OPINION

on the PhD thesis for acquiring

the educational and scientific degree „Doctor“

Topic: „Optimization and parallelization of algorithms related to Coding Theory“

Author: Maria Rumenova Pashinska-Gadzheva,

Section Mathematical Foundations of Informatics (MFI), Institute of mathematics and informatics (IMI), Bulgarian academy of sciences (BAS)

Scientific advisor: Prof. Iliya Georgiev Bouyukliev, DSc

Area of higher education: 4. Natural sciences, mathematics and informatics

Professional Field: 4.6. Informatics and computer science

Scientific field: Computer science

Reviewer: Prof. Nikolay Ivanov Yankov, DSc, Konstantin Preslavsky University of Shumen

I was appointed by order № 456/03.12.2024 of IMI's director to be a member of this scientific jury, and on the first session I was selected to write this opinion. I confirm that I have received all materials for this procedure according to LDASRB (the Law for the development of the academic staff in the Republic of Bulgaria). I am not aware of any procedural infractions or instances of plagiarism in the PhD thesis that was submitted.

1. PhD student's "curriculum vitae"

The doctoral candidate Maria Pashinska-Gadzheva graduated in 2019 with a bachelor's degree in "Computer Science" at the University of Veliko Tarnovo "St. Cyril and Methodius", and then in 2020 she graduated from the master's program "Mathematical Structures in Information Security" at the same university. For the period 01.01.2021-01.01.2024, she was enrolled in full-time doctoral studies in the doctoral program "Informatics" at the MFI section. In the attached CV, as well as the other materials to this procedure, unfortunately, I did not find data on the doctoral candidate's participation in scientific projects, which I consider important because the law stipulates that the doctorate degree is "educational and scientific". Despite this remark, I know that the doctoral student is a participant in national scientific projects funded by the Bulgarian National Science Foundation, as well as in the national scientific program "Young Scientists and Postdoctoral Fellows", which I consider a plus. I know Maria Pashinska-Gadzheva from the "Professor Stefan Dodunekov" national coding seminar, and my impressions are of a competent young specialist.

2. About the candidates' doctoral education

The doctoral student was enrolled in a full-time form of study from 01.01.2021 with a study period of 3 years. By order of the Director of IMI (No. 7/02.01.2024), the doctoral study period was certified with the right for thesis defense. The preliminary discussion of the dissertation was held on 23.11.2024 at an extended meeting of the MFI section. By order of the Director of IMI, a scientific jury and the date of the defense were determined. I believe that the doctoral procedure is regular and there are no violations.

3. About the thesis and its abstract

The submitted thesis consists of: introduction (8 pages), main text (78 pages) in 5 chapters, divided into sections. Included in the dissertation is a list of contributions, a

bibliography of 83 titles, lists of publications, list of citations, as well as a list of oral presentations at scientific forums.

The thesis meets the requirements of LDASRB and RALDASRB (Rules on the application of the Law for the development of the academic staff in the Republic of Bulgaria), as well as of Regulations on the terms and conditions for acquiring scientific degrees and for holding academic positions in BAS. The abstract (in 21 pages) adequately reflects the main ideas and significant final results that are included in the dissertation.

4. Importance of the research

As is known from the work of Berlekamp, McEllis and van Tilborg from 1978, the problem of finding the weight distribution of a linear code is NP-complete. Therefore, work on simplifying algorithms, and even more so on their acceleration, optimization, and parallelization, is relevant. Thus, the contemporaneity and scientific contributions of the dissertation to the development of the topic are indisputable. The importance of the dissertation's developments is also confirmed by the two citations of the article in the proceedings of the ICAI'24 conference, included in the dissertation.

5. Degree of knowledge of the research problem

The PhD student understands the current state of the problem well enough. The list of 83 literary sources chronologically begins with works on weight distributions by Vera Pless from 1963 and Delsart from 1972, with almost half of the publications being from 2010 to date. The educational part in the degree “doctor” requires the PhD student to show her grasp of the current state of the scientific field. In this regard, I believe that Maria Pashinska-Gadzheva has successfully entered the field of Coding Theory and, in particular, the state-of-the-art algorithms that are used in the study of codes. The thesis gives a clear idea of the history and the current state of the problems under consideration and of the methods used in this research.

