# SUBJECTS

| Title of the subject: **Advanced Neural Networks** | Credit value: 6 |
|---|---|
| Title of the subject in Hungarian: Új módszerek neurális hálózatok tanításában | |
| Type of the class: <u>lecture</u> / seminar / <u>laboratory</u> / consultation <br><br> number of classes: 10 in the given semester, <br><br> (*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***) | |
| Form of evaluation (exam / practical mark / <u>project work</u> / other): <br><br> Further (*specific*) forms to be applied in knowledge testing *(if any)*: …………………….. | |
| Required preliminary studies *(if any)*: Python programming, basics of neural network | |
| Description of the subject: the brief, still informative description of the knowledge to be attained | |

The goal of this course is to highlight recent advancements in the theory of neural networks and their applications.

During the lectures and labs we will discuss, implement and analyze both the basic concepts and advanced research topics in key directions of neural networks. Discussed topics include:

Recent architectures in segmentation problem

Recent architectures in object detection

Transformer networks

Adversarial samples

Generative adversarial networks and their training

Wasserstein GANs

Multitasking networks (gradient surgery)

Domain adaptation and domain adversarial neural networks

Visualization of neural network decisions and explainable AI

Training with a low number of input samples: one-shot learning, data augmentation

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning*. MIT press.

Wani, M. A., Bhat, F. A., Afzal, S., & Khan, A. I. (2020). *Advances in deep learning*. Springer.

| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes |
|---|
| Programming |
| Theoretical knowledge of differentiation and optimization |
| Neural networks |

Subject owner (*name, position, scientific degree*): András Horváth, <u>PhD</u> / DSc / MHAS

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):

| Title of the subject: **Advanced Sensory Robotics** | Credit value: 6 |
|---|---|

Title of the subject in Hungarian: Advanced Sensory Robotics

Type of the class: <u>lecture /</u> seminar / laboratory / consultation

number of classes: 24 in the given semester,

(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***)

Form of evaluation (exam / <u>practical mark</u> / project work / other):

Further (*specific*) forms to be applied in knowledge testing *(if any)*: ……………………..

Required preliminary studies *(if any)*: ……………..

Description of the subject: the brief, still informative description of the knowledge to be attained

The goal of this course is to highlight recent results in sensory robotics-oriented applications. Local and guest lecturers will present the basic concepts and advanced research topics in key directions of systems biology. Discussed topics include:

Machine learning in robotics

Reinforcement learning

Memristor crossbar networks

Medical signal processing

Image processing

Deep learning

Deep neural networks

Prosthetics

Rapid prototyping methods

Soft robotics

Human-machine interfaces

Augmented reality

Sensors and actuators

Swarm intelligence

GPU based algorithms

Exoskeletons in rehabilitation

Simultaneous localization and mapping

Depth cameras

Distant measurement sensors

| |
|---|
| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |
| Jafari, Amir, and Nafiseh Ebrahimi, eds. *Soft Robotics in Rehabilitation*. Academic Press, 2021.<br><br>Plaat, Aske. "Deep Reinforcement Learning." *arXiv preprint arXiv:2201.02135* (2022). |
| List of those required professional competences, competence elements  to the development of which the subject characteristically, materially contributes |
| |
| Subject owner (*name, position, scientific  degree*): Dr. György Gábor Cserey, habil. associate professor, PhD |
| Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*): |

| Title of the subject: **Advanced Systems Biology** | Credit value: 6 |
|---|---|
| Title of the subject in Hungarian: Advanced Systems Biology | |
| Type of the class: <u>lecture</u> / seminar / laboratory / consultation<br><br>number of classes: 24 in the given semester,<br><br>(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***) | |
| Form of evaluation (exam / <u>practical mark</u> / project work / other):<br><br>Further (*specific*) forms to be applied in knowledge testing *(if any)*: …………………….. | |
| Required preliminary studies *(if any)*: …………….. | |
| Description of the subject: the brief, still informative description of the knowledge to be attained | |

The goal of this course is to highlight recent results in systems biology-oriented applications. Local and guest lecturers will present the basic concepts and advanced research topics in key directions of systems biology. Discussed topics include:

Dynamical Systems Theory

Cell cycle modelling

DNA nanotechnology

Interaction databases

network visualization

Signalling network, multiomics

Proteomics

Metabolic networks

Metabolomes:

Chromosome segregation

Logic approaches

Agent-based modeling

Parameter Estimation

Evolutionary genomics

Origin of life

Bacterial cell biology

Autophagy

MAP kinase signaling

Computational neuroscience

Computational immunology

Mutational signatures

Circadian clock

High content microscopy

Systems Ecology

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

Alon, U. (2019). An introduction to systems biology: design principles of biological circuits. CRC press.

Ingalls, B. P. (2013). Mathematical modeling in systems biology: an introduction. MIT press.

Klipp, E., Liebermeister, W., Wierling, C., & Kowald, A. (2016). Systems biology: a textbook. John Wiley & Sons.

Voit, E. (2017). A first course in systems biology. Garland Science.

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

Subject owner (*name, position, scientific degree*): Prof. Dr. Csikász-Nagy Attila, full professor, DSc

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):

| Title of the subject: **Advanced Topics in Systems and Control Theory** | Credit value: 6 |
|---|---|

Title of the subject in Hungarian: A rendszer- és irányításelmélet modern eszközei

Type of the class: lecture / seminar / laboratory / <u>consultation</u>

number of classes: 10x 90min in the given semester,

(*if the subject is (partially) taught in any language other than Hungarian, then the language*: **English**)

Form of evaluation (exam / practical mark / <u>project work</u> / other):

Further (*specific*) forms to be applied in knowledge testing (*if any*): ……………………..

Required preliminary studies (*if any): Computer Controlled Systems (BSc)*

Description of the subject: the brief, still informative description of the knowledge to be attained

The goal of this course is to highlight important results in nonlinear systems' and control theory and robotics. The subject of this course will be discussed in weekly consultations on the following topics:

I. Preliminaries and missing topics from the linear systems theory

- Discretization techniques: explicit/implicit Euler approach, the zero-order hold, etc.

- System operator, Gram-matrix, observability, controllability of linear time-varying systems

- Kalman decomposition and its geometric view, Luenberger normal form

- Luenberger observer for MIMO systems

- Unknown-input observability, of linear systems

- Basic control approaches, load estimation, and servo controller

- Optimal control and optimal state observation and the LQG controller loop

- Least mean squares parameter estimation (state-space, ARMAX, static models)

II. Input-affine state-space models [1, Chapter 1]

- Mathematical preliminaries: the "Lie-differential algebra"

- Distributions

- Unobservability, controllability and their geometric view
- State-space transformation, relative degree, normal form of SISO models, zero-dynamics

- I/O linearization, exact linearization

- Model classes and dynamic model extensions

III. Dissipativity theory and special cases [2, Chapter 2]

- Lyapunov theory, Lyapunov functions, domain of attraction

- La Salle's theorem, advanced stability criteria

- Induced L2 norm, small gain theory

- Passivity, feedback equivalence to a passive system, minimum phase systems,

- Dynamic invertibility, unknown-input reconstruction, asymptotic output tracking

IV. Applications in robotics [3]

- Feedback linearization of (Port-) Hamiltonian systems

- Inversion-based control vs. feedforward compensation control

- Actuator dynamics, voltage control vs. back-emf compensation control

- Simulation examples on a 4DOF robotic arm

V. Advanced Matlab/Simulink tools and techniques and their usage

- Weekly demonstration and project work

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

[1] Alberto Isidori. Nonlinear control systems. Springer-Verlag London, ed3 edition, 1995.

[2] Carsten W. Scherer and Siep Weiland. Linear matrix inequalities in control. Technical University of Delft, The Netherlands, Delft, 2005.

[3] Mark W. Spong, Seth Hutchinson, and M. Vidyasagar. Robot modeling and control. John Wiley & Sons, Ltd, 2nd edition edition, 2020.

List of those required professional competences, competence elements  to the development of which the subject characteristically, materially contributes

Analysis of complex nonlinear systems, understanding and manipulating the behavior of such physical biological, social, etc., process systems.

