Doctoral Program in the Regulation, Measurement, and Analysis of Life Processes

Program Director: *Prof. Dr. Ferenc Bari, full professor, professor emeritus*

Modern Information Technology in Medicine (Lead instructor: Prof. Dr. Ferenc Peták, Institute of Medical Physics and Medical Informatics; 28 hours/6 credits, semester 2 or 4)

Measurement of Vital Signs (Lead instructor: Prof. Dr. Ferenc Bari, Institute of Medical Physics and Medical Informatics; 28 hours/6 credits, semester 1)

Processing of Measurement Data (Lead instructor: Dr. Péter Makra, Institute of Medical Physics and Medical Informatics; 28 hours/6 credits, semester 2)

Course description

Informing students on course requirements

Program: PhD full-time training
Course: **Modern Information Technology in Medicine**
Academic year/Semester: **2025/26 2nd semester**
Educator and contact details (e-mail): **Prof. Ferenc Peták, email: petak.ferenc@med.u-szeged.hu** **Prof. Bari Ferenc, email: bari.ferenc@med.u-szeged.hu** **Dr. József Tolnai, email: tolnai.jozsef@med.u-szeged.hu** **Dr. Fodor Gergely, email: fodor.gergely@med.u-szeged.hu** **Dr. Nagy Attila, email: nagy.attila@med.u-szeged.hu**
Type of course: lecture/**seminar/practice**/laboratory
Weekly hours of the course: **2**
Credit vale of the course: **6**
Type of examination: **final exam at the end of semester**, practice exam, other:………..
Preliminary requirements (preliminary academic performance or completed course required to fulfill the purposes and requirements of the course): **none**
Purpose of course: **The primary aim of this course** is to familiarize PhD students with the latest tools and applications of information technology in medicine. The course prepares

students for the increasing demand for artificial intelligence (AI) in the health sciences. Through lectures and computer-based practical demonstrations, participants gain insight into the fundamental concepts of AI, its applications in life sciences, and its social and ethical implications.
The course also aims to provide students in the life sciences with a broad foundation in medical image processing. In this context, it addresses 3D design, modeling, and printing in medical applications, utilizing the 3D printers available at the institute. During seminars, students are further introduced to cutting-edge information technology solutions, such as the medical use of virtual and augmented reality, and the applications of eHealth, mHealth, and telemedicine.

Outcome requirements of the course (specific academic results to be established by the course):

Knowledge:

- The student has comprehensive knowledge of the applications of modern information technology in medicine and the life sciences;
- understands the basic principles, operational mechanisms, and typical applications of artificial intelligence, machine learning, and deep learning in medicine;
- knows the fundamentals of how large language models (LLMs) operate and their potential in supporting research processes and education;
- is aware of the ethical, social, and data security aspects of using artificial intelligence in healthcare;
- understands the theoretical foundations of medical image processing, including segmentation, registration, and methods for volume and distance measurement;
- knows the medical applications and technological limitations of 3D design, modeling, and printing;
- is familiar with the main components and use cases of virtual and augmented reality (VR/AR), as well as eHealth, mHealth, and telemedicine systems.

Competences:

- The student is able to interpret and apply simple machine learning models to process research data;
- use statistical tools and algorithms commonly applied in AI methodologies (e.g., regression, clustering, classification) in practice;
- independently use large language models (e.g., ChatGPT, Gemini, Copilot) to prepare research texts, support data analysis, or conduct literature reviews;
- perform basic measurements, segmentations, and modeling tasks using medical image processing software (e.g., 3D Slicer);
- create, edit, and export 3D models for medical applications and prepare them for 3D printing;
- interpret and critically analyze scientific publications related to AI applications in medicine;
- present and visualize the medical and research utility of information technology tools through presentations, posters, or digital demonstrations.

Attitudes:

- The student is open to the responsible and ethical use of new digital and AI-based technologies;

- strives to respect data security, patient rights, and scientific integrity when applying IT solutions;
- values the critical, evidence-based evaluation of technological innovations;
- demonstrates a collaborative attitude in multidisciplinary research teams (informatics, medicine, engineering).

