ÓBUDAI EGYETEM
ÓBUDA UNIVERSITY

ÓBUDA UNIVERSITY DOCTORAL SCHOOL OF APPLIED INFORMATICS AND APPLIED MATHEMATICS

OPERATIONAL PLAN

OCTOBER 2023

Table of Contents

1. MEMBERS OF THE DOCTORAL SCHOOL

1.1. CORE MEMBERS OF THE DOCTORAL SCHOOL

1.1.1. APPLIED INFORMATICS PROGRAMME

1. **Haidegger** Tamás, professor, Dr.habil.
2. **Horváth** László, professor emeritus, CSc
3. **Kovács** Levente Adalbert, professor, Dr.habil.
4. **Kozlovszky** Miklós, professor r, Dr.habil.
5. **Simon** Gyula, professor, Dr.habil.
6. **Szénási** Sándor, professor, Dr.habil.
7. **Tar** József, eprofessor, DSc
8. **Várkonyiné Kóczy** Annamária, professor, DSc

1.1.2. APPLIED MATHEMATICS PROGRAMME

1. **Baricz** Árpád, professor, Dr.habil.
2. **Kristály** Sándor, professor, Dr.habil.
3. **Nagy** Péter Tibor, professor emeritus, DSc
4. **Pogány** Tibor, professor, PhD

1.2. EMERITUS CORE MEMBERS

1. **Abaffy** József, professor emeritus, DSc
2. **Krómer** István, professor emeritus, DSc
3. **Sima** Dezső, professor emeritus, DSc
4. **Szeidl** László, professor emeritus, DSc

1.3. INTERNAL SUPERVISORS/TEACHERS OF THE DOCTORAL SCHOOL

(CM = Core Member, CME = Core Member Emeritus, S = Supervisor, A = Announcer)

- **Abaffy** József (S, A)

- **Baricz** Árpád (CM, S, A)
- **Barta** Balázs (S)
- **Busics** György
- **Drexler** Dániel András (S)
- **Eigner** György (S)
- **Felde** Imre (S)
- **Ferenci** Tamás
- **Fleiner** Rita Dominika
- **Fogarasi** József (S)
- **Fülöp** János
- **Galambos** Péter (S)
- **Galántai** Aurél
- **Galántai** László (S)
- **Gambár** Katalin Mária
- **Gulácsi** László (S)
- **Györök** György
- **Haidegger** Tamás (CM, A)
- **Hegedűs** Gábor
- **Horváth** Richárd (S)
- **Horváth** László (CM)
- **Imre** Emőke (S)
- **Jancsó** Tamás (S)
- **Kádár** Péter
- **Kertész** Gábor (S)
- **Komoróczki-Steiner** Henriette
- **Kopják** József (S)
- **Kovács** Levente Adalbert (CM, S)
- **Kozlovszky** Miklós (CM, S)
- **Kristály** Sándor (CM, S)

- **Krómer** István (CME)
- **Laufer** Edit (S, A)
- **Lovas** Róbert (S)
- **Mező** István
- **Molnár** Gábor Péter (S)
- **Molnár** András (S)
- **Mosavi** Amir (S)
- **Nagy** Péter Tibor (CM, A)
- **Nagy** Gyula
- **Nemcsics** Ákos
- **Nyers** József
- **Péntek** Márta (S)
- **Pődör** Andrea
- **Pogány** Tibor (CM)
- **Póser** Valéria (S)
- **Rácz** Ervin (S)
- **Rudas** Imre
- **Sájevicsné Sápi** Johanna
- **Seebauer** Márta
- **Sergyán** Szabolcs
- **Sima** Dezső (CME)
- **Simon** Gyula (CM, A)
- **Szeidl** László
- **Széll** Károly (S)
- **Szénási** Sándor (CM, S)
- **Szenes** Katalin (S)
- **Szilágyi** László (S)
- **Takács** Márta (S)
- **Tar** József (CM, S)

- **Tick** Andrea
- **Tick** József
- **Vámossy** Zoltán (S)
- **Verőné Wojtaszek** Malgorzata (S)
- **Vörösné Bánáti-Baumann** Anna
- **Zoller** Vilmos
- **Zrubka** Zsombor János (S)

1.4 EXTERNAL MEMBERS

(CM = Core Member, CME = Core Member Emeritus, S = Supervisor, A = Announcer)

- **Andréka** Péter
- **Barkai** László
- **Belfiore** Nicola
- **Csendes** Tibor
- **Csiszár** Orsolya
- **Dombi** József
- **Domokos** József (S)
- **Faragó** István
- **Farkas** Csaba (S)
- **Fazekas** István
- **Fegyverneki** Sándor
- **Földváry** Lóránt
- **Fullér** Róbert
- **Hegedűs** Csaba (S)
- **Horváth** Ildikó
- **Izsák** Ferenc
- **Kacsuk** Péter
- **Katona** József (A)
- **Komzsik** Lajos
- **Kovács** József (S)

- **Kővári** Attila (S)
- **Lovrics** Anna
- **Maros** István
- **Odry** Péter (S)
- **Odry** Ákos (S)
- **Orosz** Gábor Tamás
- **Papp** Zoltán
- **Renner** Gábor
- **Rontó** Miklós
- **Rövid** András
- **Ruppert** Tamás (S)
- **Sarcevic** Péter (S)
- **Szeidl** György

2. ON THE DOCTORAL EDUCATION

2.1. INTRODUCTION

The University's Doctoral School of Applied Informatics, accredited in 2009, aims to train technical researchers who are well versed in both "soft" and "hard" computing theory, and who are able to independently solve research and development problems based on real industrial needs by applying their interdisciplinary knowledge in a synergistic and creative way.

The first four years of the School's activities have been guided by the need to move beyond the traditional disciplinary approach. In many cases, the scientific problems motivated by real-world industrial applications can only be solved by applying the full range of tools of applied informatics. In this way, the boundaries between previously sharply separated disciplines are blurred, and the project-oriented approach required to solve practical problems generates synergies between disciplines. Intelligent engineering (mechatronics) systems use mathematical, modelling, computational and information technology tools developed in the field of engineering computation. On the other hand, the research topics of the Intelligent Engineering Systems theme are natural application areas for the Computational Engineering theme.

The engineering technologies of 21st century industry make extensive, intensive and now indispensable use of the scientific and mathematical knowledge of our time. This is particularly true in the undergraduate courses in computer engineering, electrical engineering and mechatronics engineering, and to a much greater extent in the masters and doctoral programmes that build on them. This has led to new challenges and the emergence of new research directions, strongly

underpinned by mathematics and science. Taking into account the needs and opportunities, the University of Óbuda requested in 2013 and received on 31 January 2014 the opportunity to transform the Doctoral School of Applied Informatics into an interdisciplinary Doctoral School of Applied Informatics and Applied Mathematics.

2.2. THE PROFESSIONAL BACKGROUND AND BASIS OF THE DOCTORAL SCHOOL'S CURRICULUM

To develop the curriculum for the expanded interdisciplinary Doctoral School, we have considered and taken into account the following:

- the current training and outcome requirements of the underlying domestic bachelor's (BSc) and master's programmes in computer science and mathematics,
- the training programmes of the national doctoral schools in the field of computer science.
- the training programmes of the national doctoral schools in mathematics,
- the Institutional Development Plan of Óbuda University,
- the analyses and recommendations of the leading international professional organisations (IEEE, SIAM, ACM) dealing with and defining training in informatics and applied mathematics and related fields,
- the applied mathematics doctoral programmes of foreign universities and their structure, with particular reference to the following materials:
- 1996 SIAM Report on Mathematics in Industry
- 2012 SIAM Report on Mathematics in Industry
- SIAM Working Group Report on Graduate Education for Computational Science and Engineering (1998)
- http://www.acm.org/education/curricula-recommendations

2.2.1 INDUSTRIAL MATHEMATICIAN TRAINING IN THE USA

SIAM's 1996 and 2012 reports address the state of and opportunities for applied mathematics in the US. The key elements of their findings are:

a) The major skills required of applied (non-academic) mathematicians:

- Modeling and problem solving skills in diverse and changing fields.
- Interest in applications, knowledge and flexibility.
- Computer knowledge and experience.
- Written and oral communication skills.

- strong abstraction and analytical skills, logical thinking.
- an ability to formulate and solve problems in the best way.

b) The areas of knowledge identified and considered important by the users are:

- modelin and simulation
- mathematical formulation of the problems
- problem solving
- development of algorithms and software
- statistical analysis
- verification
- accuracy and reliability analysis

c) The main mathematical knowledge areas prioritised for applications:

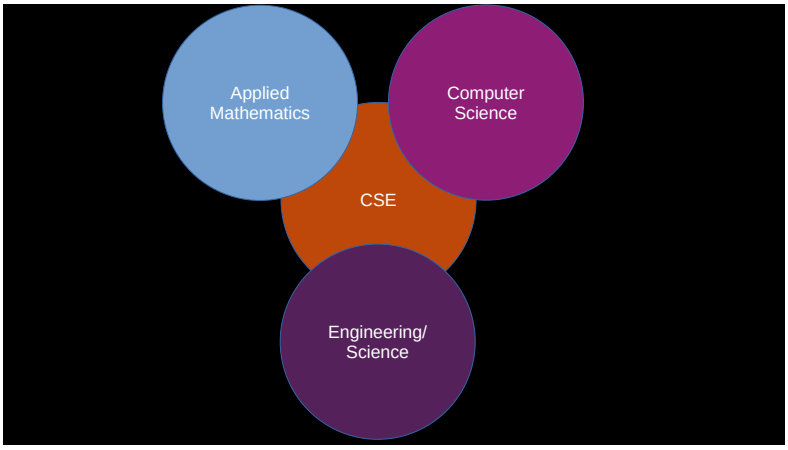
- Modeling and simulation
- Numerical methods/analysis
- Statistics
- Calculus of probabilities
- Engineering analysis/differential equations
- Operation research/optimization
- Discrete mathematics

d) Topics proposed as priorities for applied mathematics courses:

- To introduce a significant number of mathematical applications in engineering, natural sciences, sociology, etc.
- To gain experience in formulating and solving real application problems.
- Computer skills.
- High-Performance Computing (HPC).
- Communication and teamwork.

2.2.2 ENGINEERING CALCULATIONS DISCIPLINE AND TRAINING

Closely related to applied mathematics and computer science is the rapidly developing interdisciplinary field of Computational Science and Engineering (CSE or CE). CSE encompasses the tools of science/engineering applications, applied mathematics, numerical analysis and computer science.



CSE requires knowledge of the application domain, mathematical modelling, numerical analysis, algorithm development, software writing and implementation, analysis, visualisation and validation of results. The professional background considered relevant for CSE is the following:

1. Applied mathematics

- Calculus
- Basics in applied mathematics
- Linear algebra
- Real/complex-analysis
- Szoftware design, programming and testing
- Data structures and algorithms
- Numerical analysis

2. Basic knowledge in application areas.

Proposed core topics for CSE training:

1. mathematics and computer science

- Numerical analysis
- Applied Mathematics
- Computer science
- Data analysis

2. Applications (working knowledge as an absolutely integral part of the training).

2.3. THE TRAINING CONCEPT AND GENERAL STRUCTURE OF THE DOCTORAL SCHOOL

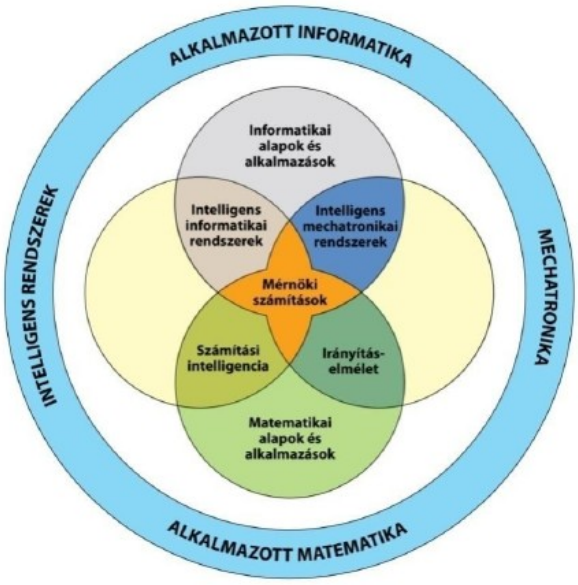
In view of the above, the training concept of the new Doctoral School of Applied Informatics and Applied Mathematics is to create an interdisciplinary doctoral school,

- in which the disciplines of applied informatics and applied mathematics are separated but at the same time organically linked,
- while preserving the structure and content of the existing accredited Doctoral School in Applied Informatics, to provide a doctoral programme in applied mathematics with the explicit aim of strengthening research in technical mathematics.

The Doctoral School will be composed of two disciplinary programmes, corresponding to the two disciplines:

- Applied Computer Science Programme (programme leader: Imre Rudas)
- Applied Mathematics Programme (programme leader: Aurél Galántai)

The following figure shows the basic concept of the targeted training plan and the interrelationship between the different fields of study:



The curriculum is built around the basic sciences of computer science and mathematics, as well as the applied computer science and mathematics research at the university, which is particularly relevant to the field of intelligent and mechatronic systems.

The central part of the training concept is engineering computation, which is a symbiosis of intelligent engineering systems, intelligent mechatronic systems, applied mathematics and computer science. Around this are built the sub-programmes resulting from the interactions between the four key areas. In addition to the above, the design and operation of the sub-programmes are significantly influenced by the three research groups of the University of Óbuda's University

Research, Innovation and Service Centre (Centre for Life Science Controls, BioTech Research Centre, Antal Bejczy iRobotics Centre) and the doctoral school's Virtual Research Laboratory in the Neumann János Faculty of Computer Science, which uses the Dassault Systemes 3DEXPERIENCE Platform.

Applied computer science programme (Imre Rudas)	
Subprogrammes	**Subprogramme Leader**
I.1. Foundations and Applications of Informatics	Várkonyiné Kóczy Annamária, professor
I.2. Cyber medical systems	Levente Kovács, professor
I.3. Cyber physical systems	József Tar, professorr
I.4. Engineering calculations and models	Imre Rudas, professor

Applied Mathematics Programme (Aurél Galántai)	
Subprogrammes	**Subprogramme Leader**
M.1. Mathematical Foundations and Applications	Aurél Galántai, professor
M.2. Engineering Calculations and Models	Imre Rudas, professor

2.4. THE STRUCTURE OF THE DOCTORAL SCHOOL'S CURRICULUM

Some of the general requirements of the educational programme are given in the "Regulations of the Doctoral School of Applied Informatics and Applied Mathematics (13 October 2023), Annex 2: Credit Regulations". As certain details of the Operating Rules were affected by parliamentary decisions taken in 2023, updates had to be introduced in the previous version in order to comply with these requirements. The "Credit Regulations" also refers to the general rules on the credits that can be earned in doctoral studies, as set out in Annex 2 of the EDHSz, and in order to reduce redundancies in general and to ensure clarity of the material, only the most important elements are repeated in the current description of the educational programme.

The doctoral programme consists of 8 semesters. During the 8 semesters, the student must complete 240 credits in order to obtain the degree, as follows:

- Subjects: at least 32 credits, with 8 credits per subject.
- Research report (written and oral) every semester:
- Semesters 1-4: 8-8 credits,

- Semesters 5-8: 15-15 credits (total: 92 credits).
- Publications related to the research topic: at least 75 credits.
- Active participation in a research project: 6-10 credits/project.
- Participation in teaching: maximum 60 credits, 1 contact hour per week = 2 credits.

According to the credit regulations, the student must take at least four (4) courses and pass them with distinction.

Out of the minimum of 4 courses, 2 courses are compulsory courses in a discipline related to the doctoral topic (applied computer science, applied mathematics). A further 1 subject related to the subject of the doctoral thesis from another scientific programme, while the remaining 1 subject is of an applied nature, chosen from sub-programmes I.1 to I.3 or M.1 to M.2.

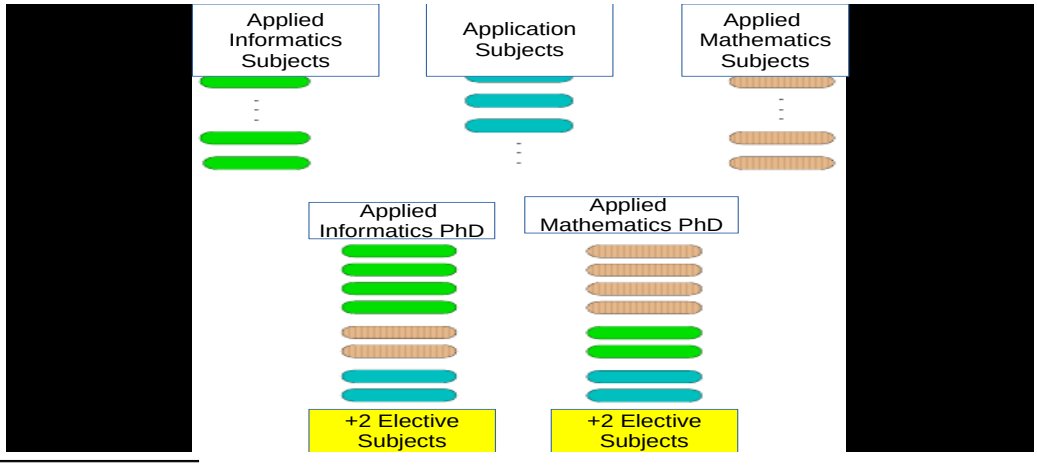
The symmetry of the training structure and the credit balance of the common fields of training allow the student, where justified, to switch between the two disciplines (change of subject) on the proposal of the subject supervisor and with the agreement of the Doctoral School's Council. In case of a change of discipline (subject), the new discipline requirements must be fulfilled in order to obtain the diploma or to start the degree.

