Course title: *English for Academic Purposes (heavy focus on writing)*
(only in the spring semester)
The course is limited, the lecturer of the course decides how many students can get into the subject!

Lecturer: Viktória Tafferner
tafferner.viktoria@uni-obuda.hu

Course objectives: The course is to address a broader portfolio of academic skills or study skills as academic writing cannot happen away from academic reading and academic thinking. The target audience for the course is both home and international students in Phd programs who would like to develop their academic language and research skills in English. Students are to be prepared for assignments, publication; the sense of apprenticeship into the craft of the academic will be developed, as well as students' thinking skills, such as analysis, argument and criticality.

By the end of the course, students will be able to:

- Identify author's main claims, supporting points,
- Distinguish voices and viewpoints
- Articulate and assess author's thesis, purposes, audiences, contexts, bias, and credibility
- Locate, evaluate, and use academic sources
- Demonstrate and apply knowledge of basic essay structure, including introduction, body and conclusion
- Employ the various stages of the writing process, including pre-writing, writing and re-writing
- Demonstrate ability to write for an academic audience
- Employ quotation, paraphrase and summary
- Introduce, position and integrate source material into the body of an essay
- Recognize and correct basic grammatical errors, specifically errors of subject/verb agreement, verb tense, pronoun agreement, usage of prepositions and articles
- Improve academic and idiomatic vocabulary
- Identify effective writing techniques in his or her own work and in peer writing
- Employ correct citation styles, including parenthetical, in-text citation and works-cited pages
- Evaluate sources for relevance and reliability, evaluate arguments and evidence critically
- Avoid plagiarism
- Write clear and appropriate thesis statements

Lectures: 20 hours

Course description:

The course could be delivered in a blendid format
We apply the same principle when designing the class/homework activities. We aim for students' active engagement in learning activities.

Learning activities will include the following:

- analysing texts: students can be given a text and asked to analyse it. They might be asked to analyse the logical structure of arguments or evaluate the weight of evidence offered by the text's authors.
- concept mapping: students create a diagram showing how concepts are related to the central, starting idea and to one another.
- criticism: students are provided with a text and should evaluate the author's argument.
- discussion forum: students might research a topic in advance of the session, then share their reflections, insights and questions.
- feedback/peer review: students can give feedback to work written or presented by other students; they should also have opportunity to receive formative and summative feedback on their own work, perhaps indicating particular strengths, elements that should be corrected or targets for subsequent work.
- flipped learning: the content of the course is delivered through set readings or, more typically, prepared video lectures, allowing lecture time for more interactive engagement such as group discussions, reviewing drafts or question and answer sessions.
- note taking: students will be asked to take a set of outline or more detailed notes on a written text.
- paraphrase: students rewrite a given passage in their own words
- planning: students develop an outline plan for an essay or presentation.
- presenting: students deliver a short talk on a prepared topic, typically to an audience of their peers. The talk would normally be accompanied by visual presentation slides.
- reading/annotation: the quality of students' writing is largely determined by the quality of their reading, thus we should provide the repeated opportunity for students to read academic work. Such exemplary work will be taken from students' own disciplines
- reflection: students are asked to reflect on what they have learnt, and how they have responded to set tasks, encouraging the development of metacognition as they step back from the task to consider what they have learnt from completing the task.
- reviewing literature: students are given one or more texts, or search for relevant texts themselves, and construct a written (or oral) review of the literature, summarising the argument of each piece, evaluating each, grouping texts into categories and drawing distinctions between different author's findings.

Topics:

Course Introductions
General Writing Rules
Academic Writing: Audience, Purpose/Strategy & Organization
Academic Writing: Style
Academic Writing: Presentation
General-to-Specific Texts: Introduction
General-to-Specific Texts: Sentence-level Definitions
General-to-Specific Texts: Paragraph-level Definitions
Avoiding Plagiarism: Overview & Paraphrasing
Avoiding Plagiarism: Summarizing
Avoiding Plagiarism: Quoting, Citing
Language Focus: Evaluative Language & Hedging
Research Papers: Format & Methods
Research Papers: Results

Research Papers: Introductions
Research Papers: Discussion & Conclusion
Research Papers: Abstracts
Academic Presentation

Requirements:

Homework assignments
In class assignments
In class participation
Midterm exam
Final exam

Evaluation method: submission of research proposal/journal article/conference paper according to relevant stage of doctoral studies.

Recommended References:

1. Belcher, W., 2019. Writing your journal article in twelve weeks. 2nd ed.
2. Hewings, M. and Thaine, C., n.d. 2012. Cambridge Academic English
3. Marshall, S., 2019. Grammar for academic purposes. Montréal: Pearson
4. Swales, J.M. and Feak, C.B. 2012. Academic Writing for Graduate Students: Essential Tasks and Skills, 3rd ed. Michigan Series in English for Academic and Professional Purposes: University of Michigan, Ann Arbor, MI.
5. Durst., G.G., Cathy Birkensetein, and Russel (2021) They say. W. W. Norton & Company.
6. Rugg, G. and Petre, M. (2020a) The Unwritten Rules of PhD Research. London, England: Open University Press.
7. Gray, T. (2020) Publish & Flourish: Become a prolific scholar. Albuquerque: NM State, Teaching Academy.

PROGRAM OF APPLIED INFORMATICS

Course title: *Dynamic Satellite Geodesy*

Lecturer: Lóránt Földváry, associate professor, PhD
foldvary.lorant@emk.bme.hu

Course objective: The main objective is to acquire basic knowledge on gravity field models, its mathematical background, and challenges of using huge amount of satellite-borne gravity data.

Lectures: 20 hours

Course description:

Two-body problem. Atmospheric drag, perturbations. Orbit determination. Dynamic, kinematic and semi-kinematic orbits. Spherical harmonic representation of the gravity field, spherical harmonic analysis. Determation of the gravity field using the Stokes integral. Determation of the gravity field using passive and active satellites. Deticated gravity satellite missions (CHAMP, GRACE, GOCE), and beyond (GRAIL, GRACE-FO, future satellite missions).

Evaluation method: classical colloquium, oral examination

Recommended References:

1. Günter Seeber, *Satellite Geodesy*, 2 Revised edition, Publisher: de Gruyter, ISBN-10: 3110175495, ISBN-13: 978-3110175493, pp. 612, 2003.
2. William M. Kaula, *Theory of Satellite Geodesy: Applications of Satellites to Geodesy*, Dover Earth Science, Publisher: Dover Publications, ISBN-10: 0486414655, ISBN-13: 978-0486414652, pp. 160, 2000.
3. Douglas E. Smylie, *Earth Dynamics: Deformations and Oscillations of the Rotating Earth*, 1st Edition, Publisher: Cambridge University Press, ISBN-10: 052187503X, ISBN-13: 978-0521875035, pp. 553, 2013.

Course title: *Computer arithmetics and floating point error analysis*

Lecturer: Aurél Galántai, professor emeritus, DSc
galantai.aurel@nik.uni-obuda.hu

Course objective: Introduction to the most up-to-date computer arithmetics, the floating point arithmetic standard and the elements of interval arithmetic.

Lectures: 20 hours

Course description:

The basic principles of the floating point error analysis. Multiple precision arithmetics. Basic arithmetic operations. Computational methods for elementary functions. Other types of arithmetic. Introduction to interval arithmetic. Diagnostical tools.

Evaluation method: classical colloquium and/or written solution of a special task

Recommended References:

1. R. Brent, P. Zimmermann, *Modern Computer Arithmetic*. Cambridge University Press, 2011.
2. F. Chaitin-Chatelin, V. Frayssé, *Lectures on Finite Precision Computations*. SIAM, 1996.
3. B. Einarsson, Ed., *Accuracy and Reliability in Scientific Computing*. SIAM, 2005.
4. N. J. Higham, *Accuracy and Stability of Numerical Algorithms*. SIAM, 1996
5. R. E. Moore, R. B. Kearfott, M. J. Clous, *Introduction to Interval Analysis*. SIAM, 2009
6. I. Koren, *Computer Arithmetic Algorithms*. 2nd ed., A K Peters, Ltd. NatickV, MA, 2002.
7. W. Miller and C. Wrathall, *Software for Roundoff Analysis of Matrix Algorithms*. Academic Press, New York, 1980.
8. J-M. Muller, *Elementary Functions: Algorithms and Implementation*. 2nd ed., Birkhauser, 2006.
9. J-M. Muller, *et al*., *Handbook of Floating-Point Arithmetic*. Birkhauser, 2010
10. M. L. Overton, *Numerical Computing with IEEE Floating Point Arithmetic*. SIAM, 2001.
11. B. Parhami, *Computer Arithmetic*. Oxford University Press, 2000.
12. W. Tucker, *Validated numerics: a short introduction to rigorous computations*. Princeton University Press, 2011.
13. J. H. Wilkinson, *Rounding Errors in Algebraic Processes*. Dover, 1994.

Course title: *Application of GIS-based thematic maps*

Lecturer: Andrea Pődör, associate professor, PhD
podor.andrea@amk.uni-obuda.hu

Course objective: Many specialties in which spatial data are displayed use GIS to analyze their data and present problems. The resulting visual solutions, however, can be misleading without a basic understanding of cartography. For this reason, the course aims to provide an overview of the theoretical background, operation, and applications of different visual methods.

Lectures: 20 hours

Course description:

With the advent of GIS, map makers have another important tool at their disposal, but it doesn't matter how we use it. In order to avoid the "black box effect", the main goal of the course is to investigate GIS mapping methods, how we can use software to create thematic maps, and what algorithms are behind each analytical function. What are the procedures that are still a problem. Which tools of cartographic visualization are available in GIS software and their evaluation.
Data analysis, database creation, theoretical model design using subtype and domain.
Examination of data abstraction, cases of group formation of data classification, examination of related representation methods. Problems of classification methods in thematic maps. Basics of designing visualization, from the right color choices to writing. Levels of symbolization. Examining the research results of map use in the light of these.
Graphical representation methods: Basic thematic mapping methods, their software solutions, their applicability. Dynamic and interactive display methods. Problems of two- and multivariate representation methods. Virtual and three-dimensional display space. Possibilities of depicting time.
Generalization in case of special topics, investigation of algorithms supporting generalization.
Geovisualization and modern space. Display options for geostatistical analyzes.

Evaluation method: classical oral examination.

Recommended References:

1. Kraak, M. J. and F. J. Ormeling, Cartography visualization of spatial data. New York, Guildford Press, 2011
2. DiBiase, D., DeMers, M., Johnson, A., Kemp, K., Luck, A.T., Plewe, B., Wentz, E., Geographic Information Science & Technology Body of Knowledge, Washington, D.C.: Association of American Geographers, pp. 120, 2006. Link: http://www.aag.org/galleries/publications-files/GIST_Body_of_Knowledge.pdf
3. Slocum, T. A., McMaster, R. B., Kessler, F. C., & Howard, H. H. (2022). Thematic cartography and geovisualization. CRC Press.
4. Field, K. E. N. N. E. T. H. (2018). Cartography: a compendium of design thinking for mapmakers Redlands. California: Esri Press, 549, 3.

Course title: *Advanced Computer Architectures*

Lecturer: Dezső Sima, professor emeritus, DSc
sima@uni-obuda.hu

Course objective: The lecture provides an overview of the evolution of multithreaded, multicore processors subdivided into the processor categories of client, server and mobile processors. The lecture emphasizes the design space concept, interrelations and emerging trends. Case examples support better insight into the subject presented.

Lectures: 20 hours

Course description:

Overview of the evolution of Intel's Core 2 family; client HED, server and mobile processors. Evolution of the client processors; ISA extensions, interconnects, power management, memory and IO connections. Appearance and evolution of AMD's Zen-based architectures. Evolution of multicore server processors. Emergence of mobile devices (smartphones, tables) design paradigm of mobile processors, word market issues, evolution of ARM ISA-based architectures. Evolution of the microarchitecture of mobile processors.

Evaluation method: classical oral examination.

Recommended references:

1. The subject, by its very nature, follows the latest developments, which are followed, if at all, by available literature several years late. By contrast, the electronic book made available to students aims to be "up to date" and is rich in ample references to the literature.

Course title: *Modelling of Parallel and Concurrent Processes*
(only in the fall semester)

Lecturer: Márta Seebauer, associate professor, CSc
seebauer@uni-obuda.hu

Preliminary knowledge: algorithms, theory of graphs, computer architectures, C programming

Course objective: The basic algorithms and simulation models of parallel and concurrent processes. Hardware and software tools of model's realization.

Lectures: 20 hours

Course description:

The problems of increasing the computing performance. Methods of performance testing. The metric of parallelism and the factors related to parallelization. Functional and data parallelism. The embarrassingly parallel problems.

Development and classification of parallel computing systems. Topography and topology. Flynn's taxonomy. SIMD data parallel architecture, MIMD multiprocessors and multicomputers. GRID systems, virtual supercomputers, cloud computing.

Software tools of parallel and concurrent systems: middleware, programming languages. Debugging and efficiency of parallel algorithms. Message passing and data parallel models. Algorithms using processor farm, mesh, tree, and pipe topology. Realization and efficiency of sorting and filtering algorithms. Shared memory systems. Data integrity and memory consistency models.

Assessment method: oral exam.

Recommended References:

1. Sima, Dezső, Fountain Terence, Kacsuk, Peter: Advanced computer architectures: A design space approach / Dezső Sima, Terence Fountain, Peter Kacsuk. - Harlown, England: Addison Wesley, 1997. - 766 p. - (International Computer Science Series), ISBN 0-201-42291-3
2. Tanenbaum, Andrew S.: Structured Computer Organization / Andrew S. Tanenbaum. - 6. ed. - Pearson Prentice Hall, 2012. - 808 p., ISBN 978-0132916523.
3. Wilkinson, Barry - Allen, Michael: Parallel programming: Techniques and applications using networked workstations and parallel computers / Barry Wilkinson; Michael Allen. - 2nd ed. - New Jersey: Person Prenctice Hall, 2005. - 467 p. ISBN 0-13-140563-2
4. Kirk, David B.: Programming Massively parallel Processors: A Hands-on Approach / David B. Kirk, Wen-mei W. Hwu. - Burlington, USA: Morgan Kaufmann, 2010. - XVIII, 258 p. ISBN 978-0-12-381472-2
5. Ian Foster-Carl Kesselman: The Grid: Blueprint for a New Computing Infrastucture. – Elsevier, 2004. – ISBN 1-55860-933-4

6. Robert Robey, Yuliana Zamora: Parallel and High Performance Computing. - Manning, 2021. - 704 p., ISBN 978-1617296468.
7. Pavan Balaji (Editor): Programming Models for Parallel Computing (Scientific and Engineering Computation). -The MIT Press, 2015. - 488 p., ISBN 978-0262528818.

Course title: *GPU Programming*

Lecturer: Sándor Szénási, professor, PhD
szenasi.sandor@nik.uni-obuda.hu

Course objective: Nowadays, GPU programming is a widely used tool thanks to the the well usable programming tools and frameworks. The main topic of this course is the CUDA C programming language developed by NVIDIA Corporation. Students have to complete an individual project work during the semester.

Lectures: 20 hours

Course description:

1. Specialties of the GPU hardware
2. CUDA C environment
    a. device model
    b. memory model
    c. execution model
3. Creating kernels
    a. using one block
    b. using multiple blocks
4. Synchronization
    a. inside one block
    b. between multiple blocks
    c. streams
5. Using shared memory
6. Atomic operations
7. Further optimization
    a. occupancy
    b. optimal block size
8. CUDA libraries
    a. CUBLAS
    b. cuFFT
    c. cuRANDOM
9. Multi-GPU programming

Evaluation method: classical oral examination.

Recommended References:

1. R. Ansorge, "Programming in Parallel with CUDA: A Practical Guide New Edition", Cambridge University Press, 2022, ISBN 1108479537
2. G. Barlas, "Multicore and GPU Programming: An Integrated Approach", Morgan Kaufman, 2022, ISBN 0128141204

3. T. Masters, "Modern Data Mining Algorithms in C++ and CUDA C: Recent Developments in Feature Extraction and Selection Algorithms for Data Science", Apress, 2020, ISBN 1484259874
4. T. Soyata, "GPU Parallel Program Development Using CUDA", Chapman and Hall/CRC, 2018, ISBN 1498750753
5. J. Cheng, M. Grossman, T. McKercher, "Multicore and GPU Programming", Wrox, 2014, ISBN 1118739329

Course title: *Processing from segmentation to object-oriented classification*

Lecturer: Malgorzata Wojtaszek Verőné, associate professor, Csc
wojtaszek.malgorzata@amk.uni-obuda.hu

Course objective: This module aims at introducing on advanced remote sensing and digital image processing knowledge, techniques and skills for getting information from imagery and ability to solve complex tasks based on remote sensing. Introduction to the object-based image analysis (OBIA). Strategy for creating suitable image objects, the main types of image segmentation. Feature extraction as a critical step in classification. Object-oriented classification concepts and methods (algorithms), eCognition approach: rule set, assign class, nearest neighbour classification, fuzzy logic and other advanced classification technics. Emphasis is placed on gaining a practical understanding of the principles behind each technique and a consideration of their appropriateness in different applications.

Lectures: 20 hours

Contents of the course:

Recent trends in remote sensing and earth observation

The fundamentals of image: a mathematical framework to describe and analyze images as two- and three-dimensional signals in the spatial and spatio-temporal domains.

Basic and advanced techniques of digital image processing: it covers the fundamental concepts required to understand and apply commonly used and more advanced algorithms for pre-processing of remotely sensed data, image manipulation and characterisation.

Basic and advanced techniques of image classification: It covers the fundamental concepts of pixel- and object-based classification technics. It focuses on an image classification knowledge, techniques and skills for getting information from imagery and ability to solve complex tasks based on remote sensing.

Object-based image analysis (OBIA). Segmentation methods: contour-based segmentation and its application in digital image processing. Surface segmentation algorithms: histogram and region-based methods.

Segmentation methods in the eCognition environment. Combining different algorithms, the role of hierarchy in segmentation and classification processes.

Feature extraction (e.g. spectral and geometric features, textural measures, neighbourhood relations), the rules for selecting attributes for efficient classification.

Object-based classification (OBIA): basic and advanced methods, with special emphasis on methods using fuzzy logic. Artificial Intelligent (AI) in classification.

