ISSN 0005-1179 (print), ISSN 1608-3032 (online), Automation and Remote Control, 2024, Vol. 85, No. 12, pp. 1209–1211.

The 11th International Conference on Physics and Control

A. L. Fradkov[*,**]

[*]*Institute for Problems of Mechanical Engineering, Saint Petersburg, Russia*
[**]*Saint Petersburg University, Saint Petersburg, Russia*
e-mail: fradkov@mail.ru

Abstract—The scientific and organizational issues of the 11th International Conference on Physics and Control (PhysCon 2024) held on Sept. 9–12, 2024 in Istanbul, Turkey are considered. A brief survey of keynote and plenary talks is presented.

Keywords: International Conference, Physics and Control

DOI: 10.31857/S0005117924120067

The 11th International Conference on Physics and Control (PhysCon 2024) was held from September 9 to 12 at Kadir Has University in Istanbul. The event was organized by Turkish universities Kadir Has and Bilkent with the support of the International Physics and Control Society (IPACS). Professor Fatihan Atay from Bilkent University served as the chairperson of the organizing committee. Key decisions regarding the organization were made by the supervisory board led by Eckehard Schöll, President of the IPACS and a professor at Technical University Berlin, which included the author of this report. PhysCon 2024 was dedicated to the memory of Hermann Haken (1927–2024), founder of synergetics and an inspiring pioneer in innovative work on nonequilibrium phase transitions, who was an honorary member of IPACS.

A total of 87 participants from 15 countries attended the conference, presenting 72 papers including three plenary keynotes, four invited talks, and two lectures. The distribution of presentations by country is as follows: Russian Federation – 24, Algeria – 12, Turkey – 10, Germany and Spain – six each, England – four, USA, Brazil, and Australia – two each, China, Denmark, Mexico, Uzbekistan, Iran, Italy – one each. In addition to these, five mini-symposia were also part of the program, each consisting of 3–4 thematically related presentations.

The conference covered interdisciplinary topics at the intersection of mathematics, physics, biology, electronics, and computer science. A significant portion of the presentations focused on the interface between control theory, applied mathematics, and neurobiology, particularly studying models of brain processes and their control. This emerging field can be termed cybernetical neuroscience.

The opening plenary talk by Henrik Jensen (Imperial College London) titled “Self-organized Criticality and Control” provided a brief overview of Self-Organized Criticality (SOC) followed by new insights into one of its paradigmatic models, the Forest Fire Model (FFM). The relationship between observed power-law behavior and true criticality has been debated since the model’s introduction in 1992. Recent analysis shows that it is possible to establish critical scale invariance in the model if the coupling between driving force and system size is carefully managed.

Mark Timme from Dresden Technical University presented his research on fluctuation responses and tipping points in strongly perturbed nonlinear systems. He proposed an integral consistency condition and a method for predicting the tipping point using large perturbation expansions evaluated within the consistency condition framework. This novel approach could help quantitatively predict significantly nonlinear response dynamics and bifurcations arising under high-amplitude forcing in non-autonomous dynamical systems.

Michael Small from the University of Western Australia delivered a talk titled "Delay Embedding Choice and Why It Matters," building upon Takens' theorem, which guarantees accurate embedding of a deterministic nonlinear dynamic system given a time series under rather general conditions. Since the 1980s, many methods have been suggested to estimate the observation interval (delay) needed to ensure accurate embedding, but most are based on heuristic approaches. Michael introduced a new topologically grounded method for choosing delay, leveraging concepts from persistent homology and topological data analysis, ensuring the best attractor reconstruction for given data.

Eckehard Schöll's lecture "Nonequilibrium Phase Transitions and Nucleation Phenomena in Synchronizing Networks" addressed phase transitions in nonlinear dynamical systems far from thermodynamic equilibrium. The lecture was dedicated to the memory of Hermann Haken. Although concepts from thermodynamics and statistical physics had been used to describe self-organization, formation of spatio-temporal structures, coexistence of phases, critical phenomena, and first-order and second-order nonequilibrium phase transitions since the 1970s, phase transitions and critical phenomena in dynamic networks, where synchronization transitions may occur, leading to partially synchronized states and complex collective behaviors applicable to various natural, socio-economic, and technological systems, began to be studied much later. The lecture discussed these works and established connections between tipping transitions, explosive synchronization, nucleation, critical slowing down, etc., with nonequilibrium thermodynamics. In particular, the Kuramoto model with inertia, relevant to power grids, was examined, showing first-order phase transitions to synchronization through partially synchronized states, and it was demonstrated that it can be viewed as an adaptive network of phase oscillators similar to neural networks with plasticity.

