

OPINION

on dissertation entitled:

*Porous Medium Flow Simulations using Massively Parallel
Multilevel Monte Carlo Algorithm*

for awarding the educational and scientific degree “doctor”

Submitted by: *Nikolay Georgiev Shegunov*

Area of higher education: *4. Natural sciences, mathematics and computer science*

Professional filed: *4.6. Informatics and computer science*

Doctoral programme: *„Information systems“*; Chair: *„Computer informatics“*, Faculty of *mathematics and informatics, Sofia University „St. Kliment Ohridski“ (FMI-SU)*,

This opinion is prepared by: *Professor Dr. Maria Datcheva, Institute of Mechanics, Bulgarian Academy of Sciences*, member of the Scientific Jury by order № ПД 38-258/07.06.2021 г of the Rector of the Sofia University „St. Kliment Ohridski“.

1. General description of the dissertation and the provided required documents

The following documents, provided by the doctoral candidate, have been used for this opinion: a dissertation in English and abstracts in English and Bulgarian; self-assessment of compliance with the national minimum requirements, where the description of the scientific publications and the scores they bring are missing; orders for enrollment and admission to doctoral defence; summary of the scientific contributions, which contains only a list of publications and participation in conferences, but the scientific contributions are not summarized; professional autobiography.

The presented dissertation has 124 pages, and the content is organized in 6 chapters and 3 appendices containing a list of abbreviations (App.A), a list of figures and tables (App.C) and the characteristics of the used hardware resources (App.B). The dissertation includes 44 figures and 20 tables, all of them necessary to illustrate the results. The cited literature covers a total of 62 scientific articles, books and other sources. The first chapter is an introduction to the algorithms used to qualify and quantify uncertainties in processes and material model parameters. It contains a critical analysis of the approaches used so far and the motivation for the research conducted within the doctoral study. The second chapter is devoted to the main methods and models used in the dissertation for the numerical study of flow in porous media accounting for model uncertainties. Chapters 3 and 4 present the results of the application of the Multilevel Monte Carlo (MLMC) algorithm to stochastic partial differential equations, specifically the Laplace equation and the convection-reaction-diffusion equation. Chapter five presents the proposed by the candidate strategies for parallelization of the MLMC algorithm. Chapters 2 to 5 end with Conclusions, where the main results and conclusions are summarized. Chapter 6 summarizes the content of the individual chapters and the main results of the performed research work. It formulates the author's scientific contributions to the topic of the dissertation. Finally, there are addressed the possible future extensions of the research presented in the dissertation.

2. Data and personal impressions of the candidate

Nikolay Shegunov was born in 1990 in the city of Sofia. He graduated from NPMG "Acad. L. Chakalov", profile "Physics". In 2013 he received a bachelor's degree in Informatics at FMI at Sofia University "Kliment Ohridski", and in 2015 he obtained there a master's degree in Applied Mathematics. His doctoral study began in 2016 at the Fraunhofer Institute of Technical and Industrial Mathematics under the supervision of Prof. Oleg Iliev and ended as a doctoral student at FMI of Sofia University "St. Kliment Ohridski" under the supervision of Assoc. Prof. Petar Armyanov.

I do not know the doctoral candidate personally, and I became familiar with part of his research results from presentations at scientific conferences.

3. Critical analysis of the scientific and the applied achievements of the candidate

To achieve the goals set in the dissertation, the author has mastered, used and developed specific modern methods and algorithms for solving problems taking into account uncertainties in the parameters of the mathematical model. I am convinced that the doctoral candidate has conscientiously studied and worked, and fully meet the requirements for the "educational" part of the doctoral degree.

The results presented in the dissertation are original and are of both scientific significance and of interest for high-tech industrial applications. The developed in the dissertation methods and algorithms are verified and validated for specific stochastic partial differential equations and with an emphasis on flow and transport simulations in a porous medium with uncertainties in the material properties, but have the potential for wider application. The scientific contributions are divided by the candidate into fundamental, directed fundamental and applied. I accept this classification as adequate, as well as I fully accept the declared contributions of the doctoral candidate to his research topic. Among the scientific contributions, in my opinion, the most significant and recognizable are the developed original effective method for renormalization of the stochastic field for the purposes of MLMC-method and the application for the first time of the MLMC-method for solving the stochastic convection - reaction - diffusion equation. The directed fundamental and the applied scientific contributions are exceptionally connected with the main scientific goals of the doctoral work and reflect the development and optimization of the necessary apparatus and tools for their achievement, namely the MLMC-method and the realization of an efficient parallelized version of it.

