OPINION

by **Assoc. Prof. Peter Mladenov Vassilev, PhD**

Institute of Biophysics and Biomedical Engineering – Bulgarian Academy of Sciences

of a thesis for the award of the scientific degree

Doctor of Sciences

Topic: **Metaheuristic Algorithms for Nonlinear Dynamic System Identification**

Area of Higher Education 4. Natural Sciences, Mathematics and Informatics,
Professional Field 4.6. Informatics and Computer Science,

with author **Prof. Olympia Nikolaeva Roev, PhD**

1. Overview of the procedure and personal impressions of the candidate

The thesis was discussed and approved for defense following a review at an extended scientific seminar of the "Bioinformatics and Mathematical Modeling" Section at the Institute of Biophysics and Biomedical Engineering (IBPhBME) on April 28, 2026, and a decision by the Scientific Council (Minutes No. 7/May 29, 2026). Pursuant to Order No. RD-560 dated June 1, 2026, issued by the Director of IBPhBME, a scientific jury was appointed for the defense procedure of the thesis titled "Metaheuristic Algorithms for Nonlinear Dynamic System Identification," submitted by Prof. Olympia Nikolaeva Roeva, Phd for the award of the scientific degree "Doctor of Sciences" in Higher Education Area 4 (Natural Sciences, Mathematics, and Informatics), Professional Field 4.6 (Informatics and Computer Science), and the defense date was set for September 8, 2026. The materials submitted by Prof. O. Roeva are comprehensive and comply with the requirements of the Regulations for the Application of the Act on the Development of the Academic Staff in the Republic of Bulgaria (ADASRB) and the specific regulations of the Institute of Biophysics and Biomedical Engineering (IBPhBME-BAS); they convincingly demonstrate that the candidate fully meets both the minimum national requirements and the specific requirements of IBPhBME-BAS for obtaining the scientific degree of "Doctor of Sciences."

Prof. O. Roeva is a long-standing member of the Institute, holding numerous distinctions and national and international awards that attest to her qualities as a scientist. It is also worth noting that she is the first author on 80% of the publications submitted for this procedure—a fact that demonstrates her leading contribution. Having personally collaborated with the candidate on various research projects, as well as on the preparation of conference papers and journal articles, I can confidently state that she is a highly qualified scientist distinguished by her professionalism, innovative scientific mindset, and precision in developing and presenting research findings.

2. General characteristics and relevance of the thesis

The aim of the thesis is the "the theoretical investigation, development, and experimental validation of metaheuristic algorithms and hybrid methodologies, with systematic application to

bioprocess modelling and control, aimed at the design of improved, high-performance, and efficient optimization algorithms". This problem is highly relevant because, due to the increasing complexity, high dimensionality, and strong nonlinearity of modern biotechnological systems, classical approaches effective for convex optimization fail to perform well or are excessively resource-intensive. On the other hand, despite the broad applicability of most metaheuristic algorithms, some exhibit characteristic weaknesses—such as excessively slow or premature convergence, sensitivity to parameters, and so on. All this necessitates the search for hybrid algorithms capable of maintaining a better balance between global exploration and local exploitation. In her thesis, Prof. Roeva investigates the possibilities of combining various metaheuristic approaches to enhance the efficiency, robustness, and quality of the resulting solutions. The developed algorithms have been validated through the identification of nonlinear model parameters and the tuning of PID controllers. Thus, the research combines theoretical and applied aspects, demonstrating the practical implementation of the proposed methods..

3. Assessment of the results

The thesis, prepared for the degree of "Doctor of Science," is devoted to the study, development, and analysis of ten meta-heuristic and five hybrid meta-heuristic optimization algorithms. It has been established that, for the ten metaheuristic algorithms studied, the identification of parameters in the modeling and control of bioprocesses strongly depends on the structure and complexity of the optimization problem. It has been found that, for the ten metaheuristic algorithms studied, the identification of parameters in the modeling and control of bioprocesses depends heavily on the structure and complexity of the optimization problem. It has been established that, for the ten metaheuristics studied, several inherent limitations of the individual metaheuristics have been experimentally confirmed: premature convergence (e.g., GA, ALO), leading to suboptimal solutions; slow convergence rates (e.g., COA, ABC); high sensitivity to algorithm-specific parameters (GA, EFO); and an insufficient balance between search and exploitation mechanisms (ABC, ALO). The development of hybrid meta-heuristic algorithms is based on a systematic and theoretically grounded framework designed to combine complementary search mechanisms in order to overcome the limitations of standalone approaches. Hybrid meta-heuristics are structured dynamic systems in which multiple search operators interact to produce improved optimization behavior. A theorem on probabilistic convergence for hybrid metaheuristics, based on a condition of non-degenerate search, has been proven. The effectiveness of the studied and proposed algorithms has been confirmed through statistical and intercriteria analysis.

4. Major scientific and applied scientific contributions

I concur with the five scientific and two applied scientific contributions of the thesis outlined by the candidate on page 234. The theorem regarding global convergence in probability, together with the generalized theoretical framework for hybridization, is particularly significant, as it paves the way for the future development of other hybrid algorithms with suitable efficiency. The work also encompasses the practical application of approaches for bioprocess modeling and control, as well as a framework for comparing metaheuristic algorithms. This ensures that the theoretical findings successfully address real-world nonlinear optimization problems.

5. Dissemination and scientific significance of the results

The results of the thesis are presented in 20 scientific publications. Of these, 10 are in international journals with an impact factor, 6 in journals with SJR, and 4 in proceedings of international conferences indexed in Scopus. This indicates that the results have been widely disseminated. The candidate has provided a list of 304 citations in Scopus for the aforementioned publications. This number of citations unequivocally demonstrates that the results of the dissertation have received widespread recognition from independent scholars around the world and attests to their high quality.

6. Critical comments and recommendations

I have no significant critical remarks. It would be interesting in future work to investigate whether the relatively new Chess Piece Movements Optimization (CPMO) algorithm with fuzzy sets (https://doi.org/10.1007/978-3-032-22232-9_14) could be used to develop a new hybrid algorithm. There are some technical inaccuracies: on page 197, it reads "(Table ??) demonstrate that ABC-GA", whereas it should be "(Table 3.6) demonstrate that ALO-GA"; on page 206, it reads "following Eq. ??.", whereas it should be "following Eq. 2.38."

7. Compliance of the abstracts and the dissertation for the scientific degree of "Doctor of Sciences"

The thesis fully meets the requirements for the award of the academic degree of "Doctor of Sciences" It presents new theoretical generalizations and solutions to significant scientific and applied scientific problems related to the development and application of hybrid meta-heuristic algorithms. The results obtained represent an original and significant contribution by the candidate to the development of the field of study. The abstracts accurately present the structure of the thesis, its main results, and its scientific contributions..

8. Conclusion

My evaluation of the dissertation, the abstracts, and the results achieved by Prof. Olympia Nikolaeva Roeva is entirely positive. They are the result of in-depth scientific work and represent a significant and original scientific contribution. The thesis meets the requirements of the current regulatory framework. Based on the foregoing, I am confident in recommending that the Academic Jury should award Prof. Olympia Nikolaeva Roeva the scientific degree of "Doctor of Sciences" in Area of Higher Education 4. Natural Sciences, Mathematics and Informatics, Professional Field 4.6. Informatics and Computer Science.

19.08.2026

Opinion prepared by:

/ Assoc. Prof. P. Vassilev /