Evaluation method: classical colloquium, oral examination

Recommended References:

1. Verőné Wojtaszek Malgorzata (2015): *Objektum-alapú képelemzés*, Elektronikus jegyzet, Óbudai Egyetem
2. Thomas Blaschke - Stefan Lang – Geoffrey J. Hay (2008) *Objekt-Based Image Analysis*. ISBN: 978-3-540-77057-2, Springer

Course title: *Digital image processing*

Lecturer: Várkonyiné Kóczy Annamária, professor, DSc
varkonyi-koczy@uni-obuda.hu

Course objective: The aim of the course is to familiarize students with the classical and non-conventional meth-ods, together with the theoretical and applicational aspects of digital image processing, com-puter graphics, digital image analysis, and geometric modelling. The accomplishment of the subject establishes and helps the stakeholders to evolve their research skills, as well as the abil-ities of developing new methods, algorithms, and models in the field.

Lectures: 20 hours

Contents of the course:

Methods, algorithms, and models of digital image processing and computer vision. Geometric transformations. Transformed domain methods of digital signal- and image processing, 1D and 2D Fourier transforms, Wavelet transform. Soft computing based methods, fuzzy, neural, anytime techniques. Noise reduction, information enhancement, edge detection, corner de-tection, object search, object recognition, computer vision, computer modeling, 3D reconst-ruction, data compression, camera calibration, real-time processing, code optimization. HDR techniques. Examples, case studies.

Evaluation method: classical colloquium, oral examination

Recommended References:

1. Gonzales, R.C., R.E. Woods: Digital Image Processing, 3rd edition, Prentice-Hall, Inc., 2008.
2. Sonka, M., V. Hlavac, R. Boyle: Image Processing, Analysis, and Machine Vision, 3rd editi-on, Thomson Learning, 2007.
3. Várkonyi-Kóczy, A.R.: “New Advances in Digital Image Processing,” Memetic Computing, Vol. 2, No. 4, pp. 283-304, Dec. 2010.

Course title: *Cognitive Infocommunications*

Lecturer: Attila Kővári, professor, PhD
kovari.attila@amk.uni-obuda.hu

Course objective: To provide the Students with an overview on the basics of Cognitive Infocommunications, and applications fields connected to the CogInfoCom area.

Lectures: 20 hours

Contents of the course:

Cognitive infocommunications (CogInfoCom) is an interdisciplinary research field that has emerged as a synergy between infocommunications and the cognitive sciences a link between the research areas of infocommunications and the cognitive sciences. The primary goal of CogInfoCom is to provide a systematic view of how cognitive processes can co-evolve with infocommunications devices where human brain may interact with these devices using the capabilities of artificially cognitive system.

Content: definitions of CogInfoCom, mode of communication: Intra-cognitive communication, Inter-cognitive communication, type of information that is conveyed between the two communicating entities, and the way in which this is done: sensor-sharing communication, sensor-bridging communication, representation-sharing communication, representation-bridging communication. Application examples in different fields of CogInfoCom. Develop student individual task.

Evaluation method: classical oral examination.

Recommended References:

1. P. Baranyi, A. Csapo, G. Sallai, „Cognitive Infocommunications (CogInfoCom)”, Springer International Publishing, 2015
2. R. Klempous, J. Nikodem, P. Baranyi, Cognitive Infocommunications, Theory and Applications, Springer, 2019
3. A. Esposito, G. Cordasco, C. Vogel, P. Baranyi, "Cognitive infocommunications", Frontiers in Computer Science, Vol 5, pp 1-7, 2023

Course title: *Architecture and function of the Security Operation Center (SOC)*

Lecturer: Valéria Póser, associate professor, PhD
poser.valeria@nik.uni-obuda.hu

Course objective: The subject focuses on the construction and the different components and operation of a large enterprise network security system. Moreover, it concentrates on the various roles of the different security teams. The subject gives insight into the alternatives from an operational view of the enterprise cybersecurity system through primarily open-source based solutions.

Lectures: 20 hours

Contents of the course:

The subject gives an introduction into the structure and function of the SOC – Security Operation Center and into the related roles, through practical examples, partly from a management point of view, partly from the operator's aspect. In addition to the SOC's basic concepts, the students learn about roles, tasks, and responsibilities. They get experience in the implementation, and the operation of cybersecurity functions, based on open-source solutions.

Evaluation method: classical colloquium, oral examination

Recommended References:

1. Arun E Thomas: Security Operations Center - SIEM Use Cases and Cyber Threat Intelligence (CreateSpace Independent Publishing Platform (2018))
2. Don Murdoch: Blue Team Handbook: SOC, SIEM, and Threat Hunting Use Cases: A condensed field guide for the Security Operations team (Volume 2) (CreateSpace Independent Publishing Platform; 1.0 edition (2018))
3. Bryce G. Hoffman: Red Teaming: How Your Business Can Conquer the Competition by Challenging Everything (Crown Business (2017))
4. Chris Sanders: Practical Packet Analysis, 3E: Using Wireshark to Solve Real-World Network Problems (No Starch Press; 3 edition (2017))
5. Nik Alleyne: Learning By Practicing - Hack & Detect: Leveraging the Cyber Kill Chain for Practical Hacking and its Detection via Network Forensics (Independently published (2018))
6. Michael Sikorski: Practical Malware Analysis: A Hands-On Guide to Dissecting Malicious Software (No Starch Press; 1st edition (2012))
7. Yuri Diogenes, Erdal Ozkaya: Cybersecurity – Attack and Defense Strategies: Infrastructure security with Red Team and Blue Team tactics (Packt Publishing (2018))

Course title: *Digital Signal Processing and its Applications*

Lecturer: Gyula Simon, professor, PhD
simon.gyula@amk.uni-obuda.hu

Course objective: The students will be able to understand the underlying principles of digital signal processing, with special emphasis on practice and applications. The Theoretical results will be illustrated by practical examples. Students will implement their own signal processing algorithms.

Lectures: 20 hours

Contents of the course:

Foundations of signal processing (Discrete time systems, linear time invariant systems, discrete time systems, time and frequency domains, Fourier Transform, DFT, z-transform). Sampling in time domain (sampling theorems, sub-sampling and over-sampling). Sampling in amplitude domain (A/D and D/A converters). Digital filters (FIR and IIR filters, digital filter structures, FIR filter design, IIR filter design). Discrete Fourier transform and its applications (windowing, FFT, circular and linear convolution). Adaptive filters (Wiener filter, LMS algorithm, the Kalman filter).

Evaluation method: classical oral examination.

Recommended References:

1. Oppenheim, AV, Shafer, RW: Discrete Time Signal Processing. Pearson, Upper Saddle River, 2010
2. Ingle, VK, Proakis, JG: Disgital Signal Processing Using Matlab V.4. PWS Publishing Company, Boston, 1997
3. Widrow, B, Stearns, SD: Adaptive Signal Processing. Prentice Hall, 1985
4. Grewal, MS, Andrews, AP: Kalman Filtering: Theory and Practice with MATLAB, 4th Edition. John Wiley & Sons, Inc., Hoboken, New Jersey, 2015
5. Mandic, DP, Kanna, S, Constantinides, AG: On the Intrinsic Relationship Between the Least Mean Square and Kalman Filters, IEEE Signal Processing Magazine, vol.32, no.6, pp.117-122, Nov. 2015
6. Baretto, A; Adjouadi, M; Ortega, FR; O-larnnithipong, N: Intuitive understanding of Kalman filtering with Matlab. CRC Press, New York, 2021.

Course title: *Deep machine learning techniques*

Lecturer: Gábor Kertész, associate professor, PhD
kertesz.gabor@nik.uni-obuda.hu

Course objective: In the last 10 years the field of artificial intelligence has once again become an active research area, caused by deep neural networks and deep learning. The application of deep learning in the field of computer vision produced results that previously seemed unachievable, and in recent years solutions based on deep machine learning emerged in technically all fields of science. During the semester, after learning the basic concept of deep learning, students will get to know different techniques on applications in computer vision and natural language processing, in practice as well.

Lectures: 20 hours

Contents of the course:

Fundamentals of deep learning. Mathematical background, optimalization. Overfitting, regularization techniques. Learning from image data, convolutional neural networks. Processing time-series data, recurrent neural networks. Natural language processing.

Evaluation method: classical oral examination.

Recommended References:

1. LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. Nature, 521(7553), 436-444.
2. Bengio, Y., Lecun, Y., & Hinton, G. (2021). Deep learning for AI. Communications of the ACM, 64(7), 58-65.
3. Goodfellow, I., Bengio, Y., Courville, A., & Bengio, Y. (2016). Deep learning. Cambridge: MIT press.
4. Chollet, F. (2021). Deep learning with Python, 2nd edition. Manning.
5. Géron, A. (2022). Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, 3rd Edition: Concepts, tools, and techniques to build intelligent systems. O'Reilly Media.

Course title: *Physiological and Pathophysiological controls*

Lecturer: Levente Kovács, professor, PhD
kovacs@uni-obuda.hu

Course objective: In case of many diseases, where the human body is not able to create or maintain the healthy conditions, sometimes an external controller could be the solution which must fulfill a very strict set of requirements but it is not just improving patients' quality of life but – if needed – it could contribute to the proper dosing of medications. The thoughts above describe the subject of physiological control which is one of the thirteen branches of the biomedical engineering science. The aim of the course is to provide an integrated introduction to the application of control engineering focusing on the most important areas of public health, especially on diabetes. The course is built on two parts: model identification and control engineering.

Lectures: 20 hours

Contents of the course:

Modelling biomedical processes, basics of system theory, classic controller design (PID), state feedback, Kálmán-filter, identification of linear systems, model-predictive control, modern robust control.

Course title: *Modern robust and nonlinear control*

Lecturer: Levente Kovács, professor, PhD; Dániel András Drexler, associate professor, PhD; György Eigner associate professor, PhD
kovacs@uni-obuda.hu
drexler.daniel@nik.uni-obuda.hu
eigner.gyorgy@nik.uni-obuda.hu

Course objective: The purpose of the subject is to introduce the latest results of control engineering from the viewpoint of biomedical engineering. The primary goal of modern robust control is to satisfy the predefined requirements against quality (related to stability primarily) and provide appropriate control action even in worst case scenarios. These can be provided by using exact mathematical and control formalism. The aim of the subject to introduce these knowledges to the students. The subject builds on MATLAB as programming framework. The subject details the transition between non-linear and linear systems, focusing on the Linear Parameter Varying (LPV), Robust Fixed Point Transformation (RFPT) and Tensor Product (TP) based control solutions. In the second part of the subject the investigation of non-linear control solutions are in the focus, starting from the system classes and basics of system theory to the exact linearization, path planning and path tracking controls.

Lectures: 20 hours

Course description:

Basics of system theory; state feedback; Kalman-filtering, H2 and/or H∞ control; μ-synthesis, handling of uncertainties, LPV modeling and control, RFPT method, TP method, nonlinear systems and classification of them, Lie algebra, controllability, observability, exact linearization, path planning and path tracking controls.

Course title: *Biomedical applications of regression models*

Lecturer: Tamás Ferenci, associate professor, PhD; Levente Kovács, professor, PhD
ferenci.tamas@nik.uni-obuda.hu
kovacs@uni-obuda.hu

Course objective: The multivariate regression models are the fundamental tools of the analysis of – amongst many other fields – empirical medical research because it makes it possible to separate the effects (with given model assumptions) thus causal inference – and its quantification – from observational data and increase of study's power in clinical trials is achievable. The course assumes the knowledge of basic regression modelling and based on that introduces advanced topics like the advanced model diagnostics, model building strategies, dealing with missing data, generalised linear models, mixed effect models and generalised additive models. The course introduces the use of R software environment to solve practical problems with it.

Lectures: 20 hours

Contents of the course:

Basics of regression modelling, modelling strategies, logistic regression, characteristics of survival data, generalised additive models, logic of fixed and random effects, predictive models.

Evaluation method: classical oral examination.

Recommended References:

1. Frank Harrell: Regression Modeling Strategies - With Applications to Linear Models, Logistic and Ordinal Regression, and Survival Analysis. Springer, 2015
2. Ewout W. Steyerberg: Clinical Prediction Models - A Practical Approach to Development, Validation, and Updating. Springer, 2019

Course title: *Biomedical experiment design and analysis*

Lecturer: Levente Kovács, professor, PhD; Miklós Kozlovszky, professor, PhD
kovacs@uni-obuda.hu
kozlovszky.miklos@nik.uni-obuda.hu

Course objective: The standards of design, implementation and analysis of biomedical experiments must match to the requirements of many disciplines. The trials raise medical, ethical, legal and economical questions and all these factors have to be satisfied at once with well controlled processes. The Evidence Based Medicine (EBM) is a requirement to make standardized, comparable studies all over the world in order to provide a foundation to the medical expert's daily work and to prepare a clinical protocol. The course has three parts. In the first half of the semester the factors and steps of design of trials will be discussed including the definition and methods of trial design as a general scientific method and the basics of animal and clinical trial design. The second main part is discussing the two classical approach of trial analysis: the basics of frequentist and Bayesian biostatistics, applicable tests and analysis and the comparison of the two approach.

The last part presents the practical use of the theoretical topics in a particular medical field which is oncology. This involves the evidence based oncological approach, design of clinical trials in oncology, Bayesian clinical trials in oncology and the statistics analysis of oncological trials.

Lectures: 20 hours

Contents of the course:

Factors and steps of design of trials, evidence based medicine, analysis of trials, of frequentist and Bayesian biostatistics, examples in oncology.

Evaluation method: classical colloquium, oral examination

Course title: *Methods and practice of health-technology assessment (HTA) for medicines and medical devices*

Lecturer: László Gulácsi, professor, PhD
gulacsi@uni-obuda.hu

Course objective: The aims of the course are to get acquainted with the concept, methods, fields of application and practice of HTA, with special regard to the role of HTA in supporting decisions related to medical technologies.

Lectures: 20 hours

Course description:

Health technology assessment (HTA) is the science of the systematic analysis of health technologies that analyzes the following aspects: a) clinical safety b) process characteristics; (c) effectiveness; (d) efficacy; (e) economic consequences; (f) social, legal, ethical and political issues. The goal of HTA is to prepare health policy, reimbursement and service purchase decisions using a multidisciplinary (economics, statistics, social sciences, epidemiology, and medicine) approaches and tools. During the course, students will learn about the concept, areas of application, main methods and practices of HTA in different European countries, with especial regard to the opportunities and challenges of application of HTA in the field of medical devices.

Evaluation method: classical colloquium, oral examination

Recommended references:

1. Gulácsi L, Péntek M. HTA in Central and Eastern European countries; the 2001: A Space Odyssey and efficiency gain. Eur J Health Econ. 2014 Sep;15(7):675-80.
2. Sabine Fuchs, Britta Olberg, Dimitra Panteli, Matthias Perleth, Reinhard Busse. HTA of medical devices: Challenges and ideas for the future from a European perspective. Health Policy . 2017 Mar;121(3):215-229.

Course title: *Costing in health care*

Lecturer: László Gulácsi, professor, PhD
gulacsi@uni-obuda.hu

Course objective: The aim of the course is to introduce the methods of costing in health care for application in health economic evaluation health technologies and health policy decision making.

Lectures: 20 hours

Course description:

Students will learn the main concepts of costing in health care. They learn methods for identifying, measuring, evaluating and costing the different items in health care. Methods of calculating costs from different perspectives and time frame will be introduced.

Evaluation method: classical colloquium, oral examination.

Recommended references:

1. Mogyorosy Z, Smith P. The main methodological issues in costing health care services. A literature review. CHE Research Paper 7, University of York. https://www.york.ac.uk/media/che/documents/papers/researchpapers/rp7_Methodological_issues_in_costing_health_care_services.pdf

Course title: *Measurement and valuation of health gains*

Lecturer: Márta Péntek, professor, PhD
pentek.marta@uni-obuda.hu

Course objective: The main aim of the course is to introduce the methods of health outcome measurement, to review their application to support clinical an financial decision making, with especial regard to their use in the development proccess of new innovative technologies.

Lectures: 20 hours

Course description:

During the course, students will learn how to assess the impact of diseases and health interventions from different perspectives (patient, patient's family, doctor, healthcare system, society). Particular emphasis will be placed on patient-reported outcomes, methods for measuring individual and societal preferences, and we will discuss options for the joint evaluation of length of life and health-related quality of life. Through the example of specific diseases, we analyse the methodological and practical issues of the application of health

Evaluation method: classical oral examination.

Recommended references:

1. Brazier J et al. The EQ-HWB: Overview of the Development of a Measure of Health and Wellbeing and Key Results., Value Health. 2022 Apr;25(4):482-491. doi: 10.1016/j.jval.2022.01.009.
2. Zoratti et al. Evaluating the conduct and application of health utility studies: a review of critical appraisal tools and reporting checklists., Eur J Health Econ. 2021 Jul;22(5):723-733. doi: 10.1007/s10198-021-01286-0
3. Zrubka Z, Csabai I, Hermann Z, Golicki D, Prevolnik-Rupel V, Ogorevc M, Gulácsi L, Péntek M. Predicting Patient-Level 3-Level Version of EQ-5D Index Scores From a Large International Database Using Machine Learning and Regression Methods. Value Health. 2022 Sep;25(9):1590-1601. doi: 10.1016/j.jval.2022.01.024.
4. Péntek M, Czere JT, Haidegger T, Kovács L, Gulácsi L. EQ-5D studies in robotic surgery: a mini-review, In: Szakál, Anikó (szerk.) IEEE 17th International Symposium on Applied Computational Intelligence and Informatics SACI 2023 : Proceedings, Budapest, Magyarország : Óbudai Egyetem, IEEE Hungary Section (2023) 818 p. pp. 519-524. , 6 p.
5. Hölgyesi Á, Poór G, Baji P, Zrubka Z, Farkas M, Dobos Á, Gulácsi L, Kovács L, Péntek M. Validation of the Musculoskeletal Health Questionnaire in a general population sample: a cross-sectional online survey in Hungary., BMC Musculoskelet Disord. 2022 Aug 13;23(1):771. doi: 10.1186/s12891-022-05716-9.
6. Farkas M, Huynh E, Gulácsi L, Zrubka Z, Dobos Á, Kovács L, Baji P, Péntek M. Development of Population Tariffs for the ICECAP-A Instrument for Hungary and their Comparison With the UK Tariffs., Value Health. 2021 Dec;24(12):1845-1852. doi: 10.1016/j.jval.2021.06.011.

Course title: *Synthesis of scientific evidence in healthcare: a systematic review and evaluation of the literature*

Lecturer: Márta Péntek, professor, PhD
pentek.marta@uni-obuda.hu

Course objective: The aim of the course is to introduce the methods of systematic literature search and analysis of scientific evidence related to health. Students should be able to search for and synthesize studies available in the health literature. Students should be able to evaluate the quality of studies published in the literature and its results on a scientific basis, as well as to communicate their own research results in accordance with international standards.

