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ВИКОРИСТАННЯ УКРАЇНСЬКОЇ ГРІД-ІНФРАСТРУКТУРИ ДЛЯ ДОСЛІДЖЕННЯ НЕЛІНІЙНОЇ ДИНАМІКИ ВЕЛИКИХ МЕРЕЖ НЕЙРОНІВ

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APPLICATION OF UKRAINIAN GRID INFRASTRUCTURE FOR INVESTIGATION OF NONLINEAR DYNAMICS IN LARGE NEURONAL NETWORKS

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Introduction. In present work the Ukrainian National Grid (UNG) infrastructure was applied for investigation of synchronization in large networks of interacting neurons. This application is important for solving of modern neuroscience problems related to mechanisms of nervous system activities (memory, cognition etc.) and nervous pathologies (epilepsy, Parkinsonism, etc.). Modern non-linear dynamics theories and applications provides powerful basis for computer simulations of biological neuronal networks and investigation of phenomena which mechanisms hardly could be clarified by other approaches. Cubic millimeter of brain tissue contains about 10^5 neurons, so realistic (Hodgkin-Huxley model) and phenomenological (Kuramoto-Sakaguchi, FitzHugh-Nagumo, etc. models) simulations require consideration of large neurons numbers. Such computations require large computing power and may be efficiently performed in grid infrastructure.

Results. Chimera state or stationary state with coherence and incoherence is recently discovered phenomenon that takes place in large networks of connected oscillators. In this state some oscillators of connected network are synchronized, while others demonstrate chaotic behavior. Chimera states are hypothesized to be concerned with memory, cognition and pathological synchronization. Possible chimera states types and conditions under which this states occur are unknown today. The main aim of this work is to find as many chimera states as possible in the networks of connected neurons described by phenomenological Kuramoto-Sakaguchi model. In this model each oscillator (neuron or other object) is characterized by its phase fi k in dimensions i,*j*, *k*. Phase evolves in time according to the equation:

$$\dot{\phi}_{i,j,k} = \frac{3}{4\pi P^3} \sum_{(i-i')^2+(j-j')^2+(k-k')^2<P^2} \sin\left(\phi_{i',j',k'} - \phi_{i,j,k} - \alpha\right),$$

where P - radius of connected neurons region, a - initial phase that describes ratio between inhibitory and excitatory coupling strengths.

Special software for simulations in Grid was developed and applied in the virtual organization «networkdynamics» in UNG. We considered cubic region with 125000, 1000000 and 64000000 neurons. Several thousands trajectories were simulated with different initial conditions and parameters. Type and occurrence of chimera state (Fig. 1) significantly depend on initial conditions, radius and initial phase.

Conclusions. About twenty different chimera states we discovered using this approach. Trajectories and animations are presented in Grid databank https://chimera.biomed.kiev.ua/.

We also plan to use the following approach for realistic simulations of neuronal networks under epilepsy and Parkinsonism to clarify the conditions and mechanisms of these pathologies.

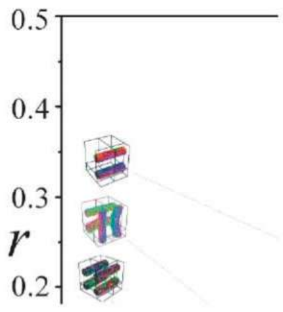

Fig. 1. Diagram of chimera states.