Introducing Signals and Systems
The Berkeley Approach

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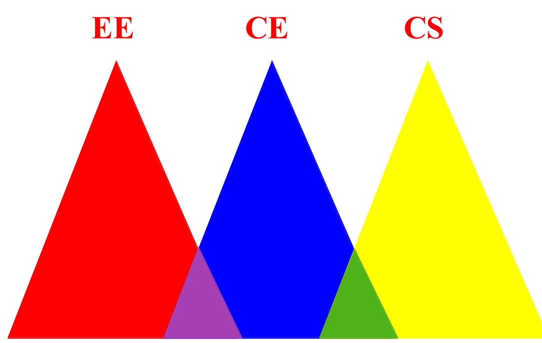
A computer without networking, audio, video, or real-time services.

Starting Point



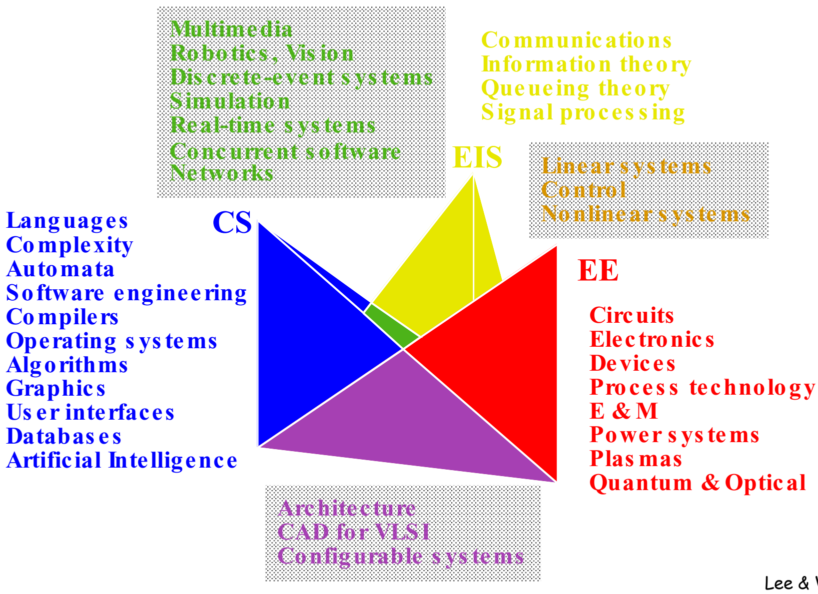
Electronics
Optics
E&M
Plasmas
...

Architecture
CAD
Systems
...

Languages
AI
Theory of Computation
...

But the juncture of EE and CS is not just hardware.
It is also mathematical modeling and system design.

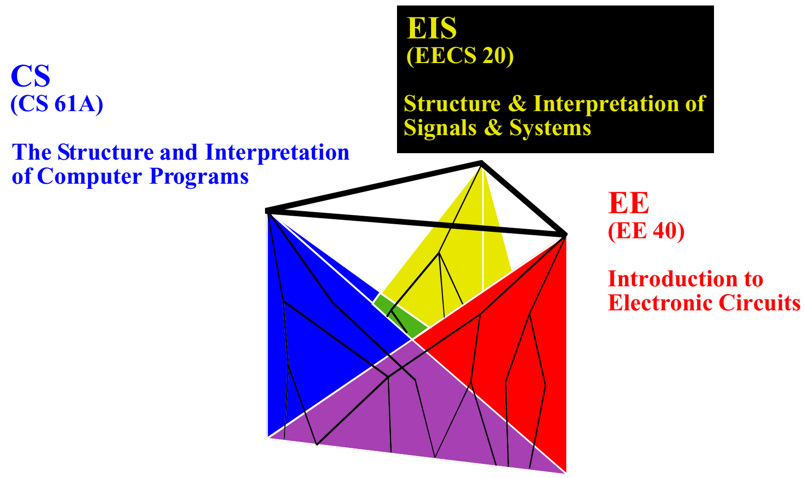
Intellectual Grouping of EE, CE, CS



Six Intellectual Groupings

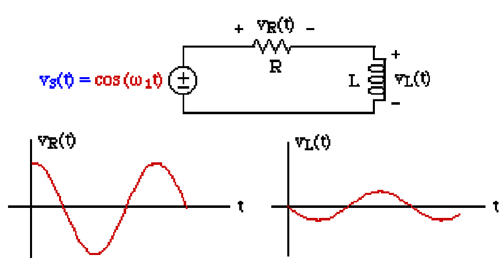
- Blue: Computer Science
- Green: Computer Information Systems
- Yellow: Electronic Information Systems
- Orange: Electronic Systems
- Red: Electronics
- Purple: Computer hardware

