EECS 16B

Designing Information Devices and Systems II

Profs. Miki Lustig and JP Tennant

Department of Electrical Engineering and Computer Science

Announcements

- Midterm #1
  - Redo is due Wed 3/13 @ 11:59pm
  - Grades to be released soon
- Lab
  - Midterm lab report due date extended to Friday 3/8 @ 11:59pm
  - Buffer lab this week, System Identification next week
- Other
 - Please post Ed questions in relevant threads

Today

- Discrete time signals and systems
  - solving for the state trajectory in discrete time
  - converting to state space form
- Hybrid systems (discrete time and continuous time)
  - "discretization" of a system

Continuous Time vs Discrete Time
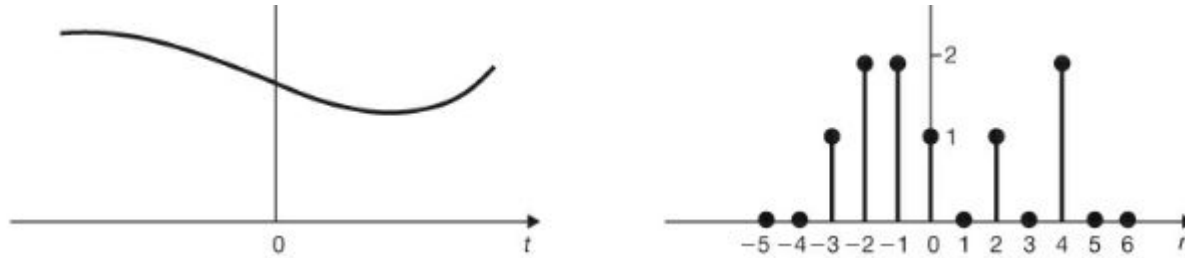
Discrete time signals may come from sampling CT signals.

Continuous Time vs Discrete Time
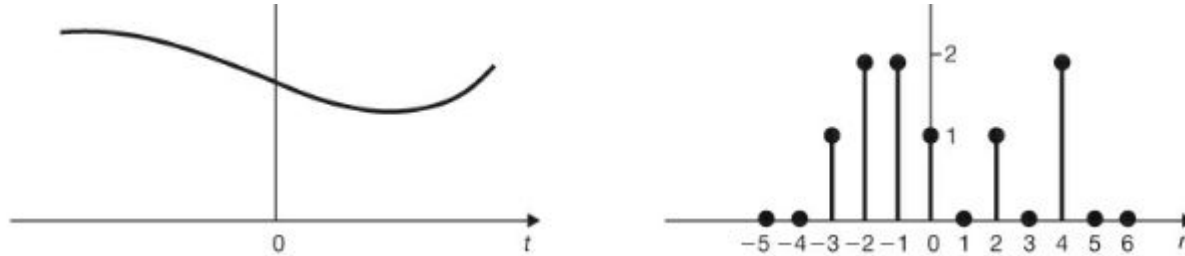
Discrete time signals may come from sampling CT signals.

There are also signals that are inherently DT, for example:
- end-of-day stock prices

Continuous Time vs Discrete Time

Discrete time signals may come from sampling CT signals.

There are also signals that are inherently DT, for example:
- end-of-day stock prices
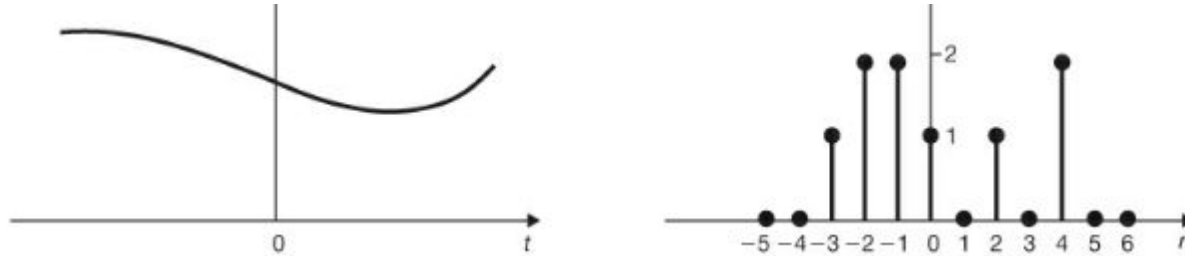- periodic population counts (census data, etc)

Continuous Time vs Discrete Time

Discrete time signals may come from sampling CT signals.

