MCE441: Intr. Linear Control Systems

Lecture 2: Control Engineering Cycle
Open-Loop and Closed-Loop
Positive vs Negative Feedback
Mathematical Models
Dynamic Modeling of Engineering Systems

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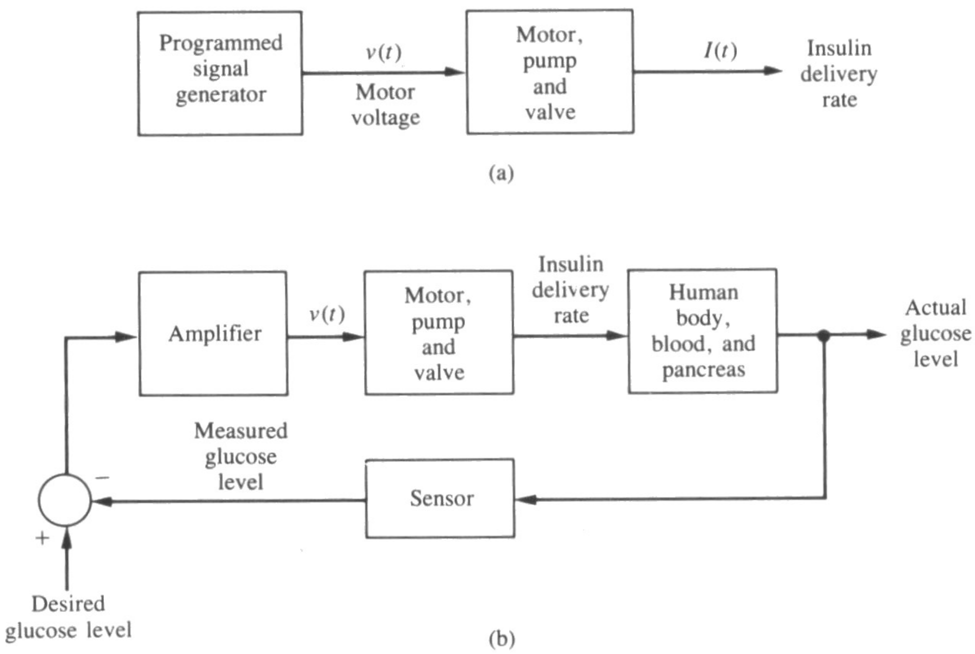
Open Loop and Closed Loop Control

- Open Loop (feedforward): Control input independent of output: Scheduling
- Useful with no uncertainties, no unpredictable disturbances: Know the future
- Closed Loop (feedback): Control input depends on output: Fundamental error correction mechanism
- If *judiciously* used, can reject disturbances, maintain stability and performance in the face of uncertainties.
- It can destabilize an open-loop stable system. Details later.

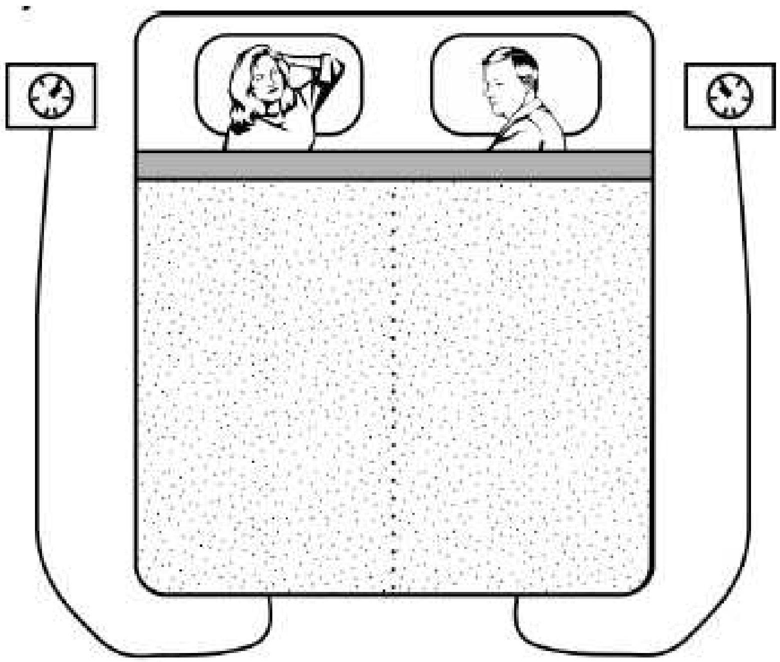
Feedforward vs Feedback: Example



Negative vs. Positive Feedback

- <u>Negative Feedback</u>: The fed back output and the reference input are subtracted
- Negative feedback has an error-compensating effect
- Still, too much or too little feedback can be destabilizing
- <u>Positive Feedback</u>: The fed back output and the input are added
- Positive feedback has a destabilizing effect
- Still, some systems can tolerate some positive feedback and remain stable. *More later...*

