

Physiological and Bioinspired Systems Development at Óbuda University

Research Activities in Budapest, a Reach Across Related Fields for the IEEE Systems, Man, and Cybernetics Society



by György Eigner, Tamás Haidegger, and Levente Kovács

The main goal of this article is to provide a short summary regarding the research activities of Óbuda University, Budapest, Hungary, related to physiological and bioinspired systems, as one of the key areas of the IEEE Systems, Man,

and Cybernetics Society (SMCS). We also intend to introduce the impact of Prof. Imre Rudas through these activities, research institutions, and facilities.

Óbuda University was founded in 2010 from the predecessor college Budapest Tech under the leadership of Prof.

Rudas (founding rector), who served in the SMCS in various positions at that time. Back then, the research activities at the university were quite fragmented and spread across the faculties for historical reasons. To treat this problem and create a more centralized and effective research capacity and structure at the university, the Research, Innovation and Service Center (EKIK) was established in 2013 (Figure 1).

The strategic goal of EKIK is to support and leverage the work of young researchers and create an ecosystem of science and innovation, where intelligent learning and organic research meet applied development. EKIK is an internationally recognized research center, offering a wide range of services in technology innovation.

EKIK is a unique organization within Óbuda University, and it sets an example on a national level. It consists of topical research centers, aiming to spearhead a focus domain within the portfolio of the university.

It consists of eight research centers that are directed by the Board of Governors, which is led by Prof. Rudas. Currently, the following units are involved:

- ◆ Antal Bejczy Center for Intelligent Robotics (iROB)
- ◆ Bio-Tech Research Center
- ◆ Physiological Controls Research Center (PhysCon)
- ◆ SmartLab Center
- ◆ Alternative Energy Sources Research Center
- ◆ Security Research Center
- ◆ Center for Scientific Dissemination
- ◆ Electric Power Conversion Systems Research Center.

EKIK participates in the development of knowledge at the university, focusing on novel tools and research environments, linking appropriate control structures and user interfaces, and helping the application of intelligent and knowledge-driven technologies to serve society. It provides application, interface, and infrastructure for the students, other units of the university, similar partners, and external contractors. The key of its success is the ability of bringing together theoretical research and development and the practical applications for innovation.

EKIK provides benefits for its members through integrated research projects, exchange programs, common publications, and European Union projects, which make it easier for industrial partners to access cutting-edge technologies. EKIK also invests in new applications and services for a wider public and in scientific dissemination and awareness raising.



Figure 1. The logo of the EKIK (EKIK is derived from the Hungarian acronym of the center).

Both the leadership and members of the centers are committed to the SMCS. Two SMCS Technical Committees—Computational Cybernetics and Cyber-Medical Systems—are chaired by colleagues of the center, including Prof. Rudas. Furthermore, the key people are Prof. Levente Kovács, chair of the Hungarian SMC Chapter, founding chair of the Hungarian Control Systems Chapter, and the current chair of the IEEE Hungary Section; Dr. György Eigner, who serves in the SMCS in various positions, including as a member of the Board of Governors; and Dr. Tamás Haidegger (current director of EKIK), who is also an enthusiastic IEEE volunteer with more than 15 years of commitment, mostly active in the IEEE Robotics and Automation Society and the SMCS, and serves as the vice chair of the IEEE Hungary Section.

Cutting-Edge Physiological and Bioinspired Research at EKIK

Prof. Rudas was one of the first researchers in Hungary who got involved in the development of soft computing systems, especially fuzzy systems. He has inspired many scientists to get in touch with the domain, and also, he was a key person in the early life of the Hungarian Fuzzy Association, driving its activity. His research was related not just to purely technical cybernetic issues and questions, but also to interdisciplinary fields. From the early years of fuzzy systems, it turned out that the multiaspect approach is essential for describing and controlling bioinspired or physiological systems because the determining properties of such systems (e.g., nonlinearities and time-varying features) can easily be handled with fuzzy logic and inference systems. Prof. Rudas' activity was the cornerstone to establish the new school of thought that led to today's cybernetic, bioinspired, and physiological research at EKIK.

