JEDLIK LABORATORIES RESEARCH REPORT

PÁZMÁNY

Pázmány Péter Catholic University

Faculty of Information Technology and Bionics

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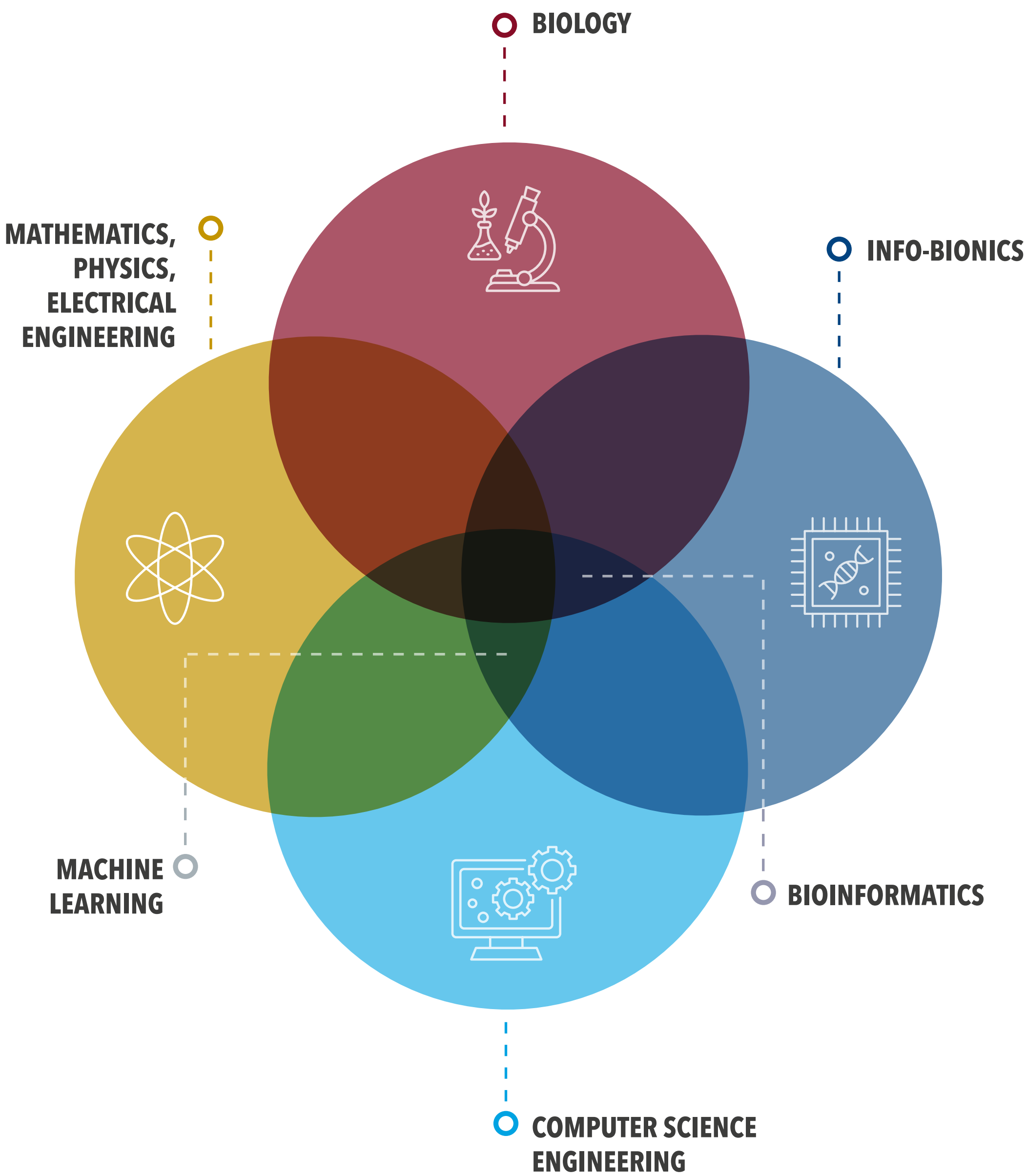
BIOLOGY
MATHEMATICS, PHYSICS, ELECTRICAL ENGINEERING
INFO-BIONICS
MACHINE LEARNING
BIOINFORMATICS
COMPUTER SCIENCE ENGINEERING

CONTENTS

PREFACE

This booklet presents the research landscape of the Jedlik Laboratories at the Faculty of Information Technology and Bionics of Pázmány Péter Catholic University, highlighting how information technology and life sciences are integrated in a single, coherent ecosystem. The laboratories span tightly coupled domains, including biology, computer science, mathematics, physics, electrical engineering, and info-bionics, with particular strengths in bioinformatics, systems biology, neuroscience, bionics, machine learning, and high-performance computing. Thirty-two research groups work end-to-end from theory and algorithms through hardware to laboratory, clinical, and industrial validation, forming an interdisciplinary environment where fundamental science and translational research continuously reinforce each other.

In recent years, the scientific output of the Faculty has reached a new level of quality and international visibility. More than half of our journal papers are now published in Q1 journals, and nearly one-third in D1 journals. The booklet's list of top publications from the past five years is organized in three tiers: papers predominantly authored by Faculty members, papers led by Faculty members within wider collaborative networks, and seminal publications in which our researchers contributed to internationally leading teams. This structure reflects not only the strength of our in-house research, but also our increasing integration into high-level international collaborations.

A defining feature of the Jedlik Laboratories is the active and early integration of undergraduate and graduate students into research and innovation. Their participation in ambitious projects has already led to six spin-off companies emerging from the Faculty, and several further deep-tech initiatives are currently in incubation. One emblematic example is Allonic, a start-up producing bio-inspired manufacturing technology for robot hands and other biomimetic devices, which grew from student projects in our sensing robotics and prosthetics laboratories into a company operating at the forefront of international robotics, attracting multi-million-euro investment and global industrial partners. Market-ready developments originating from the Jedlik Laboratories now range from advanced force sensors and quantum chemistry simulation software to molecular pre-screening platforms and medical ultrasound technologies.

A special section of this booklet is devoted to the bionics research lines we develop in connection with the Cybathlon, often described as the "Olympics of Bionics," where teams from all over the world design and deploy assistive technologies for people with disabilities in realistic everyday tasks. Our teams translate research in anatomically correct prosthetic hands, EEG-based brain–computer interfaces, functional electrical stimulation for paraplegic cycling, and vision assistance into pilot-validated systems. In the 2024 Cybathlon in Zürich, our vision assistance team achieved first place in its discipline, outperforming leading international teams and demonstrating the real-world robustness of our application for global users. These achievements underscore that Cybathlon has become a flagship translational initiative for the Faculty, linking cutting-edge research in robotics, neurotechnology and human–computer interaction to tangible improvements in mobility, autonomy and quality of life.

The scientific and human vision of Prof. Tamás Roska (1940-2014), founding dean of the Faculty and first director of the Jedlik Laboratories, remains a central guiding principle for our community. His original goal was to build a strongly research-oriented Faculty in Europe that creates genuine synergy between information technology, electronics, and neuroscience. This goal has been progressively realized through close collaboration with outstanding neuroscientists and partners from research institutes, hospitals, and industrial laboratories. Twenty-five years after the Faculty was established, research in bionics, biology, electronics, and information technology has flourished, and new multidisciplinary lines in bioinformatics, nanotechnology, robotics, artificial intelligence, and beyond-Moore computing have expanded our scope. With 32 research groups now reaching the physical capacity of our building, the sustained growth of the Jedlik Laboratories is a sign of the success of this vision, and of our responsibility to preserve and further develop Prof. Roska's heritage by continuously strengthening the conditions for high-quality, internationally competitive research.

July 30, 2026

Prof. Attila Csikász-Nagy
Director of Jedlik Laboratories
Vice Dean for Research and Innovation

RESEARCH RESULTS IN NUMBERS

NUMBER OF PUBLICATIONS IN THE TOP 10% (D1) AND TOP 25% (Q1) OF BEST JOURNALS RANKED BY SCIMAGO

	Referenced journal papers	D1	Q1	D1 ratio	Q1 ratio
2021	114	29	52	25%	46%
2022	122	26	49	21%	40%
2023	94	22	40	23%	43%
2024	107	29	51	27%	48%
2025	81	20	42	25%	52%

TOP PUBLICATIONS FROM THE LAST 5 YEARS

MAJORITY OF AUTHORS FROM OUR FACULTY

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NATURE COMMUNICATIONs, 14(1), 6159.

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NATURE, 601(7891), 105-109.

FROM RESEARCH TO SPIN-OFF COMPANIES

In 2025, the Faculty's spin-off ecosystem demonstrated that ideas born in the laboratory can develop into competitive technologies and market-ready companies. The clearest example is **Allonic**, which moved from an ITK student project to a globally visible robotics venture, attracting major international attention for its bio-inspired manufacturing platform and securing a record-scale pre-seed round that supports its next phase of industrial development. Its progress illustrates the Faculty's broader ability to transform research into practical innovation with international reach.

Alongside Allonic, several other spin-offs continued to strengthen the Faculty's innovation portfolio. Companies such as **Cytocast, Dermus, OptoForce, Streamnovation** and other ITK-linked ventures demonstrate the diversity of our translational research, spanning biotech, medical imaging, sensing, quantum chemistry software, and industrial AI applications. Some of these companies are already active on the global market, while others are in promising growth phases, but all share the same origin: research conducted at Pázmány ITK and supported by its technology-transfer ecosystem. Together, these spin-offs show that the Faculty is not only a place of scientific discovery, but also a fertile environment for creating companies with real-world impact.

Biomimetic prosthetic hand. (Allonic Inc.)

CYBATHLON – THE “BIONICS OLYMPICS”

INTRODUCTION TO OUR TEAMS COMPETING AT CYBATHLON

The Cybathlon, often referred to as the “Bionics Olympics,” is a unique competition organized by ETH Zurich, and the next event is expected to be held in Asia. It challenges teams worldwide to develop assistive technologies that help individuals with disabilities perform everyday tasks. Our research and development areas align with many of the competition challenges. The event includes races in 8 disciplines, such as brain-computer interfaces (BCIs), functional electrical muscle stimulation (FES), prosthetic limb control (ARM), device development for the visually impaired (VIS), and smart wheelchair development for the physically impaired (WHL). International technological competitions like Cybathlon are crucial for multiple reasons. They provide a platform for innovation, encouraging teams to develop cutting-edge assistive technologies. Participating in such competitions also raises awareness about the challenges faced by people with disabilities and showcases how technology can address these challenges. Moreover, it motivates teams to push the boundaries of their research and development, ultimately leading to real-world applications that can significantly improve the quality of life for individuals with disabilities. It also serves as an important platform to showcase the state of the art and increase the visibility of research groups working on these solutions.

Within the framework of the hand prosthesis race (ARM) of Cybathlon, our research group closely cooperates with Allonic LLC, which develops advanced bionic limbs by reverse-engineering human hand anatomy and biomechanics. It specializes in creating and integrating materials that mimic tissue structures through innovative fiber and textile technologies. Its prototype is a highly sophisticated robotic hand designed for precision, strength, and, above all, a natural feel. At our Faculty, we deal with various human-machine interfaces (HD-EMG, NIRS, US) and different levels of movement control to automate the fine movement motifs of the prosthetic hand.

In connection with the Brain-Computer Interface (BCI) race of Cybathlon, our research group led by Dr. Csaba Márton Köllőd is developing algorithms that convert brain signals into control commands for a digital device. The developed BCI system allows people with

Biomimetic prosthetic hand. (Allonic Inc.)

The setup of the BCI Cybathlon race can be seen with the Pilot navigating the screen with the BCI controlled mouse.

tetraplegia to perform everyday tasks in a virtual scenario, such as controlling an electric wheelchair, a robotic arm, or the cursor of a computer using only mental commands, generated by modulating their brain waves (EEG signals). This innovative approach not only demonstrates the practical applications of BCI technology, but also highlights the potential for enhancing the independence and quality of life of people with severe disabilities. Our BCI research group was one of the first research groups from Hungary to participate in Cybathlon, back in 2016. In 2024, they reached 5th place at the Global Edition.

In the field of the functional electrical muscle stimulation (FES) race of Cybathlon, our research group led by Dr. József Laczkó is developing stimulation patterns and training protocols for FES cycling training of paraplegics. Our Pilot, Csaba Szamosi, was involved in optimizing the developed protocols. Our team uses the Berkelbike Pro tricycle, a hybrid tricycle that can be driven by legs only, by arms only, or simultaneously by both legs and arms. It is equipped with a 6-channel programmable electrical stimulator that enables FES-driven leg cycling for paraplegic riders. Also, the team has previously developed its own stimulation device that is currently used in FES-driven cycling training for people with spinal cord injuries. Members of several institutions participate in the development of the stimulation patterns and training protocols: PPKE ITK, Wigner Research Centre for Physics, the University of Pécs, and the National Institute for Medical Rehabilitation in Hungary. For the FES biking race, the HunFess team combines technical sciences, natural sciences, and medical sciences, and our aim is to foster FES-based rehabilitation of people with spinal cord injuries.

Turning to the vision assistance (VIS) race of Cybathlon, our research group led by Dr. Kristóf Karacs and Dr. Anna Gelencsér-Horváth brings together a broad range of skills and expertise, spanning engineering, computer science, and human-computer interaction. Their research focuses on developing efficient methods for scene understanding, including object and structure recognition, mapping, and navigation, that can operate on resource-constrained devices, even smartphones. They integrate the resulting methods and technologies into LetSee, our easy-to-use mobile application, which has been made available to visually impaired users worldwide and enhances various aspects of their daily lives.

The aim is to create a tool that is accessible, affordable, and effective, while at the same time building on the already acquired skills of visually impaired people, giving them a strong sense of independence and the ability to stay in control.

Our pilot on the Cybathlon 2024 FES Bike Race. The tricycle is driven by his paralyzed limbs, a controller sends electrical signals to the selected muscles via surface electrodes to generate muscle forces to drive the tricycle.

Our VIS pilot attempting the task "Empty seats" during the Cybathlon Challenge 2024. The aim is to indicate which seats are empty out of the 6 available using only the application developed.

They work in close connection with visually impaired communities, and visually impaired lab members are actively involved in both developing and testing the application, as their outstanding situational awareness and insights are key to the app's development.

The research group already has experience with mobile application development for the visually impaired community; thus, it was an obvious choice to use the technology for the Cybathlon competition as well. This will help improve the marketability and accessibility of the developed solution worldwide.

In the 2024 Cybathlon in Zürich, our VIS team (EyeRider) achieved 1st place.

RESEARCH GROUPS

BIOINFORMATICS AND DATA SCIENCE

Prof. Sándor PONGOR

Head of Research Group: Prof. Sándor PONGOR

Members of the Group: Dr. Balázs LIGETI, Dr. János JUHÁSZ

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Keywords: *bioinformatics, data science, systems theory, theory of bioinformatics data, microbiomes*

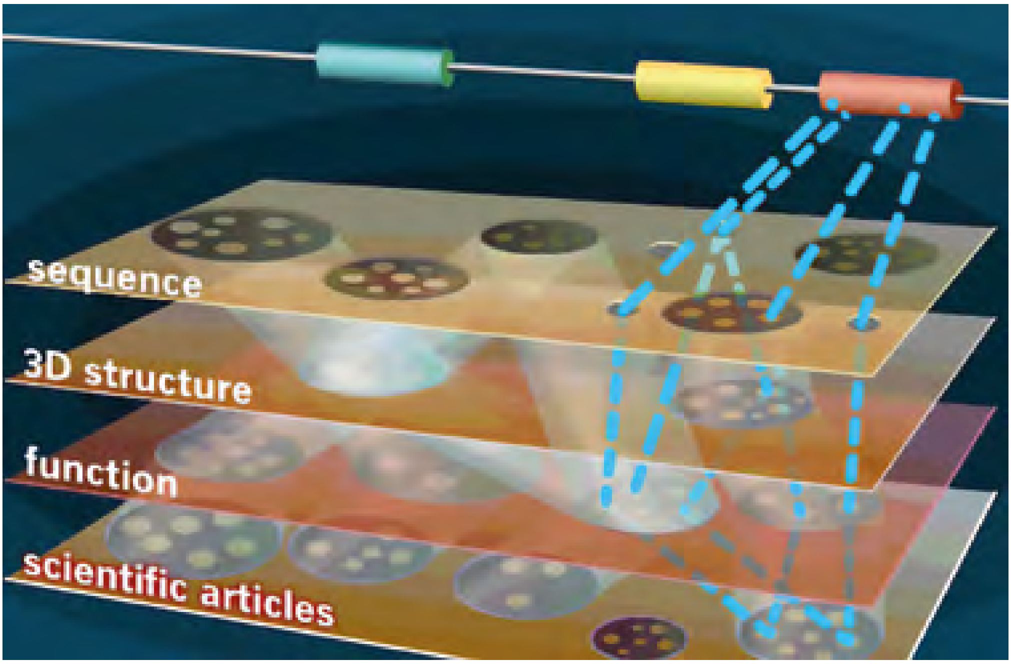
Field of research: bioinformatics; info-bionics

Our primary research area is the general theory of bioinformatics data, grounded in systems theory and network science. Historically, our core data types include sequences, 3D molecular structures, biological networks, genomes, and scientific literature. However, we continuously aim to understand the underlying principles of emerging data types and databases. Building upon this theoretical foundation, our key priority is curriculum development for BSc, MSc, and PhD programs,

- structured around three main pillars:
- Fundamentals of bioinformatics;
- Visualization and numerical representation of scientific data;
- Data interpretation and communication, including scientific writing and presentation skills.

Another research direction addresses the increasing complexity and opacity of bioinformatics workflows, which pose significant challenges to establishing universal scientific and ethical standards. The rise of artificial intelligence sheds new light on these fields, a shift to which our curriculum development efforts are actively adapting. Additionally, our ongoing projects focus primarily on the analysis of host-associated microbiomes; we work on developing methodologies to uncover their composition and interconnected networks.