There are also signals that are inherently DT, for example:
- end-of-day stock prices
- periodic population counts (census data, etc)
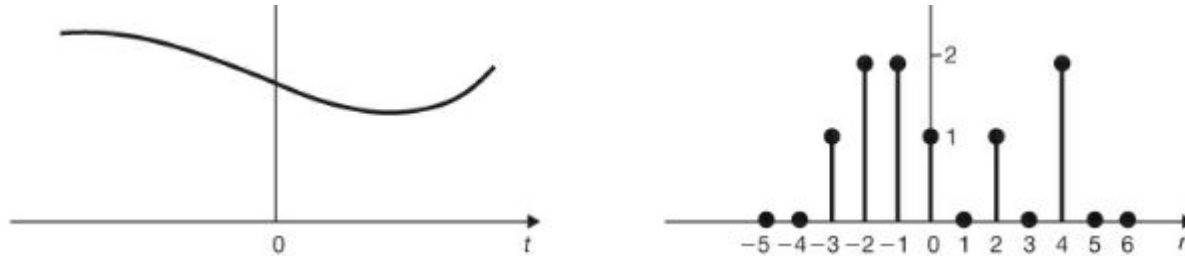- daily weather data

Continuous Time vs Discrete Time

Discrete time signals may come from sampling CT signals.

There are also signals that are inherently DT, for example:
- end-of-day stock prices
- periodic population counts (census data, etc)
- daily weather data
- etc

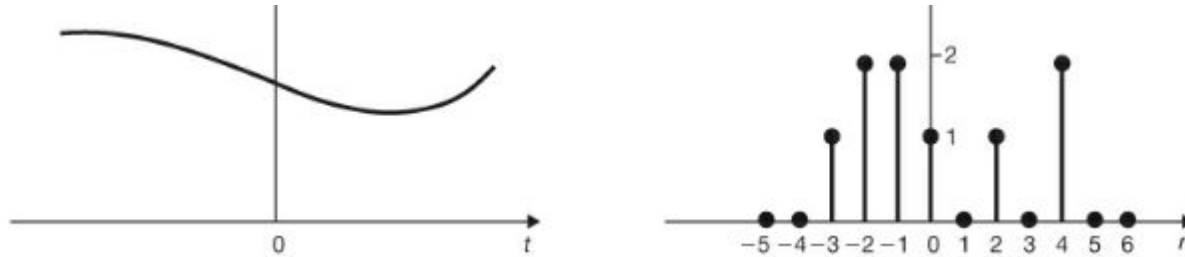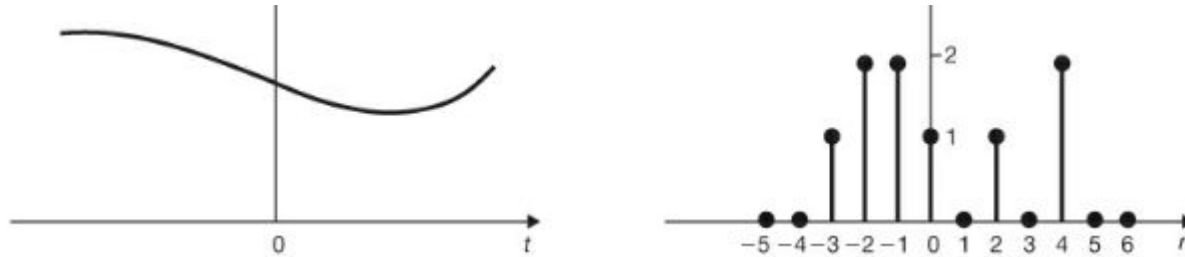# Continuous Time vs Discrete Time

Discrete time signals may come from sampling CT signals.

There are also signals that are inherently DT, for example:
- end-of-day stock prices
- periodic population counts (census data, etc)
- daily weather data
- etc

Is CT vs DT the same as analog vs digital?...

Analog vs Digital

Not exactly…

Analog means CT *and* values can be any real number.

Analog vs Digital

Not exactly…

Analog means CT *and* values can be any real number.

Digital means DT *and* a finite (although perhaps large) set of possible values.

Analog vs Digital

Not exactly…

Analog means CT *and* values can be any real number.

Digital means DT *and* a finite (although perhaps large) set of possible values.

We will mostly focus on DT but not digital, i.e. we will assume values can be any real number.

CT vs DT Duality

Continuous Time

$$\ddot{x} - 3\dot{x} + 2x = u(t)$$

differential equation

Discrete Time

$$x_i - 3x_{i-1} + 2x_{i-2} = u_i$$

difference equation

CT vs DT Duality

Continuous Time

$$\ddot{x} - 3\dot{x} + 2x = u(t)$$

differential equation

Discrete Time

$$x_i - 3x_{i-1} + 2x_{i-2} = u_i$$

difference equation

What is the order of the system on the left?