For subjects in the Applied Informatics Programme, academic performance is assessed on the basis of the criteria set out by the Department of Engineering Sciences VI of the MTA[1] (and published on the Department's website).

For topics in the Applied Mathematics Programme, the criteria for assessing scientific merit are those established by the Mathematics Division III of the MTA (and published on the website of the Division).

The inclusion of subjects is approved by the Council of the Doctoral School on the recommendation of the subject leader. With the agreement of the supervisor(s), the student may choose 2 additional subjects from among the subjects offered by the doctoral school or as a visiting student at another doctoral school.

This is shown schematically in the following figure:



1 Hungarian Academy of Sciences – Magyar Tudományos Akadémia

2.5. RESEARCH TOPICS OF THE DOCTORAL SCHOOL

2.5.1 BASICS IN INFORMATICS AND APPLICATIONS

Optimizing the filtering of gross errors in the processing of photogrammetric measurements

Thesis Supervisor: Tamás Jancsó

Description of the research topic:

There are several approaches for filtering coarse errors in the processing of photogrammetric measurements, such as. However, as the number of measurements increases, the number of coarse errors to be detected increases, which can significantly affect the assumed normal distribution of the measurements. Therefore, there is a need to develop procedures whereby measurements subject to gross error can be detected before the smoothing procedure. Recent advances in computer technology have made it possible to incorporate combinatorially based procedures into the process of detecting error-laden measurements, which are much more computationally intensive than conventional procedures, but which allow errors to be detected before the least squares smoothing process. The method to be developed can be well integrated with the conventional procedures and thus greatly improve the detection of measurements subject to gross error.

Research objectives:

To review and comparatively analyse the most important rough error screening methods and to investigate the limitations and reliability of the methods under investigation. Development and application of a hybrid coarse error filtering procedure for basic photogrammetric tasks and smoothing procedures. Development of a hybrid filtering procedure for solving nonlinear photogrammetric problems by combining the Jacobian averaging and the Gaussian least squares smoothing procedure into one procedure to increase computational/processing efficiency.

References:

[l] J. L. Awange, E. W. Grafarend, Solving Algebraic Problems in Geodesy and Geoinformatics, 2005, Springer Verlag, ISBN 3-540-23425-X

[2] T. Jancsó, Durva hibák szűrése térbeli hasonlósági transzformációnál, GEOMATIKAI KÖZLEMÉNYEK 12: pp. 27-33. (2009)

[3] T. Jancsó, Durvahiba-szűrés a fotogrammetriai hátrametszés kiegyenlítése előtt kezdő értékek megadása nélkül, GEOMATIKAI KÖZLEMÉNYEK 7: pp. 181-195. (2004)

[4] T. Jancso, Gross Error Detection of Control Points with Direct Analytical Method, In: Geo-Imagery Bridging Continents. Proceedings of the XXth ISPRS Congress, Istanbul (IAPRS 35, B3). Istanbul, 2004.07.12-2004.07.23. ISPRS, pp. 678-682.

[5] T. Jancsó, A külső tájékozási elemek meghatározása közvetlen analitikus módszerrel, GEODÉZIA ÉS KARTOGRÁFIA 46:(1) pp. 33-38. (1994)

[6] J. Zavoti, T. Jancso, The solution of the 7-parameter datum transformation problem with- and without the Gröbner basis, ACTA GEODAETICA ET GEOPHYSICA HUNGARICA 41: pp. 87-100. (2006).

National and/or international links on the above topic:

József Závoti (NyME-KTK, Hungary), Piroska Zaletnyik (BME, Hungary), Vassilios Tsioukas (Aristotle University of Thessaloniki, Greece)

Numerical stability test procedures for computer procedures (automatic error analysis) and their reliability

Thesis Supervisor: Aurél Galántai

Description of the research topic:

Theoretical testing of numerical stability of computer algorithms is usually very difficult and the results obtained do not always reflect practical experience. From a program development and user point of view, techniques that automatically decide whether a given program (algorithm implementation) is numerically stable seem to be more useful. These techniques, which are highly dependent on the type of task, are partly based on random parameter choices and partly use optimisation methods to search for error-maximising parameters

Research objectives:

1. Review and comparative analysis of the best known procedures, their reliability; examination of the methods used to evaluate the performance and reliability of the algorithms.

2. To improve the reliability of procedures.

Information protection with multi-sinusoidal signal encryption

Thesis leader: Annamária Várkonyiné Kóczy

Description of the research topic:

Today's priority research topic is the development of algorithms and procedures that provide adequate protection for the storage and transmission of personal, economic, industrial, military, etc. information. It is worth encrypting information with an algorithm whose cost of decryption is approximately equal to its value. However, effective encryption methods are usually very expensive and require complex procedures. Finding cheaper and more manageable techniques can help to better protect non-public information.

One of the new research directions in information protection is encryption based on chaotic signals [1]. Preliminary results of the subject leader suggest that similar but cheaper, easier to manage and implement encryption schemes can be developed using multi-sinusoidal signals [2]. The research topic aims to design, describe, prove, test and implement this.

Research objectives:

1. investigate encryption based on chaotic signals. Explore analogies between chaotic and multi-sinusoidal signals.

2. Synthesis and analysis of multi-sine signals.

3. Multi-sine coding and active signal amplitude homogenization. Design of encryption procedure using multi-sine waveform coding.

Literature:

[1] Chee, Ch.Y. and D. Xu, "Chaotic encryption using discrete-time synchronous chaos," Physics Letters A, vol. 348, issue 3-6, pp. 284-292, Jan. 2006.

[2] A. R. Várkonyi-Kóczy, "Synchronized Multi-Sine Measurements via DSP Methods," IEEE Trans. on Instrumentation and Measurement, vol. 46, no. 4, pp. 929-932, Aug. 1997.

Performance benchmarking of multicore processors

Thesis supervisor: Dezső Sima

Description of the research topic:

In recent years, a rapid and significant change has occurred in the field of processors; single-core processors have been predominantly replaced by multi-core processors after 2005 with core counts expected to double every two years in the next period as manufacturing technologies evolve. At the same time, the continuous increase in the number of cores places increasing demands on both the on-chip switching network and the bandwidth or size of the operational memory, to the extent that for multi-core processors (8-core or multi-core) the implementation alternatives used so far are no longer adequate and new solutions are needed.

A further characteristic of the research topic is that the intercommunication and memory bandwidth and size requirements are highly dependent on the specific application domain. The research topic will focus on possible implementation alternatives for multi-core processors and their performance ratios based on specific application domains.

Research objectives:

1. to elaborate the design space for multicore processors

2. investigating the performance of architectural alternatives in perspective application domains

International links:

A research collaboration has been established in this area with IBM's research lab in Boeblingen (Dr Peter Altevogt) and the research lab in Austin (Dr Peter Hofstee). A joint research collaboration agreement with both research labs is in place for the further development of the Cell processor.

Point cloud segmentation

Thesis leader: Zoltán Vámossy

Description of the research topic:

Nowadays, information collected about the environment is a high priority in the design of industrial, demand and service processes. The LiDAR (Light Detection and Ranging) laser scanner technology or RGB-D sensors can be used to generate three-dimensional measurement data, so-called point clouds, of the observed space. Segmenting large amounts of data is an essential step in their interpretation.

Research objectives:

Review and comparative analysis of the most important point cloud segmentation methods. To identify selection criteria relevant for different practical applications. To implement segmentations applicable in larger environments, test the method, compare results.

Literature:

[1] R. B. Rusu, “Semantic 3D Object Maps for Everyday Manipulation in Human Living Environments,” PhD dissertation, Tecnische Universitatet Muenchen, 2009.

[2] J. Porway, K. Wang, and S. Zhu, “A hierarchical and contextual model for aerial image understanding,” International Journal of Computer Vision, vol. 88. pp.254-283, 2010.

Application of soft computing methods in image information processing and 3D modelling

Thesis Supervisor: Annamária Várkonyiné Kóczy

Description of the research topic:

Image information processing and 3D modeling are key applications in a significant part of engineering: computer graphics, security engineering, control engineering, transportation systems, cartography, satellite positioning, robotics, geology, monument protection, etc. In recent years, there has been a growing interest in non-traditional methods of image information processing, based mainly on soft computing methods such as fuzzy, neural and genetic techniques. Methods based on fuzzy and other soft computational methods - filters, extractors, shape recognizers, etc. - are serious candidates for solving relevant and irrelevant information separation and modelling tasks, not only because of their good modelling, noise filtering and feature extraction properties, but also because of their adaptivity, learning ability and low computational complexity. Nonlinear techniques generally provide more reliable and accurate results compared to linear methods. In the field of image processing, the new intelligent methods not only offer advantages in distinguishing between useful information and noise for processing, but also in extracting relevant information and thereby solving tasks such as object recognition, information retrieval and image reconstruction, i.e. retrieval of hidden image information. Extracting relevant information can mean e.g. filtering out irrelevant details, which can contribute to an easier and faster interpretation of the image information, while in the case of image reconstruction, it can mean compensating for the loss of information or visual distortion caused by high dynamic range or very low dynamic range illumination by transforming intensity values into the visible light intensity range. In the field of 3D reconstruction, intelligent methods allow automatic modelling based on photographs, and in the case of laser measurements, laser 3D reconstruction.

Research objectives:

1. to explore and develop new models and procedures for image processing and machine vision based on soft computing methods.

2. to develop techniques that improve image quality from a processing perspective.

3. Explore and implement applications for biomedical, road safety, robotics, smart home monitoring systems.

Literature:

[1] A.R Várkonyi-Kóczy, “Low Complexity Situational Models in Image Quality Improvement,” in New Advances in Intelligent Signal Processing (Ser. Studies in Computational Intelligence), A. E. Ruano, A.R. Várkonyi-Kóczy, Eds., Springer Verlag, Berlin, Heidelberg, 2011.

National and/or international contacts on the above topic:

Dr András Rövid (BME)

Profs. Emil M. Petriu and Voicu Groza (University of Ottawa)

Prof. Fabrizio Russo (University of Trieste)

Prof. Jesus Urena Urena (University of Alcala de Henares)

Optimising transport management, increasing efficiency

Thesis supervisor: József Tick

Research objectives:

To study and create tools and operating environments that:

- support capacity planning and optimisation of resource use, thereby identifying necessary structural improvement opportunities and improving quality
- to map, identify and analyse data generated by the core business, in particular in view of the constantly changing set of tasks and assets
- enables the impact of decisions to be predicted and analysed ex post by ensuring a consistent methodology
- provide decision support to relevant actors and a decision support and orientation function for senior and operational management
- demonstrates that the models used in the literature can be applied to public transport.

Literature:

[1] Albert Nagy, József Tick: Review of Predictive Analytics Vendors for Transport Management Systems, In: Szakál Anikó (szerk.) IEEE 15th International Symposium on Intelligent Systems and Informatics : SISY 2017. Konferencia helye, ideje: Szabadka, Szerbia, 2017.09.14-2017.09.16. New York: IEEE, 2017. pp. 225-230. (ISBN:978-1-5386-3855-2)

[2] Albert Nagy, József Tick: Improving Transport Management with Big Data Analitycs, In: Szakál A (szerk.) IEEE 14th International Symposium on Intelligent Systems and Informatics: SISY 2016. 278 p. Konferencia helye, ideje: Szabadka, Szerbia, 2016.08.29-2016.08.31. Budapest: IEEE Hungary Section, 2016. pp. 199-203. (ISBN:978-1-5090-2866-5)

Camera-based assistance for the visually impaired by adaptation of algorithms from driver assistance and usage of external information

Supervisor: József Tick

Research aims:

The goal of the research project is the development of concepts for the transfer of image detection algorithms from the field of driver assistance to blind and visually impaired pedestrians. Furthermore, concepts for the usage of external information (e.g., GPS coordinates of crosswalks and construction sites) in order to increase the algorithms' stability and robustness will be developed.

The resulting algorithms will be integrated in a mobile assistive system that is developed at Hochschule Furtwangen University (HFU). The smartphone app consists of the text-to-speech output and the image analysis client. A camera as well as earphones or a hearing aid are connected to the smartphone. Elaborate image processing calculations are exported to the cloud service and relevant external information needed to support image detection is extracted and provided through the according cloud module. The AAL (Ambient Assisted Living) platform used in the system, has already been developed in a previous project at HFU.

Literature:

[1] Jakob Judit, Tick József: Concept for transfer of driver assistance algorithms for blind and visually impaired people, In: Szakál A (szerk.) SAMI 2017 : IEEE 15th International Symposium on Applied Machine Intelligence and Informatics. 510 p. Konferencia helye, ideje: Herlany, Szlovákia, 2017.01.26-2017.01.28. Budapest: IEEE, 2017. pp. 1-6. (ISBN:978-1-5090-5654-5).

[2] Judith Jakob, Kordula Kugele, József Tick: Defining Camera-Based Traffic Scenarios and Use Cases for the Visually Impaired by means of Expert Interviews, In: Valerie Novitzká, Štefan Korecko, Anikó Szakál (szerk.) INFORMATICS 2017: 2017 IEEE 14th International Scientific Conference on Informatics Proceedings. 437 p. Konferencia helye, ideje: Poprad, Szlovákia, 2017.11.14-2017.11.16. (IEEE) Košice: IEEE Hungary Section, 2017. pp. 128-133. (ISBN:978-1-5386-0888-3)

[3] Jakob Judith, Cochlovius Elmar: OpenCV-basierte Zebrastreifenerkennung für Blinde und Sehbehinderte, In: Stefan Betermieux, Bernhard Hollunder: Software-Technologien und -Prozesse: Open-Source Software in der Industrie, KMUs und im Hochschulumfeld: 5. Konferenz STeP, 3. Mai 2016 in Furtwangen. Konferencia helye, ideje: , Németország, 2016.05.03 Berlin: De Gruyter Oldenbourg, 2016. pp. 21-34. (ISBN:978-3-11048006-1)

Open e-Infrastructure architecture and methodology for grand challenge Big Data application scenarios

Supervisor: Robert Lovas

Research topic:

Information technology faces several challenges in the scope of scientific research, social networks, industry, agriculture, and further widely spreading Big Data application areas due to the extremely high volume, variety and velocity of generated data. In order to collect, store, and perform research analytics or simulation on such data sets, new IT solutions are required from e-Infrastructures. Recently several approaches have been emerging in the various e-Infrastructure trends; wide range of methods, tools and partial solutions are already available, e.g., leveraging on grid computing for scientific purposes, private and public cloud computing, or volunteer distributed (crowd) computing. Besides the FIWARE and LAMBDA architectures, some open source platforms (e.g. Apache Spark) have been already developed, and the major global IT companies provide services or products to support application areas addressing the above described challenges. Due to the complexity of this generic topic, the design and creation processes of the necessary e-Infrastructure might be complex IT tasks for a specific given research, analysis, or simulation use case by taking into consideration (as much as possible) the efficiency and other crucial factors.

Research goals:

The main aim of this research to elaborate an open e-Infrastructure architecture and methodology that, on one hand, takes into consideration (among others) the current features of the available IT and other resources, and on another hand, automatically orchestrates the necessary IT infrastructure (e.g., with workflows) according to the given functional and non-functional requirements. During the research and elaboration of this open architecture special attention must be paid on the interoperability, and the optimisation itself. Concerning the methodology for creation of e-nfrastructures, the research is to focus on verification, testing and scaling aspects as well.

Literature:

[1] Paul Buhler, Thomas Erl, Wajid Khattak: Big Data Fundamentals, Concepts, Drivers & Techniques, Prentice Hall, 2016

2.5.2 CYBER MEDICAL SYSTEMS

Model-based regulation of cancer

Thesis supervisor: Levente Kovács

Description of the research topic:

Cancer is one of the highest causes of mortality in developing and developed societies and is mostly an incurable disease. In order to improve the quality of life of patients and to reduce mortality data, nowadays, so-called targeted molecular therapies (CMT) based on mathematical models are increasingly appearing alongside conventional methods. This interdisciplinary field combines pathology and regulatory engineering, mathematics and informatics, and aims at the development of appropriate therapies and optimal disease management/drug delivery. One option for CMT is an anti-angiogenic-based therapy that destroys the tumour vascular network, thereby reducing the tumour size to a minimum volume.

Research objectives:

The aim of the present research is to develop methods to implement optimal CMT therapy, specifically anti-angiogenic inhibition-based therapy. The task is to create a proprietary model (modified from the literature), to identify and validate it in animal studies. To develop appropriate algorithms for the treatment and regulation of cancer (with a focus on anti-angiogenic therapy). To test the algorithms in animal experiments and in virtual (in-silico) environments.

Literature:

[1] L. Kopper and Zs. L. Kopper and Schaff, Pathology 1. Medicina, 2006.