Lectures: 20 hours

Course description:

Students will learn the main types of clinical trials and economic evaluations, the methods of systematic literature search to identify scientific evidence in healthcare. They master the techniques needed to build a literature search tailored to the research goal and to apply the systematic search in various electronic health literature databases. They learn to evaluate the results of the identified studies and to establish evidence levels. Methods and guidelines will be introduced to enable them to design clinical and health economics studies. Particular emphasis will be placed on quality standards for the reporting of medical and health economic research, which will increase the acceptance and comparability of the study results, as well as will improve the chances of publishing the research in high prectige scientific journals.

Evaluation method: classical oral examination.

Recommended references:

1. Elaine Beller et al. On behalf of the founding members of the ICASR group. Making progress with the automation of systematic reviews: principles of the International Collaboration for the Automation of Systematic Reviews (ICASR). Systematic Reviews volume 7, Article number: 77 (2018)
2. Motahari-Nezhad H, Al-Abdulkarim H, Fgaier M, Abid MM, Péntek M, Gulácsi L, Zrubka Z. Digital Biomarker-Based Interventions: Systematic Review of Systematic Reviews. J Med Internet Res. 2022 Dec 21;24(12):e41042. doi: 10.2196/41042.
3. Gulácsi L, Zrubka Z, Brodszky V, Rencz F, Alten R, Szekanecz Z, Péntek M. Long-Term Efficacy of Tumor Necrosis Factor Inhibitors for the Treatment of Methotrexate-Naïve Rheumatoid Arthritis: Systematic Literature Review and Meta-Analysis. Adv Ther. 2019 Mar;36(3):721-745. doi: 10.1007/s12325-018-0869-8. https://www.cochrane.org/news/what-are-systematic-reviews
4. Equator network. Enhancing the QUAlity and Transparency Of health Research., https://www.equator-network.org/reporting-guidelines/
5. Drummond M, Griffin A, Tarricone R. Economic Evaluation for Devices and Drugs—Same or Different? Value in Health. Volume 12, Issue 4, June 2009, Pages 402-404

6. Long-Term Efficacy of Tumor Necrosis Factor Inhibitors for the Treatment of Methotrexate-Naïve Rheumatoid Arthritis: Systematic Literature Review and Meta-Analysis. <https://pubmed.ncbi.nlm.nih.gov/30637590/> Adv Ther. 2019 Mar;36(3):721-745. doi: 10.1007/s12325-018-0869-8.

Course title: *Health economic modelling*

Lecturer: Zsombor Zrubka PhD, associate professor
zrubka.zsombor@uni-obuda.hu

Course objective: The aim of the course is to introduce the main modelling methods used in health economic evaluations and to apply them in practice.

Lectures: 20 hours

Course description:

The cost-effectiveness of health technologies (medicines and medical devices) should be assessed when preparing social security financing decisions. Health economics modeling provides an opportunity to estimate the health benefits and costs of alternative technologies in a comparative way over different time periods. Within the framework of the course, students get acquainted with the main modeling methods (decision trees, Markov models) and the methodology of probabilistic sensitivity testing and will solve practical modeling tasks.

Evaluation method: classical oral examination.

Recommended references:

1. Gulácsi L. (szerk.) Egészség-gazdaságtan és technológiaelemzés: Az egészség-gazdaságtani elemzéstől a klinikai és finanszírozási döntéshozatalig. Budapest, Magyarország: Medicina Könyvkiadó Zrt. (2012) 328 p.
2. Weinstein MC, O'Brien B, Hornberger J, et al. Principles of good practice of decision analytic modeling in health care evaluation: Report of the ISPOR Task Force on Good Research Practices-Modeling Studies. Value Health; 2003; 6(1):9-17.
3. Briggs A, Claxton K, Sculpher M: Decision Modelling for Health Economic Evaluation (Handbooks in Health Economic Evaluation) Illustrated Edition 2006, Oxford University Press, Oxford
4. Husereau, D., Drummond, M., Augustovski, F. et al. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) statement: updated reporting guidance for health economic evaluations. BMC Med 20, 23 (2022). https://doi.org/10.1186/s12916-021-02204-0
5. Mueller, Scott and Pearl, Judea. "Personalized decision making – A conceptual introduction" Journal of Causal Inference, vol. 11, no. 1, 2023, pp. 20220050. https://doi.org/10.1515/jci-2022-0050

Course title: *Quantitative synthesis of scientific evidence related to health, meta-analysis*

Lecturer: Zsombor Zrubka PhD, associate professor
zrubka.zsombor@uni-obuda.hu

Course objective: The aim of the course is to introduce the methods of quantitative evidence synthesis for health outcomes. Students should be able to perform a meta-analysis for the main types of health outcomes.

Lectures: 20 hours

Course description:

Students will learn to evaluate the results of the identified studies in a systematic review, establish evidence levels, to extract and synthesize the data using statistical methods, with especial regard to the methods of meta-analysis.

Evaluation method: classical oral examination.

Recommended references:

1. Gulácsi L. (szerk.) Egészség-gazdaságtan és technológiaelemzés: Az egészség-gazdaságtani elemzéstől a klinikai és finanszírozási döntéshozatalig. Budapest, Magyarország: Medicina Könyvkiadó Zrt. (2012) 328 p.
2. Jansen JP, Fleurence R, Devine B, et al. Interpreting indirect treatment comparisons and network meta-analysis for health-care decision making: report of the ISPOR Task Force on Indirect Treatment Comparisons Good Research Practices: part 1. Value Health. 2011;14(4):417-428.
3. Hoaglin DC, Hawkins N, Jansen JP,. et al. Conducting indirect-treatment-comparison and network-meta-analysis studies: report of the ISPOR Task Force on Indirect Treatment Comparisons Good Research Practices—part 2. Value Health. 2011;14(4):429-437.
4. Gehad Mohamed Tawfik, Kadek Agus Surya Dila, Muawia Yousif Fadlelmola Mohamed, Dao Ngoc Hien Tam, Nguyen Dang Kien, Ali Mahmoud Ahmed & Nguyen Tien Huy. A step by step guide for conducting a systematic review and meta-analysis with simulation data. Tropical Medicine and Health volume 47, Article number: 46 (2019)
5. Kay, J., Kunze, K.N., Pareek, A. et al. A guide to appropriately planning and conducting meta-analyses—Part 1: indications, assumptions and understanding risk of bias. Knee Surg Sports Traumatol Arthrosc 31, 725–732 (2023). https://doi.org/10.1007/s00167-022-07304-9
6. Kunze KN, Kay J, Pareek A, Dahmen J, Nwachukwu BU, Williams RJ 3rd, Karlsson J, de Sa D. A guide to appropriately planning and conducting meta-analyses: part 2-effect size estimation, heterogeneity and analytic approaches. Knee Surg Sports Traumatol Arthrosc. 2023 May;31(5):1629-1634. doi: 10.1007/s00167-023-07328-9. Epub 2023 Mar 29. PMID: 36988628.

7. Kunze KN, Kay J, Pareek A, Dahmen J, Chahla J, Nho SJ, Williams RJ 3rd, de Sa D, Karlsson J. A guide to appropriately planning and conducting meta-analyses: part 3. Special considerations-the network meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2023 May 16. doi: 10.1007/s00167-023-07419-7. Epub ahead of print. PMID: 37193822.

Course title: *Cloud Robotics*

Lecturer: Imre Rudas, professor, DSc
rudas@uni-obuda.hu

Course objective: Cloud Computing as a new paradigm in Information Technology provides a new horizon in Intelligent Robotics. The Course summarizes the essential cloud computing background and the possible applications in Robotics.

Lectures: 20 hours

Preliminary knowledge: Robotics

Course description:

Introduction to Cloud Computing: the main idea, basic definitions. The conventional cloud model: essential characteristics, service models, deployment models. Intelligent robotics and their applications especially in service robotics. Cloud minded robotics, the expectations and possible realizations. Public clouds: RoboEarth, ROS, Open Source Robotics Foundation (Gazebo). Developing cloud minded robotic system by using Virtual Collaboration Arena and public clouds.

Evaluation method: classical oral examination.

Recommended References:

1. K. Goldberg and B. Kehoe, Cloud Robotics and Automation: A Survey of Related Work. EECS Department, University of California, Berkeley, Technical Report UCB/EECS-2013-5, 2013
2. R. Hill, L. Hirsch, P. Lake, S. Moshiri, Guide to Cloud Computing, Principles and Practice. Springer, 2012
3. C. M. Moyer, Building Applications in the Cloud: Concepts, Patterns, and Projects, Pearson Education Inc., 2011.
4. Marinescu Dan C.: Cloud Computing, Morgan Kaufmann Publishers, 2022
5. Cloud Robotics A Complete Guide - 2020, 5STARCooks, 2021
6. Ricardo C. Mello , Moises R. N. Ribeiro, Anselmo Frizera-Neto: Implementing Cloud Robotics for Practical Applications
7. From Human-Robot Interaction to Autonomous Navigation, 2023

Course title: *Robot Modeling and Control*

Lecturer: Imre Rudas, professor, DSc; József K. Tar, professor, DSc
rudas@uni-obuda.hu
tar.jozsef@nik.uni-obuda.hu

Course objective: To provide the Students with an overview on the basic modeling methods of Classical Mechanics adapted for robots, and that of the classic control approaches.

Lectures: 20 hours

Course description:

Rotation and shift of rigid bodies: the Orthogonal Matrices. Lie Groups. Representation of Lie Groups: quaternions, spinors, Clifford Algebras. Homogeneous matrices and the Special Euclidean Group. The Forward kinematic task, free options, the Denavit-Hartenberg Conditions. The differential inverse kinematic task. Optimization under constarints, Lagrange multipliers and the Reduced Gradient Method, the auxiliary function. Generalized inverses for redundant robot arms: the Moore-Penrose pxeudoinverse, Singular Value Decomposition (SVD) and the SVD-based pseudoinverse, problem solution by the use of the Gram-Schmidt Algorithm, kinematic singularities. Building up the dynamic model of the robot using the kinematic data and the homogeneous matrices. The modified Denavit-Hartenberg conventions. Point to Point (PTP) and Cointinuous Path (CP) control. The Computed Torque Control (CTC) and its behavior for modeling errors and unknown external disturbances. The Robust VS/SM Control. The basics of adaptive controllers: Lyapunov function, function class "kappa", stability definitions, quadratic Lyapunov functions, Adaptive Inverse Dynamics Controller. Application of the Fractional Order Derivatives in control.

Evaluation method: classical colloquium, oral examination

Recommended References:

1. M. Vukobratovic, V. Potkonjak, "Scientific Fundamentals of Robotics", in Dynamics of Manipulation Robots: Theory and Application. Vol. 1., Springer- Verlag, 1982.
2. M. Vukobratovic, D. Stokic: Scientific Fundamentals of Robotics 2: Control of Manipulation Robots, Theory and Application. Secaucus, NJ, USA, New York Springer-Verlag, Inc., 1985.
3. E. Bryson, Jr., Yu-Chi Ho, Applied Optimal Control. Hemisphere, 1975.
4. Jean-Jacques E. Slotine, W. Li, Applied Nonlinear Control. Englewood Cliffs, New Jersey, Prentice Hall International, Inc., 1991
5. A.M. Lyapunov, Stability of motion. New–York and London, Academic Press, 1966.
6. B. Armstrong-H`elouvry, "Stick Slip and Control in Low Speed Motion," IEEE Trans. On Automatic Control, vol. 38., no.10, pp. 1483–1496, Oct., 1990.

7. C. Caundas de Wit, H. Ollson, K. J. Åstrom, P. Lischinsky, “A New Model for Control of Systems with Friction,” IEEE Trans. On Automatic Control, vol. 40, no. 3, pp. 419–425, March 1995.
8. J. Kennedy, R. Eberhart, “Particle Swarm Optimization.” in Proc. of IEEE Intl. Conf. on Neural Networks, Perth, pp. 1942-1948, 1995.
9. Atinga, A.; Tar, J.K. Tackling Modeling and Kinematic Inconsistencies by Fixed Point Iteration-Based Adaptive Control. Machines 2023, 11, 585. https://doi.org/10.3390/machines11060585
10. Varga, B., Horváth, R., Tar, J.K. (2022). Fractional Order Calculus-Inspired Kinematic Design in Adaptive Control. In: Müller, A., Brandstötter, M. (eds) Advances in Service and Industrial Robotics. RAAD 2022. Mechanisms and Machine Science, vol 120. Springer, Cham. https://doi.org/10.1007/978-3-031-04870-8_26

Course title: *Soft computing techniques and its applications*

Lecturer: Várkonyiné Kóczy Annamária, professor, DSc
varkonyi-koczy@uni-obuda.hu

Course objective: The aim of the course is to give overview about the background, new approaches, theories, advantages, and application possibilities of imprecise computational methods, which have low computational need, are robust against inexact and inaccurate knowledge, and data loss. Dur-ing the lectures tools, theories, and application possibilities of soft computing based methods and machine intelligence will be discussed in detail. Accomplishment of the course will result in the ecquirement of application skills of soft computing and hybrid techniques.

Lectures: 20 hours

Course description:

Conception of 'knowledge', 'optimum', 'preciseness', 'cost'. Principles of intelligent computing. Knowledge representation of soft computing techniques. History of theory and application soft computing techniques. Fuzzy set theory, logic, and decision making. Neuro computing. Genetic algorithms. Anytime techniques. Comparison of soft computing techniques, typical application areas, common elements. Modeling. Task solution and problem solution. Selection of problem solving methods. Solution of complex problems with joint application of different soft computing techniques. Case studies.

Evaluation method: classical colloquium, oral examination

Recommended References:

1. Klir, G.J., T.A. Folger: Fuzzy Sets, Uncertainty, and Information, Prentice Hall Int. Inc.,1988.
2. Jager, R. : Fuzzy Logic in Control, PhD Thesis, TU Delft, 1995.
3. Kung, S.J.: Digital Neural Networks, Prentice Hall Int. Inc., 1993.
4. Goldberg, D.E.:Genetic Algorithms in Search, Optimization, and Machine Learning, Addison-Wesley, 1989.
5. Adeli, H., Hung, S.L.: Machine Learning. Neural Networks, Genetic Algorithms, and Fuzzy Systems, Wiley, 1995.
6. Zilberstein, S.: Anytime Algorithms in Intelligent Systems, AI Magazine, Vol. 17., No. 3, pp. 73-83, 1996.

Course title: *Real-time systems and anytime algorithms*

Lecturer: Várkonyiné Kóczy Annamária, professor, DSc
varkonyi-koczy@uni-obuda.hu

Course objective: The aims of the course are (1) to familiarize students with the newest approaches and results of real-time systems and real-time processing, (2) to deepen the knowledge of the students in anytime processing.

Lectures: 20 hours

Course description:

Optimization. Soft computing techniques. Real-time systems. Anytime systems and programming environments. Requirement analysis of anytime systems, modelling techniques. Information processing with specified response time. Research management in time critical applications. Transients in information processing systems with changing architecture. Handling uncertain and vague information in real-time systems. Case studies.

Evaluation method: classical colloquium, oral examination

Recommended References:

1. H. Adeli, and S*chine Learning*. McGraw Hill, New York, USA, 1997.
2. R. K. Bhatnagar and L.N. Kanal, "Handling uncertain information: a review of numeric and non-numeric methods," in *Uncertainty in Artificial Intelligence*, Elsevier Science Publishers, 1986, pp. 3-26.
3. S. Zilberstein. "Anytime Algorithms in Intelligent Systems," *AI Magazine*, vol. 17., no. 3, pp. 73-83, 1996.
4. S. Zilberstein, "Operational Rationality through Compilation of Anytime Algorithms," PhD Dissertation, 1993.
5. S. Zilberstein *et al*., *Optimal Sequencing of Contract Algorithms, Annals of Mathematics and Artificial Intelligence*. 2002.
6. S. Russel, and P. Norvig, *Mesterséges Intelligencia – Modern megközelítésben*. Panem, 2005..L. Hung, *Machine Learning. Neural Networks, Genetic Algorithms, and Fuzzy Systems*. New York, John Wiley and Sons, 1995.
7. T. Mitchell, *Machine Learning*. McGraw Hill, New York, USA, 1997.
8. R. K. Bhatnagar and L.N. Kanal, "Handling uncertain information: a review of numeric and non-numeric methods," in *Uncertainty in Artificial Intelligence*, Elsevier Science Publishers, 1986, pp. 3-26.
9. S. Zilberstein. "Anytime Algorithms in Intelligent Systems," *AI Magazine*, vol. 17., no. 3, pp. 73-83, 1996.

10. S. Zilberstein, “Operational Rationality through Compilation of Anytime Algorithms,” PhD Dissertation, 1993.
11. S. Zilberstein *et al*., *Optimal Sequencing of Contract Algorithms, Annals of Mathematics and Artificial Intelligence*. 2002.
12. S. Russel, and P. Norvig, *Mesterséges Intelligencia – Modern megközelítésben*. Panem, 2005.

Course title: *Modern medical robotics*

Lecturer: Tamás Haidegger, PhD, professor
haidegger@uni-obuda.hu

Course objective: This course aims to present modern surgical technologies and devices to the students—from and engi-neering point of view. Image-guided surgery is one of the main focuses of the class, navigation techniqu-es, methods and employed mathematical formulas are derived. Integrated systems employing robotic de-vices for treatment delivery are also discussed and analyzed from electrical, control and system engi-neering. To solve the homeworks, students must demonstrate a basic understanding of robot control, matrix theory, image processing and network theory.

Lectures: 20 hours

Course description:

Computer-integrated surgical systems, definitions and history; medical imaging modalities, medical image processing theory and practice, image-guided surgery, principal of intra-operative navigation, surgical robots, integrated IGS systems, navigation and guidance, image segmentation and surgical planning, registration algorithm, error assessment in CIS, demonstration with Slicer 3D, demonstration with Plus, demonstration with IGSTK, homework consultation and presentation.

Evaluation method: classical oral examination.

