Robust Control

18-849b Dependable Embedded Systems

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Required Reading: Some Crisp Thoughts on Fuzzy Control, Abramovitch,D., Proceedings of the American Control Conference, June 1994.

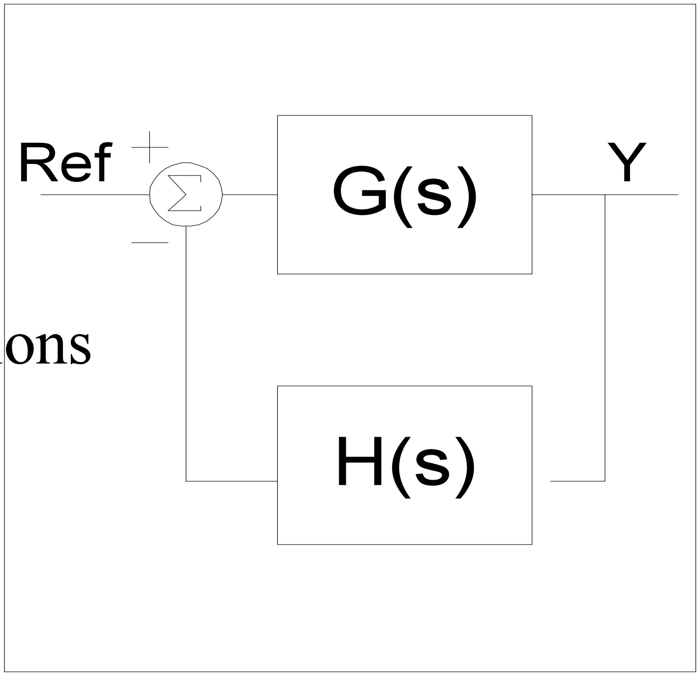
Best Tutorial: Robust Control of Linear Dynamical Systems, Chandrasekharan, P., Academic Press, 1996

Overview

- Control Theory
- Key Concepts
  - What is robustness?
  - What's the big deal?
  - Modeling
- Techniques
- Connections
- Conclusion
- Paper Discussion

Control Theory

- Conventional Control (to 1950)
  - Feedback theory
  - Classic solution to differential eq.
  - Laplace techniques and transfer funtions
  - SISO
  - Root-locus methods of stability
- Modern Control (1950 to present)
  - Reducing to n 1st order equations
  - State methods and matrices
  - Optimization
  - MIMO