Within EKIK, three research centers represent this direction: iROB, led by Dr. Péter Galambos; the Bio-Tech Knowledge Center, guided by Dr. Miklós Kozlovsky; and PhysCon, led by Prof. Kovács, the newly appointed vice president of Óbuda University who has strong ties to the SMCS.

The iROB (<http://irob.uni-obuda.hu>) is one of the leading research organizations in Hungary related to robotics, with a special focus on the application of cybernetics and machine learning for the robotics domain. Many interesting projects related to physiology, teleoperation, and telerobotics are going on at the center, which has built a strong background both in infrastructure and human resources. Uniquely, the laboratory is part of the international da Vinci Research Kit consortium, led by Johns Hopkins University, Baltimore, Maryland, and Worcester Polytechnic Institute, Massachusetts, and it has the only da Vinci surgical robot in Hungary (Figure 2). They are focusing on surgical data science, partial automation of surgical tasks, and various aspects of time delay control [1]. Furthermore, the iROB center has been involved twice already in the European Robotics League Emergency

Robots challenge with great success [2]. The most recent research portfolio and report of the center can be found at <https://tinyurl.com/BARK5-report>.

The Bio-Tech Research Center (<http://biotech.uni-obuda.hu/en>) focuses on the development of software environments and specific hardware components mostly for physiological measurement, analysis and decision support systems. They are working on exciting projects, e.g., recently invented 3D microscopy is a unique solution to support counting the different elements in the blood [3].

PhysCon (<http://physcon.uni-obuda.hu/?q=en>) focuses on translating physiological challenges to cybernetical and control problems and solving them by using advanced control theory-driven methodologies. The three centers do have many international relations and collaborators all around the world. The advisory board of EKIK is led by Prof. Ousama Khatib from Stanford University, California, and Dr. Bernd Liepert from KUKA Roboter GmbH, Augsburg, Germany.

Innovation at PhysCon

Currently, researchers at PhysCon focus on providing solutions for common diseases like cancer or metabolic syndromes. Also, key points of personalization of treatment options can be found in the portfolio of the center, mostly based on biostatistics and machine learning.

PhysCon won the European Research Council (ERC) Starting Grant in 2015 with the project “Tamed Cancer.” European Research Council grants represent the most innovative individual research grant type of the European Union. The ERC’s mission is to encourage the highest-quality research in Europe through competitive funding and to support investigator-driven frontier research across all fields, on the basis of scientific excellence. The main idea behind PhysCon’s ERC grant is to apply control engineering approaches before cancer treatment by developing control algorithms to inject the specific drugs in an automated and personalized way [4].

Cybermetabolic syndrome is another main research area of PhysCon. Metabolic syndrome is the occurrence of a group of diseases individually or in an aggregated way and not a concrete, specific disease. Typically, three out of the following five or the first one and two from the remaining four: abdominal (central) obesity, hypertriglyceridemia, low high-density lipoprotein cholesterol, high blood pressure, and high fasting plasma glucose. This definition is not arbitrary for reasons that are twofold. First, the cooccurrence of these conditions is much more typical than what would be expected purely by chance; second, they each represent a risk factor for cardiovascular disease and (type 2) diabetes mellitus; and their simultaneous effect is much higher than the separate effects combined (i.e., there is a synergistic relationship between them) [5], [6]. These conditions can be treated, and the life of patients can be more comfortable and easier by using biomedical engineering techniques developed at the PhysCon.



Figure 2. The da Vinci Research Kit at iROB.

Several problems, including tumor growth regulation, blood glucose regulation, and other biological regulatory circles can be formulated as control engineering problems, and it is possible to provide appropriate controllers with external actuators (e.g., drug pumps or injections) to replace the biological regulation. A good example is the artificial pancreas (AP) concept. Three main components are needed to realize an AP [7]:

- ◆ continuous glucose monitoring system, which provides the necessary information, i.e., the blood glucose level, about the process to be regulated
- ◆ insulin pump system, which is the external actuator and is able to inject the insulin hormone according to the determined rules or as the control algorithms require
- ◆ advanced control algorithms, which are needed for the appropriate regulatory action, i.e., to keep the blood glucose level in a narrow and healthy range.