New Introductory Course Needed



The Roots of Signals and Systems

- Circuit theory
- Continuous-time
- Calculus-based



Major models

- Frequency domain
- Linear time-invariant systems
- Feedback

Changes in Content

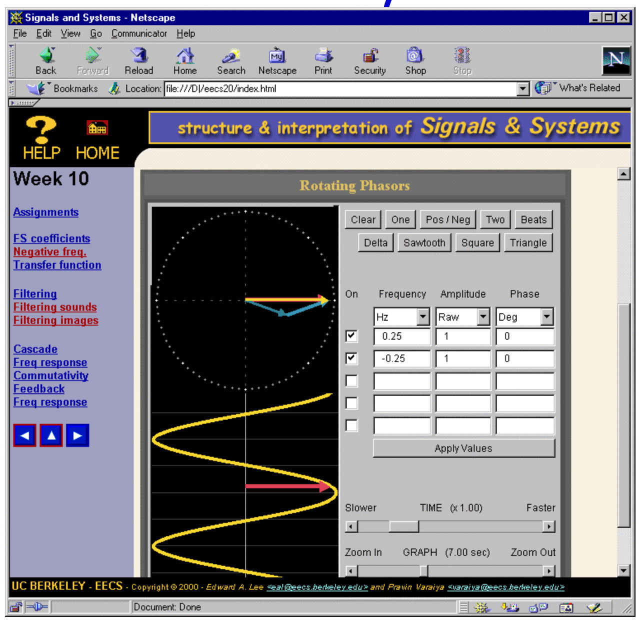
- Signal
  - used to be: voltage over time
  - now may be: discrete messages
- State
  - used to be: the variables of a differential equation
  - now may be: a process continuation in a transition system
- System
  - used to be: linear time invariant transfer function
  - now may be: Turing-complete computation engine

Changes in Intellectual Scaffolding

- Fundamental limits
  - used to be: thermal noise, the speed of light
  - now may be: chaos, computability, complexity
- Mathematics
  - used to be: calculus, differential equations
  - now may be: mathematical logic, topology, set theory, partial orders
- Building blocks
  - used to be: capacitors, resistors, transistors, gates, op amps
  - now may be: microcontrollers, DSP cores, algorithms, software components

Action at Berkeley

Berkeley has instituted a new sophomore course that addresses mathematical modeling of signals and systems from a very broad, high-level perspective.

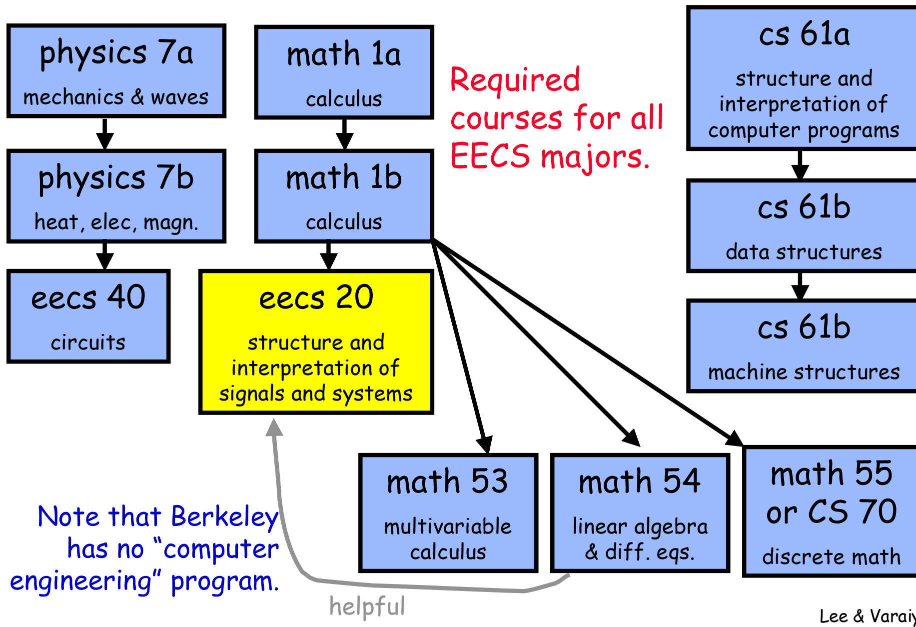


The web page at the right contains an applet that illustrates complex exponentials used in the Fourier series.

Themes of the Course

- The connection between *imperative* (Matlab) and *declarative* (Mathematical) descriptions of signals and systems.
- The use of *sets and functions* as a universal language for declarative descriptions of signals and systems.
- State machines and frequency domain analysis as complementary tools for designing and analyzing signals and systems.
- Early and often discussion of applications.

Role in the EECS Curriculum



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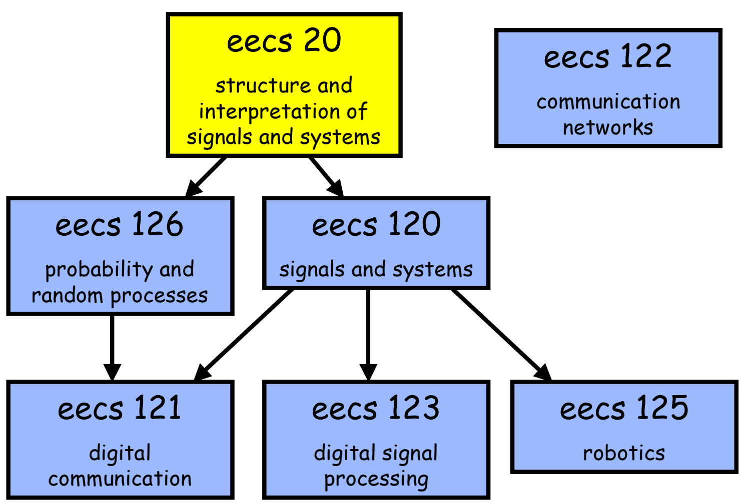
Current Role in EE