Subject owner (*name, position, scientific  degree*): Prof. Dr. Gábor Szederkényi, DSc

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):

Dr. Péter Polcz, PhD

| Title of the subject: **BIOINFORMATICS** | Credit value: 6 |
|---|---|

Title of the subject in Hungarian: BIOINFORMATIKA

Type of the class: <u>lecture </u>/ seminar / laboratory / consultation

number of classes: 12 in the given semester,

(*if the subject is (partially) taught in any language other than Hungarian, then the language*: **English**)

Form of evaluation (<u>exam</u> / practical mark / project work / other):

Further (*specific*) forms to be applied in knowledge testing *(if any)*: -

Required preliminary studies *(if any):* -

The subject of the course is an advanced theoretical and practical introduction to bioinformatics with special regard to the analysis of DNA and protein sequences. The goal is to provide students a good, up to date understanding of the contemporary cross-cutting issues of bioinformatics as well as knowledge of the main techniques and algorithms. The topics covered will include:

- Theory of bioinformatics data, core data types,
- Core operations of bioinformatics: aggregation, comparison, annotation
- Concepts of similarity, different similarity searching techniques,
- Pairwise sequence alignment algorithms
- Multiple sequence alignment algorithms,
- BLAST algorithm, its evaluation, and practical applications
- Biological databases
- Fundamentals of phylogenetics analysis
- Next generation sequencing (NGS) techniques
- Genome assembly techniques and algorithms
- Genome annotation techniques and algorithms
- Fundamentals of metagenomics analysis and techniques
- Mutation analysis, variant search techniques
- Contemporary medical applications of NGS
- Modern data representations and frameworks (i.e., network analysis docker containers, working in HPC environment, SPARK).
- Designing capability of complex pipelines.
- Modern machine learning algorithms and visualization in biology (CART, LASSO, T-SNE, PCA, etc.).
- Complex network representations and their applications

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

1. Arthur M. Lesk: Introduction to Bioinformatics, 4e, Oxford University Press, 2013, ISBN 9780199651566

2. David W. Mount: Bioinformatics: Sequence and Genome Analysis, 2e, Cold Spring Harbor, 2004, ISBN 0- 879-69712-1

3. Molecular Data Analysis Using R (Csaba Ortutay, Zsuzsanna Ortutay) ISBN: 978-1-119-16502-6

4. Next-Generation Sequencing Data Analysis (Xinkun Wang; CRC Press 2016) ISBN-10: 1482217880

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

a)       knowledge

- understanding the chemical biology of the living matter (the DNA and protein level regulatory processes in living cells and organisms)

- knowing the diagnostic tools of living organisms (genome sequencing and sequencing based diagnostic techniques)

- knowing the data acquisition and data processing methods (of biotechnology and molecular medicine)

- knowledge of the informatics infrastructure relevant for biotechnology

- knowledge of bioinformatics applications in diagnostics and bioanalytic

b)       skills

  - can design and manage bioinformatics databases, and can apply modern database-management tools

  - capability of designing and developing new algorithms and complex data analysis pipelines

Subject owner (*name, position, scientific degree*): Prof. Dr. PONGOR Sándor, MHAS

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, science. degree*):

Dr. LIGETI Balázs PhD, assistant of the professor

Dr. JUHÁSZ János PhD, assistant of the professor

| Title of the subject: **Cellular and Convolutional Neural Networks** | Credit value: 6 |
|---|---|
| Title of the subject in Hungarian: Celluláris és Konvolúciós Neurális Hálózatok | |
| Type of the class: <u>lecture</u> / <u>seminar</u> / laboratory / consultation<br><br>number of classes: 24 in the given semester,<br><br>(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***) | |
| Form of evaluation (**<u>exam</u>** / practical mark / project work / other):<br><br>Further (*specific*) forms to be applied in knowledge testing *(if any)*: …………………….. | |
| Required preliminary studies *(if any)*: …………….. | |

| Description of the subject: the brief, still informative description of the knowledge to be attained |
|---|
| 1. Notation, definitions, and mathematical foundation<br>2. Characteristics and analysis of simple CNN templates<br>3. Simulation of the CNN dynamics<br>4. Binary CNN characterization via Boolean functions<br>5. Uncoupled CNNs: unified theory and applications<br>6. Introduction to the CNN Universal Machine<br>7. Back to basics: Nonlinear dynamics and complete stability<br>8. The CNN Universal Machine(CNN-UM)<br>9. Template design tools<br>10. CNNs for linear image processing<br>11. Coupled CNN with linear synaptic weights<br>12. Uncoupled standard CNNs with nonlinear synaptic weights<br>13. Standard CNNs with delayed synaptic weights and motion analysis<br>14. Visual microprocessors – analog and digital VLSI implementation<br>15. of the CNN Universal Machine<br>16. CNN models in the visual pathway and the ''Bionic Eye'' |

| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |
|---|
| Cellular Neural Networks and Visual Computing: Foundations and Applications<br><br>by Leon O. Chua (Author), Tamas Roska (Author)<br><br>Publisher:  Cambridge University Press (August 22, 2005)<br><br>ISBN-13: 978-0521018630<br><br>ISBN-10: 0521018633 |

| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes |
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| Subject owner (*name, position, scientific  degree*): Zarándy, Ákos, prof. DSc |
|---|

| Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*): |
|---|

| Title of the subject: **Domain Specific Languages in High Performance Computing** | Credit value: 6 |
|---|---|

| Title of the subject in Hungarian: Domén-Specifikus Nyelvek Nagyteljesítményű Számításokban |
|---|

| Type of the class: lecture / seminar / laboratory / <u>consultation</u><br><br>number of classes: 24 in the given semester,<br><br>(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***) |
|---|

| Form of evaluation (exam / <u>practical mark</u> / project work / other): |
|---|

| Further (*specific*) forms to be applied in knowledge testing *(if any)*: …………………….. |
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| Required preliminary studies *(if any)*: …………….. |
| Description of the subject: the brief, still informative description of the knowledge to be attained |
| High Performance Computing applications: legacy C/C++/Fortran codes<br><br>High Performance Computing applications: new generation of Python libraries<br><br>Parallel Programming models used on CPUs: MPI, OpenMP<br><br>Parallel Programming models used on GPUs: OpenMP, OpenACC, SYCL, CUDA, etc<br><br>Defining a domain specific abstraction: embedded in C/Python<br><br>Mapping a DSL to different hardware: case study of OP2/OPS<br><br>Automatic code generation: boilerplate code + user code<br><br>Automatic code generation: traditional text-based scriping<br><br>Automatic code generation: compiler techniques - case study of OP-CG<br><br>Automatic code generation: using LLVM and MLIR |
| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |
| Required: M.B. Giles, G.R. Mudalige, Z. Sharif, G. Markall, P.H.J Kelly. *Performance Analysis of the OP2 Framework on Many-core Architectures* . (2011). ACM SIGMETRICS Perform. Eval. Rev. 38 (4) ISSN 0163-5999<br><br>Required: I.Z. Reguly, G.R. Mudalige, M.B. Giles, D. Curran and S. McIntosh-Smith, *The OPS Domain Specific Abstraction for Multi-Block Structured Grid Computations* . In proceedings of the 4th international workshop on Domain-Specific Languages and High-Level Frameworks for High Performance Computing (WOLFHPC '14).Held in conjunction with IEEE/ACM Supercomputing 2014(SC'14).<br><br>Recommended: Hager, G., & Wellein, G. (2010). Introduction to high performance computing for scientists and engineers. CRC Press. ISBN 978-1439811924 |
| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes |
| Understanding of the structure of science and engineering codes, the way they are implemented in computer code<br><br>Ability to understand levels of abstraction provided by various DSLs and libraries<br><br>Experience with coding up simple parallel algorithms running on parallel architectures<br><br>Understanding of differences between different hardware and how this is reflected in software<br><br>Ability to design automated steps from high-level abstraction to low level implementation |
| Subject owner (*name, position, scientific degree*): Dr. István Zoltán Reguly, Associate Professor, PhD |

| Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*): |
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| Title of the subject: **Electromagnetic retrodirective reflector engineering** | Credit value: 6 |
|---|---|

| Title of the subject in Hungarian: Elektromágneses retrodirektív felületek tervezése |
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| Type of the class: consultation <br><br> number of classes: 12 in the given semester |
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| Form of evaluation (exam / practical mark / project work / other): project work <br><br> Further (*specific*) forms to be applied in knowledge testing *(if any)*: - |
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| Required preliminary studies *(if any)*: - |
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| Description of the subject: the brief, still informative description of the knowledge to be attained |
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| - Introduction: reflection, refraction and scattering of electromagnetic waves <br> - Van Atta array improvement with checkerboard array <br> - Periodic structures, unit cell engineering and optimization <br> - Checkerboard arrays from microwave to optical frequencies <br> - Retrodirective surface design based on Phase Gradient Metasurfaces <br> - Retrodirective surface design based on Transformation Optics <br> - Comparison and electrical efficiency of different retrodirective solutions |

| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN): |
|---|
| - Constantine A. Balanis, Antenna Theory: Analysis and Design, 3rd Edition, ISBN: 0-471-66782-X, p. 393-399 <br> - David M. Pozar, Microwave engineering—4th ed., 2011 <br> - Alharbi, M.; Alyahya, M.A.; Ramalingam, S.; Modi, A.Y.; Balanis, C.A.;Birtcher, C.R. Metasurfaces for Reconfiguration of Multi-Polarization Antennas and Van Atta Reflector Arrays. Electronics 2020, 9, 1262. https://doi.org/10.3390/electronics908126 <br> - Fan Yang; Yahya Rahmat-Samii, "Electromagnetic Band Gap Structures in Antenna Engineering", ISBN: 9780521889919 <br> - Arbabi, A., Arbabi, E., Horie, Y. et al. Planar metasurface retroreflector. Nature Photon 11, 415–420 (2017). https://doi.org/10.1038/nphoton.2017.96 <br> - Ma, Y., Ong, C., Tyc, T. et al. An omnidirectional retroreflector based on the transmutation of dielectric singularities. Nature Mater 8, 639–642 (2009). https://doi.org/10.1038/nmat2489 |

| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes: |
|---|
| - Electromagnetic theory <br> - Circuit theory <br> - Antenna design <br> - Numerical design tools in electromagnetic engineering (Ansys-HFSS, CST) |

| Subject owner (*name, position, scientific  degree*): Zsolt Szabó, Prof.,  DSc / MHAS |
|---|

| Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*): DSc. Zsolt Szabó, full professor |
|---|

| Title of the subject: **Fetal monitoring with multimodal methods** | Credit value: 6 |
|---|---|

Title of the subject in Hungarian: Fetal monitoring with multimodal methods

Type of the class: <u>lecture</u> / seminar / laboratory / consultation
number of classes: 24 in the given semester,
(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***)

Form of evaluation (exam / <u>practical mark</u> / project work / other):
Further (*specific*) forms to be applied in knowledge testing *(if any)*: ……………………..

Required preliminary studies *(if any)*: ……………..

Description of the subject: the brief, still informative description of the knowledge to be attained

The main purpose of this course is to highlight the foundation of different fetal monitoring techniques as well as the deepening of the knowledge in the field of biomedical signal processing. Finally recent, innovative technologies are also introduced.

Discussed topics include:
- Fetal development and the basis of fetal monitoring
- Processing and evaluation of raw phonocardiographic signals
- Processing and evaluation of raw electrocardiographic signals
- Medical ultrasound in a nutshell
- Medical and engineering fundamentals of the measurement of fetal breathing movements
- Fetal cardiodiagnostical methods and their applicability
- Data science point of view in the case of medical data I.
- Data science point of view in the case of medical data II.
- Practical considerations in the case of multimodal measurements
- Short overview in recent advances of fetal monitoring

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

D. Pani, C. Rabotti, M. G. Signorini, L. Burattini "Innovative Technologies and Signal Processing in Perinatal Medicine," Springer, 2021
L. Sörnmo, P. Laguna "Bioelectrical Signal Processing in Cardiac and Neurological Applications," Elsevier, 2005
Z. Tóth, Z. Papp "Szülészet-Nőgyőgyászati Ultrahang-Diagnosztika," White Golden Book Kft., 2006
M. Berényi, F. Katona "Fejlődésneurológia, Medicina, 2012
D. Gibb, S. Arulkumaran "A magzatmonitorozás gyakorlata," Oriold és Társai Kft., 2009

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

Subject owner (*name, position, scientific degree*): Dr. Koller Miklós, PhD, associate professor

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):

| Title of the subject: **"Foundations of Quantum Nanotechnology"** | Credit value: 6 |
|---|---|

| Title of the subject in Hungarian: Bevezetés a Kvantum Nanotechnológiába |
|---|

| Type of the class: <u>lecture</u> / seminar / laboratory / consultation number of classes: 20. in the given semester, (*if the subject is taught in any language other than Hungarian, then the language*: ***English***) |
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| Form of evaluation: Essay on a selected project (10-15 pages) and Presentation |
|---|

| Required preliminary studies Physics (Mechanics, Electrodynamics and Quantum Mechanics) |
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| Description of the subject: the brief, still informative description of the knowledge to be attained |
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The goal of this course is to introduce participants into Quantum Nanotechnologies, based on (i) superconducting Josephson-junction devices; (ii) trapped-ion and (iii) photonic devices, applied to a) quantum computing, b) quantum metrology and c) quantum communication.

From classical binary to quantum qubit technology.

Nuclear magnetic resonance (NMR) qubit networks and NMR quantum computing.

Superconducting Josephson-junction qubits and qubit networks.

Trapped-ion qubits and networks.

Photonic qubits and photonic quantum computing.

Quantum Computer hardware case studies (IBM, GOOGLE, D-Wave, Rigetti, Xanadu)

Quantum Metrology case study (LIGO)

Quantum Information

Overview of recent research trends and already available applications, including an introductory experience in programming small-scale quantum computers (Qiskit-IBM-Eagle; Cirq-GOOGLE-Sycamore; Ocean-D-Wave.)

| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |
|---|

M A. Nielsen, I L. Chuang, *Quantum Computation and Quantum Information*, Cambridge Univ. Press, 2010

J. Preskill*, Lecture Notes for Physics - Quantum Computation, http://www.theory.caltech.edu/ (2004)*

A. Laucht et al., *Roadmap on quantum nanotechnologies,* Nanotechnology 32 (2021)

E.F. Combarro, *A Practical Introduction to Quantum Computing: From Qubits to Quantum Machine Learning and Beyond*, CERN, December 2021

Review Letters, 79(2):325-328, 1997. arXiv:quant-ph/9605043

M. Keil,et al. *Stern-Gerlach Interferometry with the Atom Chip,* arXiv: 2009.08112v2, Nov 2020

Barish, B. C. et al*., "LIGO and the Detection of Gravitational Waves,"* 1999, Physics Today, **52,** 44

A.W. Harrow et al., *Quantum algorithm for linear systems of equations,* Phys. Rev. Lett. **103**, 2009

E.F. Combarro, *A Practical Introduction to Quantum Computing: From Qubits to Quantum Machine Learning and Beyond*, CERN, December 2021

Shi-Yao Hou et al*. SpinQ Gemini: a desktop quantum computing platform for education and research*, EPJ Quantum Technology (2021) arXiv:2101.10017v2 [quant-ph] 22 Feb 2021

| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes |
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| Subject owner (*name, position, scientific degree*): Professor emeritus Árpád I. Csurgay MHAS |
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| Lecturer(s), instructor(s) involved in the teaching of the subject Prof. emeritus Árpád I. Csurgay MHAS |

| Title of the subject: **Human Language Technologies** | Credit value: 6 |
| --- | --- |
| Title of the subject in Hungarian: Nyelvtechnológia | |

| Type of the class: <u>lecture</u> / seminar / laboratory / consultation |
| --- |
| number of classes: 24 in the given semester, |
| (*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***) |

| Form of evaluation (<u>exam</u> / practical mark / project work / other): |
| --- |
| Further (*specific*) forms to be applied in knowledge testing *(if any)*: …………………….. |

| Required preliminary studies *(if any)*: …………….. |
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| Description of the subject: the brief, still informative description of the knowledge to be attained |
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Letters, characters, character encodings

The role of formal languages and formal grammars in natural language processing

Computational analysis and generation of word forms

Applications of computational morphology

Sentence representations and parsing methods

Knowledge representation, computational semantics, ontologies

Computational lexicology and lexicography

Methods of computer-aided translation

Machine translation technologies

Basics of corpus linguistics

Word embedding and related language-motivated technologies

| Contextual embeddings, pre-trained models and transformers in natural language processing |
|---|
| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |
| Jurafsky, D., J. H. Martin. Speech and Language Processing. Prentice Hall, (3rd ed.) 2022 (https://web.stanford.edu/~jurafsky/slp3/)<br><br>Lyndon White, Roberto Togneri, Wei Liu, Mohammed Bennamoun. Neural Representations of Natural Language. Springer Singapore (2019) |
| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes |
| Subject owner (*name, position, scientific  degree*): Gábor Prószéky, full professor, DSc |
| Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*): Attila Novák, PhD |

| Title of the subject:  **Human motor control and neurorehabilitation** | Credit value: 6 |
|---|---|
| Title of the subject in Hungarian: Human motor control and neurorehabilitation | |

| Type of the class: <u>lecture</u> / seminar / laboratory / consultation<br>number of classes: 24 in the given semester,<br>(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English)*** |
|---|
| Form of evaluation (<u>exam</u> / practical mark / project work / other):<br>Further (*specific*) forms to be applied in  knowledge testing *(if any)*: …………………….. |
| Required preliminary studies *(if any)*: …………….. |
| Description of the subject: the brief, still informative description of the knowledge to be attained |

The goal of this course is to highlight recent results in Human Movement Science and their applications in neurorehabilitation. Discussed topics include:

Biological control
Biological learning
Joint spaces, Muscle spaces, Space in the Brain, Dimension reduction
Redundancy and Variability of human limb movements
Sensorimotor transformation
Planning experiments to measure human movement
Performing experiments to measure human movement using motion analyzer systems.
Simulation and modeling of human movement
Artificial control of human movement
Functional Electrical Stimulation (FES)
Human-machine interface in neurorehabilitation.
Communicate research results in a professional manner with clinicians and patients.

