Information

- **Class webpage:**
  - [http://inst.eecs.berkeley.edu/~ee123/fa11/](http://inst.eecs.berkeley.edu/~ee123/fa11/)
Project

upsample, modulate, play sound

record, demodulate/filter/process, downsample, display
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My Research
Me - Exposed
MRI Image of a Water/plastic phantom

MRI Raw-data (2D Fourier transform)
MRI Image of a Water/plastic phantom

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MRI Raw-data (2D Fourier transform)
“Aliasing”
“Aliasing”
Signal Processing in General

- Convert one signal to another (e.g. filter, generate control command, etc.)
- Interpretation and information extraction (e.g. speech recognition)
Digital Signal Processing

• Discrete Samples

• Discrete Representation (on a computer)

• Can be samples of a Continuous-Time signal: \( x[n] = X(nT) \)

• Inherently discrete (example?)
Why Learn DSP?

- Swiss-Army-Knife of modern EE
- Impacts all aspects of modern life
  - Communications (wireless, internet, GPS...)
  - Control and monitoring (cars, machines...)
  - Multimedia (mp3, cameras, videos, restoration ...)
  - Health (medical devices, imaging....)
  - Economy (stock market, prediction)
  - More....
Advantages of DSP

- Flexibility
- System/implementation does not age
- “Easy” implementation
- Reusable hardware
- Sophisticated processing
- Process on a computer
- (Today) Computation is cheaper and
Example I: Audio Compression

- Compress audio by 10x without perceptual loss of quality.
- Sophisticated processing based on models of human perception
- 3MB files instead of 30MB - Entire industry changed in less than 10 years!
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Example II: Digital Camera

- Focus/exposure Control
- Preprocessing
- White-balancing
- Post-processing
- Color transform
- Demosaic
- Compression

http://micro.magnet.fsu.edu/primer/digitalimaging/cmossimagesensors.html
Example II: Digital Camera
Example II: Digital Camera

• Compression of 40x without perceptual loss of quality.

• Example of slight overcompression: difference enables x60 compression!
Computational Photography

DSP

*www.hdrsoft.com
Example III: Computed Tomography

x-ray source

Sinogram

cross-section
Example III: Computed Tomography

Sinogram

cross-section

x-ray source
Example III: Computed Tomography

x-ray source

Sinogram

cross-section

DSP
Example IV: MRI (again!)

k-space (Raw Data) \hspace{2cm} \text{Image}

\text{Discrete Fourier transform}
Example IV: MRI (again!)

k-space (Raw Data) \hspace{1cm} \text{Image}

Discrete Fourier transform
Example IV: MRI (again!)

k-space (Raw Data) → Image

Discrete Fourier transform
Functional MRI Example

Sensitivity to blood oxygenation - response to brain activity

Convert from one signal to another
Taking fMRI further

- fMRI decoding: “Mind Reading”
- Interpretation of signals
Course Objective

• Develop skills for
  - Analyzing and synthesizing algorithms and systems that process discrete-time signals
  - Emphasis on realization and implementation
Basic Sequences

(a) Unit sample

(b) Unit step

(c) Real exponential

(d) Sinusoidal
Cosine sequences

\[ \cos(\omega_0 n) \]

- \( \omega_0 = 0 \)
- \( \omega_0^n = \pi / 8 \)
- \( \omega_0^n = \pi / 4 \)
- \( \omega_0 = \pi \)
Sinusoidal sequences

\[ \cos(\omega_0 n) \]
DT SIGNALS: Samples of a CT signal: \( x[n] = x_a(nt) \) for \( n = 0, 1, 2, \ldots \)

or inherently discrete (Examples?)

BASIC SEQUENCES:

UNIT IMPULSE: \( \delta[n] = \begin{cases} 1 & \text{if } n = 0 \\ 0 & \text{if } n \neq 0 \end{cases} \)

UNIT STEP: \( u(n) = \begin{cases} 1 & \text{if } n \geq 0 \\ 0 & \text{if } n < 0 \end{cases} \)

EXPONENTIAL: \( x[n] = \begin{cases} A^n & \text{if } n \geq 0 \\ 0 & \text{if } n < 0 \end{cases} \)

- \( 0 < \alpha < 1 \) bounded \( |\alpha| < 1 \)
- \( -1 < \alpha < 0 \) unbounded when \( |\alpha| > 1 \)
- \( \alpha < -1 \)
**Sinusoidal:** $x[n] = A\cos(\omega_0 n + \phi)$ or $x[n] = A\cos(\omega_0 n + \phi)$

**Q:** Periodic or not? $x[n+N] = x[n]$ for $N$ integer?

**A:** If $\omega_0/T$ is rational (different than $\pi$)

To find fundamental period $N$, find smallest integers $k_1, k_2$ such that

$$\omega_0 N = 2\pi k_1$$

**Example:**

$$\cos\left(\frac{\pi}{5} n\right) \quad N=14 \quad (k=5)$$

$$\cos\left(\frac{\pi}{2} n\right) \quad N=10 \quad (k=4)$$

$$\cos\left(\frac{2\pi}{7} n\right) + \cos\left(\frac{\pi}{5} n\right) \Rightarrow N = \text{S.C.M.}\{8, 14\} = 70$$

**Another Difference:**

**Q:** Which one is a higher freq. $\omega_0 = \pi$ or $\omega_0 = \frac{3\pi}{2}$?

**A:** $\omega_0 = \pi$

**Diagram:**

- $\cos(\pi n)$
- $\cos\left(\frac{3\pi}{2} n\right) = \cos\left(\frac{\pi}{2} n\right)$
RECALL PERIODICITY AND SYMMETRY IN DTFT

\[ x(e^{j\omega}) \]

\[ w \]

\[ \text{HIGHEST FREQ!} \]

(Show Fig. 2.5)

\[ x[n] \rightarrow \square \rightarrow y[n] \]

CAUSAL: \[ y[n] = y[n-k] \text{ for } k > 0 \]

Memoryless: \[ y[n] \text{ of } n \text{ depends only on } x[n] \]

**Example:** \[ y[n] = x[n]^2 \]

LINEAR: Superposition:

\[ T\{x_1[n]+x_2[n]\} = T\{x_1[n]\} + T\{x_2[n]\} = y_1[n] + y_2[n] \]

Homogeneity:

\[ T\{ax[n]\} = ax[n] = ay[n] \]