6. Scientific contributions

Chapter 2 of the dissertation describes the developed algorithms for finding the weight distribution of a linear code, respectively high-level and low-level. The proposed high-level algorithms reduce the next codeword as a linear combination of the rows of the generating matrix of the code, the main goal being to do this only through the operation of vector addition. Two main types of algorithms have been implemented: for adding vectors over a finite field and for finding the weight of a vector over a finite field. These algorithms are extremely important for fast work with codes, and therefore parallelization through vectorization and register expansion is used. The obtained experimental results for the fast operation of the developed algorithms are compared with those implemented in Magma and GAP. A comparison between the efficiency of the algorithms implemented using different instructions is also presented. An analysis of the execution time effect of different C++ compilers when using vectorization in the implementations of practical algorithms has been performed.

Chapter 3 discusses the features of vectorizing algorithms for weight invariants with the extended AVX512 and Neon instructions. Low-level algorithms over larger simple fields of dimension up to 128 are presented, which implement vector addition using byte-wise representations via unsigned data types and saturation instructions. The efficiency of AVX512 instructions is analyzed compared to other instructions for x86 architectures.

Chapter 4 is devoted to binary linear self-complementary codes that reach the Gray-Rankin bound. This chapter contains a significant part of the new theoretical results included in the dissertation. Six new families of codes with two and three weights that reach the required bound are obtained. The main goal is the classification of linear self-complementary codes with

dimension 9. Given a code with two weights and dimension k, a new so-called SCL (Self-complimentary Lifting) construction is obtained, generating a code with dimension k+2 and two or three weights.

Chapter 5 describes the author's library LinCodeWeightInv for finding various weight invariants of linear codes. The different options for installing, compiling, and using the library in other projects are presented.

The PhD thesis under review has an adequate completeness, with the main claims and facts used being properly proven theoretically. The resulting algorithms are described with pseudocode, and the new results are illustrated in tables or graphs. A significant part of the algorithms has been implemented in practice and show improvements compared to previously known realizations.

I acknowledge and confirm the scientific and applied-scientific contributions indicated in the thesis.

7. Publications and participation in scientific forums

The list of publications on the dissertation includes 6 papers, of which five have already been published and one is in the final stage of review. Of these articles, 2 are authored solely by Maria Pashinska-Gadzheva, 3 are co-authored by the doctoral student's supervisor, Prof. Iliya Buyukliev, and 1 has two co-authors. All articles are in peer-reviewed journals. One of the publications: Mathematics by MDPI has an impact factor (JCR-2023, IF=2.2) and is in the Q1 quartile. A total of three of the published articles are included in the Scopus database, with the publication Lecture Notes in Computer Science being in the second quartile in the field of informatics and having an impact rank of 0.606. The total SJR for the published articles is 1.198. The remaining two published works are in the IMI journal "Innovative STEM Education", included in the National Reference List of Contemporary Bulgarian Scientific Publications with Scientific Review.

I believe that the participation of the doctoral student in all publications is equal to the other co-authors. The number of articles meets the requirements of LDASRB, RALDASRB, as well as the rules of BAS and IMI.

In the text of the dissertation, a list of 9 scientific talks (of which 3 have no co-authors) is attached, in which the doctoral student announced the results of this dissertation at various national and international forums. In my opinion, this approval of the results of the dissertation work exceeds the minimum requirements and shows the readiness of Maria Pashinska-Gadzheva for independent scientific research.

8. Conclusion

This PhD thesis fully meets the requirements established by the LDASRB, as well as the regulations of BAS and IMI, so I confidently suggest to the esteemed scientific jury to vote for the educational and scientific degree "Doctor" to BE ACQUIRED by Maria Rumenova Pashinska-Gadzheva in professional field 4.6. „Informatics and computer science“, scientific field „Informatics“.

Reviewer ……

/ Prof. Nikolay Yankov, PhD /

17.01.2025 г.