Future research directions, collaboration opportunities
Curriculum development in Bioinformatics (BSc, MSc, and PhD level). Interpretation of novel datatypes, database design.



To generate new insights, we must integrate diverse layers of biological data. Using bioinformatics tools to cluster within layers, as well as to map across them, is fundamental for organizing and storing structured scientific information in databases.

Key publications:

1. *Juhász, J., Ligeti, B., Gajdács, M., Makra, N., Ostorházi, E., Farkas, F. B., ... & Szabó, D. (2021).* **Colonization dynamics of multidrug-resistant Klebsiella pneumoniae are dictated by microbiota-cluster group behavior over individual antibiotic susceptibility: a metataxonomic analysis.** ANTIBIOTICS, 10(3), 268.
1. *Marini, B., Kertész-Farkas, A., Ali, H., Lucic, B., Lisek, K., Manganaro, L., Pongor, S., Luzzati, R., Recchia, A., Mavilio, F., Giacca, M. and Lusic, M. (2015).* **Nuclear architecture dictates HIV-1 integration site selection**. NATURE
1. *Juhász, J., Kertész-Farkas, A., Szabó, D and Pongor, S. (2014).* **Emergence of collective territorial defense in bacterial communities: Horizontal gene transfer can stabilize microbiomes.** PLOS ONE

NEURAL BIOINFORMATICS

Dr. Balázs LIGETI

Head of Research Group: Dr. Balázs LIGETI

Members of the Group: Bendegúz FILYÓ, Dániel KRIZSÁN, Judit JUHÁSZ, Mátyás OSVÁTH, Dr. Csaba PONGOR, Dr. János JUHÁSZ,

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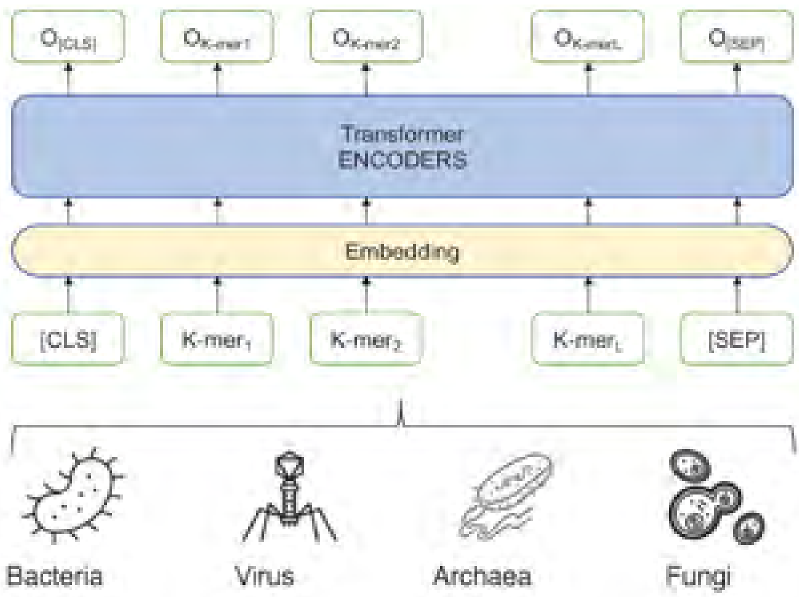
Keywords: *metagenomics, phage design, synthetic biology, neural networks*

Our research group focuses on neural-network- and sequence-based representations that capture large-scale genomic and evolutionary context. A key question in quantitative biology is how to uncover novel patterns and structures in biological data, which is crucial for modeling, predicting, and manipulating complex biological systems like a microbiome. Our most recent research focuses on understanding the complex relationships characterizing the microbiome, such as phage-bacteria interactions. Phages, which are viruses that infect bacteria, can influence the structure of the microbiome and may also serve as both therapeutics and biomarkers. We designed and implemented a genomic language model, ProkBERT (Ligeti et al., 2024), to solve such bioinformatics tasks. ProkBERT provides a reusable, neural-network-based representation that can be applied to classification, regression, or clustering tasks related to microbiomes. This allows us to efficiently address problems such as identifying plasmids or viruses in complex microbiomes, or identifying potential candidates for phage therapy.

Future research directions, collaboration opportunities

The Neural Bioinformatics Research Group offers innovative, AI-compatible bioinformatics solutions: we use artificial intelligence-based tools to design phages or plasmids, as well as to solve other genomic problems. We are open to collaborations in research, industry, and grant-based initiatives.



ProkBERT operates directly on genomic data and was trained on large corpora of microbial sequence data (bacteria, viruses, archaea, and fungi). It allows transfer learning by providing reusable sequence representations. The model is ideal for solving classification, clustering, and regression problems.

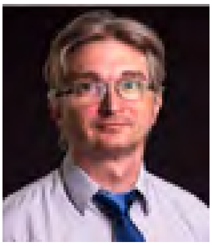
Key publications:

1. *Juhász, J., Ligeti-Nagy, N., Bodnár, B., Juhász, J., Pongor, S., Ligeti, B. (2025).* **ProkBERT PhaStyle: accurate phage lifestyle prediction with pretrained genomic language models.** BIOINFORMATICS ADVANCES

2. *Ligeti, B., Szepesi-Nagy, I., Bodnár, B., Ligeti-Nagy, N., & Juhász, J. (2024).* **ProkBERT family: genomic language models for microbiome applications.** FRONTIERS IN MICROBIOLOGY, 14, 1331233.

3. *Juhász, J., Ligeti, B., Gajdács, M., Makra, N., Ostorházi, E., Farkas, F. B., ... & Szabó, D. (2021).* **Colonization dynamics of multidrug-resistant Klebsiella pneumoniae are dictated by microbiota-cluster group behavior over individual antibiotic susceptibility: a metataxonomic analysis.** ANTIBIOTICS, 10(3), 268.

STRUCTURAL BIOLOGY



Prof. Zoltán GÁSPÁRI

Head of Research Group: Prof. Zoltán GÁSPÁRI

Members of the Group: Dr. Bianka Szalainé ÁGOSTON, Dr. Zsófia E. DOBSON-KÁLMÁN, Borbála JAKAB

Contact: gaspari.zoltan@itk.ppke.hu

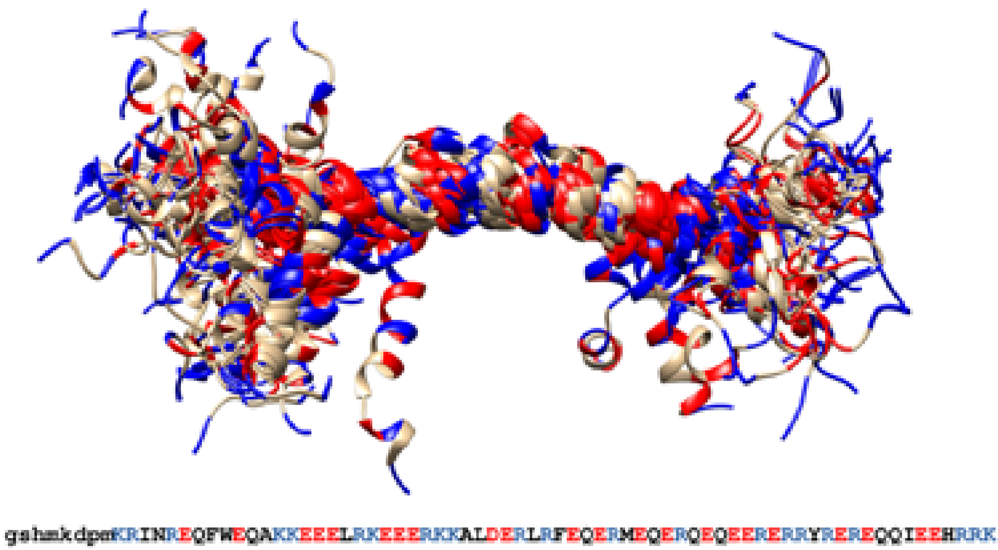
Keywords: *integrative structure modelling, protein NMR spectroscopy, postsynaptic density, protein:protein interactions*

Field of research: bioinformatics; biology

Our research focuses on the structure-function relationships of proteins with experimental and computational methods. Our experimental work centers on components of the postsynaptic density that are involved in interneuronal communication, including molecular processes related to learning and memory. The investigated protein regions include globular, fibrillar, and intrinsically disordered segments. After expression and purification, these segments are characterized using various biophysical methods, including NMR spectroscopy experiments conducted via collaborations. One of our major approaches is the combination and/or interpretation of these NMR data with molecular modeling. Another topic investigated in our group is single alpha-helices (SAHs). We use bioinformatics to detect such motifs and characterize their occurrence in various proteins. We are also working on the integrative structure modeling of the SAH region of the postsynaptic actin-binding protein Drebrin.

Future research directions, collaboration opportunities

We are open to collaborating on projects focusing on the experimental and/or computational description of the proteins of the postsynaptic density. We are especially interested in integrative structure modeling of proteins. We are also keen on studying newly described groups and functions of proteins containing single alpha-helices (SAHs).

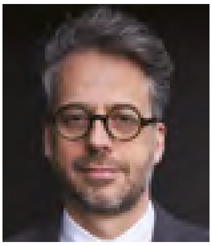


Structural ensemble (60 conformers) of the Drebrin SAH region generated based on NMR and small-angle X-ray scattering (SAXS) data. The sequence of the construct is shown at the bottom; lowercase letters indicate the expression tag. Positively charged residues (Arg, Lys) are colored blue, and negatively charged ones (Asp, Glu) are colored red in both the cartoon representation and the sequence.

Key publications:

1. *Nagy-Kanta, E., Kálmán, Zs. E., Tossavainen, H., Juhász, T., Farkas, F., Hegedüs, J., Keresztes, M., Beke-Somfai, T., Gáspári, Z., Permi, P., Péterfia, B. (2026).* **Residual flexibility in the topologically constrained multivalent complex between the GKAP scaffold and LC8 hub proteins.** FEBS JOURNAL, 293:76-95.
2. *Varga, S., Péterfia, B., Dudola, D., Farkas, V., Jeffries, Cy M., Permi, P., Gáspári, Z. (2025).* **Dynamic interchange of local residue-residue interactions in the largely extended single alpha-helix in Drebrin.** BIOCHEMICAL JOURNAL, 482:383-399.
3. *Kálmán, Zs. E., Czajlik, A., Maruzs, B., Farkas, F., Pap, I., Homonnay, Cs., Klumpler, T., Batta, Gy., Gáspári, Z., Péterfia, B. (2025).* **Structural modeling and dynamics of the full-length Homer1 multimer.** PROTEINS, 94:947-960.

SYSTEMS BIOLOGY



Prof. Attila CSIKÁSZ-NAGY

Head of Research Group: Prof. Attila CSIKÁSZ-NAGY

Members of the Group: Dr. Csaba István PONGOR, Dr. János JUHÁSZ, Tünde Éva GAIZER, Bence GAIZER, Valentina MADÁR, Bíborka PILLÉR, Petra SOMOGYVÁRI, János SZALMA, Áron WEBER

Contact: csikasz-nagy.attila@itk.ppke.hu

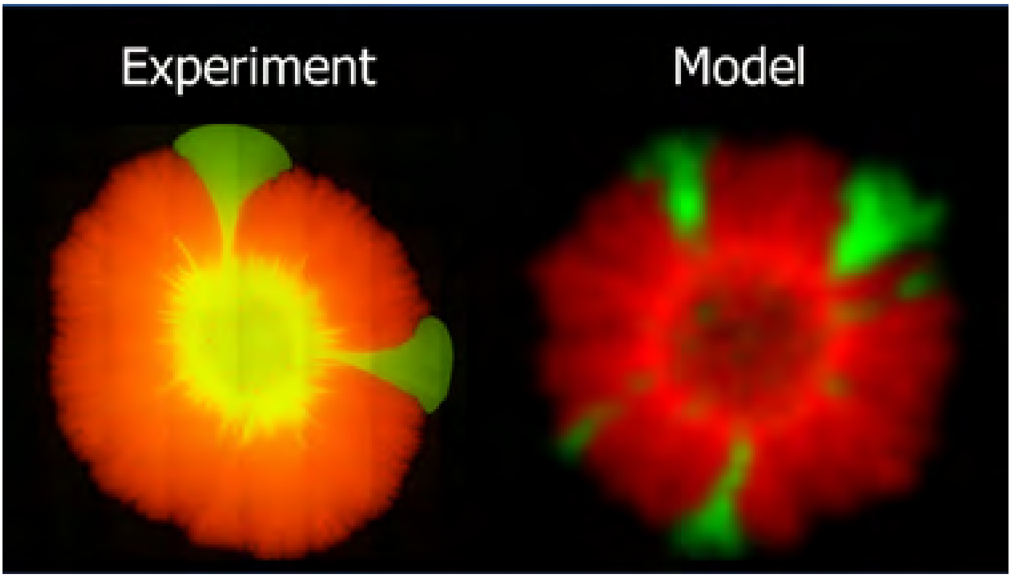
Keywords: *systems biology, simulation, bioinformatics, yeast, circadian clock*

Field of research: bioinformatics; info-bionics

We investigate the spatio-temporal dynamics of intracellular molecular interactions and intercellular interactions by combining computational systems biology modeling with experimental methods. By converting molecular networks into mathematical equations, we analyze the physiological behavior of these systems. Our research focuses on the regulation of cell growth and cell division. We collect data in collaboration with experimental laboratories and test the predictions of our models. In our own laboratory, we study cell-cell interactions among yeast strains and integrate our results with our models to deepen our understanding of intercellular communication. In cooperation with research groups within the Faculty, we also develop epidemic spread models that can support decision-making in epidemiological emergencies. With our computational systems biology methods, we also uncover the mechanisms of action of drugs, contributing to the development of safer preparations.

Future research directions, collaboration opportunities

The research group offers collaboration in experimental projects using yeast, particularly in the areas of cell communication and the ecology of microbial communities, and, from a modeling perspective, on topics such as cell division, growth, signaling, circadian rhythm, and their relationships.



Microscopic image and simulation result of a mixed colony of two yeast strains. The image on the left shows the two strains with fluorescent labeling, while on the right, the arrangement of agents, indicated by different colors, was simulated in an agent-based mathematical model.

Key publications:

1. *Ecker, A., Szabó, G., Szalma, J., Fichó, E., Reguly, I., & Csikász-Nagy, A. (2026).* **Digital twin approaches for interpretable side effect prediction in drug discovery.** DRUG DISCOVERY TODAY, 104637.
2. *Gaizer, T., Juhász, J., Pillér, B., Szakadáti, H., Pongor, C. I., & Csikász-Nagy, A. (2024).* **Integrative analysis of yeast colony growth.** COMMUNICATIONS BIOLOGY, 7.1, 511.
3. *Chakravarty, S., Hong, C.I., and Csikász-Nagy. A. (2023).* **Systematic analysis of negative and positive feedback loops for robustness and temperature compensation in circadian rhythms.** NPJ SYSTEMS BIOLOGY AND APPLICATIONS, 9.1, 5.

BARRIER MODELING AND INNOVATIVE PHARMACEUTICS

Prof. Franciska VIDÁNÉ ERDŐ

Head of Research Group: Prof. Franciska VIDÁNÉ ERDŐ

Members of the Group: Timea BESKID, Zsófia CSAPI, Ema PEROLLI, Péter SOLTÉSZ, Fanni SZEPETNEKI, Gergő GALLI, Gábor GEDEY, Sára VIEMANN, Márk ÁGH-HAMZA, Anna FOGARASI, Filoména BORSÁNYI, Máté CSANAKI

Contact: erdo.franciska@itk.ppke.hu

Keywords: *drug delivery, smart wound dressings, cosmetic product testing, biological barriers*

Field of research: biology; mathematics, physics, electrical engineering

The research group investigates various physiological barriers (whole skin, epidermis, epidermis-dermis, cornea, retina, intestine, nasal mucosa, etc.) under physiological and pathological conditions. We test various drugs and drug formulations for their penetration through these barriers. We also test and develop innovative pharmaceutical products and medical devices using physical, chemical, and biological methods. One of our main research areas is wound healing and the development of smart dressings. The other is the testing of cosmetics, which analyzes their effects on various skin properties (elasticity, barrier function, integrity, hydration, color, melanin content, erythema index, surface pH, etc.). Many BSc and MSc students work in the lab. Tutored Research Projects and Guided Individual Study tasks are performed at our lab, and those working on their diploma theses carry out the experiments. We participate in numerous national and international collaborations and present our results at congresses and workshops.

Future research directions, collaboration opportunities

Our research group cooperates closely with Tallinn University of Technology, Polish medical and technical universities, Slovak partners, as well as French universities and national companies in the field of cosmetic research. Students and researchers have the opportunity to participate in various exchange programs and complete mandatory internships with our national and international partners.

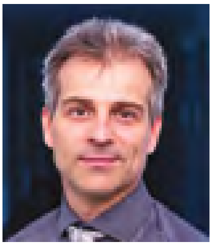
Our research project on the development of smart dressings in cooperation with the Visegrad countries and Ukraine has won EU funding. We presented this poster at the EWMA-DEWU 2026 Congress in Bremen this spring.

