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EDITORIAL

Preface for special issue on nonlinear dynamics modeling and control for brain science and brain-like intelligence

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The nervous system is an extremely large, strongly coupled, and highly nonlinear complex network with multiple scales, ranging from molecules, cells, ensembles to brain regions. Nonlinear dynamics and control science can be powerful tools to characterize the network and provide clues for the evolution of the topological and functional networks of brain. In-depth dynamical network analysis will be able to significantly advance the clinical exploration and understanding of the mechanisms underlying neurological diseases, provide quantitative assessment for clinical neurological diagnosis, and trigger effective methods for neurotherapy and rehabilitation. Neural dynamics research on the mechanism of biological intelligence, such as information coding, processing, memory, learning and reasoning, can provide new principles, new ways and new methods for brain-like intelligence. This Special Issue of *Cognitive Neurodynamics* on “Nonlinear Dynamics Modeling and Control for Brain Science and Brain-Like Intelligence” addresses specifically these issues and some experts and scholars in the field are invited to present and discuss their research results.

Chimera state of neuronal networks can be considered as a compromise strategy for encoding ability and transmission efficiency. Feng et al. (Feng 2023) design a multilayer feed-forward neuronal network and demonstrate that the strength of feed-forward effects and the initial conditions of the network largely influence the emergence of chimera states and other patterns, and they also find that chimera states propagate to deeper layers only under stringent conditions. These results contribute to a better understanding of neuronal discharge propagation and encoding schemes in feedforward neuronal networks.

In response to the experimental phenomenon that inhibitory autapses favor firing synchronization of parvalbumin interneurons in the neocortex during gamma oscillations, Jia et al. (Jia 2022) theoretically investigate the effect of inhibitory autapses on the synchronization of Gamma oscillations in interneuronal networks. In globally connected, random, small-world, and scale-free networks, weak synchronization enhancement by inhibitory autapses is simulated, illuminating the complex dynamics of synchronization by inhibitory autoregulation.

To investigate the potential mechanisms by which multiple neural signals are transmitted simultaneously in the same channel in a network, Si and Sun (Si 2022) construct a two-layer feedforward neuron network, and find that it is possible to transmit both low and high frequency signals simultaneously, or to gate or select them via frequency division multiplexing (FDM) communication. Transmission performance is related to local resonance, connectivity and background noise. This may provide new insights into the underlying mechanisms of complex signal communication between different cortical regions.

There hasn’t been any research into theoretical modeling for obsessive-compulsive disorder(OCD) yet. Yin et al. (Yin 2022) established a computational network model to study the dynamics of OCD for the first time. The model can explain the pathology of glutamatergic and dopamine system dysregulation, the effects of pathway imbalance, and neuropsychiatric treatment of OCD, according to data analysis of simulation results. The results suggest that this abnormal brain rhythm caused by abnormalities in the orbitofrontal-subcortical loop may serve as a biomarker for OCD. This can help to understand the causes of OCD and thus facilitate the diagnosis of OCD and the development of new therapies.

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Closed-loop deep brain stimulation (DBS) can apply on-demand stimulation to lower side effects in clinical neural disease treatment. Su et al. (Su 2022) propose a novel idea to modulate the pathological beta band oscillations of a basal ganglia-cortex-thalamus model using a controlled autoregressive (CAR)-fuzzy control algorithm. The CAR model first identifies the relationship between the DBS frequency parameters and the beta oscillation power, and then predicts the error between the beta power and the expected value as the input to the fuzzy controller to calculate the next stimulation frequency. This provides higher tracking reliability, response speed and robustness.

In the field of neuroscience, topological alterations in dynamic functional networks have attracted attention. Zhao et al. (Zhao 2022) investigate the dynamic functional connectivity (dFC) in cervical spondylotic myelopathy (CSM) patients, focusing on the temporal characteristics of functional connectivity state patterns and the variability of network topological organization. Both patients and healthy controls exhibit four types of dynamic functional connectivity states, while the CSM group have a significantly longer mean dwell time in state 2 than healthy controls. In addition, the topological properties of the dynamic network are variable in CSM patients.

Artificial neural network has long been studied for their extensive applications. Liu et al. (Liu 2022) propose a class of complex-valued neural networks (CVNNs) with random fluctuation of system parameters and mixed distributed and time-varying delays. They explain the stability and synchronization of the network using Lyapunov stability theory and Kronecker product and the validity of the theoretical results is verified by two numerical examples.

These articles cover a wide range of research subjects and approaches, from synchronization to multiplex communication, from disease modeling to disease control, from topological networks to functional networks, from dynamical modeling to experimentation, exploring neural information processing and cognitive function. We hope this special issue of *Cognitive Neurodynamics* will provide new ideas and guidance for research in brain science and brain-like intelligence.

References

Feng P, Yang J, Wu Y (2023) Chimera state in a feed-forward neuronal network. Cogn Neurodyn. https://doi.org/10.1007/s11571-022-09928-6

Jia Y, Gu H, Li Y (2022) Influence of inhibitory autapses on synchronization of inhibitory network gamma oscillations. Cogn Neurodyn. https://doi.org/10.1007/s11571-022-09856-5

Liu Y, Shen B, Sun J (2022) Stability and synchronization for complex-valued neural networks with stochastic parameters and mixed time delays. Cogn Neurodyn. https://doi.org/10.1007/s11571-022-09823-0

Si H, Sun X (2022) Inter-areal transmission of multiple neural signals through frequency-division-multiplexing communication. Cogn Neurodyn. https://doi.org/10.1007/s11571-022-09914-y

Su F, Wang H, Zu L et al (2022) Closed-loop modulation of model parkinsonian beta oscillations based on CAR-fuzzy control algorithm. Cogn Neurodyn. https://doi.org/10.1007/s11571-022-09820-3

Yin L, Han F, Yu Y et al (2022) A computational network dynamical modeling for abnormal oscillation and deep brain stimulation control of obsessive–compulsive disorder. Cogn Neurodyn. https://doi.org/10.1007/s11571-022-09858-3

Zhao G, Zhan Y, Zha J et al (2022) Abnormal intrinsic brain functional network dynamics in patients with cervical spondylotic myelopathy. Cogn Neurodyn. https://doi.org/10.1007/s11571-022-09807-0