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

Laczko J and Latash M.L.(2016) Progress in Motor Control – Theories and Translations, Publ. Springer Enoka R.M. (2008) Neuromechanics of Human Movement, Publ. Human Kinetics , Champaign. IL. Shadmehr R & Mussa-Ivaldi S. (2012) Biological Control and Learning, Publ. MIT Press, Cambridge MA.

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

The course focuses on natural and artificial control of human motion. The students learn how to measure, process and analyze data recorded from human movements. How hidden parameters and features of the studied movements (e.g. limb movements) can be revealed by mathematical and computational approaches? The students get insight into state of the art applications in Human Machine interfacse and neurorehabilitaion.

Subject owner (*name, position, scientific  degree*): József Laczkó PhD, Dr. Habil.

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*): Botzheim Lilla PhD, Mravcsik Mariann PhD.

| Title of the subject: **Mechanisms of cell division** | Credit value: 6 |
| --- | --- |

Title of the subject in Hungarian: A sejtosztódás mechanizmusai

Type of the class: lecture / seminar / laboratory / consultation

number of classes: 6 in the given semester,

(*if the subject is (partially) taught in any language other than Hungarian, then the language*: **English**)

Form of evaluation (exam / practical mark / project work / other): Q & A session after presentation

Further (*specific*) forms to be applied in knowledge testing (*if any*): journal club presentations (6)

Required preliminary studies (*if any*): basics of cell biology

Description of the subject: the brief, still informative description of the knowledge to be attained

1.  Cell cycle, the clock model and Xenopus
2.  Cell cycle, the domino model and budding yeast
3.  Single cell vs population studies
4.  Thresholds and transitions in biological systems
5.  Synthetic Biology and microfluidics
6.  Mitosis and chromosome dynamics
7.  Checkpoints as surveillance mechanisms of cell cycle transitions
8.  The DNA damage checkpoint
9.  The mitotic checkpoint
10. Mechanisms of adaptation and checkpoint override
11. Consequences of adaptation and the threshold model
12. Aneuploidy and its paradox in cancer

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

- Cells Escape an Operational Mitotic Checkpoint through a Stochastic Process.

Bonaiuti P, Chiroli E, Gross F, Corno A, Vernieri C, Štefl M, Cosentino Lagomarsino M, Knop M, Ciliberto A.Curr Biol. 2018 Jan 8;28(1):28-37.e7

- Implications of alternative routes to APC/C inhibition by the mitotic checkpoint complex.

Gross F, Bonaiuti P, Hauf S, Ciliberto A.PLoS Comput Biol. 2018 Sep 10;14(9):e1006449. doi: 10.1371/journal.pcbi.1006449.

- A synthetic oscillatory network of transcriptional regulators.

Elowitz MB, Leibler S. Nature. 2000 Jan 20;403(6767):335-8. doi: 10.1038/35002125.

- Dominoes and clocks: the union of two views of the cell cycle.

Murray AW, Kirschner MW. Science. 1989 Nov 3;246 (4930):614-21. doi: 10.1126/science.2683077.

- Feedback control of mitosis in budding yeast.

Li R, Murray AW.Cell. 1991 Aug 9;66(3):519-31. doi: 10.1016/0092-8674(81)90015-5.

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

Understanding the process of cell division and especially the possible mistakes occurring during such process that may fuel cancer. The students will learn how to connect historical key discoveries in the field of cell cycle control to current studies in the emergence of resistance to cancer treatment. The course will also show how mathematical models of molecular regulatory networks helped to understand such processes.

Subject owner (*name, position, scientific degree*): Andrea Ciliberto, PhD, Researcher, PhD

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):--

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| Title of the subject: **Molecular Biology of Yeast** | Credit value: 6 |
| --- | --- |

Title of the subject in Hungarian: Élesztők molekuláris biológiája

Type of the class (lecture / seminar / laboratory / consultation): consultation

number of classes: 12 in the given semester,

(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***)

Form of evaluation (exam / <u>practical mark</u> / project work / other): exam

Further (*specific*) forms to be applied in knowledge testing *(if any)*: ……………………..

Required preliminary studies *(if any)*: ……………..

Description of the subject: the brief, still informative description of the knowledge to be attained

1. Cell-Cycle Analysis in Diverse Eukaryotes
2. Life Cycles of Budding and Fission Yeasts
3. Genetic Analysis of Cell-Cycle Control in Yeast
4. Cyclins Required for Activation of Replication Origins in Yeast
5. Cyclins that Promote Mitotic Entry in Yeast
6. Control of Late Mitosis in Budding Yeast
7. The Positioning and Timing of Cytokinesis in Yeast
8. Cytokinesis
9. The Actin–Myosin Ring
10. Assembly and Contraction of the Actin–Myosin Ring
11. Membrane and Cell Wall Deposition at the Division Site
12. The Positioning and Timing of Cytokinesis in Yeast
13. Activation of Gene Expression at Start in Budding Yeast
14. Activation of S–Cdks in Budding Yeast
15. Extracellular Control of Start in Yeast: Mating Factor Signaling
16. Coordination of Cell Growth and Division in Yeast

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

David O. Morgan: Cell Cycle: Principles of Control. 2006. New Science Press: London. 297 p. ISBN: (Paperback) 9780878935086.

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

Subject owner (*name, position, scientific degree*): Dr. Csikász-Nagy Attila, full professor, DSc

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):

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| Title of the subject: **Neurobiology** | Credit value: 6 |
|---|---|

Title of the subject in Hungarian: **Neurobiológia**

Type of the class: **lecture / seminar** / laboratory / consultation

number of classes: **60** in the given semester,

(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***)

Form of evaluation (**exam** / practical mark / project work / other):

Further (*specific*) forms to be applied in knowledge testing (*if any*): ……………………..

Required preliminary studies *(if any)*: ……………..

Description of the subject: the brief, still informative description of the knowledge to be attained

The subject provides hints and concepts about the operation of the neuronal networks underlying responses to internal and/or external cues. The responses cover a broad range expanding from simple

reactions to complex behavioral manifestations, which are exemplified and characterized by experimental, modeling, and diagnostic tools at both healthy and pathological conditions. The gained knowledge is expected to provide ideas for the developing fields of machine-based information processing, machine-biological tissue interfaces, information technology-based diagnostics, and therapy of neurological diseases. Major topics of the course:

1. Olfaction – Being prepared to detect all types of chemical compounds and to figure out the odor by the activity pattern of the neurons.

2. How do we identify the objects we see? Information processing along the visual pathway.

3. Problems to be solved when moving robots are built. Levels of motor control.

4. Involuntary and voluntary movement control.

5. Intercellular communication in the nervous system. Formation of cellular networks. Directions of information flow.

6. Storing information in the central nervous system.

7. The Central Thalamus: Gatekeeper or Processing Hub?

8. The therapeutic potential of neural stem cells.

9. Optogenetics revolutionized how we study the brain.

10. Technological innovations in neurosurgery.

11. What can we learn about network operation by studying neurological diseases?

12. Recording cellular and/or network activity and correlating them with various brain states and/or behavioral manifestations.