Alexander Fradkov's (IPME RAS) lecture (see "Definition of Cybernetical Neuroscience" by Alexander Fradkov, https://arxiv.org/abs/2409.16314) introduced a new scientific area — cybernetical neuroscience, a branch of computational neuroscience aimed at studying neurobiological systems using cybernetic methods. Cybernetical neuroscience is based on mathematical models adopted in computational neuroscience (Hodgkin-Huxley model, FitzHugh-Nagumo model, Morris-Lecar model, Hindmarsh-Rose model, Landau-Stuart model, neural mass model, etc.) and the methods of cybernetics – the science of control and communication in living organisms, machines, and society. The lecture outlined the main problems, methods, and some results of cybernetical neuroscience obtained primarily at IPME RAS and St. Petersburg State University, including findings on neurointerface control ("brain-controlled machines"). The primary objectives of cybernetical neuroscience include:

1. Analyzing the conditions under which neuronal ensemble models exhibit specific regimes corresponding to real neuronal ensembles' behavior: synchronization, spiking, bursting, solitons, chaos, chimeras, etc.

2. Synthesizing external (control) actions that create these regimes in the models.

3. Estimating the state and parameters of models based on input and output variable measurements.

4. Classifying human brain states and future behaviors based on observations using adaptation and machine learning techniques.

5. Finding control algorithms (feedback synthesis) that ensure specified properties of closed-loop systems composed of interacting controlled systems and controlling agents.

In neurobiological studies, the controlled system is the nervous system or human brain, while the controlling agent can be implemented in a computer device. For the entire system to function, the nervous system or brain must be connected to external computer communication devices called neurointerfaces (brain-computer interfaces). The methodology of cybernetic neuroscience shares many similarities with that of cybernetical physics. The lecture provided several examples from cybernetical neuroscience.

Overall, PhysCon 2024 showcased cutting-edge research at the crossroads of multiple disciplines, highlighting the importance of understanding complex systems, self-organization, and nonlinear dynamics, all crucial for advancing modern technology and science.

A brief history of the conference is as follows. The first Physics and Control Conference took place in 2003 in Saint Petersburg. The second conference was held in 2005, again in Saint Petersburg. The Program Committee Co-Chairs of the first conference were the renowned physicist and Nobel laureate Zhores Ivanovich Alferov, as well as Vladimir Grigoryevich Peshekhonov, General Director of the Central Research Institute "Elektropribor," creator of gyroscopic equipment and control systems. Organization of those conferences was inspired by the emergence in the 1990s of a new scientific field at the intersection of physics and control theory. This area encompassed the control of oscillations, chaotic processes, quantum systems, and more. Later, it came to be known as cybernetic physics. Cybernetic physics explores issues of dynamics and control in complex dynamical systems arising in physics and other natural sciences: synchronization processes, nonlinear waves, chaos, solitons, quantum-mechanical processes, and others. All these topics remain highly relevant today. Subsequent conferences were held every two years in different cities and countries. In 2007, it was held in Potsdam, Germany; in 2009, in Catania, Sicily; in 2011, in León, Spain; in 2013, in San Luis Potosí, Mexico; in 2015, in Istanbul, Turkey; and in 2017, in Florence, Italy. In 2019, the conference took place in Russia, at the Innopolis University, and in 2021, due to the pandemic, it was conducted online by Fudan University in Shanghai, China. Selecting the venue and organizing team for the next conference took an extra year due to complicated political circumstances. However, the outcomes showed that the choice was correct: it allowed a substantial number of Russian specialists to maintain creative and personal ties with foreign colleagues. One successful organizational decision was allowing participants from sanctioned countries to pay the registration fee in cash upon arrival. The conference results also indicated that in the scientific field, which first emerged in our country in 2003, Russia remains among the leading nations in 2024.

The programme and the abstracts of PhysCon 2024 conference are posted on its website, see https://physcon2024.khas.edu.tr/. The proceedings will be published in the special issues of the journals: Cybernetics And Physics (http://cap.physcon.ru) and The European Physical Journal Special Topics (https://link.springer.com/journal/11734).