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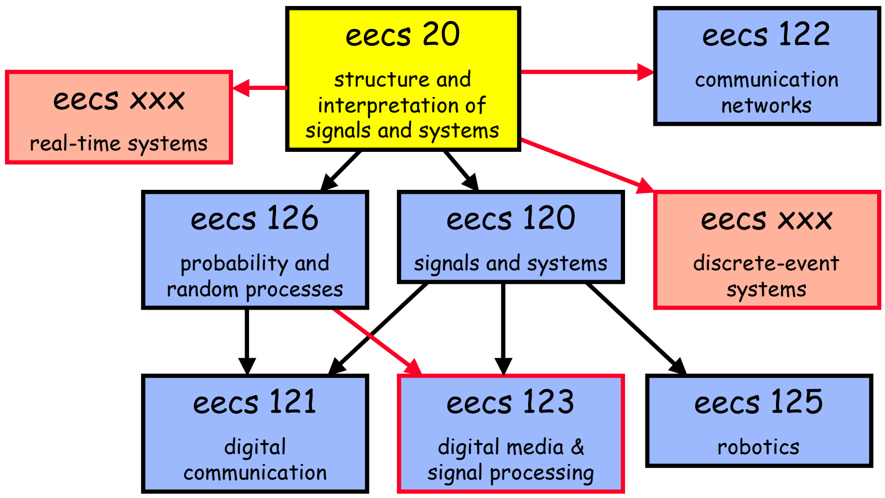
Future Role in EECS (speculative)



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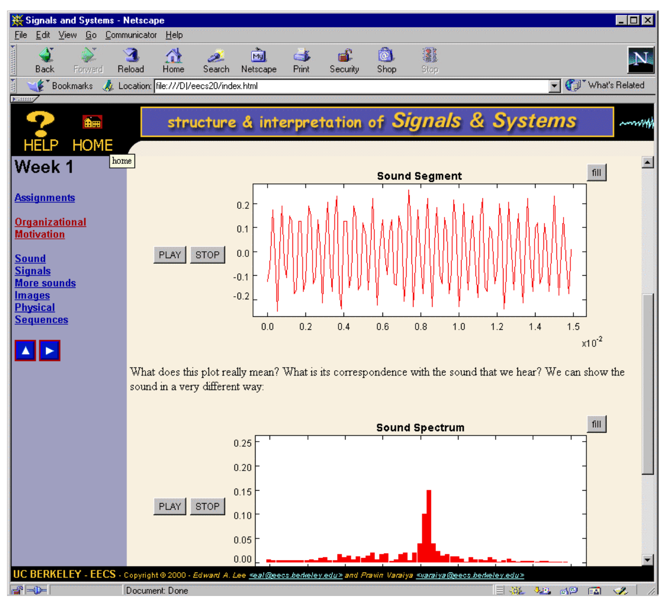
Outline

1. Signals
2. Systems
3. State
4. Determinism
5. Composition
6. Linearity
7. Freq Domain
8. Freq Response
9. LTI Systems
10. Filtering
11. Convolution
12. Transforms
13. Sampling
14. Design
15. Examples



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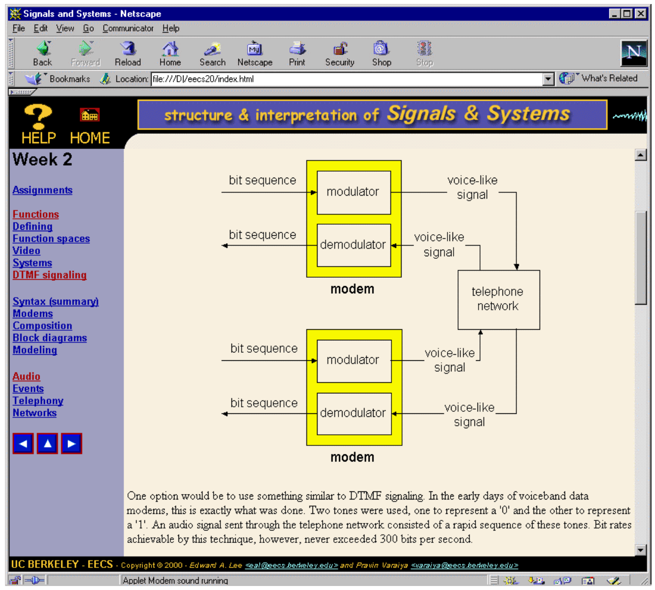

Notation

- Sets and functions
  - $Sound : Reals \to Reals$
  - $DigitalSound : Ints \to Reals$
  - $Sampler : [Reals \to Reals] \to [Ints \to Reals]$
- Our notation unifies
  - discrete and continuous time
  - event sequences
  - images and video, digital and analog
  - spatiotemporal models

Problems with Standard Notation

- The form of the argument defines the domain
  - x(n) is discrete-time, x(t) is continuous-time.
  - x(n) = x(nT)? Yes, but…
  - X(jw) = X(s) when jw = s
  - $X(e^{jw}) = X(z)$ when $z = e^{jw}$
  - $X(e^{jw}) = X(jw)$ when $e^{jw} = jw$? No.
- x(n) is a function
  - y(n) = x(n) * h(n)
  - y(n-N) = x(n-N)*h(n-N)? No.

