Signals and Systems (ELL205)

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Outline

- What are signals?
- What are systems?
- Different kinds of Signals
  - Continuous-time vs. Discrete-time signals

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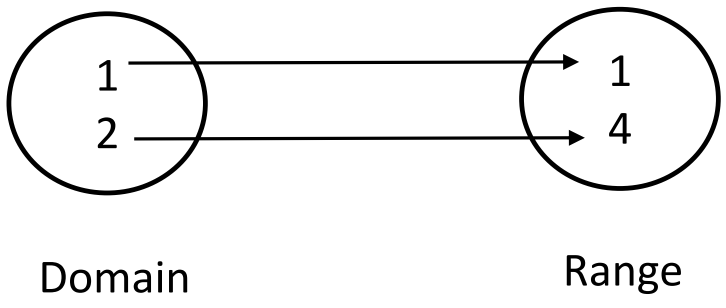

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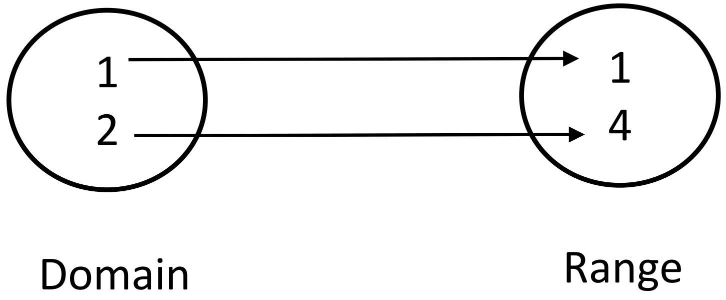

- The map between domain and range can be expressed as a set of ordered pairs:

$$< (1,1), (2,4) >$$

or by a mathematical expression, $f(x) = x^2$.

x: independent variable, $f(x)$: dependent variable.

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- Signals are functions.
- We focus on two independent variables: time and frequency. The function with independent variable as frequency are special functions known as spectrum.
- Signal can be a function of many independent variables $f(x_1, x_2, \ldots x_n)$, known as multi-dimensional function.

  Example: Black and white image

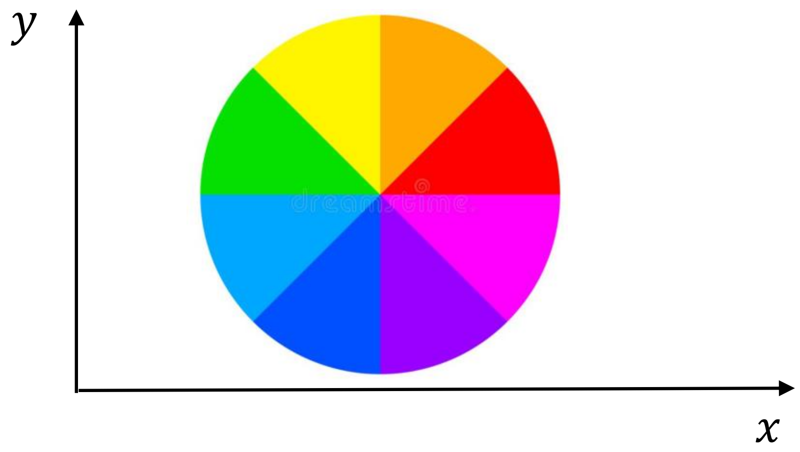
$$f(x, y) = Brightness$$

Brightness is communicated by a real number

What are signals?

- Signals can also have multi-dimensional range.

  Example: Color images



$$f(x, y) = Color$$

Color is indicated by three real numbers:
First representing **Red**, the second representing **Green**, and the third representing **Blue**.

What are signals?

Black & White Image

- Domain: $\mathbb{R}^2$ (multi-dimensional signal)
- Range: $\mathbb{R}$ (single-variate signal)

Multi-dimensional signal

Color Image

- Domain: $\mathbb{R}^2$ (multi-dimensional signal)
- Range: $\mathbb{R}^3$ (multi-variate signal)

Multi-dimensional and multi-variate signals

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Example: Amplifier

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Types of signals

Continuous-time signals vs. Discrete-time signals

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Time is the independent variable, assumed just for convenience

Types of signals

Continuous-time signals

- $x(t)$

  t is used as the independent variable

  () parenthesis is used

Discrete-time signals

- $x[n]$

  n is used as the independent variable

  [] brackets are used

Types of signals

Continuous-time signals

- $x(t)$

  t is used as the independent variable

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- Signal is defined for a continuum of values of the i.v.