Recommended References:

1. Vanja Bozovic (Ed.), ISBN 978-3-902613-18-9, 526 pp, Publisher: I-Tech Education and Publishing, 2008 under CC BY-NC-SA 3.0 license. DOI: 10.5772/54929
2. Seung Hyuk Baik (Ed), ISBN 978-953-7619-77-0, 172 pp, Publisher: InTech, 2010
3. G. Fichtinger, J. Troccaz and T. Haidegger, "Image-Guided Interventional Robotics: Lost in Translation?," in Proceedings of the IEEE, vol. 110, no. 7, pp. 932-950, July 2022, doi: 10.1109/JPROC.2022.3166253.
4. Haidegger, Tamas & Speidel, Stefanie & Stoyanov, Danail & Satava, Richard. (2022). Robot-Assisted Minimally Invasive Surgery—Surgical Robotics in the Data Age. Proceedings of the IEEE. 110. 835-846. 10.1109/JPROC.2022.3180350.

Course title: *Modern Technics and Technology of Surgery*

Lecturer: Tamás Haidegger, PhD, professor
haidegger@uni-obuda.hu

Course objective: The goal of the class is to get the students acquainted with modern surgical technologies and the supporting technical devices. The course shows the cutting-edge technologies and concepts to be used in the near future. There is a particular focus on minimally invasive surgery and image-guided surgical methods. Students will get acquainted with intraoperative navigation systems and surgical robots. To accomplish the course, students are required to understand the fundamentals of minimally invasive procedures, robot control and medical image processing methods (on a theoretical level). It is required that the students gain an overall image on the future tools of surgery, and at the end of the semester give account on their knowledge within the frames of an exam.

Lectures: 20 hours

Course description:

Get familiar with modern surgical technologies. Get acquainted with the special design, control, and safety requirements of the field. Minimally invasive surgical techniques. Computer-integrated surgery, surgical robotics, surgical CAD/CAM. The usage of patient data, imaging, and other diagnostic information in the planning and execution of interventions. Design and implementation criteria of medical robots operating in distributed systems. Surgical navigation, theoretical and practical background of electromagnetic tracking. Current research directions of surgery. Surgical ontologies and decision support systems. Automatic execution of surgical subtasks. Assessment of technical and non-technical surgical skills. Ventilation and respiratory monitoring.

Evaluation method: classical oral examination.

Recommended References:

1. Taylor, Russell H., and Peter Kazanzides. "Medical robotics and computer-integrated interventional medicine." Advances in Computers 73 (2008): 219-260.
2. Hoeckelmann, M., Rudas, I. J., Fiorini, P., Kirchner, F., & Haidegger, T. (2015). Current Capabilities and Development Potential in Surgical Robotics. Int J Adv Robot Syst, 12, 61.
3. G. Fichtinger, J. Troccaz and T. Haidegger, "Image-Guided Interventional Robotics: Lost in Translation?," in Proceedings of the IEEE, vol. 110, no. 7, pp. 932-950, July 2022, doi: 10.1109/JPROC.2022.3166253.
4. Haidegger, Tamas & Speidel, Stefanie & Stoyanov, Danail & Satava, Richard. (2022). Robot-Assisted Minimally Invasive Surgery—Surgical Robotics in the Data Age. Proceedings of the IEEE. 110. 835-846. 10.1109/JPROC.2022.3180350.

Course title: *Path Planning Strategies of Multi-Agent Mobile Robot Systems*

Lecturer: István Nagy, PhD, associate professor
nagy.istvan@bgk.uni-obuda.hu

Lectures: 20 hours

The goal of the course:

To introduce students into the basic path-planning and navigations strategies in multi-agent mobile-robot systems.

Preconditions: only basic knowledge about mobile-robots path-planning methods, some elementary knowledge about GA and ANN operations.

Subject Description:

Firstly, surveying the basic localization, path-planning, and navigations methods, valid for single agent systems. Surveying the mapping of the environment, SLAM method, how to create a point-represented mobile robot, how to model the environment. After, turn to the MAS (Multi-Agent Systems). Types of agents and definitions. Types of different environment modelling especially for topological (graph-like) maps and potential fields maps (VFF, VFH). Case studies and methods for different graph- searches (A*, A**, Dijsktra, Bellman-Ford, Floyd-Warshall) and optimal path-planning (Ant Colony, SWARM technology; Q-learning and Reinforcement Learning- RL) procedures. Using Markov decision making in MAS.

Exam Type: Classic written and oral exam

Literature

1. G. Lozenguez, On the Distributivity of Multi-agent Markov Decision Processes for Mobile Robotics, International Symposium on Swarm Behavior and Bio-Inspired Robotics, Jun 2021, Kyoto, Japan. hal-03545990,
2. J. Hao, Ho-Fung Leung, Interactions in Multiagent Systems, World Scientific Publishing, 2018.
3. N. Osman, C. Sierra (Eds), Autonomous Agents and Multiagent Systems, AAMAS2016 Workshop, Revised Selected Papers, Singapore, 2016.
4. M. Cossentino, M. Kaisers, K. Tuyls, G. Weiss (Eds), Multi-Agent Systems, 9th European Workshop, EUMAS2011, Springer, 2011.
5. M. Dorigo, . Stützle: Ant Colony Optimization, Bradford Book, MIT Press, Cambridge, Massachusetts, 2004.
6. J. Liu, J. Wu: Multi-Agent Robotic Systems. CRC Press LLC, Boca Raton, Florida, 2001.

7. Altrichter, Horváth, Pataki, Strausz, Takács, Valyon: Neurális hálózatok; Publication date 2006, Szerzői jog © 2006 Hungarian Edition Panem Könyvkiadó Kft., Budapest
8. Álmos, Győri, Horváth, Várkonyiné: Genetikus algoritmusok; Typotex, 2013.

Recommended Literature:

1. I. Nagy: Genetic Algorithms Applied for Potential Field Building in Multi-Agent Robotic System, Proc. ICCC'03, IEEE International Conf. on Computational Cybernetics, Siófok, Hungary 2003.
2. W. Elmenreich, J.A. T. Machado, I.J. Rudas, (Eds), Intelligent Systems at the Service of Mankind, Vol I., Springer, 2004.
3. O. Castillo and L. Trujillo: Multiple Objective Optimization Genetic Algorithms for Path Planning in Autonomous Mobile Robots, International Journal of Computers, Systems and Signals, Vol. 6, No. 1, 2005.
4. I.Nagy: Behaviour Study of a Multi-agent Mobile Robot System During Potential Field Building, Acta Polytechnica Hungarica, Vol. 6, Nr. 4, pp.: 111-136, 2009.

Course title: *Embedded Mobile Robotics*

Lecturer: Peter Odry, associate professor, PhD
odry.peter@uniduna.hu

Course objective: An Introduction to Theoretical Issues in Mobile Robot Manufacturing and Control.

Lectures: 20 hours

Course description:

Mobile robot structures and the principle of their operation. Structural elements of mobile robots. Implementation of propulsion mechanisms. Control systems, sensor network selection and embedding. Optimization of embedded surfaces. Sensor technology for two-wheel inverse structures. Structure of a walking robot, balancing robot structure. Structure and embedded surface of six-legged, four-legged and two-legged walker robots. Development of walking algorithms. Autonomous flying objects. Autonomous floating objects and underwater floating objects. Conditions for providing a mobile robot application. Robot localization and navigation.

Implementing and exploring robotic control in an embedded system. Create a map. Interpretation of measurement data. Questions about embedding the algorithms. Technical conditions and embedding issues for real-time image processing. Embedded soft programming procedures on a robot interface.

Evaluation method: classical oral examination.

Recommended References:

1. T. Bräunl (2008): „Embedded robotics", Berlin Heidelberg, Germany, Springer-Verlag
2. I. Kecskes, E. Burkus, F. Bazso and Peter Odry (2017) "Model validation of a hexapod walker robot" Robotica, 35 (2), pp. 419-462
3. Alchan Yun, Woosub Lee, Soonkyum Kim, Jong-Ho Kim 3, Hyungseok Yoon (2022): „Development of a Robot Arm Link System Embedded with a Three-Axis Sensor with a Simple Structure Capable of Excellent External Collision Detection", Sensors, 22(3), 1222
4. Abdelkrim Abanay, Lhoussaine Masmoudi, Mohamed El Ansari (2022): „A calibration method of 2D LIDAR-Visual sensors embedded on an agricultural robot", Optik, 249 (1), 168254
5. Weiming Liu, Xiangyu Wang, Shihua Li (2023): „Formation Control for Leader–Follower Wheeled Mobile Robots Based on Embedded Control Technique", IEEE Transactions on Control Systems Technology, 31 (1), 265 – 280
6. François Grondin, et. al. (2022): „ODAS: Open embeddeD Audition System", Front. Robot. AI, 11 (5)

7. Tannaz Torkaman, Majid Roshanfar, Javad Dargahi, Amir Hooshiar (2023): „Embedded Six-DoF Force–Torque Sensor for Soft Robots With Learning-Based Calibration”, IEEE Sensors Journal, 23 (4), 4204 – 4215
8. A Mahapatro, PR Dhal, DR Parhi, MK Mun (2023): „Towards stabilization and navigational analysis of humanoids in complex arena using a hybridized fuzzy embedded PID controller approach”, Expert Systems with Applications, 213 (C), 119251

Course title: *Issues of Mobile Robot Optimization*

Lecturer: Peter Odry, associate professor, PhD
odry.peter@uniduna.hu

Course objective: Introduction in the optimization process of mobile robot construction and control.

Lectures: 20 hours

Course description:

Summary of standard optimization procedures, application techniques, and applicability in robotics. Computing needs of optimization procedures, parallel computing options and solutions. Overview and classification of optimization process program packages. Formulation of optimization in mobile robot environment. Specifics of mobile robot optimization.

Formulation of goodness (also known as fitness) or optimum in mobile robot optimization. Uncertainty of quality measurement and correct determination. Questions of robot modelling: kinematic and dynamic model, mathematical model vs. simulation model, what's worth and what's not worth modelling. Optimization opportunities on different models and on the real robot. Choosing to measure the required parameters on the model and the real robot. Robot model and verification of optimum by measuring of a real robot operation. Classification of quality of verification results and estimation of tolerance of optimum.

Evaluation method: classical oral examination.

Recommended References:

1. I. Kecskés, P. Odry (2021): Robust optimization of multi-scenario many-objective problems with auto-tuned utility function, Engineering Optimization 53 (7), 1135-1155
2. E. Burkus, Á. Odry, J. Awrejcewicz, I. Kecskés, P. Odry (2022): „Mechanical Design and a Novel Structural Optimization Approach for Hexapod Walking Robots", Machines 10 (6), 466
3. Ákos Odry; Róbert Fullér; Imre J Rudas; Péter Odry (2018): "Kalman filter for mobile-robot attitude estimation: Novel optimized and adaptive solutions", Mechanical Systems and Signal Processing 110: pp. 569-589
4. Özge Ekrem, Bekir Aksoy (2023): „Trajectory planning for a 6-axis robotic arm with particle swarm optimization algorithm", Engineering Applications of Artificial Intelligence, 122 (6), 106099
5. Pengyu Zhao, Anhuan Xie, Shiqiang Zhu, Lingyu Kong (2023): „Pressure optimization for hydraulic-electric hybrid biped robot power unit based on genetic algorithm", Scientific Reports, 13, 60

6. Levent Türkler,Taner Akkan, Lütfiye Özlem Akkan (2022): „Usage of Evolutionary Algorithms in Swarm Robotics and Design Problems", Sensors, 22(12), 4437
7. Daniel F. N. Gordon, Christopher McGreavy, Andreas Christou, Sethu Vijayakumar (2022): „Human-in-the-Loop Optimization of Exoskeleton Assistance Via Online Simulation of Metabolic Cost", IEEE Transactions on Robotics, 38 (3), 1410 - 1429

Course title: *Introduction to Engineering Computational Methods*

Lecturer: Aurél Galántai, professor emeritus, DSc
galantai.aurel@nik.uni-obuda.hu

Course objective: An introuction to a complex and fast developing area which encompasses numerical methods, elements of software and hardware engineering, computer graphics and special application knowledge as well.

Lectures: 20 hours

Course description:

The aim, the content and the tools of the subject. A short survey of the software/hardware methods, the mathematical methods and the application areas. Computer oriented numerical methods. Basic architectures and their programming characteristics. The floating point arithmetic standards. The elements of interval arithmetic. The methods of linear algebra and nonlinear equations. Interpolation techniques and splines. Numerical derivation and integration. Adaptive techniques. Numerical stability and precision in floating point arithmetic. Computer architecture and algorithmic efficiency. Numerical softwares. Software standards and packages (BLAS, LAPACK, MATLAB, Scilab, stb.). Symbolic software packages (Maxima, Maple, etc.). Graphic visualization. Simulation techniques, the Monte-Carlo method.

Evaluation method: classical oral examination or submission of the documentation of the solution of a task.

Recommended References:

1. E. Anderson, *et.al*, *LAPACK Users' Guide*. Philadelphia, SIAM, 1992.
2. F. Chaitin-Chatelin and V. Frayssé, *Lectures on Finite Precision Computations*. Philadelphia, SIAM, 1996.
3. J. Dongarra *et al.*, *Numerical Linear Algebra for High-Performance Computers*. SIAM, 1998
4. W. Gander and J. Hrebicek, *Solving Problems in Scientific Computing Using Maple and Matlab*. Springer, 1995.
5. G. H. Golub and C. F. Van Loan, *Matrix Computations*. 2nd ed., Baltimore, The Johns Hopkins University Press, 1993. IAM, 2004
6. M. L. Overton, *Numerical Computing with IEEE Floating Point Arithmetic*, Philadelphia, SIAM, 2001.
7. J. E. Rice, *Numerical Methods, Software, and Analysis*. McGraw-Hill, 1983.
8. J. E. Rice, *Matrix Computations and Mathematical Software*. McGraw-Hill, 1983.
9. G. Stoyan, Ed., *Matlab*. Budapest, Hungary, Typotex Kiadó, 2005.

10. C. W. Ueberhuber, *Numerical Computation 1-2 (Methods, Software, and Analysis)*. Springer, 1997.
11. J. H. Wilkinson, *Rounding Errors in Algebraic Processes.* Dover, 1994.
12. Z. Zeng, *Scientific Computing with Maple Programming, lecture notes.* 2001.
13. A. Iványi, Ed., *Informatikai algoritmusok 1.-2.* ELTE Eötvös Kiadó, 2004, 2005
14. N. J. Higham, *Accuracy and Stability of Numerical Algorithms*. Philadelphia, SIAM, 1996.
15. C. B. Moler, *Numerical Computing with MATLAB*. Philadelphia, SIAM, 2004
16. M. L. Overton, *Numerical Computing with IEEE Floating Point Arithmetic*, Philadelphia, SIAM, 2001.
17. J. E. Rice, *Numerical Methods, Software, and Analysis*. McGraw-Hill, 1983.
18. J. E. Rice, *Matrix Computations and Mathematical Software*. McGraw-Hill, 1983.
19. G. Stoyan, Ed., *Matlab*. Budapest, Hungary, Typotex Kiadó, 2005.
20. C. W. Ueberhuber, *Numerical Computation 1-2 (Methods, Software, and Analysis)*. Springer, 1997.
21. J. H. Wilkinson, *Rounding Errors in Algebraic Processes.* Dover, 1994.
22. Z. Zeng, *Scientific Computing with Maple Programming, lecture notes.* 2001.

Course title: *Engineering Computational Methods 1*

Lecturer: Aurél Galántai, professor emeritus, DSc
galantai.aurel@nik.uni-obuda.hu

Course objective: Computational methods for the large computational problems of linear algebra. Approximation of multivariable functions. Computer methods for differential and integral equations.

Lectures: 20 hours

Preconditions: *Introduction to Engineering Computational Methods*

Course description:

Computer methods for large sparse matrices. The MATLAB sparse package. Interpolation techniques for multivariable real functions. Numerical differentiation and integration of several variable functions. Automatic differentiation. FFT. Computer methods and packages for ordinary differential equations. Finite difference and finite element methods for partial differential equations. Discretization methods for integral equations. Algorithms for parallel computers. Numerical stability problems and the reliability of computed results. Graphical interpretation of the solutions. Program packages (NETLIB, TOMS, NAG, IMSL, etc.).

Evaluation method: classical oral examination or submission of the documentation of the solution of a task.

Recommended References:

1. E. Anderson et al.: LAPACK Users' Guide. Philadelphia, SIAM, 1992.
2. R. E. Bank, PLTMG: A Software Package for Solving Elliptic Partial Differential Equations, User’s Guide 9.0. University of California at San Diego, 2004.
3. T. F. Coleman and C. Van Loan, Handbook for Matrix Computations. Philadelphia, SIAM, 1988.
4. G. Dahlquist and A. Björck, Numerical Methods in Scientific Computing I. Stockholm, Royal Institute of Technology, 2006.
5. J. Dongarra et al., Numerical Linear Algebra for High-Performance Computers. SIAM, 1998.
6. G. H. Golub and C. F. Van Loan, Matrix Computations. 2nd ed., Baltimore, The Johns Hopkins University Press, 1993.
7. A. Griewank, Evaluating Derivatives: Principles and Techniques of Algorithmic Differentiation, Philadelphia, SIAM, 2000.
8. J. E. Rice, Numerical Methods, Software, and Analysis. McGraw-Hill, 1983.
9. J. E. Rice, Matrix Computations and Mathematical Software. McGraw-Hill, 1983.

10. C. W. Ueberhuber, Numerical Computation 1-2 (Methods, Software, and Analysis). Springer, 1997.
11. E. F. Van de Velde, Concurrent Scientific Programming. Springer, 1994
12. C. Van Loan, Computational Frameworks for the Fast Fourier Transform, Philadelphia, SIAM, 1992.

Course title: *Engineering Computational Methods 2*

Lecturer: Aurél Galántai, professor emeritus, DSc
galantai.aurel@nik.uni-obuda.hu

Course objective: Introduction to the computer algorithms of numerical optimization.

Lectures: 20 hours

Preconditions: *Introduction to Engineering Computational Methods*

Course description:

Solution algorithms for the linear least squares method. The total least squares method. Numerical methods for unconstrained function minimization: line search methods, Newton- and quasi-Newton methods and their computer implementations. Trust region methods. Direct search methods. SUMT methods for constrained optimization. The method of sequential quadratic programming. Elements and algorithms of global optimization. Optimization program packages.

Evaluation method: classical oral examination or submission of the documentation of the solution of a task.