CT vs DT Duality

Continuous Time

$$\ddot{x} - 3\dot{x} + 2x = u(t)$$

differential equation

Discrete Time

$$x_i - 3x_{i-1} + 2x_{i-2} = u_i$$

difference equation

What is the order of the system on the left?

What is the order of the system on the right?

CT vs DT Duality

Continuous Time

$$\ddot{x} - 3\dot{x} + 2x = u(t)$$

differential equation

Discrete Time

$$x_i - 3x_{i-1} + 2x_{i-2} = u_i$$

difference equation

What is the order of the system on the left?

What is the order of the system on the right?

For DT systems, system order is determined by the largest delay in the difference equation.

(How far back do I have to look to determine the next state?)

CT vs DT Duality

Continuous Time

$$\ddot{x} - 3\dot{x} + 2x = u(t)$$

differential equation

$$x = \sum_k c_k e^{\lambda_k t}$$

form of homogeneous solution in CT

Discrete Time

$$x_i - 3x_{i-1} + 2x_{i-2} = u_i$$

difference equation

$$x_i = \sum_k c_k \lambda_k^i$$

form of homogeneous solution in DT

CT vs DT Duality

Continuous Time

$$\ddot{x} - 3\dot{x} + 2x = u(t)$$

differential equation

$$x = \sum_k c_k e^{\lambda_k t}$$

form of homogeneous solution in CT

$$\lambda^2 - 3\lambda + 2 = 0$$

characteristic equation in CT

Discrete Time

$$x_i - 3x_{i-1} + 2x_{i-2} = u_i$$

difference equation

$$x_i = \sum_k c_k \lambda_k^i$$

form of homogeneous solution in DT

$$\lambda^2 - 3\lambda + 2 = 0$$

characteristic equation in DT

CT vs DT Duality

Continuous Time

$$\ddot{x} - 3\dot{x} + 2x = u(t)$$
differential equation

$$x = \sum_k c_k e^{\lambda_k t}$$
form of homogeneous solution in CT

$$\lambda^2 - 3\lambda + 2 = 0$$
characteristic equation in CT

$$\dot{\vec{x}} = A\vec{x} + B\vec{u}$$
state space form in CT

Discrete Time

$$x_i - 3x_{i-1} + 2x_{i-2} = u_i$$
difference equation

$$x_i = \sum_k c_k \lambda_k^i$$
form of homogeneous solution in DT

$$\lambda^2 - 3\lambda + 2 = 0$$
characteristic equation in DT

$$\vec{x}_{i+1} = A\vec{x}_i + B\vec{u}_i$$
state space form in DT

CT vs DT Duality

Continuous Time

$$\ddot{x} - 3\dot{x} + 2x = u(t)$$

differential equation

$$x = \sum_k c_k e^{\lambda_k t}$$

form of homogeneous solution in CT

$$\lambda^2 - 3\lambda + 2 = 0$$

characteristic equation in CT

$$\dot{\vec{x}} = A\vec{x} + B\vec{u}$$

state space form in CT

Discrete Time

$$x_i - 3x_{i-1} + 2x_{i-2} = u_i$$

difference equation

$$x_i = \sum_k c_k \lambda_k^i$$

form of homogeneous solution in DT

$$\lambda^2 - 3\lambda + 2 = 0$$

characteristic equation in DT

$$\vec{x}_{i+1} = A\vec{x}_i + B\vec{u}_i$$

state space form in DT

A is the "*system matrix*"

CT vs DT Duality

Continuous Time

$$\ddot{x} - 3\dot{x} + 2x = u(t)$$
differential equation

$$x = \sum_k c_k e^{\lambda_k t}$$
form of homogeneous solution in CT

$$\lambda^2 - 3\lambda + 2 = 0$$
characteristic equation in CT

$$\dot{\vec{x}} = A\vec{x} + B\vec{u}$$
state space form in CT

A is the "*system matrix*"

Discrete Time

$$x_i - 3x_{i-1} + 2x_{i-2} = u_i$$
difference equation

$$x_i = \sum_k c_k \lambda_k^i$$
form of homogeneous solution in DT

$$\lambda^2 - 3\lambda + 2 = 0$$
characteristic equation in DT

$$\vec{x}_{i+1} = A\vec{x}_i + B\vec{u}_i$$
state space form in DT

A is the "*state transition matrix*"