

**ПРАВИТЕЛЬСТВО РОССИЙСКОЙ ФЕДЕРАЦИИ  
НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ УНИВЕРСИТЕТ  
«ВЫСШАЯ ШКОЛА ЭКОНОМИКИ»**

**Факультет компьютерных наук Образовательная программа «Программная инженерия»  
(ВШЭ ФКН ПИ)**

УДК 004.852

**СОГЛАСОВАНО**

Руководитель,

Стажер-исследователь,

приглашённый лектор

\_\_\_\_\_ О. Н. Качан

«\_\_\_\_\_» \_\_\_\_\_ 20\_\_г.

**УТВЕРЖДАЮ**

Академический руководитель

образовательной программы

«Программная инженерия»

профессор департамента программной

инженерии, канд. техн. наук

\_\_\_\_\_ В.В. Шилов

«\_\_\_\_\_» \_\_\_\_\_ 20\_\_г.

**ОТЧЕТ  
О НАУЧНО-ИССЛЕДОВАТЕЛЬСКОЙ РАБОТЕ**

SYNCHRONIZATION OF NEUROMORPHIC NETWORKS OF THE CLOSE WORLD FROM THE POINT  
OF VIEW OF COMPLEXES  
(заключительный)

Выполнил:

Студент группы БПИ204

образовательной программы

«Программная инженерия»

Пеганов Никита Сергеевич

\_\_\_\_\_ Н. С. Пеганов

«\_\_\_\_\_» \_\_\_\_\_ 20\_\_г.

Москва 2022

# 1 Abstract

## 2 Content

## Содержание

1	Abstract	2
2	Content	3
3	Basic terms, definitions and abbreviations	4
4	Introduction	5
5	The main part of the research report	6
6	Conclusion	7
7	Applications	9

### 3 Basic terms, definitions and abbreviations

**Graph** — a set of items connected by edges. A graph  $G$  can be defined as a pair  $(V, E)$ , where  $V$  is a set of vertices, and  $E$  is a set of edges between the vertices  $E \subseteq \{(u, v) | u, v \in V\}$ [1].

**Complex**

**Dynamical systems on graphs and complexes**

**Synchronization** — the fact of happening at the same time, or the act of making things happen at the same time[2].

**Simplicial synchronization** — a fundamental dynamical state observed in a wide variety of complex systems and capturing among other phenomena important aspects of brain dynamics and circadian rhythms[3].

**Kuramoto model** is a stylized model that explains how coupled oscillators, that in absence of interactions would have different intrinsic frequencies, can start to follow a collective coherent motion when their coupling constant  $\sigma$ , measuring the strength of their interaction, is larger than a critical value  $\sigma_c$  also called synchronization threshold[3].

## **4 Introduction**

**Task description**

**Relevance**

**Subject of research**

**Research methods**

**Purposes and objectives of the work**

**Originality and reliability of the obtained results**

**Theoretical significance**

**Practical value**

## 5 The main part of the research report

### Review and analysis of sources

"Geometry, Topology and Simplicial Synchronization"[3] by Ana Paula Millán, Juan G. Restrepo, Joaquín J. Torres and Ginestra Bianconi is a review article fully covering the area under study. It defines "Simplicial synchronization" "Kuramoto model" "Graph Laplacian" and other important definitions.

In this article Ginestra Bianconi explores how the combinatorial and statistical properties of complex networks have effects on dynamics. Simplicial complexes affect on higher-order dynamics through simplicial geometry and topology. To research it two frameworks are used: Network Geometry with Flavor (NGF) and Graph Laplacian. Exactly, spectral dimension of NGF networks is used to measure the geometry influence on dynamics.

The level of synchronization in the system is measured by the Kuramoto order parameter,

$$Z_0 = R_0 e^{i\Theta} = \frac{1}{N} \sum_{j=1}^{N[0]} e^{i\theta_j},$$

where  $R_0$  and  $\Theta$  are both real and where  $0 \leq R_0 \leq 1$  measures the overall coherence and  $\Theta = \Theta(t)$  is the phase of global oscillations.

### Selection of methods, algorithms, models for solving tasks

#### Description of selected or proposed methods, algorithms, models, techniques

#### Description of the experiment

#### Review and analysis of sources

#### Description of the experiment

## 6 Conclusion

## List of used sources

- [1] *Paul E. Black and Paul J. Tanenbaum* "graph in Dictionary of Algorithms and Data Structures [online], Paul E. Black, ed. 21 June 2021. (accessed 04.07.2022) Available from: <https://www.nist.gov/dads/HTML/graph.html>
- [2] *Cambridge University Press* Meaning of synchronization in English. // Website [dictionary.cambridge.org](https://dictionary.cambridge.org) (<https://dictionary.cambridge.org/dictionary/english/synchronization>). Viewed: 04.07.2022
- [3] *Ana Paula Millán, Juan G. Restrepo, Joaquín J. Torres and Ginestra Bianconi* Geometry, Topology and Simplicial Synchronization. P. 12



## 7 Applications

### Application 1

Link to the project repository with the source code and all used materials.

<https://github.com/NikPeg/synchronization-of-neuromorphic-networks-of-the-close-world-from-the-point-of-view-of-complexes>