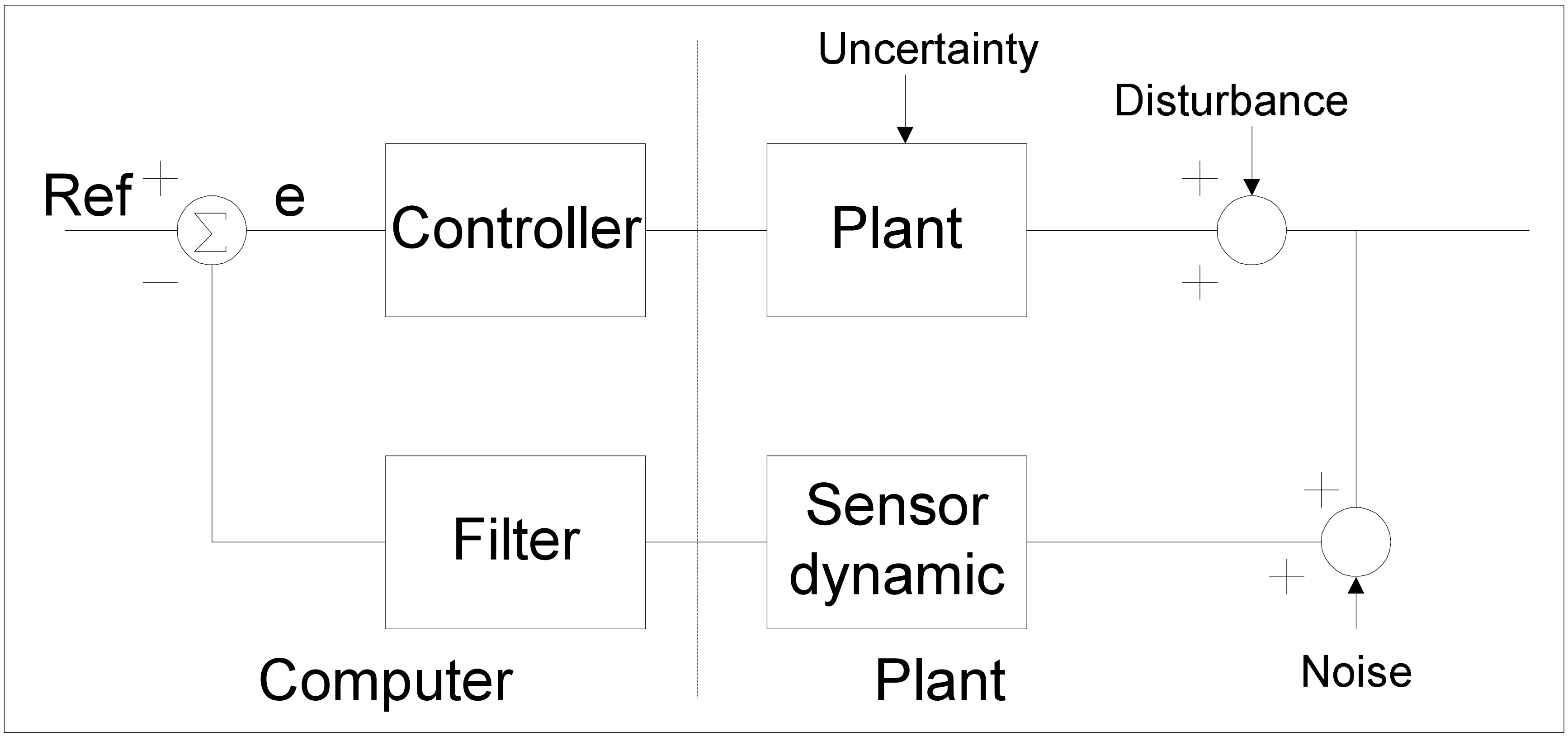


$$\dot{\vec{x}} = A\vec{x} + B\vec{u}$$

$$\vec{y} = C\vec{x} + D\vec{u}$$

Robustness

- Robust control refers to the control of unknown plants with unknown dynamics subject to unknown disturbances. - Chandrasekharan