Using the New Notation

- Discrete-time Convolution :

$$Convolution: [Ints \to Reals] \times [Ints \to Reals] \to [Ints \to Reals]$$

- Shorthand:

$$x * y = Convolution(x, y)$$

- Definition:

$$(x * y)(n) = \sum_{k=-\infty}^{\infty} x(k) y(n-k)$$

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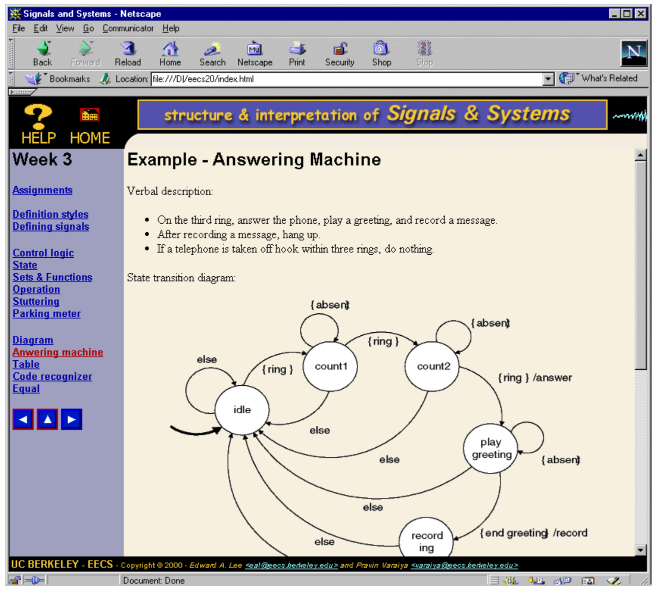

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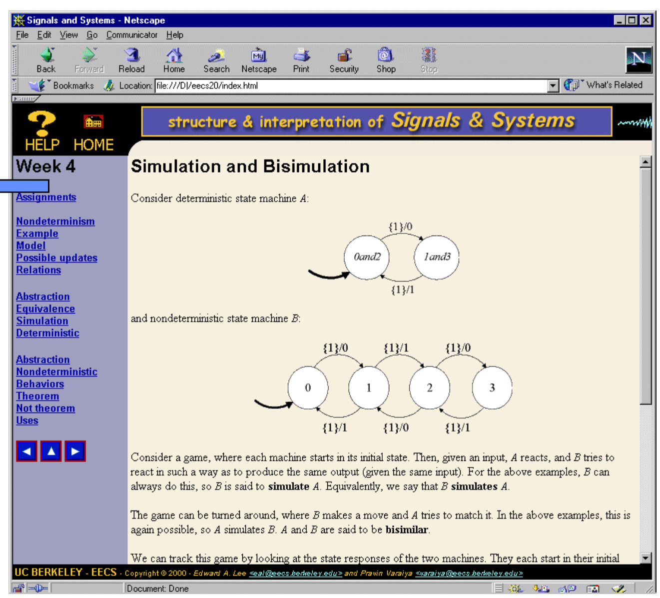

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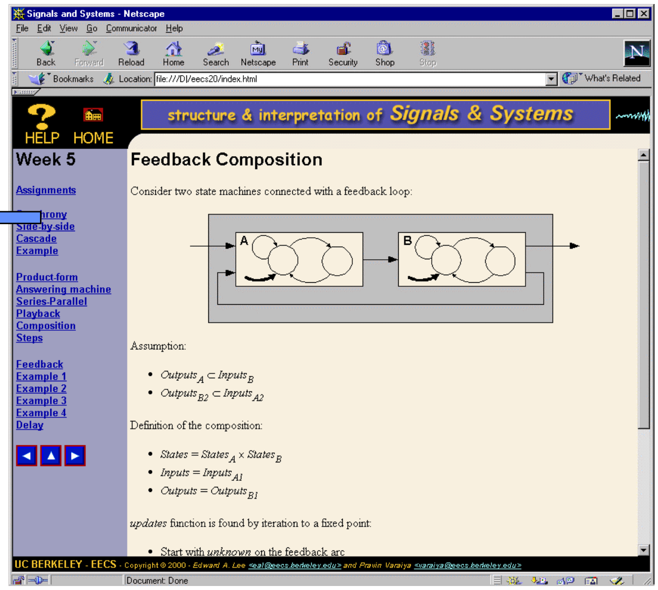

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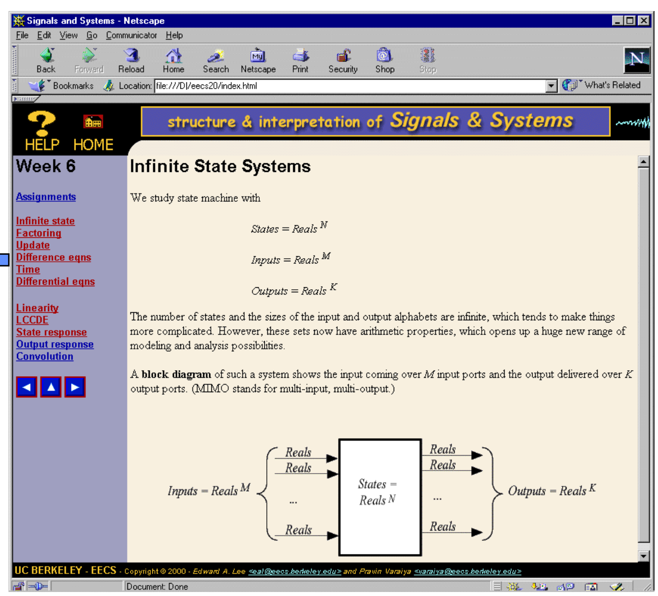

