Lecture 14 – Digital Signal Processing Summary

Assoc.Prof. Lăcrimioara GRAMA, Ph.D

Digital Signal Processing
4th year Telecommunications Technologies and Systems
Faculty of Electronics, Telecommunications and Information Technology
Technical University of Cluj-Napoca

Digital Signal Processing – Summary

- Introduction to digital signal processing
  - Continuous-time sinusoidal signals
  - Discrete-time sinusoidal signals
  - Normalized frequency
  - Alias effect
- Discrete-time signals
  - Examples of discrete-time signals
  - Classification of discrete-time signals
  - Manipulation of discrete-time signals
- Discrete-time systems
  - Examples of discrete-time systems
  - Block diagram representation of discrete-time systems
  - Classification of discrete-time systems
  - Interconnection of discrete-time systems

Digital Signal Processing – Summary (cont.)

- Analysis of discrete-time LTI systems
  - Resolving signals as impulses
  - Convolution sum and impulse response sequence
    - Convolution properties
  - Causal systems
  - BIBO stability
  - Correlation of discrete-time signals
    - Crosscorrelation sequence
    - Autocorrelation sequence
    - Correlation properties
    - Correlation of power signals
- FIR and IIR causal systems
  - Recursive and nonrecursive discrete-time systems
  - Free and forced response
- Direct-form implementation of discrete-time systems
  - Direct form I and II for IIR systems
  - Direct form for FIR systems

Digital Signal Processing – Summary (cont.)

- LTI systems described by constant-coefficient difference equations
  - FIR systems
  - IIR systems: solution of linear constant-coefficient difference equations
  - Impulse response
  - Stability of recursive LTIS
- The z-transform
  - Definition and region of convergence
  - Common z-transform pairs
  - Rational z-transform
    - Poles and zeros
    - System/transfer function of LTIS
    - Conversion from difference equations
  - Inversion of the z-transform
    - Direct evaluation
    - Power series expansion
    - Partial fraction expansion
  - Unilateral z-transform

Digital Signal Processing – Summary (cont.)

- Analysis of LTI systems in z-domain
  - Response of systems with rational system functions: transient and steady-state response
  - Causality and stability: Schür-Cohn stability test
- Fourier series for discrete-time periodic signals
- Fourier transform for discrete-time aperiodic signals
  - Definition
  - Relationship with z–transform: special case on unit circle
  - Properties
- Frequency-domain characteristics of LTIS
  - Frequency response function
  - Response to complex exponential and sinusoidal signals
- Discrete Fourier Transform
  - Definition
  - Properties
  - Remarks

Digital Signal Processing – Summary (cont.)

- Fast Fourier Transform
  - Radix-2 algorithm: decimation-in-time
  - Radix-2 algorithm: decimation-in-frequency
  - FFT split-radix algorithms
- Structures for realizing FIR systems
  - Direct-form
  - Cascade-form
  - Lattice structure
- Structures for realizing IIR systems
  - Direct-form I, II
  - Cascade-form
  - Parallel-form
  - Lattice structure
  - Lattice-ladder structure

Digital Signal Processing – Summary (cont.)

- LTI systems as frequency selective filters
    - Filter design through pole–zero placement: poles increase response and zeros decrease response (magnitude)
    - Lowpass, highpass and bandpass filters
    - Digital resonators, notch, comb and all-pass filters
- Linear-phase FIR filters
- Design of filters in frequency-domain
    - Characteristics of practical frequency selective filters
- Design of digital FIR filters
    - Design of linear-phase FIR filters using windows
    - Design of linear-phase FIR filters using the frequency-sampling method
- Characteristics of commonly used analog filters

Digital Signal Processing – Summary (cont.)

