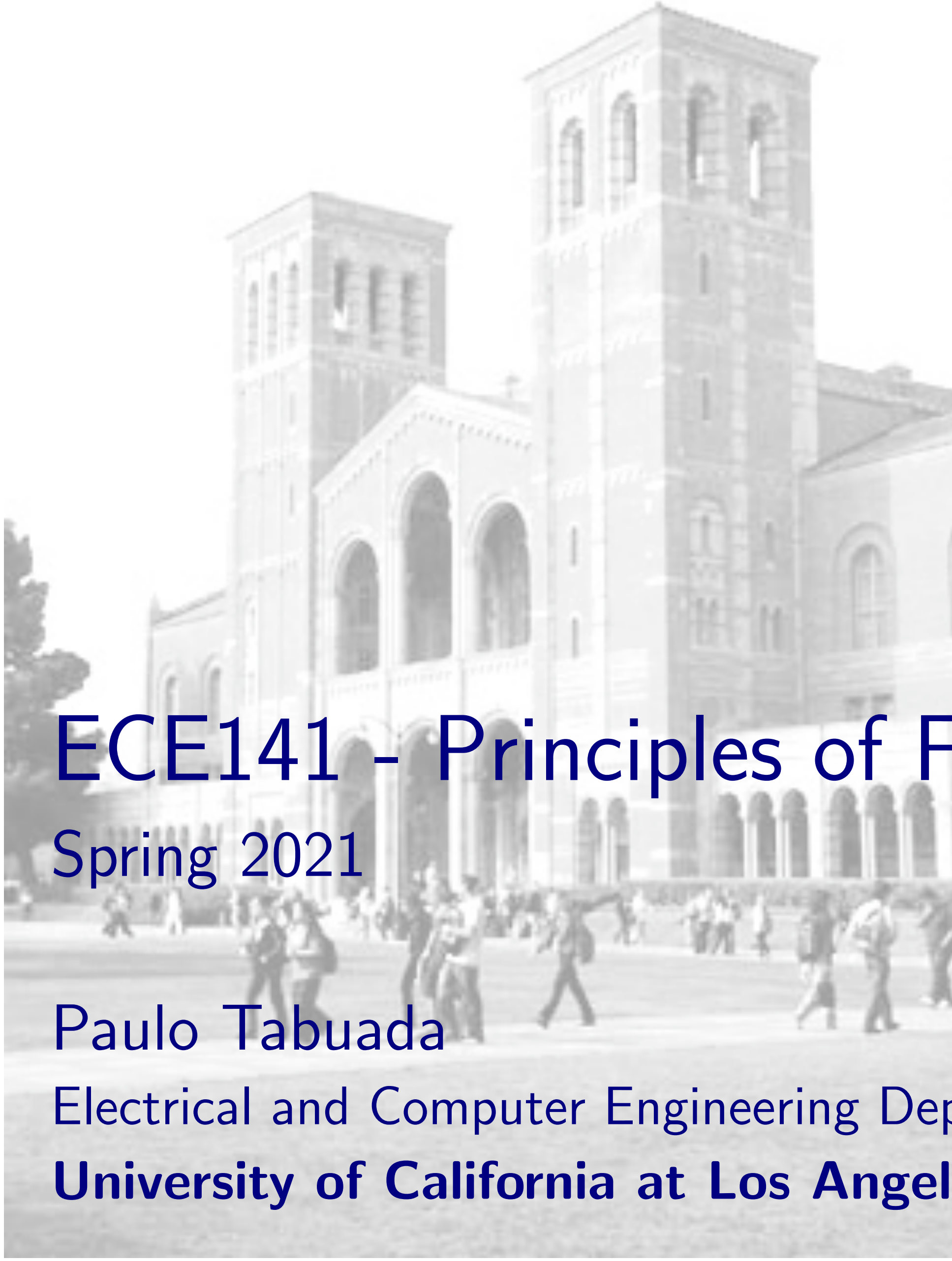

ECE141 - Principles of Feedback Control

Spring 2021

Paulo Tabuada

Electrical and Computer Engineering Department

University of California at Los Angeles

What is control engineering?

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It is the "art" of modifying the dynamic behavior of a system in order to make it work (better).

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What do I mean by “dynamic behavior”?

What do I mean by “system”?

What do I mean by “make it work”?