[2] B. Lantos, Theory and Design of Control Systems I-II. Akadémiai Kiadó, Budapest, 2001-2004.

Computer analysis of pathophysiological processes and biostatistical analysis

Thesis Supervisor: Levente Kovács

Description of the research topic:

In the pursuit of theoretical and practical medical activities, the quantitative determination of physiological processes is of increasing importance instead of qualitative investigations. In biomedical engineering research, the need for the application of mathematical-computational methods and the biostatistical analysis of the results obtained is increasingly being raised. In addition to the statistical evaluation of data collected for the understanding of various pathophysiological processes, there is a growing need to explore the causal relationships between different biological systems and to formulate them mathematically, to discuss their mechanisms of action in systems theory and to analyse them in computer models.

Research objectives:

The aim of the research is to develop methods to support the biostatistical analysis of relevant data in the exploration of cause-effect relationships and their comparison with pathophysiological knowledge. In addition to the commonly used descriptive and other elementary statistical methodologies, there is a growing need to apply advanced statistical techniques (principal component analysis, advanced regression techniques, cluster analysis) and the above mentioned methodologies. The solution is usually to use a combination of these methods.

Literature:

[1] J. Reiczigel J, A. Harnos A and N. Solymosi, Biostatisztika – nem statisztikusoknak. Pars kft., 2010.

[2] P. Armitage and G. Berry, Matthews JNS: Statistical Methods in Medical Research. Wiley-Blackwell, 2001.

[3] B. Rosner, Fundamentals of Biostatistics.Duxbury, 2010.

[4] V.Z. Marmarelis, Nonlinear Dynamic Modeling of Physiological Systems. IEEE Press, 2004.

Automatic DNA ploidy analysis on digital pathology samples

Thesis Supervisors: Béla Molnár, Miklós Kozlovszky

Description of the research topic:

Cancer research nowadays relies heavily on parameters that can be examined by high-resolution digital microscopy. Medical image processing enables the isolation and analysis of individual details of high-resolution tissue images.The morphological and morphometric parameters of the cells examined, as well as the amount of DNA contained in these cells, can be used to infer important features of the disease with good accuracy.

Research objectives:

The aim of this research is to design and develop a method or software application that can provide reproducible information on one of the fundamental diagnostic information in cancer research using image processing methods. This information is the reproduction rate of the in-vitro tissue/suspension under investigation. This is commonly assessed by means of a histogram of the amount of DNA contained in the cells under test.

Literature:

[1] K. Kayser, B. Molnar and G. Weinstein, Virtual microscopy, Veterinaerspigel Verlag, Berlin 2006.

Analysis and optimization of algorithms for processing digitised histological samples

Thesis Supervisors: Miklós Kozlovszky, Béla Molnár

Description of the research topic:

Automatic or semi-automatic segmentation, measurement, analysis and 3D reconstruction of digital images of appropriately treated and stained tissue samples taken with a high-resolution microscope in the field of medical image processing.

Research objectives:

To learn about the medical aspects of the research field (types of lesions, their detectability, identification of lesions not yet investigated). To map, compare and evaluate image processing algorithms currently used in pathology in terms of their purpose, working principle, efficiency and accuracy. Analysis of the parameter space of the algorithms identified and the potential for improvement through parameter tuning.

Literature:

[1] K. Nguyen et al., “Automated Gland Segmentation and Classification for Gleason Grading of Prostate Tissue Images,” 2010 International Conference on Pattern Recognition

[2] A.N. Esgiar et al., “Fractal analysis in the detection of colonic cancer images,” IEEE Transactions on Information Technology in Biomedicine, vol. 6, no. 1., pp. 54–58, March 2002

[3] J. Diamond et al., “The use of morphological characteristics and texture analysis in the identification of tissue composition in prostatic neoplasia,” Human Pathol, vol. 35, pp. 1121-1131, 2004.

[4] J Grace et al, “Malignant transformation of osteoblastoma: study using image analysis microdensitometry,” Journal on Clinical Pathology, vol. 46, pp. 1024-1029, 1993., DOI:10.1136/jcp.46.11.1024

[5] L. Ficsór et al., “Validation of automated image analysis (Histoquant) in colon cancer using digital slides of EGFR, COX-2, BETA-CATENIN, and cyclin D1 immunostainings,” 21th European Congress of Pathology, Istanbul, Turkey, 2007.

[6] L. Krecsák et al., “Technical note on the validation of a semi-automated image analysis software application for estrogen and progesterone receptor detection in breast cancer,” Diagnostic Pathology 2011

Building economic models to support healthcare decision-making and developing specific algorithms to describe their operation

Supervisors Levente Kovács (ÓE), Dr. Péter Andréka (GOKI)

Description of the research topic:

In the case of critical cardiological diseases, no possibility for a measurable, reproducible, comparable and acceptably accurate, exact monitoring of organ systems is currently available in the current scientific toolbox. The importance of the problem is underlined by the fact that, according to studies, the number of people suffering from serious cardiological diseases will only increase in the future due to the ageing of developed societies and the increasing costs of treating them. At the same time, the number of healthcare staff is unfortunately decreasing, so software to support healthcare decision making will become increasingly important in the future. This is compounded by the fact that the treatment of patients with serious conditions generates a huge amount of data, often of great significance, that the human brain can no longer handle without a specialised software system.

Research objectives:

1. to investigate the economic benefits of a decision support algorithm for the management of patients with severe cardiological conditions, to determine the reduction of healthcare costs by shortening the time needed to treat patients in intensive care units and to reduce the number of healthcare professionals.

Shortening the duration of ICU treatment has been shown to be associated with a reduction in complications and an improvement in patient survival and subsequent quality of life, which will also be investigated.

3. Patient safety in decision support algorithm-guided treatment can be significantly improved through various built-in self-monitoring features, the effects of which will also be investigated.

4. Prospective, randomised, multicentre clinical trials are now almost invariably used for the final assessment of cardiological therapies. However, patient recruitment often faces serious difficulties. We also plan to investigate ways of solving this problem by developing different algorithms. Get involved in the research and teaching activities of the Centre for Life Science Controls at the University of Óbuda. The medical partner for this topic is GOKI (Gottsegen György National Institute of Cardiology).

Requirement: the candidate should have English language skills, statistical knowledge and scientific publications.

Developing new model systems to describe and study certain diseases

Supervisors: Dr. Péter Andréka (GOKI), Dr. Tamás Ferenci (ÓE)

Description of the research topic:

In current medical practice, the investigation of diseases or pathological conditions is divided into organ systems, which makes it very difficult to effectively understand and treat pathological conditions resulting from interactions between organ systems. A characteristic of living organisms is the rapid (essentially instantaneous), dynamic change of the system. The need for quasi-real-time data analysis (data collection and processing) makes the study of these types of complex systems very difficult. In the last decades, evolving medicine has added many new investigative capabilities (EBM, biostatistics, clinical trials, real-word data processing, etc.). However, these capabilities do not provide complete information "per se" about diseases or their intrinsic nature. The understanding of diseases and physiological conditions has been slowed down by current methods and other methods need to be developed. Modelling is a useful tool for understanding the processes of the material world around us. It involves a simplified view of one or more properties or characteristics of a complex system (e.g. an economic process, a physical object, an interaction, a living organism, etc.), or the definition of interfaces (points) to examine the role of a given sub-process as part of the whole system or to determine its relationship to the latter. There are several possible ways of understanding complex systems, such as biological systems used to model certain diseases, e.g. cultured or engineered cell cultures and invertebrate or vertebrate animals. In recent years, however, there has been a general trend towards the use of fewer and fewer vertebrate animals in animal experiments, which can be replaced by methods such as statistical analysis, structural analysis, functional analysis, network structure analysis (including, for example, pattern recognition), analysis of random test results, evaluation of response(s) to external stimuli and the construction of various in silico virtual models. A well-designed model not only helps to understand how the system works, but can also be of great value as a decision support system for clinical practice.

Research objectives:

The aim of the topic is to describe, systematise and possibly compare model forms from the perspective of clinical practice and to select one or more model forms (animal, mathematical, biostatistical, informatics) to describe a given disease and/or therapeutic modality as accurately as possible.

The research topic requires the acquisition of a strong interdisciplinary knowledge. The candidate will be involved in research and teaching activities carried out by the Centre for Life Science Controls at the University of Óbuda. The medical partner for the topic is the GOKI (Gottsegen György National Institute of Cardiology).

Requirements: The candidate should have a good command of English, statistical skills and scientific publications.

Application of regression models in biomedical tasks

Thesis Supervisors: Tamás Ferenci, Levente Kovács

Description of the research topic:

The application of regression models is of crucial importance in the evaluation of empirical medical studies. In spite of this, practical applications often use suboptimal solutions, do not exploit the available potentials, and some problems require new solutions. The Candidate will develop, validate and calibrate regression models for biomedical applications, in particular in cardiology and diabetology, and learn state-of-the-art methods and their practical application. The task will include the management of the overall analytical workflow, following the philosophy of reproducible research. The implementation of the models must be done in an R statistical environment, and the candidate will have to become very familiar with it, including the use of the necessary libraries and other tools (rms, RMarkdown, etc.)

Research objectives:

1. development of regression models for biomedical (with a focus on cardiology and diabetology) applications, with particular attention to the incorporation of state-of-the-art solutions such as:

a. model diagnostics, specification errors, autocorrelation handling,

b. spline regression for continuous variables (GAM),

c. bootstrap and other principled model validation and use of model calibration,

d. use of regularisation (penalisation),

e. handling missing data through multiple inputs,

f. testing other regression techniques (e.g. latent class models).

2. Comparing regression models, with particular attention to:

a. propensity score methods,

b. and using machine learning (data mining) techniques.

3. Analysis workflow management according to the philosophy of reproducible research. The research topic requires the acquisition of a strong interdisciplinary knowledge. The candidate will be involved in research and teaching activities conducted by the Centre for Life Science Controls Research at the University of Óbuda. The medical partners for the topic are GOKI (Gottsegen György Gottsegen National Institute of Cardiology) and Heim Pál Children's Hospital.

Requirements: The candidate must have a good command of English and statistical skills, and a scientific publication record.

Mathematical modelling of severe pathologies and development of specific decision support algorithms for therapy

Supervisor: Dr. Péter Andréka (GOKI), Dr. Levente Kovács (ÓE)

Description of the research topic:

Today, the management of certain critically ill patients, especially when they also require circulatory and respiratory support, is a serious problem. This is due to the close interconnection of pathological functions of the organ systems. The setting of life support devices and the pharmacological and non-pharmacological treatment modalities required depend largely on the current state of the patient, which in turn may be subject to continuous and very rapid changes. Accordingly, no uniform rules can be established for the treatment of these patients and treatment must be individualised to achieve the best possible survival rates.

Research objectives:

In the present research, the aim is to develop complex monitoring of patients with severe underlying cardiological disease capable of adequate data collection and thus to develop guided, individualized therapeutic algorithms, the main components of which are:

1. respiratory or ventilatory monitoring, investigating the adaptation of the respiratory system in the above mentioned patient groups by defining a new mathematical-mechanical model.

2. study of haemodynamic changes: the primary objective is to identify and assess early changes in the patient's condition that are not yet objectifiable in the clinical setting and to allow timely intervention. Given that a poor "clinical response" (e.g. therapeutic intervention) due to late or inadequate monitoring can ultimately determine the fate of the patient, timely and appropriate intervention can be life-saving.

3. Develop a complex health (medical and nursing) decision support algorithm and patient safety system. This will continuously monitor the respiratory and haemodynamic parameters measured and derived during ventilation and circulatory support of the patient and, based on these, be able to suggest drug and device therapy options and settings that best approximate the ideal.

The methods of analysis are statistical analysis of big data sets derived from intercommunicating multifunctional monitor workstations (ventilators, circulatory support devices, haemodynamic monitors, echocardiogram devices, etc.) and mathematical simulation procedures (e.g. Monte Carlo) and mathematical models. The research topic requires the acquisition of a strong interdisciplinary knowledge. The candidate will be involved in research and teaching activities conducted by the Centre for Life Science Controls Research at the University of Óbuda. The medical partner for the topic is GOKI (Gottsegen György National Institute of Cardiology).

Requirements: The candidate should have a good command of English and statistical skills, as well as scientific publications.

Model-based therapeutic options for pathophysiological processes in a real hardware environment

Thesis Supervisor: Levente Kovács

Description of the research topic:

Model-based control of pathophysiological systems is a challenging task. With the advances in computational and mathematical tools of systems and control theory, it has become possible to analyse physiological processes and control systems analytically and computationally and to apply them in practice, in addition to complex engineering systems with significant and negligible nonlinearities. The development of appropriate target hardware, however, requires knowledge of the states of the system, i.e. an appropriate state observer, as well as on-line parameter identification.

The current topic is related to physiological and pathophysiological control, combining life sciences, control engineering, computer science and mathematics. The research work is related to an existing set of tools and methodologies, their clinical application and the development of appropriate hardware tools.

Research objectives:

The candidate will be required to develop:

- Modern state-of-the-art state and parameter estimation and identification algorithms;
- Investigate the applicability of these algorithms in a virtual (in silico) environment on real clinical and pathophysiological data, in particular for the control of type 1 diabetes (artificial pancreas);
- develop appropriate target hardware to study and control the physiological process in question, taking into account the algorithms developed;
- investigate the impact of the hardware components on the quality parameters and robustness of the developed control algorithms;
- investigate the limitations of implementing algorithms for physiological control on real hardware for systems implementing physiological control, in particular for diabetes mellitus control;

The theoretical investigation of this research topic requires the acquisition of considerable interdisciplinary knowledge. Get involved in research and teaching activities conducted by the Centre for Life Science Controls at the University of Óbuda.

Requirements: The candidate should have English language skills, knowledge of a mathematical software package (e.g., MATLAB) suitable for control theory applications and hardware modelling and integration (processor-in-the-loop), knowledge of embedded systems, scientific publications, knowledge of control theory and experience in hardware development.

Regulation of non-linear physiological processes

Supervisors Levente Kovács, András Dániel Drexler

Description of the research topic:

With the development of computational and mathematical tools in systems and control theory, it has become possible to analyze not only complex engineering systems with significant, non-negligible nonlinearity, but also physiological processes and control systems analytically and computationally. The nonlinear dynamics of physiological processes requires knowledge of the control of nonlinear systems. The topic is related to the field of physiological and pathophysiological control, combining physiological sciences, control engineering, computer science and mathematics. The research work will focus on existing tools and methodologies for artificial pancreas (diabetes) and tumour regulation, their clinical application and their introduction into university education.

Research objectives:

Develop goal-directed algorithms for the analysis of complex physiological processes and investigate the applicability of models describing the corresponding processes in control theory. Investigate the potential applications of control design based on the analysis of nonlinear systems using state-space models, soft-computing and modern robust techniques (LPV, TP). The theoretical investigation of the research topic requires the acquisition of a strong interdisciplinary knowledge. Get involved in the research and teaching activities of the Centre for Life Science Controls at the University of Óbuda.

Requirements: The candidate should have a good command of English and a knowledge of a mathematical software package (e.g. MATLAB) appropriate to the needs of systems and control theory applications, as well as a scientific publication record and a significant knowledge of control theory.

Modern robust control theory for pathophysiological processes

Thesis Supervisor: Levente Kovács

Description of the research topic:

For many diseases, where the human body is unable to produce or maintain the appropriate state, an external regulator is the solution. This can be achieved by a partially or fully automated unit, which is the input of the appropriate physiological signal or the injection of a given dose. The controller has to implement a very strict set of requirements, compliance with which not only contributes to the improvement of the patient's quality of life, but also, for example, to the optimal dosage of his/her medication, if necessary.

The aim of the present research is to develop methods that can provide a robust and/or optimal solution to provide an intervention for the control of complex physiological processes. The topic is related to the field of physiological and pathophysiological control, combining life sciences, control theory, computer science and mathematics. The research work will focus on existing tools and methodologies for artificial pancreas (diabetes) and tumour regulation, their clinical application and their introduction into university education.

Research objectives:

The candidate will be responsible to familiarize with modern robust control theory methods (Hinf, μ-synthesis, LPV, TP, RFPT). Develop goal-oriented algorithms for the control of physiological processes (mainly artificial pancreas and tumor control) and investigate the applicability of models describing the corresponding processes in control theory. Perform model experiments on the structures identified.

The theoretical investigation of the research topic requires the acquisition of considerable interdisciplinary knowledge. Be involved in the research and teaching activities of the Centre for Life Science Controls at the University of Óbuda.

Requirements: The candidate should have a good command of English and a knowledge of a mathematical software package (e.g. MATLAB) appropriate to the needs of systems and control theory applications, as well as a scientific publication record and a significant knowledge of control theory.

2.5.3 CYBER PHYSICAL SYSTEMS

Real-time mapping of the mobile robot environment

Thesis supervisor: Zoltán Vámossy

Description of the research topic:

When controlling a robot, the main task is for the system to build a map using sensor data and to determine its position in the given working environment. In most cases, a sensor system is used that can provide information for the robot's automatic navigation. The most commonly used sensors for real-time indoor navigation are RGB-D camera, LiDAR and inertial measurement unit (IMU).