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

1. Liposits Z, Kallo I (2011) **Basics of Neurobiology = Neurobiológia alapjai** (ISBN 978-963-308-034-4) Könyvfejezet/Oktatási anyag
2. Imre Kalló with the contribution of Tamás Freund, Zsolt Liposits, Zoltán Nusser, László Acsády, Szabolcs Káli, József Haller, Zsófia Maglóczky, Nórbert Hájos, Emilia Madarász, György Karmos, Miklós Palkovits, Anita Kamondi, Lóránd Erőss, Róbert Gábriel, Zoltán Kisvárday (2011) **Introduction to Functional Neurobiology = Bevezetés a funkcionális neurobiológiába** (ISBN 978-963-308-041-2) Könyvfejezet/Oktatási anyag
3. Kandel, E.R., Schwartz J.H., and Jessel, T.M.: **Principles of Neural Science**, Fifth Edition, Elsevier, ISBN-13: 978-0071390118
4. Irwin B. Levitan, Leonard K. Kaczmarek: **The Neuron: Cell and Molecular Biology**, 2015, ISBN: 9780199773893
5. Per E. Roland: **Brain Activation**, Second Edition, ISBN-13: 978-0471396307

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

a) Knowledge - Understanding

- the basic experimental/examination approaches used to collect data from the CNS for research, diagnostic and therapeutic purposes

Subject owner (*name, position, scientific degree*): **Imre Kalló**, Associate Professor, MD, PhD

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):

**Tamás Freund**, Head of the Hungarian Academy of Sciences, PhD, DSc.

**Imre Kalló**, Associate Professor, MD, PhD

**Zsolt Liposits**, Professor, MD, PhD, DSc.

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| Title of the subject: **Open Set Recognition Methodologies** | Credit value: 6 |
|---|---|

Title of the subject in Hungarian: Open Set Recognition Methodologies

Type of the class: <u>lecture</u> / seminar / laboratory / consultation

number of classes: 24 in the given semester,

(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English)***

Form of evaluation (exam / <u>practical mark</u> / project work / other):

Further (*specific*) forms to be applied in knowledge testing *(if any)*: project work

Required preliminary studies *(if any)*: Machine Learning

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Description of the subject: the brief, still informative description of the knowledge to be attained

The objective of the course is to review the fundamentals of i) the open set recognition problem and its mathematical formulation, ii) basic approaches for open set recognition, iii) recent solutions.

Discussed topics are

- Closed-set vs open-set problems (classification and recognition)
- Mathematical formulation, open-set risk
- Anomaly and novelty detection
- Out-of-distribution detection
- Open-set recognition approaches
  - SVM based solutions
  - Extreme Value Theory
  - Extreme Value Machine
  - Deep Set Networks (OpenMax)
  - Generative Approaches
- Datasets for evaluation

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

- M. Salehi, H. Mirzaei, D. Hendrycks, Y. Li, M. Rohban, and M. Sabokrou: A Unified Survey on Anomaly, Novelty, Open-Set, and Out-of-Distribution Detection: Solutions and Future Challenges, https://doi.org/10.48550/arXiv.2110.14051
- Walter J. Scheirer and Anderson Rocha and Archana Sapkota and Terrance E. Boult: Towards Open Set Recognition, IEEE Transactions on Pattern Analysis and Machine Learning, 2013, 35 (7)
- Ethan Rudd, Lalit P. Jain, Walter J. Scheirer, Terrance Boult, The Extreme Value Machine, IEEE Transactions on Pattern Analysis and Machine Intelligence (T-PAMI), 2018, 40 (3)
- Ethan Rudd, Lalit P. Jain, Walter J. Scheirer, Terrance Boult, Towards Open Set Deep Networks, Ethan Rudd, Lalit P. Jain, Walter J. Scheirer, Terrance Boult,

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

Subject owner (*name, position, scientific degree*): Dr. TORNAI Kálmán, PhD

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):

Dr. ZSEDROVITS Tamás, PhD

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| Title of the subject: **Optimization-Based Analysis and Control of Nonlinear Uncertain Systems** | Credit value: 6 |
|---|---|

Title of the subject in Hungarian: Nemlineáris bizonytalan rendszerek optimalizáción alapuló analízise és irányítása

Type of the class: lecture / seminar / laboratory / <u>consultation</u>

number of classes: 10x 90min in the given semester,

(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***)

Form of evaluation (exam / practical mark / <u>project work</u> / other):

Further (*specific*) forms to be applied in knowledge testing (*if any*): ……………………..

Required preliminary studies (*if any): Computer Controlled Systems (BSc)*

Description of the subject: the brief, still informative description of the knowledge to be attained

The goal of this course is to highlight important results in nonlinear systems' and control theory and robotics. The subject of this course will be discussed in weekly consultations on the following topics:

I. Linear Matrix Inequalities (LMI) [1], [2] and their applications

- Basic convex optimization and LMI theory, lemmas, and other common LMI techniques

- Affine, multi-affine, quadratically multi-affine, and rational parameter-dependent LMIs and their relaxation techniques: the method of vertices, the cross-corner evaluation technique, gridding,

- Linear Fractional Transformation (LFR) [2, Section 3.6]

- Finsler's lemma and parameter-dependent annihilators [2, Chapter 5]

- LMI-based domain of attraction computation, stability/passivity test, induced L2-gain computation

- Computational Lyapunov analysis of dynamically extended systems

- Stability and convergence analysis of systems with complex dynamical behavior.

- Nonlinear controller synthesis

II. Geometric Linear Parameter Varying (LPV) approaches and their applications in fault diagnosis and robust control

III. Useful numerical methods, available software tools, and their usage

- Advanced Matlab/Simulink tools and difficult linear algebra techniques

- Semidefinite program solvers and modeling tools (e.g., YALMIP, SeDuMi, SDPT3, Mosek)

- Linear Fraction Transformation implementations (e.g., LFR Toolbox, Generalized State-Space Toolbox)

- Numerical/computer algebra techniques for nonlinear parameter-dependent inequality relaxations

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

[1] Carsten W. Scherer and Siep Weiland. Linear matrix inequalities in control. Technical University of Delft, The Netherlands, Delft, 2005.

[2] Péter Polcz. Computational analysis of nonlinear uncertain systems. PhD thesis, Pázmány Péter Catholic University, Faculty of Information Technology and Bionics, 2020.

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

Analysis of complex nonlinear systems, understanding and manipulating the behavior of such physical biological, social, etc., process systems.

Subject owner (*name, position, scientific degree*): Prof. Dr. Gábor Szederkényi, DSc

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):

Dr. Péter Polcz, PhD

| Title of the subject: **Parallel Computing Architectures** | Credit value: 6 |
|---|---|
| Title of the subject in Hungarian: Parallel Computing Architectures | |
| Type of the class: <u>lecture</u> / seminar / laboratory / consultation<br>number of classes: 24 in the given semester,<br>(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***) | |

| Form of evaluation (exam / <u>practical mark</u> / project work / other): |
|---|
| Further (*specific*) forms to be applied in knowledge testing *(if any)*: …………………….. |
| Required preliminary studies *(if any)*: …………….. |

| Description of the subject: the brief, still informative description of the knowledge to be attained |
|---|
| The goal of this course is to highlight recent results in Parallel Computing Architectures and Array Computing<br>Models of computations, Evaluation criterias,<br> Effect of wiring<br>Systolic processor arrays,<br>Low level Parallelism, pipeline technology<br>To RISC-V<br>Harvard architectures, New DSP architectures<br>CNN arrays, analog computing<br>Emulated digital CNN implementations<br> Neuromorph Computations<br> FPGAs -GPGPUs<br>From HLS to HW - Turing-Church thesis<br>Bus systems<br>Fast memory systems –Cash Memories |

| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |
|---|
| John L. Hennessy, David A. Patterson, "Computer Architecture: A Quantitative Approach" 6th Edition<br>David A. Patterson, John L. Hennessy, "Computer Organization and Design: The Hardware Software Interface"<br>P.Arató, T. Visegrády,I.Jankovits, High Level Synthesis of Pipelined Datapaths, J.Wiley &Sons, 2001.<br>Fejér, Attila; Nagy, Zoltán; Benois-Pineau, Jenny; Szolgay, Péter; de Rugy, Aymar ; Domenger, Jean-Philippe<br>Hybrid FPGA–CPU-Based Architecture for Object Recognition in Visual Servoing of Arm Prosthesis<br>JOURNAL OF IMAGING 8: 2 p. 44 (2022)<br>Zarandy, A ; Horvath, A ; Szolgay, P, CNN Technology-Tools and Applications<br>IEEE CIRCUITS AND SYSTEMS MAGAZINE 18: 2 pp. 77-89. , 13 p. (2018)<br>Nagy, Z ; Nemes, Cs ; Hiba, A ; Csík, Á ; Kiss, A ; Ruszinkó, M ; Szolgay, P<br>Accelerating unstructured finite volume computations on field-programmable gate arrays<br>CONCURRENCY AND COMPUTATION: PRACTICE AND EXPERIENCE 26: 3 pp. 615-643. , 29 p. (2014) |

| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes |
|---|

| Subject owner (*name, position, scientific degree*): Prof. Péter Szolgay, DSc |
|---|
| Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):<br>András Kiss PhD, Zoltán Nagy PhD |