4. Visibility and dissemination of the achievements

The doctoral candidate has already made the results, obtained during his doctoral study, visible to the scientific community in total 5 publications (3 of them are cited in the dissertation).

1 publication in the journal Cybernetics and Information Technologies; DOI 10.2478/cait-2020-0066; without IF, with SJR(2020): 0.272, points for indicator $\Gamma_7 - 10 \times 3$

2 publications in the Springer series Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), DOI 10.1007/978-3-030-41032-2_53 и DOI 10.1007/978-3-319-73441-5_31, with SJR(2020): 0.259; points for indicator $\Gamma_7 - 10 \times 3 \times 2$

1 publication in the Springer series Lecture Notes in Computational Science and Engineering, DOI 10.1007/978-3-030-47956-5_9, with SJR(2020): 0.444, points for indicator $\Gamma_7 - 10 \times 3$

1 publication in the series CEUR Workshop Proceedings, Volume 2464, Pages 99 – 106, c SJR(2020): 0.177, points for indicator $\Gamma_7 - 10 \times 3$

Total points for indicator $\Gamma_7 - 150$, while the required minimum is 30 points (without division by the number of co-authors). The publications are in a co-authorship, for one of them there is a distribution-of-contribution protocol. I consider the contribution of the candidate as

significant in all of the publications. Nikolay Shegunov's publishing activity is very good and exceeds the minimum mandatory requirements according to Bulgarian regulations.

The results presented in the dissertation are reported by the dissertation or its co-authors at the following scientific forums:

12th International Conference on Information Systems and Grid Technologies (ISGT'2018), Sofia, Bulgaria, Nov. 16 – 17, 2018; International Conference on Large-Scale Scientific Computing, Sozopol, 2017, 2020; 11th Annual Meeting of the Bulgarian Section of SIAM, Dec. 20 - 22, 2016, Sofia, Bulgaria, 14th Annual Meeting of the Bulgarian Section of SIAM, Dec. 17-19, 2019, Sofia.

There was detect no plagiarism in this dissertation that is proven in the legally established order.

5. Expediency and completeness of the dissertation abstract

The abstract meets the requirements for its preparation – it covers all chapters of the dissertation: there is an introduction where the justification of the scientific significance of the dissertation is addressed, and in the next 3 chapters of the abstract the goals and methods of the performed research are indicated, the main results are briefly presented. the abilities and limitations of the proposed approaches and solutions are discussed. The abstract's content corresponds to the content of the dissertation. The fundamental scientific, directed fundamental and the applied scientific contributions, according to the dissertation, are separately summarised. There is a list of the candidate's publications on the topic of the dissertation (electronic copies are also provided), acknowledgements are given to the supervisors and the organizations that provided the doctoral student with access to their scientific infrastructure, and, at the end, the candidate has declared the originality of his doctoral thesis.

6. Critical comments and recommendations

There are a number of typos in the English and Bulgarian texts. In some places there are inaccuracies in the wording, imprecision in the formulations of the statements, as well as in terms of definitions of the physical processes and characteristics of the porous medium. The common terminology is not always respected, especially in the Bulgarian text. There is no list of the used symbols and notations, which hampers the reading as there are symbols and notations with more than one meaning.

My recommendation to the doctoral candidate is to consider publishing the results of his work in scientific journals with greater visibility for the scientific community in the field of his research interests.

I have no significant remarks regarding the accuracy of the obtained by the doctoral candidate results and the approaches he used in his dissertation.

7. Conclusion

After getting acquainted with the submitted for this procedure dissertation and with the the accompanying scientific papers and evaluating the significance of the achieved by the doctoral candidate fundamental scientific, directed fundamental and applied scientific contributions, I confirm that the submitted documets (dissertation and publications), as well as the quality and originality of the results and achievements presented there, meet the requirements of “ZRASRB”, the Regulations for Its application and the respective Regulations of Sofia University “St. Kliment Ohridski ” for acquisition by the doctoral

candidate of the educational and scientific degree“ Doctor ”in the area of higher education 4. Natural sciences, mathematics and informatics, professional field 4.6. Informatics and computer science. In particular, the candidate satisfies the minimum national requirements in the professional field and no plagiarism has been detected that is proven in the legally established order.

Based on the above, I **recommend** the respective Scientific Jury to award Mr. **Nikolay Georgiev Shegunov, MSc.**, the educational and scientific degree "Doctor" (PhD) in the area of higher education 4. Natural sciences, mathematics and informatics, professional field 4.6. Informatics and computer science.

11.08 2021 .

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Prof. Dr. Maria Datcheva