# Ve 216: Introduction to Signals and Systems

Yong Long

The University of Michigan- Shanghai Jiao Tong University Joint Institute
Shanghai Jiao Tong University

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Based on Lecture Notes by Prof. Jeffrey A. Fessler

# Outline

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# Motivation (1)

- We purportedly live in the "information age."
- Electrical means for storing and transmitting information have proven to be particularly efficient (fast, cheap, reliable, etc.).
- Much of the discipline of Electrical Engineering is related to the subject of information.
- This course focuses on information represented using signals, especially (but not exclusively) electrical signals, and the systems that are used to manipulate those signals.

# Motivation (2)

Although the focus of EE is generally electrical systems, the mathematical analyses apply to many physical systems.

**Example**

A bank account is like an integrator. It accumulates the input (deposits).

**Example**

A car is a mechanical system. One input is the position of the accelerator pedal, the output is the car velocity. Since velocity is the time integral of acceleration, this system is also an integrator.

The concepts in this course apply to electrical, mechanical, optical, financial and numerous other types of signals and systems.

# Motivation (3)

The course is about fundamentals (like a calculus course), and leads into the following subsequent courses, which are somewhat more focussed on applications.

- 451 (DSP), sound cards, compact disks, digital TV, ...
- 455 (digital communication), modems, cellular phones, ...
- 460 (control), cruise control, control of electric vehicles, ...
- 401 (probability and random variables), noise and random phenomena (things that limit our ability to transmit and store information)

# Outline

# What is signal processing?

## Definition

**Signal processing** is a branch of electrical engineering which pulls meaning from the broad sources of data around us.

Cool video from IEEE Signal Processing Society
`https://www.youtube.com/watch?v=EErkgr1MWw0`

# Career opportunities

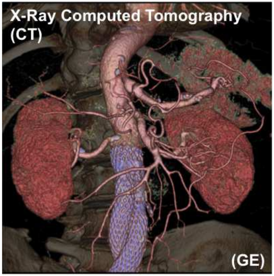
- Communications and networking: voice recognition
- Entertainment: motion-sensing gaming
- Transportation: autonomous vehicle
- Biotechnology: biometric security
- Social interactions: wearable technology, brain/computer interface, hearing aids, speech synthesis
- Healthcare: medical imaging
- Multimedia: 3D TV, streaming video
- Homeland security: radar and sonar
- Finance: stock valuation & prediction

# Example 1: Park Distance Control

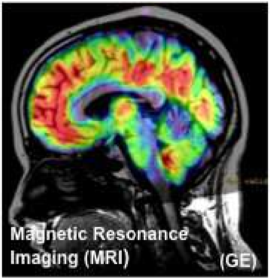
http://www.bmw.com/com/en/insights/technology/technology_guide/articles/park_distance_control

- Uses acoustic signal to determine distance from device at the rear of your vehicle to the nearest largest object behind the vehicle.
- Sends out an acoustic pulse signal, receives delayed pulse signal plus noise; must estimate delay from received signal, since delay related to distance.

# Example 2: Medical Imaging




CT: Routinely used for abdominal and chest diseases




MRI: Tumor detection and identification in the brain


PET/CT: Standard tool for assessment of tumor responses to therapy

# Example 3: China's First "Space Class"


http://news.xinhuanet.com/photo/2013-06/20/c_124883585_21.htm

- Shenzhou-10 astronauts gave lectures to students on earth
- Sending back and receiving image and speech signals over huge distance

# More Practical Applications (1)

**Example**

How can an AM radio extract and play the music from just one station when dozens of stations are transmitting simultaneously?

**Example**

Why is the sampling rate of a CD audio disk 44.1kHz?

**Example**

How can you design a filter to remove 60Hz "hum" or high-frequency "hiss" from an old audio recording?

# More Practical Applications (2)

**Example**

Basics of how sound card digitizes speech (*e.g.* for use in computer speech dictation).

**Example**

How to analyze circuits with several resistors, inductors and capacitors (RLC circuits) less painfully, without all of that ($\int$, $dt$) differential equation stuff?

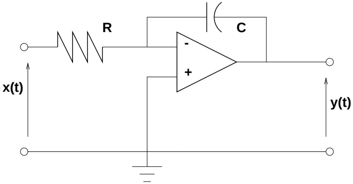
These are applications of 21st Century, but to understand them one must learn 1800's mathematics (Fourier, Laplace, Z-Transform).

# Outline

# Prerequisite Concepts

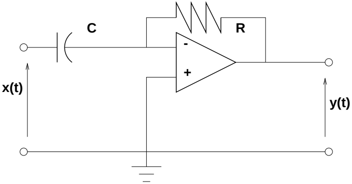
- Basic linear circuit elements:
  resistors, inductors, capacitors, ideal operational amplifier (op-amps), differential equations.
- Integrator and differentiator circuits

Integrating amplifier




$$y(t) = -\frac{1}{RC}\int_{-\infty}^{t} x(\tau)\, d\tau$$

Differentiating amplifier




$$y(t) = -RC\frac{\mathrm{d}}{\mathrm{d}t}x(t)$$

# Overview of course

1. definitions, terminology, classes
2. linear systems - convolution
3. frequency analysis (Fourier transform)
4. differential-equation (diffeq) systems
5. applications: AM radio, sampling (sound cards)
6. Laplace transform
7. Z transform (brief introduction)

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I plan to follow organization, notation, and mathematical content of text reasonably closely. Filling in the “whys.”

# MATLAB utility

1. complex arithmetic
2. plotting
3. partial fraction expansions
4. symbolic integration
5. checking results (always OK!)