DESCRIPTION OF THE COURSE

Name of course: **Multidimensoonal systems**	Code: BIE634	Semester: 7
Method of teaching: Lectures and seminars.	Lessons per week:	Number of credits:

COURSE DESCRIPTION:
2-D Systems is the necessary mathematical background for the modern image processing. 3-D Systems is the necessary mathematical background for moving images, etc...In general Multidimensional systems (m-D) theory is the necessary mathematical background for many appication image processing, X-ray enhancement, seismic data processing, geo-science, computer vision, robotics, biomedical engineering, circuits, systems, control and other areas like financial science and engineering, neuroscience, psychology, social science....
Multidimensional Systems are also a useful tool in the modelling of partial differential equations while several new applications on Applied Electromagnetics have been implemented recently.
So, m-D Systems and especially m-D Filters' Design is very important topic and necessary subject for all undergraduate electrical and computer engineers.

MULTIDIMENSIONAL SYSTEMS

1st Chapter: Discrete and Continuous Multidimensional Signals and Systems
Introduction, Region of Support, Quantization, Periodicity, Separability, Linearity, Shift Invariance, Causality.
Recursive Filters, Non-recursive Filters.
(1 week: 1.5 hour “ex cathedra", 1 hour seminar)

2nd Chapter:
Flow graphs and Networks. Space Domain Analysis. Convolution
Description of Discrete and Continuous Multidimensional Systems
(1 week: 1.5 hour “ex cathedra", 1 hour seminar)

3rd Chapter:
Conversion from one description to the other
Transfer function, States-space equations,
Impulse Response, Difference Equations
(1 week: 1.5 hour “ex cathedra", 1 hour seminar)

4th Chapter:
Realization: Direct Structure, Cascade Structure, Separable Structures, Multi-Input and Multi-output Filters, Multidimensional Filters
(1 week: 1.5 hour “ex cathedra", 1 hour seminar)

5th Chapter:
Givone-Roesser Model, Fornasini-Marchesini Model. Conversion from one model to the other Model. Modelling of Partial Differential Equations of Mathematical Physics with Givone-Roesser Model or Fornasini-Marchesini Model
(1 week: 1.5 hour “ex cathedra", 1 hour seminar)

6th Chapter:
Observability of 2-dimentional systems
Controllability and minimality of 2-dimentional systems.
(1 week: 1.5 hour “ex cathedra", 1 hour seminar)

7th Chapter:
The m-D (multidimensional) Z Transform. Region of Convergence. The Inverse m-D Z-Transform. Complex Convolution. m-D Parseval Theorem. The m-D Fourier Transform. The Sampling Process. 2-D Sampled Signals. The 2-D Sampling Theorem. Symmetries. Idealized Systems and Filters.
(1 week: 1.5 hour “ex cathedra", 1 hour seminar)

8th Chapter:
Stability. Stability Analysis in Frequency Domain. Stability Analysis in State Space. Stability Properties. Stability Theorems, Stability Tests and Criteria. m-D Lyapunov Stability Theory. Stability of Low-Order Filters.
(2 week: 2*1.5 hour “ex cathedra", 2 hour seminars)

9th Chapter:
Stability Margin. Definitions and Computation of Stability Margin with various methods. Comparison and Benchmarks
(1 week: 1.5 hour “ex cathedra", 1 hour seminar)

10th Chapter:
Systems’ and Signals’ Factorizability and Factorization. Multivariable polynomial factorization. Exact and Approximate Factorization. Methods and Results
(2 week: 2*1.5 hour “ex cathedra", 2 hour seminars)

11th Chapter:
Multidimensional Digital Filters Theory: Approximation for Nonrecursive Filters. Properties of m-D nonrecursive Filters. Linear-Phase Filters. Frequency Response. Design Based on Fourier Series. Multidimensional Window Functions. Design of 2-D Circularly Symmetric Filters. Fan Filters. Design based on McClellan Transformation
(1 week: 1.5 hour “ex cathedra", 1 hour seminar)

12th Chapter:

Multidimensional Digital Filters Theory: Approximation for Recursive Filters. Bilinear Transformation. Linear Transformations. Analog-Filter Transformations. Method of Hirano and Aggarwal. Filters with Half-Plane Symmetry. Circularly Symmetric Filters. Method of Goodman. Other Transformations.
(1 week: 1.5 hour “ex cathedra", 1 hour seminar)

13th Chapter:

m-D Filters’ Design by Optimization. Quasi-Newton Optimization Algorithms. Minimax Method. SVD (Singular Value Decomposition) based desing. Error Analysis. Stability aspects and problems of m-D systems Design. Computational Intelligence based m-D design. New Aspects and Directions for Further Research. Realization. Finite Wordlength Effects. Overflow Limit Cycles.
(1 week: 1.5 hour “ex cathedra", 1 hour seminar)

REFERENCES

[1] T.Matsuo, Y.Hasegawa, *Realization Theory of Discrete-Time Dynamical Systems, wo-Dimensional Linear Systems,* Springer-Verlag, Lecture Notes in Control and Information Sciences, Berlin-Heidelberg, 2003.

[2] B.A.Shenoi, *Magnitude and Delay Approximation of 1-D and 2-D Digital Filtersealization Theory of Discrete-Time Dynamical Systems, wo-Dimensional Linear Systems,* Springer-Verlag, Digital Signal Processing Book Series, 1999.

[3] T.Kaczorek, *Two-Dimensional Linear Systems,* Springer-Verlag, Lecture Notes in Control and Information Sciences, Berlin-Heidelberg, 1985.

[4] Wu-Sheng Lu, Andreas Antoniou, *Two-Dimensional Digital Filters,* Marcel Dekker, New York, 1992.

[5] N.K.Bose (Editor), *Multidimensional Systems Theory, Progress, Directions and Open Problems in Multidimensional Systems,* D. Reidel Publishing Company, Dordrecht, Holland 1985.

[6] N.K.Bose (Editor), *Multidimensional Systems: Theory and Applications,* IEEE Press, 1979

[7] S.G.Tzafestas (Editor), *Multidimensional Systems,* Marcel Dekker, New York, 1986.

[8] G.F.Simmons, *Introduction to Topology and Modern Analysis*, McGraw-Hill Book Company, New York, 1980.

[9] R.P.Roesser, "A discrete state-space model for image processing," *IEEE Trans. Automat. Contr.,* vol. AC-20, pp. 1-10, Feb. 1975.

[10] Various Papers in the WSEAS Transactions and Books: http://www.wseas.org

http://elfe.tu-sofia.bg/staff.htm

http://elfe.tu-sofia.bg/curriculum4.htm