R E V I E W

on a Dissertation

for obtaining the educational and scientific degree "Doctor"

Author: Maria Rumenova Pashinska-Gadzheva

Title: Optimization and Prallelization of Algorithms, Related to Coding Theory

Research area: 4. Natural Sciences, Mathematics and Informatics,

Professional field: 4.6. Informatics and Computer Science

Referee: Prof. DSc Stoyan Kapralov – Technical University of Gabrovo

On the basis of Order No. 456 / 03.12.2024 of the Director of IMI-BAS, I have been appointed as a member of the Scientific Jury in connection with the defense of the dissertation work of Maria Rumenova Pashinska-Gadzheva. According to a decision of the first meeting of the scientific jury (Minutes No. 1/17.12.2024), I have been elected as a reviewer.

This review has been prepared in accordance with the requirements of the Act on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for its Implementation and the Regulations on the Terms and Procedure for Acquiring Scientific Degrees and Holding Academic Positions at the Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences.

I have been provided with all the necessary documents: Application for admission to defense, Professional CV, Order for enrollment in doctoral studies, Protocols of passed exams, Order for expulsion from doctoral studies, Order for conducting a preliminary defense, Protocol of discussion of the dissertation work by the primary unit, List of publications on the dissertation, List of citations of publications, Copies of publications, Dissertation, Reference for contributions, Abstract, List of delivered reports, Individual scientometric indicators, Data for registration in NACID. Copies of certificates and diplomas related to the professional qualification of Maria Pashinska-Gadzheva have also been provided.

1. Brief personal data about the candidate.

Maria Rumenova Pashinska-Gadzheva obtained a bachelor's degree from the Veliko Tarnovo University "St. St. Cyril and Methodius" in Computer Science in 2019 and a master's degree from the same university in 2020 in Mathematical Structures in Information Security. In 2020, she also acquired a professional qualification as a Mathematics Teacher.

In the period January 1, 2021 - January 1, 2024, she is a full-time doctoral student at the Institute of Mathematics and Informatics of the Bulgarian Academy of Sciences. Since March 2024, she has been an assistant professor at the IMI.

2. Timeliness of the subject

Algorithm parallelization is an extremely relevant and important topic in computer science. In recent years, with the development of multi-core processors and architectures with multiple processor cores, parallelization of tasks and algorithms has become increasingly crucial for achieving high performance. With the increasing complexity of hardware architectures, multi-core and multi-threaded processors have become the standard. This creates a need for algorithms that can take advantage of these parallel resources to ensure fast task execution. In various fields, parallelization allows researchers to solve complex problems that would take too much time on traditional processors. Parallelization not only speeds up the execution of algorithms, but also opens new opportunities for optimization and innovation. The topic is extremely relevant in modern technologies and research.

Vectorization is the process of converting operations that are traditionally performed sequentially on individual data elements into operations that can be performed in parallel on multiple elements at once, using specialized vector processing instructions. Such instructions are available in modern processors. Modern processors have special vector registers that can store multiple values, depending on the architecture.

Maria Pashinska's dissertation is dedicated to problems related to the efficient implementation of basic algorithms from coding theory. The improvements proposed in the dissertation are obtained as a result of parallelization of computer calculations.

3. General characteristics of the thesis

The dissertation has a total volume of 102 pages and contains Introduction, Scientific and Applied Contributions, Approbation of the Results, Acknowledgements, five chapters, Bibliography, Presented Papers, Publications, List of Citations.

The Introduction briefly presents basic concepts related to parallelization and vectorization, as well as basic concepts from coding theory. Four main research tasks are formulated:

• Vectorized implementation of algorithms for finding spectrum of linear codes over fields with up to 64 elements.

• Expanding the capabilities of the algorithms to work with linear codes over prime fields with less than 128 elements.

• Study of binary linear self-complementary codes reaching the Gray-Rankin limit.

• Creation of a library for calculating weight invariants of linear codes over fields with up to 64 elements.

