Syllabus

1. Information regarding the programme

1.1 Higher education institution	**Babeş-Bolyai University**
1.2 Faculty	**Faculty of Physics**
1.3 Department	**Department of Physics – Hungarian Line of Study**
1.4 Field of study	**Physics**
1.5 Study cycle	**Master**
1.6 Study programme / Qualification	**Computational Physics**

2. Information regarding the discipline

2.1 Name of the discipline (en)				Digital Signal Processing			
2.2 Course coordinator				Lázár Zsolt Iosif			
2.3 Seminar coordinator				Lázár Zsolt Iosif			
2.4. Year of study	1	2.5 Semester	2	2.6. Type of evaluation	E	2.7 Type of discipline	DA

3. Total estimated time (hours/semester of didactic activities)

3.1 Hours per week	4	Of which: 3.2 course	2	3.3 seminar/laboratory	2
3.4 Total hours in the curriculum	56	Of which: 3.5 course	28	3.6 seminar/laboratory	28
Time allotment:					hours
Learning using manual, course support, bibliography, course notes					14
Additional documentation (in libraries, on electronic platforms, field documentation)					20
Preparation for seminars/labs, homework, papers, portfolios and essays					27
Tutorship					4
Evaluations					4
Other activities:					
3.7 Total individual study hours	69				
3.8 Total hours per semester	125				
3.9 Number of ECTS credits	5				

4. Prerequisites (if necessary)

4.1. curriculum	1. Mathematical analysis 2. Algebra
4.2. competencies	1. Calculus including functions, series, complex numbers 2. Programming basics

5. Conditions (if necessary)

5.1. for the course	white/blackboard, projector, computer
5.2. for the seminar /lab activities	white/blackboard, projector, computer

6. Specific competencies acquired

Professional competencies	C1.2 Using specific theories and tools (algorithms, schemes, models, protocols, etc.) for explaining the structure and the functioning of hardware, software and communication systems C1.5 Providing theoretical background for the characteristics of the designed systems C3.1 Identifying classes of problems and solving methods that are specific to computing systems C3.2 Using interdisciplinary knowledge, solution patterns and tools, making experiments and interpreting their results C3.3 Applying solution patterns using specific engineering tools and methods C3.4 Comparatively and experimentaly evaluation of the alternative solutions for performance optimization C6.1 Describing the basic concepts for representation and characterization of signals and the basic concepts of artificial intelligence C6.2 Appropriate use of methods for signal analysis and fundamental artificial intelligence algorithms C6.3 Use of simulation and programming environments to process signals and model solutions to problem classes
Transversal competencie	CT1 Honorable, responsible, ethical behavior, in the spirit of the law, to ensure the professional reputation CT3 Demonstrating initiative and pro-active behavior for updating professional, economical and organizational culture knowledge.

7. Objectives of the discipline (outcome of the acquired competencies)

7.1 General objective of the discipline	Acquiring the skills for processing signals, time series and images both offline and online, including the ability to design and implement systems optimized for a wide range of specific use cases.
7.2 Specific objective of the discipline	Students should be able to: 1. characterize different types of signals and systems. 2. Use the available theoretical and programming tools to design and implement different types of filters. Should understand the possibilities and limitations of the available alternatives. 3. Have an overview of the classical and current tools for linear, nonlinear and statistical analysis of time series. 4. Adapt the presented techniques to the different types of real signals including but not limited to biological signals, economic time series, images, etc. 5. Apply machine learning technologies for extracting useful information from a broad range of data sets.