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Dynamics: Orientation of the sails' axis of rotation.

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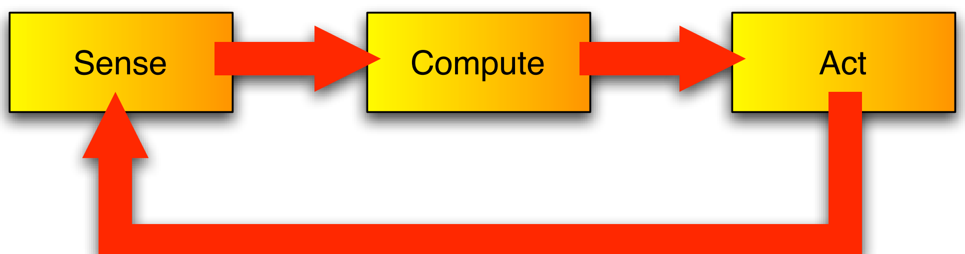

Examples

Highway congestion control provides another example of feedback control.

Objective: Avoid congestion.

System: Highway.

Dynamics: $\frac{dx}{dt} = C_{in} - C_{out}$ where x is the number of cars in the highway.

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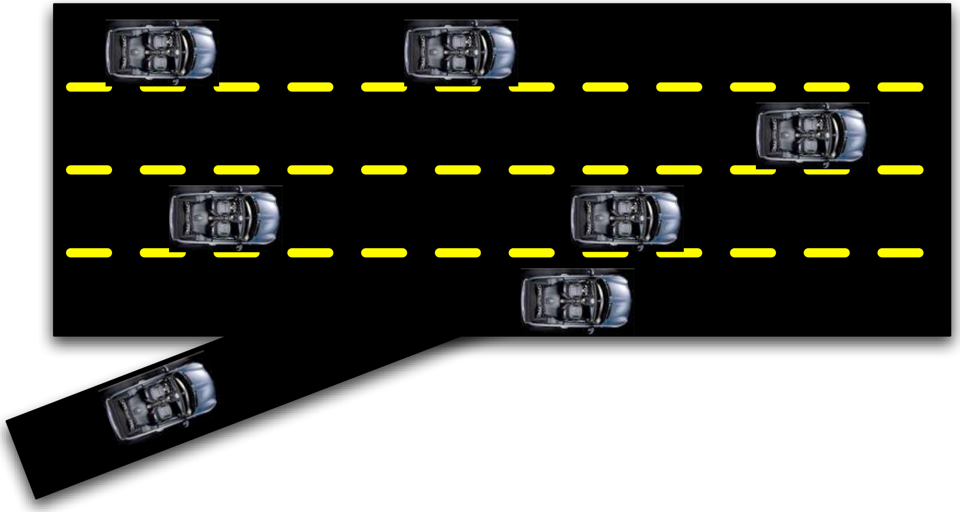

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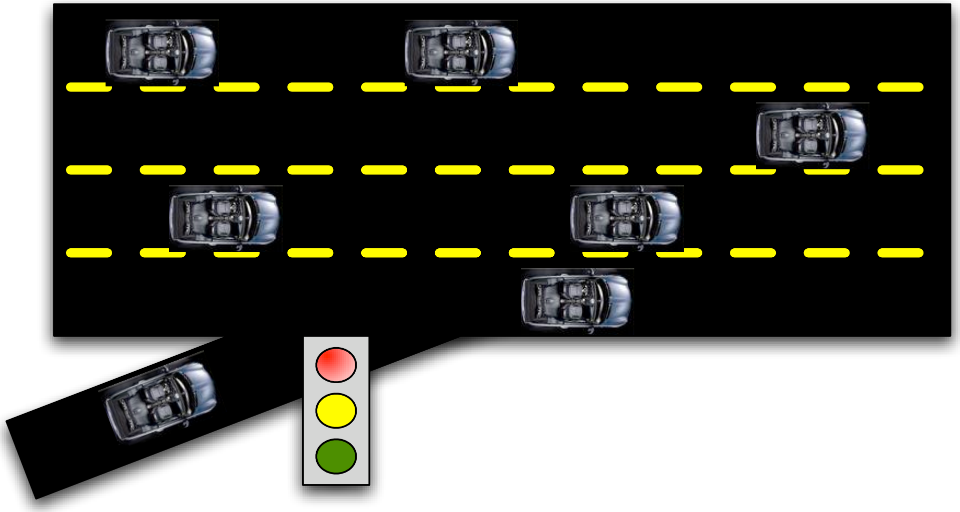