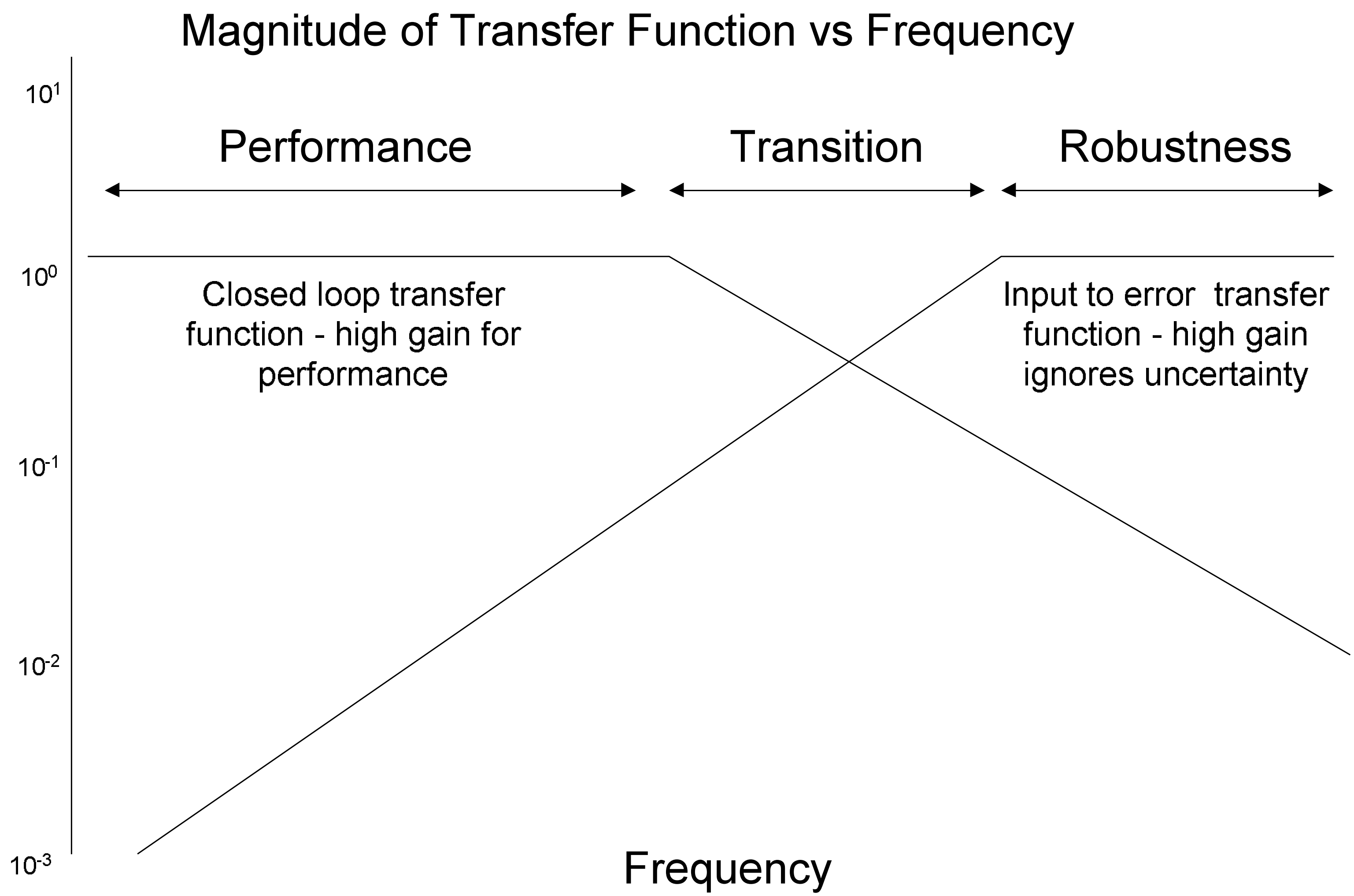
Why do we care?

- Big 3 in Control
  - Observability
  - Controllability
  - STABILITY
- Secondary Considerations
  - Performance
  - Cost
- Stocastic Control
  - Model uncertainty with probability distribributions
- Robust Control
  - Bounding the error

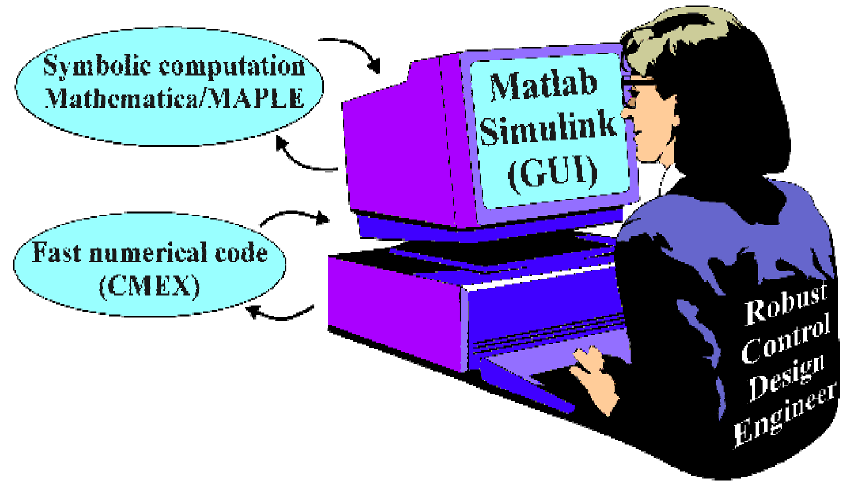
Modeling

- Why so hard?
  - Imperfect plant data
  - Real world is non-linear and time-varying
  - Higher order dynamic
  - Complexity
  - Tolerances introduce variation
  - Requires various skills
- Model Reduction
  - Simplicity for cost and computation