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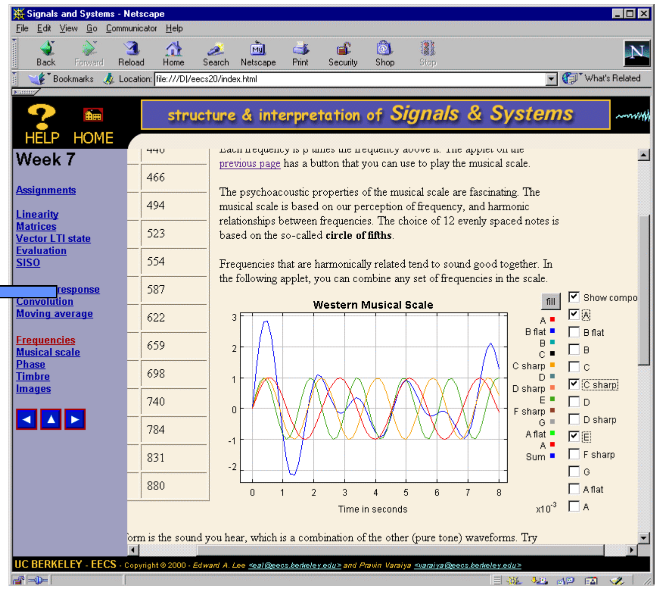

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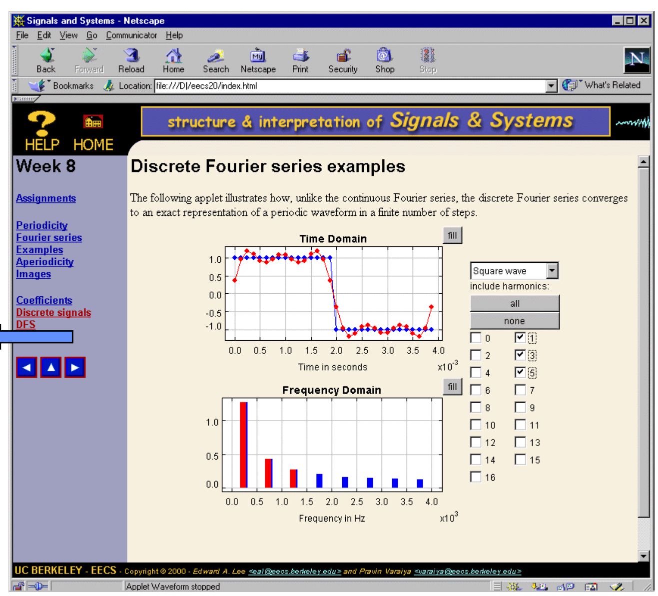

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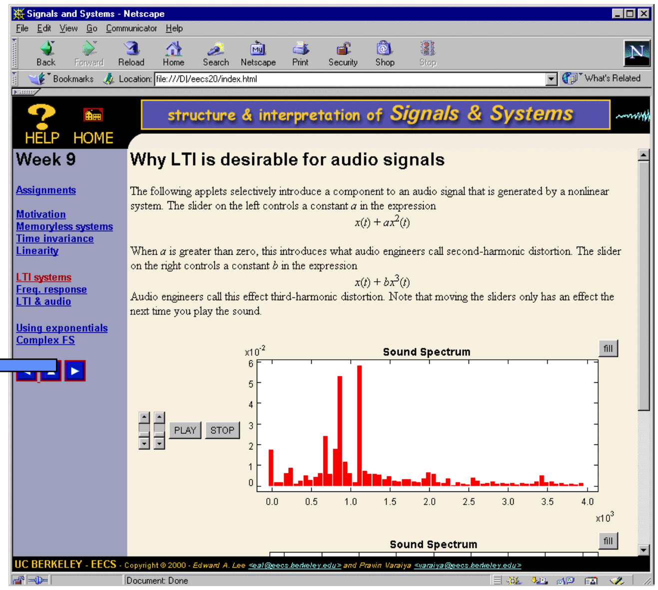