Recommended References:

1. A. Björck, *Numerical Methods for Least Squares Problems*, Philadelphia, SIAM, 1996.
2. J. E. Dennis and R. B. Schnabel, *Numerical Methods for Unconstrained Optimization and Nonlinear Equations*, Prentice-Hall, 1983, SIAM, 1996.
3. R. Fletcher, *Practical Methods of Optimization, 1-2*. Wiley & Sons, 1980, 1981.
4. A. Galántai, *Projectors and Projection Methods*, Kluwer, 2004.
5. A. Griewank, *Evaluating Derivatives: Principles and Techniques of Algorithmic Differentiation*, Philadelphia, SIAM, 2000.
6. C. T. Kelley, *Iterative Methods for Linear and Nonlinear Optimization*. Philadelphia, SIAM, 1999.
7. J. J. Moré and S. J. Wright, *Optimization Software Guide*. Philadelphia, SIAM, 1993.
8. L. E. Scales, *Introduction to Non-Linear Optimization.* Springer, 1985.
9. M. J. Quinn, *Designing Efficient Algorithms for Parallel Computers.* McGraw-Hill, 1987.

Course title: *Applied Finite Element Analysis*

Lecturer: dr. Louis Komzsik, professor emeritus
louis.komzsik@uni-obuda.hu
https://www.routledge.com/authors/i5411-louis-komzsik

Lectures: 20 hours

Course objective

Introduce the students to computational techniques of the finite element method applicable to analysis of complex systems arising in their research area.

Course scope

The technological foundation lectures will cover finite element mathematics, engineering analysis scenarios, their computational aspects, eigenvalue analysis solutions and advanced response analyses. The application focused lectures will be from the area of structural analysis, heat transfer, rotational dynamics, fluid-structure interaction, topology optimization and its mathematical solution.

Lecturing

There will be one lecture each week of the semester presented remotely from overseas. The classes will be one and a half hour long. Additional consultation will be available upon request. The classes will be held at a website to which the eligible students can join. The lecture presentation will be in English. The lecture slides will be made accessible to the students enrolled in the class in the class homepage in TEAM prior to the classes.

Course requirement

Each student will be required to produce a technical report on one of the lecture topics selected by the student and approved by the lecturer. The topic's theoretical content shall be supported by a simple implementation in any computational environment chosen by the student. A brief presentation on the same topic will be given by the student at the last class. The report and presentation will be evaluated by the lecturer to establish a grade.

Reference book

Komzsik L.: Computational techniques of finite element analysis, 2nd edition; Taylor and Francis, 2009, ISBN 978-1-4398-0294-62

Course title: *Development and application of nature-inspired algorithms*

Lecturer: Dr. Imre Felde, professor
felde.imre@uni-obuda.hu

Lectures: 20 hours

Course objective

Learning the mathematical background of bio and nature-inspired optimization heuristics and mastering their effective application in solving complex problems. Within the framework of the subject, the theoretical foundations and application possibilities of swarm theory, evolutionary and genetic algorithms are also discussed.

Content of the subject:

- Introduction.
- The swarm theory and the PSO algorithm,
- Evolutionary algorithms, genetic algorithms,
- Implementation of algorithms inspired by nature,
- Parallel processing,
- Application possibilities, practical examples

Evaluation method: classical colloquium, oral examination

References:

1. Jason Brownlee: Clever Algorithms: Nature-inspired Programming Recipes, ISBN-10: 1446785068
2. Xin-She Yang (Editor)Nature-Inspired Algorithms and Applied Optimization (Studies in Computational Intelligence) , ISBN-10: 3319676687
3. Mario D'acunto (Editor), Nature-Inspired Computation (Computer Science, Technology and Applications), ISBN-10: 163463831X [4] Anupam Shukla

Course title: *Numerical modeling and optimization of industrial processes*

Lecturer: Dr. Imre Felde, professor
felde.imre@uni-obuda.hu

Lectures: 20 hours

Course objective

Mathematical knowledge required for modeling machining and production processes and mastering their effective application in problem solving. Within the framework of the subject, the theoretical foundations of finite difference, finite element methods, thermodynamic and transformation modeling techniques are discussed.

Content of the subject:

- Introduction.
- Fundamentals of numerical modeling,
- Finite difference method, finite element method, boundary element method,
- Fundamentals of thermodynamic modeling,
- Estimation of thermal boundary conditions,
- Modeling transformation processes,
- Practical examples

Evaluation method: classical colloquium, oral examination

References:

1. C. Hakan Gur and J. Pan: Handbook of Thermal Processing of Steels,., CRC Press, Boca Raton, FL, 2008,
2. M. Necati Özışık : Heat transfer: a basic approach, Volume 1, McGraw-Hill, 1985
3. M. Necati Özışık : Heat conduction, John Wiley & Sons Australia, Limited, 1980
4. G.E. Totten, L. Xie, K. Funatani: Modeling and Simulation for Material Selection and Mechanical Design, Marcel Dekker, Inc, 2004

Course title: *Flexible and function driven shape representations*

Lecturer: Professor László Horváth CSc, PhD, Dr. habil
horvath.laszlo@nik.uni-obuda.hu

About the subject
Subject introduces into currently developing shape representations to fulfill recent new requirements against shape model. In this way, modeling behavioral functional features, complex rigid-flexible structures, and organic shapes are characterized, discussed, and exampled.

Purpose and objectives
Subject supports research which requires recent knowledge about shape centered mathematical modeling and simulation of physical system. It helps student at research in representation of flexible bodies and function driven organic shapes.

Issues and topics
Recent advances in boundary representation of shapes.
Shape model in multidisciplinary contextual environment.
Physical system that includes both rigid elements and flexible structures.
Modeling flexible bodies using Modelica language.
Functional form features with behaviors.
Generation of flexible body model using principle and method of finite element analysis.
T-spline representations, their new characteristics and compatibility with NURBS.
Geometric and organic shapes.
Model of function driven organic shapes.
Shape model for additive and traditional manufacturing processes.

Laboratory support
Students understand principles, methods, contextual connections and system issues discussing related issues on most advanced experimental models. These models are developed for this subject in the cloud environment of 3DEXPERIENCE system.

Lectures: 30 hours

Evaluation method: examination for checking the theoretical and methodological knowledge.

Recommended texts:
1. A. I. Ginnis, K. V. Kostas, P. D. Kaklis, “Construction of smooth branching surfaces using T-splines,” Computer-Aided Design, Vol. 92, pp 22-32 (2017)
2. L. Horváth, "Representing Biological Aspects in Engineering Model System," 2019 IEEE International Work Conference on Bioinspired Intelligence (IWOBI), Budapest, Hungary, 2019, pp. 000133-000138, doi: 10.1109/IWOBI47054.2019.9114437.
3. J. Limanowski, “Precision control for a flexible body representation,” Neuroscience & Biobehavioral Reviews, Vol. 134, 104401 (2022), DOI:10.1016/j.neubiorev.2021.10.023

4. T. A. Lenau, A.-L. Metze, T. Hesselberg, “Paradigms for biologically inspired design,” in Proc. of SPIE Smart Structures and Materials+Nondestructive Evaluation and Health Monitoring, Denver, Colorado, United States, 2018, DOI:10.1117/12.2296560.
5. L. Horváth, “Content Structure for Driving Object Parameters in Contextual Model of Engineering Structure, in book Computational and Experimental Simulations in Engineering, Springer, 2019, pp. 319-333, DOI: 10.1007/978-3-030-27053-7_30.

Course title: *Modeling engineering structure as multidisciplinary system*

Lecturer: Professor László Horváth CSc, PhD, Dr. habil
horvath.laszlo@nik.uni-obuda.hu

About the subject

Physical level model of product or other engineering structure is restricted to contextual part models, connection objects for parts, as well as objects for the related processes, analyses, and controls. Recently, there is a growing tendency to develop increasingly multidisciplinary systems operated engineering structures. Physical level modeling is not enough anymore: systems level modeling is required. This subject includes a set of issues to support research in this area.

Purpose and objectives

Subject supports student to recognize necessity of system based engineering modeling, to understand method which is applied from systems engineering (SE), and to connect system and physical levels of model. It helps student at research in system behavior optimizing and integrated simulation processes. In the context of this subject, phrase engineering structure is applied for multidisciplinary system-based experimental engineering configuration.

Issues and topics

Multidisciplinary systems operated engineering structures.
Functional and logical level modeling in RFLP structure.
Behavior definitions and representations for virtual execution of conceptual model.
Connection of functional and logical components.
Modeling and simulation of multi-body and multi-physic systems.
Representation of content behind information in engineering model.
System level parameter optimization.
Organized simulations for multi-physics and multi-scale systems.Organized simulations for multi-physics and multi-scale systems.

Lectures: 20 hours

Laboratory support

Students understand principles, methods, contextual connections and system issues discussing related issues on most advanced experimental models. These models are developed for this subject in the cloud environment of 3DEXPERIENCE system.

Evaluation method: examination for checking the theoretical and methodological knowledge.

Recommended texts:

1. L. Horváth, "Representations for Driving Objects in Model of Smart Engineering System," 2019 IEEE 19th International Symposium on Computational Intelligence and Informatics and 7th IEEE International Conference on Recent Achievements in

Mechatronics, Automation, Computer Sciences and Robotics (CINTI-MACRo), Szeged, Hungary, 2019, pp. 000037-000042, doi: 10.1109/CINTI-MACRo49179.2019.9105323.

2. F. Tian, M. Voskuijl, “Automated generation of multiphysics simulation models to support multidisciplinary design optimization,“ Advanced Engineering Informatics, Vol. 29, No. 4, pp. 1110-1125 (2015). DOI: 10.1016/j.aei.2015.07.004.
3. T. Huldt, I. Stenius, “State-of-practice survey of model-based systems engineering,” in Systems engineering, Vol. 22, No 2, pp. 134-145 (2019), DOI:10.1002/sys.21466.
4. L. Horváth, "Integrated Autonomous Model System as Research Media," 2022 IEEE 22nd International Symposium on Computational Intelligence and Informatics and 8th IEEE International Conference on Recent Achievements in Mechatronics, Automation, Computer Science and Robotics (CINTI-MACRo), Budapest, Hungary, 2022, pp. 125-130, DOI: 10.1109/CINTI-MACRo57952.2022.10029408.
5. L. Liu, “Application of Dassault System 3D Experience Platform in Enterprise Digitalization,” in: Frontier Computing. FC 2021. Lecture Notes in Electrical Engineering, vol 827. Springer, Singapore, pp 1407–1413, 2022. DOI: 10.1007/978-981-16-8052-6_202.

Course title: *Cyber Physical System (CPS) as it is Realized in Engineering for Robot Systems*

Lecturer: Professor László Horváth CSc, PhD, Dr. habil
horvath.laszlo@nik.uni-obuda.hu

Course objective: Advanced control and operation of system-based product requires paradigm level change in engineering application of information technology. The new paradigm is cyber physical system (CPS) where the great novelty is higher level communication between cyber and physical units mainly by utilizing intelligent sensor system power. Cyber activities in CPS also require higher level communication between lifecycle servicing model of CPS and operating CPS. Robot system is a main problem area in the world of CPS because of its high complexity and multidisciplinary character. At the same time, robot system which is contextually integrated in its environment have increasing importance and widespread in many industrial areas. Students understand necessity and means of connections between model and operating forms of CPS systems, familiarize themselves with the relevant elements of the two systems, recognize consistent contexts, and understand CPS model support for CPS operation. In the meantime, related issues in robot systems are also given. Subject helps student at research in driving connection between model and cyber units of CPS robot system.

Lectures: 20 hours

Course description:

Units and contexts in CPS system. CPS operation related objects in system-based engineering model. Driving contexts between modeled and operating CPS.
Model definition of robot system Model structure an representation related issues: robot control, direct and invers kinematics, velocity and acceleration, motion sets, and kinematic relations
Contextual realistic robot simulation. Situation and event driven communication within virtual CPS and with its operating CPS connection.
Information technology, computing, and mathematical means for relevant knowledge, experience, and expertise representation and communication.
Robot system behavior and its simulation and validation.

Laboratory support

Students understand principles, methods, contextual connections and system issues discussing related issues on most advanced experimental models. These models are developed for this subject in the cloud environment of 3DEXPERIENCE system.

Recommended texts:

1. L. Horváth, Developing Strategies in System Level Model of Smart Cyber Physical System," Acta Polytechnica Hungarica, Vol. 18, No. 5, pp. 55-76 (2021), DOI: 10.12700/APH.18.5.2021.5.5.
2. L. Horváth, "Intelligent Content in System Level Model of Industrial Cyber Physical System," IECON 2018 - 44th Annual Conference of the IEEE Industrial Electronics Society, Washington, DC, USA, 2018, pp. 2914-2919, DOI: 10.1109/IECON.2018.8591403.

3. P. Leitao, A. W. Colombo, S. Karnouskos, “Industrial automation based on cyber-physical systems technologies: Prototype implementations and challenges,” Computers in Industry, Vol. 81, pp. 11–25 (2016), DOI: 10.1016/j.compind.2015.08.004.
4. M. R. Endsley, “Situation Awareness in Future Autonomous Vehicles: Beware of the Unexpected,” 20th Congress of the International Ergonomics Association, Florence, Italy, 2018, pp 303-309. DOI:10.1007/978-3-319-96071-5_32.
5. J. J. van Steen, N. van de Wouw and A. Saccon, "Robot Control for Simultaneous Impact Tasks through Time-Invariant Reference Spreading," 2023 American Control Conference (ACC), San Diego, CA, USA, 2023, pp. 46-53, DOI: 10.23919/ACC55779.2023.10156028.

Course title: *Blockchain & AI - Then and Now I*

Lecturer: Dr. Katalin Szenes, CISA, CISM, CGEIT, CISSP, PhD, honorary associate professor
szenes.katalin@nik.uni-obuda.hu

The goal of education:

Besides giving an overview of very different tools related to AI and / or blockchain, used from the seventies and sometimes even till now, we would like to revive some forgotten concepts, that might be useful even today. The theoretical background of some of the chosen tools will also be detailed.

Lectures: 20 hours / semester

Preconditions: -

Assessment: classic oral examination, verbal exam.

Topics:

1. Inference by derivation using graph traversing and practical examples

1.1 The PROLOG language

1.2 Thinking robots

1.3 Introducing the handling of system time and its significance

1.4 Modelling parallel and concurrent processes – scheduling facilities

2. AI and Practice

2.1 Supporting the establishment of a mutual connection between security and corporate governance - the system PCUBE-SEC

3. Blockchain - Past and Present

3.1 How did blockchain start?

3.1.1 Before Bitcoin...

3.1.2 Bitcoin's impact on blockchain systems

3.1.3 Ethereum blockchain

3.1.4 Ethereum vs. Bitcoin

3.1.5 Smart contract

3.2 Blockchain architectures for digital currencies

3.3 Computer games based on blockchain

3.4 Layers of blockchain systems

3.5 Blockchain Development Environments

3.5.1 Azure Blockchain Workbench

3.5.2 IBM Watson Studio

3.5.3 MODEX Blockchain Database

3.5.3.1 Sample application

Recommended literature:

1. Szenes, Katalin; Tureczki, Bence. AI Assistant in a Smart Cloud. In: Szakál, Anikó (szerk.) IEEE 20th Jubilee World Symposium on Applied Machine Intelligence and Informatics SAMI (2022): Proceedings. Poprad, Szlovákia: IEEE (2022) 507 p. pp. 311-315., 5 p.
2. Tureczki, Bence; Henriette, Steiner; Szenes, Katalin. A blockchain-based dynamic support of kinematic testing. In: Anikó, Szakál (szerk.) IEEE Joint 22nd International Symposium on COMPUTATIONAL INTELLIGENCE and INFORMATICS and 8th International Conference on Recent Achievements in Mechatronics, Automation, Computer Science and Robotics (CINTI-MACRo 2022): Proceedings. Budapest, Magyarország: IEEE Hungary Section (2022) 418 p. pp. 329-334., 5 p.
3. Bence, Tureczki; Katalin, Szenes. A Blockchain-AI Synergy for supporting Emerging Technologies. In: Soliman, Khalid S. (szerk.) Proceedings of the 38th International Business Information Management Association (IBIMA): Innovation management and sustainable economic development in the era of global pandemic. Sevilla, Spanyolország: IBIMA Publishing (2021) pp. 1-5., 5 p.
4. Szenes, K.: Automatikus progamgenerálás és robotvezérlés a rezolúció elve alapján. Hungarian - Automatic program generation and robot control based on the resolution principle - University Doctor Thesis
5. Futó, I., Szeredi, J., Szenes, K.: A modelling tool based on mathematical logic – T-PROLOG; Acta Cybernetica, 1981., Szeged, Hungary, p. 363 - 375
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10. Szenes, K.: A mesterséges intelligencia kutatás egyes módszereinek alkalmazása folyamatrendszerek modellezésében. Hungarian - On the application of AI research methods in modelling process systems. Felügyelet nélküli gyártás Szeminárium, Kecskemét. J. Automatizálás (PRODINFORM) vol. XIX., No. 8., 1985. Aug., p. 28 - 30, also available in the proceedings of the conference: Felügyelet nélküli gyártás Szeminárium, Kecskemét, 1985. okt. 17-18, p. 331 - 340

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15. Blockchain For Dummies®2nd IBM Limited Edition. Published by John Wiley & Sons, Inc. 111 River St. Hoboken, NJ 07030-5774. www.wiley.com. Copyright © 2018 by John Wiley & Sons, Inc.

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17. Equational Methods in First Order Predicate Calculus ETIENNE PAUL Centre National d'Etudes des T~l~communications, 38/40 Rue du G~nkral Leclerc, 92131 lssy les Moulineaux, France 3. Symbolic Computation (1985) 1, 7-29

18. Logic and Proof Computer Science Tripos Part IB Michaelmas Term Lawrence C Paulson Computer Laboratory University of Cambridge lcp@cl.cam.ac.uk

19. S. Dharanikota, S. Mukherjee, C. Bhardwaj, A. Rastogi, A. Lal: "Celestial: A Smart Contracts Verification Framework". Microsoft Research, MS paper ID: MSR-TR-2020-43. December, 2020. India. Download: https://www.microsoft.com/en-us/research/uploads/prod/2020/12/celestial.pdf

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21. COBIT 5: A Business Framework for the Governance and Management of Enterprise IT. Copyright © 2012 ISACA. ISBN 978-1-60420-237-3. Expert Reviewer in the Subject Matter Expert Team: Katalin Szenes

22. COBIT 2019 Framework: Governance and Management Objectives. ISBN 978-1-60420-728-6. Copyright © 2018 ISACA. Member of the COBIT Working Group 2017-2018: Katalin Szenes

23. COBIT 2019 Framework: Introduction and Methodology. ISBN 978-1-60420-644-9. Copyright © 2018 ISACA. Member of the COBIT Working Group 2017-2018: Katalin Szenes

24. CISA Review Manual 27th edition. Updated for 2019 Job Practice. Copyright © 2019 ISACA. 1700 E. Golf Road, Suite 400, Schaumburg IL 30173 USA. ISBN 978-1-60420-767-5

25. Szeredi, P., Futo, I.: PROLOG Kézikönyv. (PROLOG Reference Manual - Hungarian), Journal Számológép, No 3, 4; editor: NIMIGÜSZI, Budapest, 1977

Course title: *Optimization models*

Lecturer: János Fülöp, associate professor, PhD
fulop.janos@nik.uni-obuda.hu

Course objective: The aim of the course is to give a brief overview of the basic optimization models, to introduce the students into using computer tools of modelling and solving optimization problems, and to show how to interpret and apply the results. During the course the modelling and solver software GAMS is applied. The students also use GAMS for modelling and solving the optimization problems of homework.

