Robust control of MIMO and Time-Delay Systems: an LMI approach

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Introduction

Some industrial examples (automotive and electromechanical applications).

1 Introduction to LMIs

1.1 What is an Linear Matrix Inequality?

Optimisation background, Definition

1.2 Performances and stability

H_∞ performance, Bounded Real Lemma, Internal stability (small gain theorem), well posedness, quadratic stability

1.3 Towards control design

The state feedback case, Robust stability

PART I . ROBUST CONTROL OF MIMO SYSTEMS

2 H_∞ control design

2.1 Performance analysis and specifications

- frequency-domain performance indices (sensitivity functions, stability and robustness margins, bandwith, SISO and MIMO cases)
- Selection of weight functions.
  Loop-shaping
  Mixed sensitivity problem.

2.2 Solution

- Obtaining the General control configuration
- Problem solution using LMIs (output feedback control design)

3 Uncertainty and robustness

3.1 Representing uncertainties

Unmodeled dynamics, frequency forms, unstructured uncertainties
Parametric uncertainties, LFT forms, structured uncertainties

3.2 Robust stability analysis

$M\Delta$ structure, small gain theorem
Robust stability for unstructured uncertainties.

3.3 Robust performance analysis

A simplified H_∞ criterion
Introduction to μ-analysis - structured uncertainties.

PART II . ABALYSIS AND CONTROL OF TIME-DELAY SYSTEMS

4 Why time-delay systems are of interest ?

- Some examples and inherent limitations of TDS: effect of delay on stability and performances.
- The cases of input and state system delays: main consequences in both cases
- Models of Time-delay systems (TDS)
  - Representation of infinite dimensional equations, functional differential equations, ring models ...
  - The mathematic tools associated with these representations.
  - Analysis of the coherence between these cases
- Applicative cases where delays have a strong impact: Real-time control systems, Teleoperation systems, engine control, population dynamics

5 TDS Analysis

5.1 Controllability/ Observability

5.2 Stability and Performance analysis

5.2.1 Analysis

- Analysis in the Time-domain approach: extension of the Lyapunov approach to get Lyapunov-Razumikihn and Lyapunov-Krasovskii theorems.
- Analysis in the Frequency domain approach : direct method, frequency-sweeping tests, small-gain theorem

5.2.2 Some important issues in stability analysis

- Definition and criteria for delay-dependent and delay independent stability: proposition of different LMIs criteria
- Different model transformations:
- How to choose a Lyapunov-Krasovkii functionals ?
- Main differences with constant and time-varying delays: what methods can be generalized to the latter case?

5.3 Towards robustness

- Robust stability of time-delay systems: cases of polytopic and norm-bounded uncertainties
- How to account for uncertain delays ?
- Input-Output stability : H_∞ (or $\mathcal{L}_2$ induced) criterion: Bounded Real Lemma

6 Observation

- Analysis and design of Unknown input observers: necessary and sufficient existence conditions, design procedure, and example
- H_∞ observer: design of observers to minimize the effect of external disturbances.
- Robust observers: account for system uncertainties and delay uncertainties. What about the delay margin for stability ?

7 Control

- Predictor-based methods: Smith-predictor and Finite Spectrum Assignement. Comparison and illustration of both methods
- Observer-based controller: comparison of separate observer/state feedback design and of a unique design of such controllers.
- Recent results on LPV TDS: Use of LPV approach to design Delay-scheduled state feedback controllers: stability and stabilization formulation.

8 MATLAB© session

8.1 Control of flexible structure:

- H_∞ control
- Robust stability and performance analysis

8.2 TDS

- Definition of TDS using Matlab
- illustration of predictive methods on a simple pure delay system

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