

R E V I E W
on a Dissertation
for obtaining the scientific degree "PhD"

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

Professional field: 4.5. Mathematics

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Title: ALGORITHMS FOR CHARACTERISATION OF ORTHOGONAL ARRAYS

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As a member of the scientific panel for this procedure according to order No. ПД 38-121 / 24.02.2021 г. of the Rector of Sofia University "St. Kliment Ohridski" Prof. D.Sc. Atanas Gerdzhikov. As a member of the scientific panel, I have received all the administrative and scientific documents required by the Act on the Development of the Academic Staff in the Republic of Bulgaria (ADASRB), the Rules for its implementation and the Rules on the terms and conditions for awarding of academic degrees and occupying of academic positions at Sofia University "St. Kliment Ohridski".

1. General characteristics of the dissertation and the presented materials

The dissertation studies the structure of some types of orthogonal arrays in the hemming space. Orthogonal arrays are combinatorial objects with interesting properties and wide application. Despite their connection with many combinatorial objects, their study is a difficult and interesting problem. There are two aspects of consideration in the work under discussion. One is combinatorial and the other uses an polynomial metric space, which allows the application of terminology and theory related to codes and τ - designs.

The dissertation contains 115 pages and consists of an introduction, four chapters and used literature of 59 titles in the presented bibliography.

2. Data and personal impressions of the candidate

Tanya Marinova graduated in Informatics at the Faculty of Mathematics and Informatics at Sofia University in 2011. In the period 2011-2013 she studied for a master's degree at the same faculty. During this period she was also a part-time lecturer in higher algebra. Her doctoral studies began in 2014.

I know Tanya Marinova from her appearances at the annual seminars on Coding Theory. Her presentations have always been correct, clear and well presented, despite the complexity of the subject matter.

3. Content analysis of the scientific and scientific-applied achievements of the candidate, contained in the presented dissertation and the publications to it, included in the procedure

The research presented in the dissertation can be conditionally divided into two groups. The first group refers to the characterization of the possible spectra of orthogonal arrays over the alphabet with two and three elements. The second group is for bounds for energy of orthogonal arrays. Below I will present a brief summary of the individual chapters of the dissertation.

The first chapter is introductory. Along with the introduction of the necessary concepts, it also presents additional overview information, which motivates the researched problems. Information on the structure and relationship between orthogonal arrays and its derivatives is presented. Different types of bounds, ways to determine the spectra, etc. are presented.

The second chapter is devoted to orthogonal arrays in the Hamming n -dimensional space over an alphabet with two elements. The main problem discussed in this chapter is: For a fixed strength τ and dimension n to find the minimum possible M for which an $(n, M, \tau, 2)$ orthogonal array exists. From the identity $M = \lambda 2^\tau$ this problem is equivalent to finding $\Lambda = \min \{M/2^\tau\}$, known as the minimum possible index for which there exists an $(n, M, \tau, 2)$ orthogonal array. To solve this problem in some of the cases statements have been proved. On this basis algorithms for reducing or excluding some options for the possible spectra of binary orthogonal arrays have been developed. Algorithm 1 is based on the relationship between a spectrum of a binary array and the spectrum of its derived. In further considerations, this technique is extended to consideration spectrums with respect to a vector

external to the array. Section 2.6 outlines ways to increase the efficiency of the developed algorithms. The results of using the algorithms are described in Section 2.8.

The third chapter is devoted to orthogonal arrays in the Hamming n -dimensional space over an alphabet with three elements. The methods and approaches used are similar to those in the previous chapter. However, there are very specific differences, determined not only by the cardinality of the ternary Hamming space, but also by other specific features. The statements motivating the developed algorithms are described in Section 3.2. The results of the use of the algorithms are presented in Section 3.3.

Chapter 4 examines the energies of orthogonal arrays. After defining energies in Section 4.1, the relationship between the spectra and the energies of an orthogonal array is investigated. The main problem in this chapter is to determine both the minimum and maximum energy bounds of an orthogonal array. At the end of the chapter, a comparison is made between combinatorial bounds and universal bounds.

My overall impression of the dissertation is that it is very informative, well-formed, precise, with significant scientific contributions, which are described in detail and correctly in the part **approbation of the results** in the dissertation.