Research objectives:

Review and comparative analysis of positioning and mapping methods. Application of the camera image and depth information provided by the Kinect sensor in indoor mapping. Application of typical point-based techniques for the integration of survey data into maps. Algorithms for matching individual details. Testing the selected method and comparing the results.

Literature:

[1] L. Juan and O. Gwun, “A Comparison of SIFT, PCA-SIFT and SURF,” International Journal of Image Processing (IJIP) 2010, vol. 3, no. 4, pp. 143-152.

[2] S. Thrun, J. J. Leonard, S. Bruno and K. Oussama, Eds., Springer Handbook of Robotics. Springer, 2008.

Intelligent methods to improve the safety of transport systems

Thesis Supervisor: Annamária Várkonyiné Kóczy

Description of the research topic:

Increasing the safety and efficiency of transport systems is becoming increasingly important in international research and development. Research is approaching the topic from multiple perspectives, with extensive work in the areas of complex transport system modelling, traffic management and optimisation, vehicle modelling, driverless vehicle development, autonomous navigation, smart space and accident/collision analysis. The importance of this topic is also demonstrated by the fact that recent EU studies show that the economic impact of congestion in developed European countries is as high as 2% of GDP.

Recent research results show that the complexity of the problems, the difficulty of formulating expectations and the uncertainty of information in these areas make the use of intelligent methods advantageous, and in many cases the only techniques that can be used and that lead to results. Research related to this theme focuses on fuzzy and genetic techniques, neural networks, anytime systems and their combination or combination with other mathematical, modelling, diagnostic and identification methods. Emphasis will be placed on autonomous navigation [1], intelligent space [2] and collision analysis [3], where theoretical research and practical development will be carried out in the framework of international and national proposals.

Research objectives:

1. autonomous navigation: development of navigation algorithms for robots performing 2 and 3D movements, integration into a unified descriptive framework, increasing their adaptivity and learning capabilities.
2. mart space: as a property of a "space" (transport network, transport node, underpass, hospital, bank, apartment building, room, etc.), create intelligence capable of monitoring, identifying, tracking vehicles, robots, people, optimising movements and routes, detecting unusual events, alerting when necessary.
3. collision analysis: the design and further development of an intelligent system that can automatically process images from digital photographs of the collided vehicle and its surroundings, using a combination of epipolar geometry, computer graphics and intelligent methods, to approximate the collision conditions, reconstruct the collision time sequence and perform further analysis, which can contribute to safe vehicle design and safer transport systems.

Literature:

[1] Á. Lászka, A.R. Várkonyi-Kóczy and G. Pék, “Universal Autonomous Robot Navigation Using Quasi Optimal Path Generation,” IEEE Int. Conf. on Autonomous Robots and Agents, ICARA’2009, Wellington, New Zealand, Feb. 9-12, 2009.

[2] A. R. Várkonyi-Kócz and A.A. Tóth, “ISpace – a Tool for Improving the Quality of Life,” Journal of Automation, Mobile Robotics & Int. Systems, vol. 3, no. 4, pp. 41-45, 2009.

[3] A. R. Várkonyi-Kóczy, A. Rövid and M.G. Ruano, “Soft Computing Based Car Body Deformation and EES Determination for Car Crash Analysis Systems,” IEEE Trans. on Instrumentation and Measurement, vol. 55, no. 6, pp. 2300-2308, Dec. 2006.

National and/or international contacts on the above topic:

Prof. Péter Korondi (University of Debrecen)

Dr András Rövid (BME)

Hideki Hashimoto (University of Tokyo, Jp.)

Profs. Maria Graca & Antonio Ruano (University of Algarve, Pt.)

Application of soft computing methods in "anytime" systems

Thesis Supervisor: Annamária Várkonyiné Kóczy

Description of the research topic:

The characteristic features of today's modern measurement, control, diagnostic, etc. systems include, on the one hand, increasing complexity and, on the other hand, operation in the required response time. Diagnostic systems are able to quickly identify faults in the operation of a given technology and to neutralise/reverse their effects within certain limits. Obviously, the available computing capacity is a key issue, but the actual operation of the system is also greatly influenced by the processing speeds allowed by the information processing precedence conditions, including timing and data access conditions. However carefully such application systems are designed, it is almost inevitable that severe data and/or time shortages will not occur at critical operational stages, which could result in a malfunction of the diagnostic or control system.

To deal with these problems, anytime systems can be used to advantage, being able to adapt adaptively to the amount of computing resources/time currently available and to incomplete, inaccurate, uncertain data. These systems are based on models and algorithms that provide some level of acceptable quality of response in the event of data loss or critical timing conditions, thus allowing the information processing process to continue/be continued.

Under the guidance of the topic leader, intensive research work has been carried out in this area for several years. Based on the studies carried out, it seems appropriate to research and develop the potential applications of soft computing methods, in particular fuzzy systems and neural networks, in anytime systems. The issues that need intensive research include finding and maintaining a favourable balance between computational complexity and accuracy, with conflicting requirements. Another aspect of the investigations may be the "transient" behaviour of the procedures used. Indeed, the tuning properties of the procedures have a significant impact on the quality of the results.

Another very interesting issue is the intelligent monitoring of anytime systems and

how to plan the propagation of a degraded result due to data loss or critical timing in the information processing chain, i.e. how the increase in uncertainty affects the specific operation of the downstream processing elements and the results they compute.

To develop this topic, a deeper knowledge is needed

- generalised anytime systems,
- soft computing methods, in particular fuzzy techniques and neural networks,
- transient analysis,
- the design of complex technology measurement and control systems, and
- design of computerised monitoring systems

research areas. The research topic is in several respects related to national and international collaborations, and its successful development could make a significant contribution to the design and implementation of application systems with the requirements outlined above, based on a fundamentally new approach, and to the development of computer-based monitoring systems that are available even in the event of corrupted information flows or timing problems.

Deep Learning methods in industrial robot applications

Thesis Supervisor: Péter Galambos

Description of the research topic:

Machine learning, and in particular deep neural networks, or deep learning technology, has radically transformed the information technology industry. From text analysis to self-driving vehicles to robot arm motion planning, to name but a few examples, a whole range of tasks that cannot be handled with analytical methods or can only be handled with modest efficiency are becoming solvable. In the early days of robotics, roughly from 1960 to 1990, analytical and numerical methods were largely developed to handle basic tasks such as inverse kinematics and inverse dynamics, motion control, or even collision-free trajectory planning. These techniques are still essential today and, thanks to advances in computers, allow real-time or even faster computation.

The growing demand for increasingly complex robotic applications in the era of the 4th industrial revolution presents researchers and engineers with tasks that cannot be approached by traditional methods due to their complexity. Such tasks include detecting the environment and recognising objects, manipulating different, even unknown objects, or handling flexible workpieces. Equally challenging is the supervision of new types of applications, mainly collaborative, and the implementation of event logging for quality assurance purposes. The unlimited amount of data available through automated data collection must be used to extract information that is useful to an actor in the ecosystem. For an expert, this may not be a problem, but it is a task that is not yet solved in computer-aided automated data analysis. It is an emerging research task in the field of robotics, with deep implications for several engineering and scientific disciplines (e.g. robotics, computer science, computer science).

Research objectives:

As the research topic involves many disciplines, the possible objectives are also manifold. We are looking for applicants who are challenged to tackle cross-disciplinary research problems. The variety of possible directions is illustrated in the following points:

- Understanding current robotic applications of deep neural networks and providing a scientific overview.
- Developing a general approach to effectively combine well-established analytical and algorithmic methods with machine learning-based methods.
- To implement RGB-D modality-based environment detection, segmentation and object recognition using a convolutional neural network.
- Object grasping design based on recognized geometric features and grasping geometry.
- - Segmentation of robot arms and real-time configuration recognition from RGB-D data streams.

- Recognition and logging of different phases of a collaborative robot application based on status data extracted from the robot controller and external sensor data. Predict abnormal operation based on learned features.

Literature:

[1] V. Nath és S. E. Levinson, Autonomous Robotics and Deep Learning, 2014 edition. New York: Sprin-ger, 2014.

[2] I. Goodfellow, Y. Bengio, és A. Courville, Deep Learning. MIT Press, 2016.

[3] Sergey Levine, Peter Pastor, Alex Krizhevsky, Julian Ibarz, és Deirdre Quillen, „Learning hand-eye coordination for robotic grasping with deep learning and large-scale data collection”, The International Journal of Robotics Research, o. 0278364917710318, jún. 2017.

[4] P. Kim, MATLAB Deep Learning: With Machine Learning, Neural Networks and Artificial Intelligence, 1st ed. edition. New York, NY: Apress, 2017.

[5] A. Zeng és mtsai., „Multi-view self-supervised deep learning for 6D pose estimation in the Amazon Picking Challenge”, in 2017 IEEE International Conference on Robotics and Automation (ICRA), 2017, o. 1386–1383.

[6] J. Sung, S. H. Jin, és A. Saxena, „Robobarista: Object Part Based Transfer of Manipulation Trajectories from Crowd-Sourcing in 3D Pointclouds”, in Robotics Research, Springer, Cham, 2018, o. 701–720.

National and/or international contacts on the above topic:

Ádám Csapó (SZE, Győr); Dr. eng. Cosmin Copot (University of Antwerp, Faculty of Applied Engineering, Department of Electromechanics, Op3Mech); OptoForce Kft.

Semantic programming of robot systems

Thesis Supervisor: Péter Galambos

Description of the research topic:

Traditionally, the programming of manufacturing processes using industrial robots and other computer-controlled production tools is built at the elementary level. This approach assumes a thorough knowledge of the circumstances, including the type of manufacturing equipment, the geometry of the specific manufacturing layout and the technology used. It follows that manufacturing programmes represent technological knowledge in a way that does not allow generalisation, i.e. portability. Any change in circumstances will entail modifications to the production programmes. Modern semantic technologies raise the possibility of describing technological processes in a more general way, thus ensuring the portability of programs and semantic task descriptions. This is of particular importance in the field of colloborative robot applications. The scientific approach to this topic aims at developing a complex system that can produce low-level programs for specific equipment and control complex processes in a "fly-by-wire" manner, based on knowledge of the current state of the system, using different knowledge representations and semantic inferences.

Research objectives:

The research objectives are summarized in the following points:

- To learn state-of-the-art semantic information representation methods. To define reasonable test boundaries considering standard Industrial Robot Ontologies.
- To develop a generic description system covering typical task primitives of industrial robot applications (especially collaborative direction).
- Integration of different levels of knowledge representation, perception and decision making (control) for proof-of-concept purposes.
- Developing abstractions of the control layers to handle rule-based, analytical and other soft computing formulations of control laws.

Literature:

[1] P. Galambos és mtsai., „Design, programming and orchestration of heterogeneous manufacturing systems through VR-powered remote collaboration”, Robotics and Computer-Integrated Manufacturing, köt. 33, o. 68–77, jún. 2015.

[2] K. M. Lynch és F. C. Park, Modern Robotics. Cambridge University Press, 2017.

[3] M. Stenmark és P. Nugues, „Natural language programming of industrial robots”, in IEEE ISR 2013, 2013, o. 1–5.

[4] E. Prestes és mtsai., „Towards a core ontology for robotics and automation”, Robotics and Autonomous Systems, köt. 61, sz. 11, o. 1193–1204, nov. 2013.

[5] L. Kunze, T. Roehm, és M. Beetz, „Towards semantic robot description languages”, in 2011 IEEE International Conference on Robotics and Automation, 2011, o. 5589-5595.

[6] F. van Harmelen, V. Lifschitz, és B. Porter, Handbook of Knowledge Representation. Elsevier, 2008.

National and/or international contacts on the above topic:

Ádám Csapó (SZE, Győr); Dr. eng. Cosmin Copot (University of Antwerp, Faculty of Applied Engineering, Department of Electromechanics, Op3Mech)

Safety engineering for surgical robots

Thesis supervisor: Tamás Haidegger

Description of the research topic:

In the last 30 years, the development and application of various robots has become increasingly important, which previously played a role mainly in automotive manufacturing. These robots are almost never allowed to come into physical contact with their operators or other humans due to existing safety regulations. Nowadays, however, in a rapidly developing world, human-centred robotic systems have become of paramount importance, so-called service robots. Using robots in the home, in home care or even in healthcare, new software problems arise from the direct human-machine physical contact. Robotic technology holds the potential to radically transform the current healthcare system, introducing cost-effective home care, telediagnostics, telemedicine and telesurgery, and therefore it is critical to address safety risks. At the same time, the interaction of robots with humans in a distributed workspace requires a number of factors to be taken into account and inadequate protocols are being used by different manufacturers and developers. Many standards exist for industrial operations, but there are no adequate global guidelines for service robots and safe human-machine interfaces. This can lead to serious safety problems in the use and application of different devices. As part of the research work, the safety protocols used on the robots and devices currently under development should be examined along a common guideline. The PhD student will be tasked with assessing, through simulations, the critical and non-standardised factors of an available service robot and then assessing these risks in real life. Taking into account the different international regulatory backgrounds, he/she will develop a methodology for objective safety measurement procedures for the human-service robot interface.

Research objectives:

Analysis of safety-critical human-machine interfaces (home care, healthcare applications, shared workspace). Objective evaluation of currently existing systems from a safety perspective. To develop a measurement procedure and criteria for safe human-machine interface. Simulations and real tests of typical applications of the new method, validation of the classification system.

Literature:

[1] Sami Haddadin (2011). - Towards Safe Robots: Approaching Asimov’s 1st Law. PhD thesis, DLR, 2011.

[2] Haddadin, S., Haddadin, S., Khoury, A., Rokahr, T., Parusel, S., Burgkart, R., ... & Albu-Schäffer, A. (2012, October). A truly safely moving robot has to know what injury it may cause. In Intelligent Robots and Systems (IROS), 2012 IEEE/RSJ International Conference on (pp. 5406-5413), 2012.

[3] Kazanzides, P., Kouskoulas, Y., Deguet, A., & Shao, Z. (2012, May). Proving the correctness of concurrent robot software. In Robotics and Automation (ICRA), 2012 IEEE International Conference on (pp. 4718-4723). IEEE.

[4] Bresolin, D., Di Guglielmo, L., Geretti, L., Muradore, R., Fiorini, P., & Villa, T. (2012, September). Open problems in verification and refinement of autonomous robotic systems. In Digital System Design (DSD), 2012 15th Euromicro Conference on (pp. 469-476). IEEE.

National and/or international contacts on the above topic:

Dr. Gernot Kronreif, Austrian Center for Medical Innovation and Technology (ACMIT), Wiener Neustadt, Austria

Control of time-delay systems for telesurgery applications

Thesis Supervisor: Tamás Haidegger

Description of the research topic:

In the last decades, telesurgery has grown into an independent research and then application area. In 1973, the first concept of a telesurgery robot was born at NASA, and after several successful developments, the first transcontinental intervention was performed in 2001. In 2005, the first regular robotic telesurgery and diagnostic service was launched in Canada, but the management of long delays is still a major challenge. With the right algorithms and model-based predictive controllers, the requirements for stability and transparency can be met for real-time interventions over long distances. The student's task is to investigate through simulations the critical factors of a modelled teleoperation operating theatre system and to design different prediction procedures and control algorithms on the given simulation framework.

Research objectives:

To understand the concept of long-distance teleoperation, to select the most efficient algorithms after processing the relevant literature. To explore and test currently applied control design methods, to develop new options. Application of model predictive controllers on master-slave based surgical robotics systems. Development of a concrete MPC algorithm, selection and design of a testing environment, validation methodology, implementation of tests and critical evaluation of results.

Literature:

[1] Kazanzides, P., Fichtinger, G., Hager, G. D., Okamura, A. M., Whitcomb, L. L., & Taylor, R. H. (2008). Surgical and interventional robotics-core concepts, technology, and design [Part I-II-III]. IEEE Robotics & Automation Magazine, 15(2-3-4).

[2] Varkonyi, T. A., Rudas, I. J., Pausits, P., & Haidegger, T. (2014, July). Survey on the control of time delay teleoperation systems. In Intelligent Engineering Systems (INES), 2014 18th International Conference on (pp. 89-94). IEEE.

National and/or international contacts on the above topic:

Prof. Peter Kazanzides, CISST, Johns Hopkins University, Baltimore, MD, USA

Kinematic synthesis of closed 6R chains and bond theory

Thesis Supervisor: Gábor Hegedűs

Description of the research topic:

Closed 6R mechanisms have been studied for a long time and an old and famous problem is the construction of new closed 6R mechanisms. In our research, we will investigate the new mechanism discovered by Josef Schicho and his co-researchers.

Schicho's method of factorization of polynomials over dual quaternions, we aim to construct and investigate new chains. The classification of closed 6R chains will lead us towards the bonding theory discovered by Josef Schicho and co-researchers. Using the bonds defined in bond theory, we can well describe the geometric properties of closed 6R chains. We also want to better understand these geometric features, such as the relationship between bonds and DH parameters.

Research objectives:

Our main goal is to classify closed 6R chains using bond theory. We also want to use this bond theory to classify the self-movements of parallel Stewart Gaugh platforms. An important step forward would also be to construct new chains using the factorization algorithm discovered by Josef Schicho et al.

Literature:

[1] G. Hegedüs, J. Schicho and H. P. Schröcker, "Bond Theory and Closed 5R Linkages." in Latest Advances in Robot Kinematics. Springer Netherlands, 2012, pp. 221-228.