Key publications:

1. *Nirwan, V. P., Bajusz, B., Fabók, N., Dimlic, M. R., Budimir, J., Mqatywa, T., Gyöngy, M., Ferencz, M., Kocsi,s D., Bondarenko, O., Rolduhina, M., Lengyel, M., Antal, I., Hengsbach, R., Erdő, F., Fahmi, A. (2026).* **Hybrid Nanofibers for Multimodal Accelerated Wound Healing**. ADV HEALTHC MATER
2. *Kocsis, D., Sztankovics, D., Józsa, L., Németh, A., Garay, T., Naszlady, M. B., Lengyel, M., Vecsernyés, M., Antal, I., Sebestyén, A., Erdő, F. (2025).* **In Vitro Functional and Structural Evaluation of Low-Complexity Artificial Human Epidermis for 3D Tissue Engineering.** BIOENGINEERING (Basel)
3. *Szederkényi, G., Kocsis, D., Vághy, M. A., Czárán, D., Sasvári, P., Lengyel, M., Naszlady, M. B., Kreis, F., Antal, I., Csépányi-Kömi, R., Erdő, F. (2024).* **Mathematical modeling of transdermal delivery of topical drug formulations in a dynamic microfluidic diffusion chamber in health and disease.** *PLOS ONE*

BIOMICROFLUIDICS

Dr. András József LAKI



Dr. Kristóf IVÁN

Head of Research Group: Dr. András József LAKI, Dr. Kristóf IVÁN

Members of the Group: Mária LAKI

Contact: laki.andras.jozsef@itk.ppke.hu, ivan.kristof@itk.ppke.hu

Keywords: *microfluidics, Lab-on-a-chip, prototyping, flow test, validation*

Field of research: biology; info-bionics

The Biomicrofluidics Research Group specializes in the design, fluid dynamic modeling, fabrication, and testing of microfluidic devices. In our research and development, we incorporate and advance state-of-the-art manufacturing technologies, such as soft lithography, laser cutting, and layer bonding.
Our laboratory takes an interdisciplinary approach - integrating physics, chemistry, biology, and engineering - to provide innovative microfluidic solutions for food safety, biomedical diagnostics, and particle separation.
By leveraging the latest scientific advancements, we aim to make significant contributions to both the scientific community and industry. We are highly committed to disseminating our findings and collaborating closely with industry partners to ensure our research translates quickly into practical, real-world applications.

Future research directions, collaboration opportunities

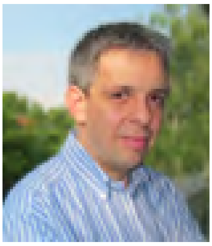
With technology solutions ranging from TRL 1 to TRL 9, we can translate a biological protocol into a functional lab-on-a-chip prototype, which can then be scaled up for mass production.

We can develop a Lab-on-a-chip device from a biological protocol to a functional prototype, which can be scaled up for mass production.

Key publications:

1. *Ponmozhi, J., Dhinakaran, S., Varga-Medveczky, Z., Fónagy, K., Bors, L. A., Iván, K. and Erdő, F. (2021).* **Development of skin-on-a-chip platforms for different utilizations: Factors to be considered.** MICROMACHINES 12(3) Paper: 294.
2. *Kós, T., Iván, K., and Laki, A. J. (2021).* **Particle separation with deterministic lateral displacement presented** at SELECT BIOSCIENCES LAB-ON-A-CHIP AND MICROFLUIDICS EUROPE 2021 CONFERENCE, ROTTERDAM, THE NETHERLANDS
3. *Lengyel, M., Kállai-Szabó, N., Antal, V., Laki, A. J., and Antal, I. (2019).* **Microparticles, Microspheres, and Microcapsules for Advanced Drug Delivery.** SCIENTIA PHARMACEUTICA, 87(3).

COMPUTATIONAL NEUROSCIENCE



Dr. Szabolcs KÁLI

Head of Research Group: Dr. Szabolcs KÁLI

Members of the Group: Gábor FARKAS, Máté MOHÁCSI, Luca TAR

Contact: kali.szabolcs@koki.hu

Keywords: *neurobiology, hippocampus, neuronal models, network dynamics, simulations*

Field of research: biology; info-bionics

The Computational Neuroscience research group uses various mathematical and simulation tools to study the dynamics and functions of both single neurons and networks in the hippocampus, often in combination with experiments conducted at the Institute of Experimental Medicine. Computational neuroscience offers a range of quantitative tools that allow us to describe the data in a succinct manner, to formulate our hypotheses about neural function clearly and precisely, and to link different scales and levels of organization through the application of mechanistic models. Models are, on the one hand, constrained by experimental data and, on the other hand, provide novel predictions that are testable using experimental methods. Some of the main focus areas of our group are the following: synaptic integration and nonlinear processing in neuronal dendrites; the origin and functions of population dynamics that are characteristic of the hippocampus, including theta and gamma oscillations and sharp-wave ripple events; the storage and retrieval of spatial and memorial representations in the hippocampus; and fitting of neuronal parameters based on experimental data and quantification of the expected precision of parameter inference.

Future research directions, collaboration opportunities

The research group's theoretical and simulation-based research relies heavily on various types of experimental data, while also aiding in the interpretation of experimental results and the integration of data from different modalities. Furthermore, the research employs numerous methods from other theoretical fields, such as statistics, machine learning, and the theory of dynamical systems.

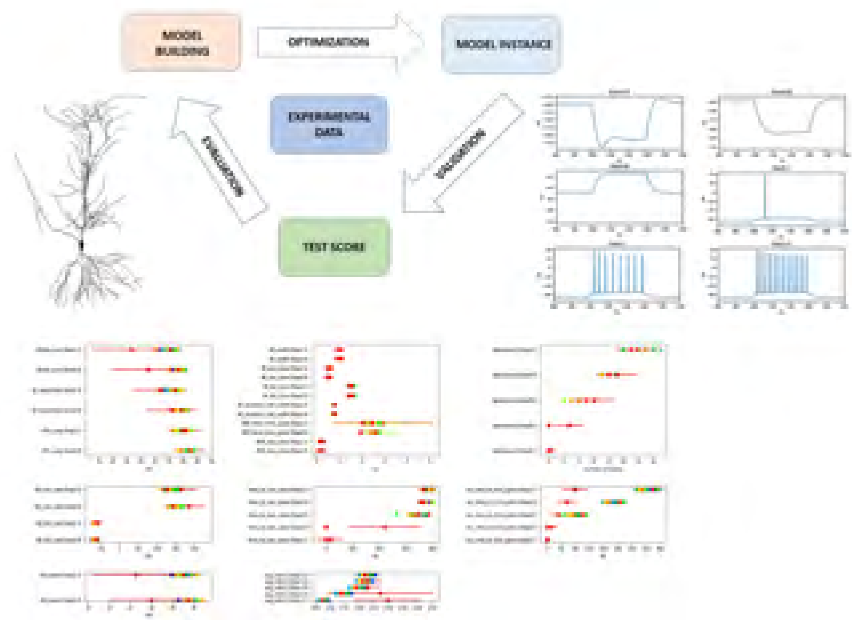


Illustration of a data-driven modeling workflow for building detailed models of neurons. Morphological and biophysical data are used to construct models whose unknown parameters are tuned via automated methods to match electrophysiological recordings. Models are then validated in an automated manner, quantitatively comparing their behavior with experimental data from various paradigms.

Key publications:

1. *Mohácsi, M., Török, M.P., Sáray, S., Tar, L., Farkas, G., Káli, S. (2024).* **Evaluation and comparison of methods for neuronal parameter optimization using the Neuroptimus software framework.** PLOS COMPUTATIONAL BIOLOGY, 20(12):e1012039.
2. *Romani, A., Antonietti, A., Bella, D., Budd, J., Giacalone, E., Kurban, K., Sáray, S., Abdellah, M., Arnaudon, A., Boci, E., Colangelo, C., Courcol, J. D., Delemontex, T., Ecker, A., Falck, J., et al. (2024).* **Community-based reconstruction and simulation of a full-scale model of the rat hippocampus CA1 region.** PLOS BIOLOGY, 22(11):e3002861.
3. *Ecker, A., Bagi, B., Vértes, E., Steinbach-Németh, O., Karlócai, M. R., Papp, O. I., Miklós, I., Hájos, N., Freund, T. F., Gulyás, A. I., Káli, S. (2022).* **Hippocampal sharp wave-ripples and the associated sequence replay emerge from structured synaptic interactions in a network model of area CA3**. ELIFE, 11: e71850.

INTEGRATIVE NEUROSCIENCE

Prof. István ULBERT

Dr. Domonkos HORVÁTH

Head of Research Group: Prof. István ULBERT, Dr. Domonkos HORVÁTH

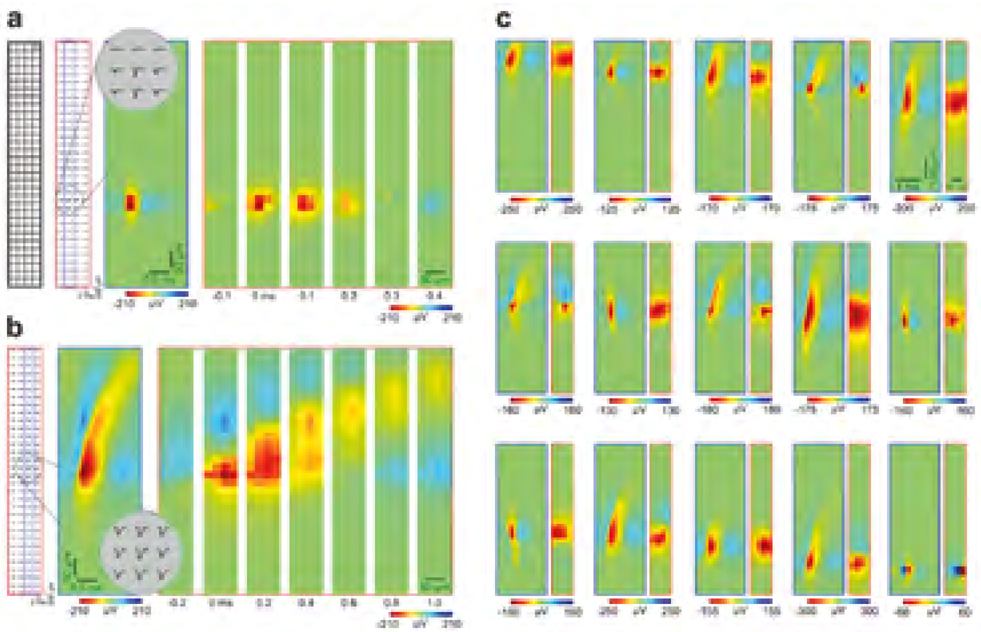
Members of the Group: Dr. Lucia WITTNER, Dr. Richárd FIÁTH, Dr. Gergely MÁRTON, Dr. Csaba Márton KÖLLŐD, Dr. Domokos MESZÉNA, Dr. András ADOLF

Contact: ulbert.istvan@ttk.hu, horvath.domonkos.aron@itk.ppke.hu

Keywords: *electrophysiology, optogenetics, BCI, human studies*

Field of research: biology; info-bionics

The laboratory covers a broad range of disciplines, including electrophysiology, materials science, microchip and microelectromechanical systems (MEMS), computing, neuroscience, and optical imaging. The aim of the research is to investigate the physiological and pathological function of the central nervous system. The laboratory staff is involved in several collaborative projects in the field of in vivo and in vitro electrophysiology and optical imaging. In 2014, the laboratory joined the Hungarian National Brain Research Program, in which it participates in the design and testing of thin-film electrodes. Main research areas: design and validation of new nervous system instruments; investigation of evoked potentials, as well as spontaneous and epileptic cortical activities; mapping of thalamocortical neural networks responsible for sensory information processing; development of brain-computer interfaces. The group is also responsible for teaching a BSc and an MSc course, in which students can learn about electrophysiological recording methods and their applications.



Spatiotemporal profiles of high-resolution spike waveforms of sorted single units. (a) Left: schematic of the recording site layout. Middle left: Mean spike waveforms of a cortical neuron with a narrow spike (putative interneuron) on all channels. Middle right: Color map showing the spatiotemporal profile of the spike waveform on channels (n = 32) framed by the blue rectangle in the middle left (column of sites which contain the peak waveform channel). The inset at the top demonstrates magnified mean spike waveforms on nine adjacent channels which recorded the spikes with the largest amplitudes. Right: Color maps illustrating the twodimensional spatial profiles of the spike waveform on all channels (red rectangle in the middle left) at multiple time points (time step, 0.1 ms). Time zero corresponds to the trough (negative peak) of the spike waveform. (b) The spatiotemporal profile of the spike waveform of a neuron with a wide spike (putative principal cell). Note the longer duration and the dorsal propagation of the spike in the color maps (time step on the right, 0.2 ms). (c) Additional examples (n = 15) of extracellular spike waveforms of various single units.

Key publications:

1. *Windolf, C., Yu, H., Paulk, A. C., Meszéna, D., Muñoz, W., Boussard, J., ... & Varol, E. (2025).* **DREDge: robust motion correction for high-density extracellular recordings across species.** NATURE METHODS, 22, 788–800.
2. *Horváth, C., Ulbert, I., and Fiáth, R. (2024).* **Propagating population activity patterns during spontaneous slow waves in the thalamus of rodents.** NEUROIMAGE, 285, 120484.
3. *Hofer, K. T., Kandrács, Á., Tóth, K., Hajnal, B., Bokodi, V., Tóth, E. Z., Erőss, L., Entz, L., Bagó, S. G., Fabó, D., Ulbert, I. and Wittner, L. (2022).* **Bursting of excitatory cells is linked to interictal epileptic discharge generation in humans.** SCIENTIFIC REPORTS, 12, 6280

NEURAL CIRCUITS AND COMPUTATION

Dr. Balázs RÓZSA

Head of Research Group: Prof. József Balázs RÓZSA

Members of the Group: Dr. Levente CSERI, Dr. Attila CSOMOS, Dr. Flóra Zsófia FEDOR, Dr. Viktória KISS, Dr. Ervin KOVÁCS, Dr. Miklós MADARÁSZ, Dr. Zoltán MUCSI, Dr. Dénes PÁLFI, Dr. Linda SULCZ-JUDÁK, Dr. Gergely SZALAY, Anna JÁSZ, Bálint KOCSIS, Tibor LŐRINCZ, Katalin WÉBER

Contact: rozsabal@femtonics.eu

Keywords: *3D two-photon microscopy, photostimulation, neuronal networks, decision-making and learning, translational neuroscience*

Field of research: biology; two-photon microscopy

Our laboratory aims to make brain function visible and controllable at a new level through state-of-the-art imaging and photostimulation technologies. At the core of our work is 3D two-photon microscopy, which enables real-time investigation of neuronal network activity with high spatial and temporal resolution. The microscopes developed by Femtonics Ltd., together with 3D acousto-optic scanning technology, significantly increase measurement speed and signal quality, while online motion correction allows precise recordings even in moving, behaving animals.

Our research focuses on uncovering previously unknown brain signaling systems that shape reward, punishment, decision-making, and learning across the neocortex and hippocampus. A key priority is the development of targeted photostimulation methods that open new possibilities for causal investigation of neuronal networks. Within BrainVisionCenter, and in collaboration with Botond Roska, we also contribute to human retinal measurements. The laboratory conducts two-photon microscopy-based acute animal experiments and cell culture studies in a strictly controlled, legally compliant environment. Our work is driven by innovation, technological excellence, and a translational vision.

Future research directions, collaboration opportunities

Our research group offers collaboration opportunities in advanced 3D two-photon imaging, photostimulation, acute animal experiments, and cell culture studies. We are open to joint basic and translational research projects, technology development partnerships, and participation in national and international grant applications.

The 3D two-photon microscopy and photostimulation technologies open new possibilities for real-time, cellular-level investigation and targeted modulation of neuronal networks.

Key publications:

1. *Gonzalez, Kevin C., et al. (2026).* **Movement-stabilized three-dimensional optical recordings of membrane potential changes and calcium dynamics in hippocampal CA1 dendrites.** NEURON, 114.10,1818-1832.
2. *Judák, L., Dobos, G., Ócsai, K., Báthory, E., Szebik, H., Tarján, B., ... & Rózsa, B. (2025).* **Moculus: an immersive virtual reality system for mice incorporating stereo vision.** NATURE METHODS, 22(2), 386-398.
3. *Judák, L., Chiovini, B., Juhász, G., Pálfi, D., Mezriczky, Z., Szadai, Z., ... & Rózsa, B. (2022).* **Sharp-wave ripple doublets induce complex dendritic spikes in parvalbumin interneurons in vivo.** NATURE COMMUNICATIONS, 13(1), 6715.

NEUROMODULATION

Prof. Loránd ERŐSS

Head of Research Group: Prof. Loránd ERŐSS

Member of the Group: Prof. István ULBERT, Dániel FABÓ, László HALÁSZ, Zsófia JORDÁN

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Keywords: *neuromodulation, movement disorders, epilepsy, pain*

In the biotechnological sense, neuromodulation lies at the frontier between natural science, medicine, and engineering, and aims to improve the quality of life of people with neurological diseases using a wide range of implantable and extracorporeal, electrical and chemical technologies. With the founding of the group, we created an interdisciplinary workshop where the above disciplines meet. Our goal was to create an integrative center where research in the field, everyday clinical medicine, university graduate and postgraduate medical and bionics training, and the neuromodulation industry can develop in close cooperation. In such an environment, on the one hand, research conducted at the center can directly shape medical practice and information technology, as well as medical undergraduate and postgraduate education; on the other hand, clinical needs and experiences also directly influence research and industrial development.

The most modern operating theater complex in the country and in Europe has been built at the National Institute of Mental, Neurological and Neurosurgery.