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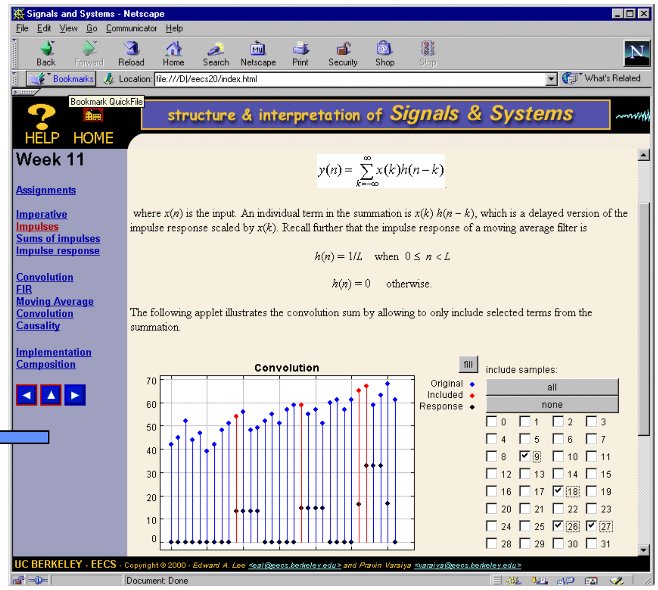

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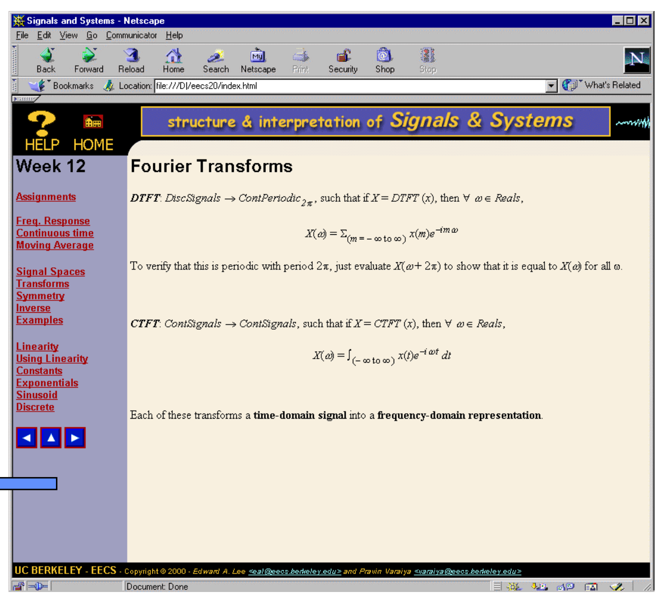

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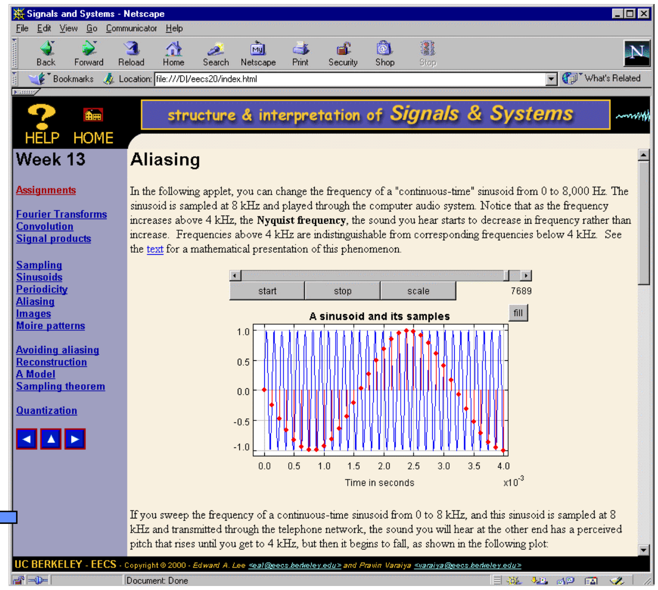

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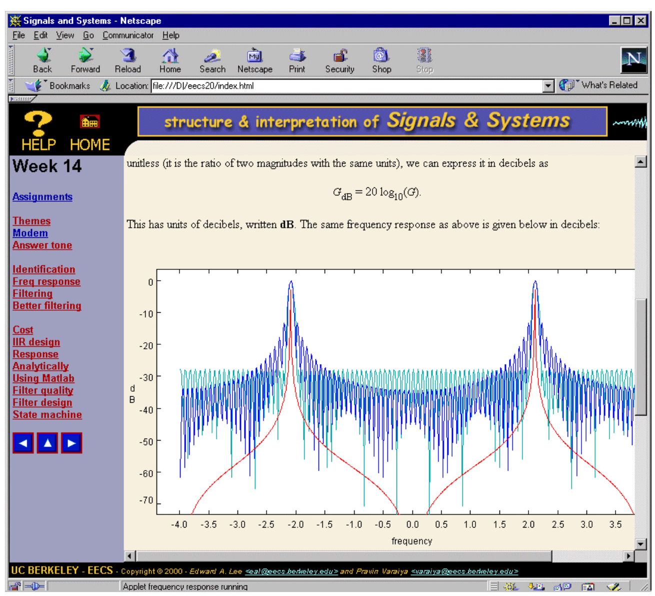