- Design of digital IIR filters
  - Design of IIR filters from analog filters
    - IIR filter design by approximation of derivatives
    - IIR filter design by impulse invariance
    - IIR filter design by bilinear transformation
  - Frequency transformations
    - Frequency transformations in the analog domain
    - Frequency transformations in the digital domain
  - Design of IIR filters in the discrete domain
    - Padé Approximation Method

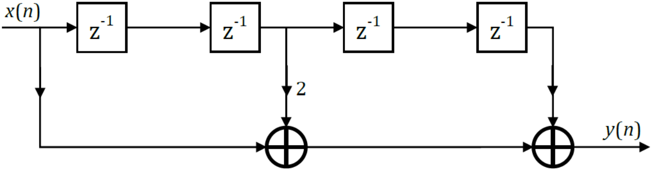
Exam Example (January 2019)

Eng1. A digital notch filter is required to remove an undesirable 60-Hz hum associated with a power supply in EKG recording application. The sampling frequency used is 720 Hz.

a) 1.0p Design a second-order FIR notch filter and
b) 1.0p A second-order pole-zero notch filter
for this purpose. In both cases choose the gain G so that $|H(\omega)| = 1$ for $\omega = 0$.
c) 0.5p Evaluate the impulse response of the FIR notch filter;
d) 0.5p For $r = 0.9$, write the input-output relationship corresponding to the IIR notch filter.

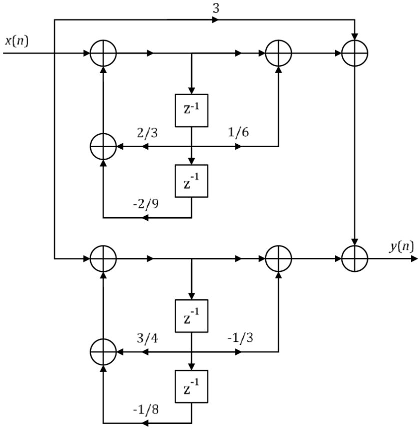
Exam Example (January 2019) (cont.)

Eng2. Determine the transient and the steady-state response of the FIR filter shown in the figure, to the input signal $x(n) = 10 \exp j\frac{\pi n}{2} u(n)$. Let $y(-1) = y(-2) = y(-3) = y(-4) = 0$.



Exam Example (January 2019) (cont.)

Eng3. For the system described in the next diagram, evaluate the impulse response sequence (2.5p), specifying the region of convergence (0.5p) so that the filter to be causal.



Exam Example (January 2019) (cont.)

Ro1. Consider the system described by the transfer function

$$H(z) = P\frac{1+\frac{1}{2}z^{-1}+\frac{1}{3}z^{-2}}{A_3(z)}$$

with the lattice parameters $K_1 = 1/4$, $K_2 = 1/2$ and $K_3 = -4/5$; P is a constant.

a) 0.8p Write the expression of the transfer function, evaluating first the $A_3(z)$ polynomial;
b) 0.5p Write the corresponding input-output relationship;
c) 1.7p Sketch the lattice-ladder structure (ladder parameters - 0.7p, lattice-ladder structure - 1p).

Exam Example (January 2019) (cont.)

Ro2. An analog sinusoidal signal

$$x_a(t) = 2\cos(120\pi t) + 4\sin(140\pi t) - 6\cos(160\pi t) + 8\sin(180\pi t)$$

is sampled by 2560 Hz. Determine the 512-point DFT for the discrete-time signal obtained after sampling (1.5p) and evaluate the magnitude (0.75p) and phase (0.75p) spectra.

Exam Example (January 2019) (cont.)

Ro3. Using Padé approximation method, determine the five parameters corresponding to a filter described by the transfer function

$$H(z) = \frac{b_0}{1 + a_1 z^{-1} + a_2 z^{-2} + a_3 z^{-3} + a_4 z^{-4}}$$

knowing that the desired unit impulse response is

$$h_d(n) = \left\{\ldots, 0, \underset{\uparrow}{1}, -\frac{1}{2}, \frac{1}{3}, -\frac{1}{4}, \frac{1}{5}, -\frac{1}{6}, \frac{1}{7}, \ldots\right\}$$

Examination is the best platform for building up your future. So take it seriously and give it a hard push. I hope you can do good.

An exam is not only a test of your academic knowledge, it is a test of your calmness, stability and courage.