Key publications:

1. *Jordán, Zs., Szabó, J. P., Sákovics, A., Kelemen, A., Halász, L., Erőss, L. and Fabó, D. (2024).* **Epileptiform discharges in the anterior thalamus of epilepsy patients**. ISCIENCE, 27(5) P: 109582.
2. *Várkuti, B., Halász, L., Hagh Gooie, S., Miklós, G., Smits Serena, R., van Elswijk, G., McIntyre, Cameron C., Lempka, Scott F., Lozano, Andres M. and Erőss, L. (2024).* **Conversion of a medical implant into a versatile computer-brain interface**. BRAIN STIMULATION, 17(1) pp. 39-48.
3. *Ujma, Péter P., Dresler, M., Simor, P., Fabó, D., Ulbert, I., Erőss, L. and Bódizs, R. (2022).* **The sleep EEG envelope is a novel, neuronal firing-based human biomarker**. *SCIENTIFIC REPORTS, 12(1) P: 18836.*

QUANTITATIVE BIOLOGY OF CELL DIVISION

Prof. Andrea CILIBERTO

Head of Research Group: Prof. Andrea CILIBERTO

Contact: ciliberto.andrea@itk.ppke.hu

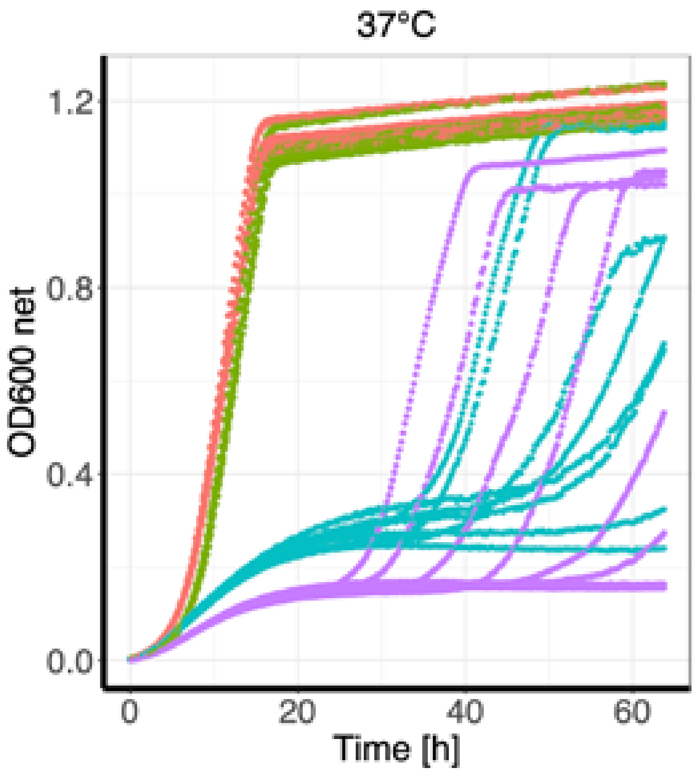
Keywords: *cell division, chromosome segregation, emergence of resistance, mathematical models*

Field of research: biology; cell biology

Our group studies how cells react when cell division is arrested, an effect elicited by numerous anti-cancer drugs. When cell division cannot be completed correctly, cells stop dividing; many of them die, but some manage to restore proliferation. These are cells that manage to overcome the effect of the drugs, and eventually can become insensitive to them. This behavior underlies the emergence of resistance to cancer treatment, a well-known limitation in treating cancer patients. Our group performs evolution experiments in the laboratory and develops mathematical models to explain them. The final goal is to find ways to delay, predict, and govern the emergence of resistance to drugs that impact cell proliferation. Experimental work is primarily done in our twin lab at IFOM (Milan, Italy), while in Budapest researchers analyze data and produce models aimed at understanding and predicting the outcomes of new experiments.

Future research directions, collaboration opportunities

We look for MSc or PhD students who have knowledge in analyzing data and producing mathematical models of molecular networks. We offer the unique opportunity of integrating their activities with the experimental work performed in the IFOM lab.

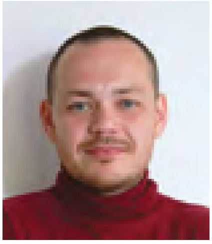


Adaptive evolution in cells impaired in cell division. We plot the optical density (a measure of cell number) as a function of time. Different populations select clones able to divide at different time points.

Key publications:

1. *Stier, A.B., Bonaiuti, P., Juhász, J., Gross, F., Ciliberto, A. (2025).* **Increased risk of slippage upon disengagement of the mitotic checkpoint**. PLOS COMPUTATIONAL BIOLOGY, *21(3): e1012879.*
2. *Macaluso, F., Bos, T., Chiroli, E., Bonaiuti, P., Apuan, J. C., Gross, F., Pompei, S., Rice, L.M., Ciliberto, A. (2025).* **Evolutionary adaptation to hyperstable microtubules selectively targets tubulins and is empowered by the spindle assembly checkpoint**. CELL REPORTS, 44(2):115323
3. *Pavani, M., Chiroli, E., Cancrini, C., Gross, F., Bonaiuti, P., Villa, S., ... & Ciliberto, A. (2023).* **Triap1 upregulation promotes escape from mitotic-slippage-induced G1 arrest**. CELL REPORTS, 42(3):112215.

TRANSLATIONAL ONCOLOGY



Dr. Tamás GARAY

Head of Research Group: Dr. Tamás GARAY

Members of the Group: Nikolett DOBOS, András MERÉNYI, Vanda DÉVÉNYI, Hanna OLÁH, Dávid PITTNER, Lara BLONSKI, Luca SZABÓ

Contact: garay.tamas@itk.ppke.hu

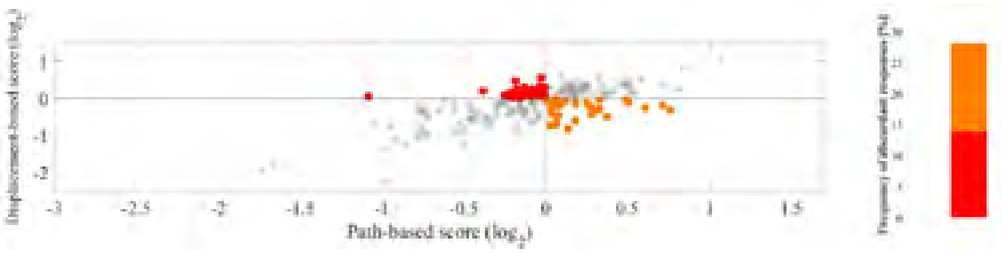
Keywords: *cancer cell lines, extracellular vesicles, cell migration*

Field of research: biology; cell biology

The Laboratory of Translational Oncology was co-founded by the Department of Internal Medicine and Oncology of Semmelweis University and the Faculty of Information Technology and Bionics of Pázmány Péter Catholic University. Accordingly, this Laboratory has the unique opportunity to address questions arising in daily clinical routine by combining medical-biological and engineering approaches (bench-to-bedside). Similarly, scientific results can be easily transferred into the clinic to serve as a starting point for new scientific questions and for new therapeutic approaches (bedside-to-bench). For our investigations, we have a comprehensive cell culture laboratory with cutting-edge techniques; our aim is to identify new therapeutic targets and prognostic and predictive markers (nucleic acids and proteins, extracellular vesicles) in histological tumor samples or liquid biopsies, which could be crucial for understanding tumor processes. Effects of activation and inhibition of potential target molecules are tested in tumor cell models. Particular attention is paid to changes in the migratory activity of tumor cells, as cell migration is an inevitable process during the formation of metastases.

Future research directions, collaboration opportunities

In collaborations, we can best serve our common goals through cellular models (migration, proliferation, and invasion assays), the analysis of clinical samples and data, and statistical analyses.

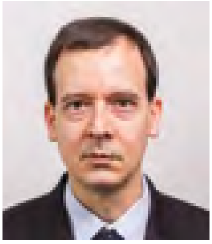


Divergent treatment responses across migration parameters and tracking methods. Scatter plot showing log2-transformed normalized values of displacement-related versus path-related parameters for each cell line - treatment combination. Each dot represents the normalized treatment response relative to control. Gray dots indicate concordant parameter changes, red dots indicate increased displacement with decreased path-related measures, and orange dots indicate decreased displacement with increased path-related measures. Vertical and horizontal lines denote no change (log2 = 0). Right-hand panel: Bar charts summarizing the proportion of discordant responses, expressed as a percentage of all evaluated conditions. Colors correspond to those used in scatter plots. The displacement-based score is the average value of mean squared displacement (MSD), displacement (D), and maximal displacement (Max D). The path-based score is the average value of total traveled distance (TTD), velocity (V), and average velocity (AV).

Key publications:

1. *Bányai, G., Naszlady, M.B., Juhász, J., Horváth, A., Hegedűs, B., Garay, T. (2026).* **Revisiting single-cell migration parameters from 2D video microscopic measurements.** EUROPEAN JOURNAL OF CELL BIOLOGY
2. *Németh, A., Bányai, G. L., Andrészek, M., Dobos, N. K., Köllőd, C., & Garay, T. (2025).* **Comparison of in vitro migration assays evaluating nintedanib's migration inhibitory effects on melanoma cells.** SCIENTIFIC REPORTS, 15(1), 42599.
3. *Németh, A., Bányai, G. L., Dobos, N. K., Kós, T., Gaál, A., Varga, Z., ... & Garay, T. (2024).* **Extracellular vesicles promote migration despite BRAF inhibitor treatment in malignant melanoma cells.** CELL COMMUNICATION AND SIGNALING, 22(1), 282.

ANALYSIS AND CONTROL OF DYNAMICAL SYSTEMS



Prof. Gábor SZEDERKÉNYI

Head of Research Group: Prof. Gábor SZEDERKÉNYI

Members of the Group: Dr. Péter POLCZ, Balázs CSUTAK, Gergely HORVÁTH, Dávid SOMOGYI, Gyula MOLNÁR, Zita WAGNER

Contact: szederkenyi@itk.ppke.hu

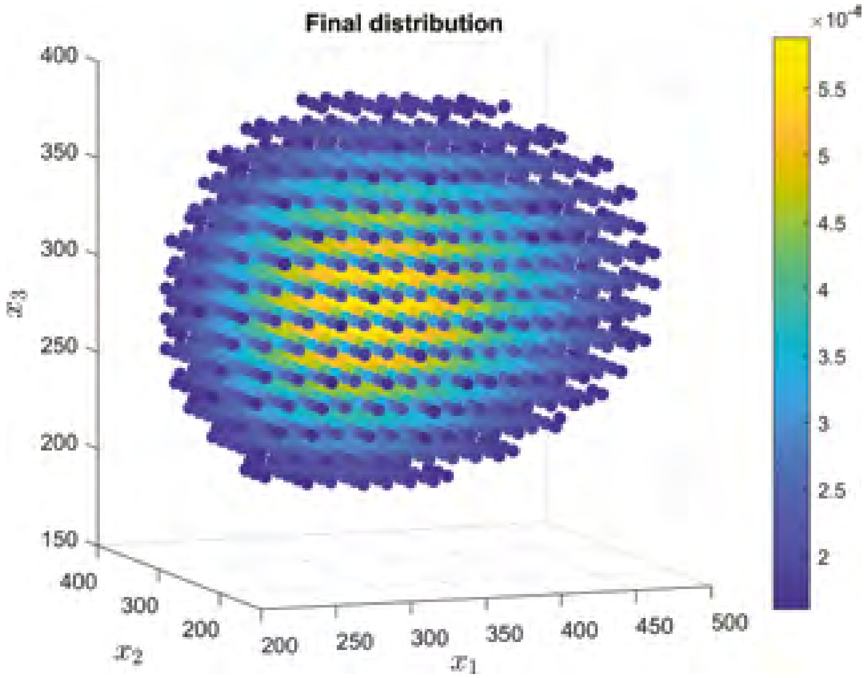
Keywords: *dynamical systems, networked models, nonlinear control, system identification*

Field of research: computer science engineering; info-bionics

The application of mathematical models describing a certain aspect of reality is indispensable for the understanding and efficient operation of technological or natural systems. When we are interested in the evolution of certain quantities, usually in time and/or space, we use dynamic models. The deep understanding and targeted manipulation of such models' behavior are studied within systems and control theory, which provides a common framework for handling dynamical models from different application fields and thus helps form an interdisciplinary viewpoint. The primary target of our research is the analysis, control, and identification of biologically motivated systems, matching the main focus of the Faculty. In our work, we pay special attention to positive systems, where the state variables remain nonnegative during operation, usually due to physical, chemical, or biological constraints. Our latest research problems are related to biochemical reaction networks and compartmental models, including the deterministic and stochastic description of gene regulation networks, networked flow models, and epidemic processes.

Future research directions, collaboration opportunities

The group is open to student and researcher exchange (e.g., in the framework of the Erasmus program) as well as to joint research in interdisciplinary areas related to nonlinear systems and control theory.



Controlled stationary probability density function of a 3-dimensional repressilator model, where the control goal was to increase the probability of the originally improbable (middle) region of the state space.

Key publications:

1. *Wiersdalen, S., Pereira, M., Lang, A., Szederkényi, G., Auriol, J., & Kulcsár, B. (2026).* **Linear Lyapunov Functions for Nonlinear Compartmental Systems**. IEEE TRANSACTIONS ON AUTOMATIC CONTROL
2. *Vághy, M. A., & Szederkényi, G. (2025).* **Asymptotic stability of delayed complex balanced reaction networks with non-mass action kinetics**. JOURNAL OF NONLINEAR SCIENCE, 35(1), 20.
3. *Polcz, P., Reguly, I. Z., Tornai, K., Juhász, J., Pongor, S., Csikász-Nagy, A., & Szederkényi, G. (2025).* **Smart epidemic control: A hybrid model blending ODEs and agent-based simulations for optimal, real-world intervention planning**. PLOS COMPUTATIONAL BIOLOGY, 21(5), e1013028.

DATA. MEDIA. COMMUNITY

Dr. Gergely István LUKÁCS

Head of Research Group: Dr. Gergely István LUKÁCS

Members of the Group: Dr. Zoltán MÁTHÉ, Kornél GÁTMEZEI, Klaudia SZILI, Benedek NAVRATYIL, Tamás Béla KIS, Boldizsár KOVÁCS, Zita RADVÁNYI

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Keywords: *data engineering, artificial intelligence, benchmarking, human relationships*

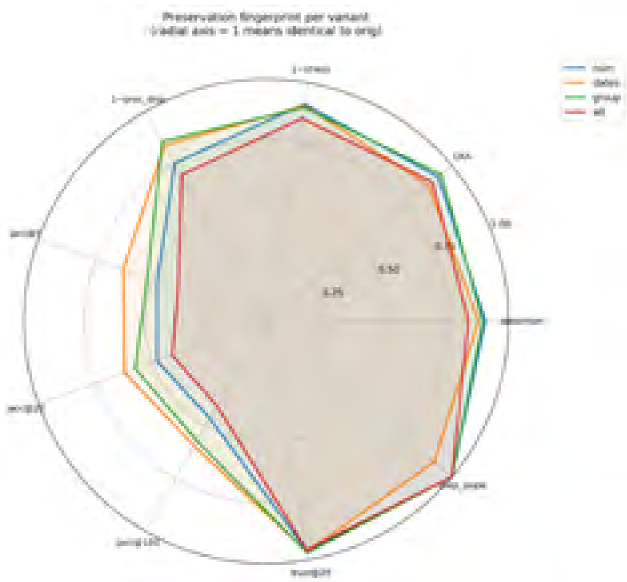
Field of research: computer science engineering; machine learning

Our research group focuses on application-driven research in data-intensive systems and artificial intelligence, combining broad expertise with practical impact. Our work spans relational, horizontally scalable, time-series, unstructured, and vector databases. We study their design, application, benchmarking, and emerging industry trends. In machine learning, our primary focus is on structured data analytics and the application of large language models. Over the past several years, we have benchmarked relational databases, big data platforms, and vector databases. Our current research centers on the evaluation of generative AI systems, including retrieval-augmented generation (RAG), LLM-as-a-Judge, vector embeddings, anonymization, and text-to-SQL.

We see significant societal impact in environmental sustainability and, even more importantly, in strengthening human relationships and communities. We have extensive experience in developing integrated environmental and water management databases. Our interdisciplinary collaborations include the development and evaluation of voice-based social media platforms, social network analysis of hospital chaplaincy communities, and benchmarking the quality of large language model responses to relationship-related questions.

Future research directions, collaboration opportunities

We welcome research, industrial, and interdisciplinary collaborations in data engineering, artificial intelligence, and AI evaluation. We support industry-driven student projects, provide expert consulting, and seek partnerships with social scientists to explore the impact of digitalization and AI on human relationships and communities.

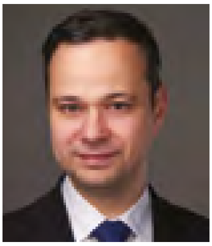


Impact of anonymization on vector embeddings in ITOps data, measured by changes in embedding-based similarity metrics. Kornél Gátmezei, RAG-Enhanced LLMs and Their Evaluation, Master's Thesis, 2026.

Key publications:

1. *Yang, Z. Gy., Stajer, L. A., Lukács, G. (2025).* **Under the hood: An inside look at PULI models** In: Tómács, Tibor (szerk.) PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON FORMAL METHODS AND FOUNDATIONS OF ARTIFICIAL INTELLIGENCE EGER, MAGYARORSZÁG: ESZTERHÁZY KÁROLY KATOLIKUS EGYETEM LÍCEUM KIADÓ
2. *Horváth, A., Oláh, A., Pintér, A., Siklósi, B., Lukács, G., Reguly, I. Z., Tornai, K., Zsedrovits, T., Máthé, Z. (2025).* **Anomaly Detection Algorithms for Real-Time Log Data Analysis at Scale.** IEEE ACCESS 13 pp. 136288-136311, 24 p.
3. *Lukács, G., Jani, M. (2016).* **Analyzing speech and music blocks in radio channels: Lessons learned for playlist generation**. IN: ROBLES, R; TALLON-BALLESTEROS, A J; PIT, PICHAPPAN (SZERK.) ELEVENTH INTERNATIONAL CONFERENCE ON DIGITAL INFORMATION MANAGEMENT (ICDIM) NEW YORK, AMERIKAI EGYESÜLT ÁLLAMOK: INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

FINANCIAL AI RESEARCH (FAIR LAB)



Dr. Norbert FOGARASI

Head of Research Group: Dr. Norbert FOGARASI

Members of the Group: Ádám BURGERT, Artur SAHAKYAN, Attila RÁCZ, Bence GÉCZI, Mohamed Malek AL-FAKIH , Mohammed BALAWI, Péter LANSZKI, Péter MLINKÓ

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Keywords: *computational finance, quantitative financial modeling, intelligent trading systems, financial time series analysis, neural networks in finance*

Field of research: computer science engineering; machine learning

The Financial AI Research Lab conducts interdisciplinary research at the intersection of computational finance, artificial intelligence, and optimization. Our goal is to develop advanced quantitative methods and intelligent decision-support systems for complex financial problems.