Lectures: 20 hours

Course description:

Topics: Practical models of linear optimization. Interpretation of duality and shadow prices. Practical models of integer optimization. The branch-and-bound method. Application of tolerances. Logical constraints in optimization problems. Optimization in networks. The traveling salesman problem. Practical models of nonlinear optimization. Portfolio optimization models. Optimization models of discriminant analysis and clustering. Goal programming. Fractional programming. Data envelopment analysis.

Evaluation method: classical oral examination.

References:

Compulsory:

1. R. Rosenthal: A GAMS Tutorial. http://www.gams.com/dd/docs/gams/Tutorial.pdf
2. Brooke, D. Kendrick, A. Meeraus, GAMS – A User's Guide, 2014. http://www.gams.com/dd/docs/bigdocs/GAMSUsersGuide.pdf
3. W.L. Winston, J.B. Goldberg: Operations Research: Applications and Algorithms, Thomson Brooks/Cole, 2004.

Recommended:

1. H.P. Williams, Model Building in Mathematical Programming, Wiley, 1995.
2. F.S. Hillier, G.J. Libermann: Introduction to Operations Research, McGraw-Hill, 2005.
3. Fresh, actual documents that can be downloaded from the link: www.gams.com.

Course title: *Statistical Hypothesis Testing*

Lecturer: Márta Takács, professor, PhD
takacs.marta@nik.uni-obuda.hu

Course objective: The goal of the subject is to present statistical hypothesis testing methods applied in engineering researches.

Lectures: 20 hours (partially in consultative forms)

The subject prerequisites: basic mathematical and probability knowledge

Course description:

Event mathematics and basic probability theory (review). Mathematical statistics – the basic definitions. Collecting, summarizing and visualizing data.Descriptive statistics. Distribution of sampling statistics. Point estimation and confidence intervals. Bivariate and multivariate analysis. Correlation. Hypothesis testing. Inference with two populations. Goodness of fit. Regression. Using of statistical software tools (R, Matlab). Statistical methods related to the students' research fields – preparing a statistical investigation related to the students' thesis.

Evaluation method: classical colloquium, oral examination

PROGRAM OF APPLIED MATHEMATICS

Course title: *Fuzzy Optimization and Decision Making*

Lecturer: Róbert Fullér, professor, CSc
fuller.robert@nik.uni-obuda.hu

Course objective: To explain:

- How to make decisions under uncertainty
- How to choose appropriate aggregation operators to decision process where trade-offs are allowed;
- How to solve linear programming problems with soft objective function and constraints;
- How to use fuzzy sets for finding a good compromise solution to multiple objective programs.

Lectures: 20 hours

Course description:

Fuzzy set theory provides a host of attractive aggregation connectives for integrating membership values representing uncertain information. These connectives can be categorized into the following three classes union, intersection and compensation connectives. Union produces a high output whenever any one of the input values representing degrees of satisfaction of different features or criteria is high. Intersection connectives produce a high output only when all of the inputs have high values. Compensative connectives have the property that a higher degree of satisfaction of one of the criteria can compensate for a lower degree of satisfaction of another criteria to a certain extent. In the sense, union connectives provide full compensation and intersection connectives provide no compensation. In a decision process the idea of trade-offs corresponds to viewing the global evaluation of an action as lying between the worst and the best local ratings. This occurs in the presence of conflicting goals, when a compensation between the corresponding compabilities is allowed. Averaging operators realize trade-offs between objectives, by allowing a positive compensation between ratings. In goal programming we are searching for a solution from the decision set, which minimizes the distance between the goal and the decision set. In fuzzy programming we are searching for a solution that might not even belong to the decision set, and which simultaneously minimizes the (fuzzy) distance between the decision set and the goal.

Evaluation method: classical oral examination.

Recommended References:

1. C. Carlsson and R. Fullér: “Fuzzy Reasoning in Decision Making and Optimization,” in Studies in Fuzziness and Soft Computing Series. Vol. 82, Berlin-Heildelberg, Springer-Verlag, 2002.

2. Chiranjibe Jana, Ghulam Muhiuddin, Madhumangal Pal, Peide Liu eds., Fuzzy Optimization, Decision-making and Operations Research: Theory and Applications, Springer, 2023, ISBN 978-3-031-35667-4

Course title: *Neuro-fuzzy systems*

Lecturer: Róbert Fullér, professor, CSc
fuller.robert@nik.uni-obuda.hu

Course objective: Introduction to neuro-fuzzy systems.

Lectures: 20 hours

Course description:

To enable a system to deal with cognitive uncertainties in a manner more like humans, one may incorporate the concept of fuzzy logic into the neural networks. The resulting hybrid system is called fuzzy neural, neural fuzzy, neuro-fuzzy or fuzzy-neuro network. Neural networks are used to tune membership functions of fuzzy systems that are employed as decision-making systems for controlling equipment. Although fuzzy logic can encode expert knowledge directly using rules with linguistic labels, it usually takes a lot of time to design and tune the membership functions which quantitatively define these linquistic labels. Neural network learning techniques can automate this process and substantially reduce development time and cost while improving performance. We will explain the most used fuzzy inference schemes (Tsukamoto, Takagi-Sugeno, Mamdani) and learning rules (delta, generalized delta, Kohonen). We will show how to minimize the error function in fuzzy reasoning schemes by neural networks.

Evaluation method: classical colloquium, oral examination

Recommended References:

1. Robert Fullér, Introduction to Neuro-Fuzzy Systems, Advances in Soft Computing Series, Springer-Verlag, Berlin/Heildelberg, 2000, 2013, 2014, 289 pages.
2. Robert Fullér, Neural Fuzzy Systems, Åbo Akademis tryckeri, Åbo, ESF Series A:443, 1995, 249 pages (free download).

Course title: *Neuro-symbolic hybrid artificial intelligence*

Lecturer: Orsolya Csiszár, assistant professor, PhD
csiszar.orsolya@uni-obuda.hu
csiszar.orsolya@hs-aalen.de

Course objective: AI techniques, especially deep learning models, are revolutionizing the business and technology world. However, one of today's greatest challenges in deep learning is the increasing need to address the problem of interpretability and to improve model trasparency, performance, and safety (XAI: eXplainable Artificial Intelligence). Combining neural networks with continuous logic and multi-criteria decision-making tools can contribute to better interpretability, transparency, and safety in medical, engineering, and business applications. This approach, together with other evolving methods belongs to neuro-symbolic hybrid artificial intelligence; a novel area of AI research that combines traditional rules-based approaches with modern deep learning techniques. Neuro-symbolic models have been shown to obtain high accuracy with significantly less training data than traditional models. Neural networks and symbolic systems can complement each other's strengths and weaknesses, enabling systems that are accurate, sample efficient, and interpretable.

Lectures: 20 hours

Topics:

- Introduction: Deep learning and its current limits
- Causality, causal reasoning
- Aggregation and intelligent decision-making: avaraging fuctions, conjunctions, disjunctions, mixed functions (uninorms, nullnorms)
- Elements of nilpotent fuzzy logic, nilpotent connective systems
- Elements of multi-criteria decision-making, preference modeling
- Hybrid approaches: intuitive vs. symbolic AI systems
- Oveview of methods to explain AI: local/global model-agnostic approaches
- Interpretable neural networks using fuzzy logic and MCDM tools

Evaluation method: classical colloquium, oral examination

Recommended References:

1. J. Dombi, O. Csiszar, Explainable Neural Networks based on Fuzzy Logic and Multi-criteria Decision Tools, Springer Nature, Studies in Fuzziness and Soft Computing, STUDFUZZ, Vol. 408, 2021
2. Alexander Amini and Ava Soleimany, MIT 6.S191: Introduction to Deep Learning, IntroToDeepLeraning.com
3. Gleb Beliakov, Ana Pradera, Tomasa Calvo Aggregation Functions: A Guide for Practitioners, Studies in Fuzziness and Soft Computing, Volume 221, Springer, 2007

4. C. Molnar, Inteerpretable machine learning a guide for making black boksz models explainable, https://christophm.github.io/interpretable-ml-book/ , 2019
5. Zachary Susskind, Bryce Arden, Lizy K. John, Patrick Stockton, Eugene B. John, Neuro-Symbolic AI: An Emerging Class of AI Workloads and their Characterization, arXiv:2109.06133
6. K. Alvarez, J. C. Urenda, O. Csiszar, G. Csiszar, J. Dombi, G. Eigner, V. Kreinovich, To- wards Fast and Understandable computations: Which „And" – and „Or" –Operatins Can Be Represented by the Fastest (i.e., 1-Layer) Neural Networks? Which Activations Functions Allow Such Representations?, Acta Polytechnica Hungarica, Vol. 18, No. 2, p. 27-45, 2021.
7. O. Csiszar, G. Csiszar, J. Dombi, How to implement MCDM tools and continuous logic into neural computation? Towards better interpretability of neural networks, Knowledge-Based Systems, https://doi.org/10.1016/j.knosys.2020.106530, 2020
8. J. C. Urenda, O. Csiszar, G. Csiszar, J. Dombi, O. Kosheleva, V. Kreinovich and G. Eigner, Why Squashing Functions in Multi-Layer Neural Networks, IEEE International Conference on Systems, Man, and Cybernetics, https://scholarworks.utep.edu/cs_techrep/1398/ , 2020

Course title: *Numerical analysis*

Lecturer: József Abaffy, professor emeritus, DSc
abaffy.jozsef@nik.uni-obuda.hu

Course objective: Gaussian elimination and error analysis. The conjugate gradient method. Iterative methods. Iterative methods for sparse matrices. ABS methods. Hessenberg transformation. QR decomposition. Eigenvalue problem: Householder and Lánzos methods. Least squares method. Determination of the degree of the orthogonal polynomials approximation. Matrix inversion. Univariate optimization methods. (Golden ratio. Parabola. Newton and other methods). Armijo-Goldstein conditions, backtracking. Unconditional minimization methods (conjugated directions methods. Newton and quasi-Newton methods. BFGS method). Relation between optimization and nonlinear equations. Solving equations with one unknown: secant method. Newton's method. The modified Newton's method. Solving systems of nonlinear equations. The gradual approximation method. Generalized Newton's method. Broyden's method.

Lectures: 20 hours

Course description:

The student need to write a some page essay. The student in oral exam present the essay in a few minits which happens in the last week of teaching in a time defined by me. This oral exam proves that it was written by the student. Also included in the oral exam is that the student should be able to briefly explain a topic of my choice using the slides, demonstrating that he or she has acquired knowledge from topics not selected for the essay. The result, of course, affects the final mark. The essay must be submitted in my fach, in the room 422, before the last week of teaching. During the exam the student can use the essay, and present the MATLAB program in own computer, if it was written for mark 5.

Evaluation method: classical colloquium, oral examination

Recommended References:

1. Ralston, P.Rabinowitz: A First Course in Numerical Analysis, McGraw-Hill, 1965
2. (DS) J.E. Dennis, JR, R.B.Schnabel: Numerical Methods for Unconstrained Optimization and Nonlinear Equations, Prentice Hall Series in Computational Mathematics, New Jersey, USA, 1983
3. (G) H. Golub, C.F. Van Loan: Matrix Computation, North Oxford Academic Press, Oxford 1983
4. O. Aberth: Introduction to Precise Numerical Methods, Academic Press 2007
5. C.B. Moler: Numerical Computing with MATLAB, SIAM 2007
6. L.R. Scott: Numerical Analysis, Princeton University Press, 2011
7. M. Kubicek, D. Janovska, M. Duncova: Numerical Methods and Algorithm, translation, VSCHT Praha 2005

Course title: *Convex functions*

Lecturer: Árpád Baricz, professor, PhD
baricz.arpad@nik.uni-obuda.hu

Course objective: The goal of this course is to give an overview about properties of convex, logarithmically convex, geometrical convex, generalized convex, quasi-convex functions.

Lectures: 20 hours

Course description:

Properties of convex functions. Differentiable convex functions. Convex functions and their extrema. Inequalities for convex functions. Quasiconvex and quasiconcave functions. Logarithmically convex and concave functions. Geometrical convex and concave functions. Completely monotone functions and their properties. Bernstein functions and their properties. Logarithmically completely monotone functions and their properties. Generalized convex functions. Convex functions with respect to power means. Logarithmically and geometrically concave and convex distributions. Inequalities of Prekopa-Leindler type.

Evaluation method: classical oral examination.

Recommended References:

1. Á. Baricz, Geometrically concave univariate distributions, J. Math. Anal. Appl. 363 (2010) 182-196.
2. G.H. Hardy, J.E. Littlewood, G. Pólya, Inequalities, Cambridge Univ. Press, Cambridge, 1934.
3. C. Niculescu, L.E. Persson, Convex Functions and Their Applications, Springer, New-York, 2006.
4. R.L. Schilling, R. Song, Z. Vondracek, Bernstein functions, De Gruyter, Berlin, 2010.
5. R. Webster, Convexity, Oxford Univ. Press, Oxford, 1994.
6. J.M. Borwein, J.D. Vanderwerff, Convex functions: constructions, characterizations and counterexamples, Cambridge Universits Press, 2010.
7. C. Niculescu, L.E. Persson, Convex Functions and Their Applications, second ed., Springer, New-York, 2018.

Course title: *Special functions*

Lecturer: Árpád Baricz, professor, PhD
baricz.arpad@nik.uni-obuda.hu

Course objective: In this course our aim is to give an overview on the main properties of the most important special functions, which appear in engineering sciences.

Lectures: 20 hours

Course description:

Euler gamma and beta functions. Dirichlet integrals. Hurwitz and Riemann zeta functions. Stirling's asymptotic results on gamma function. Digamma function. Bohr-Mollerup theorem. Gauss and Kummer hypergeometric functions and their properties. Elliptic integrals. Airy functions. Bessel and modified Bessel functions of the first and second kinds. Integral representations. Product representations. Mittag-Leffler identities. Stieltjes transformations. Zeros of Bessel functions and their properties. Struve and Legendre functions. Coulomb wave functions. Generalized Marcum and Nuttall functions and their properties. Completely monotone Bessel functions and their properties.

Evaluation method: classical oral examination.

Recommended References:

1. G.E. Andrews, R. Askey, R. Roy, Special Functions, Cambridge Univ. Press, Cambridge, 1999.
2. Gil, J. Segura, N.M. Temme, Numerical Methods for Special Functions, SIAM, Philadelphia, 2007.
3. F.W.J. Olver, D.W. Lozier, R.F. Boisvert, C.W. Clark, NIST Handbook of Mathematical Functions, Cambridge Univ. Press, New York, 2010.
4. G. Watson, A Treatise on the Theory of Bessel Functions, Cambridge Univ. Press, Cambridge, 1922.
5. C. Viola, An Introduction to Special Functions, Springer, 2016.
6. R. Beals, R. Wong, Special Functions and Orthogonal Polynomials, Cambridge University Press, 2016.

Course title: *Sampling theorems for deterministic signals*

Lecturer: Tibor Pogány, university professor, PhD
pogany.tibor@nik.uni-obuda.hu

Course objective: One of the most efficient method in digital to analog reconstruction of deterministic signals (element of certain function classes) is the Whittaker-Kotel'nikov-Shannon (WKS) sampling series. The mathematical background of sampling theorems, methods and truncation error evaluation are in the focus of the course.

Lectures: 20 hours

Course description:

Elements of Fourier analysis; Fourier transform. Band-limited signals, Nyquist rate, WKS sampling series expansion. Poisson summation formula. Reproducing kernel Hilbert space and sampling. Sampling in Bernstein and Paley-Wiener spaces. Piranashvili theorem. Kramer's lemma. Irregular (non-uniform) sampling. Kadec ¼-theorem. Yen's approach to sampling signal reconstruction. Errors in reconstruction, error upper bounds. Aliasing in sampling reconstruction and non-band limited signals. Time-shifted and average sampling signal reconstruction.

Evaluation method: classical oral examination.

Recommended References:

1. J. R. Higgins, Sampling Theory in Fourier and Signal Analysis. Foundations. Oxford, Clarendon Press, 1996.
2. J. G. Higgins and R. L. Stens, Eds., Sampling Theory in Fourier and Signal Analysis. Advanced Topics. Oxford University Press, 1999.
3. A. I. Zayed, Advances in Shannon's Sampling Theory. Boca Raton, CRC Press, 1993.
4. A. J. Jerri, The Shannon Sampling Theorem - Its Various Extensions and Applications - A Tutorial Review, Proceedings of the IEEE 65 (11) (1977), 1565-1596.
5. P.L. Butzer, W. Splettstösser, R.L. Stens, The sampling theorem and linear prediction in signal analysis. Jahresber. Deutsch. Math.-Verein. 90 (1988), no. 1, 70 pp.
6. M. Unser, Sampling 5ö-years after Shannon, Proc. IEEE 88 (2000), no. 4, 569-587.
7. Yu. I. Khurgin, V. P. Yakovlev, Progress in the Soviet Union on the theory and applications of bandlimited functions, Proc. IEEE 65 (1977), no. 5, 1005-1028.

Course title: *Sampling series reconstruction of stochastic signals*

Lecturer: Tibor Pogány, university professor, PhD
pogany.tibor@nik.uni-obuda.hu

Course objective: The digital-to-analogue conversion of discretized/sampled stochastic processes in the mean-square sense (Balakrishnan, Parzen, 1957) and with probability 1 (Belyeav, Lloyd, 1959) we realize with the help of the Whittaker–Kotel'nikov–Shannon (WKS) sampling series. The course is a short invitation to mathematics of sampling reconstruction of stochastic signals (processes, random fields), with a comprehensive overeview of the reconstruction error analysis and estimation.

