Digital Signal Processing

Code: 03.S.08.O.209

Course Managers: Dan Stefanoiu, Bogdan Dumitrescu

Duration: 42 h course, 28 h laboratory applications

ECTS value: 5 credits / 60

Objective. This course aims to introduce the students the basic concepts of Digital Signal Processing field.

Course structure. The course is structured into 8 chapters, as listed: next.

Lab structure. The laboratory works are developed following 6 themes, as listed in the end (see LABORATORY THEMES). There are 6 simulation algorithms to be designed for each theme.

Main references

[OpSc85] Oppenheim A.V., Schafer R. – *Digital Signal Processing*, Prentice Hall, Upper Saddle River, New Jersey, USA, 1985 (English).

[PrMa96] Proakis J.G., Manolakis D.G. – *Digital Signal Processing. Principles, Algorithms and Applications.*, third edition, Prentice Hall, Upper Saddle River, New Jersey, USA, 1996 (English).

[SoSt89] Söderström T., Stoica P. – *System Identification*, Prentice Hall, London, UK, 1989 (English).

[StD96a] Stefanoiu D. – *Introduction to Digital Signal Processing*, “Politehnica” University Press, Bucharest, Romania, 1996 (Romanian).

[StD96b] Stefanoiu D. – *Computing Techniques of Digital Signal Processing*, “Politehnica” University Press, Bucharest, Romania, 1996 (Romanian).

[StD03] Stefanoiu D. – *Data Compression*, Printech Press, Bucharest, Romania, 2003 (Romanian).

[SCS05] Stefanoiu D., Culita J., Stoica P. – *A Foundation of System Modeling and Identification*, Editura Printech, Bucureşti, România, 2005 (Romanian).

COURSE CONTENTS

1. Overview (3h / 3h)
    1.1. Historical notes
    1.2. The concept of “signal”
    1.3. Signal classifications
    1.4. General problem of Signal Processing
    1.5. A solution: Fourier expansion
2. Discrete signals algebra (6h / 9h)
    2.1. Time-shift invariant systems
    2.2. Stability
    2.3. Causality
    2.4. Description and representation of signals by using difference equations (signal graphs, Tellegen’s Theorem)
3. Frequency representation of signals (3h / 12h)
    3.1. Types of Fourier Transforms (Continuous, Discretized, Fourier Series, Discrete Time)
    3.2. Properties of Fourier Transforms (convolution properties and symmetry properties)
    3.3. Z Transform (short recall)
4. Sampling of signals (3h / 15h)
    4.1. The sampling-interpolation duality.
    4.2. Basic sampling theorems (Vallée Poussin, Shannon-Kotel’nikov, Shannon-Nyquist)
    4.3. Aliasing
    4.4. Exact interpolation
5. Discrete Fourier Series (3h / 18h)
    5.1. Definition
    5.2. Properties (convolution properties and symmetry properties)
6. Discrete Fourier Transforms (6h / 24h)
    6.1. Duality between finite length sequences and periodic sequences
    6.2. Circular and linear convolution properties
    6.3. Symmetry properties
    6.4. Recovering the Z Transform from its values on unit circle
7. Fast Fourier Transform algorithms (12h / 36h)
    7.1. Fundamental principle of FFT algorithms
    7.2. Goertzel Algorithm
    7.3. Decimation-in-time (basic algorithm, complexity, improvements through butterfly structure)

- 7.4. Decimation-in-frequency (basic algorithm, correlation with decimation-in-time by using Tellegen's theorem)
- 7.5. Cooley-Tukey Algorithms
- 7.6. Singleton Algorithms
- 7.7. Composite Algorithms
- 7.8. Examples: signals with length divisible by 3 or by 4

8. Spectral analysis (6h / 42h)
   - 8.1. Spectral analysis problem (smoothing signals spectra)
   - 8.2. Bartlett procedures
   - 8.3. Welch procedures
   - 8.4. AR and ARMA modeling (Levinson-Durbin algorithm)

LABORATORY THEMES

1. Goertzel Algorithm (2h / 2h)
2. FFT algorithms with decimation-in-time (4h / 6h)
3. FFT algorithms with decimation-in-frequency (2h / 8h)
4. Bartlett algorithm (4h / 12h)
5. Welch algorithm (2h / 14h)
6. Levinson-Durbin algorithm (4h / 18h)
7. Shannon-Fano algorithm (data compression) (2h / 20h)
8. Static Huffman algorithm (data compression) (4h / 24h)
9. Adaptive Huffman algorithm (data compression) (4h / 28h)