[2] G. Hegedüs, J. Schicho and H. P. Schröcker, "Construction of overconstrained linkages by factorization of rational motions." in Latest Advances in Robot Kinematics. Springer Netherlands, 2012. pp. 213-220.

Szabad(ka) II. mechatronic structure drive control optimisation

Thesis supervisor.

Description of the research topic:

The Free(ka) II is a six-legged embedded mechatronic system with 3 DOF per leg, suitable for research on complex drive control tasks. In complex actuation of devices, the question arises which is the minimum sensor interface that can serve the device and provide the right conditions for the device during operation. To investigate whether the selected sensor surface is sufficient or not to solve the fast tasks protecting the structure. To investigate the need to introduce a minimum number and type of additional sensors that do not primarily support the primary control tasks of the device, but are involved in a more precise control of the movement of the structure, such as the effects of cogwheel cogging in the wrists, foot slippage during walking, etc. To review the control solutions published so far for six-legged walking robots. To summarise the solutions so far. To search for solutions that drive the robot/manipulator with good quality at minimum sensor measurement data volume. To investigate the advantages of using fuzzy control for Free(ka) II embedded mechatronic system, to search for the possibilities of minimum computational demand/maximum drive performace. Verify the research results on real robot/manipulator. In the verification process, the results of comparing the operating parameters of the equipment with the results of the computer model will be used to estimate the "behaviour" of the equipment with high confidence, even in extreme cases, by modelling linear and non-linear applications. It is thus possible to modify the drive control procedure in such a way that, even under extreme realistic running conditions, the robot/manipulator is minimally or not at all damaged. The task of drive control encompasses several partially independent tasks, both the matching of run parameters and the development of intelligent search algorithms to interpret and incorporate deviations into the model.

Research objectives:

To build a complete mechatronic model of the robot/manipulator. To search for the minimum required sensor surface during the drive-control development to solve the fast structure optimized protective control loops. Generate run quality measurement un. fittness functions which can be used to quantify the results. Analyze the quality of the fitness functions with respect to robot/manipulator control. To compare the results measured on the robot/manipulator and those generated by the simulated model, and then interpret the differences. Search for drive control procedures with the best parameters according to the defined fitness functions. Carry out a comparative analysis. Estimate the "behaviour" of the robot/manipulator under extreme and nonlinear conditions with the simulation model built. Estimate the expected effects on the structure. Run the robot/manipulator under the modelled extreme conditions and measure the effects. Perform a joint analysis of the results.

Literature:

[1] I. Kecskés and P. Odry, Protective Fuzzy Control of Hexapod Walking Robot Driver in Case of Walking and Dropping. Springer, Vol 313, 2010, pp 205-217.

[2] A. L. Nelson, G. J. Barlow and L. Doitsidis, “Fitness functions in evolutionary robotics: A survey and analysis,” Robotics and Autonomous Systems, vol 57, 2009, pp 345_370.

National and/or international contacts on the above topic:

Fülöp Bazsó, MTA KFKI (RMKI) Budapest

László Négyessy, MTA, SzOTE, Pázmány Péter TE

Szabad(ka) II. mechatronic structure optimisation and verification

Thesis supervisor: Péter Odry

Description of the research topic:

The Free(ka) II six-legged, 3 DOF per leg embedded mechatronic system is suitable for testing and verification of complex mechatronic research results. During the verification process, the comparison of the device's operating parameters and computer model results will yield results that can be used to estimate the "behaviour" of the device with high confidence, even in extreme cases, by modelling linear and non-linear applications in the future. It is thus possible to modify the structure or the program interface in such a way that, even under extreme realistic execution, the robot/manipulator is minimally or not at all damaged. The verification process involves several partially independent tasks, ranging from the matching of run parameters to the development of intelligent search algorithms to formulate and model the interpretation of the deviations.

Research objectives:

To build a complete mechatronic model of the robot manipulator. To compare the results measured on the robot manipulator with those generated by the simulated model, then to interpret the deviations and search for the model structure that generates the minimum deviations compared to the real robot structure. Generate run quality (un. fitness) functions to quantify the results. Estimate the "behaviour" of the robot/manipulator under extreme/nonlinear conditions using the simulation model constructed. Estimate the expected effects on the structure. Run the robot/manipulator under the modelled extreme conditions and measure the effects. Perform a joint analysis of the results.

Literature:

[1] E. Burkus and P. Odry, “Autonomous Hexapod Walker Robot “Szabad(ka)””, Acta Polytechnica Hungarica, vol 5, no 1, 2008, pp. 69-85.

[2] M. F. Silva and J. A. Tenreiro Machado, “Kinematic and dynamic performance analysis of artificial legged systems,” Robotica, vol. 26, 2008, pp. 19–39.

National and/or international contacts on the above topic:

Fülöp Bazsó, MTA KFKI (RMKI) Budapest

László Négyessy, MTA, SzOTE, Pázmány Péter TE

2.5.4 ENGINEERING COMPUTATIONS AND MODELS I

Comparison of numerical methods for systems of linear equations and their technical application

Thesis Supervisor: József Abaffy

Description of the research topic:

Theoretical and practical investigation of numerical methods for systems of linear equations. Choice of algorithms as a function of practical numerical problems, comparison on practical and known test problems.

Research objectives:

- Review and comparative analysis of known methods Software design and comparison of methods.
- Methodological and content improvement of known procedures, with special emphasis on the pivoting capabilities of ABS methods.

Literature:

[1] J. Abaffy and E. Spedicato, ABS Projection Algorithms: Mathematical Techniques for Linear and Nonlinear Equations. Ellis Horwood Ltd., Chichester, England, 1989.

[2] G. H. Golub and C. F. Van Loan, Matrix Computations. 2nd ed., The Johns Hopkins University Press, Baltimore, 1993.

Development of efficient and stable algorithms for solving special-structure nonlinear systems of equations and optimization problems

Thesis Supervisor: Aurél Galántai

Description of the research topic:

Special nonlinear systems of equations with large but sparse structure occur in many settings (discretizations, optimization). One of the most important such areas is the solution of conditional optimization problems via Kuhn-Tucker equations (NCP methods).

Research objectives:

- review and comparative analysis of the literature on special large-scale sparse structure nonlinear problems.
- to develop, implement and apply new, more efficient and stable (projective) methods than previously available.

Examining theoretical and practical issues related to HOSVD

Thesis Supervisor: László Szeidl

Description of the research topic:

The application of higher order tensor decomposition techniques in a variety of theoretical and applied research areas (numerical analysis, control theory, signal processing, image processing, psychometrics, data mining, etc.). The research area focuses mainly on HOSVD based approaches.

Research objectives:

To analyse the theoretical issues arising in HOSVD-based numerical approximation of multivariate functions and to apply the results to the modelling and numerical analysis of practically relevant problems.

Literature:

[1] L. Szeidl, L. et al., “Numerical Reconstruction of the HOSVD Based Canonical Form of Polytopic Dynamic Models,” Proc. of International Symposium on Computational Intelligence and Intelligent Informatics (ISCIII 2007), Agadir, pp. 111-116, 2007.

[2] L. Szeidl, L. et al., “HOSVD Based Method for Surface Data Approximation and Compression,” Proc. of International Conference on Intelligent Engineering Systems (INES 2008), Miami, pp. 197-202, 2008.

[3] L. Szeidl. and P. Várlaki, “HOSVD based canonical form for polytopic models of dynamic systems,” J. Advanced Computational Intelligence, vol. 13, no.1, pp. 52-60., 2009.

[4] A. Rövid and L. Szeidl, “Image processing using polylinear functions on HOSVD basis,” in: Towards Intelligent Engineering and Information Technology. I. J. Rudas, J. Fodor, J. Kacprzyk, Eds, Springer-Verlag, Berlin-Heidelberg, 2009, pp. 419-434.

[5] A. Rövid, L. Szeidl and T. Hashimoto, “Numerical Reconstruction and Compression of Thermal Image Sequences,” in 2012 Fifth International Conference on Emerging Trends in Engineering and Technology, Himeji, Japan, pp. 298-302.

Solving inverse heat transfer problems using bio-inspired algorithms

Thesis Supervisor: Imre Felde

Description of the research topic:

Due to the strong non-linearity and ill-posedness of the mathematical problem, the characteristics of the heat flux density characteristic of the transient heat transfer process cannot be derived directly, and its estimation is possible by solving the Inverse Heat Conduction Problem (IHCP). Different heuristics are available to deal with the IHCP, one type of which is based on the use of bio-inspired or nature-inspired algorithms. The objective of this research topic is to solve the IHCP problem using bio-inspired algorithms.

Research objectives:

1. to explore the potential of some selected algorithms (swarm intelligence based, GA, EA, etc.) for solving IHCP.
2. investigations based on the algorithms

Literature:

[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

International contacts on the above topic:

Universidad de Sao Paulo, Brazil

Universidad Autonomia de Nuevo Leon, Mexico

Representation of flexible bodies and function driven organic shapes

Supervisor: László Horváth

Research topic:

Topic contextually connects two recent research areas in the scope of contextual shape modeling. One is mathematical modeling and simulation of physical system that includes both rigid elements and flexible structures. Other is modeling of function-driven organic shapes. Geometrical and physical properties of a general flexible bodies model are generated using finite element analysis and are undergone dynamical analyses. Organic shapes require modeling which is different from modeling of geometric shapes. Research establishes contextual connection of mathematical, functional, and behavioral modeling and simulation.

Research goals:

This research serves investigation and definition inside and outside contexts of flexible body and function driven organic shape representations then elaboration new mathematical and behavior

models. Results are awaited to provide better understand of contextual model for engineering structures which include flexible bodies and function driven organic shapes. Analyze behaviors and contexts of flexible bodies and function driven organic shapes. Reveal relevant existing research results and define plan of own research work. Study the modeling capabilities in the 3DExperience platform for the relevant roles (See: “Laboratory software” below). Propose new contextual connections and related models. As new own contribution, develop driving contextual connections, mathematical models, behavior representations, and related virtual processes in accordance with the own research plan. Develop experimental engineering model which is appropriate for verification the above results using capabilities available in the 3DExperience. Research in this topic is motivated by industrial problem solving related research capabilities available at the 3DExperience platform. In this way, results can be validated in industrially eligible model and they are potentially suitable for industrial problem solving. At the same time, this means joining to the recent trend for integration of theory and practice.

Laboratory software

Modeling capabilities are available for this student research at the Laboratory of Intelligent Engineering Systems in the 3DExperience platform from cloud for the relevant researcher roles below. Basic modeling capabilities are also available for the development of the experimental engineering model in integration with role related capabilities. Flexible Bodies Library (FBZ) is based on Modelica language to establish direct connection with model developed in 3DExperience. Function Driven Generative Designer (GDE) to explore and generate organic shapes using functional specification. Systems Simulink Export (XSK) serves export Modelica compliant systems behavior models from the 3DEXPERIENCE for simulation within Simulink environment.

Literature:

Recent actual and time-honored classical publications about relevant research results should be surveyed. The planned research should be placed in former published results of others to prove its novelty.

System behavior optimizing by tuning system parameters in engineering models

Supervisor: László Horváth

Research topic:

Recent main change in leading industries is introduction of strongly system operated industrial products. This new situation has fundamentally changed traditional engineering modeling and simulation and placed new emphasis on system level modeling of engineering structures. In this way, research is about improving system level behavior representations using principle of system parameters optimizing in engineering model environment.

Research goals:

This research topic serves investigation and definition system level parameter optimization including systems engineering background, system behaviors, algorithms, and mathematical methods. Results are awaited to provide better understand system level parameter optimization. Analyze system behaviors and related parameters. Reveal relevant existing research results and define plan of own research work. Study the modeling capabilities in 3DExperience platform for the relevant roles (See: “Laboratory software” below). Propose method for tuning systems parameters considering multiple criteria and multiple cases. As new own contribution, develop system parameters optimizing algorithms and related procedures to improve the overall system behavior. Define mathematical optimization criteria using simulation results in accordance with the own research plan. Develop experimental engineering model which is appropriate for verification the above results using capabilities available in the 3DExperience. Research in this topic is motivated by industrial problem solving related research capabilities available at the 3DExperience platform. In this way, results can be validated in industrially eligible model and they are potentially suitable for industrial problem solving. At the same time, this means joining to the recent trend for integration of theory and practice.

Laboratory software

Modeling capabilities are available for this student research at the Laboratory of Intelligent Engineering Systems in the 3DExperience platform from cloud for the relevant researcher roles below. Basic modeling capabilities are also available for the development of the experimental engineering model in integration with role related capabilities. Dynamic Systems Designer (SDY) for the modeling, simulation and validating engineering systems immersed in model-based systems engineering. Compliant with the open Modelica language and includes domain specific Modelica libraries for modeling and simulation of multi-body and multi-physic systems. Systems Behavior Optimization (DOY) to optimize and tune systems parameters of a device or its controller for multiple criteria and multiple cases. Systems Simulink Export (XSK) serves export Modelica compliant systems behavior models from the 3DEXPERIENCE® Platform for simulation within a Simulink environment.

Literature:

Recent actual and time-honored classical publications about relevant research results should be sur

veyed. The planned research should be placed in former published results of others to prove its novelty.

Integrated simulation processes to drive geometry and simulation parameters in engineering models

Supervisor: László Horváth

Research topic:

Conventional engineering model includes standalone or slightly integrated simulations. Need for simulations in multi-physics and multi-scale systems placed the emphasis on organized simulations which are defined in organized experiments. This new situation basically changed the innovation process for generic modeling of engineering structures. In the context of this topic, phrase engineering structure is applied for multidisciplinary system-based experimental engineering configuration.

Research goals:

This research topic is aimed to make research in integrated and coordinated simulations for multi-physics, multi-scale system. Purpose of research is to conceptualize and define models for complex simulation processes, physics connections methods, and parameter driving of simulations. Results are awaited to provide better understand of multi-physics, multi-scale system related contextual simulations. Analyze simulations in multi-physics and multi-scale systems. Reveal relevant existing research results and define plan of own research work. Study the modeling capabilities in 3DExperience platform for the relevant roles (See: “Laboratory software” below). Propose method for tuning systems parameters considering multiple criteria and multiple cases. As new own contribution, develop models for processes, physics connections methods, and parameter driving of simulations in accordance with the own research plan. Define mathematical optimization criteria using simulation results. Develop experimental engineering model which is appropriate for verification the above results using capabilities available in the 3DExperience. Research in this topic is motivated by industrial problem solving related research capabilities available at the 3DExperience platform. In this way, results can be validated in industrially eligible model and they are potentially suitable for industrial problem solving. At the same time, this means joining to the recent trend for integration of theory and practice.

Laboratory software

Modeling capabilities are available for this student research at the Laboratory of Intelligent Engineering Systems in the 3DExperience platform from cloud for the relevant researcher roles below. Basic modeling capabilities are also available for the development of the experimental engineering model in integration with role related capabilities. Simulation Process & Optimization (SPI) to integrate simulations into re-usable and deployable processes to power research. Multiscale Experiment Creator (SWR) creates, executes, explores, monitors, and evaluates collaborative simulation for multi-physics, multi-scale system experiments. Definition coupling schemes between physics is available. Multiscale Systems Analyst (MCO) ensures Dymola Behavioral Modeling where collaborative simulation experiments require Dymola. Compliant with the open Modelica language and includes domain specific Modelica libraries for modeling and simulation of multi-physic systems.

Literature:

Recent actual and time-honored classical publications about relevant research results should be surveyed. The planned research should be placed in former published results of others to prove its novelty.

Two-way driving connection between model and cyber units of CPS robot system

Supervisor: László Horváth

Research topic:

Recent new paradigm of cyber physical system (CPS) changed research and development of multidisciplinary engineering structures. In the context of this topic, phrase engineering structure is applied for multidisciplinary system-based experimental engineering configuration. CPS exists in virtual (complex model) and field operating forms. Its production is done in production system which is the third a CPS in the scenario and is based on the recent paradigm of Industry 4.0. This research topic was defined to establish and improve communication between virtual and field operating forms of CPS robot system.

Research goals:

Research topic includes definition active logical, mathematical, and algorithmic connections between representations in robot model system and cyber units in field operating robot system. Emphasis is on finding connectable active model objects in robot model and relevant cyber unit objects then establishing connection. Other aim is proposal application actual information about physical unit operation at improving robot model representation. Actual information about physical unit operation is collected by sensor network then communicated by cyber units of CPM. Study the scenario which includes generic robot model, controller in robot model, configuration of joints for generic robot kinematic classes, recognized cyber units in robot control systems, and information derived from intelligent sensor network. Reveal relevant existing research results and define plan of own research work. Restrict the scenario to selected relevant objects. Study the modeling capabilities in 3DExperience platform for the relevant roles (See: “Laboratory software” below). As new own contribution, define and verify active logical, mathematical and algorithmic connections between representations in robot model system and cyber units in field operating form of robot system in accordance with the own research plan. Develop experimental engineering model which is appropriate for verification the above results using capabilities available in the 3DExperience. Simulate the cyber units involved. Research in this topic is motivated by industrial problem solving related research capabilities available at the 3DExperience platform. In this way, results can be validated in industrially eligible model and they are potentially suitable for industrial problem solving. At the same time, this means joining to the recent trend for integration of theory and practice.