8. Content

8.1 Course	Teaching methods	Remarks
1. Signals and systems: Definitions, representations and types of signals. Systems. Signal processing. DSP applications.	Projected slides complemented by blackboard calculations.	
2. Sequences and systems: properties, types, testing methods, visual representations. LTI systems, FIR and IIR filters. Convolution sums. Causality and stability.		
3. Continuous-time LTI systems: Convolution integral. Dirac delta and Heaviside step functions and their properties. Fourier series. Fourier transform (FT).		
4. Sampling and reconstruction: Amplitude modulation. Sampling by the Dirac comb. Aliasing. Reconstruction. Nyquist limit and anti-aliasing filters.		
5. Discrete Fourier transform and the Fast Fourier Transform. Zero padding. FFT based convolution. Deconvolution. Spectral estimation: leakage, scalloping, the effect of windowing. Spectral density estimation: the Bartlett-Welch method.		
6. Laplace transforms: properties, applications.		
7. Function representation of sequences: polynomial representation. Z-transform: properties and applications. Transfer function: applications and examples.		
8. FIR/IIR filters and the z-domain. Poles and zeros in the s-plane and the z-plane. The frequency response of continuous systems and discrete systems.		
9. The design of Infinite Impulse Response (IIR) filters: filter characteristics. Direct IIR filter design. IIR filter design via analogue filters: bilinear transformation, frequency pre-warping, impulse invariant method, pole-zero matching. Classic analogue filters. FIR filter design and applications.		
10. Introduction to time series analysis: overview of type series types, analysis methods, scope. Linear methods: Fourier analysis, short time Fourier transform (STFT)		
11. Wavelet transform (WT): Continuous WT : definitions, properties, theorems, families. Comparison with STFT. Discreet WT: wavelet and scaling functions. Applications.		
12. Random signal processing and applications.		
13. Nonlinear time series analysis and applications		
14. Connectivity measures, advanced time series analysis methods and applications.		
Bibliography		

R. Meddins, Introduction to Digital Signal Processing, Elsevier (2000)
D.G. Manolakis, Applied Digital Signal Processing, V.K. Ingle, Cambridge University Press (2011)
N. Bhatnagar, Introduction to Wavelet Transforms, CRC Press (2020)
P.J.V Fleet, Discrete Wavelet Transformations, Wiley (2019)
H. Kantz, T. Schreiber, Nonlinear Time Series Analysis (2002)
A.C. Müller, S. Guido, Introduction to Machine Learning with Python, O'Reilly (2018)
Sanei Saeid, EEG Signal Processing and Machine Learning, Wiley (2021)

8.2 Seminar / laboratory	Teaching methods	Remarks
1. Introduction to (numeric) Python programming: basics of the language, interactive mode, numeric array manipulation, data I/O.	Programming.	
2. Characterizing sequences. Unit and impulse sequences. The convolution sum.	Sequences are characterized at the blackboard based on their mathematical properties. The rest are programming tasks (frontal &individual supervised work).	
3. Examples of Fourier series and Fourier transforms. Using the FFT algorithm.	Programming	
4. Numerical demonstration of sampling and reconstruction, aliasing.	Programming	
5. Numerical demonstration of the properties of the discrete Fourier transform (leakage, scalloping, the effect of windowing). Estimating the power spectral density. Applications on sound time series.	Programming	
6. Laplace transform problems and exercises.	Theoretical work.	
7. Bode plots. Plotting the p-z diagrams.	Programming.	
8. Designing IIR filters. Problems and exercises.	Theoretical work combined with programming.	
9. Designing and applying IIR and FIR filters. Problems and exercises.	Theoretical work combined with programming.	
10. Working with short time Fourier transforms and wavelet transforms.	Theoretical work combined with programming.	
11. Random signal processing exercises.	Programming with applications on biological signals	
12. Nonlinear time series analysis exercises.	Programming with applications on biological signals	
13. Student project presentations.	Presentations	
14. Student project presentations.	Presentations	
Bibliography		

9. Corroborating the content of the discipline with the expectations of the epistemic community, professional associations and representative employers within the field of the program

The content of the discipline is consistent with courses of similar content from other foreign academic centers. To adapt to the demands of the labor market, the content of the discipline has been harmonized with the requirements of the pre-university education, research institutes and the business environment.

10. Evaluation

Type of activity	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Share in the grade (%)
10.4 Course	End of year examination	Written theoretic and practical exam	40
10.5 Seminar/lab activities	Presentation of a chosen topics	Evaluation of the presentation	15
	Homeworks	Assessing the level of completion and quality of the homework.	20
	Personal/group project	Evaluation of the presentation	25
10.6 Minimum performance standards			
50% of overall assessment of homeworks, 50% achieved at the exam. Homework assignments will be turned in every week. Over the deadline submissions are accepted but penalized.			

Date

04.05.2023

Signature of course coordinator

Signature of laboratory coordinator

Date of approval

11.05.2023

Signature of the head of department

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