Autonomy and responsibility:

- The student can independently select and apply IT and AI tools most suitable for their research goals;
- uses data processing, image analysis, and modeling software responsibly, taking ethical and data protection regulations into account;
- can independently plan and implement the methodological integration of AI, image processing, VR/AR, or 3D printing in their own research area;
- is capable of demonstrating, teaching, or adapting IT solutions for other researchers, clinicians, or students;
- independently evaluates the scientific and societal impact of technological tools in medicine.

Topics:

1. Supporting life science education through artificial intelligence (Prof. Ferenc Bari)
2. The potential of artificial intelligence in life sciences: social and ethical implications (Prof. Ferenc Peták)
3. Artificial intelligence, machine learning, and deep learning, basic concepts and simple demonstration examples in Excel (Dr. József Tolnai)
4. Using large language models to solve machine learning problems, practical demonstrations in Colab and TensorFlow (Dr. Gergely Fodor)
5. Overview and application of statistical tools used in AI methodologies (Dr. Ferenc Rárosi, Mónika Szűcs)
6. Applications of machine learning methods in drug development, from small molecules to proteins (Dr. Árpád Márki, Dr. Tamás Tarjányi)
7. Practical use of other AI tools supporting research, SCITE, Writefull, Research Rabbit, etc. (Dr. József Tolnai, Dr. Gergely Fodor)
8. Applications of artificial intelligence in medical image processing (Dr. Attila Nagy)
9. Introduction to 3D Slicer, learning basic functions, segmentation, and registration with examples; measuring volumes, distances, and angles; anatomical modeling (Dr. Attila Nagy)
10. Medical applications of 3D design and printing, practical demonstration (Dr. Gergely Fodor)
11. Applications of virtual and augmented reality in medicine (Dr. Gergely Fodor)
12. Introduction to eHealth, mHealth, and telemedicine, practical demonstrations (Dr. József Tolnai)
13. Consultation and evaluation session

Supporting methods to achieve learning outcomes:

Lectures and Practical Demonstrations

- The lectures aim to provide the theoretical background for the fundamental concepts of medical information technology, artificial intelligence, image processing, and 3D technologies.

- During interactive demonstrations, students become familiar with the operation of software tools (e.g., TensorFlow, Google Colab, 3D Slicer, Fusion 360, ChatGPT, ResearchRabbit).
- Theoretical knowledge is always linked to concrete medical or life sciences examples.
- Students practice the steps of AI modeling, image processing, segmentation, 3D design, and 3D printing using real research data.

Case Studies and Problem Solving

- Analysis of real or simulated medical research problems (e.g., image processing errors, AI bias, data privacy dilemmas, validation of diagnostic models).
- Group discussions and preparation of solution proposals with a multidisciplinary perspective.
- Students reflect on AI applications not only from a technological perspective but also from ethical and scientific viewpoints.

Independent Research and Literature Review

- Students independently search for and analyze the latest scientific publications on AI, VR, 3D printing, and telemedicine (e.g., Scopus, PubMed, Scite).
- Results of the literature review are presented in brief oral or written reports.
- The instructor provides reflective feedback on the quality of sources and the scientific reasoning.

Use of Digital Learning Environment

- Document sharing, collaborative editing, and assignment submission via CooSpace and Office 365 platforms.
- eduID-based access to international research databases.
- Controlled and reflective use of online tools (AI chatbots, ChatGPT, ResearchRabbit, etc.).

Evaluation of the acquisition of expected learning outcomes:

Requirements:

Course requirements during the semester

- Active participation in lectures and seminars.
- Independent completion and timely submission of written assignments and the final written examination paper during the semester.

Examination requirements:

Assessment and grading

The performance during the semester is evaluated on a five-point scale (1–5) based on in-class activity, interim assignments, and the final submitted tasks.

- Maximum score achievable in the final examination: 100 points

Attendance and active participation in seminars are rewarded with additional bonus points.

