

REVIEW

**by Assoc. Prof. Dr. Alexander Iliev Iliev,
Institute of Mathematics and Informatics - BAS**

In connection with the procedure for defense of a dissertation on the topic "*Neural networks for object placement tasks*" for obtaining the educational and scientific degree "Doctor", field of higher education: *4. Natural sciences, mathematics and informatics*, professional field: *4.6 Informatics and Computer Science, PhD Program "Computer Science" - Algorithms and complexity*, the department of "Mathematical Logic and Applications" at FME SU "Kliment Ohridski"

Candidate: Vladislav Valeriev Haralampiev

This review is presented based on an Order of the Rector of Sofia University "Kl. Ohridski" with № RD 38-292/02.07.2021 for the defense of a dissertation. It has been prepared based on the Law on its implementation and the Regulations for its implementation and the Regulations for the conditions and procedure for acquiring and holding academic positions at Sofia University "Kl. Ohridski".

As a member of the scientific jury, I have received all the required administrative and scientific documents of the candidate:

- extended abstract,
- dissertation in English,
- abstract to the main dissertation,
- Minutes of the first meeting of the scientific jury appointed by order of the Rector PR 38-292 / 02.07.2021 for the defense of the dissertation.

The candidate meets the criteria of Sofia University "Kl. Ohridski" for participation in the competition and was admitted to the defense of the dissertation.

1. General characteristics of the scientific work related to the dissertation of the candidate

In this dissertation a new method for using neural networks called Networks Competing with neurons is presented. These types of networks are made for specialized use in solving problems of object placement and can be used for combinatorial optimization. In this type of task, the goal is to find an optimal configuration for a certain evaluation function among a finite number of configurations. As examples of their application, the candidate pointed out the compilation of schedules, routing of vehicles, balancing of conveyors, etc. As a strength of this type of methods is the possibility of efficient parallel implementation with the possibility of hardware acceleration. This makes this algorithm competitive as it allows it to be widely used in practice while optimizing and speeding up the computational process. The disadvantage of the existing neural networks for combinatorial optimization is the poor quality of the solution reached through their use and their limited applicability. As a motivation for solving these problems, it was pointed out that the potential of neural networks for combinatorial optimization is not well assessed, which requires their further research and development. The aim of this dissertation is to present an example of a neural method that is applicable to a class of problems that return good solutions. This makes these neural networks competitive since they can offer meaningful solutions to several optimization problems. Since the number of problems for combinatorial optimization is huge, in this dissertation is considered the solution of an extensive subclass of practical problems related to the location of objects. Thus, the study of the properties of the introduced model are studied in detail.

Understanding the work in more details, the candidate considered the use of a mechanism of competition between neural networks as an improved way of decision making. Thus, neurons are divided into groups, where they compete locally and act locally within these groups. According to research, if left to work long enough, this type of system will be able to find a globally optimal solution to the modeled problem of combinatorial optimization.

The main contribution of this dissertation is the presentation of neural networks that can compete with the already established metaheuristics for combinatorial optimization. This competitiveness can be both according to the theoretical factors of this type of networks and according to the purely practical tasks as can be seen from the results of the assigned tasks. This refutes the argument of the thesis that neural networks are not suitable for solving combinatorial optimization problems. The other contribution of the work

presented in the candidate's work is the proposal to use a polynomial constraint of the algorithm, justified by finding a solution close enough to the optimal one.

2. Structure and content of the dissertation

This dissertation work with is composed of 180 pages, detailed statement in 5 chapters, a conclusion, 2 appendixes, bibliography of 107 titles located in 10 pages, there are 9 tables, 27 figures and six pseudo code snippets.

The work is organized as follows:

- Chapter 1. *Introduction*: combinatorial optimization tasks with a subclass of object placement tasks are introduced.
- Chapter 2. *Metaheuristics for combinatorial optimization*: Eight popular methods are presented, namely: Repeated local search, Simulated annealing, Tabu search, GRASP, VNS, Guided local search, Genetic algorithms, and Ant colony optimization.
- Chapter 3. *Competition-Based Neural Networks*: makes a detailed introduction to the main topic of the dissertation.
- Chapter 4. *Analysis of CBNNs*: presents the theoretical properties of the algorithm, showing why these networks can find a good solution to the problems.
- Chapter 5. *Applications of CBNNs*: the algorithm was used to solve 6 tasks for placement of objects, details were examined.
- Chapter 6. *Conclusions*: the main contributions of the dissertation are presented and guidelines for future work on the topic are proposed.
- Appendix A. *Markov chains*: basic concepts from the theory of Markov chains are presented, showing how the rate of convergence can be estimated.
- Appendix C. *Datasets based on geographic data*: describes the procedure by which geographical data are processed in the dissertation.
- Publications directly related to the dissertation: 5 publications are presented
- Declaration of originality
- Acknowledgements

3. Scientific papers published by the doctoral student in direct connection with the dissertation

- V. Haralampiev. "Theoretical Justification of a Neural Network Approach to Combinatorial Optimization". In: Proceedings of the 21st International Conference on Computer Systems and Technologies. 2020
- V. Haralampiev. "Neural network approaches for a facility location problem". In: International Scientific Journal of Mathematical Modeling. 2020
- V. Haralampiev. "Single facility location problems in k-trees". In: 58th Annual Science Conference of Ruse University and Union of Scientists - Ruse. 2019.
- V. Haralampiev. "Neural networks for facility location problems". In: Annual of Sofia University „St. Kliment Ohridski”. 2019.
- V. Haralampiev. "Dynamic facility location problems". In: Young Researchers Conference Proceedings. 2019.

4. Evaluation of the scientific and practical results and contributions in the publications submitted for the competition

According to what I read, I concluded that the candidate used peer-reviewed literature from scientifically validated sources, which makes the introductory part of the dissertation legitimate and validated. The work is written at a high professional-academic level containing the necessary depth and originality. Theoretical conclusions based on deep academic factology have been reached. Moreover, the work shows a specific practical orientation that has the potential to lead to implementation in a number of applications. Due to the stated facts, I give the highest grade to the candidate.

5. Remarks and recommendations

I have no remarks or recommendations.

6. Conclusion

Based on what has been said about the materials presented, scientific papers, their significance and contained therein scientific and applied contributions, I believe that candidate Vladislav Valeriev Haralampiev meets all the requirements of “ЗПАСРБ”, Rules for the implementation of “ЗПАСРБ” and Regulations the conditions and the order for acquiring the educational and scientific degree "Doctor" at Sofia University “Kl. Ohridski” in the professional field 4.6 Informatics and Computer Science, **I give a positive assessment** to the candidate. **I recommend** to the esteemed Scientific Jury of the competition to propose to the esteemed Faculty Council of the Faculty of Mathematics and

Informatics of Sofia University “Kl. Ohridski” to approve the dissertation of the candidate and to award him the scientific degree of Doctor in Professional Field 4.6. "Informatics and Computer Science" at Sofia University “Kl. Ohridski”.

Sofia, 31.08.2021

Reviewer:

Assoc. Prof. Dr. Alexander Iliev
/ at IMI-BAS /