Chapter 1 is an overview and introduces the range of problems studied and the approaches used. Section 1.1 is devoted to concepts, definitions and theorems from coding theory. Section 1.2 discusses the main approaches for optimization and parallelization of algorithms. The choice of vectorization as the most suitable approach for parallelization in the range of coding theory problems considered in the dissertation is justified. The implementation is based on the use of extended registers.

Chapter 2 presents the improvements in the calculation of the spectrum of linear codes made in the dissertation. Section 2.1 presents algorithms (with variants for prime and composite fields) in which the next linear combination is obtained only by adding a row from the generating matrix. The main idea is to use an additional matrix in which appropriate linear combinations are recorded. However, a

serious increase in efficiency will be obtained after low-level parallelization. Section 2.2 presents various approaches and the corresponding algorithms for adding vectors and finding the weight of a vector. Section 2.3 presents experimental results, comparing different options for choosing the representation of the fields and the implementation of the algorithms. Finally, Section 2.4 compares the efficiency of different compilers in vectorization.

Chapter 3 studies the characteristics and efficiency of different types of instructions in different architectures and, as an application, an algorithm for adding vectors by representing the elements of the field as unsigned integers is developed.

Chapters 2 and 3 explore in great detail the possibilities for improving the efficiency of calculations and demonstrate the Maria Pashinska's in-depth knowledge of the research topic.

Chapter 4 is devoted to issues from the classical algebraic and combinatorial coding theory. Four families of two-weight codes and two families of three-weight codes, which are closely related to the even-length self-complementary codes reaching the Gray-Rankin bound, are defined and studied. New constructions and classification results are obtained. A rich set of ideas, approaches and techniques is used in the research. The content of this chapter could form the basis of an independent dissertation.

Chapter 5 is a logical continuation of the research in Chapters 2 and 3. A library for calculating weighted invariants has been developed. The main purpose of the developed computer programs is the calculation of the spectrum of a linear code over a field with up to 64 elements.

4. Scientific contributions

I am agree with the contributions presented by the dissertationist in the Author's Reference with the remark that it would be better if the formulations were more generalized and reduced to 4-5 points. I believe that the main tasks set in the Introduction have been solved thoroughly and comprehensively.

5. Publications and citations

A total of 6 publications have been presented on the dissertation. The publications are in English. Three of the publications are articles in international scientific journals and three are reports at international conferences. In two of the publications the candidate is the only author. Three of the publications are co-authored with the scientific supervisor and one is with two co-authors.

In terms of volume and quality, the publications significantly exceed the minimum requirements for obtaining the educational and scientific degree "Doctor".

Some of the results in the publications have been previously presented at national and international seminars.

Two citations of one of the publications were noted.

6. The PhD-Thesis-Summary correctly reflects the content of the dissertation.

7. Notes on the dissertation

I have no critical notes.

8. Conclusion

After having familiarized myself with the dissertation work and the accompanying scientific papers presented in the procedure and based on the analysis of their significance and the scientific and applied scientific contributions contained therein, I give my positive assessment and confirm that the presented dissertation work and the scientific publications to it, as well as the quality and originality of the results and achievements presented therein, meet the requirements of the Act on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for its Implementation and the Regulations on the Terms and Procedure for Acquiring Scientific Degrees and Holding Academic Positions at the Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences for the acquisition by the candidate of the educational and scientific degree "Doctor" in the Field of higher

education 4. Natural sciences, mathematics and informatics, Professional field 4.6 Informatics and computer science.

The candidate meets the minimum national requirements in the professional field and no plagiarism has been found in the scientific papers submitted under the procedure.

Based on the above, I strongly recommend that the scientific jury award Maria Rumenova Pashinska-Gadzheva the educational and scientific degree "Doctor" in the Field of higher education 4. Natural Sciences, Mathematics and Informatics, Professional field 4.6 Informatics and Computer Science.

15.01.2025 **Signiture:**

/Prof. DSc Stoyan Kapralov/