The lab focuses on quantitative financial modeling, machine learning, financial time series analysis, portfolio optimization, algorithmic trading, and predictive analytics. We investigate how data-driven methods and intelligent algorithms can improve investment decisions, risk management, asset pricing, and the operation of modern financial systems. Particular emphasis is placed on intelligent trading systems, adaptive investment strategies, neural-network-based forecasting, and optimization methods for dynamic decision-making under uncertainty.

By combining expertise from finance, computer science, operations research, and data science, the lab bridges theoretical advances and practical applications. Our research aims to develop robust, interpretable, and scalable financial intelligence systems that transform data into actionable insights and support more efficient and informed financial decision-making.

Future research directions, collaboration opportunities

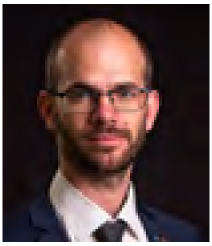
We are open to collaboration opportunities in portfolio optimization, risk management, and algorithmic trading, as well as the development of machine learning and optimization methods for complex financial problems, including participation in national and international research projects.

Computational finance is an interdisciplinary engine where algorithms, data-driven intelligence, and financial theory converge to transform market complexity into structured decision-making power.

Key publications:

1. *Racz, A., Fogarasi, N. (2025)*. **Effective Convergence Trading of Sparse, Mean Reverting Portfolios**. COMPUTATIONAL ECONOMICS, 66, 2367-2381.
2. *Racz, A., Fogarasi, N. (2024)*. **Improved Sparse Mean Reverting Portfolio Selection Using Simulated Annealing and Extreme Learning Machine.** CONTEMPORARY ECONOMICS, 18(3), 336-351.
3. *Racz, A., Fogarasi, N. (2022)*. **Trading sparse, mean reverting portfolios using VAR(1) and LSTM prediction.** *ACTA UNIV. SAPIENTIAE, INFORMATICA, 13(2), 288-302.*

HIGH PERFORMANCE COMPUTING



Dr. István Zoltán REGULY

Head of Research Group: Dr. István Zoltán REGULY

Members of the Group: Kevin Nava GARCIA,Balázs DRÁVAI

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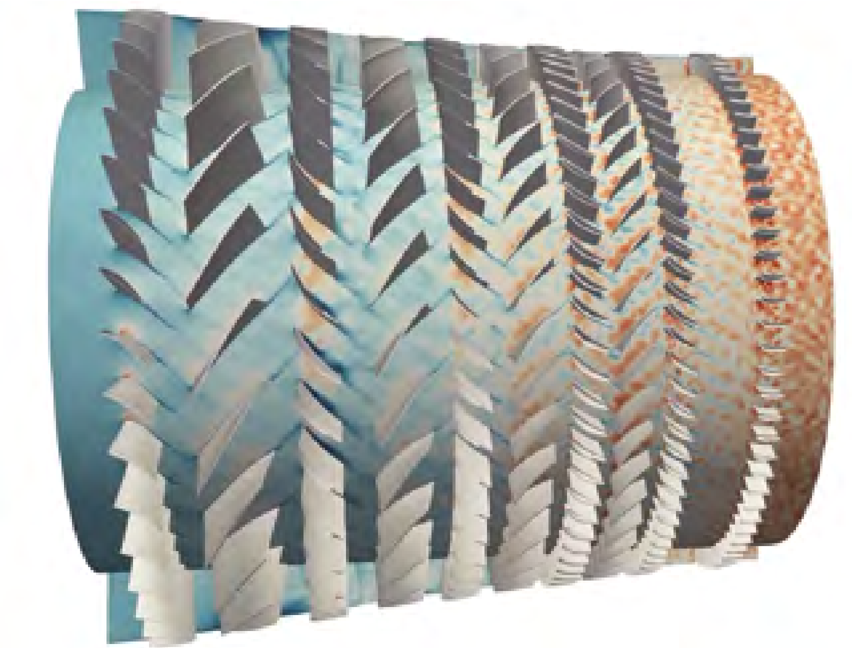
Keywords: *HPC, scientific computing, epidemiological modeling*

Field of research: computer science engineering; machine learning

The research group leverages high-performance computing across scientific fields. Our objective is to enable diverse disciplines, from epidemic modeling to jet engine design, to unlock the potential of modern computing architectures - multi-core processors, GPUs, and supercomputers. We achieve this without requiring field experts to understand these systems, allowing engineers and physicists to describe problems efficiently and concisely without dealing with parallel hardware details. Collaborating with international teams, we develop the OPS and OP2 domain-specific languages (for structured and unstructured meshes), making this approach accessible to major industrial and academic partners. Working with faculty researchers and global groups, we also developed the PanSim epidemic modeling environment. It realistically simulates the movement and interaction of millions of agents, supporting intervention planning and preparation for a more effective response to the next major pandemic.

Future research directions, collaboration opportunities

The group is continuously looking for collaboration with groups in fields relying on computational modeling, where a significant increase in computational efficiency could lead to a qualitative leap in modeled systems.

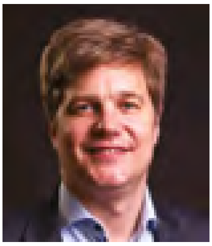


The high-fidelity simulation of aircraft engines enables the design and development of effective airplanes. The simulation process is computationally intensive - thanks to our research it can be run on the largest supercomputers in the world, built with the latest massively parallel CPUs and GPUs.

Key publications:

1. *Siklósi, B., Sharma, P. K., Lusher, D. J., Reguly, I. Z., & Sandham, N. D. (2025).* **Reduced and mixed precision turbulent flow simulations using explicit finite difference schemes**. FUTURE GENERATION COMPUTER SYSTEMS, 108111.
2. *Polcz, P., Reguly, I. Z., Tornai, K., Juhász, J., Pongor, S., Csikász-Nagy, A., & Szederkényi, G. (2025).* **Smart epidemic control: A hybrid model blending ODEs and agent-based simulations for optimal, real-world intervention planning.** PLOS COMPUTATIONAL BIOLOGY, 21(5), e1013028.
3. *Prabhakar, A., Goddard, C. R., Amirantec, D., Reguly, I. Z., Gerstenberger, A., Suhrmann, J. F., ... & Mudalige, G. R. (2022).* **Virtual certification of gas turbine engines-visualizing the DLR Rig250 compressor.** THE INTERNATIONAL CONFERENCE FOR HIGH PERFORMANCE COMPUTING, NETWORKING, STORAGE, AND ANALYSIS

MACHINE PERCEPTION AND GEO-INFORMATION COMPUTING



Prof. Csaba BENEDEK

Head of Research Group: Prof. Csaba BENEDEK

Members of the Group: Marcell KÉGL, Balázs PÁLFFY, József KÖVENDI, Balázs BÓDIS, Gergő NAGY

Contact: benedek.csaba@itk.ppke.hu

Keywords: *machine vision, pattern recognition, point cloud analysis, 3D reconstruction*

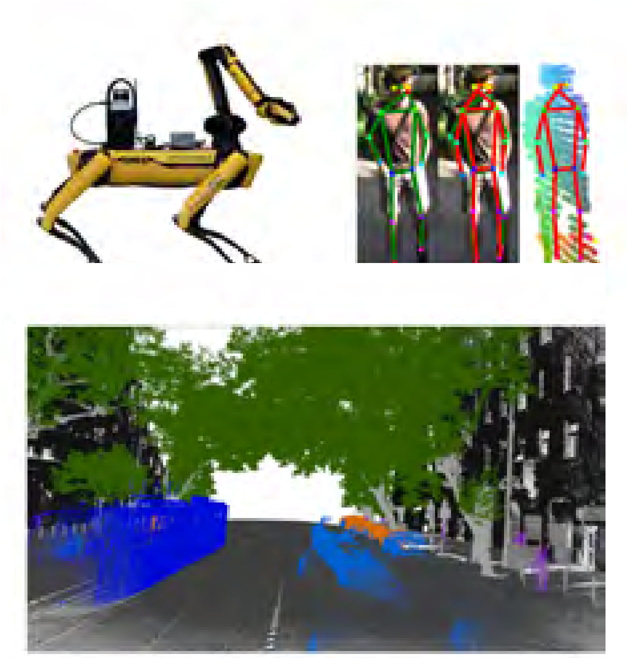
Field of research: computer science engineering; machine learning

Up-to-date 3D sensors have revolutionized the acquisition of environmental information. 3D vision systems of self-driving vehicles can be used not only for safe navigation, but also for real-time mapping of the environment, and for detecting and analyzing static and dynamic objects and scene elements. New-generation geo-information systems (GIS) store extremely detailed 3D maps of cities, consisting of dense 3D point clouds, registered camera images, and semantic metadata. Automatic filtering and processing of medical 3D data (MR, CT, or ultrasound) with rapidly evolving quality and resolution is becoming increasingly important. The use of digital tools is also playing an increasing role in cultural heritage preservation; automated scene analysis and model reconstruction from images and laser scanning data is a key task for archaeological research.

The main goal of the research and development work in the Machine Perception and Geo-information Computing Laboratory is to obtain a holistic interpretation of our environment by automatically processing and fusing the measurements of sensors that record spatial information for different applications. Our research is carried out in cooperation with PPKE ITK and the HUN-REN SZTAKI Machine Perception Research Laboratory.

Future research directions, collaboration opportunities

The research group actively participates in national and international research projects in the fields of machine vision and artificial spatial intelligence. Main application areas: environmental sensing of mobile robots and autonomous vehicles, remote sensing, satellite image analysis, and medical image processing.



Environment perception from a mobile quadruped robot equipped with LiDAR and camera sensors: results on human pose estimation and 3D scene mapping.

Key publications:

1. *Ibrahim, Y. and Benedek, Cs. (2023).* **MVPCC-Net: Multi-View Based Point Cloud Completion Network for MLS Data. Image and Vision Computing**, ELSEVIER, vol. 134, article 104675.
2. *Zováthi, Ö., Pálffy, B., Jankó, Z., & Benedek, Cs. (2023).* **ST-DepthNet: A spatio-temporal deep network for depth completion using a single non-repetitive circular scanning Lidar.** IEEE ROBOTICS AND AUTOMATION LETTERS, 8(6), 3270-3277.
3. *Benedek, Cs. (2022).* **Multi-level Bayesian Models for Environment Perception**. SPRINGER INTERNATIONAL PUBLISHING

MOBILE SENSOR PLATFORMS AND MULTIMODAL SENSING NETWORKS

Dr. András OLÁH

Dr. Kálmán TORNAI

Head of Research Group: Dr. András OLÁH, Dr. Kálmán TORNAI

Members of the Group: Attila TIHANYI, András HALÁSZ, Dániel NÉMETH, Lóránt DAUBNER, Bálint ÜVEGES

Contact: olah.andras@itk.ppke.hu, tornai.kalman@itk.ppke.hu

Keywords: *sensor data processing, mobile sensing platforms, behavior-based user identification, open-set recognition, anomaly detection*

Field of research: computer science engineering; machine learning

Our research focuses on the processing of time-series data originating from sensor-based mobile platforms, wireless sensor networks, and complex information systems. We develop artificial intelligence and machine learning methods for user identification, anomaly detection, intelligent energy applications, and data-driven decision support.

The laboratory was established in 2011. We investigate how measurements collected from mobile devices can be used for behavior-based, soft-biometric user identification on Android and iOS mobile platforms, using both built-in and external sensors.

One of our key research directions is open-set recognition, which enables systems not only to identify known users or patterns, but also to recognize unknown, previously unseen behaviors. Beyond mobile biometric identification, the methods developed in this area can also be applied in smart energy systems, smart plug-based appliance recognition, and real-time log data anomaly detection.

The laboratory also conducts research on the industrial and environmental applications of wireless sensor networks. We investigate resilient communication solutions suitable for monitoring environments characterized by hazardous phenomena, such as forest fires, as well as the role of sensor networks in precision agriculture tasks, for example in the monitoring of vineyards.

The goal of the research group is to develop robust AI/ML-based solutions that can be applied in practical environments and support the safer, more efficient, and more intelligent operation of physical and digital systems.

Future research directions, collaboration opportunities

The research group offers professional and research collaboration in sensor data processing, mobile platforms, open-set recognition, and anomaly detection. We work with partners on joint R&D projects, industrial application development, and the preparation of national and international grant proposals.

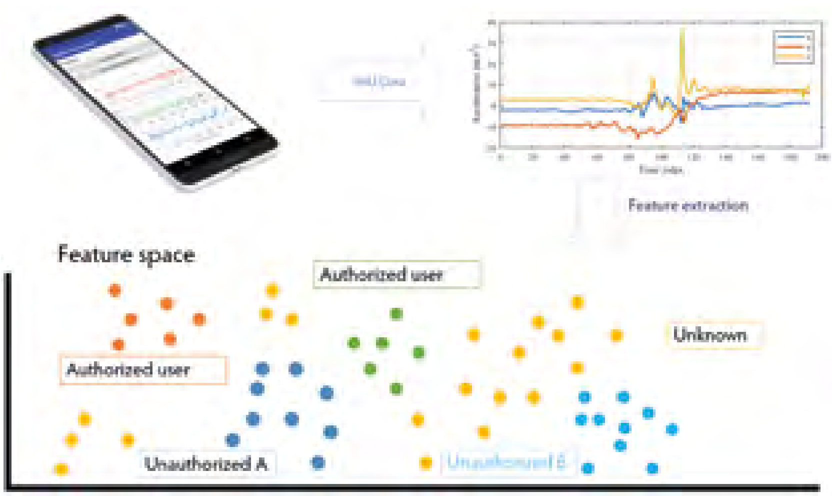


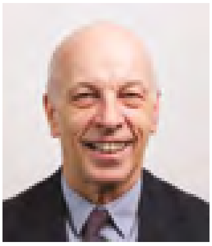
Illustration of how open-set recognition is applied to IMU sensor readings from a smartphone. The proposed method can distinguish among known users and separate their patterns from those of unknown users (i.e., users not seen by the system during training).

Key publications:

1. *Halasz, A. P., Al-Hemeary, N., Daubner, L., Juhasz, J., Zsedrovits, .T., Tornai, K. (2025).* **Adapting a Previously Proposed Open-Set Recognition Method for Time-Series Data: A Biometric User Identification Case Study.** ELECTRONICS (SWITZERLAND), 14(20), 3983.
2. *Németh, D. I., Tornai, K. (2025).* **Hybrid ILM–NILM Smart Plug system.** INTERNATIONAL JOURNAL OF ELECTRICAL POWER AND ENERGY SYSTEMS, 173 Paper: 111395.
3. *Üveges, B. Á. and Oláh, A. (2025).* **Resilient Multi-Sink, Multipath Routing for Mobility-Limited Wireless Sensor Networks in Hostile Event Monitoring**. IEEE ACCESS, vol.13, pp.107386-107409.

RECONFIGURABLE AND HETEROGENEOUS ARCHITECTURES

Dr. Zoltán NAGY



Prof. Péter SZOLGAY

Head of Research Group: Dr. Zoltán NAGY, Prof. Péter SZOLGAY

Members of the Group:

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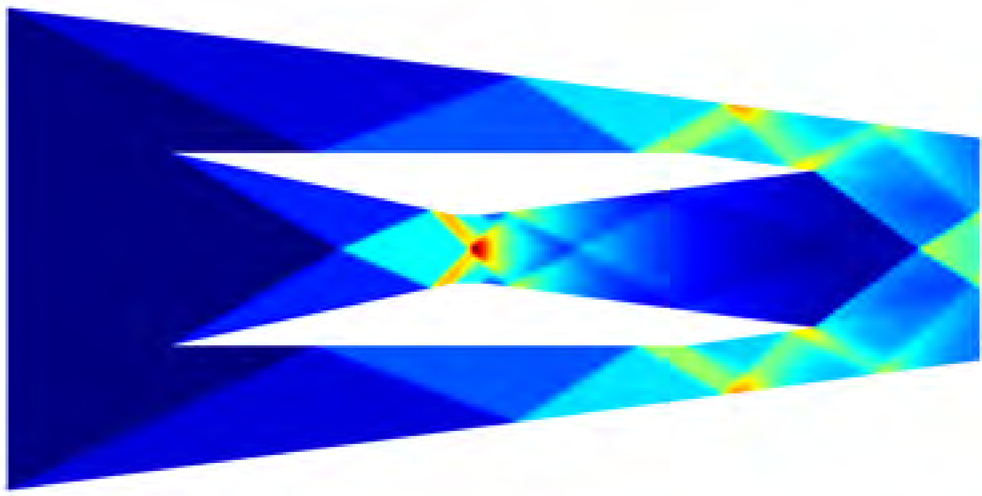
Keywords: *parallel computing, processor arrays, heterogeneous architectures, FPGA, reconfigurable computing*

Field of research: computer science engineering; machine learning

In our laboratory, we work on the design and measurement of analog and digital circuits. Currently, the main focus is the design of digital circuits on FPGA devices. The applications cover a wide range, from the simulation of complex physical systems through image processing to the acceleration of search in bioinformatics databases. We have developed a compact, low-power image processing architecture with the UAV Vision Lab. We have implemented a hybrid FPGA–CPU-based architecture for object recognition, which is the visual analysis subsystem of a prosthetic arm controller. The tasks of the system were partitioned between the FPGA fabric and the processors, based on performance measurements of the building blocks. We accelerated a charged alpha-helix detection algorithm on FPGA with the Structural Biology and Proteomics Lab. We accelerated the simulation of micromagnetic arrays on FPGA in cooperation with the Optics, Magnonics and New Generation Hardware Laboratory. During circuit design, in addition to traditional hardware description languages (VHDL, Verilog), high-level synthesis plays an increasingly important role, as it enables the architecture to be described in C/C++.