This concept can be generalized as Figure 3 shows.

At PhysCon, new control methodologies and novel ways of applying existing ones are under development and used. Physiological systems are loaded with nonlinearities, parameter drift, uncertainties, time delays, and other non-favorable effects, which are needed to be considered during the design of such systems. In recent development, successful examples are the novel control approaches, like Robust Fixed Point Transformation [8] and Linear Matrix Inequality-based control for Linear Parameter Varying systems in Tensor Product formulation [9] were developed at PhysCon, including positive control input completion for physiological systems [10].

Discussion

The unique organization of EKIK was founded by Prof. Rudas in 2013 to bring researchers together from different fields from all over the world at Óbuda University. EKIK has been successful in supporting and managing innovation, research and development, and education, and utilizing the knowledge and research results in education and economy.

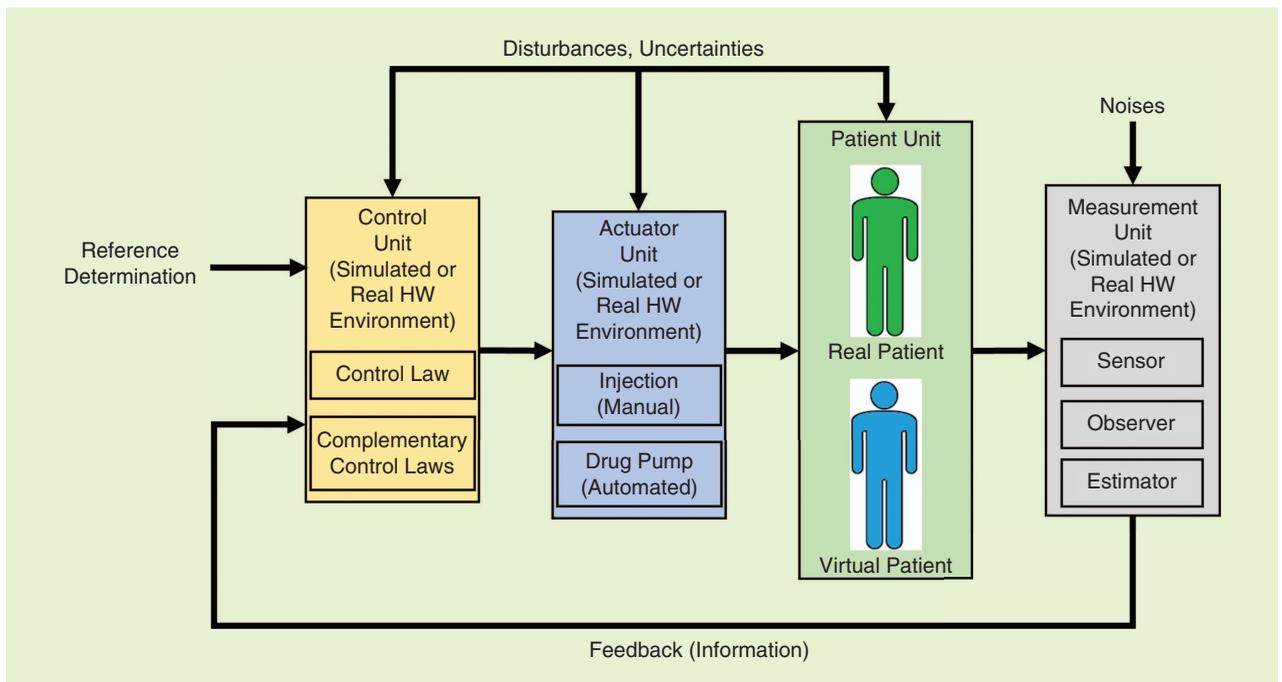


Figure 3. A conceptualization of a control system for physiological issues in general. The fundamental approach of control theory driven cancer therapy. HW: hardware.