The main contributions are:

1. Development of suitable efficient algorithms of different types for reducing the possibilities of spectra of orthogonal arrays.
2. Determining the exact value of the minimum possible index for the following parameters $\Lambda(9, 4, 2) = \Lambda(10, 4, 2) = \Lambda(11, 4, 2) = \Lambda(12, 4, 2) = 8$ and $\Lambda(10, 5, 2) = \Lambda(11, 5, 2) = \Lambda(12, 5, 2) = \Lambda(13, 5, 2) = 8$.
3. Improving the lower bound for the minimum possible index of an $(17, 108, 3, 3)$ orthogonal array.
4. Combinatorial bounds for the energies of orthogonal arrays are found

I would also like to mention the following other positive aspects:

- The known results and obtained results are summarized and presented in tables, which give a general idea of the state of the art of the considered problems.
- In each of the chapters after the first there are detailed examples that greatly help reading and understanding.

- There is independent confirmation of some of the results, as indicated on page 102. This is very important for computer results because it shows the correctness

4. Approbation of the results

The results of the dissertation are published in six articles, two of which are referenced in the Web of Science and one in Scopus:

- *Problems of Information Transmission, RefWeb of Science, Impact Factor: 0.632 (2015), Web of Science Quartile: Q3 (2015).*
- *Discrete Applied Mathematics, RefWeb of Science, Impact Factor: 0.932 (2017), Web of Science Quartile: Q3 (2017).*
- *Electronic Notes in Discrete Mathematics Ref Scopus, SJR: 0.262 (2017), SNIP 0.401 (2017).*

Two other publications are referenced in ZbMath and MathSciNet. The obtained results were reported at eight national and international scientific forums. They have been very well received by the scientific community, having been cited 12 times, 10 of which have been in impact factor or impact rank journals.

All publications are co-authored, and the doctoral student's contribution is indisputable and can be considered (according to the submitted declarations for co-authorship) to be equivalent to that of other authors.

The scientific works categorically meet and exceed many times the minimum national requirements (under Art. 2b, para. 2 and 3 of ZRASRB) and respectively the additional requirements of Sofia University “St. Kliment Ohridski” for acquiring the educational and scientific degree “Doctor” in the scientific field and professional direction of the procedure.

5. Qualities of the summary

The summary is prepared according to the requirements and correctly reflects the content of the dissertation.

6. Critical remarks and recommendations

The use of bibliographic materials in the dissertation indicates a deep scientific awareness. The dissertation is well structured, with serious motivation for solving actual problems through interesting scientific approaches. The explanation is characterized by accuracy and completeness.

Here are some comments:

- The term “optimization” is rather associated with code writing or specific non-standard presentation of data in low-level programming languages. Section 2.6 discusses ways to increase efficiency.
- The term "derived" array is introduced in Chapter Two. In my opinion, it would be more appropriate to introduce it in the first chapter, because it is used throughout the dissertation.
- The way to find the possible spectra in Chapter One is named as *algorithms*. This is formally true, but in the context of the explanation an algorithm is understood as a non-trivial sequence of steps.
- Despite the presented examples, the presentation does not give an intuitive idea of the meaning of energies of orthogonal arrays.

7. Conclusion

After getting acquainted with the dissertation presented in the procedure and the accompanying scientific papers and based on the analysis of their significance and the scientific and applied contributions contained in them, I confirm that the presented dissertation and scientific publications to it, as well as and the quality and originality of the results and achievements presented in them, meet the requirements of ZRASRB, the Regulations for its application and the respective Regulations of Sofia University “St. Kliment Ohridski” for acquisition by the candidate of the educational and scientific degree “ Doctor ” in the scientific field 4. Natural sciences, mathematics and informatics, and professional field 4.5. Mathematics. In particular, the candidate satisfies the minimum national requirements in the professional field and no plagiarism has been established in the scientific papers submitted at the procedure. Based on the above, I recommend the scientific jury to award

TANYA TODOROVA MARINOVA

educational and scientific degree "Doctor" in scientific field 4. Natural Sciences, Mathematics and Informatics, professional field 4.5. Mathematics.

13.04.2021 г.

Reviewer:

Prof. Iliya Bouyukliev