Future research directions, collaboration opportunities

Our lab contributes to the acceleration of computationally intensive tasks on programmable logic devices. After analyzing the performance of the algorithms, we identify bottlenecks and partition the tasks between different architectures (CPU/GPU/FPGA).

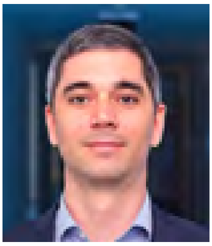


Accelerating Computational Fluid Dynamics (CFD) simulation on FPGA: shock waves in a 2D cross-section of a scramjet engine.

Key publications:

1. *Fejér, A., Nagy, Z., Benois-Pineau, J., Szolgay, P., de Rugy, A. and Domenger, J-P.* (2022). **Hybrid FPGA-CPU-Based Architecture for Object Recognition in Visual Servoing of Arm Prosthesis** JOURNAL OF IMAGING 8:2 p. 44.
2. *Zarandy, A., Horvath, A. and Szolgay, P.* (2018). **CNN Technology-Tools and Applications** IEEE CIRCUITS AND SYSTEMS MAGAZINE 18:2 pp. 77-89.
3. *Nagy, Z., Nemes, Cs., Hiba, A., Csík, Á., Kiss, A., Ruszinkó, M. and Szolgay, P.* (2014). **Accelerating unstructured finite volume computations on field-programmable gate arrays** CONCURRENCY AND COMPUTATION: PRACTICE AND EXPERIENCE 26(3) pp. 615-643.

UAV VISION



Dr. Tamás ZSEDROVITS

Head of Research Group: Dr. Tamás ZSEDROVITS

Members of the Group: Nawar AL-HEMEARY, Lóránt DAUBNER, Gergő TÉTÉNY BOR, Dániel UJHELYI, Olivér ZSUMBERA

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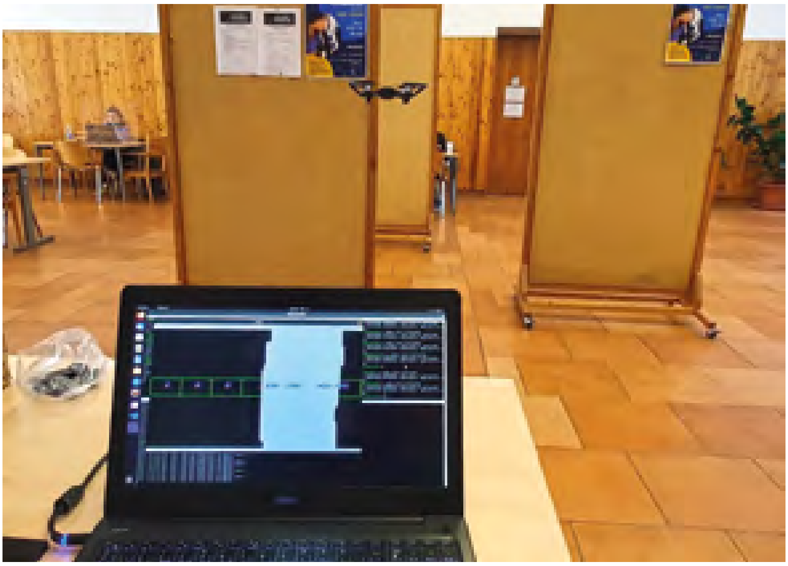
Keywords: UAV, computer vision, edge computing, autonomous navigation, 3D mapping
Field of research: computer science engineering; machine learning

The UAV Vision Lab researches unmanned aerial vehicles and computer vision. One of our central questions is how to perform the computations required for a given task with the lowest possible power consumption, using small and affordable devices. Our main topic is camera-based collision avoidance: we detect and track distant aircraft in footage from one or more cameras. The goal is the best possible detection and tracking while keeping the system's power consumption and size low, since the computation must be carried out in real time, onboard the aircraft. Another area is the ergonomic control of aircraft: we develop control methods that are more natural and faster to learn. The third topic is indoor applications. Here we investigate which tasks can be solved without external reference systems, using only onboard sensors (camera, IMU, LiDAR, rangefinder, etc.). For example, in 3D cave mapping we use a camera, IMU, and LiDAR together to create more accurate maps of cave passages, aiding exploration and supporting cavers. In addition, our students work on a collision-avoidance simulator, photogrammetric 3D building modeling, face recognition and tracking with a drone swarm, neuromorphic collision avoidance, visual indoor navigation, and the creation of a video annotation database.

Future research directions, collaboration opportunities

The UAV Vision Lab contributes to grant-based collaborations in UAV computer vision, onboard AI, and 3D mapping, with a focus on resource-constrained onboard processing, multimodal sensor data analysis, open-set recognition, and real-world drone validation. The research group provides expertise for joint R&D projects, demonstrators, and student research topics.

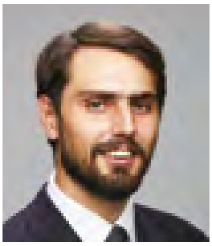


Experiment with a bio-inspired vision system for autonomous obstacle avoidance on drones. The image shows the drone flying through the clear path between the display panels in a complex environment. The system consists of pre-processing based on a mammal retina model and a U-Net for the vision task. The video is recorded by a DJI Tello drone and streamed to a laptop running ROS on Ubuntu, which handles drone control and communication, while the neural network—implemented in PyTorch—runs on the laptop's dedicated GPU.neural network with a PyTorch-based implementation on the laptop's dedicated GPU.

Key publications:

1. *Halász A.P., Al Hemeary N., Daubner L.S., Juhász J., Zsedrovits T., Tornai K. (2025).* **Adapting a Previously Proposed Open-Set Recognition Method for Time-Series Data: A Biometric User Identification Case Study.** ELECTRONICS (SWITZERLAND), 14 (20), art. no. 3983.
2. *Hiba A., Sántha L.M., Zsedrovits T., Hajder L., Zarandy A. (2020).* **Onboard visual horizon detection for unmanned aerial systems with programmable logic**. ELECTRONICS (SWITZERLAND), 9 (4), art. no. 614.
3. *Zsedrovits T., Bauer P., Hiba A., Nemeth M., Jani Matyasne Pencz B., Zarandy A., Vanek B., Bokor J. (2016).* **Performance Analysis of Camera Rotation Estimation Algorithms in Multi-Sensor Fusion for Unmanned Aircraft Attitude Estimation.** JOURNAL OF INTELLIGENT AND ROBOTIC SYSTEMS: THEORY AND APPLICATIONS, 84 (1-4), pp. 759 - 777.

ACOUSTIC IMAGING AND MEDICAL SIGNALS (AIMS LAB)



Dr. Márton Áron GODA

Head of Research Group: Dr. Márton Áron GODA

Members of the Group: Dr. Janka HATVANI, Kristóf MÜLLER, Bálint KRISTÓF, Szabolcs Mátyás PÉTER

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Keywords: *smart devices, health tracking, signal processing, artificial intelligence, remote monitoring*

Field of research: info-bionics; mathematics, physics, electrical engineering

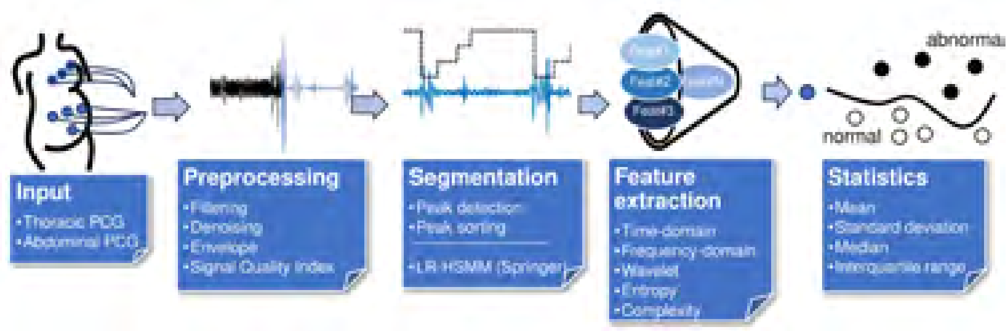
Wearable devices have become a key part of modern healthcare, enabling home monitoring and the tracking of fitness, stress, and potential heart conditions, while providing valuable insights for clinical care and everyday health management. Our lab focuses on developing standardized, robust, and validated solutions for medical signal processing to support next-generation AI-powered healthcare technologies. Traditional fetal monitoring methods, such as ultrasound and cardiotocography, have limitations for long-term and home-based monitoring. Fetal phonocardiography (fPCG) provides a simple, cost-effective alternative. Our research focuses on fPCG signals and ultrasound imaging. We developed pyPCG, a validated Python toolbox for the advanced analysis of fPCG signals.

Heart pulse monitoring is essential for cardiovascular assessment and arrhythmia detection using technologies such as ECG, pulse oximetry, smartwatches, and chest straps. These methods also have potential for biometric identification. In collaboration with the

Technion – Israel Institute of Technology and the University of Cambridge, we developed pyPPG, an open-source toolbox for photoplethysmography analysis, supporting future clinical applications such as heart failure prediction and risk assessment.

Future research directions, collaboration opportunities

The AIMS Lab welcomes collaborations in AI-based medical signal processing, wearable health technologies, and digital health innovation. We actively engage in joint research projects, clinical validation studies, open-source software development, and national and international grant proposals with academic, clinical, and industrial partners.

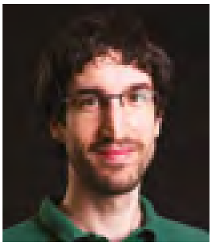


Major pyPCG steps and implemented functionality.

Key publications:

1. *Goda, M. Á., Charlton, P. H., & Behar, J. A. (2024).* **pyPPG: a Python toolbox for comprehensive photoplethysmography signal analysis.** PHYSIOLOGICAL MEASUREMENT, 45(4), 045001.
2. *Müller, K., Hatvani, J., Koller, M., & Goda, M. Á. (2024).* **pyPCG: a Python toolbox specialized for phonocardiography analysis**. PHYSIOLOGICAL MEASUREMENT, 45(12), 125007.
3. *Hatvani, J., Horváth, A., Michetti, J., Basarab, A., Kouamé, D., & Gyöngy, M. (2018).* **Deep learning-based super-resolution applied to dental computed tomography.** IEEE TRANSACTIONS ON RADIATION AND PLASMA MEDICAL SCIENCES, 3(2), 120-128.

IMPLANTABLE MICROSYSTEMS



Dr. Ágoston Csaba HORVÁTH

Head of Research Group: Dr. Ágoston Csaba HORVÁTH

Members of the Group: Dr. Zsófia BALOGH-LANTOS, Dr. Ágnes SZABÓ, Dr. Péter SERE, Bence CSERNYUS, Ákos MÓROCZ

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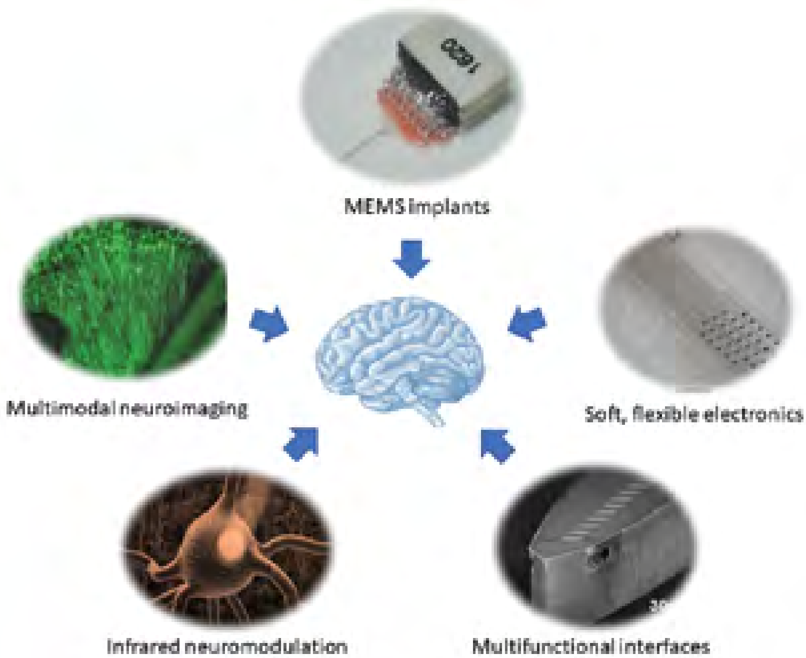
Keywords: *multimodal neural implants, optical and thermal neuromodulation techniques*

Field of research: info-bionics; mathematics, physics, electrical engineering

Our group utilizes recent advances in microengineering to create novel brain-machine interfaces at the microscale. The manufacturing and characterization of such miniaturized sensors and actuators, and their applications in vivo, require truly interdisciplinary approaches, including materials science, electronics technology, neurobiology, and informatics. One of the most challenging tasks is the development of microdevices implanted in neural tissue. Our research group is engaged in the design, implementation, and testing of microimplants that are able to record cellular communication with high spatial and temporal resolution and are also able to control cellular processes by means of optical and thermal stimulation. In the field of optical stimulation, our lab validates novel microdevices engineered to perform focal infrared stimulation in deep tissue. This technology is also leveraged to characterize the response of individual cells to infrared neuromodulation in living experimental animals.

Future research directions, collaboration opportunities

Development and testing of customizable multimodal neural implants, from design through the analysis of in vivo data.

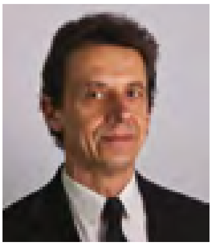


Our group combines expertise from neuroscience and engineering to create microscale devices to interrogate or stimulate brain cells. These interfaces are created using MEMS (micro-electromechanical systems) technology, which enables the combination of electrophysiology with neuroimaging, optoelectronics, or microfluidics.

Key publications:

1. *Horváth, Á. Cs., Borbély, S., Mihók, F., Fürjes, P., Barthó, P., Fekete, Z. (2022).* **Histological and electrophysiological evidence on the safe operation of a sharp-tip multimodal optrode during infrared neuromodulation of the rat cortex**. SCIENTIFIC REPORTS, 12: (1), 11434.
2. *Horváth, Á. C., Borbély, S., Boros, C. Ö., Komáromi, L., Koppa, P., Barthó, P., Fekete, Z. (2020).* **Infrared neural stimulation and inhibition using an implantable silicon photonic microdevice.** MICROSYSTEMS & NANOENGINEERING, 6: (1), 44.
3. *Fekete, Z., Csernai, M., Kocsis, K., Horváth, Á. Cs., Pongrácz, A., Barthó, P. (2017).* **Simultaneous in vivo recording of local brain temperature and electrophysiological signals with a novel neural probe**. JOURNAL OF NEURAL ENGINEERING, 14: (3), 034001.

MOVEMENT ANALYSIS AND MOTOR CONTROL



Dr. József LACZKÓ

Head of Research Group: Dr. József LACZKÓ

Members of the Group: Dr. Lilla BOTZHEIM, Dr. Mariann MRAVCSIK, Balázs RADELECZKI, Amelita FODOR

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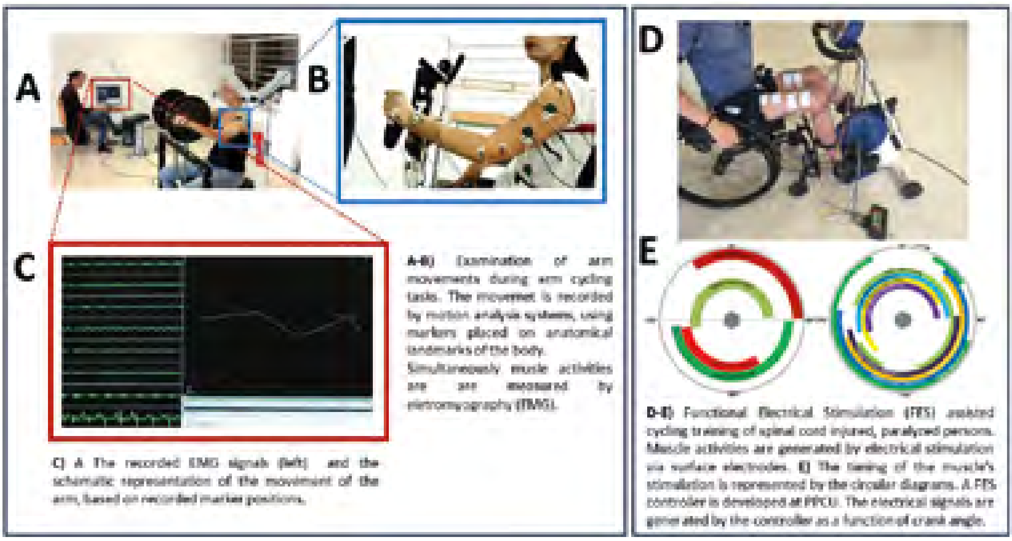
Keywords: *motor control, movement rehabilitation, functional electrical stimulation*

Field of research: info-bionics; mathematics, physics, electrical engineering

The laboratory investigates how the central nervous system controls human limb movements for the well-coordinated execution of motor tasks. Such tasks include, for instance, reaching for a target with the arm, transporting an object held in the hand, or performing cycling movements with the lower or upper limbs.

We use movement-analysis systems to record kinematic and electromyographic data during human limb movements. Markers are placed on anatomical landmarks, and their positions are recorded. Simultaneously, muscle activities are measured using surface electromyography (EMG). A particular interest of the laboratory is functional electrical muscle stimulation and its application in the rehabilitation of paralyzed people with spinal cord injuries. We continue our research in cooperation with colleagues from the Wigner Research Centre for Physics and apply our findings at the National Institute for Medical Rehabilitation.



The figure illustrates different aspects of our research, from data recording and exploratory research (Panels A–C) to practical applications (Panels D–E). Our goal is to improve the rehabilitation and living conditions of motor-impaired people through the joint application of informatics and the natural sciences.