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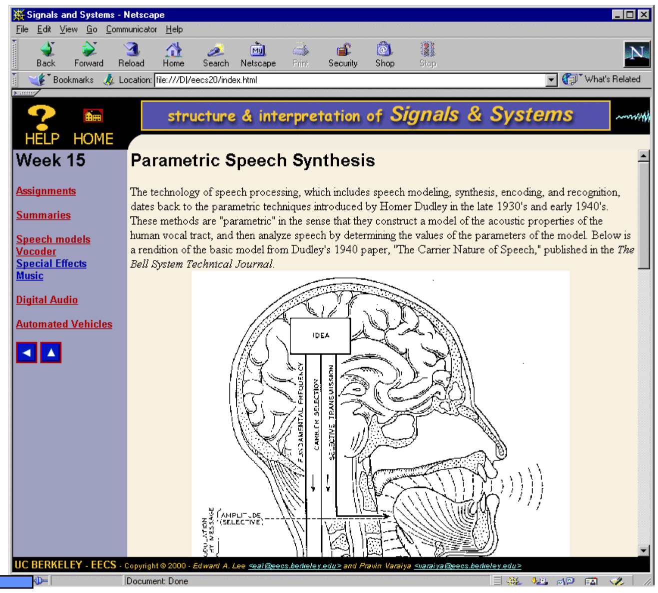
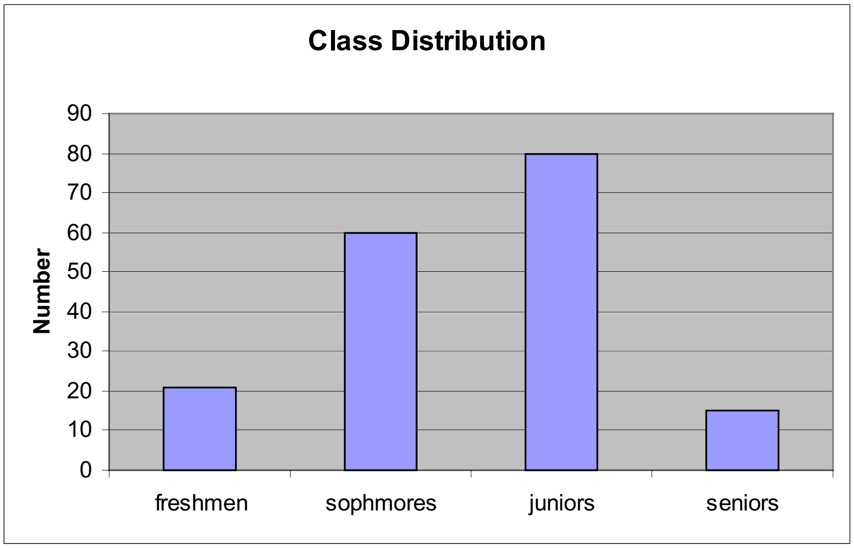


Analysis of Spring 2000 Offering

- Class standing had little effect on performance.
- On average, the GPA of students was neither lowered nor raised by this class.
- Students who attend lecture do better than those that don't.
- Taking at least one of Math 53, 54, or 55 helps by about ½ grade level.
- Taking Math 54 (linear algebra & differential eqs.) helps by about 1 grade level (e.g. B to B+).
- Computing classes have little effect on performance.

Distribution by Class Standing



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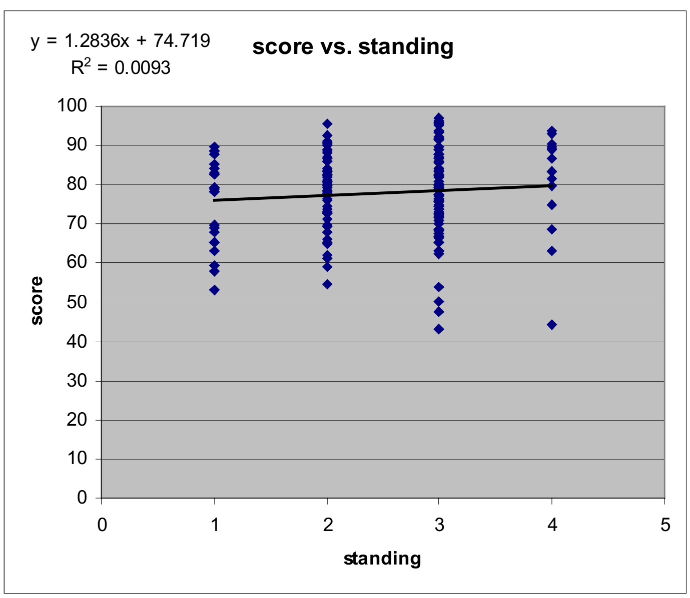
Effect of Class Standing



80 and above: A's
63 and above: B's
62 and below: C's

176 of the 227 students responded (the better ones).

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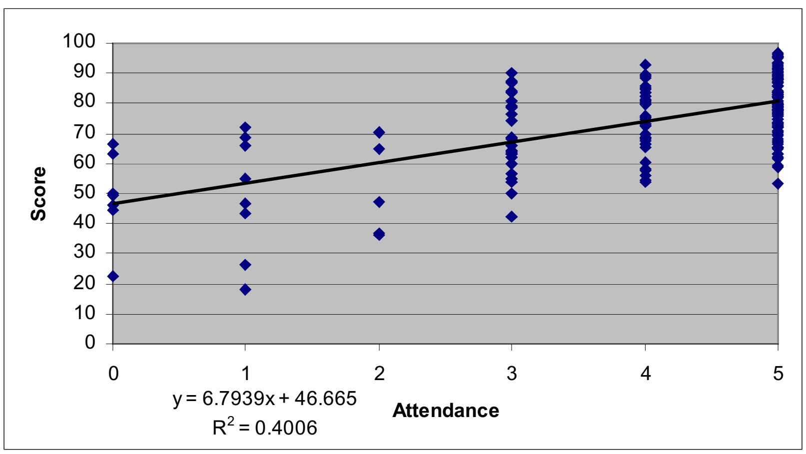
Effect of Showing Up

Students who answered the survey were those that showed up for the second to last lab.