Lectures: 20 hours

Course description:

Stochastic processes. Wide sense stationary (Hinčin stationary) stochastic processes. Harmonizable processes. Correlation function, covariance function, spectral representations. Karhunen–Cramér- Piranashvili theorem. Bandlimited stochastic processes. Random fields, isotropic and homogeneous random fields. Hilbert space of stochastic processes. Piranashvili's theorems; Piranashvili-, Loév-, Rozanov- and Cramér-type processes. Reconstruction results by Lee; characterization theorems of almost sure sampling reconstruction by Gladyshev. Non-standard (irregular) sampling. Kadec's 1/4 –theorem and Yen's sampling reconstruction models. Reconstruction errors, truncation error, truncatione error upper bounds. ”Aliasing” and non-bandlimited processes. Sampling restoration of random fields (Parzen, Someya). ”Time shifted” sampling reconstruction. Whittaker's plane sampling.

Evaluation method: classical oral examination.

Recommended References:

1. J. G. Higgins and R. L. Stens (Eds.) Sampling Theory in Fourier and Signal Analysis. Advanced Topics. Oxford University Press, 1999.
2. G. Tusnády and M. Ziermann, Ed., Idősorok analízise. Budapest, Hungary, Műszaki Kőnyvkiadó, 1986.
3. A. M. Yaglom, Correlation Theory of Stationary and Related Random Functions: Volume I: Basic Results. Berlin, Germany, Springer–Verlag, 1987.
4. A. M. Yaglom, Correlation Theory of Stationary and Related Random Functions: Volume II: Supplementary Notes and References. Berling, Germany, Springer–Verlag, 1987.
5. Z. A. Piranashvili, T. K. Pogány, On generalized derivative sampling series expansion, in H. Dutta, Lj. Kocinac, H. M. Srivastava (Eds.) Current Trends in Mathematical Analysis and its Interdisciplinary Applications, Chapter 14. Basel, Springer Nature, Birkhäuser, 2019, 491-519.

6. M.I. Yadrenko, Spectral Theory of Random Fields. Translation Series in Mathematics and Engineering. New York: Optimization Software, Inc., Publications Division; New York-Heidelberg-Berlin: Springer-Verlag. III,1983, 259p.
7. P.L. Butzer, W. Splettstösser, R.L. Stens, The sampling theorem and linear prediction in signal analysis. Jahresber. Deutsch. Math.-Verein. 90 (1988), no. 1, 70 pp.
8. M. Unser, Sampling 5ö-years after Shannon, Proc. IEEE 88 (2000), no. 4, 569-587.
9. Yu. I. Khurgin, V. P. Yakovlev, Progress in the Soviet Union on the theory and applications of bandlimited functions, Proc. IEEE 65 (1977), no. 5, 1005-1028.

Course title: *Fuzzy-based Decision Making*

Lecturer: Márta Takács, professor, PhD
takacs.marta@nik.uni-obuda.hu

Course objective: The goal of the subject is to present the basic fuzzy-based decision making models applied in engineering researches and risk analysis.

Lectures: 20 hours (partially in consultative forms)

The subject prerequisites: basic mathematical knowledge

Course description:

Uncertainty and fuzzy set representation. Operations on fuzzy sets. Fuzzy logic. Fuzzy inference mechanism/approximate reasoning. Rule-based inference. Mamdani and Takagi-Sugeno systems. Anfis systems. Fuzzy based classification models – related big data analysis possibilities. Fuzzy reasoning methods based on novel constructed operator families. Risk management systems based on fuzzy decision models. Construction of complex, fuzzy based, decision and inference simulation systems. Fuzzy models related to the students' research fields – preparing a fuzzy based simulation model related to the students' thesis.

Evaluation method: classical colloquium, oral examination

Recommended references:

1. Gy., Bárdossy and J. Fodor, *Evalution of Uncertainties and Risks in Geology.* Springer, 2004.
2. E. Czogala, "On the selection of operations and fuzzy relations in approximate reasoning," *Proc. Of International Paanel Conference on Soft Computing and Intelligent Systems*, Budapest, Hungary, 1996, pp.67-68.
3. De Baets, B. and Kerre, E. E., "The generalized modus ponens and the triangular fuzzy data model," in *Fuzzy Sets and Systems.* Vol. 59., pp. 305-317, 1993
4. D. Driankov i, *An Introduction to Fuzzy Control*. Verlag Berlin-Heidelberg-NewYork, Springer, 1996.
5. R. Fullér, "Fuzzy Reasoning and Fuzzy Optimization," *TUCS General Publication*, No 9, Turku Centre for Computer science, , September 1998.
6. E. P. Klement *et al*., *Triangular Norms*. Kluwer Academic Publishers, 2000.
7. E. H. Mamdani, B. Gaines, *Fuzzy reasoning and its Applications*. New York, Academic Press, 1981.
8. I. J. Rudas, "Evolutionary operators: new parametric type operator families," *Fuzzy Sets and Systems*, vol. 23, 1999,pp. 149-166.
9. M. Takacs, "Approximate reasoning with Distance-based Operators and degrees of coincidence," in *Principles of Fuzzy Preference Modelling and Decision Making*. B. de Baets and J. Fodor, Eds., Gent, Belgium, Academia Press, 2003.

10. T. Takagi and M. Sugeno, “Fuzzy identification of Systems and its Applications to Modeling and Control,” *IEEE Trans. S. M. C.*, vol. 15., pp. 116-132., 1985.
11. I. B. Turksen and Y. Tian, “Combination of rules or their consequences in fuzzy expert systems,” *Fuzzy Sets and Systems*, vol. 58., pp.3-44, 1993.
12. R. R. Yager, “Uninorms in fuzzy system modeling,” *Fuzzy Sets and Systems*, vol. 122., pp. 167-17, 2001.
13. L. A. Zadeh, “A Theory of approximate reasoning,” in *Machine Intelligence*. Vol. 9, New York, Halstead Press, 1979., pp. 149-194.

Course title: *Reduction techniques of fuzzy decision systems*

Lecturer: Dr.habil. Edit Laufer, associate professor, PhD
laufer.edit@bgk.uni-obuda.hu

Course objective: The aim is to introduce fuzzy approach and related concepts. The different complexity reduction techniques are demonstrated, which has vital importance in real-time and adaptive systems. Different rule base reduction techniques are investigated.

Lectures: 20 hours

Course description:

Fuzzy set theory. Fuzzy operators. Fuzzy inference systems. Complete (or dense) rule base. Rule base reduction techniques. Sparse rule base. Merging inputs, or antecedent sets. Dividing into subsystems, creating a hierarchical system. Singular value decomposition. Discretization of the output.

Evaluation method: classical oral examination.

Recommended References:

1. L. T. Kóczy, D. Tikk, Fuzzy rendszerek, Kempelen Farkas Tankönyvtár, 2001 [Online]. Available: http://www.tankonyvtar.hu/hu/tartalom/tkt/fuzzy-rendszerek-fuzzy/adatok.html
2. A. Gegov, "Complexity Management in Fuzzy Systems", Studies in Fuzziness and Soft Computing, Springer, Heidelberg, 2007
3. E. Tóth-Laufer, I.J. Rudas, M. Takács, „Operator Dependent Variations of the Mamdani-type Inference System Model to Reduce the Computational Needs in Real-Time Evaluation", International Journal of Fuzzy Systems, Vol. 16, No. 1, March 2014, pp. 57-72
4. E. Tóth-Laufer, A. Rövid, M. Takács, „Reduction Error Calculation of the HOSVD-based Rule Base Reduction in Hierarchical Fuzzy Systems", Fuzzy Sets and Systems, No. 307, pp. 67-82, 2017
5. 10.1007/978-3-030-15305-2
6. O. Nelles, "Nonlinear System Identification, From Classical Approaches to Neural Networks, Fuzzy Models, and Gaussian Processes", Second Edition, Springer Nature Switzerland, 2021, DOI: 10.1007/978-3-030-47439-3
7. J.M. Escaño, C. Bordons, K. Witheephanich, et al. "Fuzzy Model Predictive Control: Complexity Reduction for Implementation in Industrial Systems", International Journal of Fuzzy Systems vol. 21, 2008–2020 (2019), DOI: 10.1007/s40815-019-00693-z
8. G. Beliakov, J-Z. Wu, "Learning fuzzy measures from data: Simplifications and optimisation strategies", Information Sciences, vol. 494, pp. 100-113, 2019, DOI: 10.1016/j.ins.2019.04.042

9. J. Wang, X. Zhang, Y. Yao, “Matrix approach for fuzzy description reduction and group decision-making with fuzzy β-covering”, Information Sciences, vol. 597, pp. 53-85, 2022, DOI: 10.1016/j.ins.2022.03.039

10. M. Akram, G. Ali, J.C.R. Alcantud, “Attributes reduction algorithms for m-polar fuzzy relation decision systems”, International Journal of Approximate Reasoning, vol. 140, pp. 232-254, 2022, DOI: 10.1016/j.ijar.2021.10.005G. Beliakov, S. James, J-Z. Wu, “Discrete Fuzzy Measures, Computational Aspects”, Studies in Fuzziness and Soft Computing, vol. 382, Springer Cham, 2020, DOI: 10.1007/978-3-030-15305-2

11. O. Nelles, “Nonlinear System Identification, From Classical Approaches to Neural Networks, Fuzzy Models, and Gaussian Processes”, Second Edition, Springer Nature Switzerland, 2021, DOI: 10.1007/978-3-030-47439-3

12. J.M. Escaño, C. Bordons, K. Witheephanich, et al. “Fuzzy Model Predictive Control: Complexity Reduction for Implementation in Industrial Systems”, International Journal of Fuzzy Systems vol. 21, 2008–2020 (2019), DOI: 10.1007/s40815-019-00693-z

13. G. Beliakov, J-Z. Wu, “Learning fuzzy measures from data: Simplifications and optimisation strategies”, Information Sciences, vol. 494, pp. 100-113, 2019, DOI: 10.1016/j.ins.2019.04.042

14. J. Wang, X. Zhang, Y. Yao, “Matrix approach for fuzzy description reduction and group decision-making with fuzzy β-covering”, Information Sciences, vol. 597, pp. 53-85, 2022, DOI: 10.1016/j.ins.2022.03.039

15. M. Akram, G. Ali, J.C.R. Alcantud, “Attributes reduction algorithms for m-polar fuzzy relation decision systems”, International Journal of Approximate Reasoning, vol. 140, pp. 232-254, 2022, DOI: 10.1016/j.ijar.2021.10.005

Course title: *Numerical methods in model fitting problems*

Lecturer: Emőke Imre, associate professor, PhD, habil
imre.emoke@kvk.uni-obuda.hu

Course objective: To introduce the concept of parameter identification in relation to fitting of linear and non-linear models on measured data. To develop skills to solve these problems with own software, based on library subroutines.

Lectures: 20 hours

Course description:

Part 1 (basic models). Solution of non-linear equations. Direct and iterative solution of linear equations. SVD and generalized inverse. Interpolation & curve fitting. Numerical differentiation and integration. Analytical and numerical solution of ODE-s and PDE-s. Numerical problems of the analytical solution of ODE and PDE systems.
Part 2. (model fitting methods) Parameter identification in relation to fitting of linear and non-linear models on measured data. Classical and new methods with function value evaluation and with derivatives. Error estimation and reliability testing methods based on probability and geometry.

Evaluation method: classical oral examination.

Recommended References:

1. W.H. Press, B.P. Flannery, S.A Teukolsky, W.T. Wetterling. 1986: Numerical Recipes. Cambridge Univ. Press, Cambridge. 1986 1-430.
2. E., Imre; M., Hegedűs; L., Bates; S., Fityus. Evaluation of complex CPTu dissipation tests of B.E.S.T. In: Tonni, Laura; Gottardi, Guido (szerk.) Cone Penetration Testing 2022 :Proceedings of the 5th International Symposium on Cone Penetration Testing (CPT'22) London, Egyesült Királyság / Anglia : CRC Press (2022) pp. 473-479. , 7 p. ISBN: 9781003308829
3. Imre, Emoke ; Rózsa, Pál ; Bates, Lachlan ; Fityus, Stephen Evaluation of monotonic and non-monotonic dissipation test results COMPUTERS AND GEOTECHNICS 37 : 7-8 pp. 885-904. , 20 p. (2010)
4. E., Imre ; T., Schanz ; L., Bates ; S., Fityus Evaluation of complex and/or short CPTu dissipation tests In: Michael, Hicks; Federico, Pisanò; Joek, Peuchen (szerk.) Cone Penetration Testing 2018 : Proceedings of the 4th International Symposium on Cone Penetration Testing London, Egyesült Királyság / Anglia : CRC Press (2018) 756 p. pp. 351-357. , 7 p.
5. W.H. Press, B.P. Flannery, S.A Teukolsky, W.T. Wetterling. 1986: Numerical Recipes. Cambridge Univ. Press, Cambridge. 1986 1-430.

6. L. Rétháti (1988). “Probabilistic solutions in geotechnics” Amsterdam-Oxford-New York-Tokyo [Review of “Probabilistic solutions in geotechnics” Amsterdam-Oxford-New York-Tokyo]. Elsevier.
7. Roger Webster (1995) Convexity - Oxford University Press
8. Zhang, Fuzhen (2005). Zhang, Fuzhen (ed.) The Schur Complement and Its Applications. Numerical Methods and Algorithms. Vol. 4. Springer. doi:10.1007/b105056. ISBN 0-387-24271-6.
9. E.E. Walpole, R. H. Meyers. 2011. Probability & Statistics for Engineers & Scientist 9th edition. Prentice Hall.
10. E Imre (2022) A comment on the combination of the implicit function theorem and the Morse lemma DOI: 10.48550/arXiv.2301.03427
11. E Imre ; Cs Hegedus ; S Kovacs ; L Kovacs (2021) Reducing numerical work in non-linear parameter identification arxiv.org/abs/2102.08210.
12. E Imre ; Cs Hegedüs ; S Kovács (2018) Some Comments on the Non-Linear Model Fitting In: Szakál, Anikó (szerk.) IEEE 18th International Symposium on Computational Intelligence and Informatics (CINTI 2018) Budapest, Magyarország : IEEE Hungary Section pp. 173-178.

Course title: *Models of Unsaturated Soil Mechanics*

Lecturer: Emőke Imre, associate professor, PhD, habil
imre.emoke@kvk.uni-obuda.hu

Course objective: The continuum mechanical models of unsaturated soils contain material functions instead of material parameters. The determining the soil physical functions of unsaturated soils is not straightforward due to the long measurement times. The role of mathematical methods is crucial both in the evaluation of measurements (inverse analysis - parameter identification) and in the approximation of interpolation based on grain size distribution. The practical applications are presented including some large computer programs. Some discrete modeling issues - based on the statistical parameters of the grain size distribution (PSD) - is treated, including filter and internal stability rules, moreover, interpolation methods.

Lectures: 20 hours

Prerequisites: - (recommended: mechanics, soil mechanics)

Course description:

Two major issues, continuum-mechanical modeling of soils and discrete modeling of soils are discussed.

1. Basics of unsaturated soil modeling. The concept of unsaturated soil, the continuum-mechanical approach. Compressibility of the soil air-water system, capillary phenomena, suction. The state variables. Fundamentals of material equations and material functions (water retention curve, permeability function).
2. Modeling of water flow in soil (permanent, transient, one-phase, multiphase). Partial differential equations and PDE systems. Numerical and analytical solutions, boundary conditions, input soil functions. Modeling of strength and compressibility, critical state modeling.
3. Measurements of unsaturated soils. Nonlinear and linear model fitting for measurement data. Classic and new methods. Uniqueness and error of the identified parameters, reliability test with statistical and geometric methods.
4. Applications. Numerical solution of water flow PDE-s. The concept of municipal waste and the unsaturated soil model. Numerical solution of flow modeling in flood protection dams and in aquifers,. Volume-change of swelling soils and rise. Presentation of finite element computer programs (GEO-SLOPE family, HBM, Soil-vision water flow modeling family, can be used free of charge for educational purposes). Simulations with water flow and slope stability programs.
5. The entropy of a finite, discrete distribution. Grading entropy and its use to determine the functions of unsaturated soils, to design of filter composition in dams (grain size distribution for proper filtration and internal stability). Approximate interpolation methods based on grain size distribution entropy to approximate soil function - grain size distribution type models

Evaluation method: classical colloquium, oral examination

Recommended References:

1. D. G. Fredlund., H. Rahardjo 1993. Soil Mechanics For Unsaturated Soils, Wiley.
2. E. Imre 2009. Unsaturated Soil Mechanics. University notes. 125. p. electronic version
3. Á. Kézdi Handbook of Soil Mechanics: Soil testing Akadémiai Kiadó, 1974.
4. Á. Kézdi & László Rétháti 1990 Handbook of soil mechanics application of soil mechanics in practice examples and case histories Akadémiai Kiadó, 1974-1990
5. Imre, E ; Rajkai, K ; Genovese, R ; Jommi, C 2011 A transfer function of a soil water characteristic curve model for sands In: Proceedings of the Fifth International Conference London: Taylor and Francis (2011) pp. 453-459.
6. E. Imre ; I. Talata ; D. Barreto ; M. Datcheva ; W. Baille ; I. Georgiev ; S. Fityus ; V. P. Singh ; F. Casini ; G.Guida11, P. Q. Trang et al. Some Notes on Granular Mixtures with Finite, Discrete Fractal Distribution Periodica Polytechnica-Civil Engineering 2022 Paper: 7738 (2022)
7. J. McDougall: „A hydro-bio-mechanical model for settlement and other behaviour in landfilled waste", Computers and Geotechnics, 344, 2007.
8. J. Lorincz, E. Imre, S. Fityus, P.Q. Trang, T. Tarnai, I. Talata, V. P. Singh 2015. The Grading Entropy-based Criteria for Structural Stability of Granular Materials and Filters ENTROPY 17:5 pp. 2781-2811. 2015
9. W.H. Press, B.P. Flannery, S.A Teukolsky, W.T. Wetterling. 1986: Numerical Recipes. Cambridge Univ. Press, Cambridge. 1986 1-430.

Course title: *Packing, covering and the application of packing and covering*

Lecturer: Antal Joós, associate professor, PhD
joosa@uniduna.hu

Course objective: Introduction to packing and covering theory. The application of packing and covering.

Lectures: 20 hours

Course description:

Some application: wrapping and sphere packing; arrangement of atoms and sphere packing; error correcting codes and sphere packing; wifi coverage and covering by balls; covering of the surface of the Earth by satellites and covering by balls; covering of an area by transmission towers and multiple covering of the plane by circles.
Circle packing and covering on the plane, in higher dimensional space and on the sphere. Periodic circle packing and covering. Estimate of density. Circle packing in a finite container (in a square, triangle, disc, cube). Circle covering of a finite set. Packing squares and rectangles.

