

REVIEW
of a dissertation submitted for the award of the scientific degree “Doctor of Sciences”
in Professional Field 4.6 “Informatics and Computer Science” on the topic
“Metaheuristic Algorithms for Identification of Nonlinear Dynamic Systems”
by Prof. Olympia Nikolaeva Roeva, PhD

1. From the submitted professional biography of Prof. Olympia Roeva, it is evident that she was born on 16 February 1974 in Sofia. In 1998, she graduated from the Technical University of Sofia with a degree in Bioelectrical Engineering. From 2001 to 2004, she was a full-time doctoral student at the Central Laboratory of Biomedical Engineering “Prof. Ivan Daskalov” (CLBME), Bulgarian Academy of Sciences. Since 2004, she has worked at the Central Laboratory of Biomedical Engineering, BAS (which since 2010 has merged into the Institute of Biophysics and Biomedical Engineering, BAS), initially as Research Associate II degree and subsequently as Research Associate I degree.

In 2007, Prof. Olympia Roeva defended a dissertation entitled “Modelling of Functional States in *Escherichia coli* Cultivation Using Genetic Algorithms” for the award of the scientific degree then known as “Candidate of Technical Sciences” (currently “PhD”) in front of the Specialized Scientific Council on Automation and Control Systems of the Higher Attestation Commission, in the scientific specialty 02.21.12 “Bioautomation”. Since 2009, she has been an Associate Professor, and since 2021, a Professor at the Institute of Biophysics and Biomedical Engineering, BAS. During the period 2023–2025, she also held a second employment contract at the Institute of Robotics, BAS.

2. The dissertation of Prof. Olympia Roeva, PhD, is devoted to the study of existing and the development of new metaheuristic algorithms for the identification of nonlinear dynamic systems, as well as to the discussion of their behaviour. In essence, Prof. Roeva’s results are both scientific and scientifically applied.

The dissertation comprises 288 pages and is written in English. It contains a declaration of originality, a list of tables, a list of abbreviations, an introduction, six chapters, a conclusion including a list of the publications related to the dissertation, a list of their citations, and a bibliography containing 581 references, all of them in English.

Without discussing the contents in detail, I shall outline what I consider to be the most significant contributions, together with several inaccuracies in the dissertation.

In the Introduction, the aim and the tasks addressed in the dissertation are formulated.

Chapter One, "*State of the art in metaheuristic algorithms and bioprocess modelling*", presents brief notes on the main types of standard and hybrid metaheuristic algorithms (Sections 1.2 and 1.3). The chapter is particularly interesting because of the classification of these algorithms proposed in it, and in my opinion this material would be worth publishing in an appropriate journal. Section 1.4 discusses the main applications of metaheuristic algorithms to nonlinear dynamic systems for bioprocess identification. The chapter concludes with the formulation of the aim of the dissertation: "*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.*"

Chapter Two, "*Materials and Methods*", is devoted to a "*description of the cultivation processes employed as real-world benchmark systems for the validation and performance assessment of the proposed hybrid metaheuristic algorithms.*" To a large extent, the chapter has the characteristics of a survey. InterCriteria Analysis is described as one of the mathematical tools required for the subsequent exposition. There are several inaccuracies and a certain incompleteness in its presentation, but as one of the creators of this analysis, I should note that these inaccuracies do not affect the results obtained from its actual application, as presented in the following chapters.

Chapter Three, "*Metaheuristic Algorithms*", provides brief information on ten basic types of genetic algorithms, together with their pseudocodes. I am not aware of a comparable overview in the Bulgarian literature, and I believe that its publication would be useful for students and doctoral students. In Section 3.10, the definition of one of the mathematical operations, denoted by " $\otimes$ ", is missing.

Chapter Four, and especially Chapters Five and Six, constitute the central part of the dissertation.