Negative Feedback - Usually good



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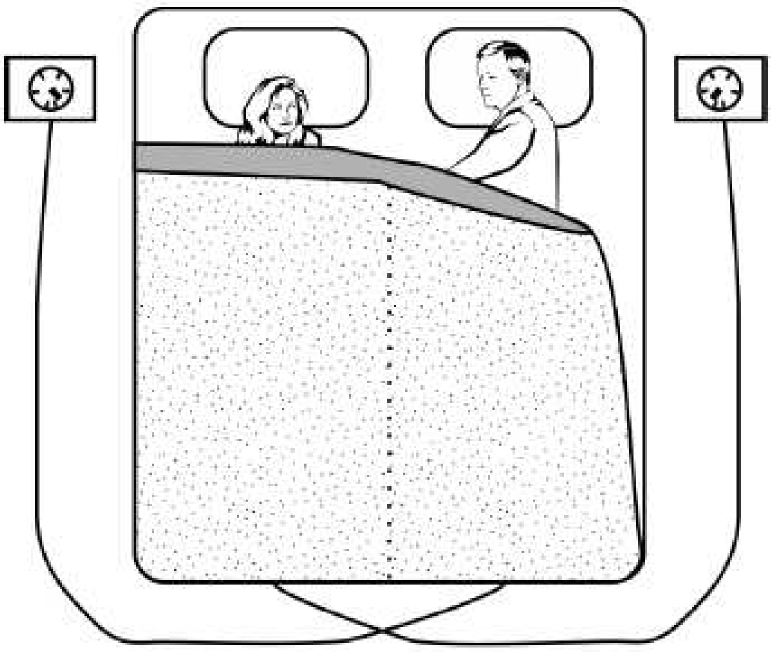
Positive Feedback - Usually bad



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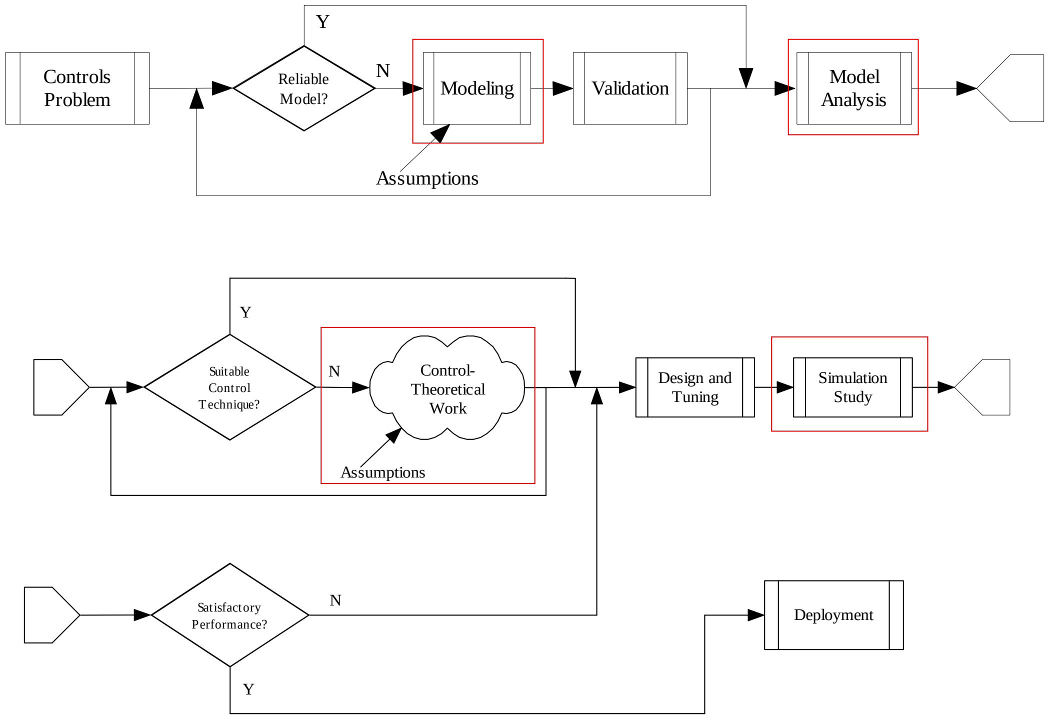
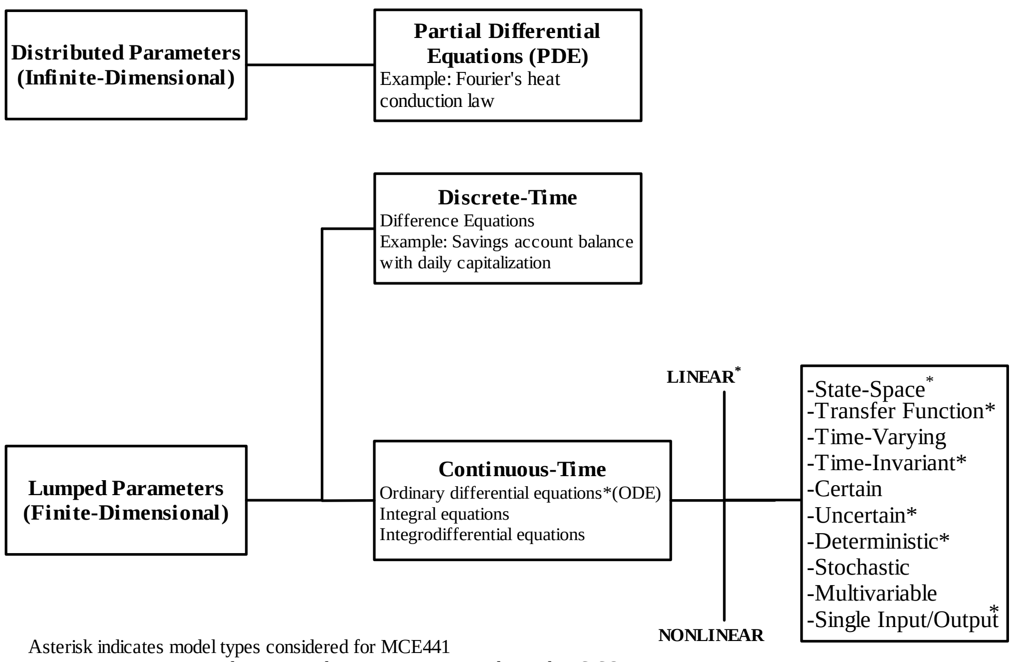
Control Design Cycle

