ABOUT THE 11TH INTERNATIONAL CONFERENCE ON PHYSICS AND CONTROL

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This issue of Cybernetics and Physics journal contains a part of the proceedings of the 11th International Conference on Physics and Control (PhysCon 2024) held on Sept. 9-12, 2024 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, Ankara 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. 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). The abstracts of the plenary talks and of the papers published in this issue of CAP are presented below. Let us start with the keynote and plenary talks.

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.

In the paper [Ankilov et al., 2024] the mathematical modelling of a mechanical system designed to control changes in the pressure of the working medium in aircraft engines and consisting of a pipeline and a pressure sensor is carried out. The pipeline is necessary to take the sensor to some distance from the engine in order to mitigate the impact of high temperatures and vibration accelerations on the sensitive element of the sensor, which is an elastic plate. The system takes into account the aerohydrodynamic and thermal effects of the working medium on the plate. Asymptotic equations of aerohydrodynamics in the models of compressible and incompressible medium are used to describe the working medium motion in the pipeline. Both linear and nonlinear models of a deformable solid body are proposed to describe the plate dynamics. When using the compressible medium model, the solution of the problem is reduced to the study of an equation with a deviating argument. To solve the problem using the incompressible medium model, Fourier and Galerkin methods are applied. As a result, for both models the solution of the problem is reduced to the study of ordinary differential equations relating the magnitude of pressure in the motor to the magnitude of deformation of the sensing element, which can be used to control the mode of operation of the motor. The solution of these equations is found with the developed software program using standard functions of Mathematica 12.0.

In [Borisenok, 2024] different feedback control algorithms for the sensing scenario based on the semiclassical Tavis-Cummings model for nitrogen-vacancy (NV) centers located in the diamond are discussed. In the frame of this model, the sensing elements are considered as non-interacting two-level quantum systems, distributed in-homogeneously due to heterogeneous local magnetic and strain environments. The dynamical system of ordinary differential equations corresponding to the model contains the set of control parameters: the detunings between the drive frequency and the cavity frequency and between the drive frequency and NV transition frequency, as well as the relaxation coefficients. Correspondingly, it opens a gate for developing feedback control algorithms for tracking the cavity field, the income signal, and the reflection signal in the model sensing system. To study the principal features of algorithmic feedback the simplified 'toy model' for the Tavis- Cummings system are formulated and alternative schemes of feedback (gradient methods, target attractor methods) to compare their pros and cons for effective control are formulated.

In [Borisenok and Gogoleva, 2024] the model of a quantum bit driven by an external classical field without decay in the rotating wave approximation. In such a model, the whole evolution of the qubit states takes place on the Bloch sphere. The model is reformulated as a unitless set of real ordinary differential equations and use the normalized external field as a feedback control parameter. The closed-loop algorithm is designed in the form of the speed gradient, driving the dynamical system towards minimizing a given nonnegative goal function expressed via the qubit variables. The achievability of the control goal is investigated, and the most important features of the speed gradient algorithm applied to a quantum system in comparison with classical systems. The proposed approach is valid for the control over the ground and excited population levels, and over the qubit phase variables.

In the paper [Bukh et al., 2024] the impact of different types of inter-layer coupling on the dynamics of a two-layer multiplex network of coupled FitzHugh–Nagumo oscillators in the excitable regime is explored numerically . For this purpose, the cases of attractive, repulsive, and periodically modulated inter-layer coupling are considered. Coupled in the ring structure, the FitzHugh–Nagumo neurons demonstrate travelling wave regimes which are different for the attractive and repulsive intra-layer coupling. It is shown that the inter-layer coupling affects not only the frequency of oscillations of individual neurons but also the spatio-temporal structures in individual layers in different ways, depending on the sign of the inter-layer coupling. It is established that complete in-phase synchronization of travelling waves is well achieved in the presence of attractive inter-layer coupling, while the repulsive inter-layer coupling induces effective anti-phase synchronization of wave regimes. When the inter-layer coupling is periodically modulated, the wave structures in both layers are distorted, and clusters of coherent and incoherent dynamics can appear in the ring space.

