ECE 1673: Linear Control Systems (4 Credits, Spring 2009)

Lecture 20: Frequency Response Design (II)

March 30, 2009

Instructor: Zhi-Hong Mao
Assistant Professor of ECE and Bioengineering
University of Pittsburgh, Pittsburgh, PA

Homework 8

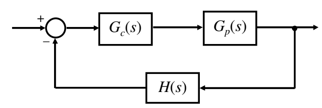
- Problems 9.1 and 9.2 (a)-(d) in the text book
- Due April 9 (Wednesday)

Outline of this lecture

- Compensation (about cascade compensation and how to derive system characteristic equation of the form $1+G_c(s)G_e(s)=0$)
- Gain compensation
- Phase-lag compensation (I)
- Concepts in modern control (I): centralized and decentralized control

Compensation

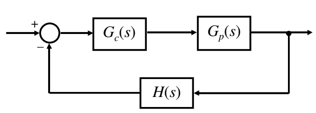
- Cascade (or series) compensation



Question: What is the characteristic equation of the above system?

Compensation

- Cascade (or series) compensation

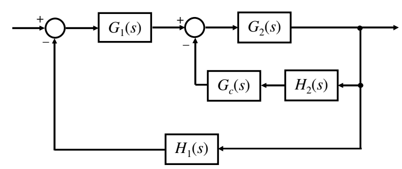


$$1+G_c(s)G_p(s)H(s)=0$$

- Many of the effects of the compensation on system characteristics are indicated by the locations of the roots of the characteristic equation

Compensation

- Cascade (or series) compensation
- Compensator within an internal loop



Question: What are the transfer function and characteristic equation of the above system?

Compensation

- Cascade (or series) compensation
- Compensator within an internal loop

$$1+G_1(s)G_2(s)H_1(s)+G_c(s)G_2(s)H_2(s)=0$$

Question: Can the above equation be transformed into the below equation?

$$1+G_c(s)G_e(s)=0$$

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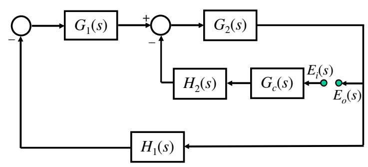
Compensation

- Cascade (or series) compensation
- Compensator within an internal loop
- A procedure to derive characteristic equation of the form $1+G_c(s)G_e(s)=0$
  – The system input is ignored, and the system is opened at the input of the compensator



Question: What is the transfer function from $E_i(s)$ to $E_o(s)$?

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Compensation

- Cascade (or series) compensation
- Compensator within an internal loop
- A procedure to derive characteristic equation of the form $1+G_c(s)G_e(s)=0$
  – The system input is ignored, and the system is opened at the input of the compensator
  – Find $G_{ol}(s)$ such that

$$E_o(s)=G_{ol}(s)E_i(s)$$

This function is called open-loop transfer function

Questions: What is the definition of open-loop function? What is the relationship between open-loop function and open-loop transfer function?

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Compensation

- Cascade (or series) compensation
- Compensator within an internal loop
- A procedure to derive characteristic equation of the form $1+G_c(s)G_e(s)=0$
  – The system input is ignored, and the system is opened at the input of the compensator
  – Find $G_{ol}(s)$ such that $E_o(s)=G_{ol}(s)E_i(s)$
  – The system characteristic equation is then

$$1-G_{ol}(s)=0$$

Question: What is the relationship between $G_e(s)$ and $G_{ol}(s)$?

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Gain compensation

- The compensator is simply a gain $G_c(s)=K$
- The effect of gain K on Nyquist diagram
  – The Nyquist diagram is enlarged or reduced but its shape cannot be changed

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Gain compensation

- The compensator is simply a gain $G_c(s)=K$
- The effect of gain K on Nyquist diagram
- The effect of gain K on Bode diagram

Question 1: How will the magnitude characteristic change with respect to the change of gain K?

Question 2: How will the phase characteristic change?

Question 3: How will the phase margin change?