Evaluation method: classical colloquium, oral examination

Recommended References:

1. W.H. Press, B.P. Flannery, S.A Teukolsky, W.T. Wetterling. 1986: Numerical Recipes. Cambridge Univ. Press, Cambridge. 1986 1-430.
2. Fejes Tóth G., Packing and covering, In: Toth, Csaba D.; Jacob E., Goodman; O'Rourke, Joseph (szerk.) Handbook of Discrete and Computational Geometry, 3rd Edition, CRC Press (2017) pp. 27-66.
3. Fejes Tóth, G., Fejes Tóth, L., Kuperberg, W. (2023). Miscellaneous Problems About Packing and Covering. In: Lagerungen. Grundlehren der mathematischen Wissenschaften, vol 360. Springer, Cham. https://doi.org/10.1007/978-3-031-21800-2_16

Course title: *Equilibria on Riemannian-Finsler manifolds*

Lecturer: Alexandru Kristály, professor, PhD
kristaly.alexandru@nik.uni-obuda.hu

Course objective: to provide an introduction into the theory of equilibrium problems, starting from the classical Euclidean notions to their geometric correspondents, formulated in terms of Riemannian and Finsler geometries. These problems provide faithful models to various phenomena in the theory of optimization on not necessarily flat spaces.

Lectures: 20 hours

Prerequisites: Calculus I

Course description:

Riemannian and Finsler manifolds (motivation and examples). Asymmetric Finsler manifolds (Matsumoto mountain slope). Geodesics on Riemannian and Finsler manifolds (connections and examples). Nonsmooth functions (derivatives). Convexity on manifolds. Dynamical systems on manifolds (invariance properties). Metric projections on manifolds (influence of the curvature). Weber-type transport problems (symmetry vs asymmetry). Nash-Stampacchia equilibria on Riemannian manifolds. Stackelberg equilibria on Riemannian manifolds (leader-follower strategies).

Evaluation method: classical oral examination.

Recommended References:

1. D. Bao, S.S. Chern and Z. Shen, “An Introduction to Riemann-Finsler Geometry,” Graduate Texts in Mathematics. Vol. 200,New York, Springer-Verlag, 2000.
2. A. Kristály, “Nash-type equilibria on Riemannian manifolds: a variational approach.” J. Math. Pures Appl. (9) 101 (2014), no. 5, 660–688.
3. A. Kristály, V. Radulescu, C. Varga, “Variational Principles in Mathematical Physics, Geometry, and Economics,” in Encyclopedia of Mathematics and its Applications. No. 136, Cambridge, UK, Cambridge University Press.
4. C. Udrişte, “Convex Functions and Optimization Methods on Riemannian Manifolds,” Mathematics and its Applications. No.297. Dordrecht, Kluwer Academic Publishers Gro-up, 1994.
5. Costea, Nicuşor; Kristály, Alexandru; Varga, Csaba Variational and monotonicity methods in nonsmooth analysis. Frontiers in Mathematics. Birkhäuser/Springer, Cham, [2021], ©2021. xvi+446 pp. ISBN: 978-3-030-81670-4; 978-3-030-81671-1
6. Bento, Glaydston de Carvalho; Cruz Neto, João Xavier; Melo, Ítalo Dowell Lira Combinatorial convexity in Hadamard manifolds: existence for equilibrium problems. J. Optim. Theory Appl. 195 (2022), no. 3, 1087–1105.
7. Lu, Hai-Shu; Li, Rong; Wang, Zhi-Hua Maximal element with applications to Nash equilibrium problems in Hadamard manifolds. Optimization 68 (2019), no. 8, 1491–1520.

Course title: *Calculus of variations and applications in partial differential equations*

Lecturer: Alexandru Kristály, professor, PhD
kristaly.alexandru@nik.uni-obuda.hu

Course objective: to provide an introduction into some problems formulated in terms of the Calculus of Variations, i.e. to find minimum/maximum or minimax points of certain energy functionals. Variational arguments (minimization methods, mountain pass theorem, saddle point theorem) and group-theoretical arguments will be combined to solve various elliptic partial differential equations.

Lectures: 20 hours

Prerequisites: Calculus I

Course description:

Historical background (brachistochron problem, Fermat principe, Zermelo navigation problem, etc). Minimization arguments. Ekeland variational principle. Ricceri variational principle. Borwein-Preiss variational principle. Critical points. Deformation lemma. Palais-Smale compactness condition. Minimax theorems. Mountain pass theorem. Saddle point theorem. Szulkin-type functionals. Multiplicity results. Principle of symmetric criticality. Rubik-type group actions. Symmetric Sobolev spaces. Compact embeddings. Variational inequalities. Nonlinear eigenvalue problems. Elliptic problems (with Dirichlet/Neumann boundary conditions). Schrödinger-type equations.

Evaluation method: classical oral examination.

Recommended References:

1. A. Kristály, V. Radulescu, C. Varga, “Variational Principles in Mathematical Physics, Geometry, and Economics,” in Encyclopedia of Mathematics and its Applications. No. 136, Cambridge, UK, Cambridge University Press.
2. A. Kristály, G. Moroşanu, “New competition phenomena in Dirichlet problems”. J. Math. Pures Appl. (9) 94 (2010), no. 6, 555–570.
3. M. Struwe, “Variational Methods”. Berlin, Germany: Springer Verlag,1990.
4. M. Willem, “Minimax Theorems”. Boston, Birkhauser, 1996.
5. Costea, Nicuşor; Kristály, Alexandru; Varga, Csaba Variational and monotonicity methods in nonsmooth analysis. Frontiers in Mathematics. Birkhäuser/Springer, Cham, [2021], ©2021. xvi+446 pp. ISBN: 978-3-030-81670-4; 978-3-030-81671-1
6. Balogh, Zoltán M.; Kristály, Alexandru Sharp isoperimetric and Sobolev inequalities in spaces with nonnegative Ricci curvature. Math. Ann. 385 (2023), no. 3-4, 1747–1773.
7. Kristály, Alexandru; Mezei, Ildikó I.; Szilák, Károly Elliptic differential inclusions on non-compact Riemannian manifolds. Nonlinear Anal. Real World Appl. 69 (2023), Paper No. 103740, 20 pp.

Course title: *Differential Geometry and Calculus of Variations*

Lecturer: Peter T. Nagy, professor emeritus, DSc
nagy.peter@nik.uni-obuda.hu

Course objective: The course deals with the basic task of calculus of variations. It applies the theory of extremal curves to the variational problems of classical mechanics and to the theory of geodesics of Riemann and Finsler spaces.

Lectures: 20 hours

Course description:

Geometry of curves and surfaces. The spherical image of surfaces, Gauss map. Lagrangian mechanics. The basic task of calculus of variation, Euler-Lagrange equations. The Legendre transformation. Second variation, sufficient conditions. Conjugate points, Jacobi's differential equations. Differentiable manifolds, tangent bundle. Riemann and Finsler manifolds. Levi-Civita connexion, curvature. Spaces of constant curvature. Lagrange mechanics on manifolds. D'Alambert principle. Free rotation of rigid bodies. First and second variations of arc-length in Riemann and Finsler spaces. Geodesics, exponential map, normal neighbourhood. Curvature tensor, Jacobi fields. Curvature and conjugate points. Minimizing property of geodesics. Gauss's lemma. Riemann and Finsler space as metric space. Completeness, Hopf-Rinow theorem. Spaces of negative curvature, Hadamard's theorem.

Evaluation method: classical oral examination.

Recommended References:

1. M. do Carmo, Differential Geometry of Curves and Surfaces. Prentice-Hall, 1976.
2. M. do Carmo, Riemannian Geometry. Birkhäuser, 1992.
3. D. Bao, et al., An Introduction to Riemann-Finsler Geometry. Springer, 2000.
4. V. I. Arnold, Mathematical Methods in Mechanics. Springer; 2nd edition,1997.
5. A. Agrachev, D. Barilari, U. Boscain: A Comprehensive Introduction to sub-Riemannian Geometry, Cambridge University Press, 2019.
6. Z. M. Balogh, A. Calogero: Infinite geodesics of sub-Finsler distances in Heisenberg groups. International Mathematics Research Notices, 2021, pp. 4805-4837.

Course title: *Basics in Optimal Control*

Lecturer: József K. Tar, professor, DSc
tar.jozsef@nik.uni-obuda.hu

Course objective: To provide the Students with the fundamental mathematical tools of optimal controllers.

Lectures: 20 hours

Course description:

Optimization under constarints, Lagrange multipliers and the Reduced Gradient Method, the auxiliary function. Simulation examples using the MS EXCEL-SOLVER-VISUAL BASIC programming tools for discrete time approximation. Turning to the continuous time approximation: the co-state. Formulation used by the variational calculus, artificial energy (Hamiltonian) function, analogy with Classical Mechanics' Hamiltonian formulation and the flow of incompressible fluids. Certain special cases: the LQR controller, Riccati equations. Adaptive solution with Fixed Point Iterative methods based on the concept of Banach Space and Banach's Theorem.

Evaluation method: classical oral examination.

Recommended References:

1. V.I. Arnold: Mathematical Methods of Classical Mechanics, Springer - Verlag, 1989.
2. J. K. Tar et al., System and Control Theory with Especial Emphasis on Nonlinear Systems. Typotex, 2012.
3. V. Jurdjevic: Geometric Control Theory. Cambridge University Press, 1997.
4. J.K. Tar, J.F. Bitó, L. Nádai and J.A. Tenreiro Machado: Robust Fixed Point Transformations in Adaptive Control Using Local Basin of Attraction, Acta Polytechnica Hungarica, 6(1), 2009.
5. A. Atinga and . J. K. Tar, “Application of Heavy and Underestimated Dynamic Models in Adaptive Receding Horizon Control Without Constraints”, Syst. Theor. Control Comput. J., vol. 2, no. 2, pp. 1–8, Dec. 2022.
6. B. Varga, H. Issa, R. Horváth, and J. Tar, “Accelerated Reduced Gradient Algorithm with Constraint Relaxation in Differential Inverse Kinematics”, Syst. Theor. Control Comput. J., vol. 1, no. 2, pp. 21–32, Dec. 2021.
7. H. Issa, B. Varga and J. K. Tar, "A Receding Horizon-type Solution of the Inverse Kinematic Task of Redundant Robots," 2021 IEEE 15th International Symposium on Applied Computational Intelligence and Informatics (SACI), Timisoara, Romania, 2021, pp. 000231-000236, doi: 10.1109/SACI51354.2021.9465618.

Course title: *Near optimal solution of the inverse kinematic task of redundant, non-special robot arms using differential approaches*

Lecturer: József K. Tar, professor, DSc
tar.jozsef@nik.uni-obuda.hu

Course objective: To providev the Student with the fundamental, Group Theory-based formulation of the forward and invesre kinematic task of non-special redundant robot arms.

Lectures: 20 hours

Course description:

Rotation and shift of rigid bodies: the Orthogonal Matrices. Groups, continuous groups, group algebra, Lie Groups, the Lie graoup as an embedded hypersurface, the tangent space at the identity element, exponential functions, transformed tangents at the identity elements, Lie algebra, structure coefficients, Clebsch-Gordan series. Representation of Lie Groups: quaternions, spinors, Clifford Algebras. Homogeneous matrices and the Special Euclidean Group. The Forward kinematic task. The differential inverse kinematic task. Optimization under constarints, Lagrange multipliers and the Reduced Gradient Method, the auxiliary function. Generalized inverses for redundant robot arms: the Moore-Penrose pxeudoinverse, Singular Value Decomposition (SVD) and the SVD-based pseudoinverse, problem solution by the use of the Gram-Schmidt Algorithm, kinematic singularities. Iterative methods based on the concept of Banach Space and Banach's Theorem.

Evaluation method: classical oral examination.

Recommended References:

1. J. K. Tar et al., System and Control Theory with Especial Emphasis on Nonlinear Systems. Typotex, 2012.
2. G. G. Hall, Applied group theory. London: Longmans, Green and Co, 1967
3. K. N. Srinivasa Rao, The Rotation And Lorentz Groups And Their Representations For Physicists. Wiley-Interscience.
4. K. N. Srinivasa Rao, Linear Algebra And Group Theory For Physicists. Wiley - Interscience, 1996.
5. H. Issa, B. Varga and J. K. Tar, "A Receding Horizon-type Solution of the Inverse Kinematic Task of Redundant Robots," 2021 IEEE 15th International Symposium on Applied Computational Intelligence and Informatics (SACI), Timisoara, Romania, 2021, pp. 000231-000236, doi: 10.1109/SACI51354.2021.9465618.
6. Hemza Redjimi, József K. Tar: Approximate model-based state estimation in simplified Receding Horizon Control, INTERNATIONAL JOURNAL OF CIRCUITS, SYSTEMS AND SIGNAL PROCESSING, DOI: 10.46300/9106.2021.15.13, Volume 15, 2021, pp. 114-124

7. B. Varga, H. Issa, R. Horváth, and J. Tar, “Accelerated Reduced Gradient Algorithm with Constraint Relaxation in Differential Inverse Kinematics”, Syst. Theor. Control Comput. J., vol. 1, no. 2, pp. 21–32, Dec. 2021.

Course title: *Geometric Approach in the Adaptive Control of Nonlinear Systems*

Lecturer: József K. Tar, professor, DSc
tar.jozsef@nik.uni-obuda.hu

Course objective: To provide the Students with the recently developed geometric approach in the adaptive control of nonlinear systems

Lectures: 20 hours

Course description:

The use of approximate models in adaptive control: Kolmogorov's universal approximators, neural networks and fuzzy systems-based models, tensor product models, Weirstarss' and Stone's approximators. Scaling problems. The expected and realized response model. Transformation of the control task into an iteration. Antecedents: the use of spacial Lie groups for problem formulation. Banach spaces, Banach's Theorem. Applications for SISO and MIMO systems. Application examples.

Evaluation method: classical oral examination.

Recommended References:

1. J.K. Tar, J.F. Bitó, L. Nádai and J.A. Tenreiro Machado: Robust Fixed Point Transformations in Adaptive Control Using Local Basin of Attraction, Acta Polytechnica Hungarica, 6(1), 2009.
2. K. Kósi, J.K. Tar and I.J. Rudas: Improvement of the Stability of RFPT-based Adaptive Controllers by Observing "Precursor Oscillations", In Proc. of the 9th IEEE Intl. Conf. on Computational Cybernetics, Tihany, Hungary, 2013, pp. 267-272
3. A. Dineva, J.K. Tar and A.R. Várkonyi-Kóczy: Novel Generation of Fixed Point Transformation for the Adaptive Control of a Nonlinear Neuron Model, In proc. of the IEEE International Conference on Systems, Man, and Cybernetics, October 10-13, 2015, Hong Kong (SMC 2015), pp. 987-992.
4. B. Csanádi, P. Galambos, J.K. Tar, Gy. Györök and A. Serester: A Novel, Abstract Rotation-based Fixed Point Transformation in Adaptive Control, In the Proc. of the 2018 IEEE International Conference on Systems, Man, and Cybernetics (SMC)
5. Atinga, A.; Tar, J.K. Tackling Modeling and Kinematic Inconsistencies by Fixed Point Iteration-Based Adaptive Control. Machines 2023, 11, 585. https://doi.org/10.3390/machines11060585
6. Issa, H.; Tar, J.K. Improvement of an Adaptive Robot Control by Particle Swarm Optimization-Based Model Identification. Mathematics 2022, 10, 3609. https://doi.org/10.3390/math10193609

Course title: *Mathematical Methods, and Programming for Control Theory*

Lecturer: Krisztián Kósi, PhD
kosi.krisztian@nik.uni-obuda.hu

Course objective: To give the students an overview of mathematical methods used in Control Theory. the course contains a programming part that shows the algorithms in Julia language and discusses the coding efficiency in sense of efficient code writing, and efficient code running time.

Lectures: 20 hours

Course description:

The course contains the generatlization of real numbers' space:

- Metrics, Metric Spaces, Convergent Series in Metric Space, Norm, Normed Space, Banach Space, Banach's Fixed Point Theorem.
- Solving Linear and Non-Linear equations.
- Solving Linear and Non-Linear ODE systems, with numerical methods.
- Gram-Schmidt method.
- Homogeneous Matrices, and Rodriguez Formula.
- Mathematical model making, Euler-Lagrange equations.

Advantages of using Unix or Linux type operating systems. Terminal-based shell commands, scripts, and programs.

Evaluation method: classical oral examination.

Recommended References:

1. A. N. Kolmogorov, S. V. Fomin, Elements of the Theory of Functions and Functional Analysis, ISBN: 978-0486406831
2. Gilbeert Strang, Introduction to Linear Algebra, ISBN: 978-09802327-7-6
3. Nádai László, Rudas J. Imre, Tar József Kázmér, System and Control Theory with Especial Emphasis on Nonlinear Systems, ISBN: 978-963-2796-76-5
4. Bitó, J.F.; Rudas, I.J.; Tar, J.K.; Varga, Á. Abstract Rotations for Uniform Adaptive Control and Soft Modeling of Mechanical Devices. *Appl. Sci.* **2021**, *11*, 7939. https://doi.org/10.3390/app11177939
5. Issa, H.; Tar, J.K. Improvement of an Adaptive Robot Control by Particle Swarm Optimization-Based Model Identification. Mathematics 2022, 10, 3609. https://doi.org/10.3390/math10193609

Course title: *Non-Linear control with Fixed Point Iteration –based methods*

Lecturer: Krisztián Kósi, PhD
kosi.krisztian@nik.uni-obuda.hu

Course objective: To give the students an overview of the Non-Linear control. The course contains the necessary mathematical tools, and extends the basic ideas of the Non-Linear systems to the Adaptive Non-Linear control. The Examples are coded in Julia language.

Lectures: 20 hours

Course description:

The course contains certain fundamental physical and mathematical issues as

- Necessary mathematical and software tools
- Lagrangian Mechanics
- Introduction to Nonlinear Systems
- Stability in sense of Lyapunov
- Lyapunov's „first" method to determine stability
- Introduction to Lyapunov's „second" method
- Barbalat's lemma, and introduction to Robust Control
- Example: VS/SM controller
- Introduction to Adaptive Control
- Fixed Point Iteration –based control
- Example for SISO Systems
- Example for MIMO Systems

Evaluation method: classical oral examination.

Recommended References:

1. A. N. Kolmogorov, S. V. Fomin, Elements of the Theory of Functions and Functional Analysis, ISBN: 978-0486406831
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