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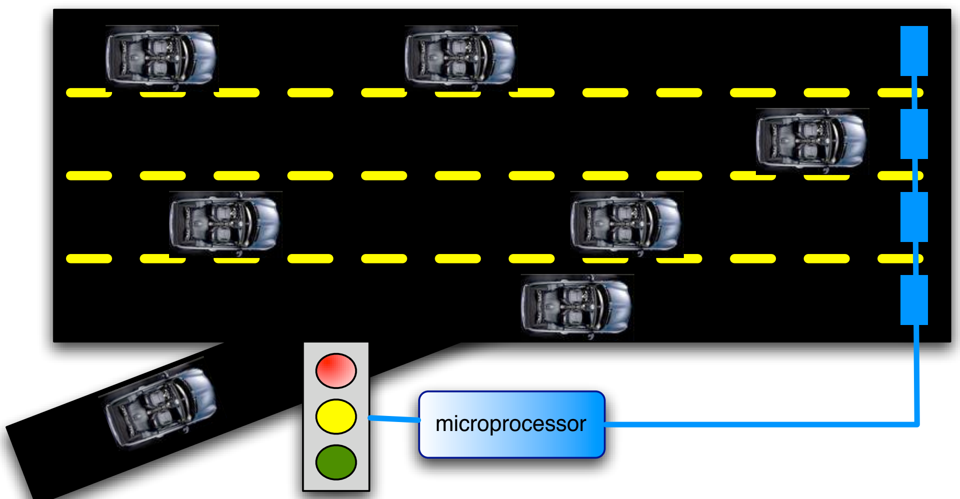
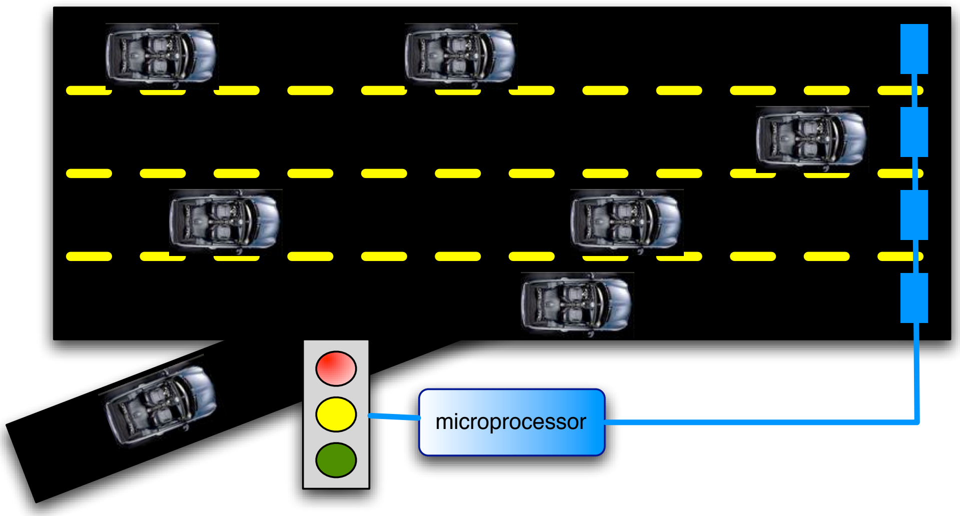
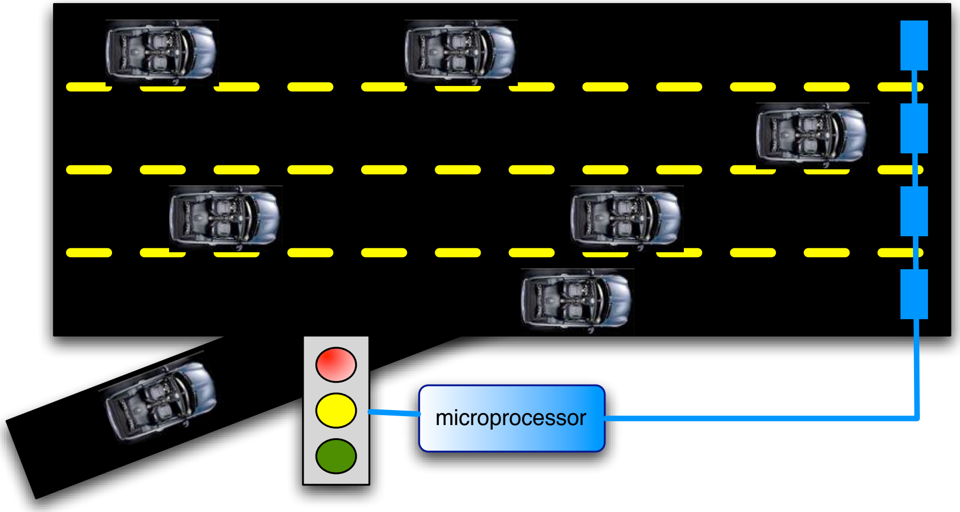




