

DOCTORAL STUDY COURSE DESCRIPTION

Course title	Scientific area	Faculty	Department
Advanced signal processing	Informatics Engineering (T 007)	Faculty of Mathematics and Informatics	Institute of Data Science and Digital Technologies

Methods of studies	Credits, ECTS	Methods of studies	Credits, ECTS
Lectures	0	Consultation (autumn semester)	1
Individual work	4	Practical assignments	2

Course summary

The course covers modern methods of digital signal processing: random signal processing, multidimensional and multirate signal processing, nonlinear processing, as well as the theory of adaptive filters. The primary focus is on developing theoretical knowledge and practical skills through practical assignments, the presentation of results, and discussion. The obtained knowledge can be applied to the analysis of signals from various sources and to solving interdisciplinary problems.

The course combines independent studies (literature analysis), consultations, and practical assignments. The final format of the course is determined individually with student. The course topics may be aligned with the student's doctoral research.

- Theoretical knowledge is obtained through independent study of the literature and consultation with the course lecturers and researchers.
- Knowledge is reinforced through experimental work in digital signal processing. Students solve various problems involving the processing of one-dimensional and two-dimensional signals. Course participants are given up to 5 practical assignments covering the main topics of the course. The results of these assignments are presented during consultation sessions.
- Theoretical knowledge is assessed during the exam.

The content of the course:

1. MULTIDIMENSIONAL SIGNAL PROCESSING. Multidimensional signals and systems. Analysis of multidimensional signals. Filtering of multidimensional signals. Spectral analysis. Multidimensional transforms. Multirate signals.
2. STATISTICAL PROCESSING OF RANDOM SIGNALS. Random variables and processes. Random signals. Information theory. Signal entropy. Ergodicity and stationarity of random signals. Statistical characteristics and their estimation. Bayesian theory. Statistical signal models. Statistical methods for parameter estimation. Parametric and nonparametric analysis of random signals.
3. ADAPTIVE SIGNAL PROCESSING. Mathematical foundations. Optimal linear filtering. Adaptive algorithms. Theory of adaptive filters. Tasks of adaptive processing: noise removal, system identification, system modeling.
4. NONLINEAR SIGNAL PROCESSING. Nonlinear effects in signals. Nonlinear signals. Nonlinear filters. Nonlinear spectral analysis methods. Nonlinear statistical methods. Volterra sequences and models. Chaos theory, Lyapunov exponents. Fractal signal analysis. Phase-based signal processing. Deep learning methods for signal processing. Applications of nonlinear processing.
5. OTHER SIGNAL PROCESSING TECHNIQUES. Matrix signal processing: mathematical foundations, matrix geometry, signal models, beamforming, direction analysis. Analysis of sparse signals: fundamentals of signal sparsification (decimation), signal reconstruction methods, sparse filters.

6. PROCESSING OF SPECIFIC SIGNALS. Speech signal processing: nature and properties of signals, signal modeling, coding. Physiological signal processing: examples of heart rate and electroencephalogram signals. Noise and its removal from signals. Distortions and signal enhancement.
Literature list
K. Pal et al. <i>Advanced methods in biomedical signal processing and analysis</i> . 2022, Elsevier Science & Technology, 434 psl. (el. išteklis).
N. Dey. <i>Intelligent speech signal processing</i> . 2019, Academic Press, 212 psl. (el. išteklis).
B. Farhang-Boroujeny. <i>Adaptive filters: theory and applications</i> . 2013, John Wiley & Sons, 778 psl. (el. išteklis).
D. G. Manolakis, et al. <i>Statistical and adaptive signal processing: spectral estimation, signal modeling, adaptive filtering, and array processing</i> . 2005, Artech House, 806 psl. (el. išteklis).
M. H. Hayes. <i>Statistical digital signal processing and modeling</i> . 1996, John Wiley & Sons, 608 psl.
D. E. Dudgeon, R. M. Mersereau. <i>Multidimensional digital signal processing</i> . 1984, Prentice-Hall, 400 psl.

Consulting persons	Scientific degree	Key publications
Gintautas Tamulevičius	D. Sc.	https://elaba.mb.vu.lt/dmsti/?aut=Gintautas+Tamulevičius
Gražina Korvel	D. Sc.	https://elaba.mb.vu.lt/dmsti/?aut=Gražina+Korvel
Povilas Treigys	D. Sc.	https://elaba.mb.vu.lt/dmsti/?aut=Povilas+Treigys