Laboratory software

Modeling capabilities are available for this student research at the Laboratory of Intelligent Engineering Systems in the 3DExperience platform from cloud for the relevant researcher roles below. Basic modeling capabilities are also available for the development of the experimental engineering model in integration with role related capabilities. Mechatronic Systems Designer (SMQ) provides Modelica and 3DEXPERIENCE related capabilities to develop, simulate and validate complex mechatronic systems. Robotics Engineer (RTS) provides capabilities for simulation and validation robot system behavior. Robotics in the V6 system provides capabilities

for model definition of robot system, robot control, direct and invers kinematics, velocity and acceleration, motion sets, kinematic relations, and realistic robot simulation. Basic modeling capabilities are available in integration.

Literature:

Recent actual and time-honored classical publications about relevant research results should be surveyed. The planned research should be placed in former published results of others to prove its novelty.

Unconventional network computation methods

Thesis supervisor name: Péter Kádár

Description of the research topic:

Conventionally, the flows of electric power networks can be computed using iterative Load-Flow methods. The different applications and new techniques (neural networks, heuristic solutions, optimization solutions) give rise to new approaches.

Research objectives:

In this work, after enumeration of these techniques, sample applications will be developed for different techniques and their efficiency will be evaluated.

The potential of intelligent innovative decision support systems for energy-conscious building design

Thesis supervisor: István Krómer

Description of the research topic:

In the first phase of building design, the efficient energy assessment of possible options is not solved, but the use of IT tools can significantly facilitate the identification of optimal solutions. A complex design model, based on fuzz logic for design parameters and technical conditions and neural networks for consumer behaviour, would provide more accurate results on the expected energy consumption of the designed buildings than the currently used average consumer model.

Research objectives:

The aim of the research is to create a decision support system that can provide reliable data for the selection of the applicable solutions already at the design stage.

Literature:

[1] D. Kolokotsa, “Artificial Intelligence in Buildings: A review on the application of fuzzy logic.” Advances in Building Energy Research, vol. 1, issue 1, 2007.

[2] C. Diakaki et al., “A multi-objective decision model for the improvement of energy efficiency in buildings.” Energy, vol. 35, 2010.

2.5.5 MATHEMATICAL PRINCIPLES AND APPLICATIONS

Multistage methods in the projective class of ABS and their parallelization

Thesis Supervisor: József Abaffy

Description of the research topic:

ABS methods cover the majority of methods for solving finite-step linear as well as nonlinear systems of equations. One of the most important properties of the ABS class of methods is that the algorithms implemented in it can be well parallelized. An example is the implicit Gaussian elimination. It has been shown in [5] that most of the linear and quadratic programming methods and other optimization methods can be derived from the ABS method class. In [2], an application of the two-stage method to ABS has been shown. In [3], it was shown that finding an admissible solution and constructing the projection matrix H of the ABS class can be done in parallel, thus significantly reducing the number of operations required to start the two-stage method. The results obtained in the two papers can thus be combined in a suitable algorithm, which could be the first result of a PhD thesis. The above results can also be transferred to the multistage case (4). The doctoral thesis is, furthermore, thus, the realization and practical application of this extension, with special emphasis on the possibility of parallelization. In addition to the required mathematical results, the doctoral student should therefore also apply the results, e.g. using MATLAB language programs, and preferably to a concrete problem.

Research objectives:

The results obtained in the two articles can thus be combined in a suitable algorithm, which could be the first result of the PhD thesis. The above results can be transferred to the multistage case [4]. Furthermore, the PhD topic is, therefore, the implementation and practical application of this extension, in particular the possibility of parallelization. In addition to the mathematical results required, the doctoral student must therefore also apply the results, e.g. using MATLAB language programs, and preferably to a concrete problem.

Literature:

[1] J. Abaffy and E. Spedicato, ABS Projections Algorithms: Mathematicall Techniques for Linear and Nonlinear Algebraic Equations. Ellis Horwood Ltd, Chichester, England, 1989.

[2] J. Abaffy and E. Allevi, “A modified L-shaped method,” Journal of Optimization Theory and Applications, vol. 123, no. 2, 2004, pp. 255-270.

[3] J. Abaffy, X. J. Liang and Z. Q. Xia, “A modified non-simplex active set method for the standard LP problem”, PU.M.A., vol. 23, no. 1, 2012, pp. 1-12.

[4] A. Prékopa, Stochastic Programming. Kluwer Academic Publisher, 1995.

[5] Z. Liwei, X. Zunquan and F. Enmin, Introduction to ABS methods in Optimization. Dalian University of Technology Press, 1998.

Solving nonlinear systems of equations by ABS projection methods and their applications

Supervisors: József Abaffy, Aurél Galántai

Description of the research topic:

ABS methods are basically a class of methods for solving finite-step linear systems of equations. Later on, methods for solving nonlinear systems of equations were derived from it [1], [2]. One of the main fundamental properties of the ABS method class is that the algorithms implemented in it can be well parallelized. As an example, the implicit Gaussian elimination is worth mentioning. Methods solving nonlinear systems of equations can also be parallelized.

Recent results suggest that the ABS class of methods can be applied not only to solve n*n nonlinear systems of equations, but also to solve underdetermined systems of equations [3], [4].

Research objectives:

The thesis topic is to summarize the nonlinear systems of equations, obtain new results, and implement the algorithms in MATLAB. The task is also to compare the algorithms in ABS with currently curated algorithms, which can be found, for example, in MATLAB. Furthermore, the parallelization of major ABS nonlinear algorithms is a PhD topic. Choosing from the implemented algorithms, the PhD student is also tasked with applying them to a real-world problem.

Literature:

[1] J. Abaffy J. and E. Spedicato, ABS Projections Algorithms: Mathematicall Techniques for Linear and Nonlinear Algebraic Equations. Ellis Horwood Ltd, Chichester, England, 1989.

[2] A. Galántai,: Projectors and Projection Methods. Kluwer Academic Press, 2004

[3] J. Ortega and W. Rheinboldt, Iterative Solution of Nonlinear Equations in Several Variables. Academic Press, 1970

[4] other relevant papers

Generalised gamma convolutions and indefinitely divisible distributions

Thesis Supervisor: Árpád Baricz

Description of the research topic:

Generalized gamma convolutions and indefinitely divisible distributions play an important role in probability theory. Several of the known distributions are known to be indefinitely divisible distributions, but their proof often requires special techniques involving special functions such as Tricomi hypergeometric functions, parabolically cylindrical functions, first and second order modified Bessel functions. Mourad Ismail has investigated the subject in several papers and in his proofs of the proportions of the aforementioned special functions he proved that they are Stieltjes transformed.

Research objectives:

In the proposed research, we would like to continue Ismail's research on the issues related to generalized gamma convolutions and related classes of distributions and densities as formulated in Lennart Bondesson's book [Generalized gamma convolutions and related classes of distributions and densities. Lecture Notes in Statistics, 76. Springer-Verlag, New York, 1992]

Optimization with linguistic variables

Supervisor: Róbert Fullér

Description of the research topic:

Suppose we are given a mathematical programming problem in which the functional relationship between the decision variables and the objective function is not completely known. Our knowledge-base consists of a block of fuzzy if-then rules, where the antecedent part of the rules contains some linguistic values of the decision variables, and the consequence part consists of a linguistic value of the objective function. We could use fuzzy reasoning method to determine the crisp functional relationship between the objective function and the decision variables, and solve the resulting (usually nonlinear) programming problem to find a fair optimal solution to the original fuzzy problem.

Research goals:

To solve real-life optimization problems in imprecise environment where the input data are obtained from subjective judgements.

Bessel sampling

Thesis leader: Tibor Pogány

Description of the research topic:

The theory of J, Y -Bessel sampling sets is based on the articles by Whittaker, Higgins, Zayed, Jerri as well as Knockaert, where signals with Hankel transforms were sampled by the mentioned authors according to Kramer's procedure. At present, a new theory of I-Bessel sampling sets is due, where the sampling set consists of zero spaces of the modified I-Bessel function and the kernel of the sampling sets is a certain transform of I. If the correlation function of the stochastic process is one of these special functions, then the spectral production of the original process is known by the Karhunen-Cramér theorem, and the process can be reconstructed by Bessel sampling.

Research objectives:

Similar results can be expected if I is replaced by Struve H, modified Struve L, and Hankel function. Other expected results: line truncation error estimation, "average" Bessel sampling lines, modified kernel Bessel sampling with convergence acceleration, either in the sense of L2 or P = 1.

Literature:

[1] D. J. Maširević et al., “Sampling Bessel functions and Bessel sampling,” Proceedings of the 8th International Symposium on Applied Computational Intelligence and Informatics, May 23-25, 2013, Timisoara, Romania, pp. 79-84.

[2] L. Knockaert, “A class of scaled Bessel sampling theorems,” IEEE Trans. Signal Process., vol. 59, no. 11, 2011, pp. 5082-5086.

[3] A. Ya. Olenko and T. K. Pogány, “A precise upper bound for the error of interpolation of stochastic processes,” Theor. Probab. Math. Statist., AMS, USA, vol. 71, 2005, pp. 151-163.

[4] A. Ya. Olenko and T. K. Pogány, “Time shifted aliasing error upper bounds for truncated sampling cardinal series,“ J. Math. Anal. Appl., vol. 324. 2006, pp. 262–280.

[5] A. Ya. Olenko and T. K. Pogány, “On sharp bounds for remainders in multidimensional sampling theorem,” Sampling Theory in Signal and Image Processing, vol. 6, no. 3, 2007, 249-272.

[6] A. Ya. Olenko and T. K. Pogány, “Average sampling reconstruction of harmonizable processes,” Comm. Statist. Theor. Methods, vol. 40, no. 19-20, 2011, pp. 3587-3598.

[7] T. Pogány, “On the Brown aliasing error upper bound for homogeneous random fields,” Signal Processing, vol. 33, 1993, pp. 127-129.

[8] T. Pogány, “Almost sure sampling restoration of bandlimited stochastic signals,” in Sampling Theory in Fourier and Signal Analysis: Advanced Topics. J.R.Higgins, R.L.Stens, Eds., Oxford University Press, Oxford, 1999, pp. 203-232.

[9] T.K. Pogány, “Local growth of Weierstraß σ-function and Whittaker-type derivative sampling,” Georgian Mathematical Journal, vol. 10, no. 1, 2003, pp. 157-164.

[10] T. K. Pogány, “Whittaker-type derivative sampling reconstruction of stochastic L^α(Ω) - processes,” Applied Mathematics and Computation, vol. 187, no. 1, 2007, pp. 384-394.

[11] T. Pogány and P. Peruničić, “On the sampling theorem for homogeneous random fields,” Theory Probab. Math. Stat., vol. 53, 1996, pp. 153-159.

[12] I. Zayed, Advances in Shannon's Sampling Theory. CRC Press, New York, 1993.

Integral form and summation of function series

Thesis leader: Tibor Pogány

Description of the research topic:

The application of Mathieu, alternating Mathieu, Neumann, Kapteyn, Schlömilch and Dini series is well known in both engineering and natural sciences, see among others [1, 2] and the literature mentioned there. Their integral forms are discussed in the literature listed. The mathematical tools are: Laplace integral of Dirichlet series, Cahen formula, integral of Bessel functions.

Research objectives:

One main research direction deals with the relation between alternating Mathieu series and Hilbert-Eisenstein series introduced by Hauss about twenty years ago, while the other research direction treats Schlömilch and Dini series as sampling series. Some results have already been obtained in the first research topic and are presented in the book chapter [2].

Literature:

[1] Á. Baricz and T. K. Pogány, “Integral representations and summations of modified Struve function,” Acta Math. Hung.,2012.

[2] Á. Baricz and T. K. Pogány, “Properties of the product of modified Bessel functions,” Springer Volume: Analytic Number Theory, Approximation Theory, and Special Functions - In Honor of Hari M. Srivastava.

[3] Á.Baricz, D. Jankov and T. K. Pogány, “Integral representations for Neumann-type series of Bessel functions I_ν, Y_ν and K_ν,“ Proc. Amer. Math. Soc., vol. 140, no. 3, 2012, pp. 951-960.

[4] Á.Baricz, D. Jankov and T. K. Pogány, “Turán type inequalities for Krätzel functions,” J. Math. Anal. Appl., vol. 388, no. 2, 2012, pp. 716-724.

[5] Á.Baricz, D. Jankov and T. K. Pogány, “Neumann series of Bessel functions,” Integral Transforms Spec. Func., vol. 23, no. 7, 2012, pp. 529-538.

[6] D. Jankov, T. K. Pogány and R. K. Saxena, “Extended general Hurwitz-Lerch Zeta function as Mathieu (a, λ) - series,” Appl. Math. Letters, vol. 24, no. 8, 2011, pp. 1473-1476.

[7] D. Jankov and T. K. Pogány, “Integral representation of functional series with members containing Jacobi polynomials,” Math. Balkan, vol. 26, no. 1-2, 2012, pp. 103-112.

[8] D. Jankov and T. K. Pogány, “Integral representation of Schlömilch series,” J. Classical Anal., vol. 1, no. 1, 2012, pp. 75-84.

[9] G. V. Milovanović and T. K. Pogány, “New integral forms of generalized Mathieu series and related applications,” Appl. Anal. Discr.Math., vol. 7, no.1, 2013, pp. 180-192.

[10] T. K. Pogány, H. M. Srivastava and Z. Tomovski, “Some families of Mathieu a - series and alternating Mathieu a - series,” Appl. Math. Comput., vol. 173, no. 1, 2006,pp. 69 - 108.

Theoretical and practical issues in modelling stochastic systems

Thesis Supervisor: László Szeidl

Description of the research topic:

Modelling and numerical solution of specific problems in the field of science-natural sciences-economics (transport informatics, logistics, telecommunication networks, etc.).

Research objectives:

Modelling processes of a stochastic nature usually requires deep mathematical, engineering and computer science knowledge to solve a wide range of problems. The primary objective is to provide an overview of the theoretical, algorithmic, methodological and software background required to study the problems. Based on this, the next task is to develop a model that fits the specific problem, identify the model parameters and analyse the resulting model numerically.

Literature:

[1] P. Michelberger, L. Szeidl and P. Várlaki, Alkalmazott folyamat-statisztika és idősoranalízis. Typotex Kiadó, Budapest, 2001.

[2] J. Izsák J. and L. Szeidl, Fajabundancia-eloszlási modellek. Pars Könyvek, Nagykovácsi, 2009.

[3] N. Fodor et al., “MV-WG: a new multi-variable weather generator,” Meteorology and Atmospheric Physics, vol. 107, 2010, pp. 91–101.

[4] C. Ricotta et al., “A partial ordering approach for functional diversity,” Theoretical Population Biology, VOL. 80, 2011, pp. 114-120.

[5] L. Lakatos, L. Szeidl, and M. Telek, Introduction to Queueing Systems with Telecommunication Applications, Springer, New York Heidelberg Dordrecht London, 2013.

Ranking decision units in the Data Envelopment Analysis methodology

Thesis supervisor: János Fülöp

Description of the research topic:

Data Envelopment Analysis is now a widely accepted methodology for measuring the relative effectiveness of decision making units. However, one of the shortcomings of the classical methodology is that it sometimes shows too many decision units as efficient. Intensive research is underway to develop methods that rank decision units more disaggregatedly, including those considered effective according to the classical methodology.

Research objectives:

The research aims to review methods for ranking alternatives to Data Envelopment Analysis in addition to ranking methods for multivariate decision making, and to examine how methods in one area can be adapted to other areas.

Literature:

[1] W.W. Cooper, L.M. Seiford and J. Zhu, Eds., Handbook on Data Envelopment Analysis. Kluwer Academic Publishers, 2004.

Solving global optimization problems with special structures

Thesis Supervisor: János Fülöp

Description of the research topic:

Practical optimization problems are often nonconvex, i.e. they may have many local optima, and therefore global optimization techniques have to be applied to solve them. An efficient solution of global optimization problems is possible only if the structure and special properties of the problem can be exploited to advantage in the methodology. Examples of such special structures are inverse convexity, difference of convex functions and monotonicity, etc.

Research objectives:

The main objective of the research would be to develop a methodology based on separating the convexity and non-convexity properties of a given non-convex task and exploiting this advantageously. The research would specifically investigate how the methodology can be adapted when optimizing on an efficient set of multi-objective optimization tasks, which is a well-known global optimization task with a special structure.

Development of symbolic algorithms to minimize overestimation of interval inclusion functions

Thesis Supervisor: Tibor csendes

Description of the research topic:

It is well known that one of the weaknesses of interval arithmetic-based inclusion functions, which play an important role in reliable numerical computations, is the sometimes considerable overestimation, the significant deviation of the conservative bounds from the set of values. On the other hand, several forms of rewriting are known that reduce this phenomenon and improve the quality of the inclusion functions substantially. The proposed research aims to implement in a symbolic algebra system an automatic rewriting that is expected to improve the efficiency of the computational procedures that are built on top of it.

Research objectives:

1. implement a symbolic transformation procedure in Mathematica or Maple
2. demonstrate the quality and impact of rewritten versions of interval inclusion functions by exhaustive computer testing.