At this point, our colleagues work in several fields, such as robotics, physiological control, and telemedicine, and online education, system theory, applied informatics, and utilization of alternative energy sources are also among our duties. The commitment and the high preparedness of our fellow workers is the root of our success within the SMCS community.

About the Authors

György Eigner (eigner.gyorgy@nik.uni-obuda.hu) earned his B.Sc. degree in mechatronics engineering in the Bánki Donát Faculty of Mechanical and Safety Engineering at Óbuda University, Budapest, Hungary, in 2011 and his M.Sc. degree in biomedical engineering at the Budapest University of Technology and Economics, Hungary, in 2013. He earned his Ph.D. degree at Óbuda University in 2017, where he is currently an adjunct professor in the John von Neumann Faculty of Informatics. He is a Member of the IEEE.

Tamás Haidegger (haidegger@irob.uni-obuda.hu) earned his M.Sc. degrees from the Budapest University of Technology and Economics in electrical engineering and biomedical engineering in 2006 and 2008, respectively, and his Ph.D. degree in 2011. He is an associate professor at Óbuda University, serving as the director of the University Research, Innovation and Service Center, and as the technical lead of medical robotics research at the Antal Bejczy Center for Intelligent Robotics. He is also a research area manager at the Austrian Center of Medical Innovation and Technology, working on minimally invasive surgical simulation and training, medical robotics and usability/workflow assessment through ontologies.

Levente Kovács (kovacs@uni-obuda.hu) earned his M.Sc. degrees in electrical engineering in 2000 at the Politehnica University of Timisoara, Romania, and biomedical engineering in 2011 at the Budapest University of Technology and Economics, Hungary. He earned his Ph.D. degree at the Budapest University of Technology and Economics in 2008. He is a Senior Member of the IEEE.

References

- [1] A. Takács, D. Á. Nagy, I. Rudas, and T. Haidegger, "Origins of surgical robotics: From space to the operating room," *Acta Polytech. Hung.*, vol. 13, no. 1, pp. 13–30, 2016.
- [2] B. Takács *et al.*, "Extending AUV response robot capabilities to solve standardized test methods," *Acta Polytech. Hung.*, vol. 13, no. 1, pp. 157–170, 2016.
- [3] A. Bánáti, P. Kacsuk, and M. Kozlovsky, "Reproducibility analysis of scientific workflows," *Acta Polytech. Hung.*, vol. 14, no. 2, pp. 201–217, 2017.
- [4] D. A. Drexler, J. Sági, and L. Kovács, "Modeling of tumor growth incorporating the effects of necrosis and the effect of bevacizumab," *Complexity*, vol. 2017, Nov. 2017. doi: 10.1155/2017/5985031.
- [5] J. Kaur, "A comprehensive review on metabolic syndrome," *Cardiol. Res. Pract.*, vol. 2014, 2014. doi: 10.1155/2014/943162.
- [6] S. Mottillo *et al.*, "The metabolic syndrome and cardiovascular risk: A systematic review and meta-analysis," *J. Am. College Cardiol.*, vol. 56, no. 14, pp. 1113–1132, 2010.
- [7] L. Kovács and G. Eigner, "System engineering approach of diabetes treatment," *Int. J. Diabetes Clin. Diagn.*, vol. 3, no. 116, pp. 1–6, 2016.
- [8] L. Kovács, "A robust fixed point transformation-based approach for type 1 diabetes control," *Nonlin. Dyn.*, vol. 89, no. 4, pp. 2481–2493, 2017.
- [9] L. Kovács and G. Eigner, "Tensor product model transformation based parallel distributed control of tumor growth," *Acta Polytech. Hung.*, vol. 15, no. 3, pp. 101–123, 2018.
- [10] D. Drexler, J. Sági, and L. Kovács, "Positive nonlinear control of tumor growth using angiogenic inhibition," *IFAC-PapersOnLine*, vol. 50, no. 1, pp. 15068–15073, 2017.

SMC