

## REVIEW

regarding a dissertation for the acquisition of the educational and scientific degree "doctor" in a scientific specialty:

Informatics

in a professional direction:

4.6. "Informatics and computer science"

Author of the dissertation:

mag. Vasil Stefanov Kolev

Dissertation topic:

### **METHODS FOR BUILDING WAVELET AND MULTIWAVELET FILTER BANKS**

Reviewer: Prof. Dr. Eng. Alexander Bogdanov Bekyarski

#### **1. Relevance of the problem developed in the dissertation in scientific and scientific-applied terms**

The topic of the presented dissertation "METHODS FOR BUILDING WAVELET AND MULTIWAVE FILTER BANKS" quite naturally reveals the presence of actuality related to the wide spread of methods and means for the development and practical application of wavelet and multi-wave filter banks. The topic has a direct relationship, both in the field of traditional methods, for image analysis, processing, coding and recognition, and also in the perspective methods and algorithms for artificial intelligence and neural networks with deep learning.

#### **2. Degree of knowledge of the state of the problem and creative interpretation of the literary material**

The degree of knowledge of the state of the problem and creative interpretation of the literary material is noticeable throughout the dissertation work. But it can be emphasized that through the essence of chapter 1 "Overview and analysis of the methods for building wavelet and multiwavelet filter banks" of the dissertation work, where a large part of the cited 153 scientific publications are analyzed, the subject of the dissertation is argued, mainly in terms of regarding the need for new more efficient methods and algorithms for designing wavelet and multiwavelet filter banks.

#### **3. Correspondence of the chosen research methodology and the set goal and tasks of the dissertation with the contributions achieved**

The correspondence of the chosen research methodology and the set goal and tasks of the dissertation work with the achieved contributions is well justified and it should be emphasized that the set goal and tasks of the dissertation work are defined and closely related to the achieved results and contributions in the dissertation work. This statement should include the justification of the goals and tasks in the dissertation work, the fully justified significance and necessity in a scientific-applied and applied sense of research in the chosen scientific field. A correct approach has been proposed, in which the doctoral student has formulated precisely and in a synthesized form both the goal and the tasks in his dissertation work, as follows:

### **Objective of the dissertation**

To develop methods and algorithms for multiscaling and multiwavelength functions and possible applications in different (multi)filters.

### **The following main tasks derive from the set goal of the dissertation work:**

1. Development of methods for building scalars and multiscalers

functions of polynomials and splines

2. Algorithms for a fast and accurate Bauer method

### **4. Brief analytical description of the nature and assessment of the credibility of the material on which the contributions of the dissertation are based**

The dissertation has a volume of 150 pages. The realization of the correctly set goal and corresponding tasks of the dissertation work is the subject of the following chapters of the dissertation, between which consistency in the presentation, logical connection and methodical presentation of the new important, regarding the contributions of the dissertation, theoretical and practical solutions in the field of the subject have been achieved of the dissertation.

The subject of research in chapter 2 are methods for constructing scaling and multiscaling functions from polynomials and splines - method by changing the basis, direct method, method of the outer scalar product. Methods for constructing wavelet and multiwavelet functions are proposed.

In chapter 3 of the dissertation "Development of Spectral Decomposition Methods" the product of a matrix filter, Method of quadratic equations, Method of roots of polynomials, Cepstral method, Bauer's method, are developed.

In chapter 4 of the dissertation «Development of algorithms for a fast and accurate Bauer method», an algorithm for a fast Bauer method is proposed and developed;



Methods for solving NMU in BMB, algorithms for Fast Bauer method (scalar and vector case).

In chapter 5 of the dissertation «Experimental studies of the developed methods for building wavelet and multiwave filter banks», all the results of the experimental studies are presented in more detail, as well as a comparative analysis of the classical and fast Bauer method for spectral decomposition, an experimental study of modules without multiplication for a 5/3 filter bank implemented on a reprogrammable integrated circuit. A comparison is made between different applications of orthogonal multiwavelet filters for processing gray level test images and images from scanned photographic plates.

## **5. Scientific and/or scientific-applied contributions of the dissertation work**

The main results achieved in this dissertation are summarized and presented in a synthesized form in the form of the following contributions:

### **Scientific contributions:**

The scientific contributions are:

1. Three methods have been developed for directly obtaining scalar and vector functions: change of basis [item 2.1], direct method [item 2.2], and external method scalar product [i.e. 2.3]
2. An author's work of an Alpert matrix filter was developed [i.e. 3.1]
3. Two proprietary orthogonal multiscaling functions with exact values were developed using the BMB spectral decomposition method and their complementary orthogonal multiwave functions [i.e. 5.1.4.2 (A)];

### **Scientific and applied contributions:**

Scientific and applied contributions include the development of:

- scaling and multiscaling functions from a linear B-spline [i.e. 2.1.3.1, item 2.2.1, and item 2.3.1], quadratic B-spline [item. 2.1.2.1, item 2.1.3.2], cubic Hermitian spline [item 2.1.2.2, item 2.1.3.3, item 2.2.2, and item 2.3.2], quintic Hermitian spline [item 2.1.3.4], and Legendre polynomials [pt. 2.1.3.5, item 2.2.3, and item 2.3.3] by using the developed method by changing the basis, direct method, and method by the outer scalar product;
- author's numerical methods for solving NMU by the classical and fast Bauer method for spectral decomposition (Algorithm 1 - for calculation of a fast Bauer method [item 4.2] and Algorithm 2 - for calculation of an accurate Bauer method [item 4.2] ), a comparative analysis of the built-in functions 'dare' and 'idare' in Maple and Matlab for solving ODAUR, and orthogonal multiscaling functions were obtained by the

fixed point method and Newton's method [item 5.1.4.2(A)], [ item 4.3.1] - [item 4.3.3], [item 4.4], and [item 4.5.1];

- an author's lifting scheme of Alpert's multi-filter bank with different quantization of the  $\sqrt{3}$  coefficient was researched and developed for gray-level image analysis and restoration [item 5.2.1];

- the modules without multiplication on a reprogrammable integral are realized circuits of the Xilinx company from the Virtex and Spartan series for a perfectly restoring biorthogonal 5/3 filter bank [item 5.3].

## **6. Evaluation of the degree of personal participation of the doctoral student in the contributions**

The scientific and scientific-applied contributions described above appear in the doctoral student's publication activity, which is sufficient in terms of volume and content. They have been promoted in appropriate and established scientific forums in the field of the dissertation, which means that the results of the dissertation have gained appropriate popularity and recognition in scientific circles. In this regard, the personal participation of the doctoral student in the contributions is manifested and is indisputable and confirmed by the presence of 6 publications - 4 presented at conferences, 2 - journals with quartile Q3. Of these, 4 publications are independent, 2 are co-authored. Three of the publications are indexed in Scopus.

The main results achieved in this dissertation are summarized and presented in a synthesized form in the form of the following contributions:

## **7. Evaluation of publications on the dissertation work**

The main achievements in the dissertation work have been popularized in 6 scientific publications, in journals and scientific conferences. All publications are of theoretical and applied importance, related to the dissertation and to the professional direction 4.6. "Informatics and computer science".

I accept the publication activity as completely sufficient in volume, at a high scientific level and sufficiently popularized in a national and international scientific plan. In confirmation of the presence of a significantly high degree of popularization of the doctoral student's publication activity, it should be noted the presence of a total of 5 citations.

## **8. Using the results of the dissertation work in scientific and social practice**

In the dissertation presented for review, there are no directly indicated data regarding the use of the results of the dissertation work in scientific and social practice, but



undoubtedly their theoretical value, confirmed by the conducted experimental studies, are a guarantee of the real possibilities for their application in scientific and social practice. As a completely real basis for future theoretical and practical use of the results of the dissertation work in scientific and social practice, the doctoral student's participation in new international and national research projects on the subject of the dissertation can be considered.

#### **9. Assessment of the compliance of the abstract with the requirements for its preparation, as well as the adequacy of reflecting the main points and contributions of the dissertation work**

The volume of the abstract is 54 pages. Its design fully corresponds to the requirements for the preparation of an abstract for a dissertation and adequately reflects the main points and contributions of the dissertation work. I believe that the abstract correctly and sufficiently reflects the most essential of each chapter of the dissertation, presents in a synthesized form the main results achieved in the respective chapters and outlines the scientific, scientific-applied and applied contributions indicated in the dissertation work.

#### **10. Opinions, recommendations and notes**

I am familiar with the version of the current dissertation work for the internal defense of the dissertation and I can declare that the majority of the remarks presented to the doctoral student were taken into account in the final design of the dissertation. Therefore, only the following minor editorial notes are presented in this review:

- it is not correct to include the doctoral student's publications in the list of literature, but if it is necessary to cite them in the text, to add and use numbering in the list of the doctoral student's publications;
- it is unnecessary to have formulas in the list of notations in the dissertation;
- the overview first chapter in the abstract should be presented more briefly;
- in the abstract it is not necessary to present a list of all the literature in the dissertation.

I believe that in his future scientific activity and scientific production, as a scientist and specialist, the doctoral student will continue to demonstrate and develop his rich possibilities in the current and prospective topics of the dissertation work.

#### **11. Conclusion**

I believe that the general positive assessment of the theoretical and practical results achieved during the development of this dissertation work, defined as scientific and applied contributions, reflected in a sufficient number of scientific publications and in

appropriate scientific journals and conferences, are fully sufficient grounds for a clear a positive conclusion regarding the qualification of the doctoral student and his qualities as a scientist in his chosen scientific field, confirmed in the dissertation work. Therefore, I consider it completely justified to recommend to the Honorable Scientific Jury to award the educational and scientific degree "doctor" to M.Sc. Vasil Stefanov Kolev in professional direction 4.6. "Informatics and computer science"

in the scientific specialty Informatics.

**Date: 18/06/2024**

Rev

**Prof. Dr.**