Literature:

[1] G. Alefeld and J. Herzberger, Introduction to interval computation. Academic Press, 1983.

[2] E. Antal, T. Csendes, and J. Virágh, Nonlinear Transformations for the Simplification of Unconstrained Nonlinear Optimization Problems. Accepted for publication in CEJOR.

Development and testing of symbolic algorithms to simplify nonlinear optimization problems

Thesis Supervisor.

Description of the research topic:

The difficulty of solving nonlinear optimization problems lies largely in the complexity of the objective function and the constraint functions. Although it may seem difficult, there are theoretical and practical possibilities, based on the two literature references given, to simplify these functions in such a way that the solutions of the new problem can be matched to the solutions of the original problem.

Research objectives:

1. to implement and improve the described procedure towards the most complete usability possible.
2. exhaustive testing of the resulting algorithm by solving standard test problems in the field and real practical problems.

Literature:

[1] T. Csendes and T. Rapcsák, “Nonlinear coordinate transformations for unconstrained optimization. I. Basic transformations,” J. of Global Optimization, vol. 3, 1993, pp. 213-221.

[2] T. Rapcsák and T. Csendes, “Nonlinear coordinate transformations for unconstrained optimization. II. Theoretical background,” J. of Global Optimization, vol. 3, 1993, pp. 359-375.

Stochastic modelling of abrasive manufacturing surfaces

Thesis Supervisor: Sándor Fegyverneki

Description of the research topic:

During abrasive manufacturing process, when the tool has an indefinite edge (grinding, abrasive grinding), stochastic models play a major role in describing the resulting surfaces and other manufacturing related parameters. Comparison of Greenwood-Williamson, Majumdar-Bhushan, etc. models. Development of new simulation techniques and comparison with those in the literature (Blackmore-Zhou, Weierstrass-Mandelbrot). Comparison of fractal dimension and fractal index. Determination of surface characteristics (fractal dimension, topothesis) and their relation to other mechanical and manufacturing problems. Description, simulation, visualization and determination (estimation) of stochastic fields of stationic isotropic and anisotropic stochastic fields. Applications.

Research objectives:

1. Review of basic models, simulation and estimation techniques.
2. Classification, mathematical and tribological characterisation of surfaces obtained during the abrasive manufacturing process.
3. Development of estimation techniques. Simulation of suitable surfaces based on mechanical and surface characteristics.
4. Measurement, processing and visualisation of profilograms.

Robust estimates and their properties

Thesis Supervisor: Sándor Fegyverneki

Description of the research topic:

It is common for measurement data to have outliers that are different from the others, which can be due to error or real measurement. A further problem is the persistent nature of the contamination deposited on the data. From both a user and research point of view, it is important to develop and improve methods to filter out or handle outliers or contamination. For different types of distributions, it is important to develop appropriate parameter estimates, to numerically determine the estimates and to specify their properties. This is particularly important for random vectors or when the independence of the data (the sample) cannot be assumed. In particular, the estimation of parameters (development of the corresponding numerical procedures) for the three-parameter Weibull distribution family, the Gamma distribution family and the Student distribution family (degrees of freedom cannot be an integer). Also, parameter estimates for the multivariate version of the Student distribution family.

Research objectives:

1. to review the theory of robust estimation, including the numerical algorithms used.
2. to develop estimators for the listed families of distributions and to study the properties of the estimators. Develop simulation techniques to demonstrate robustness.

Solver algorithms for large systems of linear equations

Thesis Supervisor: Csaba Hegedűs

Description of the research topic:

When solving large systems of linear equations, a common problem is that the number of conditions of the system is very large, which makes fast convergence practically impossible, and in some cases, even finding a solution with the desired accuracy. One solution method in such cases is preconditioning. The disadvantage is that for each type of matrix a different method has to be developed. Convergence is often slow due to some very small eigenvalues or singular values. Conjugate direction methods give the possibility to construct the solution separately for the subset of eigenvectors with small eigenvalues. Starting with the initial_vector constructed here, we can then use conjugate direction methods to achieve convergence speeds as if the small eigenvalues were not present. The subject is the development and testing of such algorithms.

Numerical solution of complex diffusion problems in several dimensions

Thesis Supervisor.

Description of the research topic:

In the natural sciences, it has been observed in several phenomena that the change in concentration of certain substances is super- or subdiffusive instead of the expected diffusive dynamics. The model for such phenomena is a partial differential equation where the spatial differential operator is of fractional order. Although several numerical methods for the numerical approximation of the solution of these problems have been developed in the last decade, several details need further development.

Research objectives:

For multidimensional problems, approximation methods should be developed that model the boundary conditions well and their convergence can be proved. It would be worthwhile to investigate whether such a method could be accelerated, for example, by rewriting to ADI type, by choosing a special linear solver method.

Literature:

[1] M. Gunzburger, R. Lehoucq and K. Zhou, “Analysis and approximation of nonlocal diffusion problems with volume constraints,” SIAM Review, vol. 54, 2012, pp. 667-696.

[2] M.M. Meerschaert and C. Tadjeran, “Finite difference approximations for fractional advection-dispersion flow equations,” Journal of Computational and Applied Mathematics, vol. 172, no. 1, 2004, pp. 65-77.

Automatic setting of parameters for optimisation algorithms

Thesis supervisor: István Maros

Description of the research topic:

Computer implementations of optimization algorithms are governed by a number of parameters. The correct setting of these parameters largely determines the reliability and efficiency of the solution. Unfortunately, the correct parameter values are mostly task or task family dependent. Some of the parameters are numerical, others are strategic. It would be ideal to be able to set the best parameter values based on the analysis of the task to be solved. However, even this is not enough, as there is evidence that the correct (optimal) values change during the solution. Comprehensive research in this area has not yet been done.

Research objectives:

1. to investigate the potential of the pretest for some selected algorithms (e.g. simplex for linear programming, branch and bound for solving mixed integer problems).
2. To investigate the on-the-fly "tuning" of the algorithms.

Literature:

[1] I. Maros and G. Mitra, “Investigating the Sparse Simplex Algorithm on a Distributed Memory Multiprocessor,” Parallel Computing, vol. 26, no. 1, 2000, pp. 151-170.

International contacts on the above topic:

University of Edinburgh, Scotland, United Kingdom,

Imperial College, London, United Kingdom.

Fuzzy optimisation

Thesis Supervisor: Róbert Fullér

Description of the research topic:

Fuzzy optimization refers to optimization problems with fuzzy parameters. It can be seen that, for a linear programming problem with a generally noncorrect setup, replacing the real coefficients by symmetric triangular fuzzy numbers makes the problem a correct setup. This is also true for the system of equations Ax=b, i.e. the fuzzy extension is nothing more than a regularization of the original problem.

Research objectives:

The task is to investigate in which cases a fuzzy extension is a regularization of the original problem.

Intelligent decision models

Thesis Supervisors:Róbert Fullér

Research topic description:

Computationally intelligent methods play an increasingly important role in the creation and operation of engineering systems. In the last decades, computational models and techniques have been developed to handle the increased complexity of systems from an engineering point of view. Fuzzy theory plays a significant role in engineering solutions to these problems. The aggregation of uncertain, imprecise information appears in numerous application areas related to the development of intelligent systems (neural networks, multi-criteria decision support systems, etc.). Ordered Weighted Averaging (OWA) operators were introduced by Ronald R. Yager for aggregating criteria in multi-criteria decision problems. OWA operators are well suited to selection problems where the alternative that best satisfies the criteria must be chosen from among several candidates and on the basis of often conflicting opinions of several experts, and where, of course, there is no mathematically unique best solution. Subjective factors are also involved in the decision. The choice of the appropriate aggregation operator is not a simple task, since it is first necessary to determine the degree of compensation, i.e. the extent to which poorer performance on one criterion can be offset by better performance on other criteria. The most important aggregation operators are t-norms (intersection), t-norms (union), and averaging operators. The union gives a high output value whenever any of the inputs indicating the degree of satisfaction is high, while the intercept gives a high output value only when all the inputs are high. The averaging operator has the property that a criterion with a higher satisfaction level can compensate for the low satisfaction level of another criterion. Our goal is to investigate - how to make a decision under strong uncertainty - how to choose the appropriate aggregation operator for decision processes where smoothing is allowed - how to model decision maker preferences with fuzzy sets.

Research objectives:

The doctoral topic will include, on the one hand, the development of decision-preparation methods and procedures based on this state-of-the-art mathematical model, the creation of decision models (determination of compensation rates, project ranking, development of a mechanism for the criterion-based evaluation of alternatives, determination of aspect weights in multi-criteria decision tasks, modelling of real decision problems and construction of utility functions for the criterion-based evaluation of alternatives).

OWA operators in decision support

Theme leader: Róbert Fullér

Description of the research topic:

The Ordered Weighted Averaging (OWA) operators were introduced by Ronald R. Yager for the treatment of aggregation problems where the criteria are of nearly equal importance. Choosing the appropriate aggregation operator is not a simple task, since one must first determine the degree of compensation, i.e., the extent to which poorer performance on one criterion is offset by better performance on other criteria.

Research objectives:

The task is to identify an OWA operator whose level of compensation is given and takes into account sub-performances as well as possible.

Dependency analysis using multi-valued logical operators

Thesis Supervisor: József Dombi

Description of the research topic:

One of the most important objectives of data mining is the exploration of correlations: the basic algorithm of statistical methods is correlation calculus. However, for discrete categories this procedure is not applicable and other indicators need to be introduced. A significant problem is that data mining tasks involve huge databases and only very simple operations are allowed. The Frank operator of the continuous logic satisfies the identity of the measure and by using it it is possible to perform novel association tests. In this case the computational demand is minimal and allows the analysis of basic discrete categories.

Research objectives:

1. Combining the results with classical methods.
2. Development of a visual representation.
3. Examination of multiple correlations.. overview mapping of correlation analyses.
4. To investigate the properties of the Frank operator.
5. Frequencies and operator parameter fitting.
6. Combining the results with classical methods.
7. Development of a visual representation.
8. Examination of multiple correlations.

Literature:

[1] E. P. Klement, R. Mesiar and E. Pap, Triangular norms.

[2] M. J. Frank, On the simultaneous associativity.

Robot control based on Voronoi diagram approximation

Thesis Supervisor.

Description of the research topic:

The most successful application of fuzzy systems is fuzzy control. The common feature of different solutions is that they describe the condition using continuous logic and the set membership functions are one-dimensional. The basic problem is that the number of variables (m) and the number of categories (n) used would require nm rules, which are not feasible to specify, and therefore the methods are aimed at dealing with incomplete rule sets. However, if the rule system is constructed on the basis of sample (typical) examples, the Voronoi diagram defines the domain of validity of the rule, but then the function of membership to a one-dimensional set is replaced by the inflation procedure. Thus the rule set can remain bounded. The approximation power of the procedure determines its goodness.

Research objectives:

1. study and implementation of classical procedures for fuzzy control.
2. Efficient computation of hyperplane equations of the Voronai diagram.
3. Application of the inflating procedure.
4. To study the efficiency of approximation.
5. Practical application and tests.

Literature:

[1] H. T. Nguyen and M. Sugeno, Fuzzy systems, Modeling and Control. Kluwer Academic Pub., 1998.

2.5.6 ENGINEERING COMPUTATION AND MODELS II

Optimal management on Carnot groups

Thesis Supervisor: Péter Nagy

Description of the research topic:

Optimal control problems of nonholonomic mechanical systems with transitive symmetry groups can be well modeled by studying the balinvariant sub-Riemannian geometry of so-called Carnot groups. The simplest case of a Carnot group is the Heisenberg group, which is a two-step nilpotent Lie group with a 1-dimensional center, provided that the subspace defining the preferred balinvariant distribution does not contain the center. In these nonholonomic geometries, geodesics describe the optimal trajectories. The structure of geodesics involving the singular left invariant distribution is well known in the theory of Riemannian nilsocities, but little is known about optimal trajectories in the general case, and many open and interesting problems can be formulated in this context.

Research objectives:

In the proposed research we intend to study the geodesics and isometries of sub-Riemannian spaces of classical groups using computer algebra tools.

Comparison of new SVD- and fixed-point transform-based adaptive control methods with classical model-based methods in nonlinear paradigms

Thesis Supervisor.

Description of the research topic:

Classical adaptive control methods such as "Adaptive Inverse Dynamics", "Adaptive Slotine-Li Robot Control" or "Global Linearization" are model-based methods that exploit some fine details of the available analytical models and assume that the dynamical interactions between the system from the outside and between its components are known. In practice, this information is generally not available in its entirety (e.g. we only have models of certain 'dominant' subsystems), is imprecise, and does not exclude unknown external interactions that may manifest themselves in 'model-different' behaviour of the controlled system towards the controller. This is generally a difficulty for classical methods, while the new approach aims to eliminate these difficulties and reduce the computational complexity.

Research objectives:

1. 1. to review the best known methods, to simulate suitable paradigms in computer programs and to accumulate computational results.
2. 2. to implement newer methods and to compare their performance on the same paradigms, and to propose improvements to the new methods based on the results of the tests.

Comparison of new SVD- and fixed-point transform-based adaptive control methods with classical "Soft Computing" based methods in nonlinear paradigms

Thesis Supervisor: Imre Rudas

Description of the research topic:

Classical "Soft Computing" based approaches can be considered as model-based procedures that either "model" only the system to be controlled or the whole control task, but these models are not "analytical" in nature, but are based on universal approximation structures. They have the advantage of being self-learning and easy to incorporate knowledge that can be expressed in ordinary human language into the model, but have the disadvantage of being 'poorly scalable' or 'the curse of dimensionality', i.e., the fact that the size of the required universal approximation structures increases non-polynomially with increasing degrees of freedom of the system. The proposed new approaches aim to eliminate these difficulties of "traditional soft computing".

Research objectives:

1. 1. to review the best known procedures, simulate suitable paradigms in computer programs and accumulate computational results.
2. 2. to implement and comparatively test the operation of newer methods on the same paradigms, and to propose improvements to the new methods based on the test results.

Combining adaptive control techniques based on the algebraic application of abstract Lie groups with a Robust Fixed Point Transform based method

Thesis Supervisor: József Tar

Description of the research topic:

For the purpose of "temporal, situation-dependent" system modelling, initial results were obtained by using different abstract Lie groups for "system identification", in which a multiplication by a special matrix was applied in each control cycle, and the model was used by using invertible matrices of these special matrices with very low operational requirements. In addition, methods based on the "Robust Fixed Point Transform (RFPT)", which can be stabilised by tuning a control parameter, have proved to be well suited for the control of smooth systems, and have been shown to further refine the control signals derived from the approximate system models used in the controller in a simple, geometrically well interpreted way.

Research objectives:

1. the aim is to combine these two types of methods for the control of systems whose models have very little and unreliable knowledge.
2. to introduce limiting procedures to reduce the initial large feedback signal of the identification algorithm.

A new geometric approach to adaptive control of nonlinear systems using fractional derivatives

Thesis Supervisor: József Tar

Description of the research topic:

Different variants of the recently developed geometric-principled adaptive control at OU are based on the observation of the responses of physical systems to different excitations that are phenomenologically appropriate. The responses may be derivatives of different orders depending on the physical nature of the systems under study, which may cause the noise sensitivity of this approach. While the equations of state of most 'idealised' classical physical systems, described by models that are assumed to be complete for all their subsystems, are usually systems of differential equations or integral equations of state for the integral derivatives of the physical state (e.g. acceleration in mechanics or the rate of loading of some reagent in chemical processes), more recently, there has been a growing use of fractional derivatives and integrals to describe the "inertia" or "memory" in the behaviour of the observed and controlled variables of partially modelled physical systems over time, which are usually based on the internal dynamics of coupled subsystems not modelled in detail (e.g. The basic mathematical idea of fractional derivatives is as old as that of integer derivatives (it can be found in the correspondence of L'Hospital and Leibniz from the 17th century), but their physical and technical applications have only been spreading since the first quarter of the 20th century as various possible generalisations of the concept of integer derivatives. They can be important tools not only in the control of fractional order systems but also in the control of integer order systems, both for noise filtering and for temporal sharpening of the control dynamics, and can be used to support the proposed adaptive method.

Research objectives:

1. to study, analyze and simulate in computer programs models of different physical systems as paradigms and to accumulate computational results.
2. To implement and comparatively study the operation of different combinatorial control methods on the same paradigms.
3. To develop proposals for the further development of new methods based on the test results.

A non-Lyapunov function-based method for cognitive adaptive control of non-smooth dynamical systems

Thesis Supervisor: József Tar

Description of the research topic:

Lyapunov's 2nd "direct" method is commonly used for the design of adaptive control of nonlinear systems, which is a mathematically difficult technique and requires skilled designers. As a substitute, methods based on "Robust Fixed Point Transform (RFPT)", which can be stabilized by tuning a control parameter, are well established for the control of smooth systems, but cannot be applied to non-smooth systems without further considerations (e.g. chemical reactions where, for reasons of physical interpretability, negative concentrations or negative time derivatives at 0 concentration cannot occur), or for mechanical arms that can move unhindered up to a collision but bounce back from there with more or less collision energy loss. These systems are 'smooth' within certain ranges, but lose their smoothness at the boundaries of these ranges. These range limits may not be directly measurable.

