DEFINING SIGNALS AND SYSTEMS

What is a signal?

- A ***signal*** is a function of an *independent* variable such as time or location.

What are some common examples of time-dependent signals?

- 60 Hz outlet voltage
- Current used in a flashlight
- Speech and music
- Stream-flow in the South Canadian river
- Morse code (like SOS)
- Video

What are some of the characteristics of the above signals?

- some are electrical in nature, others require a **transducer** to get an analogous electrical signal
- some are continuous in time, while others are either **discrete** from the get-go (like Morse code) or **sampled** from continuous signals to get discrete signals.

While **continuous-time** and **discrete-time** signals share many commonalities, there are important differences in the definition and analysis (Digital Signal Processing) of these signals.

Digital signal processing: The **extraction** of features from noisy or garbled measurements (signals) and their use (enhancement, synthesis, analysis or recognition). Applications include:

- Communications
- Multimedia
- Radar and sonar
- Seismic analysis
- Biomedical
- Control systems

Related areas are:

- Image processing
- Pattern recognition
- Computer vision
- Control systems
- System identification

Necessary areas of expertise for DSP systems:

- Digital hardware
- Software programming/engineering
- Systems theory (mathematics)

All of these areas are strongly reflected in the Computer Engineering degree available through the School of Electrical and Computer Engineering. All but the software engineering is reflected in the Electrical Engineering degree.

Characterizing signals

Multi-channel vs. multi-dimensional signals

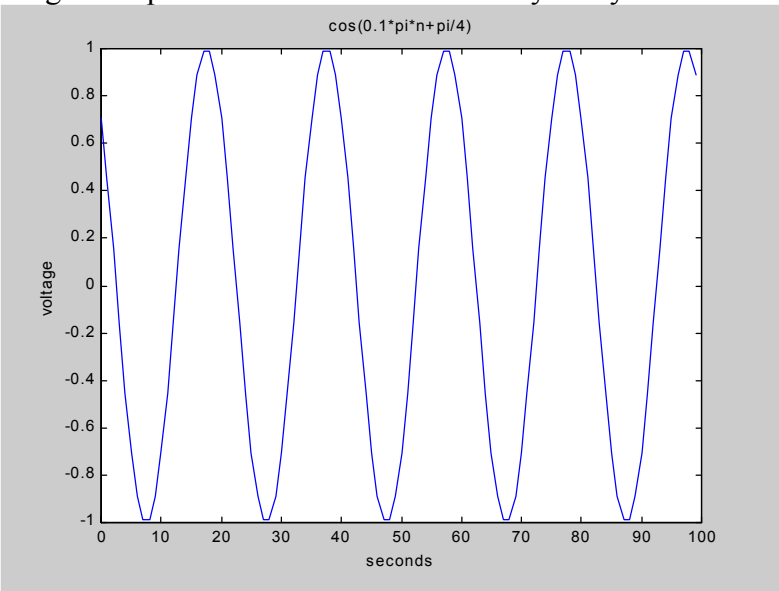
- **Multi-channel** signals are exemplified by the low-, mid- and high-frequency channels in a hearing-aid or the red-, green- and blue-channels in a color television system:

$$x[n] = \begin{bmatrix} x_l[n] \\ x_m[n] \\ x_h[n] \end{bmatrix}$$

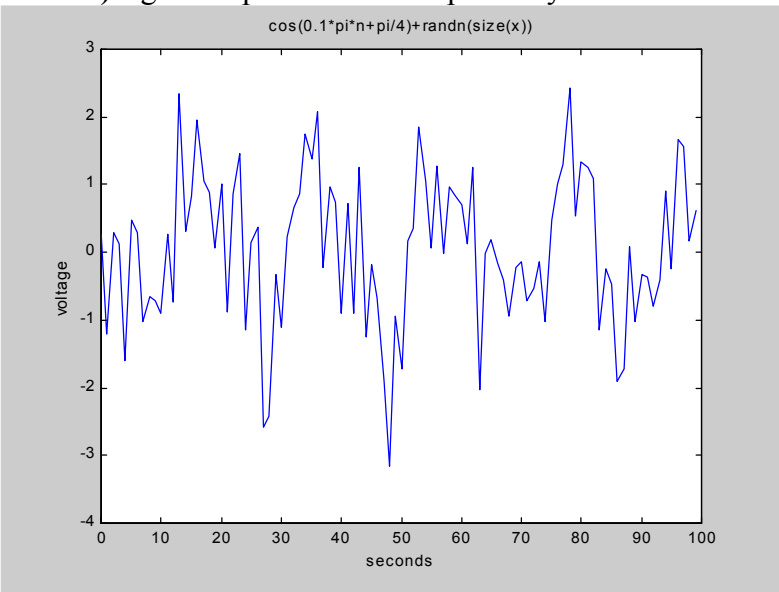
- **multi-dimensional** signals are exemplified by pixel values in a gray-scale digital image: e.g. $x[m,n] = 240$ or the 512x512 image of "Lena"

Deterministic vs. random

- **Deterministic** signal amplitudes can be described analytically



- **Random (stochastic)** signal amplitudes are not precisely described



Discrete-time vs. digital signals

- **Discrete-time** signals are time quantized (sampled) but not amplitude quantized
- **Digital** signals are both sampled and amplitude quantized (A/D'd)

What is a transducer?

- A transducer is a device that converts energy in one form to another.
  For example, a microphone transducer converts sound pressure waves into a voltage signal.

What is a system?

- a ***system*** is a device (machine), process or algorithm which has (multiple) inputs and (multiple) outputs. Digital systems are implemented using either software or digital circuitry. Analog (electrical) systems are implemented using circuit devices such as resistors, operational amplifiers and capacitors. This class is concerned only with the development of digital systems.

The basic elements of a DSP system are:

- A/D converter (sampler, quantizer and anti-aliasing filter)
- DSP
- D/A converter (hold and anti-imaging filter)
- $\Sigma\Delta$ modulator (if not A/D and D/A) – This is called the "all digital" solution