- The mean for those who responded was 78, vs. 65 for those who did not respond (two grades, e.g. B to A-).
- The standard deviation is much higher for those who did not respond.
- A t-test on the means shows the data are statistically very significant.

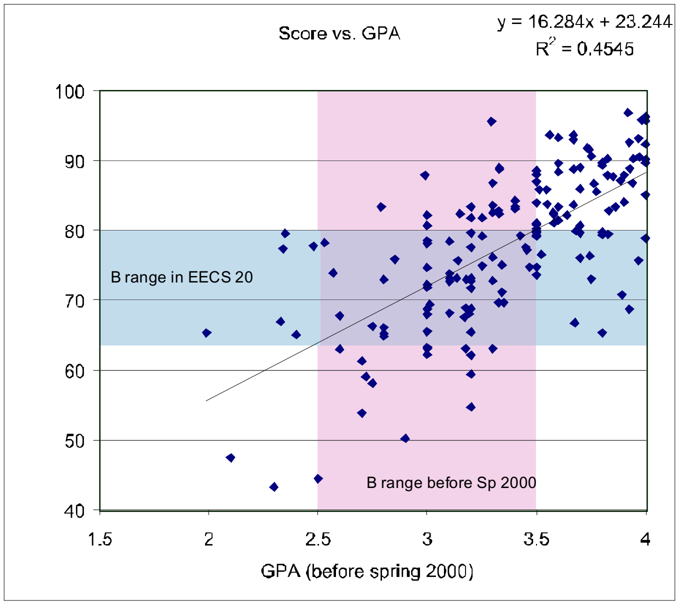
We conclude that the respondents to the survey do not represent a random sample from the class, but rather represent the diligent subset.

Attendance in Class vs. Score



Attendance is measured by presence for pop quizzes, of which there were five.

Effect on GPA



On average, students' GPA was not affected by this class.

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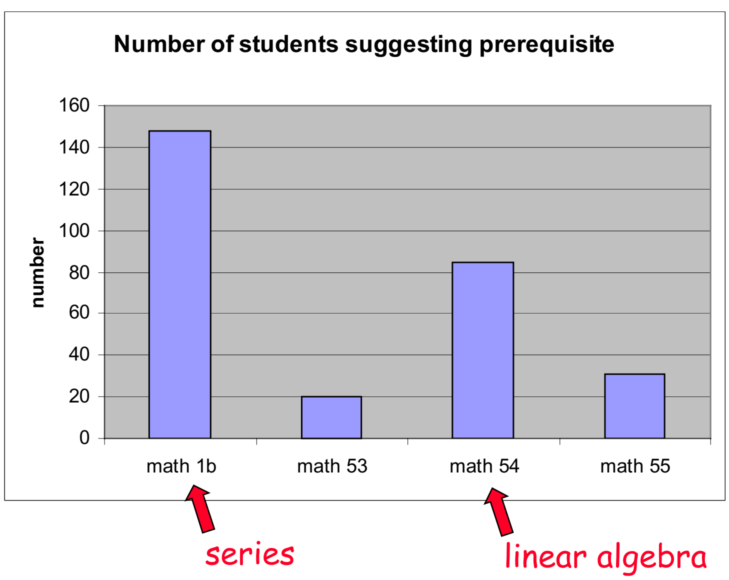
Student Opinion on Prerequisites



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Differences from Tradition

- No circuits
- More discrete-time, some continuous-time
- Broader than LTI systems
- Unifying sets-and-functions framework
- Emphasis on applications
- Many applets and demos
- Tightly integrated software lab

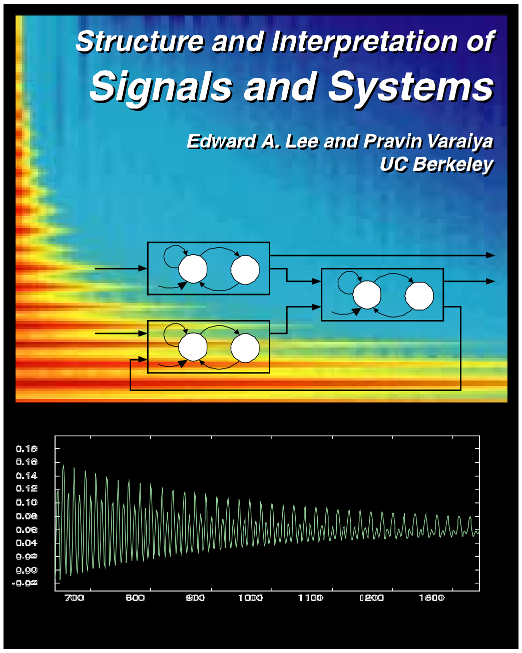
Text draft (Lee & Varaiya) and website available.

Bottom-Up or Top-Down?

Bottom-up:
- foundations first
- derive the applications

Top-down:
- applications first
- derive the foundations

Textbook



Draft available on the web.