; QFT (1970's) ...

- enable to design for certain stability margins (robustness)
- QFT allows to handle uncertainties explicitly
- restricted to SISO case

Later control methodologies:

State-space techniques; $\mathbb{H}_2$ theory (1970's)

- provide unified framework for MIMO controller synthesis
- difficult to deal with uncertainties

$\mathbb{H}_\infty$ theory (1980's)

- provide tools for dealing with uncertainties

Robust control:

unstructured uncertainties and small gain theorem;
structured uncertainties and μ-synthesis ...

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Robust control:

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To study robust control we need some background ...

What is this course about? (revised)

$\mathbb{H}_2$ and $\mathbb{H}_\infty$ optimal control: unified framework for MIMO synthesis

- state-space methods
- nominal stabilization and performance

Robust control: dealing with model uncertainties

- small gain theorem and its use
- μ - synthesis
- $\mathbb{H}_\infty$ loop shaping

Course outline

Lecture 1: Introduction and Background

- some topics in algebra
- Banach and Hilbert spaces
- spaces of signals and systems

Lecture 2: MIMO LTI systems

- poles and zeros of MIMO systems
- coprime and spectral factorizations
- state-space machinery

Lecture 3: Nominal stabilization

- generalized plant setting
- well posedness and internal stability
- Youla/Kucera parameterization

Lecture 4: Nominal performance

- standard $\mathbb{H}_2$ problem
- standard $\mathbb{H}_\infty$ problem
- performance limitations

Lecture 5: Unstructured uncertainties

- uncertainty representation
- small gain theorem
- robust stabilization and performance

Lecture 6: Structured uncertainties

- structured singular values
- μ-synthesis

Lecture 7: $\mathbb{H}_\infty$ loop shaping

Course literature

Course book:

"Essentials of Robust Control" by K. Zhou and J.C. Doyle

Other books:

"Robust and Optimal Control" by K. Zhou, J.C. Doyle and K. Glover

"Linear Robust Control" by M. Green and D.J.N. Limebeer

"Design Methods for Control Systems" by O.H. Bosgra and H. Kwakernaak

"A Course in Robust Control Theory a Convex Approach" by D.E. Dullerud and F.G. Paganini

Slides etc.

The lectures are based on:

- slides from the previous years by A. Gulchak, A. Rantzer and B. Bernhardsson
  http://www3.control.lth.se/ furobust/07/
- “Linear Control Systems” course at Technion-IIT by L. Mirkin
  not available online
- “Essentials of Robust control” course by Kemin Zhou
  http://www.ee.lsu.edu/kemin/essentials.htm

You may find useful also the slides from:

- “Robust control” at Delft University by C. Scherer
  http://www.dcsc.tudelft.nl/ cscherer/robust.html
- “Robust control” at the University of Stuttgart by C. Scherer
  http://www.ist.uni-stuttgart.de/education/courses/robust/overview.shtml