$$\frac{dx}{dt} = C_{in} - C_{out}$$

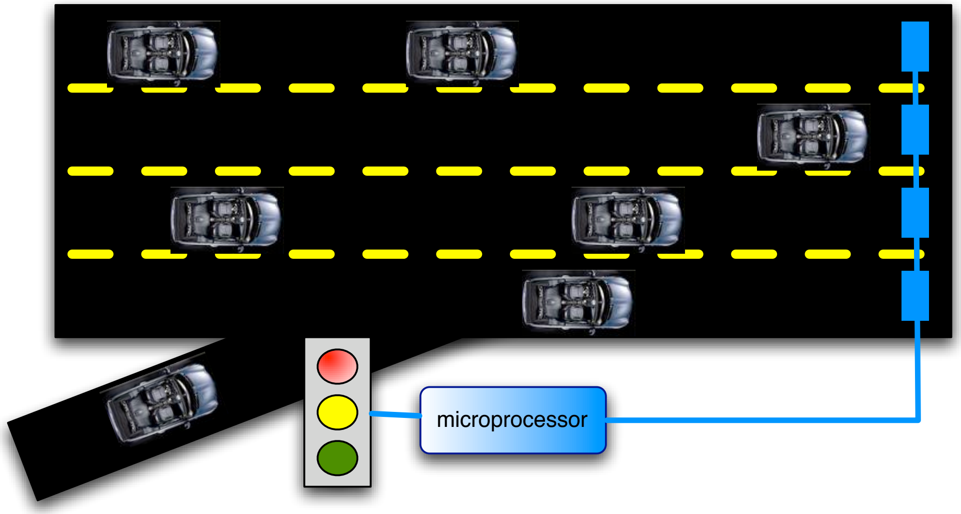
If we want to have $x \leq k$ when do we turn the green light on and when do we turn the red light on?



$$\frac{dx}{dt} = C_{in} - C_{out}$$

If we want to have $x \leq k$ when do we turn the green light on and when do we turn the red light on?

Measure x. If $x < k$ turn the green light on. If $x \geq k$ turn the red light on.



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Pretty simple, right? Why do we need to study control then?

$$
\begin{aligned}
\dot{p} &= \frac{I_{yp} - I_{zp}}{I_{xp}} qr + \frac{L}{I_{xp}} \\
\dot{q} &= \frac{I_{zp} - I_{xp}}{I_{yp}} pr + \frac{M + M_T}{I_{yp}} \\
\dot{r} &= \frac{I_{xp} - I_{yp}}{I_{zp}} pq + \frac{N}{I_{zp}} \\
\dot{\phi} &= p + (q \sin\phi + r \cos\phi) \tan\theta \\
\dot{\theta} &= q \cos\phi - r \sin\phi \\
\dot{\psi} &= (q \sin\phi + r \cos\phi) \sec\theta
\end{aligned}
$$

Other examples of control:

Hard disk drive control

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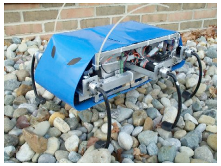 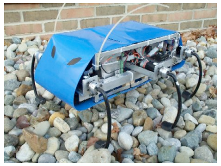 Robotics