Chapter Four, "*Application of metaheuristic algorithms for parameter optimization problems*", discusses applications of the ten metaheuristic algorithms described in Chapter Three, which are used for identifying parameters in nonlinear bioprocess models. I am not a specialist in biotechnology and therefore cannot comment on the significance and usefulness of the results presented in this chapter. However, as a mathematician, I would note that here, as in Chapter Three, there are mathematical expressions containing denominators for which it is not discussed whether they are guaranteed to be non-zero. The chapter concludes with an interesting analysis of the strengths and weaknesses of the metaheuristic algorithms used. In my opinion, this

analysis, together with the results from Chapter One mentioned above, would be suitable for publication in a separate paper.

Chapter Five, *“Hybrid Metaheuristic Algorithms”*, contains descriptions of five original algorithms developed over a period of four years by Prof. Roeva, jointly with Assoc. Prof. Dafina Zoteva or Assoc. Prof. Tsonko Slavov. The performance of each of these algorithms has been investigated. A theorem on convergence in probability has been proved for the new hybrid metaheuristics. There is a contradiction between formula (5.1), on the one hand, and formulas (5.6) and (5.7), on the other. This can easily be avoided if, in formula (5.1), the symbol “ $\subset$ ” (subset) is replaced by the symbol “ $\in$ ” (belonging).

Chapter Six, *“Application of hybrid metaheuristic algorithms for parameter optimization problems”*, contains a description of the results obtained from applying the new hybrid metaheuristic algorithms to problems of parameter identification in models. Here, the definition of the operation denoted by “ $\odot$ ” is missing.

It would be interesting in future work to describe the new algorithms in terms of Generalized Nets, with the aim of investigating the possibility of developing new hybrids based on the existing algorithms described in the dissertation.

As is very accurately stated in the abstract with regard to Chapter Seven, *“Conclusion and future work directions: “The dissertation ... presents a study of the development, analysis and application of metaheuristic and hybrid metaheuristic optimization algorithms for solving complex nonlinear parameter-identification problems in bioprocess modelling and control.”* The effect of the proposed hybrid metaheuristic algorithms is presented. It is particularly positive that directions for further research in the field of the dissertation are outlined, and Prof. Olympia Roeva plans to continue working along these lines.

I recommend that the dissertation be further developed into a monograph, to be published either in the series “Bulgarian Academic Monographs” of the Prof. Marin Drinov Publishing House of the Bulgarian Academy of Sciences, or in one of Springer’s book series.

I accept the stated *“Contributions of the thesis ”*.

3. The PhD synopsis is 42 pages long and is presented in Bulgarian and English. In terms of both length and content, it meets the requirements for an accurate, complete and concise presentation of the dissertation.

4. There are 20 scientific publications on the topic of the dissertation, which may be classified as follows:

- 10 articles in journals with an Impact Factor, with the Impact Factor exceeding 2 in each case;
- 6 articles in journals with an SJR indicator;
- 2 articles in journals without such indicators;
- 2 conference papers.

All publications are in English. They fully satisfy the requirements of the Regulations of the Institute of Biophysics and Biomedical Engineering, BAS, for the award of the scientific degree “Doctor of Sciences”.

5. Prof. Olympia Roeva has submitted a list of 304 citations to the 20 publications included in the list of works related to the dissertation, indexed in the Web of Science and Scopus databases. One of her articles has received 163 citations. Thus, the requirements of the Regulations of the Institute of Biophysics and Biomedical Engineering, BAS, are fully satisfied.

6. I have known Prof. Olympia Roeva since 2001, when she joined the Central Laboratory of Biomedical Engineering, BAS, as a doctoral student. I was a reviewer in the procedure for her appointment as Professor, which she successfully completed.

7. The dissertation of Prof. Olympia Roeva, PhD, satisfies the requirements for the scientific degree “Doctor of Sciences” under the Regulations on the Specific Conditions at the Institute of Biophysics and Biomedical Engineering, BAS and under the Act on the Development of the Academic Staff in the Republic of Bulgaria.

The considerations set out above provide sufficient grounds for me to give a positive evaluation of the dissertation and to recommend that the distinguished members of the Scientific Jury vote in favour of awarding **Prof. Olympia Nikolaeva Roeva, PhD**, the scientific degree “**Doctor of Sciences**” in Professional Field **4.6 “Informatics and Computer Science”**.

22 August 2026

Reviewer:.....
(Acad. Krassimir Todorov Atanassov, DSc, DSc)