Key publications:

1. *Radeleczki, B., Mravcsik, M., Bozheim L. and Laczko, J. (2023).* **Prediction of leg muscle activities from arm muscle activities in arm and leg cycling** THE ANATOMICAL RECORD 306(4) pp. 710-719.
2. *Botzheim, L., Laczko, J., Torricelli, D., Mravcsik, M., Pons, J. L. and Barroso, F. O. (2021).* **Effects of gravity and kinematic constraints on muscle synergies in arm cycling** JOURNAL OF NEUROPHYSIOLOGY 125(4) pp. 1367-1381.
3. *Mravcsik, M., Klauber, A., Putz, M., Kast, C., Mayr, W. and Laczko, J. (2019).* **Tricycling by FES of quadriceps muscles leads to increased cycling speed over series of trainings of persons with flaccid paraplegia** PROCEEDINGS OF THE 13TH VIENNA FES WORKSHOP pp. 133-135.

PROSTHETICS

Dr. György CSEREY

Head of Research Group: Dr. György CSEREY,

Members of the Group: Dr. Sándor FÖLDI, Dr. Miklós KOLLER, Márton Bese NASZLADY, Péter András HERING, Dorka KECSKÉS, Zsófia BEKŐ, Henrik STURCZ, Botond MÓZSIK, Szilárd SZATMÁRI

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Keywords: *prosthetics, biomimetics, humanoid robotics, soft robotics, textile technologies, bionic interfaces, exoskeletons*

Field of research: info-bionics; mechatronics engineering

The Prosthetics Lab develops biomimetic artificial limbs, wearable human–machine interfaces, and technologies supporting their industrialization and scalable manufacturing. Its core research focuses on humanoid robotic hands for prosthetic and teleoperation/industrial applications, integrating advanced manufacturing and textile technologies. Another major area is rehabilitation robotics, particularly the development of a soft robotic exoskeleton using the Faculty's emulated elastic actuator ("software spring") for habilitation and rehabilitation, supported by AI-driven control systems. The lab also investigates digital twins for personalized rehabilitation by integrating movement, physiological, and sensor data to optimize therapy and monitor recovery. Research extends to AI- and robotics-enabled rehabilitation environments with intelligent sensing, fall detection, physiological monitoring, and caregiver support for hospitals, rehabilitation centers, nursing homes, and home care. Additional work includes multimodal AI assistants for people with disabilities, providing communication, navigation, and health monitoring support. The lab also conducts AI-based movement analysis, combining sensor and computer-vision data for objective rehabilitation assessment, personalized feedback, and applications in sports performance and injury prevention.

Future research directions, collaboration opportunities

The Prosthetics Lab collaborates on AI-driven rehabilitation, personalized digital twins, intelligent assistive environments, accessible AI technologies, advanced prosthetics and exoskeletons, and objective movement analysis. Joint research integrates robotics, biosensors, computer vision, and human–machine interfaces to improve rehabilitation, independent living, and clinical decision support.

Biomimetic prosthetic hand. (Allonic Inc.)

Key publications:

1. *Csigó, K. and Cserey, Gy. (2026). Human Shadows in Machine Minds:* **Quantitative Study Interpreting AI Responses to the Rorschach Test.** JMIR MENTAL HEALTH 13.1, e88186.
2. *Endrei, T., Földi, S., Makk, Á., & Cserey, G. (2025).* **Learning to suppress tremors: a deep reinforcement learning-enabled soft exoskeleton for Parkinson's patients.** FRONTIERS IN ROBOTICS AND AI, 12, 1537470.
3. *Tasi, B. J., Koller, M., & Cserey, G. (2019).* **Design of the anatomically correct, biomechatronic hand.** ARXIV PREPRINT ARXIV, 1909.07966.

SENSING-ACTUATING ROBOTICS

Dr. Miklós KOLLER

Head of Research Group: Dr. Miklós KOLLER

Members of the Group: Prof. György CSEREY, Dr. Sándor FÖLDI, Dr. Gergely FELDHOFFER, Dr. Janka HATVANI, Dr. Dániel HAJTÓ, Márton Bese NASZLADY, Boldizsár BALOG, Attila RÉPAI, Rizal MAULANA, Zsombor Ágoston MICSKÓ, Eszter BIRTALAN, Réka KISS, Áron Boldizsár KÖVES, Marvin Serge FUENTES, Zsuzsanna ROHÁN, Liza KONDRÁT, Bálint SZALAI-BENEDEK, Zalán TARI, Benedek VARGA, Réka FÉLEGYHÁZI-TÖRÖK, Regő László SZABÓ, Katalin JUHÁSZ, Zita BARDOCZY

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Keywords: *robotics and intelligent systems, biomedical engineering, human–machine interfaces, computational modeling and machine learning*

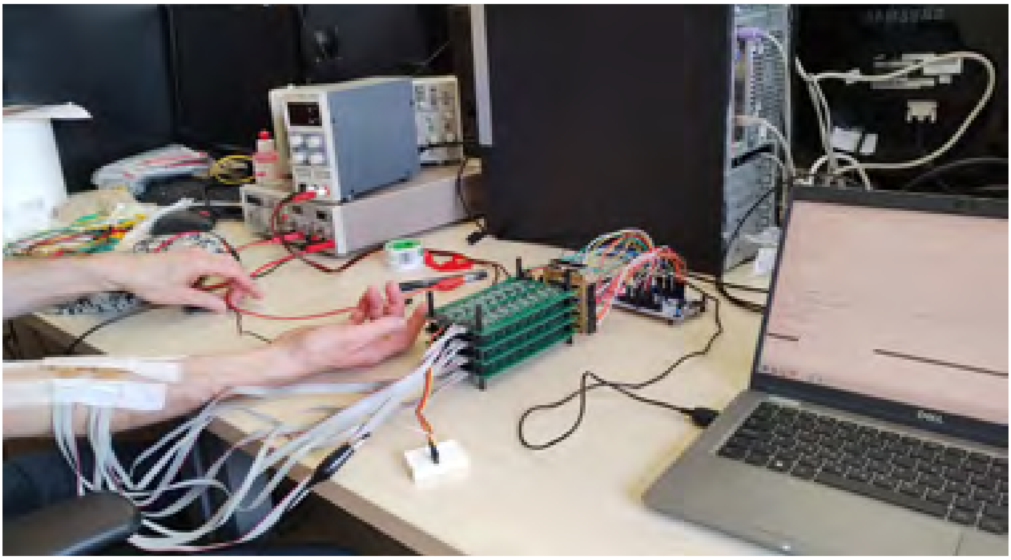
Field of research: info-bionics; machine learning

Our laboratory develops intelligent sensing, modeling, and machine learning methods at the intersection of biomedical engineering, robotics, and industrial applications. A major focus of our research is the development of advanced human–machine interfaces, with particular emphasis on sensing and control solutions for hand prostheses. We investigate optimal sensor configurations, develop high-density electromyography (HD-EMG) acquisition systems and signal decomposition algorithms, and model muscle activation and metabolic processes using near-infrared spectroscopy (NIRS). We also conduct research on diffuse optical tomography for measurement and data evaluation, as well as on vascular signal recording and pulse diagnostics, integrating both hardware and software solutions.

In robotics, we reconstruct industrial optical assembly workstations in both physical and simulation environments and investigate Vision-Language-Action (VLA)-based robotic manipulation. Our virtual reality research includes the development of systems for divers that reconstruct underwater environments from sonar measurements.

Future research directions, collaboration opportunities

Based on our research focus, we offer professional cooperation in the following fields: smart medical devices for home monitoring and cardiovascular risk detection; intelligent prosthetics, exoskeletons, and human–machine interfaces; and AI-based control algorithms.



High-density electromyographic measurement with the in-lab-developed device.

Key publications:

1. *Birtalan, E., Koller, M. (2026).* **The impact of tactile sensor configurations on grasp learning efficiency--a comparative evaluation in simulation.** ARXIV PREPRINT ARXIV, 2601.10268.
2. *Polcz, P., Schäffer, K., Koller, M. (2024).* **Posture estimation for a high degree of freedom anthropomorphic tendon-based hand model–A simulation experiment.** EUROPEAN CONTROL CONFERENCE
3. *Ignácz, A., Földi, S., Sótonyi, P., Cserey, Gy. (2021).* N**B-SQI: A novel non-binary signal quality index for continuous blood pressure waveforms.** BIOMEDICAL SIGNAL PROCESSING AND CONTROL, 70: 103035.

SPORT BIONICS AND DATA INTELLIGENCE

Dr. László Bálint GRAND

Head of Research Group: Dr. László Bálint GRAND

Members of the Group: Gábor NAGY, Dominik HOMOKI, Yara GODA

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Keywords: *wearable sensors, markerless motion analysis, sport analytics, machine learning, rehabilitation*

Field of research: info-bionics; machine learning

The Sport Bionics and Data Intelligence Lab focuses on objective, data-driven assessment of human movement and performance in sport and rehabilitation. Our research combines data from wearable sensors (IMU, EMG, ECG/HRV) and video-based measurements with markerless and marker-based motion analysis, machine learning, and deep learning. Current application areas include biomechanical analysis in kayak-canoe and swimming, sport analytics based on underwater and above-water camera systems, monitoring of fatigue and technical efficiency, and quantitative assessment of movement disorders and rehabilitation processes. The methods developed in the lab aim to turn large-scale multimodal datasets into interpretable feedback for athletes, coaches, clinical partners, and researchers. Our work is strongly application-oriented: we integrate sensor-based data acquisition, computer vision, biomechanical modeling, and cloud-based processing into systems that support performance improvement, injury prevention, and the evaluation of therapeutic effectiveness.

Future research directions, collaboration opportunities

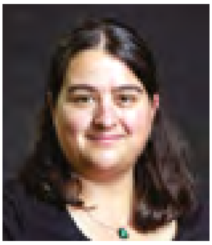
The lab offers collaboration with sports clubs, clinical partners, research institutes, and industry teams in multimodal movement measurement, sport analytics, rehabilitation monitoring, and AI-based data processing. We are open to joint grant proposals, student projects, and validation studies.

Multimodal movement analysis in sport and rehabilitation by combining wearable sensors, video-based tracking, and machine learning.

Key publications:

1. *Nagy, G., Katona, P., Gannorouwa, L., Grand, L. (2025).* **Machine Learning-Based Stroke Segmentation in Kayaking Using Integrated IMU and EMG Data.** ICSPORTS 2025, pp. 256-264.
2. *Négyesi, J., Petró, B., Salman, D. N., Khandoker, A., Katona, P., Wang, Z., Almaazmi, A. I. S. Q., Hortobágyi, T., Váczi, M., Rácz, K., Pálya, Z., Grand, L., Kiss, R. M., Nagatomi, R. (2022).* **Biosignal processing methods to explore the effects of side-dominance on patterns of bi- and unilateral standing stability in healthy young adults.** FRONTIERS IN PHYSIOLOGY, 13, 965702.
3. *Nagy, G., Komka, Z., Szathmáry, G., Katona, P., Gannoruwa, L., Erdős, G., Tarjányi, P., Tóth, M., Krepuska, M., Grand, L. (2020).* **Multimodal Approach for Kayaking Performance Analysis and Improvement.** INTERNATIONAL JOURNAL OF COMPUTER SCIENCE IN SPORT, 19(2), pp. 51-76.

HUNGARIAN BIONIC VISION CENTER (ARTIFICIAL INTELLIGENCE LAB)



Dr. Anna GELENCSÉR-HORVÁTH

Dr. Kristóf KARACS

Head of Research Group: Dr. Anna GELENCSÉR-HORVÁTH, Dr. Kristóf KARACS

Members of the Group: Viktor KARACS, Márton Menyhért JUSZTIN, Arnold ARADI, Gergely DINYA, Dorka Boglárka ERŐS, Péter HALÁSZ, Márk PÉTER

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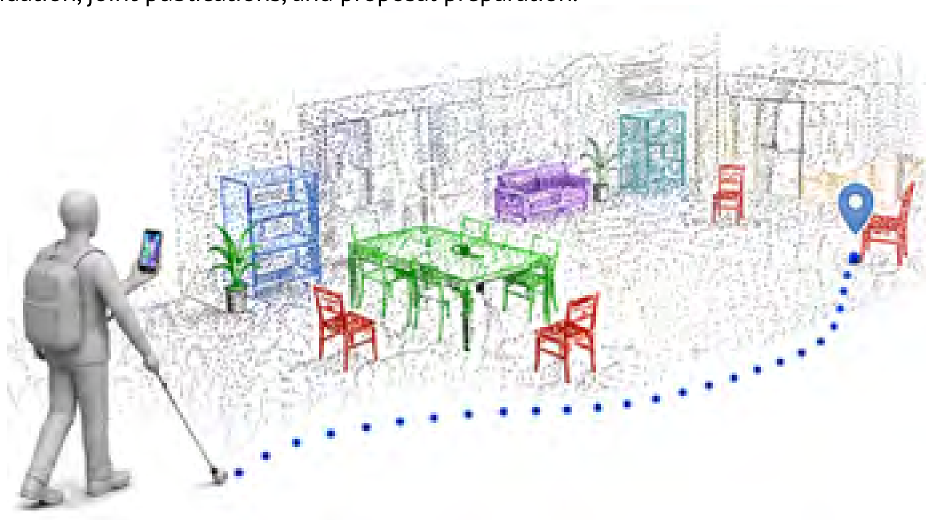
Keywords: *computer vision, 4D scene understanding, real-time mapping and navigation, assistive technology*

Field of research: machine learning; computer science engineering

Our research focuses on computer vision and 4D scene understanding for object and structure recognition, mapping, and navigation, while designing these processes to be fast, resource-efficient, and modular. A core part of our work is how task-dependent or general scene understanding can be achieved with low computational requirements, using only a single handheld phone camera and depth sensor. The aim is to perform planning and mapping of the environment simultaneously on an arbitrarily long video stream in dynamic scenes. We integrate our research results into the framework of our LetSee application, which was developed for visually impaired users and provides, for example, audio feedback for complex tasks such as route following, object localization, and interaction with objects. At the 2024 Cybathlon, in the vision assistance (VIS) race for technologies supporting visually impaired people, our team, EyeRider, achieved an outstanding first-place result. Our visually impaired pilot completed the tasks independently, using only a single mobile phone with no network connection. This demonstrated, in a live, real-world setting, that a portable, resource-constrained solution can not only be competitive but can also outperform more complex, heavyweight systems.

Future research directions, collaboration opportunities

Our group offers professional and research collaboration in computer vision, 3D/4D scene understanding, semantic mapping, and real-time, resource-efficient AI systems. We focus on application-oriented assistive technologies and contribute through method development, validation, joint publications, and proposal preparation.



Overall concept of 4D scene understanding, mapping, and navigation in dynamic environments for the visually impaired. We develop algorithms that operate under limited computational resources, using only a handheld camera and depth sensor.

Key publications:

1. *Gelencsér-Horváth, A., Dinya, G., Halász, P., Erős, D., Muqsit, I. M., Karacs, K. (2026).* **SceneVGGT: VGGT-based online 3D semantic SLAM for indoor scene understanding and navigation.** IEEE INTERNATIONAL CONFERENCE ON IMAGE PROCESSING
2. *Dinya, G., Gelencsér, A., Kupán, K., Küpper, C., Karacs, K., Gelencsér-Horváth, A. (2026).* **SAMannot: A Memory-Efficient, Local, Open-Source Framework for Interactive Video Instance Segmentation Based on SAM2.** JOURNAL OF OPEN RESEARCH SOFTWARE
3. *Gelencsér-Horváth, A., Németh, J., Karacs, K. (2026).* **Bringing Mobile Computer Vision to Visually Impaired People: Designing a Versatile Phone-Based AI Assistant.** MOBILITY OF VISUALLY IMPAIRED PEOPLE, SPRINGER NATURE SWITZERLAND

LANGUAGE TECHNOLOGY

Prof. Gábor PRÓSZÉKY

Head of Research Group: Prof. Gábor PRÓSZÉKY

Members of the Group: Dr. Attila NOVÁK, Dr. Borbála NOVÁK, Kamran IBIYEV, Mram KAHLA, László PAKSI, Dr. Győző YANG ZIJIAN

Contact: proszeky.gabor@itk.ppke.hu

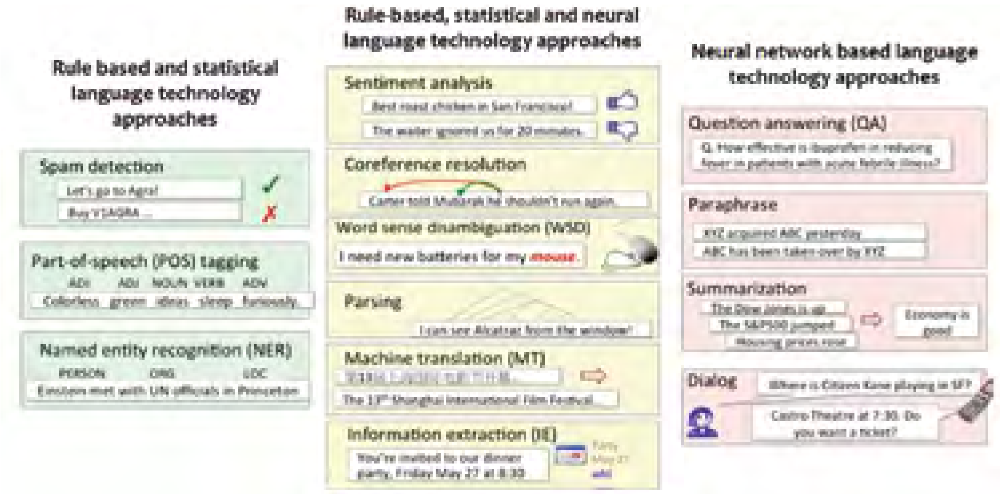
Keywords: *LLMs, hungarian language, LoRA*

Field of research: machine learning; computer science engineering

The Language Technology Research Group at PPKE ITK focuses primarily—but not exclusively—on the Hungarian language and other languages (currently Arabic and Azerbaijani), the fine-tuning of transformer models for various tasks, LoRA technology, and the creation of the text corpora required for these purposes. We collaborate with the HUN-REN Research Centre for Linguistics, whose Institute for Language Technologies and Applied Linguistics provides part of the computational infrastructure required for the solutions described above.

