Modelling of the complex signals and processing them with the linear and non-linear methods

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45 hours: 15 lectures (in total 30 hours), 15 Seminars (in total 15 hours)

Week #	Tasks/Topics	Study Material
1	General characterization of signals. The notion of a signal. Classification of signals. General characteristics of signals.	[1,7]
2	Modeling signals. Generate regular and random signals. Modeling practical problems.	[1,8]
3	Noise and its types. Noise in physical processes. Modelling noise. Flicker Noise. Noise colours. White noise.	[2,4]
4	Preliminary statistical processing of signals. Building histograms. Calculating probability density function. Calculating cumulative distribution function. Basic statistical characteristics of signals.	[8]
5	Correlation analysis of signals. Covariance and correlation functions. Correlation characteristics of random signals and their calculation. Examples.	[1,8]
6	Spectral analysis of signals. Fourier transform of a signal. Continuous and discrete Fourier-transform. Inverse Fourier transform. Examples. Building spectrograms. Windowed Fourier-Transform. Calculating power spectrum of a signal.	[4]
7	Wavelet analysis of signals. General characterization of wavelet functions. Waveletseries expansion for signals. Energy features of signals. Wavelet spectrograms and the wavelet diagrams of signals, scalogram. Plotting wavelet coefficients.	[9]
8	Generating and processing chaotic signals. General characteristics of deterministic chaos. Generating chaotic signals by logistic map. Chaotic signals in the Lorenz system. Identification and processing of chaotic signals. Practical examples.	[1,3,5]
9	Fractal and multifractal analysis of signals.	[5,10]

	Definitions of fractal and multifractal. Fractality of signals. Methods for calculating fractal dimension. *Hausdorff–Besicovitch and Renyi*dimensions. Multifractal analysis examples.	
10	Correlation dimension of signals. Attractor and construction of its correlational dimension. Reconstruction of an attractor. Methods for reconstructing dynamic systems from time series.	[7]
11-12	Lyapunov exponents for time series and their interpretation. Methods of computing Lyapunov exponents for dynamical system of equations and for time series.	[1,4,8]
13-15	Entropy in data analysis. Statistical notion of entropy. Entropy and information in time series. Principle of maximum entropy. Methods of calculating entropy and Shannon information. R/S analysis. Hurst's empirical law. Hurst exponent and methods of its calculation.	[3,4,8]

Literature:

[1] H.G. Schuster, Deterministic Chaos, 2nd Edition, Physik-Verlag (1995).
[2] F. Moon. Chaotic Vibration, Wiley: N.Y.,1987.
[3] P.G. Drazin, Nonlinear Systems, Cambridge University Press (1992).
[4] A.J. Lichtenberg and M.A. Lieberman, Regular and Chaotic Dynamics, 2ndEdition, Springer-Verlag (1994).
[5] S. H. Strogatz, Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry and Engineering, Addison-Wesley, 1994.
[6] T. Tel and M. Gruiz, Chaotic Dynamics, Cambridge University Press, 2006.
[7] H. Stark and J.W. Woods, Probability and Random Processes with Application to Signal Processing Prentice Hall 2002.
[8] Vinay K. Ingle and John G. Proakis: Digital Signal Processing Using MATLAB, Brooks/Cole/Thomson Learning, 2001.
[9] C. Chui, An Introduction to Wavelets, Ac. Press, 2001.
[10] J. Feder, Fractals, SpringerScience,1989.