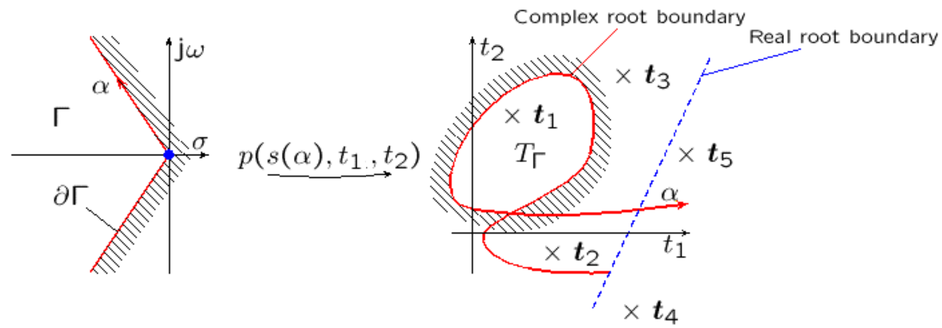
Performance vs Robustness



Tools / Techniques / Metrics



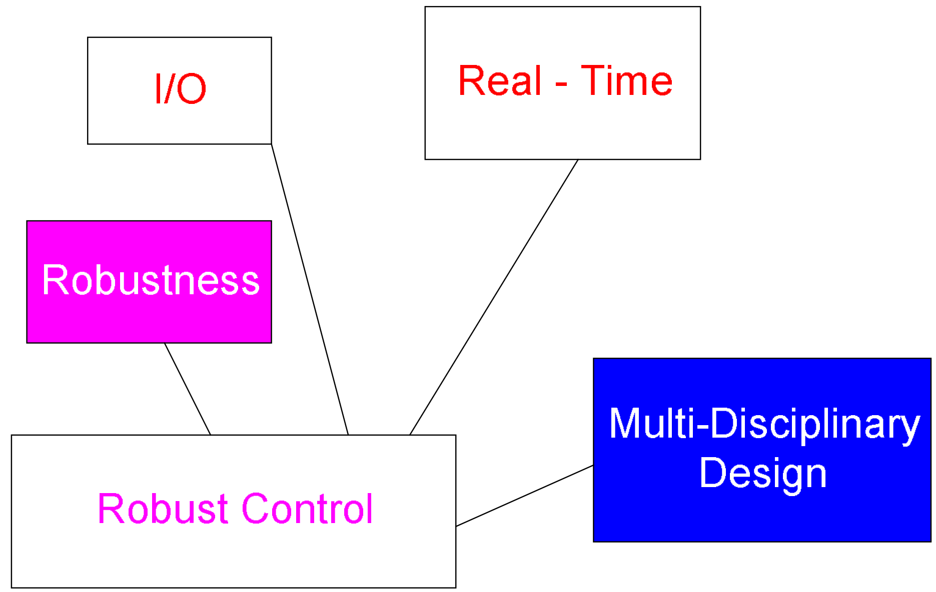
- Adaptive Control
  - System identification
  - Dual role of Control
- H_2 and $H_{infinity}$
  - Frequency domain (stability)
  - Norms are generalization of length
  - Used to bounds ouput power (H_2) or energy ($H_{infinity}$)
- Parameter Estimation
  - Selection of best controller
  - Clues how to change system



- Lypanov
  - Only general method for non-linear
- Fuzzy Control
  - Uncertain sets

Connections

- Multi-Disciplinary
  - Modeling requires mechanical, electrical, processs people, applied maths
- I/O
  - Interface with the plant
- Real Time
  - Sampling rates
- Robustness



Conclusions

- New concern for extremes of operation
- Trade-off between conservatism (robustness) and performance
- Good models are difficult to construct
- Research in last 15 years has lead to growth in techniques
- Techniques have been criticized for accesibility, tediousness, general application, and conservatism
- Tools to handle complexity introduce issue of correctness
- Gap between theory and practice closing?

Paper: Crisp Thoughs on Fuzzy ...

- Controversial
- Common sense applications only?
- Sample rate drives performance
- Success relies on lots of sensors
- No help in generating control laws