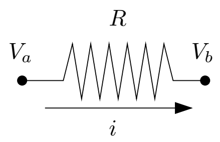


Classification of Models



Asterisk indicates model types considered for MCE441
Linear, time-invariant, single input, single output systems are denoted as SISO-LTI

Dynamic Modeling of Electrical Systems

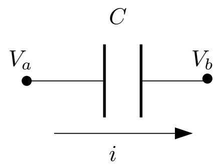


<u>Linear Resistor</u>

Variables:
Current i: Amperes (A)
Voltage V_{ab}: Volts (V)
Parameters:
Resistance R: Ohms (Ω)
1 A= 1 V/A

Law:

$i = \frac{V_a - V_b}{R}$



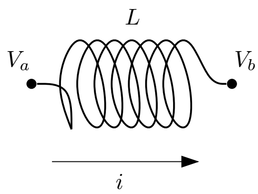
<u>Ideal Capacitor</u>

Variables:
Charge q: Coulomb (C)
Parameters:
Capacitance C: Farad (F)
1 A=1 F.V/s
1 C=1 F.V

Laws:

$i = C\frac{dV_{ab}}{dt}$

$q = CV_{ab}$ (integral form)



<u>Ideal Inductor</u>

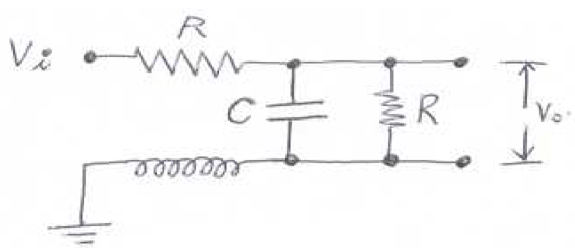
Parameters:
Inductance L: Henry (H)
1 V=1 H.A/s

Law:

$V_{ab} = L\frac{di}{dt}$

electrical systems...

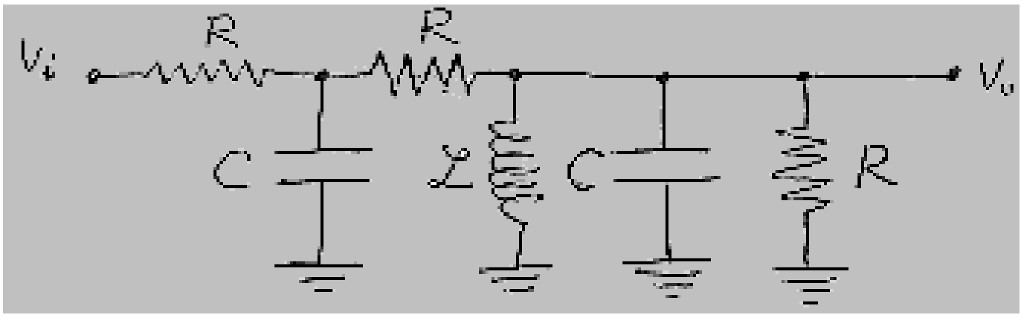
- Other elements: Op-Amps, Diodes (non-linear) presented later, if needed
- <u>Kirchhoff's Laws:</u>
- **Voltage Law**: "The sum of voltage differences around a loop must equal zero"
- **Current Law**: "The sum of currents at a node must be zero"
- Simple example: Find the input/output differential equation (in terms of V_o and V_i):



Solution

More difficult example

Find the input/output differential equation (in terms of V_o and V_i):



Solution

We can easily write all equations describing the system. Elimination of unwanted variables to produce the desired I/O equation can be difficult and tedious. The Laplace transform will greatly facilitate the process.

Solution

Solution

Exercise: Check that the required equation is

$$(RC)^2\dddot{V}_o + 4RC\ddot{V}_o + \left(3 + \frac{R^2C}{L}\right)\dot{V}_o + \frac{2R}{L}V_o = V_i$$