پردازش سیگنال دیجیتال

درس ۱

مقدمه‌ای بر پردازش سیگنال دیجیتال

Introduction to Digital Signal Processing

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Course Details

- Objective
  - Establish a background in Digital Signal Processing Theory

- Required Text
  - **Discrete-Time Signal Processing**,
  - Prentice Hall, 3rd Edition
  - Alan Oppenheim, Ronald Schafer, John Buck

DSP is Everywhere

- **Sound applications**
  - Compression, enhancement, special effects, synthesis, recognition, echo cancellation,…
  - Cell Phones, MP3 Players, Movies, Dictation, Text-to-speech,…
- **Communication**
  - Modulation, coding, detection, equalization, echo cancellation,…
  - Cell Phones, dial-up modem, DSL modem, Satellite Receiver,…
- **Automotive**
  - ABS, GPS, Active Noise Cancellation, Cruise Control, Parking,…
- **Medical**
  - Magnetic Resonance, Tomography, Electrocardiogram,…
- **Military**
  - Radar, Sonar, Space photographs, remote sensing,…
- **Image and Video Applications**
  - DVD, JPEG, Movie special effects, video conferencing,…
- **Mechanical**
  - Motor control, process control, oil and mineral prospecting,…

Course Outline

- **Introduction to Digital Signal Processing**
- **Discrete-Time Signals and System**
  - Discrete-Time Signals: Sequences (2.1)
  - Discrete-Time Systems (2.2)
  - Linear Time-Invariant Systems (2.3)
  - Properties of Linear Time-Invariant Systems (2.4)
  - Linear Constant-Coefficient Difference Equations (2.5)
  - Frequency-Domain Representation of Discrete-Time Signals (2.6)
  - Representation of Sequences by Fourier Transforms (2.7)
  - Symmetry Properties of the Fourier Transform (2.8)
  - Fourier Transform Theorems (2.9)
- **The z-Transform**
  - z-Transform (3.1)
  - Properties of the Region of Convergence (ROC) of the z-Transform (3.2)
  - The Inverse z-Transform (3.3)
  - z-Transform Properties (3.4)

Course Outline

- **Sampling of Continuous-Time Signals**
  - Periodic (Uniform) Sampling (4.1)
  - Frequency-Domain Representation of Sampling (4.2)
  - Reconstruction of a Bandlimited Signal from Its Samples (4.3)
  - Discrete-Time Processing of Continuous-Time Signals (4.4)
  - Continuous-Time Processing of Discrete-Time Signals (4.6)
  - Changing the Sampling Rate Using Discrete-Time Processing (4.6)
  - Digital Processing of Analog Signals (4.8)
- **Transform Analysis of Linear Time-Invariant Systems**
  - The Frequency Response of LTI Systems (5.1)
  - System Functions: Linear Constant-Coefficient Difference Equations (5.2)
  - Frequency Response for Rational System Functions (5.3)
  - Relationship between Magnitude and Phase (5.4)
  - All-Pass Systems (5.5)
  - Minimum-Phase Systems (5.6)
  - Linear Systems with Generalized Linear Phase (5.7)

Course Outline

- **Structures for Discrete-Time Systems**
  - Block Diagram Representation (6.1)
  - Signal Flow Graph Representation (6.2)
  - Basic Structures for IIR Systems (6.3)
  - Transposed Forms (6.4)
  - Basic Structures for FIR Systems (6.5)
  - Finite Precision Numerical Effects (6.7)
  - Effects of Coefficient Quantization (6.8)
  - Effects of Round-Off Noise in Digital Filters (6.9)
- **Filter Design Techniques**
  - Filter Specifications (7.1)
  - Design of Discrete-Time IIR Filters from Continuous-Time Filters (7.2)
  - Discrete-Time Butterworth, Chebyshev and Elliptic Filters (7.3)
  - Frequency Transformations of Lowpass IIR Filters (7.4)
  - Design of FIR Filters by Windowing (7.5)
  - Optimum Approximations of FIR Filters (7.7)

Course Outline

- **The Discrete-Fourier Transform**
  - Representation of Periodic Sequences: The Discrete Fourier Series (8.1)
  - Properties of the Discrete Fourier Series (8.2)
  - The Fourier Transform of Periodic Signals (8.3)
  - Sampling the Fourier Transform (8.4)
  - The Discrete Fourier Transform (8.5)
  - Properties of the DFT (8.6)
- **Computation of the Discrete-Fourier Transform**
  - Fast Fourier Transform Algorithm (9)
- **Fourier Analysis of Signals Using the Discrete Fourier Transform (10)**
- **Parametric Signal Modeling (11)**
- **Discrete Hilbert Transform (12) ***
- **Cepstrum Analysis and Homomorphic Deconvolution (13) ***
- **Applications *** (Audio DSP, Image DSP, Video DSP, …)
- **Advanced Topics in DSP ***
  - Multi-Rate DSP, Linear Prediction, Power Spectrum Estimation, …

Signal Processing

- **Humans** are the most advanced signal processors
  - speech and pattern recognition, speech synthesis,…
- We encounter **many types of signals** in **various applications**
  - **Electrical signals:** voltage, current, magnetic and electric fields,…
  - **Mechanical signals:** velocity, force, displacement,…
  - **Acoustic signals:** sound, vibration,…
  - **Other signals:** pressure, temperature,…
- Most real-world signals are **analog**
  - They are continuous in time and amplitude
  - Convert to voltage or currents using sensors and transducers
- **Analog circuits** process these signals using
  - Resistors, Capacitors, Inductors, Amplifiers,…
- **Analog signal processing** examples
  - Audio processing in FM radios
  - Video processing in traditional TV sets

Limitations of Analog Signal Processing

- **Accuracy limitations** due to
  - Component tolerances
  - Undesired nonlinearities
- **Limited repeatability** due to
  - Tolerances
  - Changes in environmental conditions
    - Temperature
    - Vibration
- **Sensitivity to electrical noise**
- **Limited dynamic range** for voltage and currents
- **Inflexibility to changes**
- **Difficulty of implementing certain operations**
  - Nonlinear operations
  - Time-varying operations
- **Difficulty of storing information**

Digital Signal Processing

- Represent signals by a sequence of numbers
  - Sampling or analog-to-digital conversions
- Perform processing on these numbers with a digital processor
  - Digital signal processing
- Reconstruct analog signal from processed numbers
  - Reconstruction or digital-to-analog conversion


analog signal

A/D

digital signal

DSP

digital signal

D/A

analog signal

- **Analog input – analog output**
  - Digital recording of music
- **Analog input – digital output**
  - Touch tone phone dialing
- **Digital input – analog output**
  - Text to speech
- **Digital input – digital output**
  - Compression of a file on computer

Pros and Cons of Digital Signal Processing

- **Pros**
  - Accuracy can be controlled by choosing word length
  - Repeatable
  - Sensitivity to electrical noise is minimal
  - Dynamic range can be controlled using floating point numbers
  - Flexibility can be achieved with software implementations
  - Non-linear and time-varying operations are easier to implement
  - Digital storage is cheap
  - Digital information can be encrypted for security
  - Price/performance and reduced time-to-market
- **Cons**
  - Sampling causes loss of information
  - A/D and D/A requires mixed-signal hardware
  - Limited speed of processors
  - Quantization and round-off errors