

BioE 2696/ECE 2695: Control Theory in Neuroscience  
(3 Credits, Spring 2009)

## Interim Review

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

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## Outline

- Six basic concepts

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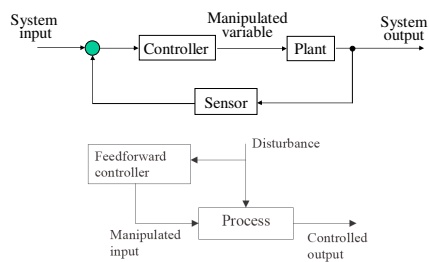
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## Concepts (1)

- Feedback
  - Open-loop and closed-loop; feedback control and feedforward control



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### Concepts (1)

- Feedback
  - Open-loop and closed-loop; feedback control and feedforward control
  - Advantages and disadvantages

Compared to open-loop control, feedback can be used to reduce steady-state error, reduce the system errors to disturbances, reduce the system's sensitivity to parameter variations, speed up the transient response, and stabilize the system. However, feedback may create instability.

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### Concepts (2)

- Transfer function
  - LTI systems
  - Laplace transform and inverse transform

Exercise: Find impulse response of the following system.

$$G(s) = \frac{s^2 + 2s + 2}{s^2 + 3s + 2}$$

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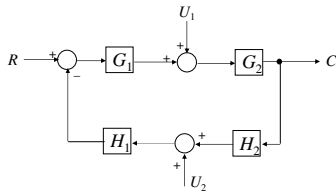
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### Concepts (2)

- Transfer function
  - LTI systems
  - Laplace transform and inverse transform
  - Block diagrams

Exercise: Determine the output  $C$  due to  $U_1$ ,  $U_2$ , and  $R$ .



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## Concepts (2)

- Transfer function
  - LTI systems
  - Laplace transform and inverse transform
  - Block diagrams
  - What does a transfer function tell us?

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## Concepts (2)

- Transfer function
  - LTI systems
  - Laplace transform and inverse transform
  - Block diagrams
  - What does a transfer function tell us?
    - Model of the system dynamics in differential equations
    - Impulse response
    - Steady-state response to a step input
    - Frequency response
    - Characteristics of the natural response (transient response)
    - Stability of the system

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## Concepts (3)

- Time-domain analysis
  - First-order and second order systems
    - Why do we emphasize first-order and second-order systems?
    - Time constant, dc gain, damping ratio, and natural frequency
  - Time responses
    - Step response
    - Time response specifications in design (rise time, overshoot, settling time, and steady state value)
    - System identification based on time responses
  - Steady state accuracy
  - Transient response
  - Effect of poles and zeros

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### Concepts (4)

- Frequency-domain analysis
  - Frequency response function (magnitude change, phase shift, and bandwidth)
  - System identification based on frequency responses

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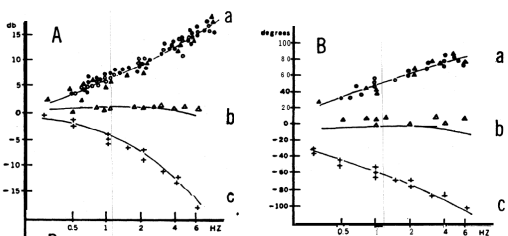
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### Concepts (4)

- Frequency-domain analysis
  - Frequency response function (magnitude change, phase shift, and bandwidth)
  - System identification based on frequency responses
  - Visualizing frequency response function




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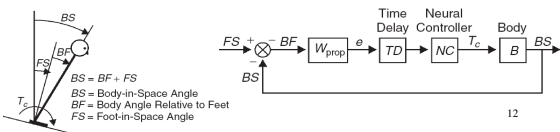
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### Concepts (5)

- Stability
  - Stability and maneuverability
  - BIBO stability for LTI systems and stability criterion
  - A little more about time delay
    - Effects of time delay in open-loop and closed-loop control
    - Approximation of time delay with a rational transfer function



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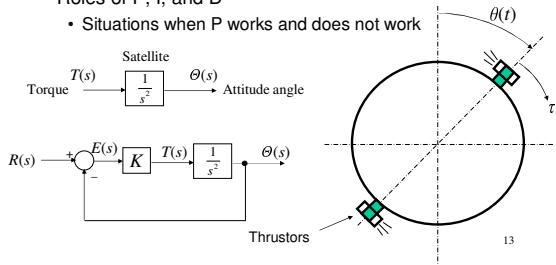
### Concept (6)

- PID controller

$$G_c(s) = K_p + \frac{K_I}{s} + K_D s \quad G_c(s) = K_p + \frac{K_I}{s} + \frac{K_D s}{1 + s / \omega_{pd}}$$

- Roles of P, I, and D

- Situations when P works and does not work




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### Concept (6)

- PID controller

$$G_c(s) = K_p + \frac{K_I}{s} + K_D s \quad G_c(s) = K_p + \frac{K_I}{s} + \frac{K_D s}{1 + s / \omega_{pd}}$$

- Roles of P, I, and D

- Situations when P works and does not work
- Situations when "I" works and does not work

**Question:** When time delay is introduced, do you want to increase  $K_I$  or decrease  $K_I$ ?

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### Concept (6)

- PID controller

$$G_c(s) = K_p + \frac{K_I}{s} + K_D s \quad G_c(s) = K_p + \frac{K_I}{s} + \frac{K_D s}{1 + s / \omega_{pd}}$$

- Roles of P, I, and D

- Situations when P works and does not work
- Situations when "I" works and does not work
- Situations when D works and does not work

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### Concept (6)

- PID controller

$$G_c(s) = K_p + \frac{K_I}{s} + K_D s \quad G_c(s) = K_p + \frac{K_I}{s} + \frac{K_D s}{1 + s/\omega_{pd}}$$

- Roles of P, I, and D



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### Concept (6)

- PID controller

$$G_c(s) = K_p + \frac{K_I}{s} + K_D s \quad G_c(s) = K_p + \frac{K_I}{s} + \frac{K_D s}{1 + s/\omega_{pd}}$$

- Roles of P, I, and D

Closed-loop response	Rise time	Overshoot	Settling time	Steady-state error
$K_p$	Decrease	Increase	Small change	Decrease
$K_I$	Decrease	Increase	Increase	Eliminate
$K_D$	Small change	Decrease	Decrease	Small change

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Four-wheel drive

It is not always good to have more control...

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