<br>

| Title of the subject: **Physics of Computation** | Credit value: 6 |
|---|---|
| Title of the subject in Hungarian: A számítások végzésének fizikája | |
| Type of the class: <u>lecture</u> / <u>seminar</u> / laboratory / consultation | |

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|---|
| number of classes: 12 in the given semester, <br><br> (*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English)*** |
| Form of evaluation (exam / <u>practical mark</u> / project work / other): Further (*specific*) forms to be applied in knowledge testing *(if any)*: …………………….. |
| Required preliminary studies *(if any)*: ……none……….. |
| Description of the subject: the brief, still informative description of the knowledge to be attained |
| An overview of various computing paradigms and the physics that enables them: analog computers, mechanical, chemical computing, digital computing machines, quantum computers. Understanding the physical limits of computation. <br><br> Analog computing <br><br> Neural models of computation <br><br> Mechanical computers, <br><br> Digital computers and binary switches <br><br> Magnetolectronics <br><br> Optical computing <br><br> Quantum computers <br><br> Speed, footprint and von Neumann bottleneck in computing <br><br> Power dissipation in computing |
| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |
| M. Wolf: The Physics of Computing Morgan Kaufmann; 1st edition (November 16, 2016) ISBN-10 : 0128093811 <br><br> Hey, Anthony. Feynman and computation. CRC Press, 2018. <br><br> Marković, Danijela, Alice Mizrahi, Damien Querlioz, and Julie Grollier. "Physics for neuromorphic computing." Nature Reviews Physics 2, no. 9 (2020): 499-510. <br><br> Bennett, Charles H. "The thermodynamics of computation—a review." International Journal of Theoretical Physics 21, no. 12 (1982): 905-940. |
| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes |
| Subject owner (*name, position, scientific  degree*): György Csaba, PhD associated professor |
| Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*): <br><br> Adam Papp PhD |

| Title of the subject: **Predictive Control of Nonlinear Stochastic Systems** | Credit value: 6 |
|---|---|

| Title of the subject in Hungarian: Nemlineáris sztochastikus rendszerek prediktív irányítása |
|---|

| Type of the class: lecture / seminar / laboratory / <u>consultation</u><br><br>number of classes: 10x 90min in the given semester,<br><br>(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***) |
|---|

| Form of evaluation (exam / practical mark / <u>project work</u> / other):<br><br>Further (*specific*) forms to be applied in knowledge testing *(if any)*: ……………………….. |
|---|

| Required preliminary studies *(if any): Computer Controlled Systems (BSc)* |
|---|

| Description of the subject: the brief, still informative description of the knowledge to be attained |
|---|

The goal of this course is to highlight important results in nonlinear systems' and control theory and robotics. The subject of this course will be discussed in weekly consultations on the following topics:

I. Model Predictive Controller (MPC) techniques [1], [2]

- Basic MPC techniques employing linear prediction models

- Receeding horizon control, offline control, and preliminary control feasibility test

- Nonlinear MPC (NMPC) and convex approximations

- Stochastic (N) MPC and convex approximations

- Unknown-input reconstruction, parameter estimation, and state observation in an MPC framework

II. Gaussian process (GP) regression models [3], [4]

- Multivariate function approximation from measurements using Gps

- Hyperparameter tuning using log-likelihood optimization

- Sparse GP approximations: FITC, VFE, distance-based dictionaries

- Dynamic model calibration using GPs

- Prediction models augmented with Gps

- Stochastic GP model-based predictions using different model approximations (e.g., Taylor approximation or analytic moment calculations)

- MPC approaches employing nonlinear prediction models augmented with GP regressors (GP-MPC)

- GP-MPC implementation techniques and approximations:

III. Useful numerical methods, available software tools, and their usage

- Advanced Matlab/Simulink tools and techniques relevant in the field

- Algorithmic differentiation tools (e.g., CasADi) and gradient-based nonlinear optimization solvers (e.g., IPOPT, FORCES PRO)

- GPML Toolbox for GP manipulation

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

[1] Pablo S. González Cisneros and Herbert Werner. Nonlinear model predictive control for models in quasi-linear parameter varying form. International Journal of Robust and Nonlinear Control, 30 (10):3945–3959, 2020.

[2] Ali Mesbah. Stochastic model predictive control: An overview and perspectives for future research. IEEE Control Systems Magazine, 36 (6):30–44, December 2016.

[3] Carl Edward Rasmussen and Christopher K. I. Williams. Gaussian processes for machine learning. Adaptive computation and machine learning. MIT Press, 2006.

[4] Marc Peter Deisenroth. Efficient reinforcement learning using Gaussian processes – Revised version. PhD thesis, Faculty of Informatics Institute for Anthropomatics Intelligent Sensor-Actuator-Systems Laboratory (ISAS), 2017.

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

Analysis of complex nonlinear systems, understanding and manipulating the behavior of such physical biological, social, etc., process systems.

Subject owner (*name, position, scientific degree*): Dr. Péter Polcz, PhD

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| Title of the subject: **Recent Advances in Drug Delivery Research** | Credit value: 6 |
|---|---|

Title of the subject in Hungarian: A gyógyszer beviteli kutatások legújabb eredményei

Type of the class: lecture / seminar / laboratory / <u>consultation</u>

number of classes: 6 in the given semester,

(*if the subject is (partially) taught in any language other than Hungarian, then the language*: **English**)

Form of evaluation (exam / practical mark / project work / other): Q & A session after presentation

Further (*specific*) forms to be applied in knowledge testing *(if any)*: journal club presentations (6)

Required preliminary studies *(if any)*: Drug research and development BSc subject (NOT compulsory)

Description of the subject: the brief, still informative description of the knowledge to be attained

1. Anatomical and molecular properties of the *blood-brain barrier*
2. Anatomical/cellular properties of *nasal* drug delivery route
3. Anatomical features of *dermal* drug delivery route
4. Methodological opportunities for testing *dermal* drug delivery (in vitro, ex vivo, in vivo)
5. Microfluidic diffusion chambers

6. Drug formulation techniques to enhance *dermal* drug absorption
7. Physical methods to enhance *dermal* drug delivery
8. Tricks for overcoming the *blood-brain barrier*
9. Studying species differences in the skin
10. Opportunities to reduce the number of experimental animals in drug delivery studies
11. Testing *dermal* barrier permeability in healthy and diseased conditions.
12. Testing *blood-brain barrier* permeability in healthy and diseased conditions.

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

Kocsis D, Klang V, Schweiger EM, Varga-Medveczky Z, Mihály A, Pongor C, Révész Z, Somogyi Z, Erdő F. Characterization and ex vivo evaluation of excised skin samples as substitutes for human dermal barrier in pharmaceutical and dermatological studies. Skin Res Technol. 2022 Jun 21. doi: 10.1111/srt.13165

Kocsis D, Horváth S, Kemény Á, Varga-Medveczky Z, Pongor C, Molnár R, Mihály A, Farkas D, Naszlady BM, Fülöp A, Horváth A, Rózsa B, Pintér E, Gyulai R, Erdő F. Drug Delivery through the Psoriatic Epidermal Barrier-A "Skin-On-A-Chip" Permeability Study and Ex Vivo Optical Imaging.

Int J Mol Sci. 2022 Apr 11;23(8):4237. doi: 10.3390/ijms23084237

Ponmozhi J, Dhinakaran S, Varga-Medveczky Z, Fónagy K, Bors LA, Iván K, Erdő F. Development of Skin-On-A-Chip Platforms for Different Utilizations: Factors to Be Considered. Micromachines (Basel). 2021 Mar 10;12(3):294. doi: 10.3390/mi12030294.

Lukács B, Bajza Á, Kocsis D, Csorba A, Antal I, Iván K, Laki AJ, Erdő F. Skin-on-a-Chip Device for Ex Vivo Monitoring of Transdermal Delivery of Drugs-Design, Fabrication, and Testing.

Pharmaceutics. 2019 Sep 2;11(9):445. doi: 10.3390/pharmaceutics11090445.