Future research directions, collaboration opportunities

We are happy to collaborate with institutions in Hungary or abroad in any area of language technology that we are researching.



Main research areas of our Language Technology Research Group.

Key publications:

1. *Lipp, V. and Prószéky, G. (2025).* **Challenges and strategies for a unified approach: The Hungarian case.** IN: RESI, R. AND STEURS, F. (ED.) HANDBOOK OF TERMINOLOGY: TERMINOLOGY PLANNING IN EUROPE. AMSTERDAM: JOHN BENJAMINS, 218-238.
2. *Yang Zijian Gy., Bánfi, Á., Dodé, R., Ferenczi, G., Földesi, F., Hatvani, P., Héja, E., Lengyel, M., Madarász, G., Osváth, M., Sárossy, B., Varga, K., Váradi, T., Prószéky, G., Ligeti-Nagy, N. (2025).* **ChatPULI: Enhancement to the first Hungarian conversational model.** ANNALES MATHEMATICAE ET INFORMATICAE, 61, 261-274.
3. *Novák, A. and Novák, B. (2022).* **Cross-lingual transfer of knowledge in distributional language models: Experiments in Hungarian.** ACTA LINGUISTICA ACADEMICA, 69(4), 405-449.

SMART SENSORY COMPUTING

Dr. András HORVÁTH

Head of Research Group: Dr. András HORVÁTH

Members of the Group: Dóra Eszter BABICZ, Bálint MAGYAR, Zsófia MOLNÁR, Adrienn RÁCZ

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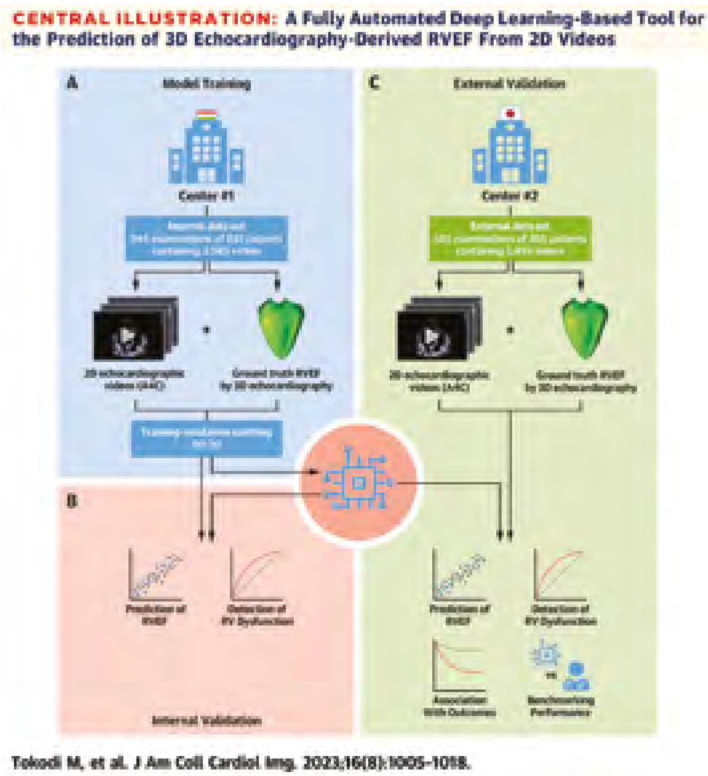
Keywords: *computer vision, machine learning, AI safety*

Field of research: machine learning; computer science engineering

The Smart Sensory Computing Lab focuses on research in machine vision and artificial intelligence, with a strong emphasis on real-world applications.
Our main applied research areas include medical image analysis (e.g., detecting cancer cells in microscopic images and supporting ophthalmic diagnosis based on fundus images), face recognition-based access control systems, and intelligent urban vision systems that detect and track vehicles and pedestrians.
Our fundamental research aims to achieve a deeper understanding of learning and vision processes, with a particular focus on improving the generalization capabilities of neural networks. We draw inspiration from the functioning of the human nervous system to develop models that perform well even with limited data.
Our goal is to create intelligent systems that operate reliably with minimal data usage and are capable of making accurate inferences from only a few examples.

Future research directions, collaboration opportunities

Our research group offers professional and research collaboration opportunities in the fields of computer vision and artificial intelligence. We have previously participated in several successful grant projects, including OTKA, GINOP, ONR, and EU Horizon programs.

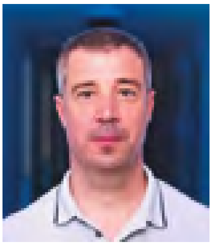


Example output of our developed system, which creates a three-dimensional model from two-dimensional ultrasound images and estimates key parameters such as the heart's ejection fraction.

Key publications:

1. *Szabó, G., Bonaiuti, P., Ciliberto, A., & Horváth, A. (2025).* **Enhancing yeast cell tracking with a time-symmetric deep learning approach.** NPJ SYSTEMS BIOLOGY AND APPLICATIONS, 11(1), 25.
2. *Tokodi, M., Magyar, B., Soós, A., Takeuchi, M., Tolvaj, M., Lakatos, B. K., ... & Kovács, A. (2023).* **Deep learning-based prediction of right ventricular ejection fraction using 2D echocardiograms.** CARDIOVASCULAR IMAGING, 16(8), 1005-1018.
3. *Barna, L., Dudok, B., Miczán, V., Horváth, A., László, Z. I., & Katona, I. (2016).* **Correlated confocal and super-resolution imaging by VividSTORM.** NATURE PROTOCOLS, 11(1), 163-183.

APPLIED MATHEMATICS



Prof. Mihály KOVÁCS

Head of Research Group: Prof. Mihály KOVÁCS

Members of the Group: Gyula MOLNÁR, Loránd Csongor LACZKÓ

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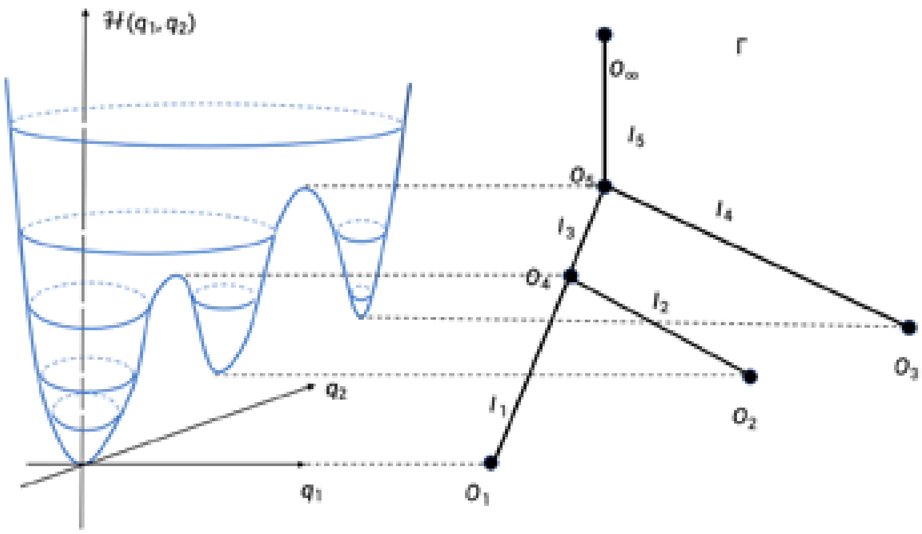
Keywords: *partial differential equations, stochastic differential equations, numerical analysis, quantum graph, random field*

The mathematical models of many time- and space-dependent processes are described by partial differential equations. If there is uncertainty in the equation, then the uncertainty can be modeled using stochastic partial differential equations. If a process taking place in a given location and/or at a given time instance is also affected by events further away in space and/or time, then the process can be described using non-local differential equations. The focus of the group's work is the mathematical theory and numerical analysis of the above equations. Recent research topics include the application of stochastic partial differential equations to generate Gaussian random fields on metric graphs, to provide input for various statistical models. The solution of these models requires finite element solutions of elliptic problems on metric graphs, which become large as the size of the network grows. To speed up the solution and reduce memory requirements, one may employ domain decomposition methods; this is also one of the group's current research areas. To speed up computations, we also employ reinforcement learning for adaptive step-size selection in iterative PDE solvers.

Future research directions, collaboration opportunities

The research group can assist with the numerical solution of models described by various differential equations. These models can be deterministic or even stochastic, in order to account for the uncertainties inherent in the underlying processes.



The asymptotic behavior of stochastic Hamiltonian particle transport can be characterized by a stochastic differential equation defined on a metric graph.

Key publications:

1. *Kovács, M., Vághy, M. (2025).* **Neumann-Neumann type domain decomposition of elliptic problems on metric graphs.** BIT NUMERICAL MATHEMATICS 65: (2) 25.
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FUNCTIONAL ELECTROMAGNETIC STRUCTURES

Prof. Zolt SZABÓ

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Keywords: *metamaterials, electromagnetic sensing, metaantennas*

Field of research: mathematics, physics, electrical engineering

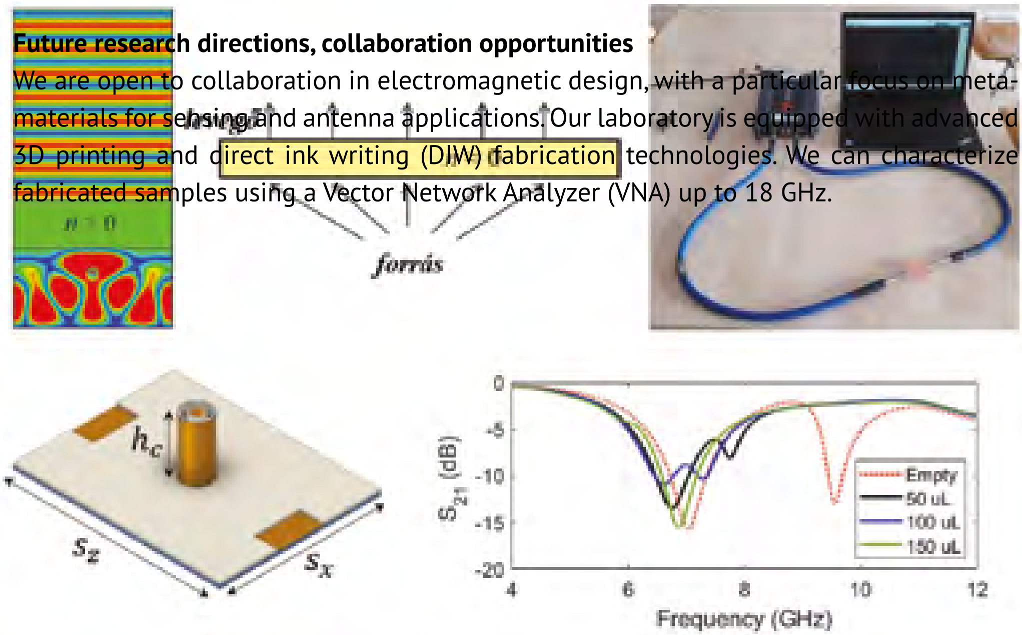
In our laboratory, we design, manufacture, and characterize electromagnetic structures and metamaterials with special properties. In the structures we investigate, we apply not only changes in chemical composition but also geometric structuring to create these special properties. The lab aims to develop metamaterials ranging from the microwave region to the visible light range. The metamaterials we create are used, for example, in telecommunications components, biological sensing, and imaging below the diffraction limit.

We have recently been awarded a four-year grant from the National Research, Development and Innovation Office of Hungary (NKFIH) for the project A-152477, Metamaterial-based Lab-on-Chip Sensing. Lab-on-chip (LoC) technology has transformed biomedical diagnostics, environmental monitoring, and chemical analysis by integrating multiple laboratory functions onto a single miniaturized platform. A key element of any LoC system is the sensor. Because the electromagnetic response of samples varies with frequency, different regions of the spectrum offer distinct sensing advantages. Microwave frequencies are particularly well suited to the detection of samples containing polar molecules, such as water.

The primary goal of the project is therefore to develop microwave sensors operating in the 1–18 GHz range that are enhanced by metastructures—specifically metamaterial-inspired resonators and photonic crystals—and integrated with 3D-printed microfluidic channels. This approach aims to improve sensitivity beyond that of existing LoC systems for the detection of low-concentration biomolecules (e.g., glucose) and environmental pollutants (e.g., heavy metals) in microliter-scale sample volumes. In parallel, the project seeks to establish a cost-effective fabrication route (target unit cost below €25), thereby making advanced diagnostic tools more accessible for healthcare, environmental monitoring, and industrial applications.

Future research directions, collaboration opportunities

We are open to collaboration in electromagnetic design, with a particular focus on metamaterials for sensing and antenna applications. Our laboratory is equipped with advanced 3D printing and direct ink writing (DIW) fabrication technologies. We can characterize fabricated samples using a Vector Network Analyzer (VNA) up to 18 GHz.



The electromagnetic behavior of a metasurface with a near-zero refractive index. The measurement setup of a subwavelength resonator. The geometry and microwave response of the dual-technology fluidic level sensor.

Key publications:

1. *Kálovics, M., Szolgay, P., Iván, K., Szabó, Zs. (2024).* **Microwave resonance based lab-on-a-chip local pressure sensing.** IEEE SENSORS JOURNAL*, vol. 24, no. 8, pp. 12085-12093.*
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3. *Szabo, Zs., Park, G-H., Hedge, R. and Li, E-P. (2010).* **A Unique Extraction of Metamaterial Parameters Based on Kramers–Kronig Relationship**. IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, 58(10) pp. 2646-2653.

OPTICS, MAGNONICS AND NEW GENERATION HARDWARE

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Keywords: *spintronics, magnonics, beyond moore computing*

Field of research: mathematics, physics, electrical engineering, computer science engineering

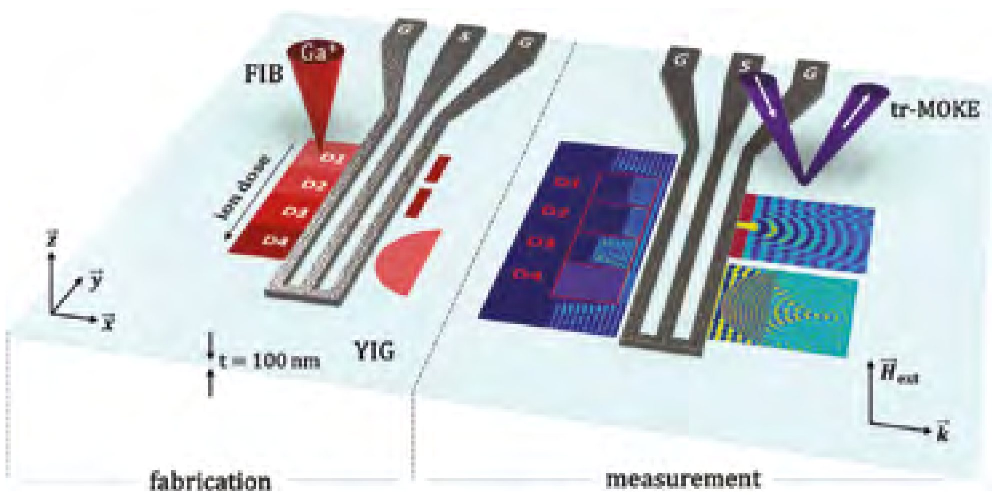
For decades, progress came from making transistors smaller – but that road is running out, just as artificial intelligence is demanding more computing power than ever before. The way forward may not lie in better chips, but in better physics. Our lab works exactly at this frontier, where physics, computing, and AI meet: we ask how the natural dynamics of magnetic and electronic systems can become computation, rather than merely running it. Our focus is physics-inspired computing, where realizing a complex physical process directly yields the result of a computation. We pursue this idea on three fronts: analog circuits, oscillatory neural networks, and magnonic devices.

Oscillatory neural networks (ONNs) encode information not in voltage levels but in the phase relationships between coupled oscillators. In magnonic devices, wave interference performs complex computations.

Our main instrument is a unique TR-MOKE setup (Time-Resolved Magneto-Optical Kerr Effect microscope) that measures the dynamic behavior of nanomagnets and spin waves at high frequencies, down to the picosecond and nanometer scales. We can perform a wide range of optical and high-frequency electrical measurements, allowing us to characterize both the physical properties of our samples and their performance as computing elements.

Future research directions, collaboration opportunities

Participation in EU projects, collaborations with TU Munich and other leading German, French, and Italian universities.



Fabrication and measurement of a magnonic computing system – as done in collaboration with our colleagues at TU Munich. Kiechle, M., Papp, Á., Mendisch, S., Ahrens, V., Golibrzuch, M., Bernstein, G. H., Porod, W., Csaba, Gy. and Becherer, M. (2023). "Spin-Wave Optics in YIG Realized by Ion-Beam Irradiation." Small 19, no. 21: 2207293.

Key publications:

1. *Greil, J., Angotti, A., Kohl, F., Papp, Á., Wagner, M., Cocconcelli, M., Del Giacco, A. et al. (2026).* **Microscaled Tunable Magnonic RF Phase Shifters.** ARXIV PREPRINT ARXIV, 2606.14280.
2. *Rudner, T., Porod, W. and Csaba, Gy. (2024).* **Design of oscillatory neural networks by machine learning.** FRONTIERS IN NEUROSCIENCE, 18: 1307525.
3. *Papp, Á., Porod, W. and Csaba, Gy. (2021).* **Nanoscale neural network using non-linear spin-wave interference.** NATURE COMMUNICATIONS 12(1): 6422.

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