OPINION

by

Assoc. Prof. Miglena Nikolaeva Koleva, DSc
University of Ruse "Angel Kanchev"

on

dissertation „Composite numerical methods and scalable tile algorithms"
of Dimitar Georgiev Slavchev,

for awarding the educational and scientific degree "Doctor"

in the doctoral program „Computational Mathematics"
in professional field 4.5 "Mathematics"

This opinion is prepared according to the order No 24/31.01.2022 of the Director of the Institute of Information and Communication Technologies, Bulgarian Academy of Sciences", by which I was elected as a member of the scientific jury and according to the decision of the first meeting of the jury held on 2.02.2022 to prepare an opinion.

1. Description of the presented materials

As a member of the scientific jury, I received the following documents:

- A copy of the order stating the right to defence the dissertation;
- Dissertation;
- Abstract of the dissertation in Bulgarian and English languages;
- List of dissertation publications;
- Copies of the dissertation publications;
- Information about the implementation of the minimum requirements of IICT-BAS;
- Declaration of originality;

The submitted documents are in accordance with Law for Development of Academic Staff in Republic of Bulgaria (LDASRB), the Regulations for the Application of LDASRB and the rules and conditions and specific requirements IICT-BAS for acquisition scientific degrees and competitions for academic positions occupation.

2. Relevance of the problem developed in the PhD thesis

In the present PhD Thesis, parallel speed-up and accuracy of tile methods for solving dense systems of linear algebraic equations are discussed. Such equations arise after the discretization of non-local problems, as boundary integral equations, fractional diffusion models, etc. Due to the high computational complexity, the computational process is expensive, which necessitates improving its efficiency.

In the dissertation the two-dimensional flow around airfoils problem and parabolic and elliptical problems for anomalous diffusion, described with Laplace operator of fractional order $\alpha \in (0,1)$, are considered.

The increased interest in recent years and the development of numerical methods for fractional differential equations, including those with fractional Laplacian, is due to their numerous applications in fluid dynamics, quantum mechanics, electricity, ecology, finance, etc.

3. Level of the knowledge of the state of the problem

The dissertation presents an overview of known results related to the research topic, clearly states the motivation, as well as the main methods for solving the problems. The bibliography of the dissertation includes 90 titles.

The PhD student is well acquainted with the state and the results obtained in the specialized scientific literature

4. General description of the dissertation and scientific contributions

The dissertation is in a volume of 140 pages, contains 47 Figures and 7 Tables The structure includes an Introduction, 4 chapters, Conclusion, approbation of the results, a list of publications included in the dissertation, Bibliography and two Appendices.

The abstract in Bulgarian includes 40 pages and those in English is 36 pages and completely corresponds to the content of the dissertation.

The *Introduction Section* to the dissertat presents the relevance of the topic, an overview of the existing results, goals and objectives of the dissertation, methodology and structure of the dissertation.

Chapter 1 presents the utilized tile methods for solving dense systems of linear algebraic equations. Direct methods and methods based on hierarchical semi-separable compression are presented. Also, estimation of their computational complexity is discussed.

Chapter 2, studies a numerical method for a computational simulation of laminar flow around Zhukovsky airfoils. The method is based on spline collocation with interpolation in parts. Comparison results for the efficiency of the computational process using direct methods and Hierarchically Semi-Separable (HSS) compression method and implementation in the STRUMPACK package are discussed.

The remaining part of the dissertation is devoted to problems modelling anomalous diffusion.

In *Chapter 3* is discussed boundary value stationary problem with fractional elliptic operator of order $\alpha \in (0,1)$, defined in square and circle domain. Fractional Laplacian is described by Riesz potencial. For the discretization finite element method is applied.

Results from experimental comparative analysis, based on the realization of HSS compression and ULV-like factorization in the software library STRUMPACK are discussed.

In Chapter 4 is studied the computational performance and accuracy of the hierarchical

solver based on HSS compression for a parabolic problem with fractional diffusion. The computational process involves solving a sequence of systems of linear equations on each time layer.

Results from experimental comparative analysis, based on the realization of HSS compression and ULV-like factorization and its parallel implementation in the STRUMPACK software package are presented.

The conclusions to each chapter present a thorough analysis of the results, conclusions and prospects for further research.

The scientific contributions formulated by Dimitar Slavchev accurately reflect the results obtained in the dissertation.

Briefly, the main scientific and applied-scientific contributions of the dissertation are:

- The performance of variety software packages for solving systems linear algebraice quations with dense matrices, is investigated.
- The numerical complexity, parallel performance and relative error of an HSS compression is studied.
- It is shown that for the flow around Zhukovsky airfoils problem with boundary element method discretization, the sequential ordering of the nodes on the bordersof the airfoils has suitable structure for HSS compression. In order to improve the effectiveness of the HSS compression, five methods for reordering of the unknowns are proposed and studied. For three of them the author of the dissertation has developed his own algorithms and program implementation.
- A method, algorithm and program implementation for the numerical solution of a parabolic space fractional diffusion problem are developed.

5. Publications on the dissertation

Dimitar Slavchev presented a list of 7 publications included in the dissertation. All papers are with SJR rank. Two of them are stand-alone publications, and the others are co-authored with the supervisor Prof. S. Margenov, DSc.

The results of the dissertation have been reported at 5 international conferences and 2 workshops.

The credits in group of indicators "G" are 220 and many times exceed the required 50 credits according to the Minimum National Requirements under LDASRB, the Regulations for the Application of LDASRB and the rules and conditions and specific requirements of IICT-BAS for obtaining educational and scientific degree "Doctor" in professional field 4.5 Mathematics.

6. Conclusions

The topic of the dissertation is relevant, the goals are clearly set, significant scientific and scientific-applied results are obtained. A comprehensive study with prospects for

development is presented. There is no doubt about the personal participation of the doctoral student in the development and the obtained contributions.

The presented dissertation corresponds to all criteria and indicators for acquiring the educational and scientific degree "Doctor", according to the Law for development of the academic staff in the Republic of Bulgaria, the Rules of BAS for scientific degrees and for holding academic positions at IICT-BAS.

I strongly recommend to the scientific jury to award Dimitar Georgiev Slavchev the educational and scientific degree "Doctor" in the professional field 4.5 Mathematics, doctoral program "Computational Mathematics".

На основание
331Д

10.03.2022 Opi