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:

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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:

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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:

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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.