

Review

of the thesis of Prof. Dr. Olympia Nikolaeva Roeva
“Metaheuristic Algorithms for Nonlinear Dynamic System Identification”,
presented for awarding the scientific degree “doctor of science”
in Professional area 4.6 Informatics and computer science
by Prof. Dr. Maria Nisheva-Pavlova – Faculty of Mathematics and Informatics,
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Pursuant to Order 560/01.06.2026 of the Director of the Institute of Biophysics and Biomedical Engineering (IBPhBME) I am nominated as a member of the scientific jury for the defense of the submitted thesis in professional area 4.6 Informatics and computer science, entitled “Metaheuristic Algorithms for Nonlinear Dynamic System Identification”. At the first meeting of the scientific jury, held on 09.06.2026, I was appointed as a reviewer for the procedure.

1. General characteristics of the dissertation and the presented materials

The dissertation is dedicated to a contemporary and complex topic in the field of Informatics. It is written in English and contains 312 pages of text, including preface, seven chapters, list of references, list of tables, list of figures, and list of abbreviations.

In addition to the dissertation, the following are also presented on the procedure:

- abstracts in Bulgarian and English;
- a European-style CV;
- copy of diploma for educational and scientific degree “doctor”;
- lists of publications submitted for participation in previous procedures for academic development;
- certificate of fulfillment of the minimum requirements for obtaining the scientific degree “doctor of science” in the professional field Informatics and computer science;
- a separation protocol for the contributions of the co-authors of the publications under the procedure;
- list and copies of the candidate’s publications by dissertation results;
- reference for noticed citations of the candidate’s publications;
- a list of scientific forums where results from the dissertation have been presented.

2. Applicant data

Prof. Olympia Roeva has Master's degree in Bioelectrical engineering, acquired at the Technical University – Sofia. In 2007, she defended a PhD thesis in the field of modeling of bioprocess systems using genetic algorithms. During the period 1998-2001 she worked as a specialist at the Institute of Microbiology – BAS, and since 2001 her professional biography has been connected with the current IBPhBME – BAS (consecutively as a doctoral student, research associate, associate professor, professor).

I know Prof. Olympia Roeva from her work as a part-time lecturer in the Master's program in Artificial Intelligence at the Faculty of Mathematics and Informatics of Sofia University St. Kliment Ohridski for the last two academic years. I have excellent impressions of her thoroughness, analytical skills, precision, adaptability and ability for teamwork.

3. Relevance of the research area and significance of the research problem

The dissertation is dedicated to research in the field of hybrid metaheuristic algorithms. It explores the theoretical foundations of hybridization in metaheuristic optimization and, based on the theoretical results obtained, proposes and investigates new hybrid metaheuristic algorithms.

The area of research in the dissertation is complex and contemporary, and its relevance is determined by the wide range of significant applications of the considered types of algorithms in modeling and controlling bioprocess systems.

4. Analysis of the content, results and contributions of the doctoral thesis

The dissertation includes a preface, seven chapters, and a list of references.

The preface presents the field, purpose, research hypothesis, and objectives of the study and summarizes the content of the individual chapters of the dissertation.

The first chapter presents an overview of the current state of research in the field of metaheuristic algorithms and bioprocess modeling. Classical optimization methods and their inherent limitations are reviewed and the theoretical foundations of metaheuristic optimization are discussed. A comprehensive classification of metaheuristic algorithms is presented and hybrid metaheuristic approaches are studied from the perspective of the theoretical foundations of hybridization. A taxonomy of hybrid approaches is proposed and suitable illustrative examples are considered. The open questions in the field, to which the research of the dissertation is directed, are formulated.

In the second chapter, the cultivation processes used as benchmark systems for validation and performance evaluation of the metaheuristic and proposed hybrid algorithms are presented. An appropriate theoretical basis for the problems of parameter identification of the nonlinear model is presented. The theoretical foundations of inter-criteria analysis are discussed together with conventional statistical performance analysis. Thus, a combined evaluation framework is proposed that provides multidimensional and reliable assessment of algorithmic efficiency and reliability.

Chapter 3 analyzes the characteristics of 10 metaheuristic optimization algorithms, representing different classes within the metaheuristic paradigm. These algorithms were chosen to provide methodological diversity in terms of population structure and information exchange mechanisms.

Chapter 4 presents the results of a systematic and in-depth study of the application of the selected algorithms to parameter optimization problems in bioprocess systems. A comparative analysis is performed in terms of solution accuracy, convergence behavior, and computational efficiency. The results form the methodological basis for the development of the advanced hybrid approaches presented in the next two chapters.