Luca Anna Bors and Franciska Erdő Overcoming the Blood–Brain Barrier. Challenges and Tricks for CNS Drug Delivery, Sci. Pharm. 2019, 87(1), 6; https://doi.org/10.3390/scipharm87010006

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

Analyzing and synthetizing ability to make short, informative presentations on recent scientific results on the field of drug delivery across the physiological barriers.

Getting theoretical background knowledge on the field of physiological barriers and making and evaluating the drug delivery experiments.

Subject owner (*name, position, scientific degree*): Franciska Vidáné Erdő, PhD, associate professor, PhD

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):

| Title of the subject: **Reinforcement learning in robotics** | Credit value: 6 |
|---|---|
| Title of the subject in Hungarian: Reinforcement learning in robotics | |

| Type of the class: <u>lecture</u> / seminar / laboratory / consultation |
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| number of classes: 24 in the given semester, |
| (*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***) |

| Form of evaluation (exam / <u>practical mark</u> / project work / other): |
|---|
| Further (*specific*) forms to be applied in knowledge testing *(if any)*: …………………….. |

| Required preliminary studies *(if any)*: …………….. |
|---|

| Description of the subject: the brief, still informative description of the knowledge to be attained |
|---|
| The goal of this course is to highlight the foundations of reinforcement learning (RL) and its general applicability to robotic problems. In addition to reviewing RL-fundamentals, the course includes a brief review of classical approaches to basic robotics computational problems (direct and inverse kinematical problem, etc), in order to help the deeper understanding of how modern RL-approaches work. Discussed topics include: <br> - General concepts of deep neural networks <br> - Modern architectures, training strategies and fine details of practical realizations <br> - General formalism of the RL-problem <br> - The main RL-apporaches: value-based and policy-based <br> - Latest results on modern value-based and policy-based approaches, hybrid methods I. <br> - Latest results on modern value-based and policy-based approaches, hybrid methods II. <br> - Environmental simulators in a nutshell (pyBullet, MuJoCo, etc) <br> - Baseline algorithms in existing simulated environments <br> - Recap on theoretical aspects of robotic manipulators <br> - Constructional aspects of a new simulated environment, interfacing with a modern RL-algorithm <br> - Training strategies of the realized environment-agent combination, debug opportunities <br> - Sim-to-real considerations and the necessary extensions to the created combinaton |

| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |
|---|
| I. Goodfellow, Y. Bengio, A. Courville, "Deep learning," MIT Press, www.deeplearningbook.org , 2016 <br> R. S. Sutton, A. G. Barto, "Reinforcement Learning: An Introduction," 2nd edition, MIT Press, incompleteideas.net/book/the-book-2nd.html , 2020 <br> Cs. Szepesvári, "Algorithms for Reinforcement Learning," Morgan&Claypool Publishers, https://sites.ualberta.ca/~szepesva/rlbook.html , 2009 <br> J. Achiam, "Spinning Up Documentation," https://spinningup.openai.com , 2020 <br> L. Sciavicco, B. Siciliano: "Modelling and Control of Robot Manipulators," 2nd edition, Springer, 1999 <br> Lectures of UC Berkeley "Deep Reinforcement Learning" by Sergey Levine, https://rail.eecs.berkeley.edu/deeprlcourse/ 2021 |

| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes |
|---|

| Subject owner (*name, position, scientific degree*): Dr. Koller Miklós, PhD, associate professor |
|---|

| Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*): |
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<br>

| Title of the subject: **Simulation of biological experiments** | Credit value: 6 |
|---|---|
| Title of the subject in Hungarian: Biológiai kísérletek szimulációi | |
| Type of the class: lecture / seminar / laboratory / <u>consultation</u> | |

| number of classes: 6 in the given semester, |
| --- |
| (*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***) |

| Form of evaluation (exam / <u>practical mark</u> / project work / other): |
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| Further (*specific*) forms to be applied in knowledge testing *(if any)*: …………………….. |

| Required preliminary studies *(if any)*: …………….. |
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| Description of the subject: the brief, still informative description of the knowledge to be attained |
| --- |

Mathematical modelling techniques to simulate experiments in biological systems. Modelling and experimental techniques and how one cam move between them will be highlighted. Key topics include:

Oscillators: cell cycle, circadian clock, repressillator

Biological switches: differentiation, apoptosis

Adaptation: chemotaxis

Whole cell modelling

| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |
| --- |

Klipp, E., Liebermeister, W., Wierling, C., & Kowald, A. (2016). Systems biology: a textbook. John Wiley & Sons.

Ingalls, B. P. (2013). Mathematical modeling in systems biology: an introduction. MIT press.

Elowitz, M. B., & Leibler, S. (2000). A synthetic oscillatory network of transcriptional regulators. Nature, 403(6767), 335-338.

Tyson, J. J., Chen, K. C., & Novak, B. (2003). Sniffers, buzzers, toggles and blinkers: dynamics of regulatory and signaling pathways in the cell. Current opinion in cell biology, 15(2), 221-231.

Karr, J. R., Sanghvi, J. C., Macklin, D. N., Gutschow, M. V., Jacobs, J. M., Bolival Jr, B., ... & Covert, M. W. (2012). A whole-cell computational model predicts phenotype from genotype. Cell, 150(2), 389-401.

| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes |
| --- |

The PhD students will learn to interpret experimental results and design mathematical models to simulate them. They will also understand how to design experiment, which can lead to results contributing to model development.

| Subject owner (*name, position, scientific degree*): Attila Csikász-Nagy, full professor, DSc |
| --- |

| Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*): |
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| Title of the subject: **Spatial data analysis** | Credit value: 6 |
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|---|
| Title of the subject in Hungarian: Téradatok elemzése |
| Type of the class: lecture / <u>seminar</u> / laboratory / <u>consultation</u><br><br>number of classes: 52 in the given semester,<br><br>(*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***) |
| Form of evaluation (<u>exam</u> / practical mark / project work / other):<br><br>Further (*specific*) forms to be applied in knowledge testing *(if any)*: - |
| Required preliminary studies *(if any)*: - |
| Description of the subject: |
| The primary goal of the subject is to obtain basic theoretical and practical knowledge of sensors and algorithmic tools used in spatial information systems focusing on applications of remote sensing and medical imaging. The course provides an overview of the operating principles of the various 3D sensing technologies and their areas of use, the data structures describing the provided measurements, with a special emphasis on the automated data processing methods and algorithms, which nowadays play a prominent role due to the heterogeneity of the available data, and the large and continuously expanding size of current spatial databases.<br><br>Main topics:<br><br>1. Concept of spatial information sciences, main types and applications of spatial information systems<br><br>2. Operation principles of geospatial and medical 3D data collection sensor technologies and tools<br><br>3. Geometric reference systems, spatial geometric transformations, projective geometry<br><br>4. Formation and representation of various data types: 2D images (optical visible/infrared, radar, X-ray images), 2.5D distance maps, real 3D Lidar point clouds and 3D voxel models (e.g. CT, MR)<br><br>5. Geospatial and medical databases: data acquisition and data storing models<br><br>6. Data quality standards and quality assurance. Hardware and software tools in spatial information system, database management issues.<br><br>7. Automatic processing and interpretation of spatial data sets: segmentation of data from different sources, separation of different classes, recognition and reconstruction of spatial objects<br><br>8. Hierarchical description of complex spatial scenes, stochastic optimization techniques (Markov fields, Markov point processes)<br><br>9. Automatic 3D model generation from raw measured data, processing of 3D point clouds (e.g. LIDAR) and voxel models (e.g. computed tomography).<br><br>10. Time sequence analysis, registration, and change detection for multitemporal data<br><br>11. Basic concepts of augmented and mixed reality systems |
| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |

Csaba Benedek: "Multi-level Bayesian Models for Environment Perception," Springer International Publishing, 202 pages, ISBN 978-3-030-83654-2, 2022

Pinliang Dong, Qi Chen, "LiDAR Remote Sensing and Applications", CRC Press, 220 pages, ISBN 978-1-138-74724-1, 2017

Dougherty Geoff, "Medical Image Processing", Springer, 396 pages, ISBN: 978-1-441-99769-2, 2011

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

Algorithm development, computer programming, machine learning applications

Subject owner (*name, position, scientific degree*): Csaba Benedek, full professor, DSc

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):

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| Title of the subject: **Structural biology** | Credit value: 6 |
|---|---|

Title of the subject in Hungarian: *Szerkezeti biológia*

Type of the class: <u>lecture</u> / seminar / laboratory / consultation

number of classes: 12 in the given semester,

(*if the subject is (partially) taught in any language other than Hungarian, then the language*: **English**)

Form of evaluation (exam / practical mark / <u>project work</u> / other): a 3-5 page proposal on the complex structural investigation of a chosen biomacromolecule: rationale, methods, possible difficulties etc.

