AL- MUSTAQBAL UNIVERSITY COLLEGE
DEPARTMENT OF BIOMEDICAL ENGINEERING

Signals and Systems for BME

BME 322

Lecture 2

- Description and analysis of systems -

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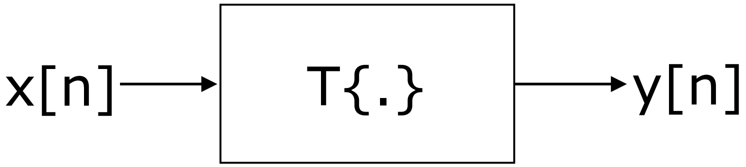
Discrete-Time Systems

- Discrete-Time Sequence is a mathematical operation that maps a given input sequence x[n] into an output sequence y[n]

$$y[n] = T\{x[n]\}$$



Basic System Properties

- Memoryless systems
- Causality
- Linearity
- Time Invariance
- Linear Time Invariant (LTI)

Memoryless systems & systems without Memory

- Memoryless systems & systems without Memory

A system is memory-less if the output y[n] at every value of n depends only on the input x[n] at the same value of n.

- Static and Dynamic Systems

Static system is memory-less whereas dynamic system is a not memoryless system.

Examples

- Memoryless Systems

Square

$$y[n] = (x[n])^2$$

Sign

$$y[n] = \text{sign}\{x[n]\}$$

- Not Memoryless Systems

$$y[n] = x[n - n_o]$$

Ex 1: $y(t) = 2\,x(t)$

For present value t=0, the system output is $y(0) = 2x(0)$.

Here, the output is only dependent upon present input. Hence the system is memory less or static.

Ex 2: $y(t) = 2\,x(t) + 3\,x(t-3)$

For present value t=0, the system output is $y(0) = 2x(0) + 3x(-3)$.

Here $x(-3)$ is past value for the present input for which the system requires memory to get this output. Hence, the system is a dynamic system.

Causal and Non-Causal Systems

A system is causal it’s output is a function of only the current and previous samples

Backward Difference (Causal)

$$y[n] = x[n] - x[n-1]$$

Forward Difference (Non-Causal)

$$y[n] = x[n+1] + x[n]$$

Examples

Ex 1: $y(n) = 2\,x(t) + 3\,x(t-3)$

For present value t=1, the system output is $y(1) = 2x(1) + 3x(-2)$.

Here, the system output only depends upon present and past inputs. Hence, the system is causal.

Ex 2: $y(n) = 2\,x(t) + 3\,x(t-3) + 6x(t+3)$

For present value t=1, the system output is $y(1) = 2x(1) + 3x(-2) + 6x(4)$. Here, the system output depends upon future input. Hence the system is non-causal system.

Liner and Non-liner Systems

A system is said to be linear when it satisfies superposition and homogenate principles. Consider two systems with inputs as $x_1(t)$, $x_2(t)$, and outputs as $y_1(t)$, $y_2(t)$ respectively. Then, according to the superposition and homogenate principles,

$$T\{x_1[n]+x_2[n]\}=T\{x_1[n]\}+T\{x_2[n]\} \quad \text{(additivity)}$$

$$and$$

$$T\{ax[n]\}=aT\{x[n]\} \quad \text{(scaling)}$$

Liner and Non-liner Systems

$$T\,[a_1\,x_1(t) + a_2\,x_2(t)] = a_1\,T[x_1(t)] + a_2\,T[x_2(t)]$$

$$T\,[a_1\,x_1(t) + a_2\,x_2(t)] = a_1\,y_1(t) + a_2\,y_2(t)$$

From the above expression, is clear that response of overall system is equal to response of individual system.

Example

Ex: $(t) = x^2(t)$

Solution:

$y_1(t) = T[x_1(t)] = x_1^2(t)$

$y_2(t) = T[x_2(t)] = x_2^2(t)$

$T[a_1 x_1(t) + a_2 x_2(t)] = [a_1 x_1(t) + a_2 x_2(t)]^2$

Which is not equal to $a_1 y_1(t) + a_2 y_2(t)$. Hence the system is said to be non linear.

Time Invariance

A system is said to be time variant if its input and output characteristics vary with time. Otherwise, the system is considered as time invariant.

- The condition for time invariant system is:

  $y(n, t) = y(n-t)$

- The condition for time variant system is:

  $y(n, t) \neq y(n-t)$

Where $y(n, t) = T[x(n-t)]$ = input change

$y(n-t)$ = output change

Example

Ex: $y(n) = x(-n)$

$y(n, t) = T[x(n-t)] = x(-n-t)$

$y(n-t) = x(-(n-t)) = x(-n + t)$

$y(n, t) \neq y(n-t)$. Hence, the system is time variant.