The fifth chapter presents the new hybrid metaheuristic optimization algorithms proposed by the author of the dissertation. The mathematical foundations of these algorithms are examined and their properties are investigated.

Chapter 6 is devoted to an analysis of the results of the application of the proposed hybrid metaheuristic algorithms to the tasks of identifying model parameters and tuning PID controller parameters.

The final seventh chapter summarizes the results obtained and formulates the contributions of the dissertation. The author's publications related to the procedure are presented.

The main contributions of the doctoral thesis of Prof. Olympia Roeva may be summarized as follows:

- A systematic analysis of 10 metaheuristic algorithms has been performed and guidelines for hybridization have been formulated to overcome their inherent limitations.
- A generalized theoretical framework for hybridization of metaheuristic algorithms is proposed, based on their representation as stochastic dynamical systems.
- New hybrid metaheuristic algorithms have been created and component integration schemes and corresponding algorithmic structures for each of them have been developed.

- A theorem for global convergence in probability of hybrid metaheuristic algorithms has been proven.
- A comparative analysis of the behavior and performance of hybrid metaheuristic algorithms has been performed.
- A multi-level framework for evaluating and comparing metaheuristic algorithms is proposed.

The dissertation appropriately brings together valuable scientific and applied scientific results, published in a total of 20 papers. It makes an excellent impression with the scope and depth of the presentation. Its text consistently follows the logic of the set main goal of the study and the formulated series of tasks into which the goal is decomposed. The achieved results are original and significant and fully correspond to the set goal. I accept the formulation of the contributions of the dissertation proposed by its author and I appreciate them very highly.

5. Publications on the doctoral thesis. Reflection on the works of other authors

According to Scopus data, the author of the dissertation has over 130 scientific publications, which have been cited by more than 1,300 publications by other authors.

A total of 20 scientific publications were submitted for participation in this procedure:

- five papers – in a scientific journal with IF, falling into Q1 of the JCR for the scientific field of the dissertation;
- four papers – in scientific journals with IF, falling into Q2 of the JCR for the scientific field of the dissertation;
- one paper – in a scientific journal with IF, falling into Q3 of the JCR for the scientific field of the dissertation;
- six papers – in scientific journals with SJR;
- four papers – in conference proceedings indexed in Scopus and Zentralblatt.

None of these publications has been used in previous procedures for academic development in which the author of the dissertation participated. One of the papers is single-authored, the remaining 19 are co-authored. A declaration is presented by the co-authors of 16 of the joint papers that the main contributions in these papers regarding the development and application of the metaheuristic algorithms and hybrid metaheuristics presented in them are by Prof. Olympia Roeva.

Data are presented for 304 noted citations of publications based on the results of the dissertation in works by other authors, published in journals, refereed and indexed in WoS and/or Scopus.

In this way, the author of the dissertation accumulates a total of 304 ($5*25+4*20+1*15+6*10+4*6$) points under the group of indicators "Г" and 1824 ($304*6$) points under the group of indicators "Д" and therefore fulfills and significantly exceeds the requirements of the Regulations on the specific conditions for the acquisition of scientific degrees and for the occupation of academic positions at the IBFBMI – BAS for the acquisition of the scientific degree “doctor of science” in professional area 4.6 Informatics and Computer Science.

6. Abstract

The abstract meets all the requirements for its preparation and fully and accurately presents the topic, purpose, content, achieved results and contributions of the dissertation.

7. Critical Remarks and Recommendations

The dissertation is carefully and correctly written. Its presentation is competent, well-reasoned and thorough. I have no significant comments on its content. My recommendations for the version of the dissertation submitted for preliminary discussion in IBPhBME are fully reflected in its final version.

8. Summary

Summing up, I consider that the dissertation of Prof. Olympia Roeva fully satisfies and significantly exceeds the requirements of the national regulations and the specific conditions and requirements of the Institute of Biophysics and Biomedical Engineering. Its author has achieved significant research results that make an original contribution to the field of Informatics. My assessment of the dissertation, the abstract and the scientific contributions of their author, Prof. Olympia Roeva, is **positive**.

Therefore, **I advise the honorable scientific jury to award to Prof. Olympia Nikolaeva Roeva the scientific degree “doctor of science” in professional area 4.6 Informatics and Computer Science.**

Sofia, August 10, 2026

Prof. Dr. Maria Nisheva-Pavlova