Further (*specific*) forms to be applied in knowledge testing (*if any*): ……………………..

Required preliminary studies (*if any*): ……………..

Description of the subject: the brief, still informative description of the knowledge to be attained

The goal of the course is to provide introduction to the structural analysis of biological macromolecules by highlighting the fundamentals and the most recent developments. Topics include:

Fundamentals of protein structure

Fundamentals of the 3D structure of nucleic acids

Low-resolution structure analysis methods: circular dichroism, FT-IR, UV-VIS, SAXS

Sample preparation for structural studies

Macromolecular X-ray crystallography

Macromolecular NMR spectroscopy

Solid-state NMR for the investigation of biomolecules

| Cryo-electron microscopy |
| --- |
| Fluorescence-based methods to probe the structure and dynamics of proteins and complexes |
| Single-molecule methods |
| Fundamentals of molecular modeling |
| Basics of molecular dynamics calculations |
| Hybrid methods combining calculations with experimental data |
| Interpretation of protein structures to understand biological function |

| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |
| --- |
| P Moore: Visualizing the invisible. Oxford University Press, 2012, ISBN: SBN13 9780199767090 |
| I Bertini, KS McGreevy, G Parigi: NMR of biomolecules. Wiley-Blackwell, 2012, ISBN:9783527328505. |
| DC Rapaport: The art of molecular dynamics simulation. Cambridge University Press, 2004, ISBN: 978-0521825689 |
| ID Campbell: Biophyiscal techniques. Oxford University Press, 2012. ISBN 9780199642144 |

| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes |
| --- |
| Understand and interpret biomacromolecular structures, design experiments to probe functionally important structural features of proteins |

| Subject owner (*name, position, scientific degree*): Zoltán Gáspári, PhD / DSc / MHAS |
| --- |
| Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*): <br><br> Tamás Hegedűs, PhD. |

| Title of the subject: **Technology of microscale neural interfaces** | Credit value: 6 |
| --- | --- |
| Title of the subject in Hungarian: Mikroméretű implantátumok technológiája | |
| Type of the class: lecture / seminar / laboratory / consultation <br><br> number of classes: 8 in the given semester, <br><br> (*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***) | |
| Form of evaluation (exam / practical mark / project work / other): oral exam <br><br> Further (*specific*) forms to be applied in knowledge testing *(if any)*: …………………….. | |
| Required preliminary studies *(if any)*: …………….. | |

Description of the subject: the brief, still informative description of the knowledge to be attained

- Micro- and nanotechnologies to create brain-machine interfaces
- Overview of state-of-the-art materials of microimplants
- Integrated electronics for brain electrodes
- Soft, flexible materials used in implantable devices
- Integrated optoelectronic features and optical stimulation using neural interfaces
- Strategies to mitigate cellular damage on tissue-device interfaces
- Longevity and biocompatibility of neural implants
- Multimodal brain imaging methods relying on multifunctional brain electrodes

List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN)

Wellman, S. M., Eles, J. R., Ludwig, K. A., Seymour, J. P., Michelson, N. J., McFadden, W. E., ... & Kozai, T. D. (2018). A materials roadmap to functional neural interface design. *Advanced functional materials*, *28*(12), 1701269.

Ruther, P., & Paul, O. (2015). New approaches for CMOS-based devices for large-scale neural recording. *Current opinion in neurobiology*, *32*, 31-37.

Zhang, D., Chen, Q., Shi, C., Chen, M., Ma, K., Wan, J., & Liu, R. (2021). Dealing with the foreign-body response to implanted biomaterials: strategies and applications of new materials. *Advanced Functional Materials*, *31*(6), 2007226.

Goncalves, S. B., Ribeiro, J. F., Silva, A. F., Costa, R. M., & Correia, J. H. (2017). Design and manufacturing challenges of optogenetic neural interfaces: a review. *Journal of neural engineering*, *14*(4), 041001.

Shin, H., Lee, H. J., Chae, U., Kim, H., Kim, J., Choi, N., ... & Cho, I. J. (2015). Neural probes with multi-drug delivery capability. *Lab on a Chip*, *15*(18), 3730-3737.

List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes

material science, microtechnology, biomedical MEMS, implantables, bionic interfaces

Subject owner (*name, position, scientific degree*): Zoltán Fekete PhD / DSc / MHAS

Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*):

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| Title of the subject: **Translational Oncology** | Credit value: **6** |
| --- | --- |

Title of the subject in Hungarian: **Transzlációs onkológia**

Type of the class: **lecture** / seminar / laboratory / consultation

number of classes: 24 in the given semester,

(*if the subject is (partially) taught in any language other than Hungarian, then the language*: *English*)

Form of evaluation (exam / **practical mark** / project work / other):

| Further (*specific*) forms to be applied in knowledge testing *(if any)*:-- |
|---|
| Required preliminary studies *(if any)*:-- |
| Description of the subject: the brief, still informative description of the knowledge to be attained |

The goal of this course is to demonstrate examples and highlight recent results of translational oncology. Basic concepts and advanced research topics in key directions of translational clinical research will be discussed, including:

oncogenesis (oncogenes and tumor suppressor genes)

angiogenesis

metastasis formation

clinical samples (origin and aim)

primary cell cultures and cell lines

tumor heterogeneity

2D cellular models (proliferation, migration)

3D cell-models (spheroids, matrices and invasion)

animal models (PDX, tumor progression and colonization models)

| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |
|---|

Beverly A. Teicher (ed): Tumor Models in Cancer Research (2011)

ESMO Handbook of Translational Research (2015)

Geoffrey M. Cooper: The Cell: A Molecular Approach (2019)

| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes |
|---|
| Subject owner (*name, position, scientific degree*): Garay Tamás, PhD |
| Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*): |

| Title of the subject: **Wireless Sensor Networks** | Credit value: 6 |
|---|---|
| Title of the subject in Hungarian: **Vezeték nélküli érzékelő hálózatok** | |
| Type of the class: **lecture** / seminar / laboratory / consultation<br><br>number of classes: **24** in the given semester, | |

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|---|
| (*if the subject is (partially) taught in any language other than Hungarian, then the language*: ***English***) |
| Form of evaluation (exam / practical mark / project work / other): **exam** <br><br> Further (*specific*) forms to be applied in knowledge testing *(if any)*: - |
| Required preliminary studies *(if any)*: **Information and Coding Theory** |
| Description of the subject: the brief, still informative description of the knowledge to be attained |
| The followings are the main topics: <br><br>     –   Anatomy of a Sensor Node <br>     –   Protocol Stack of WSNs <br>     –   Radio Communications and fading models <br>     –   Link Management <br>     –   Multi-Hop Routing, Energy Aware Routing Techniques in WSN <br>     –   Data Aggregation and Clustering <br>     –   Time Synchronization <br>     –   Localization Techniques <br>     –   Designing and Deploying WSN Applications <br>     –   Simulators and Emulators for WSNs <br>     –   WSN applications (predictive maintenance, Industry 4.0….etc.) |
| List of the most important 2–5 pieces of *required* and *recommended* literature (lecture notes, textbooks fundamental articles) with bibliographical details (author, title, edition information (or specific pages), ISBN) |
| -   Anna Forster: Introduction to Wireless Sensor Networks, Wiley-IEEE Press, 2016. ISBN: 978-1118993514 <br> -   Fahmy, Hossam Mahmoud Ahmad: Concepts, applications, experimentation and analysis of wireless sensor networks. Springer Nature, 2020. ISBN: 9783030580148 <br> -   Zagrouba, Rachid, and Amine Kardi. "Comparative study of energy efficient routing techniques in wireless sensor networks." Information 12.1 (2021): 42. |
| List of those required professional competences, competence elements to the development of which the subject characteristically, materially contributes |
| a.     Knowledge <br> •   He/she is familiar with the communication protocol development for wireless sensor networks <br> •   In the Infocommunication Technologies, he/she has deeper theoretical and practical knowledge in protocol development and implementation. <br> b.   Skills <br> •   He/she is able to use traditional algorithms in communication protocol development. <br> •   He/she uses the infodommunicaton technology tools and standards at a skill level. <br> c.   Attitude <br> •   He/she is able to perform the development tasks on a professionally high level |
| Subject owner (*name, position, scientific degree*): **András Oláh, PhD, associate professor** |
| Lecturer(s), instructor(s) involved in the teaching of the subject, if any (*name, position, scien. degree*): - |