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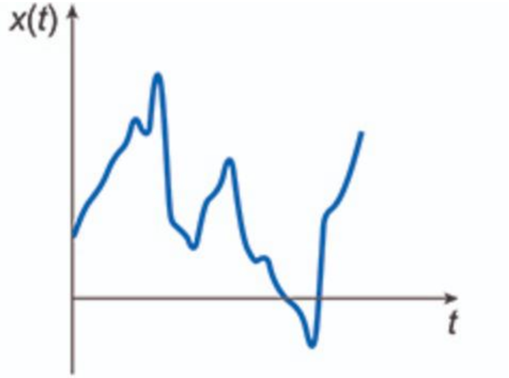
- Example:



Discrete-time signals

- $x[n]$

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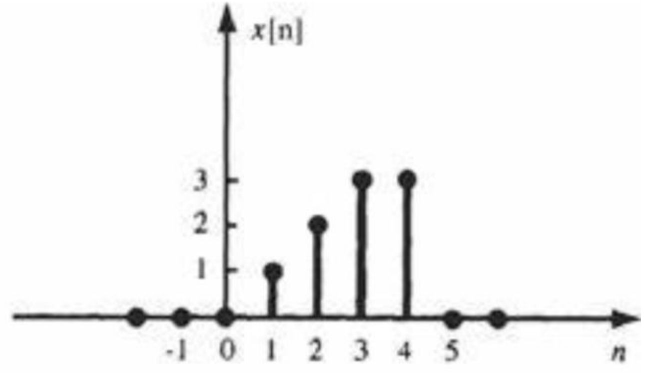
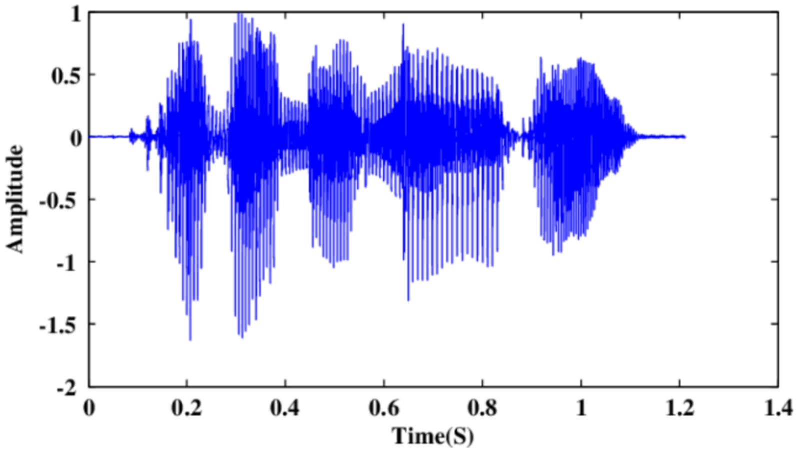
- Example:



Types of signals

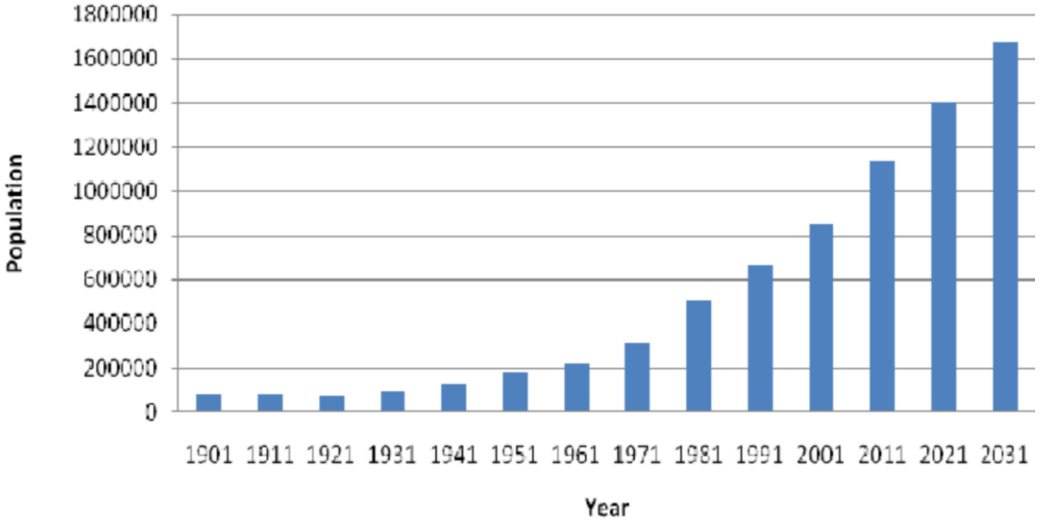
Continuous-time signals

- Examples are speech signals



Discrete-time signals

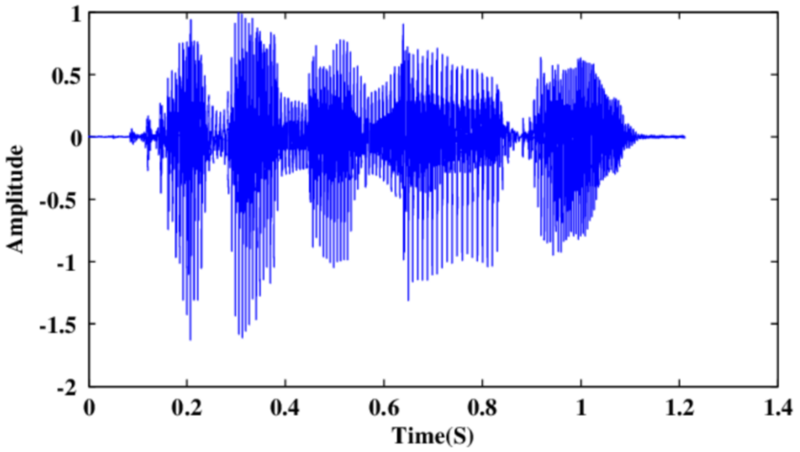
- Examples are population growth



Types of signals

Continuous-time signals

- Examples are speech signals



Discrete-time signals

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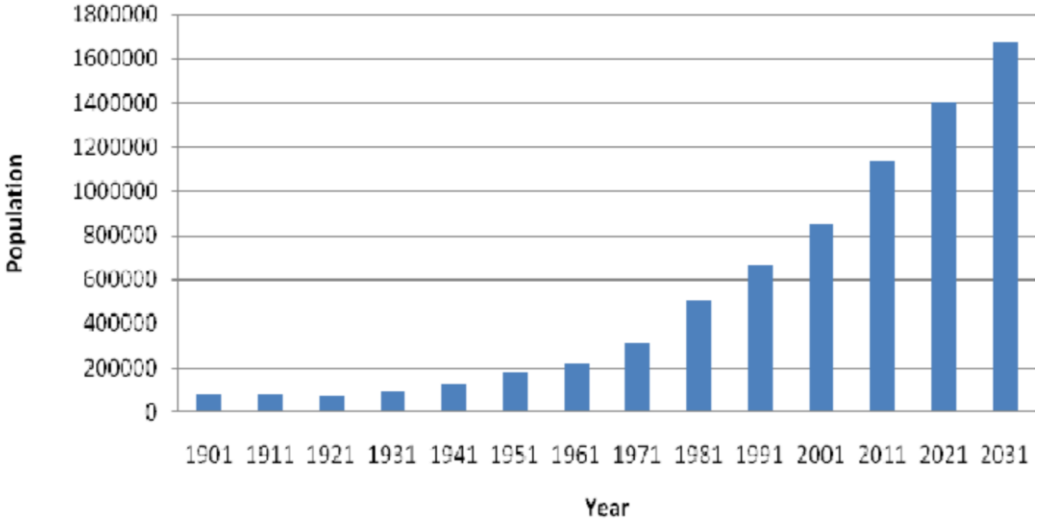

All physical signals are CT signals but CT signals cannot be stored in computer, and that is, bad.

Types of signals

- Thus, $x(t) \rightarrow x[n]$ by sampling.
  - Music → MP3
  - Picture → JPEG

Types of signals

- Thus, $x(t) \rightarrow x[n]$ by sampling.
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- Thus, $x(t) \rightarrow x[n]$ by sampling.
- Thus, $x[n] \rightarrow x(t)$ by interpolation.
  - Zero-order hold interpolation (good for ears).
  - Linear interpolation (good for eyes).
  - Ears and eyes respond to different kinds of errors.