Grades of the course are determined as follows:

- 0 - 49 points: Failed (1)
- 50 - 62 points: Passed (2)
- 63 - 73 points: Satisfactory (3)
- 74 - 84 points: Good (4)
- 85 - 100 points: Excellent (5)

Mandatory reading list:

• Comprehensive and up-to-date literature covering the entire scope of the course is not available. • The specialized books relevant to individual subtopics generally exceed the depth required for this course, and their availability may vary over time.
Recommended reading list: • Instructor-prepared teaching materials distributed during classes • Instructor-developed e-learning materials

Course description

Informing students on course requirements

Program: PhD full-time training
Course: **Measurement of vital signs**
Academic year/Semester: **2025/26 1st semester**
Educator and contact details (e-mail): **Prof. Ferenc Bari** bari.ferenc@med.u-szeged.hu
Type of course: **lecture/**seminar/practice/laboratory
Weekly hours of the course: **2**
Credit vale of the course: **6**
Type of examination: final exam at the end of semester, practice exam, other:… five scale report
Preliminary requirements (preliminary academic performance or completed course required to fulfill the purposes and requirements of the course): N**one**
Purpose of course: To familiarize students with techniques for processing biological signals, measuring biopotentials, and the different types and applications of electrodes. For accurate measurements, it is important to learn and understand effective techniques for filtering electrical noise. In today's medical practice, it is becoming increasingly important to be able to quickly and efficiently assess the condition of vital organs using increasingly accurate instruments and measurement techniques, and then to intervene accordingly. Young researchers need to have a thorough understanding of the measurement capabilities of EEG, spectroscopic devices, and ultrasound diagnostics. A thorough knowledge of new tools and measurement methods for examining circulatory processes, movement, and respiration is essential in today's medicine and research. The aim of the course is to teach these as thoroughly as possible.
Outcome requirements of the course (specific academic results to be established by the course):

Topics: 1. Measurement theory 2. Processing of biological signals Improving the signal-to-noise ratio Digitization Sampling 3. Origin of biopotentials, electrodes for measuring biopotentials Modeling of electrodes Electrode polarization Electrode types (macroelectrodes) Microelectrodes 4. Amplification of biopotentials Input resistors, differential amplifiers 5. Electrical signals and interference Noise filtering. Sampling 6. Examination of the electrical activity of the heart 7. Electroencephalography, EEG 8. Sensors and signal converters in medical technology 9. Analog-to-digital converters: principles, biopotentials, and solutions 10. Laws of light absorption Spectroscopic devices Pulse oximeter Diagnostic applications of ultrasound Diagnostic applications of ultrasound Blood pressure and blood flow measurement Factors influencing blood pressure Direct blood pressure measurement methods Indirect blood pressure measurement methods Blood flow and cardiac output measurement 11. Motion analysis Tools for analyzing human movements Application of motion analysis in medical practice 12. Respiratory examination Measurement of flow velocity and inspired/expired volume Measurement of respiratory mechanics
Supporting methods to achieve learning outcomes:
Evaluation of the acquisition of expected learning outcomes:
Mandatory reading list: Ákos Jobbágy, Sándor Varga: Medical Biology Measurement Technology, 2013 Literature review as discussed
Recommended reading list:

Course description

Informing students on course requirements

Program: PhD full-time training
Course: **Processing and analysis of measurement data**
Academic year/Semester: Year 1 / Semester 2
Educator and contact details (e-mail): **Dr Péter Makra** makra.peter@med.u-szeged.hu
Type of course: lecture/seminar/practice/laboratory
Weekly hours of the course: 2
Credit vale of the course: 6
Type of examination: final exam at the end of semester, practice exam, other: written test five-scale report
Preliminary requirements (preliminary academic performance or completed course required to fulfill the purposes and requirements of the course): none
Purpose of course: Research in life sciences ever continues to expand the signal analysis toolset it leverages. Whilst it is neither realistic nor meaningful to expect researchers in this area to know the mathematical rigours of the various signal analysis methods, the efficiency of research and especially of communication between different fields of study greatly benefits if pursuers of life sciences research have a sound user-level knowledge of the signal analysis methods applicable to different problems. The aim of the course is to introduce the area of application, advantages and disadvantages and potential limitations and pitfalls of the most widespread signal analysis methods, making researchers in life sciences aware of the signal analysis aspects of their research and thus enabling them to choose the most adequate and efficient method to solve a particular problem.
Outcome requirements of the course (specific academic results to be established by the course): Upon completing the course, the student will: • be able to interpret the mathematical formalism describing major signal processing methods; • be able to understand the meaning of conditions that determine the applicability of various methods (eg, linearity, stationarity); • have developed the conceptual framework necessary to interpret phenomena in the frequency domain; • be able to extract relevant information from a spectrum;

