Time Domain Signal Processing Using MATLAB

Mohammad Sadgh Talebi
Sharif University of Technology
Outline

- Introduction
- Signal Representation
  - Examples
- System Representation
  - Temporal representation
  - Transfer Function
  - Zero-Pole-Gain Model
  - State-Space Model
  - Frequency Response Model
- Temporal Signal Analysis
  - Step Response
  - Impulse Response
  - Convolution
  - Bode Diagrams
Any signal can be defined like a mathematical variable.

Similarly, any system can be defined like a multivariate function, as stated before.

Using MATLAB, we’ll be able to determine specific properties of systems such as linearity, time-invariancy, causality, etc.
Continuous Time Signals

- MATLAB is only able to represent discrete time signals!!! But don’t worry, there’s nothing to worry about!
- By using appropriate sampling of a continuous signal, it can be converted to a discrete time signal which ideally by correct interpolation can be converted to the primal continuous signal.
- Let \( fs \) be the sampling frequency; then time index of a signal can be defined as:

\[
t = ti:1/fs:tf;
\]

\% \( ti \) is the initial time of simulation
\% \( tf \) is the final time of simulation
Discrete Time Signals

It’s simple! Let $n$ be the time index of the discrete signal, there’s several ways to assign desired values of each index, as mentioned before.
Examples

Examples of signal representations

- Unit Step:
  \[ x = \text{ones}(1, nf); \quad \% \text{nf is final time of simulation} \]

- Unit Impulse:
  \[
  x = \text{zeros}(1, nf); \\
  x(1) = 1; \quad \% \text{nf is final time of simulation}
  \]

- Cosine:
  \[
  t = -1:0.01:1; \\
  x = 2 \times \cos(2 \pi 10 t + \pi / 3);
  \]
Examples (Cont’d)

- Sinc function:

  \[ t = -1:.01:1; \]
  \[ x = \frac{\sin(\pi t)}{\pi t}; \]

- Complex exponential:

  \[ t = -1:.01:1; \]
  \[ x = \exp(j \cdot 2\pi \cdot 5\cdot t); \]
System Representation

- System Representation
  - Temporal representation
- LTI Models
  - Transfer Function
  - Zero-Pole-Gain Model
  - State-Space Model
    (To be discussed in the next session)
- Frequency Response Model
  (To be discussed in the next session)
Temporal Representation

Simply any system in time domain can be represented in several ways, such as:

a) Explicitly by a mathematical function as a relation between its inputs and outputs,

b) Explicitly by its step response or impulse response

c) Implicitly as a solution of an ODE or a difference equation.
For LTI systems we introduce the concept of Transfer Function as the Laplace Trans. of the impulse response.

**tf** command in MATLAB defines a system in complex frequency domain as following:

```matlab
tf(num,den);
% num is the numerator polynomial
% den is the denominator polynomial
```
Any system can be uniquely determined by its poles, zeros and a constant gain, in this respect we can define a system in MATLAB using aforementioned parameters.

The command \( \text{SYS} = \text{ZPK}(Z,P,K) \) creates a continuous-time zero-pole-gain (ZPK) model \( \text{SYS} \) with zeros \( Z \), poles \( P \), and gains \( K \).

Additionally, there’s another form of above command as following; \( \text{SYS} = \text{ZPK}(Z,P,K,Ts) \) creates a discrete-time ZPK model with sample time \( Ts \) (set \( Ts=-1 \) if the sample time is undetermined).
The command `step(sys)` evaluates and plots the step response of the LTI model `sys` (created with either TF, ZPK, or SS). For multi-input models, independent step commands are applied to each input channel.
The command \texttt{impulse(sys)} evaluates and plots the impulse response of the LTI model \texttt{sys} (created with either TF, ZPK, or SS). For multi-input models, independent step commands are applied to each input channel.
The command `conv(u,v)` convolves vectors `u` and `v`. The resulting vector is of length `LENGTH(A)+LENGTH(B)-1`.

If `A` and `B` are vectors of polynomial coefficients, convolving them is equivalent to multiplying the two polynomials.
The command `bode(sys)` evaluates and draws the Bode plot of the LTI model SYS (created with either TF, ZPK, SS, or FRD). The frequency range and number of points are chosen automatically.

Additionally, there’s another form of above command as following; `[mag,phase] = bode(sys,w)` and `[mag,phase,w] = bode(sys)` return the response magnitudes and phases in degrees (along with the frequency vector `w` if unspecified). No plot is drawn on the screen.
Questions

... surely, in the creation of the heavens and the earth, there are signs for the owners of wisdom ...

The Holy Quran

Thanks for your attendance.