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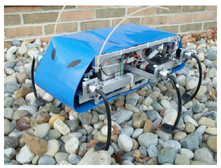
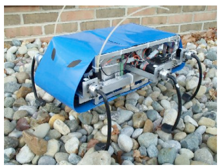
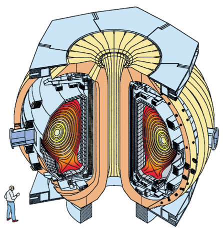
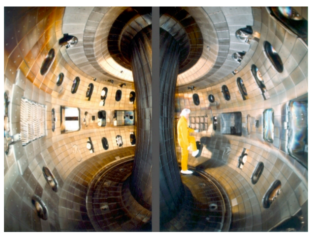
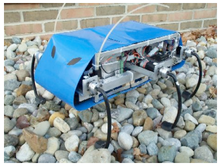
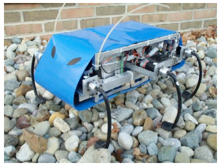
  Robotics

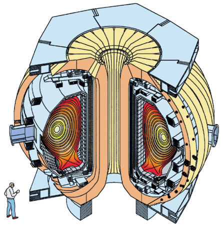
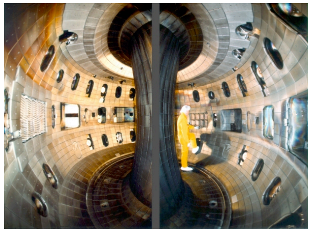
  Fusion and plasma control (Tokamak)

Examples

Other examples of control:

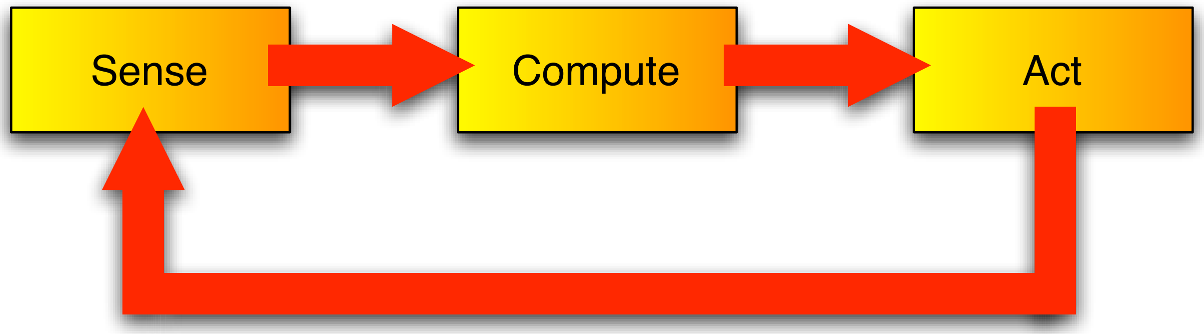
 Hard disk drive control

  Robotics

  Fusion and plasma control (Tokamak)

 Quality of service control in web servers

Common to all the examples was:



Feedback

Systems biology

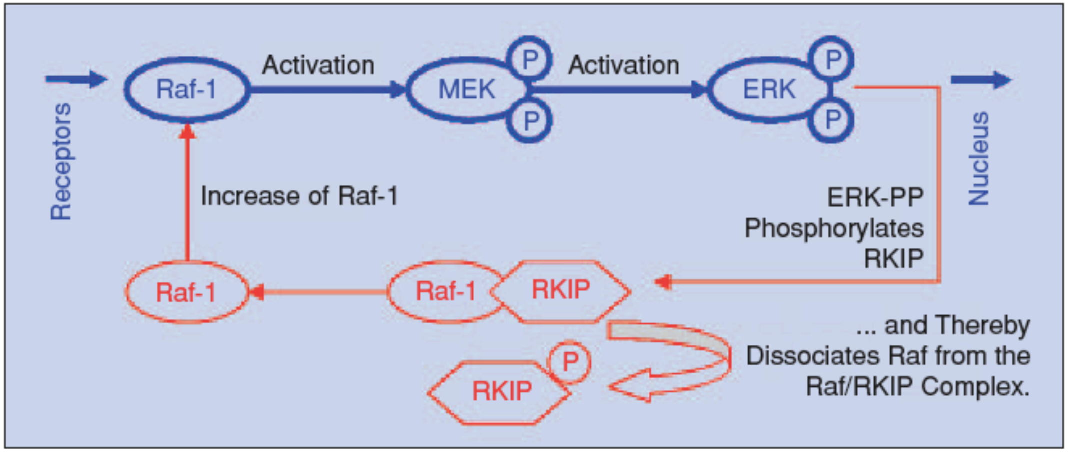


Figure 2. *A positive feedback loop in a signal transduction pathway. The main pathway, which is indicated by the thick blue lines, is realized by the sequential activation of Raf-1, upstream near the cell membrane, followed by activation of the proteins MEK and ERK through structural modifications in the form of phoshorylations indicated by the Ps. Double phosphorylated ERK translocates into the nucleus of the cell, where it effects the transcription of genes. ERK-PP also phosphorylates RKIP and releases Raf from the Raf-1/RKIP complex, and Raf in turn activates MEK. This positive feedback loop, indicated in red, leads to switch-like behavior of the pathway. Negative feedback loops on the other hand can lead to oscillations in signaling pathways.*

between the theoretician and the experimentalist, rather than the model precision (Figure 4). The modeling process itself, the discussion between modeler and experimentalist, as to which variables to include in the model and their relationship is more important than the final product, that is, the predictive model. For example, in modeling signal transduction pathways, a key research question is to identify feedback loops and characterize their effect on protein concentration profiles. In this context it is not necessary to quantify the relevant effect by, for example, predicting a change of concentration to a fraction of a percent. Since many biological responses are smooth, a qualitative assessment of whether a signal is amplified, suppressed, delayed, or accelerated is often more useful.

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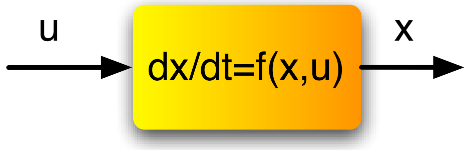
Control theory abstracts the details of the different application fields into a *mathematical model* describing how a particular system reacts to inputs.



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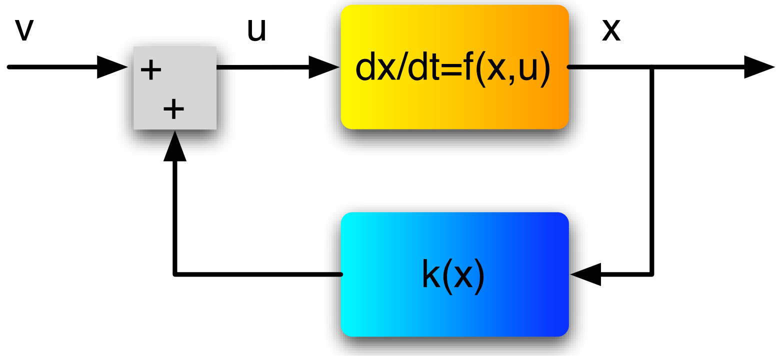

Most of the times this model does not produce the output we would like to certain inputs. We then use feedback to *change* the way that the system responds to inputs.

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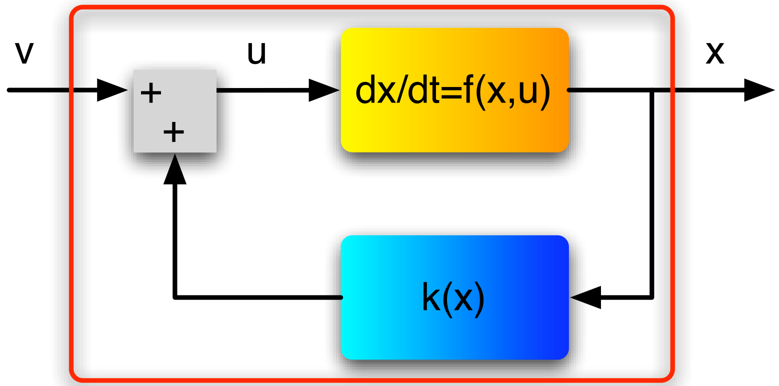

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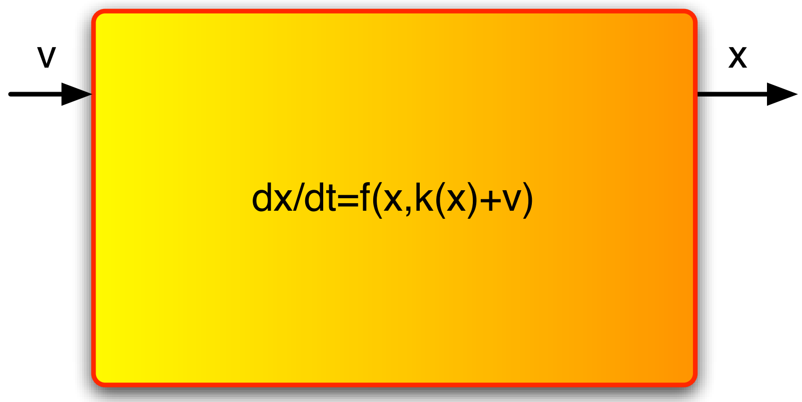