- be acquanted with the scope of application of major integral transforms and the relationships between them;
- be able to track temporal changes in signal properties using spectrograms;
- be able to interpret system properties based on their transfer functions;
- have understood the scope and technical limitations of various filters;
- be able to infer the frequency-dependent dynamics of phenomena from impedance;
- be able to deduce similarity and delay between signals using cross-correlation.
- have understood the possibilities for describing relationships between signals in the frequency domain;
- have acquired a discrete mindset necessary for describing digital signals;
- have stablished connexions between definitions applied to continuous signals and their discrete counterparts;
- be able to recognise artifacts resulting from faulty digitisation and know how to avoid them;
- be able to describe stochastic signals using appropriate characteristics;
- have understood the operating principles and quality factors of pseudo-random number generators;
- be familiar with the opportunities offered by Monte Carlo methods.

Topics:

1. **Mathematical foundations**. Complex numbers. Calculus: scope of differentiation and integration, formalism, and rules. Interpretation and discrete approximation of differential equations.
2. **Signals and systems**. Concept of signals. Continuous v discrete, deterministic v stochastic signals. Interpretation and description of systems. Linearity, stationarity, causality, time invariance.
3. **Time-domain description and processing of signals.** Mean value, root mean square (RMS). Smoothing, moving average.
4. **Spectral analysis.** Background and applications of Fourier analysis. Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT). Parseval’s theorem. Power spectral density.
5. **Signal transforms**. Laplace transform, z-transform, Hilbert transform and their relationship to the Fourier transform.
6. **Time-dependent spectral analysis.** Windowed Fourier transform. Wavelet analysis.
7. **System description via transfer function.** Filtering and transfer functions of filters.
8. **Impedance.** Application of impedance in describing AC networks and flow properties.
9. **Describing relationships between signals in time and frequency domain.** Autocorrelation and cross-correlation. Cross power spectral density. Wiener–Khinchin theorem.
10. **From analogue to digital.** Sampling theorem. Aliasing.
11. **Description of random signals.** Distribution function, density function, expected value. Generation and use of pseudo-random signals: pseudo-random number generators, dithering, Monte Carlo methods.

Supporting methods to achieve learning outcomes:
Practical examples from medical signals. Simple R scripts with variable parameters to see how these parameters affect the outcome.

Evaluation of the acquisition of expected learning outcomes:
Assessment Details:

- The evaluation consists of a computer-based test administered during the examination period.
- There are no midterm assessments.
- There are no prerequisites for examination eligibility.

Planned examination format:

- A 25-question test in CooSpace.
- Question types include: single-choice, multiple-choice and numeric response.

Grading:

- 0–50%: Fail (Grade 1)
- 51–60%: Pass (Grade 2)
- 61–70%: Satisfactory (Grade 3)
- 71–80%: Good (Grade 4)
- 81% and above: Excellent (Grade 5)

Mandatory reading list: lecture slides

Recommended reading list:

• Alan V Oppenheim – Ronald W Schafer: D*iscrete-time signal processing*. Third edition. Pearson, Harlow, 2014. ISBN 10: 1-292-02572-7, ISBN 13: 978-1-292-02572-8
• John G Proakis – Dimitris G Manolakis: *Digital signal processing. Fourth edition.* Pearson – Prentice–Hall, Upper Saddle River, New Jersey, 2007. ISBN-13: 9780131873742
• Lawrence R Rabiner – Bernard Gold: *Theory and application of digital signal processing.* Prentice–Hall, Englewood Cliffs, New Jersey, 1975. ISBN-10: 0139141014, ISBN-13: 978-0139141010