Question 4: How will the gain margin change?

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Gain compensation

- The compensator is simply a gain $G_c(s) = K$
- The effect of gain K on Nyquist diagram
- The effect of gain K on Bode diagram

Review question 1: What characteristic of frequency response is closely related to rise time?

Review question 2: What characteristic of frequency response is closely related to settling time?

Review question 3: What characteristic of frequency response is closely related to overshoot?

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Phase-lag compensation (I)

- Phase-lag compensator has the transfer function

$$G_c(s) = \frac{1 + s/\omega_0}{1 + s/\omega_p}$$

Question 1: Which one is bigger, ω_0 or ω_p?

Question 2: What is the Bode diagram for this compensator?

Question 3: Is it a low-pass filter or high-pass filter?

Question 4: What is the gain reduction at high frequency?

Question 5: What is the frequency at which the maximum phase lag occur?

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Centralized control vs. decentralized control

- Centralized control allows system components (or agents in a multi-agent system) to be intentionally directed with demanded precision
- However, centralized control may be
  - Computationally intensive (a "big-brother" controller is needed to make all the decisions)
  - Less reliable (it is disastrous if the centralized controller is disabled)
  - Considerably demanding of communication resources

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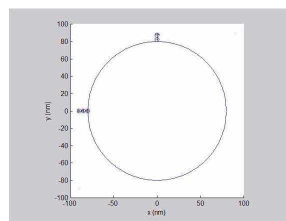
Centralized control vs. decentralized control

- Examples of decentralized control



Intersecting flows of aircraft

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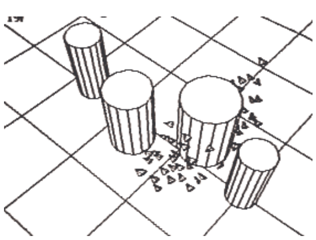
Centralized control vs. decentralized control

- Examples of decentralized control



Flight formation

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Centralized control vs. decentralized control

- However, we still need centralized control

Honda

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Talk Announcement: Benedum 360, 10:00 am today!

Distributed Consensus in Multi-vehicle Cooperative Control

Prof. Wei Ren, Utah State University

Abstract: While autonomous vehicles that perform solo missions can yield significant benefits, greater efficiency and operational capability will be realized from teams of autonomous vehicles operating in a coordinated fashion. Potential applications for multiple autonomous vehicles include autonomous household appliances, hazardous material handling systems, distributed reconfigurable sensor networks, surveillance and reconnaissance, space-based interferometry, and future autonomous combat systems. To enable these applications, a variety of cooperative control capabilities need to be developed. These capabilities include formation control, rendezvous, attitude alignment, flocking, foraging, task and role assignment, payload transport, air traffic control, and cooperative search. Execution of these capabilities requires that individual vehicles share a consistent view of the objectives and the world. Information consensus guarantees that vehicles sharing information over a network topology have a consistent view of information that is critical to the coordination task. By necessity, consensus algorithms are designed to be distributed, assuming only neighbor-to-neighbor interaction between vehicles. Consensus algorithms have applications in rendezvous, formation control, flocking, attitude alignment, and sensor networks.

The purpose of this talk is to overview our recent research in distributed consensus algorithms and their applications in multi-vehicle cooperative control. Theoretical results on distributed consensus algorithms where the dynamics of the information state evolve according to first- and second-order dynamics and according to rigid body attitude dynamics and Euler-Lagrange equations will be introduced. Application examples of the distributed consensus algorithms in multi-vehicle cooperative control including rendezvous and formation keeping for wheeled mobile robots, UAV formation flying, deep space spacecraft attitude alignment, and synchronization of networked Euler-Lagrange systems will also be introduced.

References

- C. L. Phillips and R. D. Harbor. Feedback Control Systems, 4th Edition, Prentice Hall, 2000.
- http://en.wikipedia.org/wiki/Pholcidae
- http://www.mpoweruk.com/semiconductors.htm