Research objectives:

1. 1. to develop model-independent observers that can detect when the boundary of the smoothness range is reached.
2. 2. to improve the RFPT-based method in terms of the behaviour at the range limit.

New, unconventional adaptive data representation and control methods

Thesis supervisors: József Tar, Annamária Várkonyiné Kóczy

Description of the research topic:

Nowadays, adaptive control of complex, imprecisely known, highly non-linear and/or varying dynamical processes and systems is a growing concern. The general spread of model-based approaches and the emergence of intelligent, unconventional data representation and control methods are of great help in solving these problems. The research will focus on new methods that have recently come to the fore in this area (e.g. wavelet-based controllers, anytime controllers, situation control, Robust Fixed Point Transform-based control), the combination and further development of which could lead to further beneficial techniques. The work builds on the previous results of the theme leaders and is closely related to ongoing national and international collaborative research.

Research objectives:

To review the main methods known from the literature and critically analyse the paradigms. To explore, investigate and develop possible combinations of methodologies and techniques found in the literature.

To further develop the most promising methods, to create and apply new methods. Conducting comparative studies.

Literature:

[1] Soumelidis, F. Schipp, J. Bokor, “On hyperbolic wavelets,” in Preprints of the 18th IFAC World Congress, S. Bittandi, A. Cenedese, and S. Zampieri, Eds., Milano, Italy, August 28 – Sep. 2, 2011, pp. 2309–2314.

[2] M. Kratmüller, “Combining Fuzzy/Wavelet Adaptive Error Tracking Control Design,” Acta Polytechnica Hungarica, vol. 7, no. 4, 2010, pp. 115-137.

[3] J.K. Tar, I.J. Rudas and K.R. Kozlowski, “Fixed Point Transformations-Based Approach in Adaptive Control of Smooth Systems,” Lecture Notes in Control and Information Sciences, vol. 360. M. Thoma and M. Morari, Eds., Robot Motion and Control, 2007.K. R. Kozlowski, Ed., Springer Verlag London Ltd., 2007, pp. 157-166.

[4] A.R. Várkonyi-Kóczy, “Model Based Anytime Soft Computing Approaches in Engineering Applications.” in Soft Computing Based Modeling in Intelligent Systems. V. Balas, J. Fodor, A.R. Várkonyi-Kóczy, Eds., Ser. Studies in Computational Intelligence, Springer Verlag, Berlin, Heidelberg, 2009, pp. 63-92.

Inequalities for special functions and their applications

Thesis Supervisor: Árpád Baricz

Description of the research topic:

In the planned research we intend to deal with the most known and important inequalities related to special functions and their applications. One of the more important inequalities is the so-called Turan type inequality, which has appeared in several applied problems. This topic has been investigated in a relatively large number of papers, however, for many important special functions we do not yet know how they behave according to their parameters. We believe that the results on special functions appearing for indefinitely divisible distributions can be applied to the study of Turan-type inequalities. For example, for modified Bessel functions, the key step was provided by certain Stieltjes transformations. In addition, we would like to study inequalities that give mostly lower and upper bounds on special functions (such as the generalized Marcum function) that have applications in engineering.

The best constant problem for Sobolev inequalities

Thesis Supervisor: Sándor Kristály

Description of the research topic:

Determining the best constant in a Sobolev inequality and the existence of an extremal function is one of the most researched directions in calculus of variations. These problems are closely related to the so-called isoperimetric inequalities. In 2013, A. Kristály and S. Ohta proved a rigidity theorem stating that a Finsler manifold with non-negative Ricci curvature satisfying the so-called Caffarelli-Kohn-Nirenberg inequality with the best constant is isometric with a normalized vector space. For a more general result including curved spaces in the Bishop-Gromov sense, see Crystal A, S. Ohta [Caffarelli-Kohn-Nirenberg inequality on metric measure spaces with applications, Mathematische Annalen, 2013, accepted].

Research goals:

We want to further investigate the problem of best constants and extremal functions for Sobolev inequalities. The aim of the research is to prove topological rigidity results on Riemann-Finsler spaces and Heisenberg groups. For Heisenberg groups, a positive answer could bring us closer to the solution of the Pansu conjecture, where the isoperimetric object is considered to be the so-called "bubble" set. Furthermore, we are convinced that there is a very deep connection between inequalities on higher order Sobolev spaces (e.g., Rellich inequality) and the structure of the space.

Symmetrization methods in partial differential equations

Thesis Supervisor: Sándor Kristály

Description of the research topic:

In mathematical physics, anisotropic phenomena appear which cannot be studied by classical methods. While in the case of isotropic phenomena, where the second-order differential operator is usually the Laplace operator, the standard symmetry and group action is provided by the orthogonal (possibly the unitary group), in the anisotropic case no similar group structure is known.

Research objectives:

One of the aims of this research is to identify/characterize the symmetry groups that generate Wulff-radius solutions of anisotropic phenomena. Our conjecture is that the existence of such a group structure is excluded, but proving this seems very difficult. The other objective would be to prove existence and multiplicity results even in the isotropic case using critical points, where one of the basic tools is the so-called critical symmetry principle. We would also like to investigate these phenomena in the case of elliptic problems with discontinuities in nonlinear members, where we will need multivalued analysis and non-smooth critical point theory. Finally, we would like to understand the nature of the solutions of some specific differential equations interpreted on a Riemannian manifold and their invariance with respect to the isometry set.

Sub-Finsler geometry

Thesis supervisor: Péter Nagy

Description of the research topic:

The notion of a sub-Finsler manifold was introduced for the geometric modelling of a variational problem satisfying a nonholonomic constraint. The nonholonomic constraint is given by a tangent distribution of the manifold on which a point dependent Banach norm is given. If this norm can be derived from scalar multiplication, we obtain a sub-Riemannian manifold. In a sub-Finsler manifold (similar to a sub-Riemannian manifold), the extremal curves tangent to the preferred distribution can be determined using the Pontrjágin criterion known in optimal control theory. The shortest extremal curves connecting two points define a metric space on the manifold. Sub-Finsler metrics can be extended to Finsler metrics with a special structure. The extremal curves of the sub-Finsler metric coincide with the geodesics of the extended Finsler metric only in special cases.

Research objectives:

In the proposed research, we aim to develop examples of sub-Finsler manifolds in which the invariant of the extended Finsler metric can be used to provide estimates of the distances of pairs of points that cannot be connected to the geodesics of the extended Finsler metric.

The roots of Ehrhart polynomials (The roots of Ehrhart polynomials)

Thesis supervisor: Gábor Hegedűs

Description of the research topic:

In our joint work with A.M. Kasprzyk, we succeeded in proving Golybshev's conjecture for smooth polytopes: the roots of the Ehrhart polynomials of every smooth polytope of dimension at most 5 are real parts of -1/2. This work was based on the computation of the surface of lattice polytopes using Ehrhart polynomials, which we applied to both reflexive and smooth polytopes. Our approach is completely elementary but extremely computationally intensive, so we welcome applicants for this PhD topic who are familiar with Maple or MATLAB programming.

Research objectives:

Our main goal in this research: we want to generalize Golybshev's conjecture. We want to classify and better understand reflexive polynomials using the roots of their Ehrhart polynomial.

Literature:

[1] Hegedüs, Gábor, and Alexander M. Kasprzyk. "Roots of Ehrhart polynomials of smooth Fano polytopes." Discrete and Computational Geometry 46, no. 3 (2011): 488-499.

[2] Hegedüs, Gábor, and Alexander M. Kasprzyk. "The boundary volume of a lattice polytope." Bulletin of the Australian Mathematical Society 85.01 (2011): 84-104.

[3] Matthias Beck and Sinai Robins, "Computing the continuous discretely, integer-point enumeration in polyhedra. Undergraduate Texts in Mathematics, Springer, New York, 2007

Interval halving and numerical-analytical techniques for nonlinear boundary value problems

Thesis Supervisor: Miklós Rontó

Description of the research topic:

In recent years, an important issue in the application of numerical-analytical methods based on the so-called series approximation to nonlinear boundary value problems is how to weaken the sufficient conditions for convergence. This condition depends crucially on the length of the interval and the Lipschitz constant (matrix) of the function on the right-hand side of the differential equation. It is known that for initial-value problems, convergence of different numerical methods can be achieved by dividing the interval by an appropriate step interval. This basic idea is also used for boundary value problems in the well-known shooting method, where the boundary value problem can be derived from a sequential numerical solution of initial-value problems. However, when using analytical or numerical-analytical methods, interval splitting is not known, but could be used to weaken the convergence conditions.

Research objectives:

To establish the possibility of interval bisection when applying a numerical-analytical method based on a series approximation for general form nonlinear boundary value problems. To prove that this method can improve the convergence condition by a factor of two, similarly as for periodic boundary value problems.

Literature:

[1] A. Ronto and M. Ronto, “Periodic successive approximations and interval halving,” Miskolc Mathematical Notes, vol. 13 , no. 2, 2012, pp. 459-482,

[2] M. Rontó and A. M. Samoilenko, Numerical–analytic methods in theory of boundary–value problems. World Scientific, Singapore, 2000.

[3] A. Ronto, M. Ronto M. and N. Shchobak, Constructive analysis of periodic solutions with interval halving, Boundary Value problems 2013, DOI:10.1186/1687-2770-2013-57.

[4] A. Rontó and M. Rontó, “Successive Approximation Techniques in Non- Linear Boundary Value Problems for Ordinary Differential Equations,” in Handbook of Differential Equations, Ordinary Differential Equations., F. Batelli and M. Feckan, Eds., vol. 4, Elsevier B.V., 2008, pp. 441- 592.

Development of a polynomial version of numerical -analytic methods based on sequential approximation for certain nonlinear boundary value problems

Thesis Supervisor: Miklós Rontó

Description of the research topic:

The study of different types of boundary value problems associated with nonlinear ordinary differential equations is of great interest to both mathematicians and engineers. The numerical-analytical methods based on the so-called series approximation, developed in recent years, in contrast to the known methods, provide the possibility to study simultaneously the two most important problems of boundary value problems - the existence of the solution and the approximate determination of the solution. In previous research, relatively little attention has been paid to the practical definition or use of higher-order approximations in the context of existence studies. In this area, the use of appropriate interpolation polynomials in research would be a gap.

Research objectives:

To develop new numerical-analytical methods based on serial polynomial approximation for general form nonlinear boundary value problems. Choice of appropriate interpolation polynomials. Proof of uniform convergence. Error estimation of the approximate solution. Existence test. Symbolic calculations.

Literature:

[1] A. Ronto et al., Numerical-analytic technique for investigation of solutions of some nonlinear equations with Dirichlet conditions, Boundary value problems. 2011, DOI>10.1186/1687-2770-2011-58

[2] M. Rontó and A. M. Samoilenko, Numerical–analytic methods in theory of boundary–value problems. World Scientific, Singapore, 2000.

[3] M. Ronto and A. Galántai, “A computational modification of the numericalanalytic method for periodic BVPs,” Nonlinear Oscillations, vol. 2, no. 1 1999, pp. 109–114.

[4] A. Rontó and M. Rontó, “Successive Approximation Techniques in Non- Linear Boundary Value Problems for Ordinary Differential Equations,” in Handbook of Differential Equations, Ordinary Differential Equations. F. Batelli and M. Feckan, Eds., vol. 4, Elsevier B.V., 2008, pp. 441- 592.

Stability analysis of elliptical and parabolic flat arcs

Thesis supervisor: György Szeidl

Description of the research topic:

Flat elliptic or parabolic arcs are frequently encountered in engineering applications. Under conservative loading (e.g. constant directional load on the axis of symmetry of the structure), derive the equations describing the behaviour of the structure, the value of the critical load, the behaviour of the structure after loss of stability under the assumption of geometric nonlinearity and different kinematic models. Investigate what happens if the structure is not flat. The calculations can be carried out using a semi-analytical model or a finite element model, work these out as well.

Literature:

[1] V. V. Bolotin, Dynamic Stability of Elastic Systems. Holden Day, San Francisco, 1964.

[2] N. A. Alfutov, Stability of Elastic Structures. Springer, 1999.

[3] C. J. Guo et al., “In-plane elastic stability of fixed parabolic shallow arches,” Science in China Series E: Technological Sciences, vol. 52, no. 3, 2009, pp.596–602.

[4] J. Cai and J. Feng, “Buckling of parabolic shallow arches when support stiffens under compression,” Mechanics Research Communications, vol. 37, 2010, pp. 467–471.

[5] P. R. Calhoun and D. A. DaDeppo, “Nonlinear finite element analysis of clamped arches,” J. Struct. Eng., vol. 109, 1983, pp. 599–612.

2.6. THE SUBJECTS OF THE DOCTORAL SCHOOL

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.

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 artithmetics. Basic arithmetic operations. Computational methods for elementary functions. Other types of arithmetic. Introduction to interval arithmetic. Diagnostical tools.

Evaluatin 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: *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 detection, object search, object recognition, computer vision, computer modeling, 3D reconstruction, 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 edition, 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 mehod: classical colloquium, oral examination.

Recommended references:

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, nad 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 compu-ting. Knowledge representation of soft computing techniques. History of theory and applica-tion soft computing techniques. Fuzzy set theory, logic, and decision making. Neuro compu-ting. 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 program-ming environments. Requirement analysis of anytime systems, modelling techniques. Informa-tion processing with specified response time. Research management in time critical applicati-ons. Transients in information processing systems with changing architecture. Handling uncer-tain 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, associate 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, associate 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

Field: Fundamental research topic subject

Credits: 8 credit

Leading/responsible person: István Nagy, associate professor, PhD

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*. Phila-delphia, 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*, Phila-delphia, 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*, Phila-delphia, 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.

S

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*

Lecturers:
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
6. Szenes, K.: An application of a parallel systems planning language in decision support - production scheduling. Procds. of the IFIP W.G. 5.7 Working Conf. APMS. (Advances in Production Management Systems), Bordeaux, France, 24 - 27 Aug., 1982. ed.: G. Doumeingts & W. A. Carter, North Holland, 1984, p. 241 – 249. reference in Computer Abstracts: No. 1827.
7. Szenes, K.: A comparison of the traditional and a new principle way of parallel systems description, simulation and planning, Procds. of the 8th Winterschool on Operating Systems, Visegrad, Hungary, 31 Jan.- 4 Feb., 1983
8. Szenes, K.: PCUBE - an AI system for planning process systems; Procds. of the 5th Symp. on Microcomputer and Microprocessor Applications, Budapest, Hungary, 29. Sept. - 1. Oct., 1987., ed.: OMIKK-TECHOINFORM, p. 551-562
9. Szenes, K.: Planning the activity schedule of process systems by the means of an AI based system Procds. of the 27th International MATADOR Conf., 20-21. Apr., 1988., Manchester, ed.: B. J. Davies, UMIST, MACMILLAN Education Ltd.,1988., p. 139 - 144
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
11. Szenes, K.: Enterprise Governance Against Hacking. Procds. of the 3rd IEEE International Symposium on Logistics and Industrial Informatics - LINDI 2011 August 25–27, 2011, Budapest, Hungary, ISBN: 978-1-4577-1840 © 2011 IEEE, IEEE Catalog Number: CFP1185C-CDR [CD-ROM], 229-233 (http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=6026102 2011.01.23.)
12. Szenes, K., Tureczki, B.: “Blockchain basics, applications”. Presentation & Workshop. Workshop material: https://nextcloud.sztaki.hu/s/ya4LRkz75Kmj4og#pdfviewer. Presentation slides: https://www.slideshare.net/secret/IgHgKBIQ4w5ePj. “Blockchain and deep learning” workshop. SZTAKI (Számítástechnikai és Automatizálási Kutatóintézet). 2019. September 5. Hungary, H-1111 Budapest, XI., Kende street 13-17.
13. Luis Emilio Alvarez-Dionisi: Technology-Based Trust with Blockchain. ISACA Journal, 2020 Vol. 6., © 2020 ISACA. All rights reserved. www.isaca.org. Editor: ISACA - Information Systems Audit and Control Association, USA

14. Games You Will Enjoy Playing in the Binance Smart Chain. 2021-09-13, Binance BlogBinance. https://www.binance.com/ph/blog/421499824684902750/games-you-will-enjoy-playing-in-the-binance-smart-chain
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.
16. Szenes, K., Tureczki, B.: Supporting Corporate Governance on a Blockchain basis. https://www.cybersecurity-review.com/supporting-corporate-governance-on-a-blockchain-basis/. In: CYBER SECURITY REVIEW 2021: 2 pp. 1-6., 6 p. (2021)
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
20. S. Satija, A. Mehra, S. Singanamalla, K. Grover, M. Sivathanu, N. Chandran, D. Gupta, S. Lokam: “Blockene: A High-throughput Blockchain Over Mobile Devices”.OSDI 2020. 14th USENIX Symposium on Operating Systems Design and Implementation. Organized by: USENIX. November 4-6, 2020. Download: https://www.microsoft.com/en-us/research/uploads/prod/2020/10/blockene-osdi20-5f97c46c0dae1.pdf
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. 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. 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

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.
3. 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, Towards 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.* Sprin-ger, 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

2. Jean-Jacques Slotine, Weiping Li, Applied Nonlinear Contorl, ISBN: 978-0130408907

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. 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. 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.

6. 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)

7. 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