In the paper [Goldobin, 2024] the equations providing moments of interspike intervals are derived for quadratic integrate-and-fire neurons principle characteristics of the synaptic activity of neurons subject to symmetric alpha-stable noise. This statistics can be presented with the values of the moments of these intervals. For the integrate-and-fire type models, the formalism of first passage time provides partial differential equations for a rigorous calculation of these values for neurons subject to a white Gaussian noise. However, the procedure of derivation of these equations is quite sophisticated and the results for Gaussian noise are not as trivial as they can appear if one does not look at the rigorous derivation procedure. The derivation of analogous partial differential equations for the case of alpha-stable (L´evy) noise is even more involved. The obtained results are presumably generalizable to other integrate-and-fire type models (e.g., leakage ones).

In the paper [Kovaleva and Smirnov, 2024] the anti-resonance phenomenon analogous to the Fano resonance in the classical system of two oscillators with nonlinearity is studied. The focus of the work is on the effects of nonlinearity in the system. The explicit form of the solution for the full nonlinear problem is obtained for the arbitrary type of the nonlinearity and in a wide range of the parameters. The results of the analytical study show very good agreement with the data of the direct numerical simulations. The peculiarities resulted from the multiplicity of the solutions are discussed.

The paper [Simonyan et al., 2024a] reports the results of a partial-time analysis of EEG signals from healthy volunteers obtained during the recording of polysomnography with an expanded arrangement of electrodes (19 leads). An analysis of the characteristics of frequency patterns (their number, duration, and energy power) was carried out in theta – band (4 – 6 Hz) in five brain areas (central, occipital, frontal zones, and left and right hemispheres). A comparison of the obtained characteristics was carried out according to the chronotypes of the respondents. Based on the results of the study, it was possible to demonstrate chronobiological patterns of nocturnal EEG activity in healthy volunteers. REM sleep stage in groups of participants with morning and evening chronotypes demonstrates statistically significant differences in the number and duration of EEG oscillatory patterns for different areas of brain activity.

In the paper [Simonyan et al., 2024b] the changes in the synchronization based on wavelet bicoherence are studied in the case of real EEG and ECG signals recorded during nocturnal sleep in patients with obstructive apnea and healthy volunteers. The study involved 72 subjects. The study protocol was approved by the Ethics Committee of the Saratov State Medical University, Ministry of Health of the Russian Federation. The synchronization between the EEG and ECG signals in group of patients with obstructive sleep anoea demonstated a significant increase in the band [0:7; 1:8] Hz against the background of relatively healthy participants. The maximum number of reliable differences between the groups under consideration was recorded in the deep N3 stage of sleep in the EEG channels F3, Fz, C3, P3, Pz, O1, T3.

The paper [Tkachenko and Balandin, 2024] explores the concept of managing coupled buildings under seismic excitation. Connecting two closely spaced structures enables the redistribution of energy and reduction of structural responses. To minimize the resulting damage, the use of smart control is proposed. Smart control operates using feedback, allowing the system to adapt in real-time. To solve the problem of finding an optimal control, the paper suggests considering it within the framework of multicriteria optimization problems, with the criteria being the maximum deformation of each building described using the generalized H2-norm. A new method for solving multicriteria problems using linear matrix inequalities (LMIs) and Hermeyer convolution is proposed. Detailed examples are provided for a system of two coupled buildings. The results of computing the optimal smart control for systems of varying dimensions, as well as the outcomes of modeling using real earthquake data, are presented. MATLAB software, utilizing the SDPT3 and YALMIP libraries, is employed for performing the calculations and visualizing the results.

An interesting and exciting special talk on growth and stability of nanoparticles was given by the Rector of Kadir Has University Prof. Dr. Sondan Durukanoğlu Feyİz before the closure of the conference.

Finally, I would like to express sincere gratitude to the team of PhysCon2024 organizers led by Fatihan Atay and Deniz Eroglu for the excellent conference organization.

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