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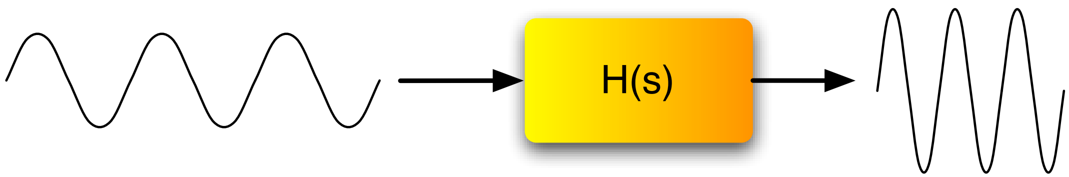
The major advances in control theory have been associated with changes in models or in the way in which models are interpreted:

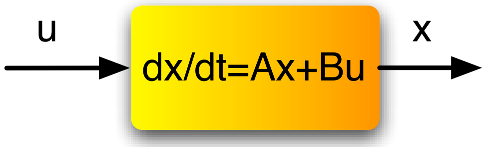
Before the 60's: Frequency domain. A control system is seen as a signal processing device:



Signals and Systems (ECE102) Principles of Feedback Control (ECE141)

The major advances in control theory have been associated with changes in models or in the way in which models are interpreted:

60's and 70's: Linear state-space models. Frequency interpretations become complicated for larger and more complex systems. Linear differential equations were used instead. Fundamental notions of controllability and observability were introduced by Kalman. The world was nice since the models were linear!



Linear Systems: State-Space Approach (ECE142)

Linear Dynamic Systems (M240A)

Some details regarding ECE141 - Spring 2021

Instructor:

Paulo Tabuada

66-147F Engineering IV Building

tabuada@ee.ucla.edu

Teaching Assistants:

Ushasi Ghosh

Jianwei Sun

Office hours:

Tuesdays from 4:00 to 5:50 pm via Zoom

https://ucla.zoom.us/j/97605217183?pwd=b3RRMjFwTTZmZEpCaXFxZVpWNkxPdz09

Book:

Feedback Control of Dynamical Systems

G.F. Franklin, J.D. Powel, and A. Emami-Naeini

7th edition

Some details regarding ECE141 - Spring 2021

Grades

Final grade computed according to:

Homework (20%) + Project (20%) + Midterm (25%) + Final (34%)+Survey (1%)

Grade letters obtained from percentage points according to the following table:

A+	100% – 93.75%	B+	81.25% – 75%	C+	62.5% – 56.25%	D+	43.75% – 37.5%
A	93.75% – 87.5%	B	75% – 68.75%	C	56.25% – 50%	D	37.5% – 31.35%
A-	87.5% – 81.25%	B-	68.75% – 62.5%	C-	50% – 43.75%	D-	31.35% – 25%
F	below 25%						

Some details regarding ECE141 - Spring 2021

Homework (includes Matlab assignments)

Homework is due every Tuesday by 2pm and is to be uploaded to CCLE/gradescope.

Late homework is not accepted except by previous arrangement with the instructor or in case of emergency.

Collaboration on homework is allowed. However, each student must submit their own work, which should reflect a thorough understanding of the assigned problems.

Midterm

05/06/21 in class (via Zoom). Open book.

Final

06/08/21 from 8AM to 11AM. Open book.

Some details regarding ECE141 - Spring 2021

We will follow the book very closely and will cover:

Week 1:	Introduction and review Chapter 2
Week 2:	Review Chapters 2 and 3
Week 3:	Chapter 3
Week 4:	Chapter 4
Week 5:	Chapter 4
Week 6:	Chapter 5 (midterm)
Week 7:	Chapter 5
Week 8:	Chapter 6
Week 9:	Chapter 8
Week 10:	Wrap-up